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EDITED BY

J. NEWTON FRIEND, D.Sc., Ph.D., F.I.C.,

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THE PERIODIC TABLE.*

Periods.	Group O.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.
		1 H 1·0078							
First short period	*2* He 4·0022	*3* Li 6·940	*4* Be 9·02	*5* B 10·83	*6* C 12·0036	*7* N 14·008	*8* O 16·0000	*9* F 19·00	
Second short period	*10* Ne 20·18	*11* Na 23·000	*12* Mg 24·30	*13* Al 26·97	*14* Si 28·08	*15* P 30·982	*16* S 32·065	*17* Cl 35·457	
First long period: Even series	*18* A 39·94	*19* K 39·105	*20* Ca 40·09	*21* Sc 45·15	*22* Ti 47·90	*23* V 50·95	*24* Cr 52·04	*25* Mn 54·95	*26* Fe 55·84 / *27* Co 58·95 / *28* Ni 58·69
First long period: Odd ,,		*29* Cu 63·55	*30* Zn 65·38	*31* Ga 69·72	*32* Ge 72·60	*33* As 74·934	*34* Se 79·2	*35* Br 79·915	
Second long period: Even series	*36* Kr 82·9	*37* Rb 85·43	*38* Sr 87·63	*39* Y 88·93	*40* Zr 91·2	*41* Nb 93·3	*42* Mo 96·0	*43* Ma ...	*44* Ru 101·65 / *45* Rh 102·9 / *46* Pd 106·7
Second long period: Odd ,,		*47* Ag 107·880	*48* Cd 112·40	*49* In 114·8	*50* Sn 118·70	*51* Sb 121·76	*52* Te 127·5	*53* I 126·932	
Third long period	*54* Xe 130·2	*55* Cs 132·81	*56* Ba 137·36	*57* La 138·90	*58* Ce 140·2 / *59* Pr 140·9	*60* Nd 144·25 / *61* Il	*62* Sm 150·43 / *63* Eu 152·0	*64* Gd 157·0 / *65* Tb 159·2	
Fourth long period		*66* Dy 162·46 / *67* Ho 163·5	*68* Er 167·6 / *69* Tm 169·4	*70* Yb 173·0 / *71* Lu 175·0	*72* Hf 178·6	*73* Ta 181·3	*74* W 184·1	*75* Re ...	*76* Os 191·0 / *77* Ir 193·04 / *78* Pt 195·2
Fifth long period: Even series		*79* Au 197·21	*80* Hg 200·6 0	*81* Tl 204·3	*82* Pb 207·22	*83* Bi 209·00	*84* Po [210]	*85* ...	
Fifth long period: Odd ,,	*86* Nt 222	*87* ...	*88* Ra 225·95	*89* Ac ...	*90* Th 232·15	*91* Pa ...	*92* U 238·15		
Volume in this series of text-books.	1	2	3	4	5	6	7	8	9

* The Revised International Atomic Weights for 1929 are adopted in this Table as accepted by the Council of the Chemical Society.

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J. NEWTON FRIEND, D.Sc., PH.D., F.I.C.,
CARNEGIE GOLD MEDALLIST.

VOLUME XI.

ORGANOMETALLIC COMPOUNDS.

PART II.

DERIVATIVES OF ARSENIC.

BY

ARCHIBALD EDWIN GODDARD, M.Sc. (B'ham), A.I.C.

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GENERAL INTRODUCTION TO THE SERIES.

DURING the past few years the civilised world has begun to realise the advantages accruing to scientific research, with the result that an ever-increasing amount of time and thought is being devoted to various branches of science.

No study has progressed more rapidly than chemistry. This science may be divided roughly into several branches: namely, Organic, Physical, Inorganic, and Analytical Chemistry. It is impossible to write any single text-book which shall contain within its two covers a thorough treatment of any one of these branches, owing to the vast amount of information that has been accumulated. The need is rather for a series of text-books dealing more or less comprehensively with each branch of chemistry. This has already been attempted by enterprising firms, so far as physical and analytical chemistry are concerned; and the present series is designed to meet the needs of inorganic chemists. One great advantage of this procedure lies in the fact that our knowledge of the different sections of science does not progress at the same rate. Consequently, as soon as any particular part advances out of proportion to others, the volume dealing with that section may be easily revised or rewritten as occasion requires.

Some method of classifying the elements for treatment in this way is clearly essential, and we have adopted the Periodic Classification with slight alterations, devoting a whole volume to the consideration of the elements in each vertical column, as will be evident from a glance at the scheme in the Frontispiece.

In the first volume, in addition to a detailed account of the elements of Group 0, the general principles of Inorganic Chemistry are discussed. Particular pains have been taken in the selection of material for this volume, and an attempt has been made to present to the reader a clear account of the principles upon which our knowledge of modern Inorganic Chemistry is based.

At the outset it may be well to explain that it was not intended to write a complete text-book of Physical Chemistry. Numerous excellent works have already been devoted to this subject, and a volume on such lines would scarcely serve as a suitable introduction to this series. Whilst Physical Chemistry deals with the general principles applied to all branches of theoretical chemistry, our aim has been to emphasise their application to Inorganic Chemistry, with which branch of the subject this series of text-books is exclusively concerned. To this end practically all the illustrations to the laws and principles discussed in Volume I. deal with inorganic substances.

Again, there are many subjects, such as the methods employed in the accurate determination of atomic weights, which are not generally regarded as forming part of Physical Chemistry. Yet these are

subjects of supreme importance to the student of Inorganic Chemistry and are accordingly included in the Introduction.

Hydrogen and the ammonium salts are dealt with in Volume II., along with the elements of Group I. The position of the rare earth metals in the Periodic Classification has for many years been a source of difficulty. They have all been included in Volume IV., along with the Elements of Group III., as this was found to be the most suitable place for them.

Many alloys and compounds have an equal claim to be considered in two or more volumes of this series, but this would entail unnecessary duplication. For example, alloys of copper and tin might be dealt with in Volumes II. and V. respectively. Similarly, certain double salts—such, for example, as ferrous ammonium sulphate—might very logically be included in Volume II. under ammonium, and in Volume IX. under iron. As a general rule this difficulty has been overcome by treating complex substances, containing two or more metals or bases, in that volume dealing with the metal or base which belongs to the highest group of the Periodic Table. For example, the alloys of copper and tin are detailed in Volume V. along with tin, since copper occurs earlier, namely, in Volume II. Similarly, ferrous ammonium sulphate is discussed in Volume IX. under iron, and not under ammonium in Volume II. The ferro-cyanides are likewise dealt with in Volume IX.

But even with this arrangement it has not always been found easy to adopt a perfectly logical line of treatment. For example, in the chromates and permanganates the chromium and manganese function as part of the acid radicles and are analogous to sulphur and chlorine in sulphates and perchlorates; so that they should be treated in the volume dealing with the metal acting as base, namely, in the case of potassium permanganate, under potassium in Volume II. But the alkali permanganates possess such close analogies with one another that separate treatment of these salts hardly seems desirable. They are therefore considered in Volume VIII.

Numerous other little irregularities of a like nature occur, but it is hoped that, by means of carefully compiled indexes and frequent cross-referencing to the texts of the separate volumes, the student will experience no difficulty in finding the information he requires.

Particular care has been taken with the sections dealing with the atomic weights of the elements in question. The figures given are not necessarily those to be found in the original memoirs, but have been recalculated, except where otherwise stated, using the following fundamental values:

Hydrogen	= 1·00762.	Oxygen	= 16·000.
Sodium	= 22·996.	Sulphur	= 32·065.
Potassium	= 39·100.	Fluorine	= 19·015.
Silver	= 107·880.	Chlorine	= 35·457.
Carbon	= 12·003.	Bromine	= 79·916.
Nitrogen	= 14·008.	Iodine	= 126·920.

By adopting this method it is easy to compare directly the results of earlier investigators with those of more recent date, and moreover it renders the data for the different elements strictly comparable throughout the whole series.

Our aim has not been to make the volumes absolutely exhaustive,

as this would render them unnecessarily bulky and expensive; rather has it been to contribute concise and suggestive accounts of the various topics, and to append numerous references to the leading works and memoirs dealing with the same. Every effort has been made to render these references accurate and reliable, and it is hoped that they will prove a useful feature of the series. The more important abbreviations, which are substantially the same as those adopted by the Chemical Society, are detailed in the subjoined lists, pp. xvii–xix.

The addition of the *Table of Dates of Issue of Journals* (pp. xxi–xxviii) will, it is hoped, enhance the value of this series. It is believed that the list is perfectly correct, as all the figures have been checked against the volumes on the shelves of the library of the Chemical Society by Mr. F. W. Clifford and his staff. To these gentlemen the Editor and the Authors desire to express their deep indebtedness.

In order that the series shall attain the maximum utility, it is necessary to arrange for a certain amount of uniformity throughout, and this involves the suppression of the personality of the individual author to a corresponding extent for the sake of the common welfare. It is at once my duty and my pleasure to express my sincere appreciation of the kind and ready manner in which the authors have accommodated themselves to this task, which, without their hearty co-operation, could never have been successful. Finally, I wish to acknowledge the unfailing courtesy of the publishers, Messrs. Charles Griffin & Co., who have done everything in their power to render the work straightforward and easy.

J. NEWTON FRIEND.

March 1930.

PREFACE.

Owing to the large number of organic arsenical compounds now existent, it has been found necessary to devote an entire work in this series to their production. The present book deals with approximately 4000 compounds, all of which contain arsenic directly linked to carbon. The last fifteen years have doubled the number of arsenicals investigated, owing to their use in gas warfare, and a vigorous search for compounds of therapeutic value. In order to assist the student, the various types of compounds have been grouped under definite headings, as detailed in the Contents List, and although such a scheme is helpful, it cannot be perfect, since some compounds may obviously belong to more than one class.

Some investigators have described long series of compounds, the preparations of which are based on a general method; to save space the method is here given in the text and the compounds themselves placed in Appendix I., which also contains tables of physical constants for large series of compounds. Owing to the rapidity with which this field of chemistry is advancing, an Appendix II. has been added, containing arsenicals prepared whilst this work has been in the press.

The Author would draw attention to the unsatisfactory state of the nomenclature of organometallic compounds in general. The designations of compounds in the present book are those used in the original memoirs, since any attempt to alter these in a work of the present description would only complicate matters. It is necessary that a closer co-operation shall exist between the leading chemical societies of the world if the organometallic field is to be saved from a chaotic mass of names during the next fifty years.

In conclusion, the Author would be grateful for reprints of original papers dealing with organometallic compounds.

A. E. GODDARD.

"Thallia,"
Glenfield, Nr. Leicester,
March 1930.

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LIST OF CHIEF ABBREVIATIONS EMPLOYED IN THE REFERENCES.

Abbreviated Title.	Journal.
Afhandl. Fys. Kem.	Afhandlingat i Fysik, Kemi och Mineralogi.
Amer. Chem. J.	American Chemical Journal.
Amer. J. Sci.	American Journal of Science.
Anal. Fis. Quim.	Anales de la Sociedad Española Fisica y Quimica.
Analyst	The Analyst.
Annalen	Justus Liebig's Annalen der Chemie.
Ann. Chim.	Annales de Chimie (1719–1815, and 1914+).
Ann. Chim. anal.	Annales de Chimie analytique appliquée à l'Industrie, à l'Agriculture, à la Pharmacie, et à la Biologie.
Ann. Chim. Phys.	Annales de Chimie et de Physique (Paris) (1816–1913).
Ann. Mines	Annales des Mines.
Ann. Pharm.	Annalen der Pharmacie (1832–1839).
Ann. Phys. Chem.	Annalen der Physik und Chemie (1819–1899).
Ann. Physik	Annalen der Physik (1799–1818, and 1900+).
Ann. Physik, Beibl.	Annalen der Physik, Beiblättes.
Ann. Sci. Univ. Jassy	Annales scientifiques de l'Université de Jassy.
Arbeiten Kaiserl. Gesundheitsamte	Arbeiten aus dem Kaiserlichen Gesundheitsamte.
Arch. exp. Pathol. Pharmak.	Archiv für experimentelle Pathologie und Pharmakologie.
Arch. Pharm.	Archiv der Pharmazie.
Arch. Sci. phys. nat.	Archives des Sciences physique et naturelles, Genève.
Atti Acc. Torino	Atti della Reale Accademia delle Scienze di Torino.
Atti R. Accad. Lincei	Atti della Reale Accademia Lincei.
B.A. Reports	British Association Reports.
Ber.	Berichte der Deutschen chemischen Gesellschaft.
Ber. Akad. Ber.	See *Sitzungsber. K. Akad. Wiss. Berlin.*
Ber. Deut. physikal. Ges.	Berichte der Deutschen physikalischen Gesellschaft.
Bull. Sci. Pharmacol.	Bulletin des Sciences Pharmacologiques.
Bot. Zeit.	Botanische Zeitung.
Bul. Soc. Stiinte Cluj.	Buletinul Societâtei de Stünte din Cluj.
Bull. Acad. roy. Belg.	Académie royale de Belgique—Bulletin de la Classe des Sciences.
Bull. Acad. Sci. Cracow	Bulletin international de l'Académie des Sciences de Cracovie.
Bull. de Belg.	Bulletin de la Société chimique Belgique.
Ber. Deut. pharm. Ges.	Berichte der Deutschen pharmazeutischen Gesellschaft.
Bull. Soc. chim.	Bulletin de la Société chimique de France.
Bull. Soc. franç. Min.	Bulletin de la Société française de Minéralogie.
Bull. Soc. min. de France	Bulletin de la Société minéralogique de France.
Bull. U.S. Geol. Survey	Bulletins of the United States Geological Survey.
Centr. Min.	Centralblatt für Mineralogie.
Chem. Ind.	Die Chemische Industrie.
Chem. News	Chemical News.
Chem. Weekblad	Chemisch Weekblad.
Chem. Zeit.	Chemiker Zeitung (Cöthen).
Chem. Zentr.	Chemisches Zentralblatt.
Compt. rend.	Comptes rendus hebdomadaires des Séances de l'Académie des Sciences (Paris).
Crell's Annalen	Chemische Annalen für die Freunde der Naturlehre, von L. Crelle.
Dingl. poly. J.	Dingler's polytechnisches Journal.

Abbreviated Title.	Journal.
Drude's Annalen	Annalen der Physik (1900–1906).
Electroch. Met. Ind.	Electrochemical and Metallurgical Industry.
Eng. and Min. J.	Engineering and Mining Journal.
Gazzetta	Gazzetta chimica italiana.
Gehlen's Allg. J. Chem.	Allgemeines Journal der Chemie.
Geol. Mag.	Geological Magazine.
Gilbert's Annalen	Annalen der Physik (1799–1824).
Giorn. di Scienze Naturali ed Econ.	Giornale di Scienze Naturali ed Economiche.
Helv. Chim. Acta	Helvetica Chim. Acta.
Int. Zeitsch. Metallographie	Internationale Zeitschrift für Metallographie.
Jahrb. kk. geol. Reichsanst.	Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt.
Jahrb. Miner.	Jahrbuch für Mineralogie.
Jahresber.	Jahresbericht über die Fortschritte der Chemie.
Jenaische Zeitsch.	Jenaische Zeitschrift für Naturwissenschaft.
J. Amer. Chem. Soc.	Journal of the American Chemical Society.
J. Chem. Soc.	Journal of the Chemical Society.
J. Chim. phys.	Journal de Chimie physique.
J. Gasbeleuchtung	Journal für Gasbeleuchtung.
J. Geology	Journal of Geology.
J. Ind. Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Inst. Metals	Journal of the Institute of Metals.
J. Miner. Soc.	Mineralogical Magazine and Journal of the Mineralogical Society.
J. Pharm. Chim.	Journal de Pharmacie et de Chimie.
J. Physical Chem.	Journal of Physical Chemistry.
J. Physique	Journal de Physique.
J. prakt. Chem.	Journal für praktische Chemie.
J. Russ. Phys. Chem. Soc.	Journal of the Physical and Chemical Society of Russia (*Petrograd*).
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
Landw. Jahrb.	Landwirtschaftliche Jahrbücher.
Mém. Paris Acad.	Mémoirs présentés par divers savants à l'Académie de Sciences de l'Institut de France.
Mem. Coll. Sci. Kyōtō.	Memoirs of the College of Science, Kyōtō Imperial University.
Monatsh.	Monatshefte für Chemie und verwandte Theile anderer Wissenschaften.
Mon. scient.	Moniteur scientifique.
Münch. Med. Wochenschr.	Münchener Medizinische Wochenschrift.
Nature	Nature.
Nuovo Cim.	Il nuovo Cimento.
Oesterr. Chem. Zeit.	Oesterreichische Chemiker-Zeitung.
Öfvers. K. Vet.-Akad. Förh.	Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar.
Pflüger's Archiv	Archiv für die gesammte Physiologie des Menschen und der Thiere.
Pharm. Post	Pharmazeutische Post.
Pharm. Zentr.-h.	Pharmazeutische Zentralhalle.
Phil. Mag.	Philosophical Magazine (The London, Edinburgh, and Dublin).
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phys. Review	Physical Review.
Physikal. Zeitsch.	Physikalische Zeitschrift.
Pogg. Annalen	Poggendorff's Annalen der Physik und Chemie (1824–1877).
Proc. Chem. Soc.	Proceedings of the Chemical Society.
Proc. K. Akad. Wetensch. Amsterdam	Koninklijke Akademie van Wetenschappen te Amsterdam Proceedings (English Version).
Proc. Roy. Irish Acad.	Proceedings of the Royal Irish Academy.
Proc. Roy. Phil. Soc. Glasgow	Proceedings of the Royal Philosophical Society of Glasgow.
Proc. Roy. Soc.	Proceedings of the Royal Society of London.
Proc. Roy. Soc. Edin.	Proceedings of the Royal Society of Edinburgh.

Abbreviated Title.	Journal.
Rec. Trav. chim.	Recueil des Travaux chimiques des Pay-Bas et de la Belgique.
Roy. Inst. Reports	Reports of the Royal Institution.
Schweigger's J.	Journal für Chemie und Physik.
Sci. Proc. Roy. Dubl. Soc.	Scientific Proceedings of the Royal Dublin Society.
Sitzungsber. K. Akad. Wiss. Berlin.	Sitzungsberichte der Königlich-Preussischen Akademie de Wissenschaften zu Berlin.
Sitzungsber. K. Akad. Wiss. Wien	Sitzungsberichte der Königlich-Bayerischen Akademie der Wissenschaften zu Wien.
Techn. Jahresber.	Jahresbericht über die Leistungen der Chemischen Technologie.
Trans. Amer. Electrochem. Soc.	Transactions of the American Electrochemical Society.
Trans. Chem. Soc.	Transactions of the Chemical Society.
Trans. Inst. Min. Eng.	Transactions of the Institution of Mining Engineers.
Trav. et Mém. du Bureau intern. des Poids et Mes.	Travaux et Mémoires du Bureau International des Poids et Mesures.
Verh. Ges. deut. Naturforsch. Aerzte.	Verhandlung der Gesellschaft deutscher Naturforscher und Aerzte.
Wied. Annalen	Wiedemann's Annalen der Physik und Chemie (1877–1899).
Wissenschaftl. Abhandl. phys.-tech. Reichsanst.	Wissenschaftliche Abhandlungen der physikalisch-technischen Reichsanstalt.
Zeitsch. anal. Chem.	Zeitschrift für analytische Chemie.
Zeitsch. angew. Chem.	Zeitschrift für angewandte Chemie.
Zeitsch. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitsch. Chem.	Kritische Zeitschrift für Chemie.
Zeitsch. Chem. Ind. Kolloide	Zeitschrift für Chemie und Industrie des Kolloide (continued as Kolloid-Zeitschrift).
Zeitsch. Elektrochem.	Zeitschrift für Elektrochemie.
Zeitsch. Kryst. Min.	Zeitschrift für Krystallographie und Mineralogie.
Zeitsch. Nahr. Genuss-m.	Zeitschrift für Untersuchung der Nahrungs- und Genussmittel.
Zeitsch. physikal. Chem.	Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandtschaftslehre.
Zeitsch. physiol. Chem.	Hoppe-Seyler's Zeitschrift für physiologische Chemie.
Zeitsch. wiss. Photochem.	Zeitschrift für wissenschaftliche Photographie, Photophysik, und Photochemie.

TABLE OF DATES OF ISSUE OF JOURNALS.

For the sake of easy reference, a list is appended of the more important journals in chronological order, giving the dates of issue of their corresponding series and volumes. In certain cases the volumes have appeared with considerable irregularity; in others it has occasionally happened that volumes begun in one calendar year have extended into the next year, even when this has not been the general habit of the series. To complicate matters still further, the title-pages in some of these latter volumes bear the later date—a most illogical procedure. In such cases the volume number appears in the accompanying columns opposite both years. In a short summary of this kind it is impossible to give full details in each case, but the foregoing remarks will serve to explain several apparent anomalies.

Year.	Amer. J. Sci.	Ann. Chim. Phys.	Ann. Min.	Arch. Pharm.	Dingl. Poly. J.	Gilbert's Annalen.	J. Pharm. Chim.	Phil. Mag.	Phil. Trans.	Pogg. Annalen.
1800	...	(1) 32–35	...	...	...	4–6	...	5–8	90	...
1	...	36–39	...	...	...	7–9	...	8–11	91	...
2	...	40–43	...	...	...	10–12	...	11–14	92	...
3	...	44–47	...	...	...	13–15	...	14–17	93	...
4	...	48–51	...	...	...	16–18	...	17–20	94	...
1805	...	52–55	...	...	...	19–21	...	20–23	95	...
6	...	56–60	...	...	...	22–24	...	23–26	96	...
7	...	61–64	...	...	...	25–27	...	26–29	97	...
8	...	65–68	...	...	...	28–30	...	29–32	98	...
9	...	69–72	...	...	...	31–33	(1) 1*	33, 34	99	...
1810	...	73–76	...	...	...	34–36	2	35, 36	100	...
11	...	77–80	...	...	...	37–39	3	37, 38	101	...
12	...	81–84	...	...	...	40–42	4	39, 40	102	...
13	...	85–88	...	...	...	43–45	5	41, 42	103	...
14	...	89–92	...	...	...	46–48	6	43, 44	104	...
1815	...	93–96	...	...	...	49–51	(2) 1	45, 46	105	...
16	...	(2) 1–3	...	...	...	52–54	2	47, 48	106	...
17	...	4–6	1, 2	...	...	55–57	3	49, 50	107	...
18	...	7–9	3	...	...	58–60	4	51, 52	108	...
19	(1) 1	10–12	4	...	...	61–63	5	53, 54	109	...
1820	2	13–15	5	...	1–3	64–66	6	55, 56	110	...
21	3	16–18	6	...	4–6	67–69	7	57, 58	111	...
22	4, 5	19–21	7	1, 2	7–9	70–72	8	59, 60	112	...
23	6	22–24	8	3–6	10–12	73–75	9	61, 62	113	...
24	7, 8	25–27	9	7–10	13–15	76	10	63, 64	114	1, 2
1825	9	28–30	10, 11	11–14	16–18	Continued as Pogg. Annalen.	11	65, 66	115	3–5
26	10, 11	31–33	12, 13	15–19	19–22		12	67, 68	116	6–8
27	12	34–36	(2) 1, 2	20–23	23–26		13	(2) 1, 2	117	9–11
28	13, 14	37–39	3, 4	24–26	27–30		14	3, 4	118	12–14
29	15, 16	40–42	5, 6	27–30	31–34		15	5, 6	119	15–17

* First series known as *Bulletin de Pharmacie.*

Year.	Amer. J. Sci.	Annalen.	Ann. Chim. Phys.	Ann. Mines.	Arch. Pharm.	Bull. Soc. chim.	Compt. rend.	Dingl. poly. J.	J. Pharm. Chim.	J. prakt. Chem.	Mon.* scient.	Phil. Mag.	Phil. Trans.	Pogg. Annalen.	Proc. Roy. Soc.	Quart. J. Chem. Soc.	Sitzungsber. K. Akad. Wiss. Wien.
1830	17, 18	...	43–45	7–8	31–34	...	...	35–38	16	...	...	7, 8	120	18–20	...	...	...
31	19, 20	...	46–48	...	35–39	...	...	39–42	17	...	...	9, 10	121	21–23	...	...	...
32	21, 22	1–4	49–51	(3) 1, 2	40–43	...	...	43–47	18	...	...	11 (3) 1	122	24–26	1	...	...
33	23, 24	5–8	52–55	3, 4	44–47	...	...	48–50	19	...	...	2, 3	123	27–30	2	...	...
34	25–27	9–12	56–57	5, 6	48–50	...	...	51–54	20	1–3	...	4, 5	124	31–33	...	...	...
1835	28, 29	13–16	58–60	7, 8	(2) 1–4	...	1	55–58	21	4–6	...	6, 7	125	34–36	...	...	...
36	30, 31	17–20	61–63	9, 10	5–8	...	2, 3	59–62	22	7–9	...	8, 9	126	37–39	...	...	...
37	32, 33	21–24	64–66	11, 12	9–12	...	4, 5	63–66	23	10–12	...	10, 11	127	40–42	3	...	...
38	34, 35	25–28	67–69	13, 14	13–16	...	6, 7	67–70	24	13–15	...	12, 13	128	43–45	...	...	...
39	36, 37	29–32	70–72	15, 16	17–20	...	8, 9	71–74	25	16–18	...	14, 15	129	46–48	...	...	...
1840	38, 39	33–36	73–75	17, 18	21–24	...	10, 11	75–78	26	19–21	...	16, 17	130	49–51	...	...	...
41	40, 41	37–40	(3) 1–3	19, 20	25–28	...	12, 13	79–82	27	22–24	...	18, 19	131	52–54	...	...	...
42	42, 43	41–44	4–6	(4) 1, 2	29–32	...	14, 15	83–86	(3) 1, 2	25–27	...	20, 21	132	55–57	...	...	...
43	44, 45	45–48	7–9	3, 4	33–36	...	16, 17	87–90	3, 4	28–30	...	22, 23	133	58–60	4	...	...
44	46, 47	49–52	10–12	5, 6	37–40	...	18, 19	91–94	5, 6	31–33	...	24, 25	134	61–63	...	...	...
1845	48–50	53–56	13–15	7, 8	41–44	...	20, 21	95–98	7, 8	34–36	...	26, 27	135	64–66	...	...	...
46	(2) 1, 2	57–60	16–18	9, 10	45–48	...	22, 23	99–102	9, 10	37–39	...	28, 29	136	67–69	...	...	...
47	3, 4	61–64	19–21	11, 12	49–52	...	24, 25	103–106	11, 12	40–42	...	30, 31	137	70–72	...	1	..
48	5, 6	65–68	22–24	13, 14	53–56	...	26, 27	107–110	13, 14	43–45	...	32, 33	138	73–75	...	1, 2	1
49	7, 8	69–72	25–27	15, 16	57–60	...	28, 29	111–114	15, 16	46–48	...	34, 35	139	76–78	...	2, 3	2, 3
1850	9, 10	73–76	28–30	17, 18	61–64	...	30, 31	115–118	17, 18	49–51	...	36, 37	140	79–81	...	3	4, 5
51	11, 12	77–80	31–33	19, 20	65–68	...	32, 33	119–122	19, 20	52–54	...	(4) 1, 2	141	82–84	5	4	6, 7
52	13, 14	81–84	34–36	(5) 1, 2	69–72	...	34, 35	123–126	21, 22	55–57	...	3, 4	142	85–87	...	5	8, 9
53	15, 16	85–88	37–39	3, 4	73–76	...	36, 37	127–130	23, 24	58–60	...	5, 6	143	88–90	...	6	10, 11
54	17, 18	89–92	40–42	5, 6	77–80	...	38, 39	131–134	25, 26	61–63	...	7, 8	144	91–93	6, 7	7	12–14
1855	19, 20	93–96	43–45	7, 8	81–84	...	40, 41	135–138	27, 28	64–66	...	9, 10	145	94–96	7	8	15–18
56	21, 22	97–100	46–48	9, 10	85–88	...	42, 43	139–142	29, 30	67–69	...	11, 12	146	97–99	8	9	19–22
57	23, 24	101–104	49–51	11, 12	89–92	...	44, 45	143–146	31, 32	70–72	(1) 1	13, 14	147	100–102	9	10	23–27
58	25, 26	105–108	52–54	13, 14	93–96	1	46, 47	147–150	33, 34	73–75	2	15, 16	148	103–105	9	11	28–33
59	27, 28	109–112	55–57	15, 16	97–100	1	48, 49	151–154	35, 36	76–78	3	17, 18	149	106–108	9, 10	12	34–38

* Often referred to by Series: Series 3, vols. 1–16, 1871–1886; Series 4, vols. 1–24, 1887–1910; Series 5, vols. 1–9, 1911–1919 (one vol. yearly).

Year.	Amer. Chem. J.	Amer. J. Sci.	Analyst.	Annalen.	Annalen Suppl.	Ann. Chim. Phys.	Ann. Mines.	Arch. Pharm.	Ber.	Bull. Soc. chim.	Chem. News.	Chem. Trade J.	Chem. Zeit.
1860	...	29, 30	...	113–116	...	58–60	17, 18	101–104	...	2	1, 2	...	...
61	...	31, 32	...	117–120	1	61–63	19, 20	105–108	...	3	3, 4	...	...
62	...	33, 34	...	121–124	2	64–66	(6) 1, 2	109–112	...	4	5, 6	...	...
63	...	35, 36	...	125–128	2	67–69	3, 4	113–116	...	5	7, 8	...	...
64	...	37, 38	...	129–132	3	(4) 1–3	5, 6	117–120	...	(2) 1, 2	9, 10	...	...
1865	...	39, 40	...	133–136	3, 4	4–6	7, 8	121–124	...	3, 4	11, 12	...	...
66	...	41, 42	...	137–140	4	7–9	9, 10	125–128	...	5, 6	13, 14	...	...
67	...	43, 44	...	141–144	5	10–12	11, 12	129–132	...	7, 8	15, 16	...	...
68	...	45, 46	...	145–148	6	13–15	13, 14	133–136	1	9, 10	17, 18	...	...
69	...	47, 48	...	149–152	...	16–18	15, 16	137–140	2	11, 12	19, 20	...	...
1870	...	49, 50	...	153–156	7	19–21	17, 18	141–144	3	13, 14	21, 22	...	...
71	...	(3) 1, 2	...	157–160	...	22–24	19, 20	145–148	4	15, 16	23, 24	...	...
72	..	3, 4	...	161–164	8	25–27	(7) 1, 2	149–150, 201*	5	17, 18	25, 26	...	...
73	...	5, 6	...	165–170	...	28–30	3, 4	201–203	6	19, 20.	27, 28	...	...
74	...	7, 8	...	171–174	..	(5) 1–3	5, 6	204, 205	7	21, 22	29, 30	...	...
1875	...	9, 10	...	175–179	...	4–6	7, 8	206, 207	8	23, 24	31, 32	...	...
76	...	11, 12	1	180–183	...	7–9	9, 10	208, 209	9	25, 26	33, 34	...	...
77	...	13, 14	2	184–189	...	10–12	11, 12	210, 211	10	27, 28	35, 36	...	1
78	...	15, 16	3	190–194	...	13–15	13, 14	212, 213	11	29, 30	37, 38	...	2
79	1	17, 18	4	195–199	...	16–18	15, 16	214, 215	12	31, 32	39, 40	...	3
1880	1, 2	19, 20	5	200–205	...	19–21	17, 18	216, 217	13	33, 34	41, 42	...	4
81	2, 3	21, 22	6	206–210	...	22–24	19, 20	218, 219	14	35, 36	43, 44	...	5
82	3, 4	23, 24	7	211–215	...	25–27	(8) 1, 2	220	15	37, 38	45, 46	...	6
83	4, 5	25, 26	8	216–221	...	28–30	3, 4	221	16	39, 40	47, 48	...	7
84	5, 6	27, 28	9	222–226	...	(6) 1–3	5, 6	222	17	41, 42	49, 50	...	8
1885	6, 7	29, 30	10	227–231	...	4–6	7, 8	223	18	43, 44	51, 52	...	9
86	7, 8	31, 32	11	232–236	...	7–9	9, 10	224	19	45, 46	53, 54	...	10
87	9	33, 34	12	237–242	...	10–12	11, 12	225	20	47, 48	55, 56	1	11
88	10	35, 36	13	243–249	...	13–15	13, 14	226	21	49, 50	57, 58	2, 3	12
89	11	37, 38	14	250–255	...	16–18	15, 16	227	22	(3) 1, 2	59, 60	4, 5	13

* Joining Series 1 and 2 together. Also written as (3) 1, 2, 3, etc.

Year.	Compt. rend.	Dingl. poly. J.	Gazzetta.	J. Amer. Chem. Soc.	J. Chem. Soc.	J. Pharm. Chim.	J. prakt. Chem.	J. Russ. Phys. Chem. Soc.	J. Soc. Chem. Ind.	Monatsh.	Mon. scient.*	Nature.	Phil. Mag.
1860	50, 51	155–158	...	...	...	37, 38	79–81	...	...	...	4	...	19, 20
61	52, 53	159–162	...	...	...	39, 40	82–84	...	...	...	...	...	21, 22
62	54, 55	163–166	...	...	15	41, 42	85–87	...	...	...	...	...	23, 24
63	56, 57	167–170	...	...	16	43, 44	88–90	...	...	..	5	...	25, 26
64	58, 59	171–174	...	...	17	45, 46	91–93	...	...	...	6	...	27, 28
1865	60, 61	175–178	...	...	18	(4) 1, 2	94–96	...	...	...	7	...	29, 30
66	62, 63	179–182	...	...	19	3, 4	97–99	...	...	...	8	...	31, 32
67	64, 65	183–186	...	...	20	5, 6	100–102	...	...	...	9	...	33, 34
68	66, 67	187–190	...	...	21	7, 8	103–105	...	...	..	10	...	35, 36
69	68, 69	191–194	...	...	22	9, 10	106–108	1	...	...	11	1	37, 38
1870	70, 71	195–198	...	...	23	11, 12	(2) 1, 2	2	...	...	12	1, 2, 3	39, 40
71	72, 73	199–202	1	...	24	13, 14	3, 4	3	...	...	13	3, 4, 5	41, 42
72	74, 75	203–206	2	...	25	15, 16	5, 6	4	...	...	14	5, 6, 7	43, 44
73	76, 77	207–210	3	...	26	17, 18	7, 8	5	...	...	15	7, 8, 9	45, 46
74	78, 79	211–214	4	...	27	19, 20	9, 10	6	...	...	16	9, 10, 11	47, 48
1875	80, 81	215–218	5	...	28	21, 22	11, 12	7	...	...	17	11, 12, 13	49, 50
76	82, 83	219–222	6	...	29, 30	23, 24	13, 14	8	...	...	18	13, 14, 15	(5) 1, 2
77	84, 85	223–226	7	...	31, 32	25, 26	15, 16	9	...	...	19	15, 16, 17	3, 4
78	86, 87	227–230	8	...	33, 34	27, 28	17, 18	10	...	...	20	17, 18, 19	5, 6
79	88, 89	231–234	9	1	35, 36	29, 30	19, 20	11	...	...	21	19, 20, 21	7, 8
1880	90, 91	235–238	10	2	37, 38	(5) 1, 2	21, 22	12	...	1	22	21, 22, 23	9, 10
81	92, 93	239–242	11	3	39, 40	3, 4	23, 24	13	...	2	23	23, 24, 25	11, 12
82	94, 95	243–246	12	4	41, 42	5, 6	25, 26	14	1	3	24	25, 26, 27	13, 14
83	96, 97	247–250	13	5	43, 44	7, 8	27, 28	15	2	4	25	27, 28, 29	15, 16
84	98, 99	251–254	14	6	45, 46	9, 10	29, 30	16	3	5	26	29, 30, 31	17, 18
1885	100, 101	255–258	15	7	47, 48	11, 12	31, 32	17	4	6	27	31, 32, 33	19, 20
86	102, 103	259–262	16	8	49, 50	13, 14	33, 34	18	5	7	28	33, 34, 35	21, 22
87	104, 105	263–266	17	9	51, 52	15, 16	35, 36	19	6	8	29, 30	35, 36, 37	23, 24
88	106, 107	267–270	18	10	53, 54	17, 18	37, 38	20	7	9	31, 32	37, 38, 39	25, 26
89	108, 109	271–274	19	11	55, 56	19, 20	39, 40	21	8	10	33, 34	39, 40, 41	27, 28

* See footnote, p. xxii.

Year.	Phil. Trans.	Pogg. Annalen.	Proc. Chem. Soc.	Proc. Roy. Soc.	Quart. J. Chem. Soc.	Rec. Trav. Chim.	Sitzungsber. K. Akad. Wiss. Wien.	Stahl und Eisen.	Wied. Annalen.	Zeitsch. anal. Chem.	Zeitsch. angew. Chem.	Zeitsch. Kryst. Min.	Zeitsch. physikal. Chem.
1860	150	109–111	...	10, 11	13	...	39–42	...	...	...	...	...	...
61	151	112–114	...	11	14	...	43, 44	...	...	...	...	...	...
62	152	115–117	...	11, 12	Continued	...	45, 46	...	...	1	...	...	...
63	153	118–120	...	12, 13	as J.	...	47, 48	...	...	2	...	...	...
64	154	121–123	...	13	Chem. Soc.	...	49, 50	...	...	3	...	...	...
1865	155	124–126	...	14	...	...	51, 52	...	...	4	...	...	...
66	156	127–129	...	15	...	...	53, 54	...	...	5	...	...	...
67	157	130–132	...	15, 16	...	...	55, 56	...	...	6	...	...	...
68	158	133–135	...	16, 17	...	...	57, 58	...	...	7	..	...	...
69	159	136–138	...	17, 18	...	...	59, 60	...	...	8	...	...	...
1870	160	139–141	...	18, 19	...	...	61, 62	...	...	9	...	...	...
71	161	142–144	...	19, 20	...	...	63, 64	...	...	10	...	...	...
72	162	145–147	...	20, 21	...	...	65, 66	...	...	11	...	...	...
73	163	148–150	...	21, 22	...	...	67, 68	...	...	12	...	...	...
74	164	151–153	...	22, 23	...	...	69, 70	...	...	13	...	...	...
1875	165	154–156	...	23, 24	...	...	71, 72	...	...	14	...	...	...
76	166	157–159	...	24, 25	...	...	73, 74	...	...	15	...	...	...
77	167	160	...	25, 26	...	...	75, 76	...	1, 2	16	...	1, 2	...
78	168, 169	Continued	...	27, 28	...	...	77, 78	...	3–5	17	...	2, 3	...
79	170	as Wied. Annalen.	...	28, 29, 30	...	...	79, 80	...	6–8	18	...	3, 4	...
1880	171	...	...	30, 31	...	...	81, 82	...	9–11	19	...	4, 5	...
81	172	...	...	31, 32, 33	...	...	83, 84	1	12–14	20	...	5, 6	...
82	173	...	...	33, 34	...	1	85, 86	2	15–17	21	...	6, 7	...
83	174	...	...	34, 35, 36	...	2	87, 88	3	18–20	22	...	7, 8	...
84	175	...	...	36, 37, 38	...	3	89, 90	4	21–23	23	...	8, 9, 10	...
1885	176	...	1	38, 39	...	4	91, 92	5	24–26	24	...	10, 11	...
86	177	...	2	40, 41	...	5	93, 94	6	27–29	25	...	11, 12	...
87	A. 178	...	3	42, 43	...	6	95, 96	7	30–32	26	...	12, 13	1
88	179	...	4	43, 44, 45	...	7	97	8	33–35	27	1	13, 14, 15	2
89	180	...	5	45, 46, 47	...	8	98	9	36–38	28	2	15	3, 4

Year.	Amer. Chem. J.	Amer. J. Sci.	Analyst.	Annalen.	Ann. Chim. Phys.	Ann. Mines.	Arch. Pharm.	Ber.	Bull. Soc. chim.	Chem. News.	Chem. Trade J.	Chem. Weekblad.	Chem. Zeit.	Compt. rend.
1890	12	39, 40	15	256–260	19–21	17, 18	228	23	3, 4	61, 62	6, 7	...	14	110, 111
91	13	41, 42	16	261–266	22–24	19, 20	229	24	5, 6	63, 64	8, 9	...	15	112, 113
92	14	43, 44	17	267–271	25–27	(9) 1, 2	230	25	7, 8	65, 66	10, 11	...	16	114, 115
93	15	45, 46	18	272–277	28–30	3, 4	231	26	9, 10	67, 68	12, 13	...	17	116, 117
94	16	47, 48	19	278–283	(7) 1–3	5, 6	232	27	11, 12	69, 70	14, 15	...	18	118, 119
1895	17	49, 50	20	284–288	4–6	7, 8	233	28	13, 14	71, 72	16, 17	...	19	120, 121
96	18	(4) 1, 2	21	289–293	7–9	9, 10	234	29	15, 16	73, 74	18, 19	...	20	122, 123
97	19	3, 4	22	294–298	10–12	11, 12	235	30	17, 18	75, 76	20, 21	...	21	124, 125
98	20	5, 6	23	299–303	13–15	13, 14	236	31	19, 20	77, 78	22, 23	...	22	126, 127
99	21, 22	7, 8	24	304–309	16–18	15, 16	237	32	21, 22	79, 80	24, 25	...	23	128, 129
1900	23, 24	9, 10	25	310–313	19–21	17, 18	238	33	23, 24	81, 82	26, 27	...	24	130, 131
01	25, 26	11, 12	26	314–319	22–24	19, 20	239	34	25, 26	83, 84	28, 29	...	25	132, 133
02	27, 28	13, 14	27	320–325	25–27	(10) 1, 2	240	35	27, 28	85, 86	30, 31	...	26	134, 135
03	29, 30	15, 16	28	326–329	28–30	3, 4	241	36	29, 30	87, 88	32, 33	...	27	136, 137
04	31, 32	17, 18	29	330–337	(8) 1–3	5, 6	242	37	31, 32	89, 90	34, 35	...	28	138, 139
1905	33, 34	19, 20	30	338–343	4–6	7, 8	243	38	33, 34	91, 92	36, 37	...	29	140, 141
06	35, 36	21, 22	31	344–350	7–9	9, 10	244	39	35, 36	93, 94	38, 39	...	30	142, 143
07	37, 38	23, 24	32	351–357	10–12	11, 12	245	40	(4) 1, 2	95, 96	40, 41	4	31	144, 145
08	39, 40	25, 26	33	358–363	13–15	13, 14	246	41	3, 4	97, 98	42, 43	5	32	146, 147
09	41, 42	27, 28	34	364–371	16–18	15, 16	247	42	5, 6	99, 100	44, 45	6	33	148, 149
1910	43, 44	29, 30	35	372–377	19–21	17, 18	248	43	7, 8	101, 102	46, 47	7	34	150, 151
11	45, 46	31, 32	36	378–385	22–24	19, 20	249	44	9, 10	103, 104	48, 49	8	35	152, 153
12	47, 48	33, 34	37	386–394	25–27	(11) 1, 2	250	45	11, 12	105, 106	50, 51	9	36	154, 155
13	49, 50	35, 36	38	395–401	28–30	3, 4	251	46	13, 14	107, 108	52, 53	10	37	156, 157
14	Publication	37, 38	39	...	...	5, 6	252	47	15, 16	109, 110	54, 55	11	38	158, 159
1915	ceased	39, 40	40	...	...	...	253	48	17, 18	111, 112	56, 57	12	39	160, 161
16	...	41, 42	41	...	...	...	254	49	19, 20	113, 114	58, 59	13	40	162, 163
17	...	43, 44	42	...	...	...	255	50	21, 22	115, 116	60, 61	14	41	164, 165
18	...	45, 46	43	...	...	...	..	51	23, 24	117	62, 63	15	42	166, 167
19	...	47, 48	44	...	...	...	...	52	25, 26	118, 119	64, 65	16	43	168, 169

Year.	Dingl. poly. J.	Gazzetta.	J. Amer. Chem. Soc.	J. Chem. Soc.	J. Ind. Eng. Chem.	J. Pharm. Chim.	J. Physical Chem.	J. prakt. Chem.	J. Russ. Phys. Chem. Soc.	J. Soc. Chem. Ind.	Monatsh.	Mon.* scient.	Nature.	Phil Mag.
1890	275–278	20	12	57, 58	...	21, 22	...	41, 42	22	9	11	35, 36	41, 42, 43	29, 30
91	279–282	21	13	59, 60	...	23, 24	...	43, 44	23	10	12	37, 38	43. 44, 45	31, 32
92	283–286	22	14	61, 62	...	25, 26	...	45, 46	24	11	13	39, 40	45, 46, 47	33, 34
93	287–290	23	15	63, 64	...	27, 28	...	47, 48	25	12	14	41, 42	47, 48, 49	35, 36
94	291–294	24	16	65, 66	...	29, 30	...	49, 50	26	13	15	43, 44	49, 50, 51	37, 38
1895	295–298	25	17	67, 68	...	(6) 1, 2	...	51, 52	27	14	16	45, 46	51, 52. 53	39, 40
96	299–302	26	18	69, 70	...	3, 4	...	53, 54	28	15	17	47, 48	53, 54, 55	41, 42
97	303–306	27	19	71, 72	...	5, 6	...	55, 56	29	16	18	49, 50	55, 56, 57	43, 44
98	307–310	28	20	73, 74	...	7, 8	...	57, 58	30	17	19	51, 52	57, 58, 59	45, 46
99	311–314	29	21	75, 76	...	9, 10	...	59, 60	31	18	20	53, 54	59, 60, 61	47, 48
1900	315	30	22	77, 78	...	11, 12	4	61, 62	32	19	21	55, 56	61, 62, 63	49, 50
01	316	31	23	79, 80	...	13, 14	5	63, 64	33	20	22	57	63, 64, 65	(6) 1, 2
02	317	32	24	81, 82	...	15, 16	6	65, 66	34	21	23	58	65, 66, 67	3, 4
03	318	33	25	83, 84	...	17, 18	7	67, 68	35	22	24	59	67, 68, 69	5, 6
04	319	34	26	85, 86	...	19, 20	8	69, 70	36	23	25	60, 61	69, 70, 71	7, 8
1905	320	35	27	87, 88	...	21, 22	9	71, 72	37	24	26	62, 63	71, 72, 73	9, 10
06	321	36	28	89, 90	...	23, 24	10	73, 74	38	25	27	64, 65	73, 74, 75	11, 12
07	322	37	29	91, 92	...	25, 26	11	75, 76	39	26	28	66, 67	75, 76, 77	13, 14
08	323	38	30	93, 94	...	27, 28	12	77, 78	40	27	29	68, 69	77, 78, 79	15, 16
09	324	39	31	95, 96	1	29, 30	13	79, 80	41	28	30	70, 71	79–82	17, 18
1910	325	40	32	97, 98	2	(7) 1, 2	14	81, 82	42	29	31	72, 73	82–85	19, 20
11	326	41	33	99, 100	3	3, 4	15	83, 84	43	30	32	74, 75	85–88	21, 22
12	327	42	34	101, 102	4	5, 6	16	85, 86	44	31	33	76, 77	88, 89, 90	23, 24
13	328	43	35	103, 104	5	7, 8	17	87, 88	45	32	34	78, 79	90, 91, 92	25, 26
14	329	44	36	105, 106	6	9, 10	18	89, 90	46	33	35	80, 81	92, 93, 94	27, 28
1915	...	45	37	107, 108	7	11, 12	19	91, 92	47	34	36	82	94, 95, 96	29, 30
16	...	46	38	109, 110	8	13, 14	20	93, 94	48	35	37	83	96, 97, 98	31, 32
17	...	47	39	111, 112	9	15, 16	21	95, 96	...	36	38	84	98, 99, 100	33, 34
18	...	48	40	113, 114	10	17, 18	22	97, 98	...	37	39	85	100–102	35, 36
19	...	49	41	115, 116	11	19, 20	23	99, 100	...	38	40	86	102–104	37, 38

* See footnote, p. xxii.

Year.	Phil. Trans.	Physikal. Zeitsch.	Proc. Chem. Soc.	Proc. Roy. Soc.	Rec. Trav. Chim.	Sitzungsber. K. Akad. Wiss. Wien.	Stahl und Eisen.	Wied. Annalen.	Zeitsch. anal. Chem.	Zeitsch. angew. Chem.	Zeitsch. anorg. Chem.	Zeitsch. Elektro-Chem.	Zeitsch. Kryst. Min.	Zeitsch. physikal. Chem.
1890	A. 181	...	6	47, 48, 49	9	99	10	39–41	29	3	...	...	16, 17, 18	5, 6
91	182	...	7	49, 50	10	100	11	42–44	30	4	...	...	19, 20	7, 8
92	183	...	8	50, 51, 52	11	101	12	45–47	31	5	1, 2	...	20, 21	9, 10
93	184	...	9	52, 53, 54	12	102	13	48–50	32	6	3, 4, 5	...	21, 22	11, 12
94	185	...	10	55, 56, 57	13	103	14	51–53	33	7	5–7	1	23, 24	13–15
1895	186	...	11	57, 58, 59	14	104	15	54–56	34	8	8–10	1, 2	24, 25	16–18
96	187, 188	...	12	59, 60	15	105	16	57–59	35	9	11, 12, 13	2, 3	26–28	19–21
97	189, 190	...	13	60, 61, 62	16	106	17	60–63	36	10	13–15	3, 4	28, 29	22–24
98	191	...	14	62, 63, 64	17	107	18	64–66	37	11	16–19	4, 5	29–31	25–27
99	192, 193	...	15	64, 65, 66	18	108	19	67–69	38	12	19–22	5, 6	31, 32	28–31
1900	194, 195	1	16	66, 67	19	109	20	Con-	39	13	22–25	6, 7	32–34	32–35
01	196, 197	2	17	68, 69	20	110	21	tinued as	40	14	26–29	7	34–36	36–38
02	198, 199	3	18	69, 70	21	111	22	Annalen	41	15	29–33	8	36, 37	39–42
03	200–202	4	19	71, 72	22	112	23	der	42	16	33–37	9	37–39	43–46
04	203	5	20	72, 73, 74	23	113	24	Physik.	43	17	38–42	10	39, 40	47–49
1905	204, 205	6	21	74–76	24	114	25		44	18	43–48	11	40–42	50–53
06	206	7	22	A. 77, 78	25	115	26		45	19	48–52	12	42, 43	54–57
07	207	8	23	78, 79, 80	26	116	27		46	20	52–56	13	43, 44	58–60
08	207–209	9	24	80, 81	27	117	28		47	21	56–60	14	44–46	61–64
09	209, 210	10	25	82, 83	28	118	29		48	22	61–65	15	46, 47	65–69
1910	210	11	26	83, 84	29	119	30		49	23	65–69	16	48, 49	70–74
11	210, 211	12	27	84, 85, 86	30	120	31		50	24	69–73	17	49, 50	75–77
12	211, 212	13	28	86, 87	31	121	32		51	25	73–79	18	50–52	78–80
13	212, 213	14	29	88, 89	32	122	33		52	26	79–83	19	52, 53	81–86
14	213, 214	15	30	89, 90	33	123	34		53	27	84–90	20	54	86–88
1915	215, 216	16	Publication	...	34	...	35		54	28	90–93	21	55	89, 90
16	216, 217	17	of matter	...	35	...	36		55	29	94–98	22	...	91, 92
17	217	18	of scientific	...	36, 37	...	37		56	30	99–101	23	...	92
18	217	...	interest now	...	37	...	38		57	31	102–104	24	No	92
19	...	...	abandoned.	...	38	...	39		58	32	105–109	25	issue*	...

* Remainder of vol. 55 appeared in 1920.

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INORGANIC CHEMISTRY.

VOLUME XI. PART II.

A TEXT-BOOK OF INORGANIC CHEMISTRY.

VOL. XI. PART II.

ORGANOMETALLIC COMPOUNDS.

CHAPTER I.

ALIPHATIC ARSENICAL COMPOUNDS.

Compounds of the Type $RAsH_2$.

The primary alkyl arsines are prepared by the reduction of the corresponding arsinic acids or their salts, using amalgamated zinc dust in alcoholic solution, in an atmosphere of hydrogen. In the case of *methylarsine*, methyldichloroarsine may be reduced instead of the arsinic acid, and for *n-propylarsine* the reduction is carried out in sulphuric acid. The compounds are highly refractive, colourless liquids, very poisonous, soluble in carbon disulphide and other organic solvents, but only slightly soluble in water. The methyl derivative on prolonged heating at a high temperature decomposes, yielding methane, hydrogen, and arsenic, but in the case of the ethyl compound some *triethylarsine* is also formed. Oxidation with atmospheric oxygen converts these bodies into *arsenoxides*, but dilute nitric acid or silver nitrate converts them to alkylarsinic acids. Bromine in carbon disulphide solution removes the arsenic from methylarsine as arsenious bromide, whilst the halogen in ether solution converts the ethyl compound into *ethyldibromoarsine*. Sulphuric acid reacts with ethylarsine at ordinary temperatures to form a crystalline *sulphate*, which is the only sign of basic properties these compounds show, thus distinguishing them as a class from the phosphines and the amines. They react with alkyl iodides when heated in a sealed tube to form *tetra-alkylarsonium compounds* :

$$RAsH_2+3RI=R_4AsI+2HI$$

Methylarsine, $CH_3.AsH_2$,[1] may be prepared either by the reduction of sodium methylarsinate with amalgamated zinc dust in alcoholic hydrochloric acid solution, the operation being conducted in a hydrogen atmosphere, or by the reduction of methyldichloroarsine.

[1] Palmer and Dehn, *Ber.*, 1901, 34, 3594; Dehn, *Amer. Chem. J.*, 1905, 33, 101; 1908, 40, 117; Williams, *Amer. Chem. J.*, 1908, 40, 107.

It is a colourless, highly refractive liquid with B.pt. 2° C. at 755 mm., 17° C. at 1140 mm., miscible in all proportions with alcohol or carbon disulphide, but only soluble in water to the extent of 85 parts in a million. It is very poisonous, fumes in air, and has an odour resembling cacodyl. When heated for three hours at 310° C. it decomposes with formation of methane, hydrogen, and arsenic. Oxidation by atmospheric oxygen gives methylarsenoxide, but oxidation by nitric acid, silver nitrate, or aqueous potassium iodide yields methylarsinic acid. When passed into a solution of bromine in carbon disulphide, it gives arsenious bromide, hydrogen bromide, and methyl bromide, whilst with aqueous mercuric chloride, mercuric methylarsinate and mercurous chloride result. Methylarsine is converted by alcoholic iodine into methyldi-iodoarsine. Hydrogen chloride has practically no action on it, even on prolonged treatment. It combines with methyl iodide at 110° C., forming tetramethylarsonium iodide and hydrogen iodide, whilst propyl iodide and methylarsine at 100° C. yield some methylpropylarsonium iodide. Methylarsenoxide and methylarsine combine to form a red polymer, $(CH_3As)_4$.

Ethylarsine, $C_2H_5.AsH_2$, is obtained by the reduction of magnesium ethyl arsinate with amalgamated zinc dust and alcoholic hydrochloric acid. It is a very poisonous liquid, B.pt. 36° C., density 1·217 at 22° C., soluble in water to the extent of 126 parts in a million at 19° C. In dry air this arsine is oxidised to ethylarsenoxide, but with nitric acid or silver nitrate to ethylarsinic acid. When heated for three hours at 235° C. it yields triethylarsine, ethane, hydrogen, and arsenic. With stannic or mercuric chlorides, arsenic or antimony trichloride, it gives ethyldichloroarsine, whilst with bromine in ether solution, ethyldibromoarsine results. The arsine is unaffected by two hours' heating at 70° C. with hydrochloric acid of density 1·2, but with concentrated sulphuric acid at ordinary temperatures it forms a crystalline *sulphate* to which the following formula is ascribed—$2Et.AsH_2.H_2SO_4$. Sulphur dissolves in ethylarsine with the formation of ethylarsine sulphide, and when heated with alcoholic carbon disulphide at 120° C., the arsine gives triethylarsine sulphide. When heated with excess of alkyl iodide at 110° C., tetra-alkylarsonium compounds are produced, *e.g.* ethyl iodide gives tetraethylarsonium iodide.

n-Propylarsine is a liquid, obtained from propylarsinic acid by reduction with amalgamated zinc and concentrated sulphuric acid.[1]

Compounds of the Type R_2AsH.

The dialkyl arsines are formed when the corresponding oxides or dihalogenated arsines are reduced with platinised zinc in alcoholic hydrochloric acid. Reduction of the corresponding arsinic acids gives the same result. The lower members of the series are spontaneously inflammable in air, and more reactive than the primary alkyl arsines. Excluding the first member of the series, dimethylarsine, they only possess feeble basic properties. Their general reactions may be readily ascertained by consulting the table given on p. 6 for dimethylarsine.

Dimethylarsine, $(CH_3)_2.AsH$.[2]—A stream of hydrogen is passed

[1] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 113.
[2] Palmer, *Ber.*, 1894, 27, 1378; Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 1.

through a mixture of platinised granulated zinc, alcohol, and concentrated hydrochloric acid, then cacodyl chloride added dropwise. The hydrogen carries off the dimethylarsine, which is washed by passing through water, dried by means of calcium chloride, and finally condensed by an ice and salt freezing mixture. It may also be obtained by reducing crude cacodyl oxide (cacodyl and cacodyl oxide) with platinised zinc and hydrochloric acid in alcoholic solution.[1]

Dimethylarsine is a colourless, spontaneously inflammable liquid, having an odour of cacodyl. It boils at 35·6° C. at 747 mm., and at 55° C. at 1·74 atmospheres. At 29° C. its density is 1·213. Its reactions are indicated in the table on page 6.

Diethylarsine, $(C_2H_5)_2.AsH$, is obtained by the reduction of diethyliodoarsine with zinc-copper couple and alcohol in a specially designed apparatus.[2] It is a colourless liquid, B.pt. 105° C., having a garlic odour and is spontaneously oxidised in air. It was considered at one time[3] that this arsine resulted from the action of certain moulds, but this idea appears to be incorrect from the behaviour of diethylarsine with mercuric chloride in hydrochloric acid solution, as compared with that of the gas obtained with the moulds. When the solution mentioned is treated with the gaseous arsine, a *mercurosochloride*, $(C_2H_5)_2AsCl.2HgCl$, is formed, which, on boiling with water, gives diethylchloroarsine.[4]

Di-isoamylarsine, $(C_5H_{11})_2.AsH$, is formed by the reduction of di-*iso*amylarsinic acid with amalgamated zinc and hydrochloric acid.[5] The odour of this arsine resembles that of amyl alcohol more than that of an arsine. It boils at 150° C. at 99 mm., and at 220° C. commences to decompose, yielding tri-*iso*amylarsine, hydrogen, and other products.[6] In the air it oxidises to di-*iso*amylarsinic acid, and an oil, probably di-*iso*amyl cacodyl oxide.

Compounds of the Type R_3As.

The trialkylarsines may be obtained in a variety of ways :

(1) The double salts formed by the interaction of zinc dialkyls and arsenic trihalides yield tertiary arsines on treatment with potassium hydroxide :

$$3ZnR_2+2AsX_3=2R_3As+3ZnX_2$$

(2) In poor yield by heating alloys of arsenic and sodium with alkyl iodides :

$$Na_3As+3RI=R_3As+3NaI$$

(3) By treating magnesium alkyl halides with arsenic trihalides :

$$3RMgX+AsX_3=R_3As+3MgX_2$$

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[1] See also Natta, *Atti II. Cong. Naz. Chim. Pura Appl.*, 1926, 1326.

[2] Wigren, *Annalen*, 1924, 437, 285.

[3] Biginelli, *Atti R. Accad. Lincei*, 1900, [v.], 9, ii. 210, 246.

[4] The following compounds, described by Biginelli, are of doubtful constitution: $(C_2H_5)_2AsH.2HgCl_2$; $O[AsH(C_2H_5)_2I]_2$; $O[AsH(C_2H_5)_2]SO_4$; $O[AsH(C_2H_5)_2(OH)]_2.KNO_3$; $(C_2H_5)_2HAs.O.AsH(C_2H_5)_2.4HgCl_2$; $(C_2H_5)_2AsH.2HgNO_3$.

[5] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 53.

[6] Williams, *Amer. Chem. J.*, 1908, 40, 118.

REACTIONS OF DIMETHYLARSINE.

Treatment.	Products of Reaction.
Heated in sealed tube at 335° C. for one hour with only traces of air present.	Black lustrous substance, probably $[(CH_3)As]_x$, and inflammable gases.
Slow oxidation in air.	"Erytharsine," $[(CH_3)As]_4As_2O_3$.
Pure oxygen.	Ethane, arsenic, black mass containing polymer of methylarsine.
Chlorine.	Methyldichloroarsine.
Bromine.	Hydrogen, hydrogen bromide, cacodyl bromide, $(CH_3)_2AsBr$, and cacodyl bromide hydrobromide, $(CH_3)_2AsBr.HBr$.
Iodine.	Cacodyl iodide hydriodide, $(CH_3)_2AsI.HI$.
Aqueous iodine.	Cacodylic acid, $(CH_3)_2AsO.OH$, hydrogen iodide.
*Iso*butyl iodide at 110° C. for five hours.	Dimethyldi-*iso*butylarsonium iodide, $(CH_3)_2(C_4H_9)_2AsI$.
Cetyl iodide at 100° C.	Dimethyldicetylarsonium iodide, $(CH_3)_2(C_{16}H_{33})_2AsI$.
*Iso*propyl iodide at 100° C.	Dimethyldi-*iso*propylarsonium iodide, $(CH_3)_2(C_3H_7)_2AsI$.
Allyl iodide, 3 to 4 molecules.	Dimethyldiallylarsonium iodide, $(CH_3)_2(C_3H_5)_2AsI$.
Allyl iodide, 1 molecule.	Dimethylallylarsine, $(CH_3)_2(C_3H_5)As$.
Dry hydrogen bromide at −10° C.	Cacodyl bromide, $(CH_3)_2AsBr$, hydrogen.
Dry hydrogen iodide.	Cacodyl iodide, $(CH_3)_2AsI$, hydrogen.
Concentrated sulphuric acid.	Sulphate, $2(CH_3)_2AsH.H_2SO_4$, cacodyl sulphide, $[(CH_3)_2As]_2S$, cacodylic acid.
Nitrous oxide.	No action.
Nitric oxide or peroxide; nitrous or nitric acid.	Nitrous oxide or nitrogen, cacodylic acid and other oxidation products.
Chromic oxide.	Dicacodyl, $(CH_3)_4As_2$, or cacodylic acid.
Aqueous potassium dichromate.	Reduction takes place.
Lead peroxide	Lead, lead cacodylate, dicacodyl.
Ferric chloride.	Ferrous chloride, cacodyl chloride, $(CH_3)_2AsCl$.
Auric chloride.	Dicacodyl, cacodyl chloride, cacodylic acid.
Stannic chloride.	Chlorostannide, $(CH_3)_2As.SnCl_3$, hydrogen chloride.
Phosphorus trichloride.	Cacodyl chloride, hydrogen chloride, and probably $(CH_3)_2P_4$ or $(CH_3P)_x$.
Arsenic trichloride.	Cacodyl chloride, hydrogen chloride, $(CH_3As)_x$.
Antimony trichloride.	Cacodyl chloride, antimony hydride, antimony, hydrogen chloride.
Cacodyl chloride in sealed tube at 100° C. for two to three hours.	Dicacodyl, hydrogen chloride.
Sulphur.	Cacodyl sulphide or disulphide, $[(CH_3)_2As]_2S$ or $[(CH_3)_2As]_2S_2$.
Liquid sulphur dioxide.	Cacodyl disulphide, methylarsine sulphide, (CH_3AsS), trimethylarsine sulphide, $(CH_3)_3AsS$, cacodylic acid.
Sulphur dichloride.	Cacodyl chloride, sulphur, hydrogen sulphide.
Silver nitrate or mercuric chloride.	Reduction to the metal.
Potassium ferricyanide.	Potassium ferrocyanide, dicacodyl, potassium cacodylate.
Dibromosuccinic acid.	Cacodyl bromide, succinic acid.
Acetyl iodide.	Cacodyl iodide, acetaldehyde.
Chloroformic ethyl ester.	Cacodyl chloride.
Arsenic trioxide.	Red-brown product, $(CH_3As)_x$.

(4) By the distillation of tetra-alkylarsonium iodides or their arsenic trihalide addition products with solid potassium hydroxide :

$$R_4AsI = R_3As + RI$$

(5) In one case only has the Fittig reaction been used, namely, in the preparation of tri-*n*-propylarsine by boiling a mixture of propyl chloride, arsenic trichloride, and sodium :

$$3C_3H_7Cl + AsCl_3 + 6Na = (C_3H_7)_3As + 6NaCl$$

The mixed tertiary arsines are best isolated by the following methods :

(1) The interaction of alkyl-di-iodoarsines or dialkyliodoarsines with zinc dialkyls :

$$RAsI_2 + ZnR'_2 = RR'_2As + ZnI_2$$
$$2R_2AsI + ZnR'_2 = 2R_2R'As + ZnI_2$$

(2) By treating dialkylarsines with alkyl iodides :

$$R_2AsH + R'I = R_2R'As + HI$$

(3) By the Grignard reaction, as given under (3) on page 5.

All the tertiary arsines are highly refractive liquids, with the exception of dimethyl-*n*-propylarsine, which is stated to be a crystallisable compound. Those of low molecular weight absorb oxygen from the air, yielding oxides. The trialkylarsines combine with the halogens, sulphur, alkyl iodides, and cyanogen bromide, yielding products of the types, R_3AsX_2, R_3AsS, R_4AsI, and $R_3As(CN)Br$ respectively. Mercuric chloride and the chlorides of gold, platinum and palladium also form double compounds with some of the arsines. The de-alkylation of trimethylarsine may be accomplished by distilling the arsine with iodine, the amount of the latter element present determining the number of alkyl groups removed. Complete removal of the methyl groups can, therefore, take place in three stages, as shown by the following equations :

$$Me_3As + I_2 = Me_2AsI + MeI$$
$$Me_3As + 2I_2 = MeAsI_2 + 2MeI$$
$$Me_3As + 3I_2 = AsI_3 + 3MeI$$

Trialkylarsine Oxides.—Only three compounds of this type are known —the methyl, ethyl, and *n*-propyl derivatives. The first two are formed by direct oxidation of the arsines by atmospheric oxygen, and the methyl compound also results when cacodyl oxide, $(Me_2As)_2O$, in methyl alcohol solution is treated with methyl iodide and sodium hydroxide. The propyl derivative is formed when tetra-*n*-propylarsonium hydroxide is heated in a stream of hydrogen. These oxides exhibit no acid properties but are inclined to be feebly basic, the ethyl compound yielding a nitrate, and the propyl compound a double compound with mercuric chloride.

Trialkylarsine Sulphides.—Direct addition of sulphur and trialkylarsine takes place in the case of the ethyl compound, the product also resulting from the interaction of diethylarsine and carbon disulphide at 120° C., or on heating ethylarsine disulphide at 195° C. Trimethylarsine sulphide is obtained from dimethylarsine and liquid

sulphur dioxide, or from trimethylarsine dibromide by the following reactions :

$$Me_3AsBr_2 \xrightarrow{KOEt} Me_3As(OEt)_2 \xrightarrow{H_2S} Me_3AsS$$

The intermediate ethoxide is not isolated in this reaction.

Selenium adds on directly to trimethylarsine, forming trimethylarsine selenide, a product unstable in air, but in solution fairly stable in the dark.

Trialkylarsine Dihalides, Hydroxyhalides and Cyanohalides.—These form a far more numerous class of compounds than the oxides and sulphides. Dihalides are only known in the case of methyl and ethyl compounds, and may be obtained by direct addition of the halogen. No dichlorides appear to be known with certainty. Triethylarsine dibromide has also been formed by replacing the sulphur of triethylarsine sulphide by means of concentrated hydrobromic acid. An indirect method of forming triethylarsine di-iodide consists in distilling the compound, $Et_4AsI.AsI_3$. The dihalides are rather unstable in air ; chlorine and also concentrated nitric or sulphuric acid eliminate the halogen. The iodine in triethylarsine di-iodide may be removed by potassium hydroxide, giving the corresponding oxide. Work on the mixed trialkylarsines shows that they readily add on cyanogen bromide to form cyanobromides :

$$R_2R'.As + CN.Br = R_2R'As.CN.Br$$

It is necessary to carry out this reaction in very dry solvents since traces of moisture decompose the resulting cyanobromides with formation of hydroxybromides :

$$R_2R'As.CN.Br + H_2O = R_2R'As.OH.Br + HCN$$

The hydroxybromides are so hygroscopic that it is impossible to isolate them, hence they are converted to the hydroxypicrates by the addition of picric acid. The decomposition of ethyldi-*n*-propylarsine cyanobromide by heat is of interest, and takes place according to the following equation :

$$2C_2H_5(C_3H_7)_2As.CN.Br = C_2H_5Br + C_3H_7Br + C_2H_5.C_3H_7.As.CN + (C_3H_7)_2AsCN$$

Trimethylarsine, $(CH_3)_3As$.—This compound was first mentioned by Cahours and Hofmann,[1] who stated that it was obtained by the action of potassium hydroxide on the double salt derived from arsenic trichloride and zinc dimethyl. In 1859 Cahours [2] isolated this arsine by distilling tetramethylarsonium iodide or its double salts with potassium hydroxide, after having obtained only small yields by treating sodium arsenide with methyl iodide.[3] Auger [4] in 1904 stated that the brown polymer formed when arsenomethane is treated with a trace of hydrogen chloride yields trimethylarsine when distilled in an atmosphere of

[1] Cahours and Hofmann, *Compt. rend.*, 1855, 41, 831 ; *Jahresber.*, 1855, p. 538.
[2] Cahours, *Annalen*, 1859, 112, 228.
[3] Cahours and Riche, *Annalen*, 1854, 92, 361 ; see also Buckton, *Quart. J. Chem. Soc.*, 1863, 16, 17.
[4] Auger, *Compt. rend.*, 1904, 138, 1705.

hydrogen. Another method of obtaining the arsine is to heat cacodyl, $[Me_2As]_2$, for two hours at 340° C.[1] The first attempt to employ the Grignard reagent in the preparation of this arsine was made by Hibbert,[2] who states that his method gave a yield of over 70 per cent., but the free arsine was not isolated, the compound being distilled into an excess of bromine, thus being obtained as the perbromide, Me_3AsBr_4. Renshaw and Holm[3] in 1920 reinvestigated the foregoing methods and found the following to be the most suitable for isolating the pure arsine: To a mixture of 50 c.c. of dry xylene and 30 grams of crude zinc dimethyl in an atmosphere of carbon dioxide and cooled in ice, 33·3 grams of arsenic trichloride in 50 c.c. of dry xylene are slowly added, with occasional shaking. Considerable heat is developed, and at the conclusion of the reaction the xylene is poured off from the white solid which forms, the latter dissolved in water and an excess of strong alkali added. The mixture is then distilled on the water-bath until no further product comes over. 17·4 grams of crude material were collected by the investigators. The product then fractionated gives pure trimethylarsine distilling at 51·9° to 52° C. at 736 mm.

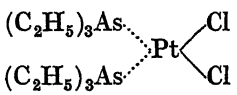
The arsine is a colourless, mobile liquid, having a density of 1·124 at 22° C. It absorbs oxygen from dry air giving trimethylarsine oxide,[4] and it combines directly with chlorine, bromine, iodine, sulphur, and selenium, whilst with mercuric chloride the double compound $2AsMe_3.HgCl_2$ is formed. The arsine combines readily with methyl iodide to form tetramethylarsonium iodide. The methyl groups of trimethylarsine may be replaced by iodine. When distilled with this element, dimethyliodoarsine, methyldi-iodoarsine, or arsenic tri-iodide are obtained, according to the amount of iodine used.

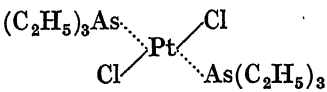
Triethylarsine, $(C_2H_5)_3As$, results together with ethyl cacodyl, $(Et_2As)_2$, by the interaction of sodium arsenide and ethyl iodide.[5] It has also been obtained by treating arsenic trichloride with zinc diethyl,[6] and by distilling tetraethylarsonium iodide with solid potassium hydroxide.[7] Auger and Billy[8] failed to obtain this arsine by the interaction of arsenic trichloride and magnesium ethyl bromide, but this was due probably to the conditions under which the experiment was carried out. The arsine is also said to occur when diethylchloroarsine is treated with sodium carbonate, bicarbonate, or hydroxide, other products being diethylarsenoxide and ethylarsenoxide.[9]

Triethylarsine is a fuming liquid, boiling at 140° C. at 736 mm. with partial decomposition, and has a density of 1·151 at 16·7° C. It has an unpleasant odour, and when gently warmed in air it inflames. It is insoluble in water, but is miscible with alcohol and ether. With concentrated nitric acid it explodes, but less concentrated acid gives the nitrate; it is miscible with concentrated sulphuric acid, the solution on warming evolving sulphur dioxide. When a solution of the arsine is slowly oxidised by air, triethylarsine oxide results, and an ether

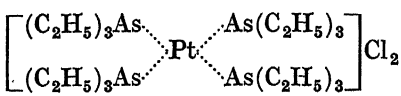
[1] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 120.
[2] Hibbert, *Ber.*, 1906, 39, 160.
[3] Renshaw and Holm, *J. Amer. Chem. Soc.*, 1920, 42, 1468.
[4] Cahours, *Annalen*, 1862, 122, 205.
[5] Landolt, *Annalen*, 1854, 89, 301.
[6] Hofmann, *Annalen*, 1857, 103, 357.
[7] Cahours, *Annalen*, 1862, 122, 192.
[8] Auger and Billy, *Compt. rend.*, 1904, 139, 597.
[9] Trochimovski, Buezwiński, and Kwapiszewski, *Rocz. Chem.*, 1928, 8, 423.

solution of the arsine, when boiled with sulphur, gives triethylarsine sulphide. With iodine, triethylarsine di-iodide is produced. The arsine combines with mercuric chloride, yielding a *mercurichloride*, M.pt. 163° to 164° C.[1] It does not reduce silver nitrate solution, but it forms *double compounds* with gold, platinum, and palladium chlorides.[2] The addition of triethylarsine dropwise to a solution of platinic chloride yields a mixture of two isomeric compounds having the formula $2(C_2H_5)_3As.PtCl_2$. Separation is effected by treatment with ether, the soluble derivative crystallising from this solvent in yellow crystals, which separate from alcohol in sulphur-yellow prisms; the ether-insoluble isomeride separates from alcohol in long, pale yellow prisms. These products have been represented by the following formulæ:





At present it is uncertain which compound should be represented by the *cis*-, and which by the *trans*-configuration. Triethylarsine again reacts with these compounds, yielding the derivative $[4(C_2H_5)_3As, Pt]Cl_2$, which is represented as follows:



The compound derived from palladium chloride and triethylarsine forms reddish-yellow prisms and has the formula $2(C_2H_5)_3As.PdCl_2$; the gold compound is rather unstable, and is represented by $(C_2H_5)_3As.AuCl$.

Tri-n-propylarsine, $(C_3H_7)_3As$.—To obtain this arsine the compound $(C_3H_7)_4AsI.AsI_3$ is distilled with solid potassium hydroxide,[3] or a mixture of propyl chloride and arsenic trichloride is boiled with sodium.[4] This body is a liquid, boiling at 158° C. at 73 mm. or 167° C. at 90 mm. When heated for two hours at 295° C. it partially decomposes, with formation of hexane and a compound which is probably $(C_3H_7As)_4$.

By treating Grignard's reagents with arsenious oxide, the following tertiary arsines have been obtained:[5] *Tri-n-butylarsine*, B.pt. 102° to 104° C. at 8 mm., density 0·9931 at 21° C.; *tri-n-amylarsine*, B.pt. 146° to 149° C. at 10 mm., density 0·9799 at 20° C.; *tri-n-hexylarsine*, B.pt. 165° to 169° C. at 6 to 7 mm., density 0·9660 at 22·5° C.; *tri-n-heptylarsine*, B.pt. 197° to 199° C. at 9 mm., density 0·9568 at 17° C.; *tri-n-octylarsine*, B.pt. 238° to 240° C. at 9 to 10 mm., density 0·9357 at 19° C.

Mixed Arsines of the Type $R'R_2As$.

Dimethylethylarsine, Me_2EtAs.[6]—Dimethyliodoarsine and zinc diethyl react to give this arsine, which is a colourless mobile liquid.

[1] Trochimovski, Buezwiński, and Kwapiszewski, *loc. cit.*
[2] Cahours and Gal, *Compt. rend.*, 1870, 70, 897, 1380; 1870, 71, 208; *Zeitsch. für Chem.*, 1870, 6, 662.
[3] Cahours, *Compt. rend.*, 1873, 76, 753; *Jahresber.*, 1873, p. 520.
[4] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 115.
[5] Cryszkiewicz-Trochimovski, *Rocz. Chem.*, 1928, 8, 250.
[6] Cahours, *Annalen*, 1862, 122, 219.

Methyldiethylarsine, $MeEt_2As$, is prepared as before, using methyldi-iodoarsine. It is a very volatile liquid, heavier than water, and combines directly with the halogens.

Methyldi-isoamylarsine, $Me(C_5H_{11})_2As$.[1] — *Iso*amylmagnesium chloride is treated with methyldichloroarsine in ether solution, and in a nitrogen atmosphere. The arsine is obtained as a liquid, B.pt. 95° to 99° C. at 11 mm.

Dimethyl-n-propylarsine, $Me_2(C_3H_7)As$, is obtained in the form of its hydriodide by the action of propyl iodide on dimethylarsine. It is a crystalline compound, insoluble in chloroform.[2]

γ-Phenylpropyldimethylarsine, $C_6H_5.[CH_2]_3.As(CH_3)_2$,[3] occurs when magnesium γ-bromopropylbenzene reacts with dimethyliodoarsine. It is a colourless, highly refractive liquid, B.pt. 133° C. at 14 mm.[4] With dimethyliodoarsine it forms an addition compound, $C_{11}H_{17}As.Me_2AsI$, consisting of colourless prisms, M.pt. 78° to 81° C.

δ-Phenyl-n-butyldimethylarsine, $C_6H_5.[CH_2]_4.As(CH_3)_2$,[5] is isolated from magnesium δ-phenyl-*n*-butyl bromide and dimethyliodoarsine. It is a colourless liquid, B.pt. 150° C. at 14 mm., and the yield is about 45 per cent.

Ethyldi-n-propylarsine, $Et(C_3H_7)_2As$.[6]—To the Grignard solution obtained from 36 grams of *n*-propyl bromide and 7·1 grams of magnesium in 300 c.c. of ether, a solution of 25·6 grams of ethyldichloroarsine in 200 c.c. of ether is added dropwise, the vessel being cooled in ice. After the addition the mixture is heated for one hour on the water-bath, then decomposed by ice and hydrochloric acid. The ether layer is separated off, and the aqueous layer extracted several times with ether. The ether solutions are washed with dilute alkali, then with water, dried over calcium chloride, the ether removed and the residue distilled, *in vacuo*, in oxygen-free carbon dioxide. The arsine is a highly refractive liquid, B.pt. 60° to 64° C. at 14 mm.; yield, 12·3 grams, or 46 per cent. It gives a cyanobromide with cyanogen bromide in petroleum.

Ethyldi-isobutylarsine, $C_2H_5[(CH_3)_2CH.CH_2]_2As$, is prepared in a similar manner to the preceding arsine. *Iso*butyl bromide, 50·8 grams and 9·7 grams of magnesium in 100 c.c. of ether, together with 32 grams of ethyldichloroarsine in 100 c.c. of ether, yield 21 grams of the arsine, this being 52·5 per cent. of the theoretical yield. It boils at 86° C. at 16 mm., and has similar properties to ethyldi-*n*-propylarsine.

Compounds of the Types R_3AsX_2 and $R_2R'AsXX'$.

Trimethylarsine oxide, $(CH_3)_3AsO$, may be obtained either by the action of oxygen on trimethylarsine,[7] or by treating cacodyl oxide in methyl alcohol solution with methyl iodide and sodium hydroxide.[8] It forms deliquescent crystals. When its aqueous solution is saturated

[1] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[2] Dehn and Wilcox, *Amer. Chem. J.*, 1908, 40, 113.
[3] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 426.
[4] Compare *ibid.*, 1920, 117, 1378.
[5] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[6] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2603.
[7] Cahours, *Annalen*, 1859, 112, 231.
[8] Auger, *Compt. rend.*, 1903, 137, 927.

at the boiling-point with molybdic acid and then concentrated, a yellow, microcrystalline substance separates,[1] having the formula

$$As(CH_3)_3(OH)_3H_3\left[As(CH_3)_3(Mo_2O_7)_2\text{—O—}(Mo_2O_7)_2As(CH_3)_3\right].3H_2O$$

If guanidinium chloride is added to the solution of the above before crystallisation occurs, the following *guanidinium salt* separates in microscopic, white plates :

$$(CN_3H_6)_3H_3\left[As(CH_3)_3(Mo_2O_7)_2\text{—O—}(Mo_2O_7)_2As(CH_3)_3\right]$$

Trimethylarsine dibromide, $(CH_3)_3AsBr_2$, occurs as prismatic, orange crystals, M.pt. 94° C., decomposing in moist air. It is formed by direct bromination of the arsine in chloroform or ether solution.[2]

Trimethylarsine sulphide, $(CH_3)_3AsS$.—The foregoing dibromide is dissolved in alcohol, treated with potassium ethoxide, filtered, and the filtrate saturated with hydrogen sulphide. It also results when methylarsenious disulphide is heated, or amongst other products when dimethylarsine is acted upon by liquid sulphur dioxide. It crystallises in needles, M.pt. 177·5° C., soluble in alcohol and chloroform, insoluble in ether. With methyl iodide it forms the double compound, $(CH_3)_3As[S.(CH_3)].I$ or $(CH_3)_3As:S(CH_3)I$, crystallising in white needles from alcohol, M.pt. 180° C. with decomposition, and decomposed by water forming CH_3SH.[3]

Trimethylarsine selenide, $(CH_3)_3AsSe$.[4] Five grams of very finely powdered selenium are added to the ether solution obtained in the preparation of trimethylarsine by the Grignard reaction using arsenic tribromide (see p. 9). Small prismatic crystals soon separate, the mixture being cooled in ice. The ether is poured off and the crystals taken up in a little hot alcohol ; when the solution is chilled, long, thin needles are deposited. The selenide thus obtained is not stable in air, giving an odour resembling that of trimethylarsine, whilst the crystals become coated with a brick-red deposit, probably of amorphous selenium. When covered with alcohol or ether, or dissolved in water and kept in the dark, the compound seems fairly stable. When exposed to light the crystals become red, and when heated decompose appreciably at 100° C., evolving vapours which are considered to be trimethylarsine, and leaving behind a black deposit of selenium. The selenide has been used for the analysis of trimethylarsine.

Triethylarsine oxide, $(C_2H_5)_3AsO$.—The slow evaporation of an ether solution of triethylarsine gives this oxide, or it may be isolated in quantity when the mass prepared from ethyl iodide and sodium arsenide is treated first with ether, then with spirit, the latter removed, and the residue distilled.[5] The oxide is an oil, heavier than and insoluble in water, but soluble in alcohol and ether. The alcoholic solution

[1] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.
[2] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 31 ; Hantzsch and Hibbert, *Ber.*, 1907, 40, 1512.
[3] Hantzsch and Hibbert, *loc. cit.*
[4] Renshaw and Holm, *J. Amer. Chem. Soc.*, 1920, 42, 1468.
[5] Landolt, *Annalen*, 1854, 89, 301.

has a neutral reaction and gives no precipitate with silver nitrate. With dilute hydrochloric or sulphuric acid the oxide is unaffected, but with nitric acid of density 1·42 it forms a *nitrate*.

Triethylarsine dichloride, $(C_2H_5)_3AsCl_2$, appears only to have been obtained in very small amounts and has never been analysed. The existence of the compound, $(CH_3)_3AsCl_2.(C_2H_5)_3AsO.2HgCl$, also described by Landolt,[1] appears to be doubtful.

Triethylarsine dibromide, $(C_2H_5)_3AsBr_2$.—Triethylarsine sulphide is treated with concentrated hydrobromic acid,[2] or triethylarsine with bromine in alcoholic solution.[3] It crystallises from chloroform in deliquescent needles, easily soluble in water and alcohol, insoluble in ether. Chlorine or nitric acid eliminates the bromine, and with concentrated sulphuric acid decomposition takes place with evolution of hydrogen bromide.

Triethylarsine hydroxybromide, $(C_2H_5)_3As(OH)Br$,[4] is formed when triethylarsine reacts with cyanogen bromide, and the resulting product is filtered in air. It forms colourless needles, M.pt. 149° to 150° C. It is really the hydrolysis product of the cyanobromide.

Triethylarsine di-iodide, $(C_2H_5)_3AsI_2$.—Direct addition of iodine to triethylarsine takes place in ether solution, or the di-iodide is obtainable on distillation of the double compound, $(C_2H_5)_4AsI.AsI_3$.[5] It is a yellow, flocculent precipitate, M.pt. 160° C., boiling with partial decomposition at 190° C. It is unstable and deliquescent in air, readily soluble in water or alcohol, sparingly soluble in ether. Nitric and sulphuric acids cause separation of iodine, whilst silver nitrate and lead acetate yield silver and lead iodides respectively. Potassium hydroxide converts the di-iodide to the oxide.

Triethylarsine cyanobromide, $(C_2H_5)_3As(CN)Br$,[6] is obtained by mixing the specially dried components in light petroleum. It melts at 67° C., is crystalline and stable, but very susceptible to moisture, readily undergoing hydrolysis.

Triethylarsine sulphide, $(C_2H_5)_3AsS$.—When triethylarsine in ethereal solution is treated with flowers of sulphur, the sulphide is produced.[7] Heating ethylarsine disulphide at 195° C., or heating ethylarsine with carbon disulphide and alcohol at 120° C., gives the same product.[8] It crystallises in white needles, M.pt. 119·5° C., soluble in spirit, warm water, or boiling ether, insoluble in cold ether. It is converted into the dibromide by concentrated hydrobromic acid. It reacts violently with concentrated nitric acid, and with aqueous silver nitrate forms silver sulphide. According to Landolt it may be boiled with potassium hydroxide without undergoing decomposition.

Tripropylarsine oxide, $(C_3H_7)_3AsO$.—When tetrapropylarsonium hydroxide is heated in a current of hydrogen, this oxide is produced.[9] With mercuric chloride it gives a double compound, $(C_3H_7)_3AsO.2HgCl_2$, which crystallises from alcohol in needles, M.pt. 60° to 60·5° C.

[1] Landolt, *Annalen*, 1854, 92, 365; *J. prakt. Chem.*, 1854, 63, 283.
[2] Dehn, *Amer. Chem. J.*, 1905, 33, 136.
[3] Landolt, *loc. cit.*
[4] Steinkopf and Müller, *Ber.*, 1921, 54, [B], 841.
[5] Cahours and Riche, *Annalen*, 1854, 92, 365.
[6] Steinkopf and Müller, *loc. cit.*
[7] Landolt, *Annalen*, 1854, 89, 326.
[8] Dehn, *Amer. Chem. J.*, 1905, 33, 135, 146.
[9] Partheil, Amort, and Gronover, *Arch. Pharm.*, 1899, 237, 136.

Ethyldi-n-propylarsine cyanobromide, $(C_2H_5)(C_3H_7)_2As(CN)Br$.[1] —Combination takes place between the two components when brought together in petroleum ether. The cyanobromide is very susceptible to moisture. When heated it is decomposed into a mixture of ethyl bromide (about 25 per cent.), propyl bromide (about 75 per cent.), ethyl-*n*-propylcyanoarsine and di-*n*-propylcyanoarsine.

Ethyldi-n-propylarsine hydroxybromide, $(C_2H_5)(C_3H_7)_2As(OH)Br$, results when the previous preparation is carried out in ether instead of petroleum ether. The body is too hygroscopic to isolate, hence picric acid is added, which gives the *picrate*, $Et(C_3H_7)_2As.OH[O.C_6H_2(NO_2)_3]$, a yellow, crystalline powder, M.pt. 85·5° C.

Ethyldi-isobutylarsine cyanobromide, $(C_2H_5)(C_4H_9)_2As(CN)Br$, is a solid, M.pt. 69° C., decomposing when heated into a mixture of ethyl bromide, *iso*butyl bromide, and di-*iso*butylcyanoarsine, B.pt. 116° C. at 16 mm.

Ethyldi-isobutylarsine hydroxybromide, isolated as the *picrate*, melts at 82° C.

Quaternary Arsonium Compounds.

This type of compound, R_4AsI, has been known since 1854, and was first obtained by the interaction of sodium arsenide and alkyl iodides in a carbon dioxide atmosphere, the resulting products being subjected to distillation. Sodium arsenide may be replaced by alloys of zinc, cadmium, or mercury with arsenic. If a sufficiently high temperature is maintained, arsenic itself reacts with alkyl iodides to form double salts of tetra-alkylarsonium iodides and arsenic tri-iodide. A more obvious method of preparation, and one which often gives excellent results with the minimum of effort, is the direct addition of alkyl iodide to trialkylarsines, and a variation of the method is to replace the latter compounds by monoalkylarsines. In the latter case, however, a higher temperature is required. The above are the principal general methods for producing the compounds, R_4AsI, where the alkyl radicals are all of the same kind. There are also special methods applying only to individual derivatives.

Considering the mixed quaternary arsonium compounds, their preparation is best indicated by the following equations:

$$RAsH_2 + 3R'I = RR_3'AsI + 2HI$$
$$R_2AsH + 2R'I = R_2R_2'AsI + HI$$
$$R_2AsX + 2R'I = R_2R_2'AsI + XI \quad (X = \text{halogen})$$
$$R_2R'As + R''I = R_2R'R''AsI$$

These arsonium iodides form addition products with the iodides of zinc, cadmium, mercury, and arsenic, and also periodides $R_4AsI.I_2$ with iodine; distillation of the iodides with solid potassium hydroxide yields tertiary arsines. The iodine may be removed by treating the arsonium compounds with moist silver oxide, when hydroxides are produced. As a general rule the arsonium iodides are well-defined, crystalline products. Treatment of the above-mentioned tetra-alkylarsonium hydroxides with halogen acids leads to the production of the corresponding salts. The tetra-alkylarsonium chlorides are not as a rule obtained in good crystal-

[1] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2603.

line form, since most of them are deliquescent, but crystalline double salts have been isolated by interaction with the chlorides of gold, mercury, platinum, and bismuth. The bromides, nitrates, and normal sulphates are deliquescent salts. The foregoing remarks also apply in general to mixed quaternary arsonium compounds.

Tetramethylarsonium iodide, $(CH_3)_4AsI$.—The double compound of the iodide with arsenic tri-iodide is formed when powdered arsenic and methyl iodide are heated together at 160° to 200° C.[1] If this reaction is carried out at ordinary temperatures or on the water-bath, the principal products are methyldi-iodoarsine and tetramethylarsonium iodide; arsenic tri-iodide and a small quantity of cacodyl iodide are also produced.[2] When methyl iodide is added to sodium arsenide in an atmosphere of carbon dioxide, the mixture on distillation gives cacodyl and tetramethylarsonium iodide.[3] Cacodyl and methyl iodide react with evolution of heat, yielding the arsonium compound and cacodyl iodide according to the equation:

$$(CH_3)_2As.As(CH_3)_2+2CH_3I=(CH_3)_4AsI+(CH_3)_2AsI.^4$$

Alloys of arsenic with zinc and cadmium are also capable of giving the arsonium compound when heated at 160° to 180° C. with methyl iodide. It may be produced from its components, trimethylarsine and methyl iodide, or by heating methylarsine with an excess of methyl iodide for eight hours in a carbon dioxide atmosphere at 110° C.[5] Arsenomethane, when heated at 100° C. with methyl iodide, gives tetramethylarsonium iodide and methylarsine di-iodide;[6] see *cyclo*-pentamethylpenta-arsine, p. 53.

Tetramethylarsonium iodide crystallises in colourless plates, melting with decomposition at 170° to 180° C., readily soluble in water or alcohol, insoluble in anhydrous ether. Its alcoholic solution, with mercuric iodide, gives the *double iodide*, $(CH_3)_4AsI.HgI_2$, consisting of yellow needles, M.pt. 184° C., readily soluble in acetone and boiling alcohol, soluble with difficulty in cold alcohol, insoluble in ether.[7] The following *double iodides* have also been described: $2(CH_3)_4AsI.ZnI_2$, pale yellow crystals; $2(CH_3)_4AsI.CdI_2$, pale yellow, prismatic needles; $(CH_3)_4AsI.AsI_3$, reddish needles, volatilising without decomposition and fairly soluble in boiling alcohol.[8] These salts when distilled with solid potassium hydroxide yield trimethylarsine.

Tetramethylarsonium iodide also combines with iodine to give a *periodide*, $(CH_3)_4AsI.I_2$, which crystallises in brown prisms, having a metallic lustre. It is sparingly soluble, and decomposes on heating into methyl iodide and cacodyl iodide.[9] When tetramethylarsonium iodide, or its double salt with mercuric iodide, is treated with moist silver oxide, **tetramethylarsonium hydroxide** results. This compound crystallises in deliquescent plates, and has a strongly alkaline reaction, the

[1] Cahours, *Annalen*, 1862, 122, 198.
[2] Auger, *Compt. rend.*, 1907, 145, 808.
[3] Cahours and Riche, *Annalen*, 1854, 92, 361.
[4] Cahours, *Annalen*, 1862, 122, 207.
[5] Dehn, *Amer. Chem. J.*, 1905, 33, 129.
[6] Auger, *Compt. rend.*, 1904, 138, 1705.
[7] Mannheim, *Annalen*, 1905, 341, 182.
[8] Cahours, *loc. cit.*
[9] Cahours, *ibid.*, 1860, 116, 366; 1862, 122, 215.

conductivity of its solution having been investigated by Bredig.[1] Tetramethylarsonium iodide gives an *additive compound* with iodoform, $I[Me_4As]\ .\ .\ .\ CHI_3$, M.pt. 165° C.[2]

Tetramethylarsonium bromide is a very deliquescent salt formed by the interaction of methyl bromide and cacodyl. The reaction is very violent and cacodyl bromide is produced as a by-product.[3]

Tetramethylarsonium chloride does not appear to have been obtained in the solid state, but it forms well-defined salts with metallic chlorides. The *mercurichloride* $(CH_3)_4AsCl.HgCl_2$ results when tetramethylarsonium iodide is heated with mercuric chloride in alcohol solution for one hour on the water-bath, and the filtrate acidified with hydrochloric acid. It forms needles from alcohol, M.pt. 175° to 176° C., sparingly soluble in cold, but readily in hot water.[4] In a similar manner the addition of platinic chloride to the arsonium chloride in aqueous solution gives the *platinichloride*, $[(CH_3)_4AsCl]_2PtCl_4$, crystallising from alcohol in yellow crystals, M.pt. 250° to 260° C., with decomposition. This has a similar solubility to the mercurichloride. A *double salt* with auric chloride is also known, $Me_4AsCl.AuCl_3$, forming yellow needles, M.pt. about 233° C., very soluble in acetone and alcohol, insoluble in ether.

Tetramethylarsonium sulphate and **nitrate** have also been isolated, both of which are deliquescent, crystalline compounds.[5]

Tetraethylarsonium iodide, $(C_2H_5)_4AsI$.—The general methods used for the preparation of tetramethylarsonium iodide may again be used for the present case. The iodide decomposes at about 160° C., is easily soluble in water or alcohol, insoluble in ether. It forms the following double compounds: *mercuri-iodide*, $(C_2H_5)_4AsI.HgI_2$, yellow, shining needles from alcohol, M.pt. 112° C.; with *zinc iodide*, $2(C_2H_5)_4AsI.ZnI_2$, pale yellow prisms from alcohol; with *cadmium iodide*, $2(C_2H_5)_4AsI.CdI_2$, prisms from alcohol, sparingly soluble in cold alcohol, fairly soluble in boiling alcohol; with *arsenic tri-iodide*, $(C_2H_5)_4AsI.AsI_3$, reddish-brown plates or reddish needles from alcohol;[6] with *bismuth iodide*, $3(C_2H_5)_4AsI.2BiI_3$, deep red crystals;[7] *periodide*, brown needles. The arsonium iodide yields the *free base* when treated with moist silver oxide, the product being a white mass, having a strongly alkaline reaction, and readily absorbing water and carbon dioxide from the air; it liberates ammonia from ammonium salts and precipitates the hydroxides of heavy metals from aqueous salt solutions.

Tetraethylarsonium bromide forms a deliquescent, crystalline mass, very soluble in water and alcohol. With *bismuth bromide* it yields $3(C_2H_5)_4AsBr.2BiBr_3$, which crystallises in citron yellow crystals.

Tetraethylarsonium chloride, $(C_2H_5)_4AsCl.4H_2O$, is a deliquescent, crystalline product, very soluble in water and alcohol, insoluble in ether.[8] It gives the following double compounds: *aurichloride*, $(C_2H_5)_4AsCl.AuCl_3$, yellow needles, darkening at 150° C., and melting

[1] Bredig, *Zeitsch. physikal. Chem.*, 1894, **13**, 301.
[2] Steinkopf and Schwen, *Ber.*, 1921, **54**, [B], 2069.
[3] Cahours and Riche, *Annalen*, 1854, **92**, 361; *Compt. rend.*, 1854, **39**, 541.
[4] Mannheim, *loc. cit.*
[5] Cahours and Riche, *loc. cit.*
[6] Cahours, *Annalen*, 1862, **122**, 201.
[7] Jorgensen, *J. prakt. Chem.*, 1871, [ii.], **3**, 340.
[8] Landolt, *Annalen*, 1854, **89**, 332.

about 171° C.; *mercurichloride*, $(C_2H_5)_4AsCl.HgCl_2$, small, white needles, M.pt. 139° C.; *platinichloride*, $[(C_2H_5)_4AsCl]_2PtCl_4$, small, compact crystals, melting at 224° C. with decomposition, sparingly soluble in cold water; with *bismuth chloride*, $3(C_2H_5)_4AsCl.2BiCl_3$, a colourless, crystalline compound.

A *hydrogen sulphate*, $(C_2H_5)_4As.SO_4H$, has also been described. It is a granular powder, easily soluble in water or alcohol.

Tetra-n-propylarsonium iodide, $(CH_3.CH_2.CH_2)_4AsI$, is obtained in the form of its double salt with arsenic tri-iodide or zinc iodide when propyl iodide is heated with arsenic or zinc arsenide at 175° to 185° C.[1] It also results when propyl iodide reacts with amalgams of arsenic with sodium or potassium, and as the mercuri-iodide on heating propyl iodide with an alloy of arsenic and mercury.[2] The arsonium iodide crystallises from water in needles, and from absolute alcohol in prisms, decomposing at 150° C., and easily soluble in water or alcohol, but insoluble in anhydrous ether. It yields the following double compounds: *mercuri-iodide*, $(C_3H_7)_4AsI.HgI_2$, forming needles from alcohol, M.pt. 120° C., readily soluble in acetone, sparingly soluble in cold alcohol, insoluble in water and ether; with *zinc iodide*, $2(C_3H_7)_4AsI.ZnI_2$; with *arsenic tri-iodide*, $(C_3H_7)_4AsI.AsI_3$, reddish-brown crystals which yield tripropylarsine on distillation with solid potassium hydroxide.

The following double salts of **tetra-n-propylarsonium chloride** have been described: *aurichloride*, $(C_3H_7)_4AsCl.AuCl_3$, forming needles from dilute alcohol containing hydrochloric acid, M.pt. 127° C.; *mercurichloride*, $(C_3H_7)_4AsCl.HgCl_2$, white needles, M.pt. 169° C.; *platinichloride*, $[(C_3H_7)_4AsCl]_2PtCl_4$, small, yellowish-red crystals from water, M.pt. 189° C.

Tetra-isopropylarsonium iodide, $[(CH_3)_2CH]_4AsI$, is obtained as a double iodide by heating *iso*propyl iodide at 175° to 180° C. with arsenic, or with an alloy of arsenic and mercury.[3] The pure iodide crystallises from water in colourless needles, which commence to darken at about 150° C. It is readily soluble in alcohol but insoluble in ether. Its *mercuri-iodide* crystallises from alcohol in yellow needles, M.pt. 114° C., very soluble in acetone, insoluble in water or ether.

The corresponding **arsonium chloride** gives the following double salts: *aurichloride*, needles, sintering about 170° C. and melting at 186° to 188° C., very soluble in acetone and warm alcohol, insoluble in ether, decomposing on exposure to sunlight with separation of metallic gold; *mercurichloride*, needles, M.pt. 171° C.; *platinichloride*, decomposing at 211° C., sparingly soluble in cold water or cold alcohol.

Tetrabutylarsonium iodide, $(CH_3.CH_2.CH_2.CH_2)_4AsI$,[4] results as a double iodide when butyl iodide and arsenic, or an alloy of arsenic and mercury, are heated at 170° to 180° C. It crystallises from water in small needles, which commence to decompose at 145° to 150° C., are easily soluble in water or alcohol, insoluble in ether. Its *mercuri-iodide* crystallises in yellow needles, M.pt. 109° C., very soluble in acetone, insoluble in water or ether.

The corresponding **arsonium chloride** gives the following derivatives: *aurichloride*, needles from alcohol containing hydrochloric acid,

[1] Cahours, *Compt. rend.*, 1873, 76, 753; *Jahresber.*, 1873, p. 519.
[2] Mannheim, *Annalen*, 1905, 341, 200, 217.
[3] Mannheim, *ibid.*, pp. 202, 219.
[4] Mannheim, *ibid.*, pp. 204, 221.

melting at about 131° C., readily soluble in acetone, sparingly soluble in water, insoluble in ether; *platinichloride*, orange crystals, M.pt. 220° C. with decomposition.

Mixed Quaternary Arsonium Compounds.

Trimethylethylarsonium iodide, $(CH_3)_3(C_2H_5)AsI$, results when ethylarsine is heated with an excess of methyl iodide in a carbon dioxide atmosphere.[1] It crystallises from alcohol in needles, which soften at 300° C. and sinter at 320° C.; it is soluble in water, chloroform, or hot alcohol, insoluble in ether.

γ - Phenylpropyltrimethylarsonium iodide, $C_6H_5.[CH_2]_3As(CH_3)_3I$,[2] crystallises from water in colourless needles, M.pt. 144° C.

δ - Phenyl - n - butyltrimethylarsonium iodide, $C_6H_5.[CH_2]_4.As(CH_3)_3I$,[3] prepared from δ-phenyl-*n*-butyldimethylarsine and methyl iodide, crystallises from alcohol, in which it is sparingly soluble, in leaflets, M.pt. 150° to 151° C. If ethyl iodide is used in this reaction, **δ - phenyl - n - butyldimethylethylarsonium iodide**, $C_6H_5.[CH_2]_4.As(CH_3)_2(C_2H_5)I$, is isolated. This is fairly soluble in alcohol, separating in leaflets, M.pt. 134° to 135° C.

Dimethyldiethylarsonium iodide, $(CH_3)_2(C_2H_5)_2AsI$, is readily formed when cacodyl reacts with ethyl iodide.[4] From alcohol it is deposited in prisms, and with iodine it forms a *periodide*, consisting of brown prisms, having a metallic lustre. The corresponding **arsonium chloride** and **bromide** are only obtained in deliquescent crystals, the former giving a *platinichloride*, which crystallises from 50 per cent. alcohol in orange-red needles.

A *sulphate* is also known, $[(CH_3)_2(C_2H_5)_2As]_2SO_4$, forming octahedra, soluble in water and alcohol; also a *nitrate*, occurring in deliquescent granules.

Dimethyldipropylarsonium iodide, $(CH_3.CH_2.CH_2)_2(CH_3)_2AsI$, occurs when cacodyl is heated with four molecular proportions of propyl iodide for two hours at 140° C.[5] Its crystals are bright yellow, and with mercuric chloride, the *double salt*, $(C_3H_7)_2(CH_3)_2AsI.HgCl_2$, is produced; this crystallises from water in white plates.

Dimethyldi-isopropylarsonium iodide, $[(CH_3)_2CH]_2(CH_3)_2AsI$. —Dimethylarsine and *iso*propyl iodide are heated together at 100° C.; it is a crystalline mass, unmelted at 230° C. It is insoluble in ether, but readily dissolves in chloroform.

Dimethyldi-isobutylarsonium iodide, $[(CH_3)_2CH.CH_2]_2(CH_3)_2AsI$, occurs when dimethylarsine and 2·5 mols. of *iso*butyl iodide are heated for five hours at 110° C.[6] From a mixture of chloroform and ether it crystallises in white plates, M.pt. 155° C., soluble in alcohol and chloroform, insoluble in ether.

Dimethylpropylisoamylarsonium iodide, $(C_5H_{11})(CH_3.CH_2.CH_2)(CH_3)_2AsI$, is obtained when the hydriodide of dimethylpropyl arsine is heated for two hours with an excess of *iso*amyl iodide.

[1] Dehn, *Amer. Chem. J.*, 1905, 33, 145.
[2] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 429.
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[4] Cahours and Riche, *Annalen*, 1854, 92, 362; *Compt. rend.*, 1854, 39, 541; Cahours, *Annalen*, 1862, 122, 209.
[5] Dehn and Wilcox, *Amer. Chem. J.*, 1908, 40, 123.
[6] Dehn and Wilcox, *ibid.*, 1906, 35, 18.

Dimethyldi-isoamylarsonium iodide, $(C_5H_{11})_2(CH_3)_2AsI$.—This iodide is obtained by heating cacodyl and *iso*amyl iodide at 180° C., and with moist silver oxide yields the **free base.** The iodide crystallises in plates; a crystalline **bromide** has also been noted.[1]

Dimethyldiallylarsonium iodide, $(CH_2:CH.CH_2)_2(CH_3)_2AsI$, obtained from dimethylarsine and allyl iodide, is a crystalline, yellow product, readily soluble in alcohol, insoluble in ether.

Dimethyldicetylarsonium iodide, $(CH_3.[CH_2]_{14}.CH_2)_2(CH_3)_2AsI$. —Formed by heating dimethylarsine and cetyl iodide at 100° C.[2] It crystallises from chloroform-ether; it melts at 53° to 54° C.

γ-Phenylpropyldimethylethylarsonium iodide, $C_6H_5.[CH_2]_3(CH_3)_2C_2H_5AsI$.[3]—Obtained from γ-phenylpropyldimethylarsine and ethyl iodide, separates from alcohol-ether in colourless leaflets; M.pt. 118° C.

Methylethyldi-n-propylarsonium iodide, $(CH_3)(C_2H_5)(C_3H_7)_2AsI$, melts at 175° C.[4]

Triethyl-β-bromoethylarsonium bromide, $CH_2Br.CH_2.As(C_2H_5)_3Br$,[5] crystallises in cubic crystals,[6] readily soluble in water, sparingly soluble in cold alcohol. It is prepared by treating triethylarsine with a large excess of ethylene bromide below 50° C. The corresponding **chloride** yields a *platinichloride*, crystallising in needles, sparingly soluble in boiling water.

Triethyl-β-aminoethylarsonium bromide, $H_2N.CH_2.CH_2.As(C_2H_5)_3Br$, occurs when the preceding compound is heated with ammonia at 100° C. From it the following *salts* have been obtained: $C_8H_{21}NAs.Cl.HCl.2AuCl_3$, crystallising in plates from hot hydrochloric acid; $C_8H_{21}NAs.Cl.HCl.PtCl_4$, sparingly soluble in boiling water.

Triethylvinylarsonium hydroxide, $(CH_2:CH)(C_2H_5)_3As.OH$, results when the foregoing β-bromoethyl compound is treated with an excess of moist silver oxide. The *aurichloride*, $C_8H_{18}AsCl.AuCl_3$, is a yellow, sparingly soluble, crystalline substance; the *platinichloride*, $(C_8H_{18}AsCl)_2PtCl_4$, forms octahedra, fairly soluble in water.

Ethylene-bis-triethylarsonium bromide, $Br.(C_2H_5)_3As.CH_2.CH_2.As(C_2H_5)_3Br$, is formed when triethylarsine and triethyl-β-bromoethylarsonium bromide are heated together at 150° C. The *aurichloride*, $C_{14}H_{34}As_2Cl_2.2AuCl_3$, gives golden, glistening plates from hot hydrochloric acid; the *platinichloride*, $C_{14}H_{34}As_2Cl_2.PtCl_4$, forms pale yellow crystals, sparingly soluble in water.

Ethyltri-isopropylarsonium iodide, $[(CH_3)_2CH]_3(C_2H_5)AsI$, is formed by heating ethylarsine and an excess of *iso*propyl iodide at 110° C. for three hours.[7]

Ethyltripropylarsonium iodide, $(CH_3.CH_2.CH_2)_3(C_2H_5)AsI$, is prepared in a similar manner to the preceding compound. It sinters at 230° C., and melts with decomposition at 237° C. The *mercuri-iodide* is a pale yellow substance.

[1] Cahours and Riche, *loc. cit.*; Cahours, *loc. cit.*
[2] Dehn and Wilcox, *loc. cit.*
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[4] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2005.
[5] Hofmann, *Annalen Suppl.*, 1861, 1, 311.
[6] Sella, *Mem. R. Accad. d. Scienze di Torino*, 1861, [2], 20, 369; *Annalen Suppl.*, 1861, 1, 311.
[7] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 112.

Ethyltri-isoamylarsonium iodide, $(C_5H_{11})_3(C_2H_5)AsI$.—Ethylarsine is heated at 140° C. in a carbon dioxide atmosphere with an excess of *iso*amyl iodide, and the product recrystallised from alcohol. It does not melt at 250° C., is readily soluble in alcohol, sparingly soluble in chloroform, and insoluble in acetone or ligroin.

Dipropyldi-isoamylarsonium iodide, $(C_3H_7)_2(C_5H_{11})_2AsI$, is obtained[1] by heating di-*iso*amylarsine and propyl iodide at 160° C.

Compounds of the Type $RAsX_2$.

The dihalogenated arsines have been obtained in many ways, the chief of which are as follows :

1. By the interaction of monoalkylarsines and halogens (or in some cases metallic chlorides),

$$RAsH_2+2X_2=RAsX_2+2HX$$

2. By treating dialkylarsines with halogens,

$$R_2AsH+2X_2=RAsX_2+HX+RX$$

3. By treating arsenic trichloride with mercury dialkyls,

$$2AsCl_3+HgR_2=2RAsCl_2+HgCl_2$$

4. By the action of heat on dialkylarsine trihalides,

$$R_2AsX_3=RAsX_2+RX$$

5. An interesting preparation is that of ethyldi-iodoarsine, where an exchange of the halogen is made between the corresponding dichloroarsine and sodium iodide in dry acetone solution,

$$EtAsCl_2+2NaI=EtAsI_2+2NaCl$$

6. The alkylarsenoxides react with halogen acids in the usual manner,

$$RAsO+2HX=RAsX_2+H_2O$$

7. When methyl iodide and powdered arsenic react at ordinary temperatures, or at 100° C., the reaction may be represented as follows, the chief products being the first two compounds on the right of the equation,

$$7MeI+4As=MeAsI_2+Me_4AsI+AsI_3+Me_2AsI$$

8. Preparations have also been achieved by reducing the corresponding arsinic acids, either by phosphorus trichloride, or by sulphur dioxide in the presence of potassium iodide in hydrochloric acid solution,

$$RAsO(OH)_2+PCl_3=RAsCl_2+HPO_3+HCl$$
$$RAsO(ONa)_2+4HCl+SO_2=RAsCl_2+H_2SO_4+2NaCl+H_2O$$
$$RAsO(OH)_2+2HCl+SO_2=RAsCl_2+H_2SO_4+H_2O$$

[1] By treating alkyl iodides with mercuric arsenide, Hg_3As_2, it was at one time supposed that hexa-alkylated diarsonium compounds were produced (Partheil and Amort, *Ber.*, 1898, 31, 596; *Arch. Pharm.*, 1899, 237, 121; Partheil, Amort, and Gronover, *Arch. Pharm.*, 1899, 237, 127; Amort, *Inaug. Dissert.*, Heidelberg, 1898; Gronover, *Inaug. Dissert.*, Heidelberg, 1899.) It was subsequently shown by Mannheim (*loc. cit.*) that these compounds were in reality tetra-alkylarsonium halides and double halides.

The dichloroarsines are highly refractive, colourless liquids, which are very irritant to the mucous membrane of the nose, and cause painful wounds if brought into contact with the skin. Treatment with hydrogen sulphide gives the *sulphide*, and chlorine at −10° C. gives *methylarsenic tetrachloride*, $MeAsCl_4$, an unstable product, decomposing on rise of temperature. The dichloroarsines of higher molecular weight are decomposed by water. Although potassium carbonate converts products of this type to oxides, silver oxide is stated to convert ethyldiiodoarsine to the corresponding acid.

Alkylarsenoxides and Sulphides.—Replacement of the halogen in the foregoing compounds by oxygen, giving alkylarsenoxides, may be brought about by distilling the dihalogenated products with aqueous potassium hydroxide:

$$RAsCl_2+2KOH=RAsO+2KCl+H_2O$$

The potassium hydroxide can be replaced by potassium carbonate when carrying out the reaction in moist benzene solution:

$$RAsCl_2+K_2CO_3=RAsO+2KCl+CO_2$$

Another variation consists in heating di-iodoarsine with calcium chloride and sodium carbonate in benzene solution. Treatment of alkyl dihalogenated arsines with hydrogen sulphide causes replacement of the halogen by sulphur.

Methyldichloroarsine, CH_3AsCl_2,[1] results when cacodyl trichloride, $(CH_3)_2AsCl_3$, is decomposed by warming at 40° to 50° C., or when cacodylic acid, $(CH_3)_2AsO.OH$, is treated with hydrogen chloride. The compound reacts with chlorine, forming methyldichloroarsine,[2] and the same product results when methylarsinic acid is added to well-cooled phosphorus trichloride.[3] Methyldichloroarsine is a colourless, heavy, mobile, strongly refractive liquid, B.pt. 133° C., which has a very irritating effect on the mucous membrane. It does not fume in air and is not decomposed by water, in which it is somewhat soluble. When treated with hydrogen sulphide, a white precipitate of the corresponding sulphide separates. When the chloroarsine is dissolved in carbon disulphide and treated with chlorine at −10° C., large crystals of *methylarsenic tetrachloride*, $MeAsCl_4$, appear, but these soon decompose at 0° C. into methyl chloride and arsenic trichloride.

Methyldi-iodoarsine, CH_3AsI_2, has been prepared in a variety of ways:

1. An alcoholic solution of methylarsenoxide is treated with an excess of hydriodic acid.[4]

2. By passing methylarsine into an alcoholic solution of iodine.[5]

3. By the action of sulphur dioxide on methylarsenic tetraiodide.[6]

4. It forms the main product of reaction when methyl iodide and arsenic react at ordinary temperatures or on the water-bath.[7]

[1] Baeyer, *Annalen*, 1858, 107, 257.
[2] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 16.
[3] Auger, *Compt. rend.*, 1906, 142, 1152.
[4] Baeyer, *loc. cit.*
[5] Palmer and Dehn, *Ber.*, 1901, 34, 3598; Dehn, *Amer. Chem. J.*, 1905, 33, 126.
[6] Klinger and Kreutz, *Annalen*, 1888, 249, 152.
[7] Auger, *Compt. rend.*, 1907, 145, 809.

5. Two hundred grams of sodium methylarsinate, 250 grams of potassium iodide, and 500 grams of water, containing 150 grams of hydrochloric acid, are saturated in the cold with sulphur dioxide.[1]

The arsine forms glistening, yellow needles, M.pt. 30° C., B.pt. 128° C. at 16 mm.; it is odourless, and volatilises unchanged at 200° C. In water it is somewhat soluble, is moderately soluble in alcohol, ether, or carbon disulphide, the solubility being increased by the presence of hydriodic acid. Hydrogen chloride and hydrogen sulphide convert it to the chloride and sulphide respectively. Iodine oxidises it to methylarsenoxide.[2] When boiled with dry sodium carbonate, in the presence of benzene, it yields the oxide.[3]

Methyldicyanoarsine, $CH_3As(CN)_2$, obtained from dimethylcyanoarsine and cyanogen bromide, melts at 115·5° to 116·5° C., and decomposes at 118° C.[4]

Methylarsenious sulphide, $CH_3As:S$, isolated from the chloride or iodide as noted before, crystallises in glistening plates from alcohol or small columns from carbon disulphide; it is insoluble in water, somewhat soluble in alcohol and ether, and very soluble in carbon disulphide. It melts at about 110° C., above which temperature it decomposes, forming arsenic sulphide. Its alcoholic solution precipitates sulphides from solutions of salts of silver, copper, mercury, lead, and platinum.

Methylarsenoxide, $CH_3As:O$. — When methyldichloroarsine is distilled with potassium hydroxide solution, it reacts according to the equation:

$$CH_3AsCl_2+2KOH=CH_3AsO+2KCl+H_2O$$

The oxide melts at 95° C., has a pungent odour and a high density. It is easily soluble in hot water, alcohol, ether, and carbon disulphide, and being feebly basic, readily dissolves in acids. When its concentrated aqueous solution is treated with halogen acids or sulphides, the corresponding salts are precipitated. When distilled with potassium hydroxide it yields arsenious oxide and cacodyl oxide.

Ethyldichloroarsine, $C_2H_5AsCl_2$.—Mercury diethyl reacts violently with arsenic trichloride to form this arsine[5]:

$$Hg(C_2H_5)_2+AsCl_3=C_2H_5AsCl_2+C_2H_5HgCl$$

It may also be prepared by treating ethylarsine with the chloride of mercury, tin, phosphorus, arsenic, or antimony.[6] It results, together with diethylchloroarsine and the arsinic acid, when arsenic trichloride reacts with magnesium ethyl bromide.[7] It is a liquid, B.pt. 156° C., having a faint, fruity odour, very soluble in water and miscible in all proportions with alcohol, ether, and benzene. It is oxidised to ethylarsinic acid by warm dilute nitric acid. It is extremely irritating in its

[1] Auger, *Compt. rend.*, 1906, 142, 1151; see also Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1375.

[2] Bougault, *Chem. Zentr.*, 1907, II, 1359.

[3] Auger, *loc. cit.*

[4] Grischkievitch-Trochimovski, Mateyak, and Zablotski, *Bull. Soc. Chim.*, 1927, [iv], 41, 1323.

[5] La Coste, *Annalen*, 1881, 208, 33; see Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1014.

[6] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 110.

[7] Auger and Billy, *Compt. rend.*, 1904, 139, 597; see M'Kenzie and Wood, *Trans. Chem. Soc.*, 1920, 117, 407.

action upon the mucous membrane of the nose and throat, and causes painful wounds on the skin.

Ethyldibromoarsine, $C_2H_5AsBr_2$, results when ethylarsine in ether solution is treated with bromine. It is an oil, B.pt. 192° C., and forms a yellow, crystalline *platinichloride*, $C_2H_5AsBr_2.PtCl_4$.

Ethyldi-iodoarsine, $C_2H_5AsI_2$, is prepared by distilling diethyliodoarsine with iodine,[1] or by heating ethyl iodide and arsenic at 100° C. for several days, arsenic tri-iodide and tetraethylarsonium iodide being formed at the same time.[2] It may also be isolated by the interaction of ethyldichloroarsine and sodium iodide in dry acetone solution.[3] It is a reddish-yellow oil, B.pt. 126° C. at 11 mm., crystallising at −9° C., and is oxidised by silver oxide to ethylarsinic acid.[4]

Ethylarsenoxide, C_2H_5AsO, results when the iodide, in benzene solution, is heated on the water-bath for two hours with a mixture of calcium chloride and anhydrous sodium carbonate, or when ethyldichloroarsine is heated with a suspension of potassium carbonate in benzene and a little water.[5] It is a colourless oil, B.pt. 158° C. at 10 mm., soluble in benzene, ether, and acetone, and readily oxidised in air.

β-Hydroxyethyldichloroarsine, $OH.CH_2.CH_2.AsCl_2$.—This compound does not appear to have been isolated in a very pure condition. It results when the corresponding oxide is treated with hydrogen chloride.[6] Phosphorus pentachloride or a small excess of phosphoryl chloride converts it into β-chloroethyldichloroarsine.

Treatment with *carbonyl chloride* gives a *compound* possessing an odour resembling ethyl chloroformate. Warm water readily hydrolyses this compound, carbon dioxide being evolved. Distillation at 10 to 11 mm. pressure gives β-chloroethyldichloroarsine and carbon dioxide, probably according to the scheme:

$$Cl.CO.O.CH_2.CH_2.AsCl_2 \longrightarrow CO_2 + Cl.CH_2.CH_2.AsCl_2$$

β-Hydroxyethylarsenoxide is a thick, viscous liquid, formed by reducing the corresponding acid with sulphur dioxide. It cannot be distilled without decomposition, does not evolve ethylene when treated with alkali hydroxide, and is converted to the arsinic acid by hydrogen peroxide.

β-Acetoxyethyldichloroarsine, $OAc.CH_2.CH_2.AsCl_2$.[7]—β-Chloroethyldichloroarsine is mixed with 20 per cent. excess of 95 to 96 per cent. acetic acid and a rapid stream of hydrogen chloride passed through the mixture. The resulting oil is fractionated several times *in vacuo*, the required product boiling at 120° to 121° C. at 9 to 10 mm., and having a density of 1·6766 at 20° C. It is sparingly soluble in water, readily soluble in ether and chloroform. When boiled with water or alkali it evolves ethylene.

β-Chloroethyldichloroarsine, $CH_2Cl.CH_2.AsCl_2$.[8]—This derivative has been prepared in several ways:

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[1] Cahours, *Annalen*, 1860, 116, 367. [2] Auger, *Compt. rend.*, 1907, 145, 809.
[3] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[4] See M'Kenzie and Wood, *loc. cit.*; Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1375.
[5] Steinkopf and Mieg, *loc. cit.*
[6] Nekrassov and Nekrassov, *Ber.*, 1928, 61, [B], 1816; Scherlin and Epstein, *ibid.*, p. 1821. [7] Scherlin and Epstein, *loc. cit.*
[8] Renshaw and Ware, *J. Amer. Chem. Soc.*, 1925, 47, 2991.

(1) The crude β-hydroxyethylarsinic acid, prepared from 100 grams of ethylene chlorhydrin, is dissolved in 350 c.c. of concentrated hydrochloric acid, 4 c.c. of normal potassium iodide solution added and the whole treated with sulphur dioxide below 50° C. until saturated. After forty-eight hours standing, the lower layer is removed, dried by solution in carbon tetrachloride and the solvent evaporated off. The residual oil (140 grams) is mixed with an equal volume of light petroleum and 127 c.c. of thionyl chloride slowly added. When the reaction is complete, the product is distilled, first at ordinary pressure, then under reduced pressure. From the fractions, 44 grams of arsenious chloride were obtained, B.pt. 39° to 41° C. at 30 mm., and 60 grams of β-chloroethyldichloroarsine, B.pt. 92° to 93° C. at 32 mm.[1]

(2) Arsenious chloride, 220 grams, and 29 grams of freshly sublimed powdered aluminium chloride, are treated with ethylene at 50° to 60° C. The reaction mixture is poured into ice-cold, 4*N* hydrochloric acid, and evaporated under reduced pressure, when the excess of arsenious chloride and the dichloroarsine volatilise without hydrolysis. The last portions of dichloroarsine may be removed from the tarry residue by distillation in a current of the vapour of 4*N* hydrochloric acid at 100° C. and 30 mm. The carbon tetrachloride extract of the total distillate is distilled to remove water and the residue distilled *in vacuo*. Under these conditions a 30-gram yield of the dichloroarsine should result. The conditions given are stated to produce consistent yields, it having been noted that the reaction is very sensitive to slight alteration of conditions.[2]

(3) To 30 grams of β-hydroxyethylarsenoxide in 50 c.c. of chloroform, 30 grams of phosphorus trichloride in a similar volume of chloroform are added. Hydrogen chloride is evolved and the reaction is completed by heating the mixture for one hour on the water-bath. After filtration, the chloroform is distilled off and the residual oil fractionated. After four fractionations, about 14 grams of pure β-chloroethyldichloroarsine are obtained, B.pt. 93° to 94° C. at 16 mm.[3]

(4) Carefully dried β-hydroxyethyldichloroarsine is treated with a slight excess of phosphoryl chloride (phosphorus pentachloride may also be added to a benzene solution of the dichloroarsine), the reaction flask being cooled during the operation. As the action proceeds the temperature is raised to 70° C., and the mixture finally heated on the water-bath until gas evolution ceases. The filtered solution, when fractionated, gives a 70 per cent. yield. Prepared by this method the boiling-point is given as 90·8° C. at 12·5 mm., 87° C. at 10 mm., or 80·6° C. at 8 mm.[4]

β-Chloroethyldichloroarsine is an oil, density 1·8401 at 20° C., practically insoluble in water, readily soluble in organic solvents. It is decomposed by boiling water, and on boiling with alkalis gives a quantitative yield of ethylene. When condensed with trimethylarsine in cold toluene it yields *dichloroarsinyltrimethylammonium chloride*, $N(CH_3)_3Cl$.

[1] Gough and King, *J. Chem. Soc.*, 1928, p. 2426.

[2] Gough and King, *loc. cit.* By a similar method, Renshaw and Ware, *loc. cit.*, also obtained the dichloroarsine, giving the boiling-point as 90° to 93° C. at 30 mm. Nekrassov and Nekrassov, *loc. cit.*, using 318 grams of arsenious chloride, 60 grams of aluminium chloride, and 70 litres of ethylene, obtained 17 grams of β-chloroethyldichloroarsine, B.pt. 89° to 90° C. at 12 mm., and possibly also a secondary arsine, B.pt. 98° to 99° C. at 15 mm.

[3] Nekrassov and Nekrassov, *loc. cit.*

[4] Scherlin and Epstein, *loc. cit.*

$CH_2.CH_2.AsCl_2$, M.pt. 181·1° C., which, on treatment with alcoholic sodium hydroxide, is converted into *arsinylethyltrimethylammonium chloride*, $N(CH_3)_3Cl.CH_2.CH_2.AsO$, M.pt. 194° C.[1]

β-Piperidinoethyldichloroarsine hydrochloride.[2]—The corresponding piperidino-acid in concentrated hydrochloric acid containing a trace of potassium iodide is reduced by passing in sulphur dioxide for fifteen minutes. The precipitate, recrystallised from 2*N* hydrochloric acid, separates in square plates, M.pt. 126° to 127° C. with gas evolution. The arsine dissolves in water and ethyl alcohol; the water solution, on treatment with saturated aqueous potassium iodide, added dropwise, yields *β-piperidinoethyldi-iodoarsine hydriodide*. This melts at 158° to 159° C., is bright yellow in colour, but gives colourless solutions in water or ethyl alcohol.

n-Propyldi-iodoarsine, $C_3H_7.AsI_2$.[3]—Magnesium propylarsenate (145 grams) and 250 grams of potassium iodide in 300 c.c. of water and 330 grams of concentrated hydrochloric acid, are reduced by passing in sulphur dioxide. When the colour of the mixture disappears, a further 200 grams of hydrochloric acid are added. The di-iodoarsine separates, is taken up in ether, dried with calcium chloride and the ether removed in a stream of carbon dioxide. The residue, distilled *in vacuo*, gives a reddish-yellow oil, B.pt. 136° to 137° C. Yield, 156 grams, which is 55 per cent. The arsine has a faint odour, resembling that of the lower homologues, but extremely irritating. Boiled in benzene solution with an excess of anhydrous sodium carbonate, it forms *n*-propylarsenoxide, which distils in carbon dioxide at 142° to 145° C. at 0·1 mm.; it is a pale yellow oil, not solidifying at −20° C.

γ-Chloropropyldichloroarsine.[4]—This derivative is obtained from γ-hydroxypropylarsinic acid by method (1) used in the preparation of β-chloroethyldichloroarsine, p. 24. The dichloroarsine boils at 120° to 122° C. at 16 mm.

γ-n-Propylaminopropyldichloroarsine hydrochloride is prepared from the amino-acid hydrochloride in the usual manner. It crystallises from hydrochloric acid in elongated, hexagonal tablets, M.pt. 195° to 196° C., which readily reduce a solution of iodine in potassium iodide and yield a yellow solid on treatment with saturated potassium iodide solution.

γ-n-Hexylaminopropyldichloroarsine hydrochloride crystallises from 2*N* hydrochloric acid in large hexagonal plates, M.pt. 190° to 192° C.

l-α-Phenylethylaminopropyldichloroarsine hydrochloride is the product of interaction of *l*-α-phenylethylamine and γ-chloropropylarsinic acid, the reaction being conducted in the usual manner. It crystallises from 2*N* hydrochloric acid in large hexagonal plates, M.pt. 194° to 196° C.

γ-Piperidinopropyldichloroarsine hydrochloride is prepared by treating the acid hydrochloride dissolved in concentrated hydrochloric acid with sulphur dioxide. From 4*N* hydrochloric acid it separates in hexagonal plates, M.pt. 194° to 196° C.

n-Butyldichloroarsine, $C_4H_9.AsCl_2$.[5]—A solution of 150 grams of

[1] Renshaw and Ware, *loc. cit.* [2] Gough and King, *loc. cit.*
[3] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[4] Gough and King, *loc. cit.*
[5] Quick and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 805.

crude *n*-butylarsinic acid in 300 c.c. of concentrated hydrochloric acid is treated with a few crystals of potassium iodide and saturated for two hours with sulphur dioxide, when 100 grams of crude chloride separate. If this is removed and the mother liquor saturated with sodium chloride, an additional yield is obtained. The product is fractionated under diminished pressure, a colourless oil resulting, which boils at 192° to 194° C.

iso-Amyldichloroarsine, $(CH_3)_2CH.CH_2.CH_2.AsCl_2$.[1]—A suspension of 19·6 grams of *iso*amylarsinic acid in 50 grams of chloroform is treated under reflux with 27·5 grams of phosphorus trichloride in 50 grams of chloroform, the latter solution being added dropwise. Considerable heat is developed, and the reaction is completed by boiling for thirty minutes on the water-bath. The mixture is filtered whilst hot, the solvent removed, and the residue fractionated in a vacuum, about 4·5 grams of product being isolated. The chloride is a colourless liquid, B.pt. 88·5° to 91·5° C. at 15 mm. with slight decomposition, and is decomposed by water.

Compounds of the Type R_2AsX.

Dialkyl Halogenated Arsines.—These derivatives, which may be regarded as substitution products of arsine or trialkylarsines, are best obtained by the reduction of the corresponding arsinic acids. This has been achieved in three ways :

(1) By the action of phosphorus trichloride on the acid,

$$3R_2AsO.OH + 4PCl_3 = 3R_2AsCl + 3POCl_3 + H_3PO_3$$

(2) By treating a solution of the arsinic acid in water with sulphur dioxide in the presence of potassium iodide, dilute hydrochloric acid being added from time to time.

(3) The arsinic acid may be reduced by sodium hypophosphite in hydrochloric acid solution,

$$2R_2AsO.OH + 3H_3PO_2 + 2HCl = 2R_2AsCl + H_2O + 3H_3PO_3$$

Other methods of obtaining these halogenated compounds are as follows :

(1) Dialkylarsenious oxides are distilled with concentrated halogen acids, sometimes in the presence of mercuric chloride, in the case of chlorides,

$$(R_2As)_2O + 2HX = 2R_2AsX + H_2O$$

(2) Tetra-alkyldiarsines are treated with halogens or alkyl halides,

$$R_2As.AsR_2 + X_2 = 2R_2AsX$$
$$R_2As.AsR_2 + 2RX = R_2AsX + R_4AsX$$

(3) Dialkylarsines are caused to interact with chlorinating agents, such as sulphur or arsenic chlorides or ethylchloroformate.

(4) Dialkylbromo- or iodo-arsines may be obtained from the corresponding chloro-compounds by interaction with potassium halides,

$$R_2AsCl + KX = R_2AsX + KCl$$

[1] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1014.

Dialkylcyanoarsines.—These compounds may be obtained: (1) By the action of hydrogen cyanide or concentrated mercuric cyanide solution upon arsenoxides. (2) By treating the foregoing halogenated compounds with potassium cyanide, replacement of the latter by sodium thiocyanate yielding *thiocyano-* derivatives, $R_2As.CNS$. (3) Trialkylarsine cyanobromides are heated *in vacuo*:

$$R_3As.CNBr \longrightarrow R_2As.CN + RBr$$

Dialkylarsenoxides.—These oxides are best prepared by treating dialkyl halogenated arsines with alkali or alkali carbonates. They may also be formed by the reduction of dialkylarsinic acids or by the distillation of a mixture of arsenic acid and the potassium salt of a fatty acid.

Dialkylarsenious sulphides.—The sulphides may be of two types, $(R_2As)_2S$ and $(R_2As)_2S_2$. The monosulphides result—

(1) When secondary arsines are treated with sulphur, excess of the latter leading to the formation of disulphides:

$$2R_2AsH + S_2 = (R_2As)_2S + H_2S$$
$$2R_2AsH + 3S = (R_2As)_2S_2 + H_2S$$

(2) The corresponding halogenated arsines are decomposed by hydrogen sulphide or barium hydrosulphide, yielding arsines:

$$2R_2AsX + H_2S = (R_2As)_2S + 2HX$$
$$2R_2AsX + Ba(SH)_2 = (R_2As)_2S + BaX_2 + H_2S$$

(3) Hydrogen sulphide reduces dialkylarsinic acids to sulphides:

$$2R_2AsO.OH + 3H_2S = (R_2As)_2S + S_2 + 4H_2O$$

This last equation applies to an aqueous solution of the acid; with a concentrated alcoholic solution it is possible to obtain the disulphide. Liquid sulphur dioxide reacts with dialkylarsines, giving disulphides as one of the products of reaction.

Distillation of dimethylchloroarsine with aqueous sodium selenide yields *dimethylarsenious selenide.*

All the halogenated compounds are oils, possessing penetrating and repulsive odours. They are not decomposed by water, cacodyl iodide being volatile in steam. Reduction by platinised zinc in alcoholic solution in the presence of hydrogen chloride, or reduction by electrolysis, leads to the formation of arsines, R_2AsH. Distillation with sodium, iron, tin, zinc or zinc amalgam gives cacodyl compounds. Dimethylchloroarsine forms additive compounds with many metallic chlorides. With chlorine R_2AsCl_3 results, the methyl derivative decomposing at 40° to 50° C. as follows:

$$R_2AsCl_3 = RAsCl_2 + RCl$$

The dialkyl halogenated arsines combine with alkyl halides, the resulting product depending upon experimental conditions, *e.g.* dimethylbromoarsine may give rise to tetramethylarsonium mono- or tri-iodide with methyl iodide, whilst methyl bromide yields trimethylarsine dibromide.

The cyano- compounds are low-melting solids. With methyl iodide they yield tetra-alkylarsonium mono- and tri-iodides, and under suitable conditions the cyanogen group, –CN, may be oxidised to carboxyl, –COOH.

Only two oxides are known with certainty, dimethyl- and diethyl-

arsenoxides, both being liquids. Di-*iso*amylarsenoxide is supposed to be a solid, but its existence is doubtful. Dialkylarsenious sulphides are only known in the methyl and *iso*amyl series.

Dimethylfluoroarsine, *Cacodyl fluoride,* $(CH_3)_2AsF$, is obtained by distilling cacodyl oxide with hydrofluoric acid.[1] It is a colourless liquid of repulsive and penetrating odour, insoluble in water.

Dimethylchloroarsine, *Cacodyl chloride* $(CH_3)_2AsCl$, may be prepared by the following methods :

(1) Cacodyl oxide is treated with fuming hydrochloric acid, then mixed with an excess of mercuric chloride. The mass is diluted somewhat with more hydrochloric acid and the whole distilled, the chloride passing over.[2]

(2) By treating cacodyl with chlorine water.[3]

(3) By the interaction of cacodyl and methyl chloride.[4]

(4) By the action of ethyl chloroformate, sulphur dichloride, or arsenic trichloride on dimethylarsine.[5]

(5) By the slow addition of cacodylic acid to well-cooled phosphorus trichloride.

(6) By dissolving cacodylic acid in hydrochloric acid and adding to it the calculated quantity of sodium hypophosphite dissolved in an excess of the same solvent.[6]

Cacodyl chloride is a liquid having a very offensive odour, does not solidify at −45° C., and boils at 109° C.[7] It is heavier than water, miscible with alcohol but insoluble in water and ether; when warmed in air it burns with a pale yellow flame. It may be reduced to dimethylarsine either by treatment with platinised zinc and alcoholic hydrogen chloride,[8] or electrolytically.[9] When heated with zinc, iron, or tin at 90° to 100° C. the chloride is converted into cacodyl. If introduced into chlorine gas, the chloride is spontaneously inflammable,[10] but the passage of chlorine into a well-cooled solution of cacodyl chloride in carbon disulphide yields cacodyl trichloride.[11] Methyl iodide, when heated for three hours at 100° C. with cacodyl chloride, gives methyl chloride and tetramethylarsonium tri-iodide.[12] The following reaction takes place between cacodyl chloride and metallic sodium in absolute ether :

$$2(CH_3)_2AsCl + 2Na = [(CH_3)_2As]_2 + 2NaCl.^{13}$$

Bunsen, in his researches on cacodyl chloride,[14] noted that a double compound, $(CH_3)_2AsCl.CuCl$, was formed on mixing an alcoholic solution of cacodyl oxide with a hydrochloric acid solution of cuprous chloride. The product consisted of white granules, decomposed by hot water and insoluble in alcohol and ether. More recently, Lee, Thing, and Dehn [15] have isolated a number of these double compounds, which will now be described.

[1] Bunsen, *Annalen*, 1841, 37, 38.
[2] Bunsen, *ibid.*, p. 31 ; Baeyer, *Annalen*, 1858, 107, 262.
[3] Bunsen, *Annalen*, 1842, 42, 35.
[4] Cahours, *Annalen*, 1862, 122, 197.
[5] Dehn and Wilcox, *Amer. Chem. J.*, 1908, 40, 125.
[6] Auger, *Compt. rend.*, 1906, 142, 1152; see Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1016.
[7] Lee, Thing, and Dehn, *J. Amer. Chem. Soc.*, 1923, 45, 2996.
[8] Palmer, *Ber.*, 1894, 27, 1378.
[9] Dehn, *Amer. Chem. J.*, 1908, 40, 97.
[10] Bunsen, *Annalen*, 1841, 37, 31.
[11] Baeyer, *ibid.*, 1858, 107, 266.
[12] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1453.
[13] Lee, Thing, and Dehn, *J. Amer. Chem. Soc.*, 1923, 45, 2997.
[14] Bunsen, *Annalen*, 1842, 42, 22.
[15] Lee, Thing, and Dehn, *loc. cit.*

With Mercurous Chloride.—Equimolecular quantities of mercurous chloride and cacodyl chloride when mixed under water slowly combine to form a white, powdery additive compound. This mixture when boiled undergoes decomposition according to the equation :

$$(CH_3)_2AsCl+2HgCl+2H_2O=(CH_3)_2AsO.OH+3HCl+2Hg$$

With Mercuric Chloride.—Equimolecular quantities of the two compounds when treated as above soon yield a white, odourless, solid additive compound. The latter decomposes on heating with water with formation of cacodylic and hydrochloric acids, mercurous chloride and mercury. When filtered, the hot aqueous filtrate deposits odourless, glistening, rhombic plates, which decompose without melting at 210° C., and have the composition $(CH_3)_2AsCl(OH)HgCl$. The formation of this product is represented by the equations :

$$(CH_3)_2AsCl+HgCl_2=(CH_3)_2AsCl_2.HgCl$$
$$2(CH_3)_2AsCl_2.HgCl+3H_2O=(CH_3)_2AsCl(OH)HgCl$$
$$+(CH_3)_2AsO.OH+4HCl+HgCl$$

With Cuprous Chloride.—1·5 grams of anhydrous cuprous chloride and 2·4 grams of cacodyl chloride are mixed under petroleum ether and the whole shaken and allowed to stand, when a white additive product separates. This, when filtered, washed with petroleum ether and dried *in vacuo*, corresponds to the formula $(CH_3)_2AsCl.2CuCl$.

With Cupric Chloride. Using equal weights of the two substances and carrying out the operation as before, the additive compound corresponds to $(CH_3)_2AsCl.CuCl_2$; but if the petroleum ether is replaced by ordinary ether the compound agrees with the formula $(CH_3)_2AsOH.CuCl_2$, whilst with anhydrous ether it agrees with $[(CH_3)_2As]_2O.2CuCl_2$, and ethyl chloride is also produced.

With Ferric Chloride. Equimolecular quantities of ferric chloride and cacodyl chloride in absolute ether deposit green crystals of ferrous chloride after standing for some months, and hydrolysis of the ethereal solution yields cacodylic acid. This points to the formation of $(CH_3)_2AsCl_3$ during the reaction.

With Platinic Chloride.[1] Dimethylchloroarsine forms a platinichloride, $2(CH_3)_2AsCl.PtCl_4$, a brick-red precipitate, soluble in hot water, giving a colourless solution from which the co-ordinated compound $[(CH_3)_2As]_2O.PtCl_2.H_2O$ separates in colourless needles, which are dehydrated at 160° C. This compound, with potassium bromide or iodide, silver nitrate or sulphate, yields, respectively, $[(CH_3)_2As]_2O.PtBr_2.H_2O$ (colourless), $[(CH_3)_2As]_2O.PtI_2.H_2O$ (yellow), $[(CH_3)_2As]_2O.Pt(NO_3)_2.H_2O$ and $[(CH_3)_2As]_2O.PtSO_4.H_2O$.

Basic cacodyl chloride, " Basic cacodyl superchloride " (Bunsen), $(CH_3)_2As(OH)_2Cl$.—Bunsen first prepared this compound by treating cacodylic acid with concentrated hydrochloric acid :

$$(CH_3)_2AsO.OH+HCl=(CH_3)_2As(OH)_2Cl$$

It may, however, be isolated by passing a current of moist air through an ethereal solution of cacodyl chloride :

$$2(CH_3)_2AsCl+O_2+2H_2O=2(CH_3)_2As(OH)_2Cl$$

[1] Bunsen, *Berz. Jahresber.*, 1842, **21**, 500.

The substance melts at 85° C., is soluble in water and alcohol but insoluble in ether, chloroform, and carbon disulphide.

Dimethylarsenic chloride, *Cacodyl trichloride,* $(CH_3)_2AsCl_3$,[1] crystallises in plates or columns from ether, fuming in air. At 40° to 50° C. the trichloride froths and decomposes into methyl chloride and methyldichloroarsine. It is prepared by passing chlorine into a solution of cacodyl chloride in carbon disulphide, or by adding powdered cacodylic acid in small quantities to phosphorus pentachloride mixed with dry ether.

Dimethylbromoarsine, *Cacodyl bromide,* $(CH_3)_2AsBr$.—This compound was first isolated by distilling the double compound of cacodyl oxide and mercuric chloride with very concentrated hydrobromic acid,[2] and later, by the action of methyl bromide on cacodyl.[3] In recent years the substance has been re-investigated and the following methods of preparation used:

(1) A solution of 22 grams of sodium hypophosphite in 75 c.c. of concentrated hydrobromic acid is added in two portions to a solution of 28 grams of cacodylic acid in 45 c.c. of hydrobromic acid. The reaction is completed by gently warming, keeping the temperature below 60° C. The cacodyl bromide is separated off, dried over calcium chloride, then distilled in a carbon dioxide atmosphere. B.pt. 128° to 129° C., yield 28 grams, or 74 per cent.[4]

(2) Molecular quantities of potassium bromide and cacodyl chloride with three to four volumes of absolute alcohol are heated under reflux for four to five hours, air being excluded. The mixture is then distilled from a sand-bath and the distillate treated with five to ten volumes of water, when the bromide is precipitated; it is separated, dried over calcium chloride, and fractionated. The yield is nearly quantitative, and the product boils at 130° C.[5]

Cacodyl bromide is a yellow oil, which gives a hydrobromide, $Me_2AsBr.HBr$. This double compound is formed along with hydrogen bromide, hydrogen, and cacodyl bromide, when dimethylarsine is treated with bromine.[6] It crystallises in white plates, soluble in hot chloroform, insoluble in ether, and decomposed by water into cacodyl bromide and hydrogen bromide. When 5·28 grams of cacodyl bromide and 17 grams of methyl iodide were heated in a sealed tube for two hours at 100° C., 11·6 grams of tetramethylarsonium tri-iodide were formed, together with 0·2 gram of the mono-iodide, whilst three hours' heating at 100° C. of 2·2 grams of cacodyl bromide with 1·5 c.c. of methyl bromide in a carbon dioxide atmosphere only gave 0·8 gram of trimethylarsine dibromide. Tetramethylarsonium tri-iodide, when heated for six hours in a sealed tube at 100° C. with cacodyl bromide, is converted into the mono-iodide.[7]

Dimethyliodoarsine, *Cacodyl iodide,* $(CH_3)_2AsI$, was originally prepared by Bunsen[8] by the distillation of cacodyl oxide with concentrated hydriodic acid, and in small quantity by the interaction of cacodyl and methyl iodide.[9] Distillation of the periodide, $Me_4AsI.I_2$, also gives the

[1] Baeyer, *Annalen*, 1858, 107, 266.
[2] Bunsen, *Annalen*, 1841, 37, 38.
[3] Cahours, *Annalen*, 1862, 122, 207.
[4] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1454.
[5] Lee, Thing, and Dehn, *J. Amer. Chem. Soc.*, 1923, 45, 2996.
[6] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 15.
[7] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1454, 1462.
[8] Bunsen, *Annalen*, 1841, 37, 52.
[9] Cahours and Riche, *Annalen*, 1854, 92, 362; Cahours, *Annalen*, 1862, 122, 207.

iodo-arsine, and it results amongst other products when methyl iodide reacts with powdered arsenic at the ordinary temperature, or on the water-bath.[1] It has more recently been prepared from cacodylic acid as follows :[2] 250 grams of cacodylic acid and 800 grams of potassium iodide are dissolved in 1000 c.c. of water and the whole saturated with sulphur dioxide. Dilute hydrochloric acid (1 : 1) is added from time to time, the cacodyl iodide separating as an oil as the reduction proceeds. The end-point of the reaction is reached when sulphur commences to separate. The oily layer is removed, dried over calcium chloride, and distilled; 380 grams of cacodyl iodide may be isolated, which is 90 per cent. yield. This method may be varied as follows: Sulphur dioxide is passed into a solution containing 225 grams of cacodylic acid, 450 grams of potassium iodide, 150 grams of concentrated sulphuric acid, and 1850 c.c. of water.[3] The iodide thus prepared is a yellow liquid, B.pt. 154° to 157° C., freezing to a pale yellow solid at about −35° C.

Two preparations of the iodide from cacodyl chloride have recently been devised. The first[4] is analogous to method (2) used for cacodyl bromide (p. 30). The yield is nearly quantitative, and the product boils at 155° to 160° C. The second method consists in treating a dry acetone solution of sodium iodide with cacodyl chloride.[5] The yield in this case is 58 per cent., and the boiling-point 154° to 155° C.[6]

Cacodyl iodide is a yellow oil of penetrating odour, soluble in organic solvents but insoluble in water; it is volatile in steam. When heated in air it inflames, iodine vapours being evolved. It is decomposed by nitric and sulphuric acids with separation of iodine.

When dimethylarsine and iodine are heated in a sealed tube, the *hydriodide*, $(CH_3)_2AsI.HI$, is produced. This crystallises in large, pale yellow needles, which soften and darken at 160° C. and melt at 175° C., are soluble in alcohol, but easily decomposed by water, giving hydrogen iodide and cacodyl iodide. The latter, when heated with methyl iodide for one hour at 100° C., yields tetramethylarsonium tri-iodide.[7]

Dimethylcyanoarsine, *Cacodyl cyanide*, $(CH_3)_2AsCN$. — This cyanide, prepared by Bunsen[8] by distilling cacodyl oxide with concentrated hydrocyanic acid, or better, by the action of concentrated mercuric cyanide solution on the oxide, has been investigated again more recently. It is obtained from cacodyl chloride and potassium cyanide (see Cacodyl bromide, method (2), p. 30), and also from cacodyl oxide in the following manner: 44 grams of cacodyl oxide in two portions are heated with five times the calculated quantity of anhydrous hydrocyanic acid in a sealed tube for two hours at 100° C. The excess of hydrocyanic acid is then removed in a stream of carbon dioxide and the residue distilled, the cyanide distilling at 160° C. The yield is 35 grams or 64 per cent.[9]

Cacodyl cyanide crystallises in glistening prisms, M.pt. 32·5° C., the boiling-point according to different investigators varying between 138°

[1] Auger, *Compt. rend.*, 1907, 145, 809.
[2] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1373; see also Burrows and Turner, *ibid.*, 1921, 119, 426.
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[4] Lee, Thing, and Dehn, *loc. cit.*
[5] Steinkopf and Schwen, *loc. cit.*
[6] See also Wigren, *Annalen*, 1924, 437, 285.
[7] Steinkopf and Schwen, *loc. cit.*
[8] Bunsen, *Annalen*, 1841, 37, 23; see also *Annalen*, 1842, 42, 18.
[9] Steinkopf and Schwen, *loc. cit.*

and 160° C. It was said to be exceedingly poisonous, but Lee, Thing, and Dehn [1] recently state that their preparation was not found to be excessively poisonous, and suggest that it probably has the cyanide and not the *iso*cyanide structure. It is readily soluble in alcohol and ether, but sparingly soluble in water. It reduces mercurous nitrate solution, and yields silver cyanide with silver solutions. When treated with methyl iodide for two hours at 100° C. in a carbon dioxide atmosphere, tetramethylarsonium tri-iodide and a little mono-iodide are formed. When hydrolysed with dilute sulphuric acid and then neutralised with calcium hydroxide, the calcium salt of *dimethylarsinecarboxylic acid* is obtained. The *free acid*, $(CH_3)_2As.CO_2H$, is formed by decomposition of this salt with acids. It turns blue litmus red and gives stable salts with metals and alkaloids.[2]

Dimethylthiocyanoarsine, $(CH_3)_2As.CNS$,[3] results when acetone solutions of dimethylchloroarsine and sodium thiocyanate are mixed. It is a colourless, pale yellow oil, B.pt. 92° C. at 17 mm., having a strong, irritating odour. It is readily miscible with the usual organic solvents.

Methylethyliodoarsine, $(CH_3)(C_2H_5)AsI$.[4]—Ethyldichloroarsine (250 grams), dissolved in 122 grams of sodium hydroxide in 200 c.c. of water and 600 c.c. of alcohol, is treated with 75 c.c. of methyl iodide under reflux. After a few hours the solution is neutralised, freed from alcohol, acidified with hydrochloric acid, and reduced by sulphur dioxide. The iodoarsine separates as an oil, which is collected, dried, and distilled under reduced pressure, about 138 grams of product being obtained. It is a yellow, oily liquid, B.pt. 65° C. at 14 mm., boiling with slight decomposition under atmospheric pressure, spontaneous ignition occasionally occurring.

γ-Phenylpropylmethylchloroarsine, $C_6H_5.[CH_2]_3CH_3.AsCl_2$.[5]—γ-Phenylpropyldimethylarsine (45 grams), in carbon tetrachloride solution, is treated with chlorine (1 mol.) in the same solvent and the pale yellow solution evaporated. The residue is heated at 160° to 180° C., when it rapidly decomposes with evolution of methyl chloride; distillation of the final residue yields 22 grams of the chloride as a colourless liquid, B.pt. 164° to 167° C. at 14 mm. The corresponding bromide is obtained in a similar manner and is a colourless liquid, B.pt. 177° to 180° C. at 16 mm.

Dimethylarsenious sulphide, *Cacodyl sulphide*, $[(CH_3)_2As]_2S$, is most readily obtained by adding the calculated quantity of sulphur to dimethylarsine.[6] It is also formed when hydrogen sulphide is passed into an aqueous solution of cacodylic acid, or by distilling a mixture of barium hydrosulphide and cacodyl chloride in a carbon dioxide atmosphere.[7] Dimethylarsenious sulphide is a transparent, non-fuming liquid, having a most disagreeable odour, like that of mercaptan. It does not solidify at −40° C., is volatile in steam, and boils above 100° C. It inflames in air, is miscible in all proportions with alcohol and ether, and is insoluble in water. When treated with copper nitrate in

[1] Lee, Thing, and Dehn, *J. Amer. Chem. Soc.*, 1923, 45, 2997.
[2] French Patents, 521119, 521469; from *Chem. Zentr.*, 1921, iv. 870.
[3] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1016.
[4] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 426.
[5] Burrows and Turner, *loc. cit.*; 1920, 117, 1373.
[6] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 37.
[7] Bunsen, *Annalen*, 1841, 37, 18.

alcoholic solution it forms the *double compound* $[(CH_3)_2As]_2S.3CuS$, which is stable in air and crystallises in octahedra.[1]

Dimethylarsenious disulphide, *Cacodyl disulphide*, $[(CH_3)_2As]_2S_2$, occurs when the preceding compound is treated with sulphur, or when hydrogen sulphide is passed into a concentrated alcoholic solution of cacodylic acid.[2] It may also be obtained from dimethylarsine by interaction with the requisite amount of sulphur, or by dissolving the arsine in liquid sulphur dioxide, other products of the reaction being methylarsenious sulphide, trimethylarsine sulphide, and cacodylic acid.[3] It crystallises in rhombic plates, M.pt. 50° C., insoluble in water, soluble in alcohol or ether.

Dimethylarsenious selenide, *Cacodyl selenide*, $[(CH_3)_2As]_2Se$, is a yellowish liquid of very penetrating odour, resulting when pure cacodyl chloride is distilled with an aqueous solution of sodium selenide It does not fume in air, is insoluble in water, but soluble in organic solvents.

Dimethylarsenoxide, *Cacodyl oxide*, $[(CH_3)_2As]_2O$.—This oxide is the chief constituent of *Cadet's fuming liquid*,[4] obtained by the distillation of equal quantities of arsenic acid and potassium acetate.[5] The crude product from this reaction is treated with fuming hydrochloric acid and mercuric chloride, distillation of the mixture yielding cacodyl chloride, the latter being converted to the oxide by distilling with aqueous potassium hydroxide.[6] Cacodyl chloride also yields the oxide when treated with dry sodium carbonate.[7] Another method of preparation consists in reducing cacodylic acid with sulphur dioxide.[8]

Cacodyl oxide is a colourless, mobile, non-fuming, non-inflammable liquid of intolerable odour. It crystallises at −25° C. and boils at about 120° C., has a vapour density of 7·55, and a specific gravity of 1·462 at 15° C. It should be pointed out that these constants have probably been worked out on a product still containing some cacodyl and on further investigation they may be found to be erroneous. It is readily soluble in alcohol and ether, but sparingly soluble in water, and in the air it slowly oxidises to cacodylic acid. Mercury and silver oxides are reduced by cacodyl oxide, and when distilled with halogen acids the oxide yields cacodyl halides. When treated with methyl iodide and sodium hydroxide in methyl alcohol solution it becomes methylated, forming trimethylarsine oxide.

The following compounds were described by Bunsen,[9] but are of doubtful composition: *basic cacodyl chloride*, $Me_4As_2O.6Me_2AsCl$, and a corresponding *bromide* and *iodide*; also $Me_4As_2O.HgCl_2$, forming white plates from water.[10]

Dimethylarsine chlorostannide, $(CH_3)_2AsCl.SnCl_2$ or $(CH_3)_2As.SnCl_3$, results when dimethylarsine reacts with stannic chloride.[11] It crystallises in large, colourless needles, which sublime at 100° C., are

[1] Bunsen, *Annalen*, 1843, 46, 11. [2] Bunsen, *ibid.*, p. 16.
[3] Dehn and Wilcox, *loc. cit.*
[4] A discussion of the mechanism of the reactions accompanying the formation of Cadet's oil is given by Valeur and Gailliot, *Compt. rend.*, 1927, 185, 956.
[5] Bunsen, *Annalen*, 1837, 24, 271; 1839, 31, 175; 1841, 37, 6; 1842, 42, 15.
[6] Baeyer, *Annalen*, 1858, 107, 262, 282.
[7] Auger, *Compt. rend.*, 1906, 142, 1153.
[8] Auger, *ibid.*, 1903, 137, 926.
[9] Bunsen, *Annalen*, 1841, 37, 49.
[10] See Dehn, *Amer. Chem. J.*, 1908, 40, 127.
[11] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 39.

stable in dry air, easily soluble in ether, but sparingly soluble in chloroform.

Diethyliodoarsine, $(C_2H_5)_2AsI$, is formed when the compound $(C_2H_5)_4AsI.AsI_3$ is distilled.[1] It is a liquid, which yields *tetraethyldiarsine*, $(C_2H_5)_2As.As(C_2H_5)_2$, on distillation with zinc amalgam.

Diethylcyanoarsine, $(C_2H_5)_2As.CN$,[2] results when triethylarsine cyanobromide is heated *in vacuo*. It melts at about 50° C. and boils at 74° C. at 12 mm.

Diethylarsenoxide, $[(C_2H_5)_2As]_2O$,[3] results when diethylchloroarsine is treated with sodium carbonate, sodium hydrogen carbonate, and sodium hydroxide. The oxide boils at 225° to 230° C., density 1·2986.

Di-n-propyliodoarsine, $(C_3H_7)_2AsI$.[4]—To a cooled mixture of 187 grams of *n*-propyldi-iodoarsine, 81 grams of sodium hydroxide and 125 c.c. of water, 75 grams of *n*-propyl bromide are added and the whole stirred for sixteen hours. The mixture is heated on the water-bath until all the bromide disappears, and is then treated with 100 c.c. of water and 110 c.c. of concentrated hydrochloric acid, when some of the iodoarsine separates. The mixture is then decolorised by passing in sulphur dioxide, and the resulting liquor subjected to distillation. A yield of about 63 grams of the iodoarsine is obtained as a yellow oil, B.pt. 103·5° to 106° C. at 12·5 mm., strongly irritant to the mucous membrane of the nose.

Methylisoamylchloroarsine, $(CH_3)(C_5H_{11})AsCl$, and **Di-isoamylchloroarsine,** $(C_5H_{11})_2AsCl$.—A solution of 93 grams of methyldi-*iso*amylarsine in 150 c.c. of dry petroleum ether is treated with 28 grams of dry chlorine. After standing for several hours the solvent is removed by a stream of carbon dioxide, methyldi-*iso*amylarsine dichloride remaining. This, when heated in carbon dioxide, commences to decompose at 186° C., and at 210° C. a distillate comes over. The residue yields two fractions: (*a*) B.pt. 68° to 72° C. at 11 mm., is methyl*iso*amylchloroarsine; (*b*) consists of about 24 grams of di-*iso*amylchloroarsine, B.pt. 114° to 122° at 11 mm. Methyl chloride and *iso*amyl chloride are also obtained in the decomposition of methyldi-*iso*amylarsine dichloride.

Basic di-isoamylchloroarsine, $6(C_5H_{11})_2AsCl.[(C_5H_{11})_2As]_2O$.[5] This compound is the condensation product formed when *iso*amyl chloride (2 mols.) and arsenic trichloride (1 mol.) are condensed in the presence of sodium. It is a colourless oil, B.pt. 263° C. at 750 mm. and 148° C. at 33 mm., has a peculiar odour, and is soluble in the usual organic solvents, but insoluble in water. When distilled, a small quantity of white, soapy solid is formed, which is probably *iso*amyl cacodyl oxide, $[(C_5H_{11})_2As]_2O$.

Di-isoamylarsine chlorodibromide, $(C_5H_{11})_2AsClBr_2$, is obtained by the action of bromine on the preceding compound in ether solution. It is a white, crystalline solid, M.pt. 124° to 125°, soluble in ether and chloroform, and slowly dissolves in water with formation of di-*iso*amylarsinic acid.

[1] Cahours and Riche, *Annalen*, 1854, **92**, 365.
[2] Steinkopf and Müller, *Ber.*, 1921, **54**, [B], 841.
[3] Trochimovski, Buczwiński, and Kwapiszewski, *Roczn. Chem.*, 1928, **8**, 423.
[4] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, **61**, [B], 1911.
[5] Dehn and Wilcox, *Amer. Chem. J.*, 1906, **35**, 49; Steinkopf, Dudek, and Schmidt, *loc. cit.*, deny the existence of this substance.

Di-isoamylarsine sulphide, $[(C_5H_{11})_2As]_2S$, is prepared by passing hydrogen sulphide through a suspension of the chloride in water. It crystallises in white needles, M.pt. 29° to 30° C., easily soluble in ether or carbon disulphide, sparingly soluble in alcohol and insoluble in water.

Compounds of the Type $RAsO(OH)_2$.

(1) The most satisfactory method of obtaining the alkylarsinic acids of the type $R.AsO(OH)_2$ is by the interaction of alkyl halides and alkali arsenites. This may be represented by the following scheme :—

$$As(ONa)_3 + RI \longrightarrow RAs(O)(ONa)_2 + NaI$$

or :

$$Na.As(O)(ONa)_2 + RI \longrightarrow RAs(O)(ONa)_2$$

(2) Another method, which has only been applied to *n*-butylarsinic acid in the aliphatic series, but which appears to be capable of much greater application, consists of oxidising alkyldichloroarsines by sodium toluene-*p*-sulphonchloroamide ("Chloramine-T"). The obvious drawback of this method compared with the preceding one is that it is necessary to prepare an organic arsenical compound as starting material for the process.

(3) Methylarsine or methylarsenious oxide may be oxidised by oxygen, or methylarsenious oxide or methyldi-iodoarsine by iodine.

Methylarsinic acid, $CH_3.AsO(OH)_2$.—The following general method of preparation for acids of this type has recently been given by Quick and Adams :[1] One gram-molecule of arsenious oxide is dissolved in sufficient 10*N* sodium hydroxide solution to produce tri-sodium arsenite. This is placed in a round-bottomed flask fitted with a mechanical stirrer and reflux condenser. A little more than one gram-molecule of alkyl iodide is added, the mixture being stirred and refluxed, until 1 c.c. when titrated with standard iodine indicates that 80 to 90 per cent. of the sodium arsenite has disappeared. The method of isolation varies slightly according to the acid being prepared, but in all cases acidification with hydrochloric acid is used at some stage of the operation, and since the arsinic acids show some tendency to be soluble in this acid, excess should be avoided.

Methylarsinic acid was previously prepared by the action of oxygen on methylarsine or methylarsenoxide,[2] and also by the oxidation of methylarsenoxide or methyldi-iodoarsine with iodine.[3] It crystallises in monoclinic, prismatic plates from alcohol.[4] It is easily soluble in water or alcohol, and is a strong, dibasic acid, liberating carbon dioxide from carbonates. Its heats of neutralisation and solution have been studied,[5] and also its behaviour towards indicators.[6] When treated

[1] Quick and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 805.
[2] Palmer and Dehn, *Ber.*, 1901, 34, 3597 ; Dehn, *Amer. Chem. J.*, 1905, 33, 124.
[3] Bougault, *Chem. Zentr.*, 1907, ii. 1359.
[4] Dufet, *Chem. Zentr.*, 1902, ii. 1498.
[5] Astruc and Baud, *Compt. rend.*, 1904, 139, 212.
[6] Astruc, *Compt. rend.*, 1902, 134, 660.

with an excess of phosphorus trichloride (with cooling), methyldichloroarsine is isolated.[1] The acid, when melted with sodium hydroxide at 250° to 280° C., is decomposed, yielding methane and sodium arsenate.[2] When a boiling solution of methylarsinic acid is saturated with sodium bicarbonate and then treated with an equimolecular quantity of antimony trichloride, the compound $CH_3.AsO(O.SbO)_2$ is obtained.[3] The following salts of methylarsinic acid are known :—

Sodium methylarsinate (*Arrhenal, New Cacodyl*), $CH_3.AsO(ONa)_2$, is obtained from sodium arsenite and methyl iodide in dilute alcoholic solution.[4] Using the general method of preparation already outlined : 99 grams of arsenious oxide in 300 c.c. of 10*N* sodium hydroxide, and 150 grams of methyl iodide, are heated on the water-bath for two hours. An equal volume of alcohol is then added to precipitate the sodium methylarsinate, which is then purified by solution in a small bulk of water and reprecipitation by alcohol. This salt has been isolated with varying amounts of water of crystallisation.[5] The water may be driven off by heating to 130° C.[6] When the salt is reduced with sulphur dioxide in the cold, in the presence of potassium iodide and hydrochloric acid, it gives methyldi-iodoarsine,[7] and on heating with sodium hypophosphite and dilute sulphuric acid, *methyl arsenic* $(MeAs)_4$ is obtained.[8] Reduction of the sodium salt by concentrated hydriodic acid converts it into methylarsenic tetra-iodide, consisting of reddish-brown, six-sided plates.[9] With hydrogen sulphide the sodium salt yields methylarsine disulphide.

When an aqueous solution of sodium methylarsinate is saturated with molybdic acid, concentrated and treated with an excess of guanidinium chloride, two *guanidinium salts* are obtained. They may be separated by their differing solubilities, the more soluble salt crystallising in needles of composition : [10]

$$(CN_3H_6)_8H_2\left[\begin{matrix} & CH_3 & \\ As(Mo_2O_7)_4 & & (Mo_2O_7)_4.As \\ & Mo_2O_7 & \end{matrix}\right].8H_2O$$

This salt is only obtained in alkaline solution. The less soluble salt crystallises in rectangular plates having the formula :

$$(CN_3H_6)_2[As.CH_3(Mo_2O_7)_3].11H_2O$$

Silver methylarsinate, $CH_3.AsO(OAg)_2$, forms pearly, glistening crystals, which explode on strong heating and decompose gradually on exposure to light.[11]

Magnesium methylarsinate, $CH_3AsO.O_2Mg.5H_2O$, is a crystalline

[1] Auger, *Compt. rend.*, 1906, 142, 1152.
[2] Auger, *ibid.*, 1908, 146, 1280.
[3] Barthe and Minet, *ibid.*, 1909, 148, 1610.
[4] Meyer, *Ber.*, 1883, 16, 1440; Klinger and Kreutz, *Annalen*, 1888, 249, 149; Favrel, *Bull. Sci. Pharmacol.*, 1913, 20, 337.
[5] Astruc and Baud, *Compt. rend.*, 1904, 139, 212, give $3H_2O$; Astruc, *ibid.*, 1902, 134, 660, gives $5H_2O$; Adrian and Trillat, *ibid.*, p. 1231, give $6H_2O$.
[6] For use in medicine, see Gautier, *ibid.*, p. 329; *ibid.*, 1903, 136, 690, 832; *Bull. Soc. Chim.*, 1903, [3], 29, 546; Leprince, *J. Pharm. Chim.*, 1903, [vi.], 17, 22; *Chem. Zentr.*, 1903, i. 280.
[7] Auger, *Compt. rend.*, 1906, 142, 1151.
[8] Auger, *ibid.*, 138, 1705.
[9] Klinger and Kreutz, *Annalen*, 1888, 249, 152.
[10] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.
[11] Bueyer, *Annalen*, 1858, 107, 257; Klinger and Kreutz, *loc. cit.*

product, one litre of water dissolving 2·118 grams at 22° C. and 3·085 grams at 99° C.[1]

Barium methylarsinate, $CH_3AsO.O_2Ba.5H_2O$, crystallises in colourless needles, and may be obtained in the anhydrous state by precipitation from its aqueous solution by alcohol.[2]

Calcium methylarsinate, $CH_3AsO.O_2Ca.H_2O$, crystallises from its solution in dilute acetic acid after neutralisation with ammonium hydroxide.[3]

Yohimbine methylarsinate.—Prepared from 130 parts of acid and 368 parts of yohimbine; melts at 140° C.[4]

Pyrobismethylarsinic acid, $CH_3.AsO(OH).O.AsO(OH).CH_3$.—This anhydride of methylarsinic acid is prepared by heating the latter in a stream of hydrogen at 130° C.[5] If the temperature is raised from 170° to 180° C., decomposition to methyl alcohol and arsenious oxide occurs. The acid is reconverted to methylarsinic acid when treated with water. Similarly, the mono-sodium salt of methylarsinic acid yields *sodium pyrobismethylarsinate*, di-sodium methylarsinate at 140° C. in a carbon dioxide stream giving a mixture of sodium carbonate and sodium pyrobismethylarsinate.

Di-iodomethylarsinic acid, $CHI_2.AsO(OH)_2$, crystallises in yellow tablets containing one molecule of water of crystallisation. It is decomposed by boiling nitric acid into arsenic acid and iodine, whilst with hot sodium hydroxide, methylene iodide and arsenic acid are produced. The *silver salt* is a white precipitate, insoluble in water. For the preparation of di-iodomethylarsinic acid, see tetra-iodocacodylic acid, p. 45.

Ethylarsinic acid, $C_2H_5.AsO(OH)_2$, is best prepared by the general method for the type described under methylarsinic acid.[6] It has also been obtained from ethyldichloroarsine by prolonged warming with concentrated nitric acid, and the latter also oxidises ethylarsine disulphide to the arsinic acid.[7] Another method consists in treating ethyl iodide with tri-sodium arsenite in the presence of alcohol,[8] or with tri-potassium arsenite in aqueous alcohol solution.[9] The acid crystallises in needles, M.pt. 95° to 96° C., 100 parts of water dissolving 70 parts of the acid at 27° C. and 112 parts at 40° C.; 100 parts of 95 per cent. alcohol also dissolve 39·4 parts of acid at 25° C. The *sodium salt* is known in therapy as "*Mon-arsone.*" The *silver salt* crystallises in pearly scales; the *magnesium salt* is a white powder, soluble in acids, insoluble in alkali. One litre of water dissolves 2·31 grams of the salt at 22° C., and one litre of alcohol 0·3 gram at 25° C. Reduction of the magnesium salt by amalgamated zinc dust and alcoholic hydrochloric acid gives ethylarsine.

Propylarsinic acid, $C_3H_7.AsO(OH)_2$, crystallises from alcohol in needles or small plates, M.pt. 126° to 127° C., readily soluble in water and alcohol, insoluble in ether (100 parts of water dissolve 43 parts of

[1] Dehn, *Amer. Chem. J.*, 1905, 33, 136.
[2] Bayer, *loc. cit.*
[3] Meyer, *Ber.*, 1883, 16, 1442.
[4] American Patent, 1305402.
[5] Baud, *Compt. rend.*, 1904, 139, 411.
[6] Quick and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 805.
[7] La Coste, *Annalen*, 1881, 208, 34; Dehn, *Amer. Chem. J.*, 1905, 33, 134.
[8] Auger, *Compt. rend.*, 1903, 137, 927.
[9] Dehn, *loc. cit.*

acid at 26° C.). It has been prepared by the general method,[1] and also by the interaction of tri-potassium arsenite and propyl iodide in aqueous alcohol solution.[2] The reaction in the latter case is represented as follows, the second equation showing the side reaction also occurring :

$$As(OK)_3+C_3H_7I=C_3H_7.AsO(OK)_2+KI$$
$$C_2H_5OK+C_3H_7I=C_2H_5.O.C_3H_7+KI$$

The acid is isolated from the reaction mixture in the form of its *magnesium salt* by the aid of magnesia mixture, the free acid being obtained by adding the requisite amount of sulphuric acid. The yield of magnesium salt by this process is 42 per cent., and it forms pearly white, soapy crystals, containing half a molecule of water of crystallisation.

n-Butylarsinic acid, $C_4H_9.AsO(OH)_2$, may be prepared by the general method given under methylarsinic acid,[3] or by oxidation of *n*-butylchloroarsine with sodium toluene-*p*-sulphonchloroamide ("Chloramine-T"). The process is as follows:[4] The chloroarsine (1 mol.) dissolved or suspended in cold acetone (20 c.c. per gram of arsine), is treated with a 10 per cent. solution of Chloramine-T (2 mols.) in cold water. The reaction is completed by boiling for thirty minutes under reflux, the acetone then distilled off and the Chloramine-T separated by filtration of the cold solution. If the arsinic acid is only sparingly soluble in water, it separates with the sulphonamide and is removed by shaking with cold aqueous sodium carbonate, in which it is soluble. Should the arsinic acid be soluble in water, the solution is evaporated to dryness, and the residue then extracted as before. Acidification of the solution precipitates the arsinic acid. By this method, a 74 per cent. yield of *n*-butylarsinic acid results. The acid melts at 160° C., is soluble in water, and forms an insoluble *magnesium salt* when its solution is treated with magnesia mixture.

iso-Amylarsinic acid, $C_5H_{11}.AsO(OH)_2$, occurs as shining scales, M.pt. 194° C., insoluble in ether. Water (100 parts) dissolves 0·82 part of the acid at 28° C., and 100 parts of 95 per cent. alcohol, 2·2 parts at 21° C.[5] When heated for four hours at 285° C. the acid decomposes, giving *iso*amyl alcohol, arsenious oxide, and water.[6]

Allylarsinic acid, $CH_2=CH.CH_2.AsO(OH)_2$, is crystalline, and melts at 128° to 129° C.[7]

Substituted Alkylarsinic Acids of the Type, $RAsO(OH)_2$.

β-Hydroxyethylarsinic acid, $CH_2OH.CH_2.AsO(OH)_2$.[8]—Ethylene chlorhydrin, 80 grams, is slowly added to a solution containing 100 grams of arsenious oxide, 120 grams of sodium hydroxide, and 300 c.c. of water. It is necessary to cool and shake the solution during the operation, or some chlorhydrin is lost as ethylene oxide. After twelve

[1] Quick and Adams, *loc. cit.*
[2] Dehn and M'Grath, *J. Amer. Chem. Soc.*, 1906, 28, 352.
[3] Quick and Adams, *loc. cit.*
[4] Burton and Gibson, *Trans. Chem. Soc.*, 1924, 125, 2275.
[5] Dehn and M'Grath, *loc. cit.*
[6] Dehn and Williams, *Amer. Chem. J.*, 1908, 40, 116.
[7] Quick and Adams, *loc. cit.*; see also *Chem. Zentr.*, 1921, ii. 1065.
[8] Gough and King, *J. Chem. Soc.*, 1928, p. 2432; compare British Patents, 191028, 191029 (1922), 206152 (1924); Adams and Quick, *J. Amer. Chem. Soc.*, 1922, 44, 811; Edee, *ibid.*, 1928, 50, 1394.

hours the mixture is warmed for thirty minutes on the water-bath, 1500 c.c. of water are added, and the liquor made acid to Congo red, using hydrochloric acid. The whole is then evaporated until a copious deposit of salt and arsenious oxide is formed, the solid removed, washed twice with 90 per cent. alcohol, the united filtrates evaporated to dryness at 50° C., and the residue extracted with 100 c.c. of alcohol. Removal of the solvent leaves a viscous syrup of crude β-hydroxyethylarsinic acid.[1] Treatment of the acid with hot ammoniacal calcium chloride solution yields a sparingly soluble *calcium salt*, crystallising from dilute solution in hexagonal leaflets.

γ-Hydroxypropylarsinic acid.[2]—Trimethylene chlorhydrin, 95 grams, is stirred with the sodium arsenite solution from 100 grams of arsenious oxide, 120 grams of sodium hydroxide, and 300 c.c. of water at 50° to 60° C. until homogeneous. An equal bulk of water is then added, the liquor neutralised to Congo red and evaporated to dryness at 50° C. The residue, extracted with 150 c.c. of hot alcohol, gives a syrup of the impure arsinic acid on removal of the solvent. The acid yields a crystalline *calcium salt*. It reacts with sulphur dioxide in hydrochloric acid solution, forming the *di-ester* of *γ-hydroxypropyldichloroarsine*,

$$OH.C_3H_6.As\begin{matrix}O.C_3H_6.AsCl_2\\O.C_3H_6.AsCl_2\end{matrix},$$

B.pt. 35° C. at 0·16 mm., and *γ-hydroxypropylarsinous acid*, $(AsCl_2.C_3H_6.O)_2As.C_3H_6.OH$. The ester when treated with thionyl chloride gives γ-chloropropyldichloroarsine.

β-Chloroethylarsinic acid, $CH_2Cl.CH_2.AsO(OH)_2$,[3] is obtained by the oxidation of β-chloroethyldichloroarsine: (1) The dichloroarsine (57 grams), suspended in 228 c.c. of water, is dissolved by the passage of chlorine below 50° C. The solution is repeatedly evaporated with water at 60° C., and the residue finally crystallised from acetone, 35 grams of the required acid being isolated in the form of pearly plates; M.pt. 134° to 135° C. (2) Two grams of the dichloroarsine are treated with a few c.c. of water, then an excess of 30 per cent. Perhydrol. The product crystallises from alcohol in plates or needles, M.pt. 133° C.[4] The acid obtained by these methods may be recrystallised from acetone, or precipitated from this solvent by carbon tetrachloride.

Derivatives of β-Chloroethylarsinic Acid.[5]

Triethylamine-ββ′β″-triarsinic acid, $N[CH_2.CH_2.AsO(OH)_2]_3$.—Five grams of the β-chloroethylarsinic acid and 6·3 grams of carbamide are heated on the water-bath with sufficient water to give a liquid, and more water added occasionally to liberate ammonia by hydrolysis of the carbamide. The reaction is discontinued when a sample contains no un-ionised chlorine, and then excess of carbamide is removed by

[1] Compare Nekrassov and Nekrassov, *Ber.*, 1928, 61, [B], 1816; Scherlin and Epstein, *ibid.*, p. 1821; Edee, *loc. cit.*, states that the acid is very hygroscopic, and melts between 157° and 159° C.

[2] Gough and King, *loc. cit.*

[3] Gough and King, *loc. cit.*

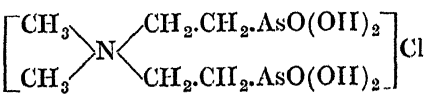
[4] Nekrassov and Nekrassov, *loc. cit.*; compare Scherlin and Epstein, *loc. cit.*

[5] Gough and King, *loc. cit.*

extraction with 30 c.c. of boiling ethyl alcohol. The residue is dissolved in 15 c.c. of water and the solution made neutral to Congo red paper. On cooling, the required acid separates in clusters of needles, which yield a crystalline *calcium* or *barium salt* on treatment in ammoniacal solution with calcium or barium chloride. A soluble and amorphous *magnesium salt* is also known. In the above reaction, acetamide and ammonium acetate may also be used as sources of ammonia.[1]

Methyldiethylamine-$\beta\beta'$-diarsinic acid, $N.CH_3[CH_2.CH_2.AsO(OH)_2]_2$.—Three grams of β-chloroethylarsinic acid and 2 c.c. of water are maintained at 100° C., and 33 per cent. aqueous methylamine solution added occasionally to keep the whole neutral. All the chlorine is ionised after about fifteen hours, the mixture then being neutralised to Congo red by hydrochloric acid, evaporated to dryness and freed from methylammonium chloride by boiling with ethyl alcohol. The residue is crystallised from aqueous alcohol, 1·9 grams of rectangular plates being produced, M.pt. 192° to 194° C.

β-Dimethylaminoethylarsinic acid hydrochloride and Dimethyldiethylammonium chloride $\beta\beta'$-diarsinic acid.—β-Chloroethylarsinic acid (6 grams) is treated with dimethylamine in the manner described above. The reaction is complete in about twenty hours, the mixture then being acidified with hydrochloric acid, evaporated and freed from dimethylammonium chloride by boiling with chloroform. The residue, in a minimum of water, is treated with alcohol until no further precipitation takes place. The solid, 0·5 gram, crystallises from aqueous alcohol in compact masses, and is dimethyldiethylammonium chloride $\beta\beta'$-diarsinic acid, having the structure :

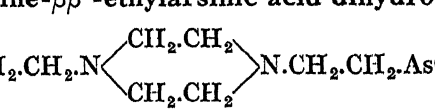


The alcoholic filtrate is concentrated to 10 c.c. and slowly treated with 120 c.c. of acetone. The precipitate, on crystallisation from ethyl alcohol, yields 4·9 grams of β-dimethylaminoethylarsinic acid hydrochloride, M.pt. 138° to 140° C. The quaternary ammonium compound may also be obtained by the interaction of β-dimethylaminoethylarsinic acid and β-chloroethylarsinic acid.

β-Dimethylaminoethylarsinic acid methochloride is obtained by the interaction of β-chloroethylarsinic acid and trimethylamine in the usual manner. It forms elongated plates, melting with gas evolution at 187° to 188° C.

β-Piperidinoethylarsinic acid, obtained by using piperidine, crystallises in lustrous plates.

NN'-Piperazine-$\beta\beta'$-ethylarsinic acid dihydrochloride,



obtained by the use of piperazine hydrate, forms hexagonal plates, which are unmelted at 280° C. but gradually darken above 220° C.

[1] Detection of un-ionised chlorine in this and subsequent preparations is carried out by treating a sample with an excess of silver nitrate in nitric acid, filtering off the silver halide, and boiling the filtrate with excess of potassium hydroxide to hydrolyse any unchanged chloro-acid.

γ-Chloropropylarsinic Acid and its Derivatives.

γ-Chloropropylarsinic acid.—Chlorine is passed into a suspension of 40 grams of γ-chloropropyldichloroarsine in 160 c.c. of water until complete solution results. Repeated evaporation with water, followed by crystallisation from water, yields elongated, hexagonal plates, M.pt. 146° to 148° C. The acid forms *calcium* and *barium salts*.

γ-Aminopropylarsinic acid results when the preceding acid is heated at 110° C. for eight hours with ammonium hydroxide (density 0·88). It forms compact, microscopic prisms, very soluble in water but insoluble in ethyl alcohol.

γ-Dimethylaminopropylarsinic acid is the condensation product of the chloro-acid and dimethylamine. It is isolated in the form of its *hydrochloride*, consisting of slightly deliquescent needles, M.pt. 108° to 110° C.

γ-Dimethylaminopropylarsinic acid methochloride is formed when the dimethylamine in the preceding preparation is replaced by trimethylamine. It crystallises in compact prisms, M.pt. 174° to 176° C.

γ-n-Propylaminopropylarsinic acid.—Six grams of γ-chloropropylarsinic acid are heated under reflux for twelve hours with 40 c.c. of alcohol and 10 grams (6 mols.) of *n*-propylamine. On distillation, followed by heating under reduced pressure with sodium hydroxide, the excess of amine and alcohol are removed; the residue is acidified with hydrochloric acid, dried, and extracted with alcohol. The resulting solution yields the *hydrochloride* of the acid, which melts at 210° to 212° C. The free acid is isolated as follows: The hydrochloride (0·47 gram) is treated with 1 gram-molecule of sodium hydroxide, the solution evaporated to dryness, the residue extracted with 2 c.c. of methyl alcohol, and 12 c.c. of ethyl alcohol added. The acid slowly separates in needles, M.pt. 222° to 224° C., neutral to litmus, and yielding a white, basic arseno-compound when warmed with hypophosphorous acid containing a trace of potassium iodide. The foregoing hydrochloride in alkaline solution reacts with powdered *m*-nitrobenzoyl chloride to yield *m-nitrobenzopropylaminopropylarsinic acid*, M.pt. 132° to 134° C. The corresponding *benzoyl* compound is a non-crystallisable oil.

γ-n-Hexylaminopropylarsinic acid is formed when the chloro-acid and *n*-hexylamine are heated for twenty hours at 100° C. The hydrochloride separates from ethyl alcohol in short, flat plates, M.pt. 221° to 223° C. The *m-nitrobenzoyl* derivative forms white plates, M.pt. 118° to 120° C., but the corresponding *m-aminobenzoyl* compound cannot be obtained in crystalline form. Condensation of the acid with ethyl chloroformate gives *γ-carbethoxy-n-hexylaminopropylarsinic acid*, consisting of long, flat plates, M.pt. 58° to 60° C., and the amino-hydrochloride with phenylcarbamide yields *γ-phenylcarbamyl-n-hexylaminopropylarsinic acid*, melting indefinitely at 118° to 124° C.

γ-Piperidinopropylarsinic acid results when the chloro-acid and piperidine are heated for six hours at 100° C. It is isolated as the *hydrochloride*, which crystallises from boiling alcohol in square plates; M.pt. 162° to 164° C.

γ-4-Hydroxy-2 : 2 : 6-trimethylpiperidinopropylarsinic acid, obtained by heating the chloro-acid and vinyldiacetone-methylamine in alcoholic solution for two days, forms white crystals, M.pt. 162° C., which are deliquescent.

γ-2 : 2 : 6-Trimethylpiperidinopropylarsinic acid.—γ-Chloropropylarsinic acid and 2 : 2 : 6-trimethylpiperidine, when heated in alcoholic solution for six hours, yield the required acid. It crystallises from methyl alcohol-ether in deliquescent, microscopic crystals, M.pt. 150° to 160° C.

γ-Piperazinopropylarsinic acid is isolated in the form of its *dihydrochloride* from the chloro-acid and piperazine hydrate. Benzoylation yields *γ-4-benzoylpiperazinopropylarsinic acid*, crystallising from aqueous acetone as a white solid, M.pt. 204° to 206° C.

γ-Carbethoxypiperidinopropylarsinic acid, from the chloro-acid and ethyl nipecotinate, is an amorphous, deliquescent solid.

Compounds of the Type $R_2AsO.OH$.

This group of compounds is of historical importance, since its lower members formed part of Bunsen's classic work on cacodyl. The most recent method of preparation, and one which appears to be fairly general, consists in treating alkyl dihalogenated arsines with alkyl halides in the presence of sodium hydroxide. Oxidation of alkyldichloroarsines has also been effected by the action of bromine water. Sodium hypochlorite and electrolytic oxidation have also been used for oxidising mixtures of cacodyl and cacodyl oxide to dimethylarsinic acid.[1] Hydroxyalkylarsinic acids are readily prepared by the interaction of halogenated alkyl or hydroxyalkylarsines and the sodium salts of hydroxyalkyl- or alkylarsinic acids.

These acids are characterised by great stability towards oxidising agents, the methyl and ethyl compounds being unaffected by concentrated nitric acid or aqua regia, except of course when iodine is substituted in the alkyl radical.

Dimethylarsinic acid, *Cacodylic acid,* $(CH_3)_2AsO.OH$, was originally obtained by the oxidation of cacodyl oxide in air, or better, by oxidation with mercuric oxide under water ;[2] also from methylarsenoxide by the action of methyl iodide and sodium hydroxide in methyl alcohol solution.[3] More recent methods of preparation are as follows :[4] (1) The oil obtained by the distillation of arsenious oxide and potassium acetate, which consists of a mixture of cacodyl and cacodyl oxide, is agitated with the required amount of sodium hypochlorite solution in the presence of hydrochloric acid. The completion of the reaction is indicated by the disappearance of the cacodyl oxide, and by testing the mixture with starch iodide paper. The solution is then treated with sodium hydroxide until neutral to Congo red, evaporated down until the sodium chloride separates, then taken to dryness, and extracted with 96 per cent. alcohol. The extract gives a 70 per cent. yield of pure cacodylic acid, and a further 20 per cent. is obtainable from the mother liquors. (2) The oil used in the previous method may be converted to the acid (80 per cent. yield) by dissolving in dry acetone to which is added rather more water than is required by the following equations, and then passing oxygen through the mixture :

$$[(CH_3)_2As]_2O+H_2O+O_2=2(CH_3)_2AsO.OH$$
$$2[(CH_3)_2As]_2+2H_2O+3O_2=4(CH_3)_2AsO.OH$$

[1] Earlier methods of isolation consisted in oxidising arsenoxides with air or mercuric oxide. [2] Bunsen, *Annalen*, 1843, 46, 2. [3] Auger, *Compt. rend.*, 1903, 137, 926. [4] Guinot, *J. Pharm. Chim.*, 1923, [vii.], 27, 55.

(3) By the anodic oxidation of the oil, dissolved in 20 per cent. sulphuric acid. This method gives a 70 to 80 per cent. yield.

Cacodylic acid crystallises in triclinic prisms,[1] M.pt. 200° C., very readily soluble in water and dilute alcohol, less so in absolute alcohol, insoluble in anhydrous ether. At 22° C., 100 parts of water dissolve 82·9 parts of acid.[2] The acid is not attacked by feeble reducing agents, but phosphorous acid on warming gives cacodyl oxide, and stannous chloride in the presence of acid yields the chloride. The acid is monobasic, and its aqueous solution has a neutral reaction towards helianthin, but is acid towards phenolphthalein.[3] In concentrated solutions of sodium hydroxide the acid functions in a tribasic manner, as $(CH_3)_2As(OH)_3$.[4] It is also an amphoteric electrolyte.[5] The electrolytic dissociation constant[6] and heat of neutralisation[7] have been determined, also the electrical conductivity of the magnesium salt.[8] Towards oxidising agents the acid shows great stability, being unaffected by fuming nitric acid, aqua regia, aqueous chromic acid,[9] or potassium permanganate.[10] When hydrogen sulphide is passed into an aqueous or alcoholic solution of the acid, cacodyl sulphide is formed. Sulphur dioxide is without action on an aqueous solution of cacodylic acid, but with the sodium salt of the acid, cacodyl oxide is produced.[11] Treatment with phosphorus trichloride or the calculated quantity of hypophosphorous acid in hydrochloric acid solution gives cacodyl chloride, whilst excess of hypophosphorous acid yields cacodyl.[12] Phosphorus pentachloride in the presence of ether gives cacodyl trichloride.[13] Solution of the acid in concentrated hydrofluoric acid gives a *basic fluoride*, $(CH_3)_2As(OH)_2F.(CH_3)_2AsF_3$, consisting of deliquescent prisms; whilst with hydrochloric acid, $(CH_3)_2As(OH)_2Cl$ is obtained; but hydrogen chloride passed into warm cacodylic acid gives methyldichloroarsine.[14] With an equimolecular quantity of antimony trichloride, the *antimony compound*, $(CH_3)_2As(\ O).O.SbCl_2$ is obtained.[15] When cacodylic acid, sodium hypophosphite, and methyl iodide are boiled together in the presence of a little hydrochloric acid, whilst a stream of carbon dioxide is passed in, tetramethylarsonium iodide is formed.[16] Decomposition of the acid occurs when it is heated with solid sodium hydroxide, methane and sodium methylarsinate being obtained at 180° C., whilst methane and sodium arsenate are the products at 260° C.[17] Electrolytic reduction

[1] Bunsen, *Ann. Phys. Chem.*, 1854, 42, 149.
[2] Dehn, *Amer. Chem. J.*, 1902, 28, 361.
[3] Imbert, *Compt. rend.*, 1899, 129, 1245.
[4] Hantzsch, *Ber.*, 1904, 37, 1076, 2705; see also Müller and Bauer, *Compt. rend.*, 1904, 138, 1099.
[5] Veley, *Trans. Chem. Soc.*, 1907, 91, 162; see also v. Zawidzki, *Ber.*, 1903, 36, 3325; 1904, 37, 153, 2280; Johnston, *Ber.*, 1904, 37, 3625.
[6] v. Zawidzki, *loc. cit.*; see also Johnston, *loc. cit.*; Hantzsch, *Ber.*, 1904, 37, 2707.
[7] Imbert, *loc. cit.*; Baud and Astruc, *Compt. rend.*, 1907, 144, 1346.
[8] Walden, *Zeitsch. physikal. Chem.*, 1887, 1, 533.
[9] Bunsen, *Annalen*, 1843, 46, 9.
[10] La Coste, *Annalen*, 1881, 208, 32.
[11] Auger, *Compt. rend.*, 1903, 137, 927.
[12] Auger, *ibid.*, 1906, 142, 1152.
[13] Baeyer, *Annalen*, 1858, 107, 263.
[14] Bunsen, *Annalen*, 1843, 46, 35; Hantzsch, *Ber.*, 1904, 37, 1081; Baeyer, *Annalen*, 1858, 107, 272.
[15] Barthe and Minet, *Compt. rend.*, 1909, 148, 1609.
[16] Auger, *Compt. rend.*, 1906, 142, 1152.
[17] Auger, *ibid.*, 1908, 146, 1280.

of cacodylic acid at an amalgamated zinc cathode in 2*N* sulphuric acid yields principally cacodyl, only a little dimethylarsine being obtained:

$$(CH_3)_2AsO_2H \longrightarrow (CH_3)_2As.As(CH_3)_2 \longrightarrow (CH_3)_2AsH$$

When the acid is oxidised at a platinum anode in alkaline solution the reaction takes the following course: $(CH_3)_2AsO_2H + 8O = 2CO_2 + H_3AsO_4 + 2H_2O$.[1]

The following salts of cacodylic acid have been isolated:

Lithium cacodylate.—A white, crystalline powder, soluble in water and alcohol.[2]

Sodium cacodylate, $(CH_3)_2AsO_2Na.H_2O$.—Forms prismatic crystals from alcohol;[3] commercial products often contain 2 to 3 molecules of water. It is said to be hydrolysed in aqueous solution.[4] Sodium cacodylate, on treatment with molybdic acid, followed by guanidinium chloride, yields a *guanidinium salt*, crystallising in anhydrous plates, which have the composition:[5]

$$(CN_3H_6)_2\left[\begin{matrix}As(CH_3)_2(Mo_2O_7)_2\\(OH)_2\end{matrix}\right]$$

Potassium cacodylate, $(CH_3)_2AsO_2K.H_2O$. A very deliquescent product, sparingly soluble in alcohol, insoluble in ether.[6] It forms a *molybdenum salt* with molybdic acid, which crystallises in needles of composition:

$$K_2H\left[\begin{matrix}As(CH_3)_2(Mo_2O_7)_2\\(OH)_2\end{matrix}\right]^{7}$$

Silver cacodylate, $(CH_3)_2AsO_2Ag.2(CH_3)_2AsO_2H$. Is of indistinct crystalline form; it occurs when the acid is treated in warm aqueous solution with silver carbonate for several days, the resulting solution evaporated, and the residue extracted with water. The salt Me_2AsO_2Ag forms long needles, very soluble in water and alcohol, and is obtained from the acid and silver oxide; the double salt, $(CH_3)_2AsO_2Ag.AgNO_3$, is derived from the acid and silver nitrate in alcoholic solution, and yields scales, easily soluble in water, sparingly soluble in alcohol, and affected by light.

Magnesium cacodylate, $[(CH_3)_2AsO_2]_2Mg.(?)H_2O$.—A white powder.

Mercuric cacodylate, $[(CH_3)_2AsO_2]_2Hg$.—Deliquescent prisms, obtained from yellow mercuric oxide and cacodylic acid in absolute alcohol. Is very soluble in cold water, the solution decomposing on warming; insoluble in ether.

Calcium cacodylate, $[(CH_3)_2AsO_2]_2Ca.9H_2O$.—White needles, losing water of crystallisation at 115° C.; soluble in water and alcohol.

Barium cacodylate.—A very deliquescent crystalline powder.[8]

Ferric cacodylate, $[(CH_3)_2AsO_2]_3Fe$.—A yellowish powder.

[1] Fichter and Elkind, *Ber.*, 1916, 49, 246.
[2] Siboni, *Chem. Zentr.*, 1902, i. 744.
[3] Bunsen, *Annalen*, 1843, 46, 16.
[4] Hantzsch, *Ber.*, 1904, 37, 1076.
[5] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.
[6] Bunsen, *loc. cit.*
[7] Rosenheim and Bilecki, *loc. cit.*
[8] Annoni, *Chem. Zentr.*, 1905, ii. 751.

Guaiacol and *strychnine* cacodylates are known and are white powders,[1] and an *antipyrin cacodylate*[2] has also been described.[3]

Tetra-iodocacodylic acid, $(CHI_2)_2AsO.OH$.—This product is the result of a curious reaction between amorphous arsenic and iodoform.[4] The two bodies are heated for several hours on a boiling water-bath in the presence of benzene or toluene, and the resulting product oxidised by nitric acid in the cold. The reactions taking place are represented as follows :

$$3CHI_3+2As=CHI_2.AsI_2+(CHI_2)_2AsI$$
$$CHI_2.AsI_2+4HNO_3=CHI_2.AsO(OH)_2+4NO_2+H_2O+I_2$$
$$(CHI_2)_2AsI+3HNO_3=(CHI_2)_2.AsO.OH+3NO_2+H_2O+I$$

The di-iodomethylarsinic acid is extracted with cold water, leaving the tetra-iodocacodylic acid mixed with free iodine. The latter is removed by benzene or toluene, the acid dissolved in ammonium hydroxide and reprecipitated by acid. It crystallises in sulphur yellow crystals, insoluble in water, soluble in fifty parts of boiling acetic acid, and in eight to ten parts of boiling nitric acid. Prolonged boiling with nitric acid causes decomposition, iodine, carbon dioxide, and arsenic acid being produced. Hot sodium hydroxide solution yields methylene iodide and arsenic acid. The *sodium salt* crystallises from 90 per cent. alcohol in pale yellow crystals containing six molecules of water of crystallisation.

Dithiodimethylarsinic acid, *Dithiocacodylic acid,* $(CH_3)_2AsS.SH$.—This acid is unknown in the free state, but its salts are readily obtained by the action of hydrogen sulphide on salts of cacodylic acid, or by treating cacodyl disulphide with metallic salts.[5] In this way the following salts have been isolated: *gold salt,* $(CH_3)_2AsS_2Au$, an insoluble pale yellow powder; *copper salt,* $(CH_3)_2AsS_2Cu$, an insoluble yellow powder; *lead salt,* $(CH_3)_2AsS_2Pb$, colourless scales, insoluble in water, very sparingly soluble in alcohol; *antimony salt,* $[(CH_3)_2AsS_2]_3Sb$, short, golden yellow needles; *bismuth salt,* $[(CH_3)_2AsS_2]_3Bi$, golden scales, very sparingly soluble in water, alcohol, or ether.

Diethylarsinic acid, *Ethylcacodylic acid,* $(C_2H_5)_2AsO.OH$.[6]—This acid is obtained either by the direct oxidation of ethyl cacodyl in air or alcoholic solution, or by shaking ethyl cacodyl with finely divided mercuric oxide in the presence of water. In the latter case the mercuric salt is formed, and on the addition of baryta water the mercury is precipitated as mercuric oxide. Excess of baryta water is then removed by passing in carbon dioxide, and the free acid liberated from its barium salt by the addition of sulphuric acid. After filtration and concentration the diethylarsinic acid crystallises in large, clear, glistening plates, melting at about 190° C.

[1] Martindale, *Inter. Congress App. Chem.*, 1909.
[2] Barthe, *Pharm. J.*, 1915, 94, 99.
[3] The following references deal with the analysis of cacodylic acid: Bougault, *Chem. Zentr.*, 1903, i. 539; Barthe and Minet, *Compt. rend.*, 1909, 148, 1610; Vitali, *Chem. Zentr.*, 1903, ii. 1416, *ibid.*, 1901, ii. 1212; Imbert and Badel, *Compt. rend.*, 1900, 130, 581; Barthe and Péry, *Chem. Zentr.*, 1901, i. 801; Haffter, *Chem. Zentr.*, 1901, i. 1109; Ganassini, *Chem. Zentr*, 1903, i. 787; Guinot, *J. Pharm. Chim.*, 1923, [vii.], 27, 55; Poggi and Polverini, *Atti R. Accad. Lincei*, 1926, [vi.], 4, 315.
[4] Auger, *Compt. rend.*, 1907, 145, 809.
[5] Bunsen, *Annalen*, 1843, 46, 21.
[6] Landolt, *Annalen*, 1854, 92, 365; *J. prakt. Chem.*, 1854, 63, 283.

The following is a more recent method of preparation:[1] 55 grams of ethyl bromide are warmed for from four to six hours with 90 grams of ethyldichloroarsine and 210 c.c. of 10*N* sodium hydroxide. Towards the end of the heating a further 20 grams of ethyl bromide are added to replace that lost during the reaction. After completion of the reaction the excess of ethyl bromide is boiled off and the mixture treated with hydrochloric acid until it is neutral to phenolphthalein, then concentrated to half its bulk. Any salts which separate are filtered off, and the filtrate acidified with hydrochloric acid until Congo red just commences to turn blue. The liquid is then further evaporated until it is about two-thirds of its original volume, when about 50 grams of crude diethylarsinic acid separate, this being purified by two crystallisations from alcohol. The crystals have an acid reaction, are odourless, have a bitter taste, and are very deliquescent in air. They are easily soluble in water and alcohol, the solutions liberating carbon dioxide from alkali carbonates. The acid shows a remarkable stability, and is unattacked by concentrated nitric acid or aqua regia. The *barium salt*, $[(C_2H_5)_2AsO_2]_2Ba.(C_2H_5)_2AsO_2H.2H_2O$, is crystalline, very soluble in water, but sparingly soluble in alcohol.

Methylhydroxyethylarsinic acid, $HO.CH_2.CH_2.As.CH_3.O_2H$.[2] Sodium methylarsinate in aqueous solution is reduced with sulphur dioxide at a temperature of 45° C. and the solution neutralised by adding sodium hydroxide (density 1·332). The solution is then maintained at 30° C., glycol chlorohydrin added, and the whole stirred for six to eight hours. The liquid is then acidified with sulphuric acid, evaporated in a vacuum and the residue extracted with hot alcohol. From this solution crystals are obtained by slow evaporation, or precipitation with acetone or ether. The resulting acid softens between 80° and 103° C., and forms water-soluble salts. The acid may also be prepared by the interaction of sodium hydroxyethylarsinate and methyl iodide.

Dihydroxydiethylarsinic acid, $(HO.CH_2.CH_2)_2As.O_2H$, is prepared by treating sodium hydroxyethylarsinate with glycol bromohydrin, whilst treatment with allyl bromide at 60° C. yields **allylhydroxyethylarsinic acid.** The preparation of alkylhydroxyalkyl- and dihydroxydialkyl-arsinic acids by the interaction of alkyl or hydroxyalkyl halides and the sodium salts of hydroxyalkyl- or alkyl-arsinic acids appears to be of general application.

Di-n-propylarsinic acid, $(C_3H_7)_2AsO.OH$, occurs when tetrapropylarsonium hydroxide is subjected to distillation and the resulting product oxidised in air.[3] It forms colourless crystals from ligroin, M.pt. 123° C., readily soluble in water, alcohol, and ether; easily soluble in hot ligroin, sparingly in cold ligroin.

Di-n-butylarsinic acid, $(C_4H_9)_2AsO.OH$, prepared in a similar manner to diethylarsinic acid, melts at 137° to 138° C. It forms a pale blue *copper salt*, $[(C_4H_9)_2AsO_2]_2Cu$.[4]

n-Propyl-n-butylarsinic acid, $(C_3H_7)(C_4H_9)AsO.OH$. Obtained from *n*-butyldichloroarsine and *n*-propyl bromide in 10*N* sodium hydroxide solution, melts at 127° to 128° C.

Di-isoamylarsinic acid, $(C_5H_{11})_2AsO.OH$, crystallises from water

[1] Quick and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 805.
[2] French Patent, 585970; see British Patent, 206152 (1924).
[3] Partheil, Amort, and Gronover, *Ber.*, 1898, 31, 590; Partheil, *Arch. Pharm.*, 1899, 237, 134.
[4] Quick and Adams, *loc. cit.*

in scales containing two molecules of water of crystallisation. It is formed when bromine acts upon di-*iso*amylchloroarsine in the presence of water.[1] The acid melts at 153° to 154° C., is readily soluble in alcohol and water, insoluble in ether; reduction by zinc and hydrochloric acid gives di-*iso*amylarsine.

Arsinoacetic Acid and its Derivatives.

Arsinoacetic acid, $(HO)_2OAs.CH_2.COOH$.—This acid was first prepared by treating *p*-aminophenylarsinoacetic acid with bromine water :[2]

$$NH_2.C_6H_4.AsO(OH).CH_2.COOH + 3Br_2 + H_2O = C_6H_2NH_2.Br_3 + 3HBr + (HO)_2OAs.CH_2.COOH$$

Removal of the tribromoaniline, followed by boiling the filtrate with magnesia mixture, precipitates *magnesium arsinoacetate*. This method was superseded by another, which treated aliphatic halogen carboxylic acids or their derivatives, such as amides or esters, with arsenious acid, *e.g.* chloroacetic acid and arsenious oxide gave arsinoacetic acid.[3] The most recent preparation [4] is based upon the following equation :

$$CH_2Cl.CO_2Na + As(ONa)_3 = CH_2(CO_2Na).AsO(ONa)_2$$

It is best carried out as follows :[5] 100 grams of powdered arsenious oxide are dissolved by the aid of heat in 300 c.c. of water containing 160 grams of sodium hydroxide, and the solution cooled to 20° C. before adding 48 grams of chloroacetic acid. After stirring for about five minutes, reaction sets in, the temperature rises to 70° or 75° C., and a transparent solution results. The solution, after standing for at least an hour, is acidified with 160 c.c. of glacial acetic acid, the temperature reduced to 40° C. by cooling, and the precipitated arsenious oxide washed with 50 c.c. of water. By pouring the filtrate into a solution of 185 grams of crystallised barium chloride in 600 c.c. of hot water, *barium arsinoacetate*, $Ba(O_2CCH_2AsO_3Ba)_2$, in a hydrated form, separates as a copious, fine precipitate. After a few minutes' stirring, the mixture is allowed to stand overnight, then filtered upon a 15 cm. Büchner funnel and thoroughly washed with water. When air-dried, the product contains 13 per cent. of water of hydration and weighs 220 grams (96 per cent. yield). To convert the barium salt to the sodium salt, the previous washed precipitate is added whilst wet to 500 c.c. of hot water containing 108 grams of anhydrous sodium sulphate, and the mixture mechanically stirred for one hour. The barium sulphate is then removed by filtration and the filtrate evaporated on a steam-bath until crystallisation commences, when the liquor is allowed to cool, and is continually stirred. The deposited crystals are filtered off and the concentration repeated, when the combined fractions give 100 to 110 grams (80 to 88 per cent.) of *sodium arsinoacetate*. This product is a white, microcrystalline powder, readily soluble in cold water, the solution being alkaline to litmus.

[1] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 52.
[2] Ehrlich and Bertheim, *Ber.*, 1910, 43, 926.
[3] Austrian Patent, 93325, Swiss Patent, 97977, from *Chem. Zentr.*, 1923, iv. 721; American Patent, 1445685.
[4] Palmer, *J. Amer. Chem. Soc.*, 1923, 45, 3023.
[5] *Organic Syntheses*, vol. iv., Wiley & Sons.

The free acid may be isolated from the barium salt in the following manner:[1] A mixture of 22·5 grams of the powdered barium salt, 100 c.c. of water, and 5 c.c. of sulphuric acid (density 1·84) is mechanically stirred at the ordinary temperature for several hours, then the barium sulphate is filtered off and the filtrate concentrated to a very small volume *in vacuo* over sulphuric acid in the cold. At crystallisation point, 25 c.c. of absolute alcohol are stirred in and the mixture filtered, the filtrate being treated with 25 c.c. of ligroin and concentrated at room temperature as before. Arsinoacetic acid crystallises out, is removed, washed with ligroin and dried. It forms colourless, shining plates, M.pt. 152° C. with gas evolution, very soluble in water and alcohol, sparingly soluble in hot glacial acetic acid, practically insoluble in ligroin, benzene, acetone, chloroform, or ethyl acetate. *Ethyl arsinoacetate*, obtained from sodium arsenite and ethyl acetate, forms light yellow leaflets, melting at about 95° C.[2]

Dichloroarsinoacetic acid, $Cl_2As.CH_2.COOH$,[3] is formed when arsinoacetic acid in chloroform solution is treated with phosphorus trichloride. The crystals which separate are removed, washed with ether to take out phosphorous acid, and recrystallised from benzene or carbon tetrachloride, the resulting product melting at 123° to 125° C. The acid is soluble in cold ether, ethyl acetate, methyl alcohol, and acetone; sparingly soluble in cold benzene, ligroin, and carbon tetrachloride; more soluble in these solvents on warming. The *methyl ester* is prepared by using methyl arsinoacetate as starting material, and is a clear liquid, boiling at 78° C. at 5 mm.

Arsinolactic acid is a viscous, yellow syrup, obtained from β-chlorolactic acid and arsenious acid.

Diarsinoadipic acid, consisting of colourless crystals, melting with decomposition at 165° C., is obtained from dibromoadipic acid and arsenious acid.[4]

Arsenoacetic acid, $HOOC.CH_2.As=As.CH_2.COOH$.[5]—This is the reduction product of arsinoacetic acid, the process being best carried out as follows,[6] and taking place according to the equation:

$$2HOOC.CH_2.AsO(OH)_2 + 8H(H_3PO_2) = HOOC.CH_2.As:As.CH_2.COOH + 6H_2O$$

Sodium arsinoacetate, 12·5 grams, and 30 grams of sodium hypophosphite ($NaH_2PO_2.H_2O$), are dissolved in 150 c.c. of cold, 15 per cent. sulphuric acid. After standing for two or three days at room temperature, the yellow deposit which forms is filtered off, washed with water and dried *in vacuo* over sulphuric acid or phosphorus pentoxide. If the mother liquid is allowed to stand for a further two days, a second crop of product is obtained. The yield should be 5 grams (74 per cent.). Arsenoacetic acid forms minute, yellow needles, unmelted below 260° C., although they undergo considerable decomposition above 200° C. The compound is insoluble in water and the usual organic solvents, but readily dissolves in pyridine, dilute sodium hydroxide, and dilute ammonium carbonate solutions. The *disodium salt* is a light, yellowish-

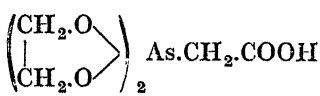
[1] Palmer, *J. Amer. Chem. Soc.*, 1923, 45, 3023.
[2] Austrian and Swiss Patents, *loc. cit.*
[3] Steinkopf and Schmidt, *Ber.*, 1928, 61, [B], 677.
[4] Austrian Patent, 93325, Swiss Patent, 97977; *Chem. Zentr.*, 1923, iv. 721.
[5] Palmer, *loc. cit.* [6] *Organic Syntheses, loc. cit.*

brown powder, readily soluble in water, giving a clear yellow solution, which reacts slightly alkaline to litmus.[1]

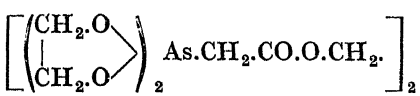
Tetra-arsenoacetic acid, $HOOC.CH_2.As=As-As=As.CH_2.COOH$.—The arsinoacetic acid from 49·5 grams of arsenious oxide and 23·63 grams of chloroacetic acid is treated with 150 grams of sulphuric acid (density 1·84) and 100 grams of sodium hypophosphite. After three hours a mixture of arsenious oxide and sodium sulphate containing a little highly coloured organic arsenic compound is filtered off and the filtrate allowed to stand in the cold. A bright red precipitate gradually separates; this is removed at three to four day intervals, washed repeatedly with water, and dried *in vacuo* over sulphuric acid, since drying in air causes the exposed surface to blacken. Altogether, five fractions yield about 25·6 grams of fairly pure product. Tetra-arsenoacetic acid is a bright, vermilion-red, microcrystalline powder, which shows signs of decomposition at about 180° C. but does not melt below 250° C. Its solubility resembles that of arsenoacetic acid. *Monosodium tetra-arsenoacetate* is a reddish-brown powder, considerably less soluble in water than disodium arsenoacetate. It is noteworthy that a *mono*sodium salt is formed in spite of an excess of sodium hydroxide.

Arsenical Compounds from α-Glycols.[2]

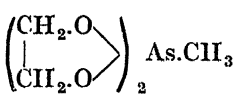
Di-ethylene glycol arsenoacetic acid,



is obtained by dissolving arsenoacetic acid in warm ethylene glycol. The yield is about 60 per cent., and the substance is bimolecular in bromoform solution. If the solution of arsenoacetic acid in ethylene glycol is heated at 100° C. for a short time, small quantities of *ethylene glycol bis* (*di-ethylene glycolarseno*) *acetate* are isolated,

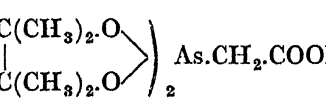


This compound melts with decomposition at 130° C. and is not hydrolysed by water to free arsenoacetic acid. If the above solution is heated at 130° C. instead of 100° C., carbon dioxide is evolved, and *di-ethyleneglycol methylarsinic acid* results:



This acid boils at 135° to 136° C. at 15 mm. If the reaction temperature is raised to 140° C. the same product results.

Dipinacol arsenoacetic acid,

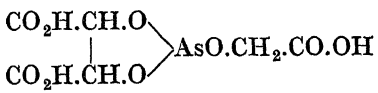


[1] Palmer, *loc. cit.*

[2] Englund, *J. prakt. Chem.*, 1928, [ii.], 120, 179.

is prepared from pinacol and arsenoacetic acid in ethyl alcohol solution. It melts with decomposition at 188° C.

When *d-tartaric acid*, not *meso*-tartaric acid, is heated with arsenoacetic acid for a few minutes in boiling glacial acetic acid solution, a substance decomposing above 250° C., and corresponding to the following formula, is obtained :



α-Arsenocarboxylic Acids.[1]

α-Arsenocarboxylic acids are prepared by the following general reaction :

$$CHRBr.COOK+K_3AsO_3=CHR[AsO(OH)_2].COOK+KBr$$

The acids are dibasic, as shown by titration, and if their diquinine salts are fractionally crystallised, optically active acids may be isolated. Neutralisation of both acidic groups causes a reversal of the sign of optical rotation. The active barium salts are not racemised in aqueous solution at 100° C., but the free acids readily racemise. This is especially the case when mineral acids are present, the racemisation being a unimolecular reaction. The following compounds are known : **α-Arsenobutyric acid**, M.pt. 127° C. ; forms a *diquinine salt* containing 5 molecules of water ; *d-α-arsenobutyric acid* has $[M]_D+25{\cdot}7°$, *barium salt* $-10{\cdot}5°$. **d-α-Arsenopropionic acid** has $[M]_D+41{\cdot}0°$, *barium salt* $-8{\cdot}5°$. **α-Arsenovaleric acid** has M.pt. 114° C., and yields a *diquinine salt* containing 4 molecules of water ; *d-α-arsenovaleric acid* has $[M]_D+19{\cdot}3°$, *barium salt* $-15{\cdot}6°$.[2]

Compounds of the Type $R_2As.AsR_2$.

These derivatives, the tetra-alkyldiarsines, which go under the name of *cacodyl compounds*, were amongst the earliest arsenicals to be investigated, and they date back to 1837. The only representatives of this group which are known with certainty are the methyl and ethyl derivatives. They may be isolated :

(1) By removing the halogen from two molecules of secondary halogenated arsines by heating with zinc or zinc amalgam,

$$2R_2AsX+Zn=R_2As.AsR_2+ZnX_2$$

(2) By reducing the corresponding arsinic acids with hypophosphorous acid.

(3) By the condensation of dialkylarsines with secondary halogenated arsines,

$$R_2AsH+R_2AsX=R_2As.AsR_2+HX$$

---

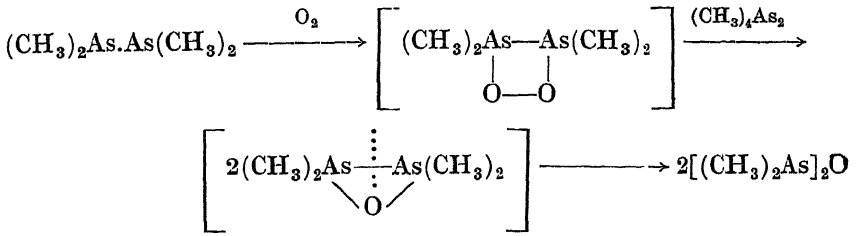
[1] Becker and Mulder, *Proc. K. Akad. Wetensch. Amsterdam*, 1928, 31, 301.

[2] The production of aliphatic di- or poly-hydroxyarsinic acids is dealt with in American Patent 1654224. Glycerol dichlorhydrin, when treated with arsenious acid in sodium hydroxide solution, the mixture being warmed and stirred during the operation, yields an acid on acidification which may be extracted with alcohol.

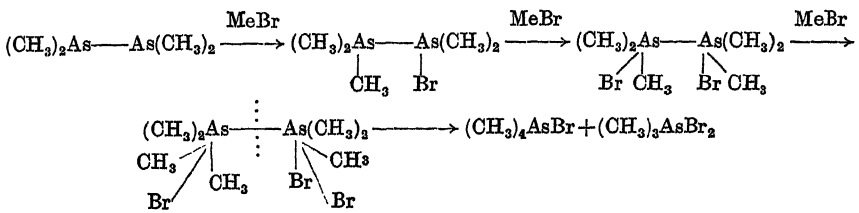
(4) By heating together sodium arsenide and alkyl iodides in a carbon dioxide atmosphere. This method gives only poor yields.

(5) By distilling a mixture of arsenious oxide and the potassium salt of a fatty acid. In addition to the required cacodyl compound, cacodyl oxide forms a fair percentage of the reaction product in this method.

One striking feature of these derivatives is their repulsive odour, and they are spontaneously inflammable. Regulated oxidation by moist air, or mercuric oxide, yields the corresponding oxides and acids. In the absence of excess of oxygen, the following scheme has been put forward to show the formation of the oxide. It is interesting to note the assumption of peroxide formation containing tetravalent arsenic.[1]



The tetra-alkyldiarsines combine directly with halogens, sulphur and alkyl iodides. In the case of sulphur, both mono- and di-sulphides are formed. In the case of tetramethyldiarsine, methyl chloride produces dimethylchloroarsine, but methyl bromide gives tetramethylarsonium bromide and trimethylarsine dibromide. The following scheme suggests the course of the reaction with methyl bromide :



The products from the interaction of tetramethyldiarsine and methyl iodide vary according to the number of molecules of the latter taking part in the reaction.

Tetramethyldiarsine, *Cacodyl,* $(CH_3)_2As.As(CH_3)_2$.—This compound was originally prepared by Bunsen,[2] by distilling equal parts of potassium acetate and arsenious oxide. Considerable quantities of cacodyl oxide are also formed during the operation. Bunsen also isolated cacodyl by heating cacodyl bromide or sulphide with mercury at 100° C., and by heating cacodyl chloride with zinc at 100° C. in a carbon dioxide atmosphere. Another early preparation consisted in adding methyl iodide in small portions to sodium arsenide, the operation being conducted in a carbon dioxide atmosphere. The yield of cacodyl, however, was small, the main product being tetramethylarsonium iodide.[3]

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.

[2] Bunsen, *Annalen*, 1837, 24, 271 ; 1842, 42, 14 ; see also Baeyer, *Annalen*, 1858, 107, 257.

[3] Cahours and Riche, *Annalen*, 1854, 92, 361 ; *Compt. rend.*, 1854, 39, 541.

Cacodylic acid is reduced to cacodyl when treated with an excess of sodium hypophosphite in hydrochloric acid solution.[1] Cacodyl may be obtained from dimethylarsine by the action of oxides of nitrogen, aqueous chromic acid, lead peroxide, cacodyl chloride, auric chloride, or potassium ferricyanide.[2] It also results when *cyclo*pentamethylpenta-arsine is distilled under atmospheric pressure in a carbon dioxide atmosphere, the decomposition commencing at 270° C.[3]

Cacodyl is a heavy oil, of intolerable odour, solidifying at −6° C. to large, glistening, quadratic prisms. It boils at about 170° C., and inflames in air or chlorine ; regulated oxidation by moist air or mercuric oxide gives cacodyl oxide and cacodylic acid. When heated for two hours at 340° C. it yields trimethylarsine and a compound, $(MeAs)_x$.[4] Electrolytic reduction of cacodyl gives dimethylarsine, but reduction with tin and hydrochloric acid gives the dark red amorphous powder, $(MeAs)_4$. As_2O_3(?), known as *Erytrarsin*. Combination takes place with sulphur, giving cacodyl sulphide and disulphide, whilst chlorine water or methyl chloride converts cacodyl to cacodyl chloride. When heated at 100° C. with methyl bromide, cacodyl yields tetramethylarsonium bromide and trimethylarsine dibromide.[5] Methyl iodide (2 mols.) and cacodyl (1 mol.) combine at ordinary temperatures giving tetramethylarsonium iodide, but methyl iodide (5 mols.) yields an equimolecular mixture of the arsonium mono- and tri-iodides.

Tetra-ethyldiarsine, *Ethyl cacodyl,* $(C_2H_5)_2As.As(C_2H_5)_2$.—One part of sodium arsenide is mixed with four to five times its weight of quartz sand and treated with ethyl iodide, the operation being conducted in a carbon dioxide atmosphere. Sufficient heat is developed to cause distillation of the ethyl iodide, which has to be replaced until the action is complete. The mass is then distilled, when a mixture of ethyl cacodyl and triethylarsine is obtained.[6] Ethyl cacodyl has also been obtained by distillation of diethyliodoarsine with zinc amalgam.[7]

Ethyl cacodyl is a faintly yellowish liquid, strongly refractive, heavier than water, and having a repulsive odour ; it boils between 185° and 190° C., and is soluble in alcohol and ether. In air or oxygen it inflames, but with dilute nitric acid it yields a red compound analogous to Bunsen's *Erytrarsin*, this soon becoming brown and in air changing to white. This compound is insoluble in water, alcohol, and ether. Ethyl cacodyl combines directly with the halogens, oxygen and sulphur, and reduces salts of silver, mercury, gold, and platinum, a property not possessed by triethylarsine. Concentrated nitric acid causes ethyl cacodyl to explode, whilst concentrated sulphuric acid dissolves it in the cold, the solution on warming evolving sulphur dioxide.

Tetra-n-propyldiarsine, *Propyl cacodyl,* $(C_3H_7)_2As.As(C_3H_7)_2$.[8]—This compound, together with arsenic, is the thermal decomposition product of *cyclo*penta-*n*-propylpenta-arsine. The latter, when distilled at 13 mm., yields propyl cacodyl as a colourless, mobile liquid, B.pt.

[1] Auger, *Compt. rend.*, 1906, **142**, 1153.
[2] Dehn and Wilcox, *Amer. Chem. J.*, 1906, **35**, 1.
[3] Steinkopf and Dudek, *Ber.*, 1928, **61**, [B], 1910.
[4] Dehn, *Amer. Chem. J.*, 1908, **40**, 120.
[5] Steinkopf and Schwen, *Ber.*, 1921, **54**, [B], 1437.
[6] Landolt, *Annalen*, 1854, **89**, 301.
[7] Cahours and Riche, *Annalen*, 1854, **92**, 365.
[8] Steinkopf and Dudek, *loc. cit.*

165° to 167° C. at 13 mm. On redistillation it boils at 168° to 170° C. at 15 mm.:

$$4(C_3H_7.As)_5 = 5(C_3H_7)_2As.As(C_3H_7)_2 + 10As$$

When heated at 100° C. with methyl iodide, it gives **dimethyl-di-n-propylarsonium tri-iodide,** consisting of dark red crystals, which melt at room temperatures.

Tetrabutyldiarsine, *Butyl cacodyl,* $(C_4H_9)_2As.As(C_4H_9)_2$.[1]—This compound is supposed to be obtained when potassium butyrate is distilled with an equal weight of arsenious oxide. The properties of the products of the distillation resemble those obtained in the case of cacodyl, but sufficient work has not been done on this compound to warrant any definite conclusions being drawn from the results.

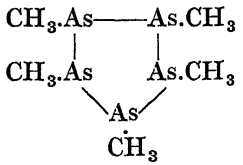
Tetravaleryldiarsine is a compound to which similar remarks apply to those mentioned above.[2]

Cacodyl carbide, $(CH_3)_2As.C{\equiv}C.As(CH_3)_2$.[3]—Magnesium ethyl bromide in ether is treated with acetylene at room temperatures, ethane being evolved and magnesium acetylene bromide separating as an oily layer. The gas is then passed into the boiling solution for one hour, the liquid cooled and shaken with 50 grams of pure cacodyl chloride. The reaction is completed by warming for one hour on the water-bath, the solution decomposed by ice, treated with 55 c.c. of concentrated hydrochloric acid and extracted with ether. The ethereal solution is dried over sodium sulphate, removal of the solvent yielding a golden yellow oil, which is purified by fractionation. The product boils at 84·5° C. at 14 mm., is strongly unsaturated, explodes on treatment with nitric acid, and is hydrolysed by alkali.

Cyclopentamethylpenta-arsine, $(CH_3As)_5$.[4]—This compound, until recently, was known as *arsenomethane,* and the formula $(CH_3As)_4$ was assigned to it. It may be isolated as follows:[5] Sodium methylarsinate, 100 grams, is stirred with 350 c.c. of 50 per cent. hypophosphorous acid for three hours at 70° C. Traces of impurity in the methylarsinate cause the formation of red and brown solid modifications of the arsine, but the intermediate can be prepared sufficiently pure by Quick and Adams'[6] modification of Meyer's reaction, the product from the second recrystallisation from alcohol being thoroughly washed with a mixture of equal volumes of alcohol and water to remove the sodium iodide and any trace of original materials. The immiscible oil is washed five times with 25 c.c. portions of 5 per cent. sodium hydroxide, followed by similar portions of water, then sealed in small containers, all in an atmosphere of carbon dioxide. The clear oil boils at 178° C. at 15 mm., but further attempts to purify it by fractional distillation under reduced pressure give immediate formation of the red, solid modification.[7] The formula $(CH_3As)_4$ assigned to the compound was based on molecular weight determinations by the cryoscopic method. Owing to extensive work, and a large number of molecular weight determinations both by

[1] Wohler, *Annalen,* 1848, 68, 127.
[2] Gibbs, *ibid.,* 1853, 86, 222.
[3] Wieland, *ibid.,* 1923, 431, 30.
[4] Auger, *Compt. rend.,* 1904, 138, 1705.
[5] Palmer and Scott, *J. Amer. Chem. Soc.,* 1928, 50, 536.
[6] Quick and Adams, *ibid.,* 1922, 44, 809.
[7] Auger, *loc. cit.,* gave the boiling-point as 190° C. at 13 mm.; compare Valeur and Gaillot, *Compt. rend.,* 1927, 185, 256.

the cryoscopic and ebullioscopic methods,[1] it has been conclusively proved that the formula $(CH_3As)_4$ is incorrect, and must be replaced by $(CH_3As)_5$. Moreover, a cyclic structure of the following nature has been given to the compound :



This formula, $(CH_3As)_5$, appears to hold good whether the determinations are carried out upon the yellow oil or the red solid.[2] It is necessary to exercise great care in preparing the compound, as the yellow oil, owing to the ease with which it is oxidised, forms the red or brownish-black modifications very readily. When *cyclo*pentamethylpenta-arsine is heated in a sealed tube with methyl iodide in an atmosphere of carbon dioxide for five hours at 100° C., it yields tetramethylarsonium mono- and tri-iodides and methyldi-iodoarsine, the reaction taking place as follows : [3]

$$(CH_3As)_5 \xrightarrow{5CH_3I} 5(CH_3)_2AsI \xrightarrow{10CH_3I} 5(CH_3)_4AsI_3$$

$$(CH_3.As)_5+5(CH_3)_4AsI_3=5CH_3AsI_2+5(CH_3)_4AsI$$

*Cyclo*pentamethylpenta-arsine, when distilled at atmospheric pressure in a carbon dioxide atmosphere, yields cacodyl and arsenic.[4]

Cyclopenta-n-propylpenta-arsine, $(C_3H_7.As)_5$.[5]—Fifty grams of magnesium propylarsinate, 51 grams of sodium hypophosphite, 60 grams of concentrated sulphuric acid, and 150 c.c. of water are heated in a carbon dioxide atmosphere for three hours on a water-bath. Twenty grams of heavy, yellow oil should result, which is washed with water, dilute sodium carbonate, and again with water, the operations being conducted in carbon dioxide. The liquid is fractionally distilled in a high vacuum, the pure product distilling at 177° to 179° C. at 1 mm., with slight decomposition. The yield is about 11 grams. The arsine is readily oxidised in air, but may be kept unchanged in a sealed tube for twelve months. The above product appears to contain about 5 per cent. of *propyl cacodyl*. When the arsine is distilled under 13 mm. pressure it decomposes into arsenic and propyl cacodyl, a colourless, mobile liquid, B.pt. 168° to 170° C. at 15 mm. (p. 52).

Aliphatic Unsaturated Arsenical Compounds.

When acetylene is passed into anhydrous arsenic trichloride, only slight absorption of the gas takes place, and the gas is again evolved if the liquid is boiled. This points to no chemical reaction taking place, or only one in which the compounds formed are decomposed by heat. If, however, anhydrous aluminium chloride is used as a catalyst, a

[1] Steinkopf, Schmidt, and Smie, *Ber.*, 1926, 59, [B], 1463.
[2] Palmer and Scott, *loc. cit.*
[3] Steinkopf, Schmidt, and Smie, *loc. cit.*
[4] Steinkopf and Dudek, *Ber.*, 1928, 61, 1906.
[5] Steinkopf and Dudek, *ibid.*

definite series of compounds results. Less efficient catalysts are mercuric chloride and anhydrous ferric chloride. In 1919, Dafert [1] obtained by the foregoing method a compound to which he assigned the formula $AsCl_3.2C_2H_2$. The properties of this derivative are similar to those of the dichlorodivinylchloroarsine described below. Green and Price, in 1921,[2] using anhydrous aluminium chloride as a catalyst, isolated three products from the reaction—namely, *β-chlorovinyldichloroarsine*, $CHCl{=}CH.AsCl_2$; *ββ′-dichlorodivinylchloroarsine*, $(CHCl{=}CH)_2AsCl$; *ββ′β″-trichlorotrivinylarsine*, $(CHCl{=}CH)_3As$. These derivatives were oxidised by Mann and Pope [3] to the following: *β-Chlorovinylarsinic acid*, $CHCl{=}CH.AsO(OH)_2$; *ββ′-dichlorodivinylarsinic acid*, $(CHCl{=}CH)_2AsO(OH)$; *ββ′β″-trichlorotrivinylarsine oxide*, $(CHCl{=}CH)_3AsO$. If the arsenic trichloride in the reaction is replaced by the tribromide, the chlorine in the foregoing arsines is replaced by bromine, the compounds containing the latter element having higher melting or boiling points than the chloro compounds.[4] From the halogen derivatives, sulphides and thiocyanates have been produced, which possess powerful, nauseating, and persistent odours, but the cyanides have little odour. Compounds which irritate the mucous membrane of the nose have been obtained by condensing the primary arsine with diphenylamine or phenyl-α-naphthylamine. The tertiary arsines readily form double salts with palladium and auric chlorides or silver nitrate, and show resemblance to triethylarsine, which also forms compounds with these chlorides. The compounds differ, however, in their action towards platinic chloride, triethylarsine forming two isomeric compounds of formula $2(C_2H_5)_3As.PtCl_2$,[5] and ββ′β″-trichlorotrivinylarsine two compounds corresponding to the formulæ $[(CHCl{=}CH)_3As]_2.Pt(CH{=}CHCl)_2$ and $[(CHCl{=}CH)_2AsCl]_2[(CHCl{=}CH)_2As.OH]_2PtCl_2$.[6] In the case of the interaction of higher hydrocarbons of the acetylene series with arsenic trihalides, no catalyst appears to have been used.

β-Chlorovinyldichloroarsine, $CHCl{=}CH.AsCl_2$, **ββ′-Dichlorodivinylchloroarsine**, $(CHCl{=}CH)_2AsCl$, and **ββ′β″-Trichlorotrivinylarsine**, $(CHCl{=}CH)_3As$ are prepared as follows: Acetylene, washed with sodium bisulphite solution and dried with sulphuric acid, is slowly passed into a solution of 38 grams of anhydrous aluminium bromide in 410 grams (16 molecular proportions) of arsenic trichloride at a temperature of 25° C. for two hours, whilst the whole is vigorously stirred. After standing for seven hours, the mixture is poured into 300 c.c. of 25 per cent. hydrochloric acid. Heat is developed and the mixture is cooled in water, stirred for fifteen minutes, the lower oily layer separated and fractionated at 30 mm. The 90° to 105° C. fraction is the crude β-chloro-compound, the 130° to 140° C. fraction is the ββ′-dichloro-compound, and the 155° to 163° C. fraction is the ββ′β″-trichloro-compound.[7] β-Chlorovinyldichloroarsine is a colourless or faintly yellow liquid, B.pt. 76° to 77° C. at 12·5 mm. or 82° C. at 16·5 mm.[8] It blisters

[1] Dafert, *Monatsh.*, 1919, 40, 313.
[2] Green and Price, *Trans. Chem. Soc.*, 1921, 119, 448.
[3] Mann and Pope, *ibid.*, 1922, 121, 1754.
[4] Lewis and Stiegler, *J. Amer. Chem. Soc.*, 1925, 47, 2546.
[5] Cahours and Gal, *Compt. rend.*, 1870, 70, 897, 1380; 71, 208.
[6] Mann and Pope, *loc. cit.*
[7] Lewis and Stiegler, *J. Amer. Chem. Soc.*, 1925, 47, 2546; see Lewis and Perkins *Ind. Eng. Chem.*, 1923, 15, 290; Green and Price, *Trans. Chem. Soc.*, 1921, 119, 448.
[8] Mann and Pope, *loc. cit.*; see Wieland, *Annalen*, 1923, 431, 30.

the skin even in dilute solution and attacks the mucous membrane of the nose. It is soluble in the usual organic solvents, but insoluble in water or dilute acids, whilst dilute alkaline solutions cause evolution of acetylene.

$\beta\beta'$-Dichlorodivinylchloroarsine boils at 108° to 109° C. at 10·5 mm., 116° to 117° C. at 15 mm., and 120° to 121° C. at 17 mm. It is more irritant to the mucous membrane than the preceding chloroarsine, the solubility of which it resembles ; it absorbs halogens, forming additive products.

$\beta\beta'\beta''$-Trichlorotrivinylarsine boils at 139° to 140° C. at 13 mm. or 144° C. at 16 mm. It crystallises on cooling in long, white needles, M.pt. 23° C. Its odour, although pungent, does not possess the irritant effects of the preceding derivatives. It is insoluble in water, dilute acids, and rectified spirit. It readily absorbs halogens. The bromo-compounds corresponding to the first two compounds described are prepared by replacing the arsenic trichloride in the previous experiment by arsenic tribromide. The temperature during the reaction ranges from 35° to 48° C., and the product isolated after distilling at 10 to 12 mm. is fractionated five times at 16 mm. The fraction boiling between 140° and 143° C. is **β-bromovinyldibromoarsine**, and the fraction 155° to 165° C., **$\beta\beta'$-dibromodivinylbromoarsine.**

β-Chlorovinyldibromoarsine, $CHCl{=}CH.AsBr_2$.—β-Chlorovinylarsenoxide (*vide infra*), 70 grams, is slowly added to a solution of 10 grams of potassium bromide in 200 c.c. of hydrobromic acid (40 per cent.). The oily liquid which separates is warmed and agitated with the hydrobromic acid solution for two to three hours. After cooling, the oily layer is collected on a dry filter paper and then distilled at 15 mm. pressure, the arsine coming over at 114° to 116° C. It is soluble in absolute alcohol and slightly soluble in ligroin.

β-Chlorovinyldi-iodoarsine, prepared in a similar manner, crystallises from ice-cold methyl alcohol in yellowish-brown crystals, M.pt. 37·5° to 38·5° C. It is somewhat soluble in ligroin and very soluble in alcohol and benzene.

β-Chlorovinylarsenoxide, $CHCl{=}CH.AsO$.—This is best prepared by mixing the corresponding dichloroarsine with one-half its weight of water and adding an excess of dilute ammonium hydroxide slowly, with stirring and cooling. The oxide is filtered off, ground to a powder, repeatedly washed with water, and finally with alcohol. It is a white, crystalline powder, M.pt. 143° C., sparingly soluble in water and carbon disulphide, more soluble in xylene, and slightly soluble in boiling alcohol.

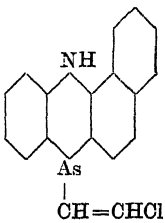
β-Chlorovinylarsinic oxide, $CHCl{=}CH.AsO_2$, results when the corresponding arsinic acid is heated in a vacuum at 110° to 115° C., one molecule of water being lost. It forms a fine, white, hygroscopic powder, decomposing violently at 242° C.

β-Chlorovinylarsenious sulphide may be isolated in about 50 per cent. yield, by treating the dichloroarsine in absolute alcohol with hydrogen sulphide. A pale yellow precipitate separates, which is purified by solution in carbon disulphide and precipitation with alcohol, the operation being repeated several times. The sulphide is thus isolated as a golden yellow oil, from which the last traces of carbon disulphide are removed by heating for an hour at 100° C. at 5 mm. pressure. The pure product is a clear, amber-coloured, plastic substance, insoluble in the usual solvents, with the exception of carbon disulphide. It cannot

be distilled without decomposition under any conditions, and it has an extremely irritant and nauseating odour, which persists in the skin for days.

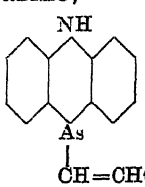
β-Chlorovinylhydroxythiocyanoarsine, $CHCl{=}CH.As(OH)CNS$, is formed by the interaction of potassium thiocyanate and the corresponding dichloroarsine in alcoholic solution. The product is a water-soluble oil, rather unstable in air.

7-β-Chlorovinyl-7 : 12-dihydro-γ-benzophenarsazine,



Five grams of β-chlorovinyldichloroarsine and six grams of phenyl-α-naphthylamine are gently heated under an air condenser for fifteen minutes. Hydrogen chloride is evolved, and after standing overnight a little xylene is added and the mixture filtered. The compound crystallises from boiling xylene in well-defined, needle-like crystals, M.pt. 213° C. Too long heating, too high temperatures, and the use of catalysts cause the formation of tar.

6-β-Chlorovinylphenarsazine,[1]



β-Chlorovinyldichloroarsine (25 grams) and 15 grams of diphenylamine are gently heated for fifteen minutes. 15 c.c. of absolute alcohol are then added, the solid filtered off, washed with alcohol and recrystallised from xylene. The crystalline product melts at 186° to 187° C., is soluble in hot xylene, acetone-carbon tetrachloride, and absolute alcohol. It is decidedly irritating to the eyes and nostrils.

β-Chlorovinylarsinic acid, $CHCl : CH.AsO(OH)_2$, is prepared either by the action of concentrated nitric acid on the dichloroarsine,[2] or better, by oxidising the β-chlorovinylarsenoxide with hydrogen peroxide and evaporating the solution to crystallising point.[3] The crystals thus obtained are flat and hexagonal, but when crystallised from acetone-carbon tetrachloride mixture, fine needles are deposited. Both types of crystals are bi-axial, positive, orthorhombic, the parameters $a : b : c$ being 1·555 : 1·565 : 1·705 ; birefringence γ-α, 150. They melt at 130° C., and are very soluble in water and alcohol. The *mono-ammonium salt* forms six-sided plates or long needles, melting with decomposition at 163° C., and the *di-silver salt* is a fine, creamy-white crystalline powder, which decomposes violently when heated alone or with concentrated nitric acid.

[1] Compare this Vol., p. 450.
[2] Mann and Pope, *loc. cit.*
[3] Lewis and Stiegler, *loc. cit.*

ββ′-Dichlorodivinylarsenious cyanide, $(CHCl{=}CH)_2AsCN$, is a colourless oil formed by the interaction of alcoholic ββ′-dichlorodivinylchloroarsine and aqueous potassium cyanide.

ββ′-Dichlorodivinylarsenoxide occurs when the corresponding arsine is treated with sodium alcoholate in alcohol solution. It is a crystalline product, M.pt. 62° to 63° C., soluble in ether and hot alcohol, slightly soluble in cold alcohol and insoluble in water.

ββ′-Dichlorodivinylarsenious sulphide is a yellowish-brown, viscous product, soluble in alcohol, insoluble in water, and has a very irritating effect on the mucous membrane.

ββ′-Dichlorodivinylarsinic acid, $(CHCl = CH)_2AsO.OH$.—ββ′-Dichlorodivinylchloroarsine is treated with a mixture of equal volumes of concentrated nitric acid and water, the reaction mixture being cooled in ice. When crystallised from water it melts at 114° to 115° C.[1] It forms a *nitrate*, consisting of needle-shaped crystals, M.pt. 99° C.; a *potassium salt*, which is a white, hygroscopic powder, M.pt. 158° C.; and a *hydrate* ($4H_2O$), colourless plates, M.pt. 49° C.; also a *sodium salt* ($4H_2O$), colourless plates, M.pt. 70° C.

ββ′-Dichlorodivinylmethylarsine, $(CHCl{=}CH)_2As.CH_3$, is formed when ββ′-dichlorodivinylchloroarsine is acted upon by magnesium methyl iodide. It is a thin, colourless oil, having a powerful, disagreeable odour; is insoluble in water but soluble in ether and absolute alcohol. When heated in a sealed tube with an excess of methyl iodide at 100° C. for three hours it gives *ββ′-dichlorodivinyldimethylarsonium iodide*, $(CHCl{=}CH)_2As(CH_3)_2I$. This compound appears to decompose at 243° C.

ββ′-Dichlorodivinylethylarsine is a colourless oil, yielding *ββ′-dichlorodivinylmethylethylarsonium iodide* with methyl iodide. This arsonium compound sublimes without change at 234° C., and is soluble in water and the usual organic media.

ββ′-Dichlorodivinyl-α-naphthylarsine is a yellow, non-crystallisable oil, insoluble in water.

ββ′β″-Trichlorotrivinylarsine dibromide, $(CHCl{=}CH)_3AsBr_2$, results when the corresponding arsine is treated with bromine in a freezing mixture, the reaction being carried out in light petroleum. It crystallises in needles, M.pt. 107° C.

ββ′β″-Trichlorotrivinylarsine oxide, $(CHCl{=}CH)_3AsO$, may be prepared either by hydrolysing the preceding dibromide with sodium hydroxide, or by acting upon the hydroxy-nitrate with sodium hydroxide solution. The oxide crystallises from benzene containing a little carbon tetrachloride in long, colourless needles, or in small plates, which melt with decomposition at 154° C.

ββ′β″-Trichlorotrivinylhydroxyarsonium nitrate, $(CHCl\ CH)_3As(OH).NO_3$, is formed when the corresponding arsine is oxidised by nitric acid. It crystallises from chloroform in needles, M.pt. 103° C., soluble in cold absolute alcohol and in water.

ββ′β″-Trichlorotrivinylmethylarsonium iodide, $(CHCl\ CH)_3As(CH_3)I$, results when the tertiary arsine and methyl iodide are heated in a sealed tube at 80° C. for twenty-two hours, then at 100° C. for two hours. It crystallises from alcohol in colourless needles, M.pt. 209° C., very soluble in water. It forms a double salt with *mercuric iodide*, $(CHCl{=}CH)_3As(CH_3)I.HgI_2$, a light yellow precipitate, M.pt.

[1] Wieland, *Annalen*, 1923, 431, 30, gives the M.pt. as 122° C.

150° to 156° C., and with *phenylmercuric iodide*, $(CHCl{=}CH)_3As(CH_3)I.C_6H_5HgI$, a *compound* melting at 147° to 148° C.

$\beta\beta'\beta''$ - Trichlorotrivinylarsine - p - toluenesulphonylimine,[1] $(CHCl{=}CH)_3As{=}N.SO_2.C_6H_4.CH_3.H_2O$. — The corresponding tertiary arsine and Chloramine T are boiled for twenty minutes in acetone solution, when condensation occurs. The arsylimine crystallises from benzene in colourless plates, M.pt. 124° C. Since no acetylene is evolved when the product is added to hot benzene containing calcium carbide, the compound may contain the grouping .NH.As(OH), instead of possessing water of crystallisation as shown above.

Platinum bis-β-chlorovinylbis-$\beta\beta'\beta''$-trichlorotrivinylarsine, $[(CHCl{=}CH)_3As]_2Pt(CH{=}CHCl)_2$.—This product results from the interaction of a dilute alcoholic solution of chloroplatinic acid and an alcoholic solution of the tertiary arsine. It crystallises from alcohol in very pale yellow needles, and from benzene in pale yellow plates, M.pt. 198° C. with decomposition.

Bis-$\beta\beta'$-dichlorodivinylchloroarsinebis-$\beta\beta'$-dichlorodivinylhydroxyarsineplatinichloride, $[(CHCl{=}CH)_2AsCl]_2[(CHCl{=}CH)_2As.OH]_2PtCl_2$.—The crystals obtained in the preceding preparation before purification are agitated with dry ether, and the ether solution allowed to evaporate spontaneously, when the platinichloride is isolated in lemon-yellow plates. Its production depends upon having a large excess of tertiary arsine present in the reaction mixture. It melts at 196° C.

Bis-$\beta\beta'\beta''$-trichlorotrivinylarsine palladichloride, $[(CHCl{=}CH)_3As]_2PdCl_2$.—Palladous chloride and the tertiary arsine readily yield this product in alcoholic solution. It forms long, yellowish-brown needles, melting with decomposition at 196° C., soluble in ether and acetone.

$\beta\beta'\beta''$-Trichlorotrivinylarsine aurichloride, $(CHCl{=}CH)_3As.AuCl$.—Obtained from potassium aurichloride and the tertiary arsine in alcohol; forms small, heavy white crystals, M.pt. 123° C., with decomposition. The crystals become purplish-grey on exposure to light.

$\beta\beta'\beta''$-Trichlorotrivinylarsine silver nitrate,[2] $(CHCl{=}CH)_3As.AgNO_3$.—Excess of silver nitrate dissolved in boiling absolute alcohol is added to an alcoholic solution of the tertiary arsine. The compound separates in fine, long, silky needles, M.pt. 144° C., stable to light when pure and dry. If an excess of the arsine is used, the *compound*, $[(CHCl{=}CH)_3As]_2.AgNO_3$, is formed, which has similar properties to the foregoing derivative.

Interaction of Hydrocarbons of the Acetylene Series with Arsenic Trihalides.[3]

Chloroheptinenearsenoxide, $C_5H_{11}.CCl{=}CH.AsO$.—Δ^{α}-Heptinene (240 parts) is heated under reflux for sixteen hours with 900 parts of arsenic trichloride. The excess of trichloride is removed in a vacuum and the residual oil dissolved in 3000 parts of moist ether. Aniline is added until no further precipitation of aniline hydrochloride occurs, the latter being removed and the filtrate washed with dilute hydrochloric acid, then with water, until neutral to Congo red. The oxide remains

[1] Mann and Pope, *Trans. Chem. Soc.*, 1922, 121, 1754.
[2] Lewis and Stiegler, *J. Amer. Chem. Soc.*, 1925, 47, 2546.
[3] American Patent, 1201692; German Patent, 296915.

as a viscous oil, which is dried over sodium sulphate, and freed from ether in a vacuum.

Chloroheptinenearsinic acid.—The above oxide (44 parts) in 400 parts of acetone is treated with 3 per cent. hydrogen peroxide until oxidation is complete. The solution is shaken with 500 parts of ether and the ethereal layer washed with dilute sodium hydroxide and water. The aqueous alkaline solution is acidified with hydrochloric acid and concentrated in a vacuum at 60° to 70° C. until the arsinic acid crystallises. It forms shining white plates, M.pt. 115° C., soluble in water, giving a neutral solution. It yields a water-soluble *sodium salt.*

Octinenebromoarsinic acid, M.pt. 129° to 130° C., is prepared in a similar manner from octinene and arsenic tribromide, the intermediate product being *octinenebromoarsenoxide.*

Derivatives of Unsaturated Higher Fatty Acids.

Chloroarsinosobehenolic acid, $C_{22}H_{40}O_3AsCl$.[1]—Pure behenolic acid and 1·25 times its weight of arsenic trichloride are heated at 140° C. for six hours, the dark, thick product being then subjected to reduced pressure to remove excess of arsenic trichloride. It is then shaken with ether and water, and the ether layer evaporated. An oil results, and this is treated with a little absolute alcohol, well cooled, and mixed with normal potassium hydroxide solution, a clear solution being formed. Addition of dilute hydrochloric acid precipitates an oil, which is taken up in ether, evaporation of the solvent yielding a mixture of behenolic acid and chloroarsinosobehenolic acid. The separation is effected by dissolving the mixture in twice its bulk of alcohol and cooling in a freezing mixture, behenolic acid separating out. More of this acid may be removed from the mother liquors by cooling to −50° C. The product obtained is a thick, light brown oil, containing 13·93 per cent. of arsenic and 6·7 per cent. of chlorine, the atomic proportions of the two elements being 1 : 1, and the quantities of the two elements in the preparation correspond to 86 per cent. of chloroarsinosobehenolic acid. The pure preparation is a brownish-red oil, soluble in alcohol, ether, benzene, chloroform, and olive oil, insoluble in water. When strongly heated it gives an arsenic mirror, and with thionyl chloride forms *chloroarsinosobehenolanilide.*[2] The *alkaline earth salts* are insoluble in water and obtained as amorphous, colourless precipitates when an alcoholic solution of the acid is treated with a methyl alcohol solution of calcium or strontium chloride containing ammonia. The *strontium salt* is known in medicine as *Elarson,* is insoluble in water, and sparingly soluble in other solvents, blackens on heating, and is decomposed by cold dilute hydrochloric acid.[3] An alcoholic solution of chloroarsinosobehenolic acid, when heated for two hours on the water-bath with normal potassium hydroxide, then saturated with hydrogen chloride, gives behenolic acid.

Yohimbine chloroarsenobehenolate is a faintly coloured powder, melting at about 90° C., soluble in water, alcohol, and acetone.[4]

[1] Fischer, *Annalen,* 1914, 403, 106; see German Patent, 257641; American Patents, 1082509, 1082510; British Patents, 18732 (1912), 10378, 10379 (1913); French Patent, 449014; German Patents, 268829, 271158, 271159.

[2] German Patent, 273219.

[3] *Iron salts* have also been obtained.

[4] American Patent, 1305462.

The *methyl ester* of chloroarsenobehenolic acid is prepared by dissolving the acid in a mixture of concentrated sulphuric acid and methyl alcohol, and warming on the water-bath to complete the reaction. An oil separates, the mixture being neutralised with sodium carbonate and extracted with ether. On working up the extract, a thick, brownish oil results, which readily dissolves in methyl alcohol; it forms a *strontium salt* which may be used for its purification. The pure ester is a thick, yellowish oil, soluble in the usual organic solvents, and decomposes on strong heating. Its methyl alcohol solution turns blue litmus a deep red. The ester is hydrolysed by methyl alcoholic potassium hydroxide to *chlorobehenolarsinic acid*, which is purified by means of its *strontium salt*, $C_{22}H_{40}O_5AsClSr$.

Methyl chloroarsinosobehenolate [1] is obtained by heating 700 parts of methyl behenolate and 900 parts of arsenic trichloride at 135° C. for nine hours. The product is worked up as above, a brown oil resulting, soluble in ether and benzene, sparingly soluble in alcohol. If behenolic anhydride is used and the heating maintained at 140° C. for six hours, *chloroarsinosobehenolic anhydride* is obtained as a brown mass, soluble in chloroform and benzene.

In a similar manner to the above, compounds have been obtained from *stearolic acid*. This acid and 1·5 times its weight of arsenic trichloride, when heated at 140° C. for six hours, gives a thick brown mass. This is dissolved in ether and shaken with water, the ethereal extract being treated as in the case of behenolic acid. A semi-solid mass is obtained which contains 10 to 11 per cent. of arsenic and 6 to 7 per cent. of chlorine. The *strontium salt* is a water-insoluble powder, containing 11 to 12 per cent. of arsenic..

[1] German Patent, 273219.

CHAPTER II.

AROMATIC ARSINES AND ARSONIUM COMPOUNDS.

Compounds of the Types $RAsH_2$ and R_2AsH.

All the mono- and diarylarsines may be prepared by the reduction of the corresponding arsinic acids, whether the benzene nucleus is substituted or not. Such reduction may be effected with zinc dust and hydrochloric acid, and, in the case of phenylarsinic acid, electrolytic reduction in aqueous alcohol solution has also been used. The primary arsines show no basic properties and readily undergo oxidation in air, forming oxides, acids, and arseno- compounds. Halogens react with these arsines, replacing the hydrogen :

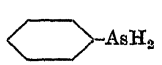
$$RAsH_2+2X_2=RAsX_2+2HX$$

Alkyl halides yield aryltrialkylarsonium halides :

$$RAsH_2+3R'X=RR_3'AsX+2HX \quad [R'=\text{alkyl}]$$

The interaction of both mono- and diarylarsines with magnesium ethyl bromide is interesting, the hydrogen in each case being replaced by the grouping MgBr, thus : $C_6H_5As(MgBr)_2$ and $(C_6H_5)_2As(MgBr)$. These magnesium compounds are readily oxidised, and also absorb carbon dioxide. Phenylarsine combines also with zinc ethyl iodide, giving $C_6H_5As(ZnI_2)$, which resembles the preceding magnesium compound in structure. The condensation products of aromatic primary arsines with aldehydes are fully dealt with on p. 67. Only one derivative of the type R_2AsH is known, namely, diphenylarsine. It is rapidly oxidised in air, and its hydrogen may be replaced by halogen in the same way as with the primary arsines.

Phenylarsine,



This substance is best prepared as follows: 400 grams of crude phenylarsinic acid, 800 grams of amalgamated zinc dust, and a little water are mixed with 1000 c.c. of ether. Two thousand c.c. of concentrated hydrochloric acid are added drop by drop, and when reduction is complete, the condenser is replaced by a funnel and delivery tube. Water is poured into the funnel, thus forcing the ether layer through the delivery tube, which is attached to a 2000 c.c. separating funnel filled with carbon dioxide. The ether solution is dried by means of calcium chloride, then distilled in a current of carbon dioxide, first at ordinary pressure until most of the ether is removed, afterwards under diminished pressure, the receiver being cooled in a freezing mixture. The product distilling at about 93° C. at 70 mm. is collected.[1]

[1] Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356 ; see Adams and Palmer, *ibid.*, 1920, 42, 2375 ; Palmer and Dehn, *Ber.*, 1901, 34, 3594 ; *Amer. Chem. J.*, 1905, 33, 147 ; Kahn, *Chem. Zeit.*, 1912, 36, 1099.

The yield is about 83 per cent. The arsine may also be prepared by the electrolytic reduction of phenylarsinic acid in aqueous alcohol solution.[1]

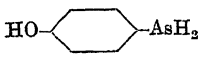
Phenylarsine is a clear, colourless liquid, boiling at 148° C. at 760 mm., 93° C. at 70 mm., 84° C. at 55 mm., 77° C. at 33 mm., and 55° C. at 14 mm.; its density is 1·349 at 25° C.; n_D 1·6082 at 25° C. In a concentrated state it smells like phenyl *iso*cyanide, but on dilution resembles hyacinths. It causes painful blisters on the skin and is highly irritating to the mucous membrane. It oxidises in air, forming the oxide, acid, and arsenobenzene; in ether or chloroform solution the last of these three products is exclusively produced. Oxidation by nitric acid gives phenylarsinic acid together with some nitrobenzene and arsenobenzene. Iodine [2] in potassium iodide gives phenylarsinic acid and phenyldi-iodoarsine, whilst methyl and ethyl iodides at 120° C. give phenyltrimethylarsonium and phenyltriethylarsonium iodides respectively, and hydrogen iodide in both cases. Phenylarsine (1 mol.) and 2 molecules of magnesium ethyl bromide interact in ether solution to give an *arsinomagnesium compound*, $As.C_6H_5(MgBr)_2$, which is readily oxidised, and reconverted to the arsine by the action of water;[3] this compound also absorbs carbon dioxide, yielding $As.C_6H_5(CO_2.MgBr)_2$, which is decomposed by water or dilute acid into phenylarsine and magnesium hydrogen carbonate. The magnesium-arsine is converted by ethyl chloroformate in benzene solution and an inert atmosphere to *ethyl phenylarsinodicarboxylate*, $As.C_6H_5(CO_2.Et)_2$, an oil, which does not crystallise at −60° C., and has a density of 1·312 at 23° C.; n_D, 1·5442 at 23° C., B.pt. 146° C. at 5 mm. or 180° to 183° C. at 20 mm. It has a slight ethereal odour, and is apparently stable in air, but is hydrolysed by alcoholic potassium hydroxide, yielding phenylarsine and potassium carbonate, together with smaller quantities of the arsenoxide and ethyl formate. Iodine in aqueous alcohol converts it quantitatively into phenylarsinic acid. The compound $As.C_6H_5(MgBr)_2$ in benzene solution is transformed by acetyl chloride into *diacetylphenylarsine*, $As.C_6H_5Ac_2$, a yellow oil, oxidising in air and reacting with methyl iodide to form phenyltrimethylarsonium iodide and acetyl iodide. With dihalogen compounds, *e.g.* carbonyl chloride or ethylene dibromide, unstable compounds are formed, which decompose, yielding arsenobenzene and carbon monoxide in the first case, arsenobenzene and ethylene in the second case. For the action of $\beta\beta'$-dichloroethyl sulphide, see p. 67. Phenylarsine (1 mol.) also reacts with zinc ethyl iodide (2 mols.) yielding zinc phenylarsine iodide, $As.C_6H_5(ZnI)_2$, and ethane (2 mols.).

Phenyliodoarsine, $C_6H_5.AsIH$.[4]—Concentrated ether solutions of 2·55 grams of diphenylarsine and 4·5 grams of phenyldi-iodoarsine are mixed in a carbon dioxide atmosphere. Raising the ether to the boiling-point causes the separation of a solid iodine compound. The solvent is removed by decantation and the solid washed with ether, the resulting phenyliodoarsine soon becoming dark and sticky on exposure to air. The ether filtrate soon gives an oil, from which

[1] Fichter and Elkind, *Ber.*, 1916, 49, 239.
[2] Compare Fleury, *Bull. Soc. chim.*, 1920, [iv.], 27, 490.
[3] Job and Reich, *Compt. rend.*, 1923, 177, 56; Job, Reich, and Vergnaud, *Bull. Soc. chim.*, 1924, [iv.], 35, 1404.
[4] Steinkopf and Smie, *Ber.*, 1926, 59, [B], 1460.

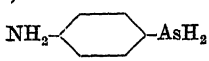
diphenyliodoarsine may be obtained. Triphenyldiarsine with two atoms of iodine also yields phenyliodoarsine. Exhaustive methiodination gives chiefly phenyltrimethylarsonium tri-iodide, together with smaller amounts of phenyltrimethylarsonium iodide and phenyldiiodoarsine. Nitric acid converts the iodoarsine into phenylarsinic acid.

4-Hydroxyphenylarsine,[1]



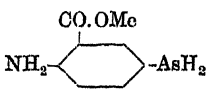
p-Hydroxyphenylarsinic acid, 218 grams, in 2500 c.c. of methyl alcohol, is treated with 400 grams of zinc dust and 1500 c.c. of hydrochloric acid (density 1·19), run in with vigorous stirring. After removing the undissolved zinc dust, the filtrate is extracted with ether and the ether solution shaken with sodium hydroxide. The arsine dissolves, and is precipitated by passing carbon dioxide through the alkaline solution, a white powder being obtained. At 70° C. it darkens, and completely decomposes at 155° C. It is soluble in sodium hydroxide, sparingly soluble in water, alcohol, and ether. It is oxidised by air, becoming yellow and finally red, owing to the formation of the dihydroxyarsenobenzene.

4-Aminophenylarsine,



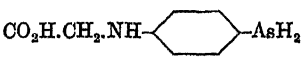
results when *p*-aminophenylarsinic acid is reduced as above. After removal of the unchanged zinc dust, the filtrate is made alkaline and steam distilled. The distillate is extracted with ether, and removal of the solvent gives a colourless oil, which rapidly oxidises in air to a yellow solid, the diaminoarsenobenzene. The arsine boils at 132° C. at 10 mm., is readily soluble in alcohol, ether, and acetic acid, sparingly soluble in water. If the *p*-aminophenylarsinic acid in the foregoing preparation is replaced by its acetyl derivative, *p-acetylaminophenylarsine* results.[2] This is a white powder, soluble in methyl alcohol and dilute hydrochloric acid, and forms a yellowish-red *co-ordination compound* with *cupric chloride*.[3]

4-Amino-5-carbomethoxyphenylarsine,[4]



is a yellow, sparingly soluble powder, obtained from the arsinic acid by reduction with zinc and hydrochloric acid in the usual way.

Phenylglycine-4-arsine,[5]

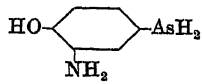


Phenylglycine-4-arsinic acid, 275 grams, in 1500 c.c. of hydrochloric acid (density 1·19) is treated with 400 grams of zinc dust, with brisk stirring. The yellow precipitate which at first appears redissolves, the yellow solution becoming colourless. The filtrate from the undissolved

[1] German Patent, 251571.
[2] German Patent, 269743.
[3] German Patent, 275216.
[4] German Patent, 269744.
[5] German Patent, 251571.

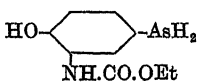
zinc dust is treated with a solution of 2500 grams of crystalline sodium acetate in 2500 c.c. of water, the *zinc salt* of the reduction product separating as a white precipitate. This is filtered off and boiled with an excess of sodium carbonate solution, the *sodium salt* of the arsine being formed; the precipitated zinc carbonate is removed. Acidification of the filtrate gives the free acid as a pale yellow precipitate, which soon darkens in air. It decomposes above 100° C., and is very sparingly soluble in water, alcohol, and ether.

3-Amino-4-hydroxyphenylarsine,



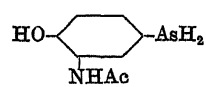
is obtained from 3-nitro-4-hydroxyphenylarsinic acid as follows: 263 grams of the acid in 3000 c.c. of hydrochloric acid (density 1·19) are allowed to react with 800 grams of zinc dust, a dirty precipitate forming at first, which gradually dissolves, giving a dark solution. To this mixture, 6000 c.c. of water are added and the whole warmed until colourless. On filtering, the *zinc double salt* of the arsine crystallises from the filtrate as it cools. This is decomposed by adding sodium acetate, the arsine extracted by ether, then removed from the latter solution by shaking with sodium hydroxide, and precipitated by the addition of acetic acid. The arsine is a white powder, darkening above 100° C., and completely decomposing at 135° C. It is soluble in sodium hydroxide, hydrochloric acid, alcohol, and ether, sparingly soluble in water. With *gold chloride* it forms a brown *co-ordination compound*, readily soluble in water, acids, alkalis, and methyl alcohol.[1] The *silver nitrate* addition product is black, and that of *cupric chloride*, yellowish-red.[2]

3-Carbethoxyamino-4-hydroxyphenylarsine,[3]



This derivative is prepared by the electrolytic reduction of the corresponding arsinic acid. It is a white, crystalline powder, M.pt. 155° to 160° C.; with *palladium dichloride* it forms a black *co-ordination compound.*[4]

3-Acetamido-4-hydroxyphenylarsine,[5]

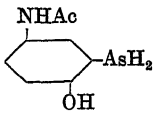


Five grams of 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene are mixed with 16 grams of zinc dust and the mixture added to a solution containing 70 c.c. of concentrated hydrochloric acid and 50 c.c. of water at 90° to 100° C. After cooling, the supernatant liquid is filtered into a

[1] German Patent, 275216.
[2] For reaction with formaldehyde sulphoxylate, see German Patent, 278648.
[3] German Patent, 267082.
[4] German Patent, 275216.
[5] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 2375.

solution of 20 grams of sodium acetate in 20 c.c. of water containing 15 c.c. of acetic anhydride in suspension. On shaking the mixture, a 90 per cent. yield of the arsine separates as white plates, insoluble in water, but soluble in excess of caustic alkali. It readily oxidises in air to the corresponding arseno-compound.

5-Acetamido-2-hydroxyphenylarsine,



prepared in a similar manner to the foregoing, also forms white plates, having similar properties to the preceding compound.

o-Chlorophenylarsine, $Cl.C_6H_4.AsH_2$,[1] is prepared in a similar way to phenylarsine, except that no ether is used, and after reduction is complete the arsine is distilled in steam from the reaction mixture. The yield ranges from 45 to 60 per cent., and the product boils at 206° C. at atmospheric pressure. Its density is 1·519 at 25° C., and its refractive index, n_D, 1·6250 at 25° C.

p-Chlorophenylarsine.—p-Chlorophenylarsinic acid, 70 grams, 350 grams of zinc dust, and 250 c.c. of methyl alcohol are placed in a flask carrying a reflux condenser with a mercury trap attached to the upper end. The cork taking the condenser has a second hole, which carries a separating funnel. Concentrated hydrochloric acid is allowed to run in from the funnel at the rate of three to four drops a minute, the total amount added being about 1000 c.c. In about three to seven days the bulk of the zinc disappears and the product is distilled in carbon dioxide. The arsine distils with the water and methyl alcohol, and after pouring off the water the alcohol is removed by distillation, 200 c.c. of ether added, and the solution dried over potassium hydroxide, being then distilled *in vacuo*, first using a stream of carbon dioxide to displace the air; after removing the ether one or two distillations give a pure product, boiling at 116° C. at 33 mm. or 159° C. at 200 mm., M.pt. 30·5° to 30·7° C. It crystallises in thin, transparent leaves, density 1·507 at 25° C., refractive index, n_D, 1·6143 at 25° C. From the above quantities a yield of 16 to 26 grams should be obtained.

o-Tolylarsine, $CH_3.C_6H_4.AsH_2$, obtained in a similar way to phenylarsine, is a colourless oil, B.pt. 121° C. at 93 mm., density 1·301 at 25° C., refractive index, n_D, 1·5925 at 25° C.

p-Tolylarsine requires rather more zinc dust than in the corresponding case of phenylarsine. It is a colourless liquid, B.pt. 113·5° C. at 44 mm., forming white, shining plates, M.pt. 20° C., density 1·295 at 25° C., refractive index, n_D, 1·5891 at 25° C. The yield is 30 to 50 per cent.

Benzylarsine, $C_6H_5.CH_2.AsH_2$,[2] results when benzylarsinic acid is reduced by amalgamated zinc dust and hydrochloric acid. It is a faint yellow liquid, B.pt. 140° C. at 262 mm. It forms a *platinichloride*, $C_7H_7.AsH_2.PtCl_4$. The arsine oxidises in air to benzylarsinic acid.

Diphenylarsine, $(C_6H_5)_2AsH$,[3] is obtained by reduction of the arsinic acid in the usual manner. It is a clear, colourless oil, B.pt.

[1] Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356.
[2] Dehn, *Amer. Chem. J.*, 1908, 40, 88.
[3] Dehn and Wilcox, *ibid.*, 1906, 35, 45.

174° C. at 25 mm., rapidly oxidised by air, forming the acid and phenylcacodyl oxide. The hydrogen is replaceable by bromine or iodine, giving diphenylarsenic tribromide and diphenyliodoarsine respectively. It has been shown, p. 63, that phenylarsine reacts with magnesium ethyl bromide, yielding an oily product, $As.C_6H_5(MgBr)_2$, and in a similar manner diphenylarsine gives a crystalline substance, $As(C_6H_5)_2MgBr$, which is less soluble, and absorbs carbon dioxide less readily than the preceding compound. The compound from $As(C_6H_5)_2MgBr$ and carbonyl chloride yields some phenylcacodyl with carbon monoxide, but with $\beta\beta$-dichloroethyl sulphide this doubling of the arsine radical does not occur. In general reactions the compound from diphenylarsine resembles that from phenylarsine.[1] Diphenylarsine also reacts vigorously with acetyl chloride in an atmosphere of carbon dioxide[2] to form *diphenylacetylarsine*, $(C_6H_5)_2As.CO.CH_3$, B.pt. 167° to 168° C. This compound decomposes on exposure to air with evolution of heat, and oxygen in the presence of water converts it into diphenylarsinic acid and acetic acid. Under the same conditions, chloro- and bromo-acetyl chloride give diphenylchloroarsine and diphenylbromoarsine respectively. Phosgene or phosphorus trichloride interacts with diphenylarsine, diphenylchloroarsine being produced in each case. Combination between diphenylarsine and benzene sulphonyl chloride produces diphenylchloroarsine, diphenyl sulphide, and a substance, $(C_6H_5)_2AsO.O.SO_2.C_6H_5$, [diphenylarsinic acid]-[benzenesulphonic acid]-anhydride. This compound also results when diphenylarsinic acid reacts with benzenesulphonyl chloride. It melts to a turbid liquid at 106° to 108° C., which becomes clear at 109° C. It readily dissolves in cold acetone, alcohol, chloroform, hot benzene, or carbon tetrachloride.

Condensation Products of Aromatic Primary Arsines with Aldehydes.[3]

Interaction between primary arylarsines and aldehydes may take one of the three courses indicated below, the final product depending upon the conditions under which the reaction takes place:

(1) $C_6H_5AsH_2+2R.CHO=C_6H_5As(CHR.OH)_2$

(2) $C_6H_5AsH_2+4R.CHO=C_6H_5As\begin{matrix}O.CHR\\ \diagup\quad\diagdown\\ CHR.O\end{matrix}AsC_6H_5+2CH_2R.OH$

(3) $2C_6H_5AsH_2+2R.CHO=C_6H_5As:AsC_6H_5+2CH_2R.OH$

With aliphatic aldehydes, condensation takes place in the presence of concentrated hydrochloric acid at room temperatures, yielding derivatives of the type shown in equation (1). In the case of aromatic aldehydes the reaction takes place with or without a solvent when dry hydrogen chloride is passed in. Heating these condensation products in the free flame decomposes them, with formation of aldehyde and phenylarsine, the latter being immediately oxidised to arsenobenzene in air, this in turn being transformed completely to triphenylarsine and arsenic:

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[1] Job, Reich, and Vergnaud, *Bull. Soc. chim.*, 1924, [iv.], 35, 1404.

[2] Steinkopf, Schubart, and Schmidt, *Ber.*, 1928, 61, [B], 678.

[3] Adams and Palmer, *J. Amer. Chem. Soc.*, 1920, 42, 2375; Palmer and Adams, *ibid.*, 1922, 44, 1356.

$$C_6H_5As(CHR.OH)_2 = C_6H_5AsH_2 + 2RCHO$$
$$2C_6H_5AsH_2 + O_2 = C_6H_5As{=}AsC_6H_5 + 2H_2O$$
$$3C_6H_5As{=}AsC_6H_5 = 2(C_6H_5)_3As + As$$

When phenyldi-α-hydroxyalkylarsines are exposed to the air for a few days, oxidation takes place with the precipitation of phenylarsinic acid, the speed of the reaction increasing in solution, particularly in carbon tetrachloride. Alkaline potassium permanganate or nitric acid in ice-water also effect the oxidation :

$$C_6H_5As(CHR.OH)_2 + 6HNO_3 = C_6H_5AsO.(OH)_2 + 2R.CHO + 3H_2O + 6NO_2$$

These condensation compounds are not easily reduced, the following reagents being without effect : zinc and acetic or hydrochloric acid ; aluminium powder and sodium hydroxide ; sodium and alcohol.

Chlorine and bromine react violently with these compounds, and with the aliphatic aldehyde compounds the following reaction takes place quantitatively in ether solution, and titration with standard iodine may be carried out :

$$C_6H_5As(CHR.OH)_2 + 2I_2 = C_6H_5AsI_2 + 2HI + 2R.CHO$$

Phosphorus pentachloride and phenyldichloroarsine react according to the equations :.

$$C_6H_5As(CHR.OH)_2 + 2PCl_5 = C_6H_5AsCl_2 + 2HCl + 2PCl_3 + 2R.CHO$$
$$C_6H_5As(CHR.OH)_2 + C_6H_5AsCl_2 = C_6H_5As : AsC_6H_5 + 2HCl + 2R.CHO$$

Some of the compounds form unstable additive products with halogen acids, and stable additive derivatives with chloroplatinic acid.

The tetrahydro-dioxadiarsines formed according to equation (2) (p. 67) are unaffected by long standing in the cold with water, dilute hydrochloric acid, or dilute sodium hydroxide, or after three hours heating with alcoholic potash. 2 : 5-*Diphenyltetrahydro*-1 : 4 : 2 : 5-*dioxadiarsine* is rapidly oxidised in air, but the higher members are more slowly attacked. The products from the action of nitric acid, phosphorus pentachloride, and iodine are the same as those described in the case of the preceding compounds. Ether solutions of dioxadiarsines cannot be titrated quantitatively with iodine, and they do not form additive products with halogen acids. Benzaldehyde (in the presence of acetic acid), anisaldehyde, and *m*-nitrobenzaldehyde, when condensed with phenylarsine, yield arsenobenzene ; *p*-chlorobenzaldehyde gives *p*-chlorobenzyl alcohol, and chloral yields phenyldichloroarsine and acetaldehyde.

Phenyldi-α-hydroxyethylarsine, $C_6H_5As[CH(CH_3).OH]_2$, is a colourless oil, B.pt. 175° to 176° C. at 22 mm. ; density, 1·252 at 25° C. ; n_D, 1·5619 at 25° C. ; yield, 81 per cent. ; *platinichloride*, M.pt. 169° to 170° C. ; *hydrobromide*, M.pt. 117° to 118° C.

Phenyldi-α-hydroxy-n-propylarsine boils at 196° to 197° C. at 24 mm. ; density, 1·176 at 25° C. ; n_D, 1·5425 at 25° C. ; yield, 70 per cent. ; *platinichloride*, M.pt. 148° to 149° C.

Phenyldi-α-hydroxy-n-butylarsine boils at 228° C. at 26 mm. or 187° C. at 10 mm. ; density, 1·116 at 25° C. ; n_D, 1·5271 ; *platinichloride*, M.pt. 119° to 121° C. ; *hydrobromide*, M.pt. 111° to 112° C. ; *hydriodide*, M.pt. 157° to 158° C.

Phenyldi-α-hydroxyisovalerylarsine boils at 170° C. at 6 mm., M.pt. 62° C.; density, 1·079 at 25° C.; n_D, 1·5202 at 25° C.; yield, 59 per cent.; *platinichloride*, M.pt. 84° to 85° C.

Phenyldi-α-hydroxy-n-heptylarsine boils at 263° to 264° C. at 2 mm.; density, 1·069 at 25° C.; n_D, 1·4650 at 25° C.

Condensation Products of Arylarsines and Aromatic Aldehydes.

The condensation between these types of compounds takes place readily in the presence of concentrated hydrochloric acid, but better yields are obtained when anhydrous hydrogen chloride is passed into the mixture in any convenient solvent and the whole mechanically stirred. As in the previous condensations, it is necessary to pass in carbon dioxide to prevent oxidation.

Phenyldi-α-hydroxybenzylarsine, $C_6H_5As[CH(C_6H_5)OH]_2$, crystallises from chlorobenzene in white, silky needles, M.pt. 193° C. It is soluble in hot benzene, sparingly soluble in hot alcohol, and insoluble in water.

Phenyldi-α-hydroxy-p-chlorobenzylarsine forms colourless needles, M.pt. 164° C., and is more soluble than the preceding compound.

Phenyldi-α-hydroxy-p-methoxybenzylarsine occurs as a yellowish oil, insoluble in water, readily soluble in organic solvents, except petroleum ether.

Phenyldi-α-hydroxy-o-carbomethoxybenzylarsine is a colourless powder, M.pt. 145° to 147° C., with loss of carbon dioxide.

o-Chlorophenyldi-α-hydroxybenzylarsine separates from ether or alcohol in white crystals, M.pt. 146° to 147° C.

p-Chlorophenyldi-α-hydroxybenzylarsine crystallises from chlorobenzene and alcohol in white, silky needles, M.pt. 218° to 218·5° C.

p-Chlorophenyldi-α-hydroxyethylarsine is a liquid, B.pt. 183° C. at 23 mm.; density, 1·336 at 25° C.; n_D, 1·5728 at 25° C.

o-Tolyldi-α-hydroxyethylarsine boils at 165° C. at 21 mm.; density, 1·244 at 25° C.; n_D, 1·5573 at 30° C.

o-Tolyldi-α-hydroxybenzylarsine crystallises from ether in white needles, M.pt. 140° C.

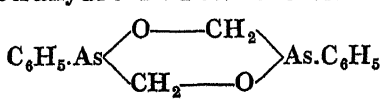
p-Tolyldi-α-hydroxyethylarsine is a colourless oil, B.pt. 176° to 177° C. at 22 mm.; density, 1·2331 at 18° C.; n_D, 1·5570 at 20° C.

p-Tolyldi-α-hydroxybenzylarsine occurs in long, white needles, M.pt. 208° C.

General Method for the Preparation of Tetrahydro-1 : 4 : 2 : 5-Dioxadiarsines.

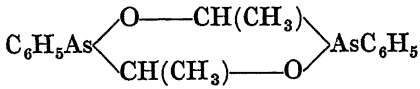
One gram-molecule of phenylarsine is cooled in ice, in an atmosphere of carbon dioxide, and dry hydrogen chloride passed through the liquid. At the same time, two gram-molecules of aliphatic aldehyde are added dropwise, and after standing for several days the mixture is distilled at ordinary pressure. The residue is fractionated under reduced pressure, the first fraction consisting of phenyldi-α-hydroxyalkylarsine, and the residue tetrahydro-dioxadiarsine in 50 to 90 per cent. yield.

2 : 5-Diphenyltetrahydro-1 : 4 : 2 : 5-dioxadiarsine,



Fifteen grams of phenylarsine, when treated with paraformaldehyde in the presence of concentrated hydrochloric acid, give about 10 grams of product. After two distillations the latter boils at 215° to 216° C. at 9 mm.; density, 1·547 at 25° C.; n_D, 1·6522 at 25° C.

2 : 5-Diphenyl - 3 : 6-dimethyltetrahydro - 1 : 4 : 2 : 5-dioxadiarsine,



This compound is prepared by the general method, or by the following process: Phenyldi-α-hydroxyethylarsine is heated in an oil-bath with half its weight of acetic anhydride for seven hours at 140° to 150° C. The reaction mixture is then distilled and the fraction from 75° to 80° C., which contains ethyl acetate, is collected. The residue is distilled under reduced pressure and the fraction from 250° to 265° C. at 10 mm. collected. A third method of preparation is to allow phenyldi-α-hydroxyethylarsine to stand for a few days in the presence of hydrogen chloride. The diarsine is a colourless oil, B.pt. 257° C. at 10 mm.; density, 1·369 at 25° C.; n_D, 1·6332 at 25° C. Its *platinichloride* separates in colourless flocks from dilute alcohol, and melts at 130° to 131° C.; the *cuprichloride* melts at 150° to 152° C.

2 : 5-Diphenyl - 3 : 6-diethyltetrahydro - 1 : 4 : 2 : 5-dioxadiarsine boils at 212° C. at 2 mm.; density, 1·336 at 25° C.; n_D, 1·6217 at 25° C.

2 : 5-Diphenyl - 3 : 6-di-n-propyltetrahydro - 1 : 4 : 2 : 5-dioxadiarsine may be prepared by the general method, or by the action of acetic anhydride on phenyldi-α-hydroxy-*n*-butylarsine. It is a pale yellow oil, B.pt. 241° to 242° C. at 2 mm.; density, 1·297 at 25° C.; n_D, 1·5856 at 25° C.

2 : 5-Diphenyl - 3 : 6-di-isobutyltetrahydro - 1 : 4 : 2 : 5-dioxadiarsine boils at 240° C. at 16 mm.; density, 1·296 at 25° C.; n_D, 1·5869 at 25° C.; the *platinichloride* has M.pt. 76° to 77° C., the *cuprichloride*, M.pt. 78° to 79° C.

2 : 5-Diphenyl - 3 : 6-difuryltetrahydro - 1 : 4 : 2 : 5-dioxadiarsine occurs as a hard mass when furfural and phenylarsine react in the presence of anhydrous hydrogen chloride. When powdered it resembles zinc dust, and burns without melting or leaving a residue. It is insoluble in all solvents.

Compounds of the Type R_3As.

There are six types of tertiary aromatic arsines known, if those containing aliphatic radicals are also included: Ar_3As, $ArAr_2'As$, Ar_2AlkAs, $ArAlk_2As$, $ArAr'AlkAs$, $ArAlkAlk'As$. For the type Ar_3As, the Fittig reaction forms the basis of a method of preparation, aryl halides and arsenic trihalides reacting in ether or benzene solution in the presence of sodium as follows:

$$3RX + AsX_3 + 6Na = R_3As + 6NaX$$

Magnesium aryl halides and arsenic trihalides also give the same products:

$$3MgRX + AsX_3 = R_3As + 3MgX_2$$

The author would recommend the first of the two methods as the better to use for these preparations. It is true that by-products tend to be produced, as in the case of tribenzylarsine, but, unless extreme care is taken, the Grignard reaction will also give more than one product during the reaction. Moreover, the extra trouble taken in drying ether for the second method, as compared with drying benzene for a Fittig reaction, does not recommend the Grignard method. Finally, those who have had much experience in preparing these compounds by the Grignard reaction know that it is almost impossible to guarantee that any two experiments carried out together in precisely the same way will give the same yield. There always seems to be some factor of uncertainty about the reaction, and the larger the quantities used in a Grignard reaction, the poorer often are the yields of tertiary arsine, whereas the preparation by the Fittig reaction can be carried out on a large scale. The following methods are also available, but not so extensively used: (1) Magnesium aryl halides are allowed to react with arsenious oxide in ether solution. (2) Some arylarsenoxides are decomposed when heated, yielding tertiary arsines and arsenious oxide. (3) Mercury diaryls react with aryl dihalogenated arsines as follows:

$$R_2Hg+RAsX_2=R_3As+HgX_2$$

Compounds of the type $ArAr_2'As$ are also prepared by the Fittig reaction, according to the equation:

$$RAsX_2+2R'X+4Na=RR_2'As+4NaX$$

In the case of mixed aliphatic-aromatic tertiary arsines, the following equations indicate the methods available:

Type Ar_2AlkAs.

(1) $2Ar_2AsX+ZnAlk_2 = 2Ar_2AlkAs+ZnX_2$
(2) $2ArMgBr+AlkAsI_2 = Ar_2AlkAs+MgBr_2+MgI_2$
(3) $C_6H_5.CH_3.AsCl+C_6H_6+[AlCl_3]=(C_6H_5)_2CH_3.As+HCl+[AlCl_3]$

Type $ArAlk_2As$.

(1) $ArAsX_2+ZnAlk_2 = ArAlk_2As+ZnX_2$
(2) $2AlkMgI+ArAsX_2 = ArAlk_2As+MgI_2+MgX_2$
(3) $ArMgBr+Alk_2AsI = ArAlk_2As+MgBrI$

Type $ArAr'AlkAs$.

(1) $Ar.MgX+Ar.Alk.AsX = Ar.Ar.'Alk.As+MgX_2$
(2) $2ArAr'AsX+ZnAlk_2 = 2ArAr'AlkAs+ZnX_2$
(3) $C_6H_5.CH_3.AsCl+C_7H_8+[AlCl_3]=C_6H_5.C_7H_7.CH_3As+HCl+[AlCl_3]$

Type $ArAlkAlk'As$.

(1) $ArAlkAsI+Alk'MgBr = ArAlkAlk'As+MgBrI$
(2) $AlkAlk'AsI+ArMgBr = ArAlkAlk'As+MgBrI$
(3) $2ArAlkAsBr+ZnAlk_2' = 2ArAlkAlk'As+ZnBr_2$

All the tertiary arsines of the types Ar_3As and $ArAr_2'As$ are solids, which form addition products with mercuric chloride of the type $R_3As.HgCl_2$, and many of them combine with platinic chloride in alcohol

solution to give well-defined, crystalline products of the type $Ar_3As.H_2PtCl_6$. These two types of addition products may be used for identifying the various arsines. Addition of halogens in carbon tetrachloride or ether solution to these tertiary arsines in the same solvents, produces pentavalent arsenicals of the type R_3AsX_2 (X=halogen). Alkyl iodides react with the arsines to form quaternary arsonium compounds of the type R_4AsI. The introduction of an alkyl radical into a tertiary arsine, forming the type Ar_2AlkAs (where the two aryl groups are the same), appears practically to destroy this property of forming additive products. When, however, two similar alkyl groups are present, as in $ArAlk_2As$, addition compounds are readily formed, *e.g.* phenyldimethylarsine, under suitable conditions, combines with derivatives of the type $RAsX_2$ (where R may be an aliphatic or aromatic radical), and also with the iodides of phosphorus, arsenic, antimony, and tin. Arsines of the type ArAlkAlk'As also exhibit a capacity for forming additive compounds with the type of derivative $RAsX_2$, as already mentioned.

Compounds containing nitro or amino groups substituted in the benzene nucleus, *e.g. tri-3-nitrotriphenylarsine*, are obtained by reducing the corresponding oxides. When the latter nitro-oxides are reduced by alcoholic phosphorous acid, *nitro-arsines* result, but reduction with tin and hydrochloric acid takes the process a stage further, forming *amino-arsines*. The only exception to this is *hexamethyltriaminotriphenylarsine*, which is formed by the interaction of dimethylaniline and arsenic trichloride.

Triphenylarsine, $(C_6H_5)_3As$.—Owing to the introduction of aromatic arsenical compounds into gas warfare, and the fact that this particular arsine can be used as a starting-point for preparing other useful products, considerable attention has been given to its methods of production. The first convenient method of preparation consisted in treating an ether solution of arsenic trichloride with bromobenzene and sodium.[1] Chlorobenzene has also been used, and dry ethyl acetate added in small quantity to induce the commencement of the reaction.[2] The two most recent methods adopted are as follows :—

(1)[3] The sodium (in the form of slices, granules, powder, or wire) is weighed out into the reaction flask and covered with benzene containing 1 or 2 per cent. of ethyl acetate, and the mixture allowed to stand for about an hour. Arsenious chloride and chlorobenzene are then slowly added, and although the reaction may become vigorous and require controlling with a freezing mixture, care should be taken that it does not become checked. In the latter case it is often difficult to start it again. After standing overnight, the mixture is filtered, the residue extracted with hot benzene and the filtrate and washings evaporated until a thermometer placed in the liquid registers 200° C. On cooling, the residue solidifies, and is almost pure triphenylarsine. The best results are obtained in this preparation when 300 c.c. of benzene are used for each 136 grams of chlorobenzene, 85 grams of arsenious chloride, and 57 grams of sodium.

(2) The preparation in this case[4] is carried out in a specially designed apparatus, the reaction vessel being made of steel, and the sodium

[1] Michaelis and Reese, *Ber.*, 1882, 15, 2876; Michaelis, *Annalen*, 1902, 321, 160.
[2] Philips, *Ber.*, 1886, 19, 1031; Michaelis and Loesner, *ibid.*, 1894, 27, 264.
[3] Pope and Turner, *Trans. Chem. Soc.*, 1920, 117, 1447.
[4] Morgan and Vining, *ibid.*, 1920, 117, 777.

introduced in a molten state. From an experiment, using 276 grams of arsenious chloride, 510 grams of chlorobenzene, and 210 grams of sodium in 1200 c.c. of xylene, a yield of 383 grams or 82 per cent. of triphenylarsine were obtained.

It has also been shown that the Friedel-Craft reaction is available for the preparation of primary, secondary, and tertiary arsines :[1]

To a boiling solution of 181 grams (1 mol.) of arsenic trichloride in 1000 grams of benzene, 335 grams (2·5 mols.) of aluminium trichloride are added over a period of three hours in 13 gram quantities, the whole being vigorously stirred. Hydrogen chloride is evolved, and the mixture is boiled for twelve hours. On cooling, two layers separate, the lower one containing an aluminium chloride double compound. The whole is shaken with ice and concentrated hydrochloric acid, the benzene layer removed, dried over calcium chloride, and the solvent distilled off. The brown oil remaining is fractionated at 12 mm., three fractions being collected : (1) B.pt. 160° to 175° C., (2) B.pt. 180° to 205° C., (3) B.pt. 210° to 230° C. (chiefly 218° to 225° C.). Fraction (3) is almost pure triphenylarsine, fractions (1) and (2) containing phenyldichloroarsine and diphenylchloroarsine. In a well carried out preparation the yields are 30 grams of primary, 6 grams of secondary, and 85 grams of tertiary arsine.

Triphenylarsine has also been prepared by the Grignard reaction.[2] More recently it has been shown that arsenious chloride can be replaced with advantage by the iodide, this method being useful when small quantities are required.[3] To the Grignard reagent from 4 grams of magnesium and 26 grams of bromobenzene in 50 c.c. of ether, 22 grams of powdered arsenious iodide are slowly added. When the reaction subsides, it is completed by boiling the mixture for thirty minutes. The mass is then decomposed and extracted in the usual manner, any volatile products being removed from the residue by heating to 200° C. at 12 mm. pressure. The product thus obtained is practically pure triphenylarsine.

Four other methods of less importance are also available for isolating triphenylarsine :

(1) By working up the residues in the preparation of diphenylchloroarsine from mercury diphenyl and phenyldichloroarsine.[4]

(2) Phenylarsenoxide is subjected to prolonged heating at 180° to 200° C., when it decomposes according to the equation :

$$3C_6H_5AsO = (C_6H_5)_3As + As_2O_3$$

(3) The Grignard solution from 15·7 grams of bromobenzene and 2·4 grams of magnesium in 30 c.c. of ether is treated with 4·9 grams of powdered arsenious oxide and the mixture heated on the water-bath for three hours. The product is then steam distilled to remove diphenyl, and extraction of the residue with ether should give 2·7 grams of triphenylarsine.[5]

(4) A rather curious method of obtaining triphenylarsine consists in the reduction of diphenylarsinic acid with phenylhydrazine ; 11

[1] Wieland, *Annalen*, 1923, 431, 30.
[2] Pfeiffer, *Ber.*, 1904, 37, 4620.
[3] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1382.
[4] La Coste and Michaelis, *Ber.*, 1878, 11, 1887.
[5] Sachs and Kantorowicz, *ibid.*, 1908, 41, 2767.

grams of the hydrazine are warmed on the water-bath, and 26 grams of diphenylarsinic acid slowly added. Nitrogen is evolved and, after the addition is complete, the melt is heated for a few minutes in an oil-bath at 150° C. Triphenylarsine crystallises out on cooling in about 60 per cent. yield theoretical.[1] The course of the reaction is indicated as follows :

$$(C_6H_5)_2AsO.OH+H_2N.NH.C_6H_5=(C_6H_5)_2As.OH+C_6H_6+N_2+H_2O$$
$$(C_6H_5)_2As.OH+H_2N.NH.C_6H_5=(C_6H_5)_2As.NH.NH.C_6H_5+H_2O$$
$$(C_6H_5)_2As.NH.NH.C_6H_5+(C_6H_5)_2AsO.OH$$
$$=(C_6H_5)_2As.N:N.C_6H_5+(C_6H_5)_2As.OH$$
$$(C_6H_5)_2As.N:N.C_6H_5=(C_6H_5)_2As.C_6H_5+N_2$$

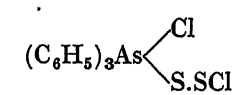
Triphenylarsine crystallises in colourless, triclinic plates, M.pt. 58° to 60·5° C., B.pt. above 360° C. in a carbon dioxide atmosphere ; density, 1·306. It is soluble in ether and benzene, sparingly soluble in cold alcohol, and insoluble in water, concentrated hydrochloric, and hydriodic acids. It combines with mercuric chloride to form a *mercurichloride*, $(C_6H_5)_3As.HgCl_2$, crystallising in leaflets, fairly soluble in alcohol. This compound is unchanged by cold potassium hydroxide, but on boiling, the following reaction takes place :—

$$(C_6H_5)_3As.HgCl_2+2KOH=(C_6H_5)_3As(OH)_2+2KCl+Hg$$

If alcoholic potassium hydroxide is used, the reaction takes the following course on warming [2] :—

$$(C_6H_5)_3As.HgCl_2+2KOH=(C_6H_5)_3As+HgO+2KCl+H_2O$$

The mercurichloride is also decomposed by hydrogen sulphide, yielding triphenylarsine, mercuric sulphide, and hydrochloric acid. Platinic chloride and triphenylarsine combine in alcoholic solution to give the *platinichloride*, $(C_6H_5)_3As.H_2PtCl_6$, consisting of pale yellow leaflets, M.pt. 285° C., soluble in hot alcohol or chloroform, sparingly soluble in hydrochloric acid. Triphenylarsine does not react with phosphorus trichloride, either in cold ether or in the absence of solvent at 78° C.[3] With 4 molecules of trichloride in a sealed tube at 160° C., some diphenylchloroarsine is produced. Antimony trichloride only appears to react slightly with the arsine, some phenyldichloroarsine resulting, whilst silicon tetrachloride does not react with it. The arsine reacts with sulphur monochloride to give an addition compound : [4]

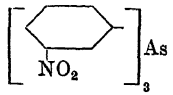


The reaction must be carried out in an indifferent solvent. This compound forms yellowish-white crystals, M.pt. 200° C., is readily soluble in carbon disulphide, chloroform, and absolute alcohol, sparingly soluble in petroleum ether or benzene and insoluble in ordinary ether. With water it yields triphenylarsine oxide, and with hydrogen sulphide or ammonium pentasulphide gives triphenylarsine sulphide. Studies of

[1] Wieland, *Annalen*, 1923, 431, 30.
[2] La Coste and Michaelis, *ibid.*, 1880, 201, 184.
[3] Challenger and Pritchard, *Trans. Chem. Soc.*, 1924, 125, 864.
[4] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2479.

the absorption spectra of chloroform solutions of triphenylarsine indicate that no bands are shown at any dilution.[1]

Tri-3-nitrotriphenylarsine,[2]

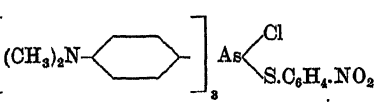


The corresponding oxide is boiled in alcoholic solution with phosphorous acid and the whole poured into water, when the arsine is obtained as a yellow, crystalline powder, M.pt. 250° C. In a similar manner, *trinitrotrichlorotriphenylarsine* is prepared, a white powder, M.pt. 252° C., soluble in alcohol, chloroform, and acetic acid. These compounds combine with halogens in the usual way.

Tri-3-aminotriphenylarsine, $(NH_2.C_6H_4)_3As$,[3] is formed by the reduction of tri-3-nitrotriphenylarsine oxide in glacial acetic acid with tin and hydrochloric acid, 20 grams of the nitro-compound yielding 9 grams of amine. It melts at 176° C., soon becomes grey in air, and is insoluble in water. It forms a *hydrochloride*, *platinichloride*, and an *acid sulphate*. The *triacetyl derivative*, obtained by boiling the amine with acetic anhydride, forms white needles, M.pt. 233° C., sparingly soluble in alcohol, and the *tribenzoyl derivative* is a crystalline powder, M.pt. 271° C., insoluble in the usual organic solvents. Phenols have not been prepared from the amine by the diazo-reaction; bromine water gives $(C_6HBr_3.NH_2)_3As(OH)_2$.

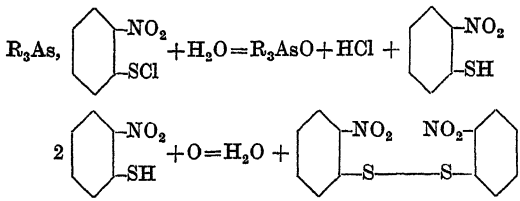
Hydrogen sulphide passed into an acetic acid solution of trinitrotriphenylarsine gives a *partially reduced product*, $(C_6H_4.NO_2)_2As(C_6H_4NH_2)$, which is slightly basic, and melts at 205° C.

Hexamethyltri-4-aminotriphenylarsine, $[C_6H_4.N(CH_3)_2]_3As$.[4]—Dimethylaniline (15 grams) and 25 grams of arsenic trichloride are mixed in the cold, the syrup dissolved in water by stirring, the solution filtered and treated with concentrated sodium hydroxide. The arsine is precipitated as a white, caseous mass, which is filtered, washed, dried, and dissolved in chloroform. The arsine is then precipitated by the addition of alcohol, and crystallises from the latter in long, white needles, M.pt. 240° C., very soluble in chloroform and dilute acids, sparingly soluble in alcohol. It may be precipitated unchanged from its solution in acids by the addition of alkali. In carbon disulphide solution the arsine reacts with sulphur monochloride on prolonged heating on the water-bath, yielding an addition product, $[(CH_3)_2N.C_6H_4]_3AsCl.S.S.Cl$.[5] This crystalline product melts at 137° to 141° C., is readily soluble in chloroform, sparingly soluble in carbon disulphide and ether. It is decomposed by dilute hydrochloric acid, giving the arsine oxide and sulphur. If the sulphur monochloride is replaced by *o*-nitrophenylsulphur chloride, the additive compound has the constitution :



[1] Purvis and M'Clelland, *Trans. Chem. Soc.*, 1912, 101, 1514.
[2] Michaelis, *Annalen*, 1902, 321, 180.
[3] Michaelis, *ibid.*, p. 183; Phillips, *Ber.*, 1886, 19, 1031.
[4] Michaelis and Rabinerson, *Annalen*, 1892, 270, 139.
[5] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2479.

This product melts with decomposition at 201° C., dissolves readily in carbon disulphide and chloroform, but is sparingly soluble in benzene, ether, and alcohol. Water or alkalis cause immediate decomposition of the compound according to the equations :



Tri-o-tolylarsine, $(CH_3.C_6H_4)_3As$.[1]—To the Grignard reagent from 26 grams of *o*-bromotoluene, 3·7 grams of magnesium and 80 c.c. of ether, 22·8 grams of arsenious iodide are gradually added, and the reaction finally completed by heating. When the product is worked up in the usual manner about 10 grams of the arsine are obtained, which crystallise from alcohol in colourless needles, M.pt. 98° C.

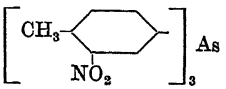
Tri-m-tolylarsine [2] is obtained by the interaction of 50 grams of *m*-bromotoluene, 18 grams of arsenious chloride, and 30 grams of sodium in 300 grams of anhydrous ether. Only two-thirds of the sodium are added at first, the remainder when the action slackens. The mixture is filtered, the ether distilled off, and the residue recrystallised from alcohol. It may also be obtained by the Grignard reaction.[3] The Grignard reagent from 23·9 grams of *m*-bromotoluene and 3·36 grams of magnesium is slowly treated with 7·2 grams of arsenic trichloride in 72 c.c. of dry benzene, and the mixture heated under reflux for about two hours. The solvent is then removed, the residue distilled in steam to remove by-products, and the arsine recrystallised from alcohol, the yield being 55 per cent. It crystallises in leaflets from alcohol, and rhombic crystals from ether, M.pt. 96° C., density 1·31 at 18° C. In benzene, alcohol, ether, and acetic acid it is readily soluble, but is only sparingly soluble in ligroin. Its *mercurichloride* melts at 174° C., is soluble in acetic acid, but less so in alcohol. This arsine, in contrast to others of the same type, very readily combines with alkyl iodides in the cold.

Tri-p-tolylarsine is derived by methods similar to those used for the corresponding phenyl compound : (1) By heating *p*-tolylarsenoxide in a sealed tube at 300° C. and extracting the resulting product with ether.[4] (2) The Grignard reagent from 9 grams of *p*-bromotoluene, when treated with arsenious oxide in ether solution, yields 1·6 grams of the arsine.[5] (3) *p*-Bromotoluene, 100 grams, 45 grams of arsenious chloride, and 40 grams of sodium in 500 c.c. of ether react to give about 49 grams (69 to 70 per cent. theoretical) of tri-*p*-tolylarsine.[6] Tri-*p*-tolylarsine crystallises in rhombic crystals, M.pt. 146° C., readily soluble in chloroform and carbon disulphide, less soluble in ether and acetic acid, and sparingly soluble in hot alcohol. Its *mercurichloride* is a

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1382.
[2] Michaelis, *Annalen*, 1902, 321, 216.
[3] Challenger and Pritchard, *Trans. Chem. Soc.*, 1924, 125, 864.
[4] La Coste, *Annalen*, 1881, 208, 26.
[5] Sachs and Kantorowicz, *Ber.*, 1908, 41, 2767.
[6] Michaelis, *Annalen*, 1902, 321, 201.

white, crystalline powder, M.pt. 246° C., sparingly soluble in hot acetic acid.

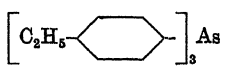
Tri-3-nitrotri-p-tolylarsine,[1]



is obtained in a similar way to the corresponding phenyl compound. It crystallises in colourless needles, M.pt. 201° C., soluble in hot alcohol and chloroform. It combines with chlorine, forming trinitrotrichloro-tri-*p*-tolylarsine dichloride (see p. 126).

Tri-3-amino-tri-p-tolylarsine, formed from the nitro-oxide by reduction with tin and hydrochloric acid, crystallises in prisms, M.pt. 198° C. It yields a *hydrochloride*, crystallising in fine, colourless needles, and a crystalline *acid sulphate*. The *triacetyl derivative* melts at 228° C., and a *tribenzyl derivative* ($CH_3.C_6H_3.NH.CH_2.C_6H_5)_3As$ is formed by heating the amino-arsine with benzyl chloride (3 mols.), but has only been isolated in the form of its *hydrochloride*. The amino-arsine also condenses with benzaldehyde and with diazobenzene chloride.

Tri-p-ethylphenylarsine,[2]



This is prepared similarly to tri-*p*-tolylarsine, the *p*-bromotoluene being replaced by *p*-bromo-ethyl benzene. It melts at 78° C., is readily soluble in ether, sparingly soluble in alcohol, and its *mercurichloride* melts at 132° C.

Tri-p-anisylarsine, $(CH_3O.C_6H_4)_3As$,[3] obtained from *p*-bromo-anisole, using the Fittig reaction, crystallises from alcohol-benzene in colourless, transparent, cubical crystals, M.pt. 156° C.

Tri-p-phenetylarsine, $(C_2H_5O.C_6H_4)_3As$, melts at 88° to 89° C., and is only obtained in poor yield by the Fittig method.

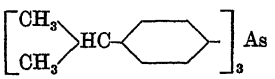
Tribenzylarsine, $(CH_2.C_6H_5)_3As$.[4]—Benzyl chloride (100 grams), 72 grams of arsenious chloride, 50 grams of sodium, and 5 c.c. of anhydrous ethyl acetate in 500 c.c. of ether are allowed to react. When the reaction slows down, a further 3 c.c. of ethyl acetate are added and the whole allowed to stand for about twenty hours. The ether is then removed and the residue mixed with alcohol, when tribenzylarsine and some dibenzylarsine dihydroxychloride, $(C_6H_5.CH_2)_2As(OH)_2Cl$, separate, leaving in solution the remainder of the latter product together with tribenzylarsine hydroxychloride, $(C_6H_5.CH_2)_3As(OH)Cl$. The precipitate is dissolved in boiling alcoholic ammonia and the solution cooled, when ammonium dibenzylarsinate remains in solution, whilst tribenzylarsine crystallises on cooling. From this method of preparation, 15 to 20 grams of tribenzylarsine, 10 grams of dibenzylarsinic acid, and 5 to 7 grams of tribenzylarsine oxide can be obtained.

Tribenzylarsine crystallises in long, colourless needles, M.pt. 104° C., readily soluble in hot alcohol or ether, sparingly soluble in cold alcohol.

[1] Michaelis, *Annalen*, 1902, **321**, 211.
[2] Michaelis, *ibid.*, 1902, **321**, 226.
[3] Michaelis and Weitz, *Ber.*, 1887, **20**, 49.
[4] Michaelis and Paetow, *ibid.*, 1885, **18**, 41; Paetow, *Inaug. Dissert.*, Rostock, 1885.

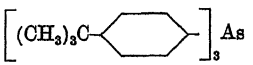
Its *mercurichloride* crystallises from boiling alcohol in white needles, M.pt. 159° C.

Tri-p-cumylarsine,[1]



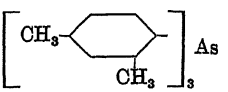
p-Bromocumene (40 grams), arsenious chloride (12 grams), and 30 grams of sodium are condensed in 300 c.c. of anhydrous ether. The arsine crystallises in prisms, M.pt. 139° to 140° C., easily soluble in ether, chloroform, and hot alcohol, sparingly soluble in cold alcohol. Its *mercurichloride* forms white needles, M.pt. 243° C.

Tri-tert.-butylphenylarsine,[2]



This arsine is prepared by the Fittig reaction, using bromo-*tert.*-butylbenzene, arsenious chloride, and sodium, heated together in ether solution. It melts at 235° C., is readily soluble in benzene, chloroform, and carbon tetrachloride, but sparingly soluble in alcohol and ether.

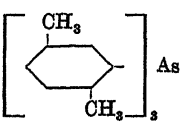
Tri-m-xylylarsine,[3]



A quantitative yield of this arsine is obtained by the interaction of 61 grams of bromo-*m*-xylene, 20 grams of arsenious chloride, and 30 grams of sodium, the reaction, when once started, going to completion without external heating. A more recent method of preparation is as follows: To the solution from 3·62 grams of magnesium and 27·9 grams of bromo-*m*-xylene in 50 c.c. of ether, 9 grams of arsenious chloride in 30 c.c. of light petroleum are gradually added. The reaction is very violent, and a greyish-green gelatinous precipitate separates out, which becomes white on standing. After several hours the mass is decomposed by water and extracted with ether, from which solution drying and evaporating gives fine, white needles. Yield, 8 grams.

Tri-*m*-xylylarsine melts at 166° C., is readily soluble in ether, petroleum, and benzene, less soluble in alcohol. When treated with thallic chloride it yields thallous chloride and *m*-xylylchloroarsine.[4] The *mercurichloride*, $(C_8H_9)_3As.HgCl_2$, melts at 257° C., is readily soluble in acetic acid, sparingly soluble in alcohol.

Tri-p-xylylarsine,[5]

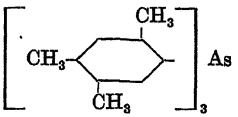


This is prepared in a similar way to the preceding compound. It crystallises in glistening, white prisms, M.pt. 157° C., soluble in ether,

[1] Michaelis, *Annalen*, 1902, 321, 235.
[2] Michaelis, *ibid.*, p. 238.
[3] Michaelis, *ibid.*, p. 220; Goddard, *Trans. Chem. Soc.*, 1923, 123, 1170.
[4] Goddard, *ibid.*
[5] Michaelis, *loc. cit.*; Goddard, *loc. cit.*

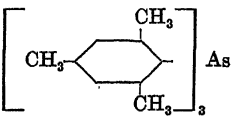
chloroform, and benzene, sparingly soluble in alcohol and petroleum. Its *mercurichloride* melts at 236° C. It is decomposed by thallic chloride in a similar manner to the *meta* compound.

Tripseudocumylarsine,[1]



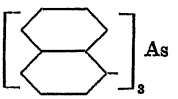
Bromo*pseudo*cumene (50 grams), 16 grams of arsenious chloride, and 21 grams of sodium in 250 c.c. of ether are heated for a prolonged period after the initial reaction ceases. The product, when worked up in the usual manner, crystallises in snow-white needles, M.pt. 223° C., very soluble in warm benzene, sparingly soluble in alcohol and light petroleum, insoluble in ether.

Trimesitylarsine,[2]



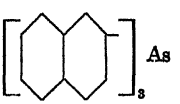
The method of preparation is similar to that of the preceding compounds, 30 grams of bromomesitylene, 9 grams of arsenious chloride, and 20 grams of sodium in dry ether being heated under reflux. It crystallises from alcohol in prismatic needles, M.pt. 170° C., readily soluble in ether, chloroform, and light petroleum, less soluble in alcohol and acetic acid.

Tri-α-naphthylarsine,[3]



A mixture of 51 grams of α-bromonaphthalene, 15 grams of arsenious chloride, and 20 grams of sodium in dry ether, after standing for twenty-four hours, are heated at 100° C. for about twenty hours. The ether is then removed and the residue dissolved in hot benzene, from which the arsine is precipitated by the addition of alcohol. Yield, 20 per cent. It is also obtained when arsenious chloride is added to magnesium α-naphthyl bromide in ether solution.[4] The arsine crystallises in rhombic plates, M.pt. 252° C., soluble in carbon disulphide and benzene, sparingly soluble in chloroform, ether, and alcohol, insoluble in light petroleum. It does not form a mercurichloride, but with *sulphur monochloride* forms an *addition product*, melting with decomposition at 175° C.[5]

Tri-β-naphthylarsine,



results when β-bromonaphthalene replaces the α-bromonaphthalene in the foregoing preparation. It gives colourless crystals, M.pt. 165° C.,

[1] Michaelis, *Annalen*, 1902, 321, 227. [2] Michaelis, *ibid.*, p. 238.

[3] Michaelis, *ibid.*, p. 242.

[4] Matsumiya, *Mem. Coll. Sci., Kyoto*, 1920, 4, 217. If the Grignard reagent is added to the arsenious chloride, the resulting product is di-α-naphthylchloroarsine.

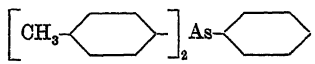
[5] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2479.

soluble in benzene, carbon disulphide, and chloroform, less soluble in alcohol and glacial acetic acid. It forms a *mercurichloride*, consisting of fine plates, M.pt. 247° C.

Tricyclohexylarsine, $(C_6H_{11})_3As$.[1]—The interaction of the Grignard reagent from 118·5 grams of *cyclo*hexylchloride, 24·3 grams of magnesium, and 100 grams of ether, with 35 grams of arsenic trichloride in 50 grams of ether, gives about 45 grams (72 per cent.) of tri*cyclo*hexylarsine. It boils at 208° to 215° C. at 11 mm., and has a solidifying point of 41° to 40° C.

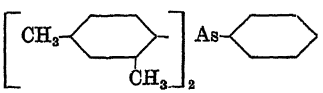
Compounds of the Type $ArAr_2'As$.

Phenyldi-p-tolylarsine,[2]



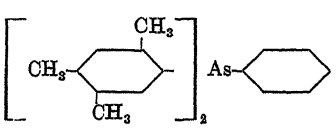
This occurs when phenyldichloroarsine (20 grams), *p*-bromotoluene (31 grams), and sodium (17 grams) react in 200 c.c. of dry ether. It forms colourless, rhombic crystals, M.pt. 101° C., easily soluble in ether, chloroform, benzene, or hot alcohol, less soluble in cold alcohol and acetic acid. Its *mercurichloride* is a white, crystalline solid, M.pt. 210° C., and the *platinichloride* is a yellow, crystalline product from alcoholic hydrochloric acid, M.pt. 256° C.

Phenyldi-m-xylylarsine,[3]



Phenyldichloroarsine (46 grams), 77 grams of bromo-*m*-xylene, and 38 grams of sodium in 400 c.c. of ether yield 45 grams (60 per cent.) of this arsine. It crystallises in triclinic crystals, M.pt. 99° C., readily soluble in most organic solvents, sparingly soluble in cold alcohol. Its *mercurichloride*, $C_6H_5.As(C_8H_9)_2$, $HgCl$, forms fine, glistening needles, M.pt. 224° C.; the *platinichloride*, $C_6H_5.As(C_8H_9)_2$, H_2PtCl_6, forms yellow needles, M.pt. above 300° C.

Phenyldipseudocumylarsine,[4]



This arsine is not so easily prepared as the preceding compounds, and it is necessary to heat 30 grams of phenyldichloroarsine, 53·5 grams of bromo*pseudo*cumene, and 30 grams of sodium in 300 c.c. of dry ether for forty-five hours to complete the reaction. The yield is 35 grams, or 70 per cent. It melts at 138·5° C. and has a similar solubility to the preceding compound. The *mercurichloride* crystallises in glistening plates from acetic acid, M.pt. 233° C., readily soluble in chloroform; the

[1] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911; compare Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.

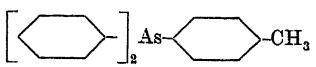
[2] Michaelis, *Annalen*, 1902, 321, 192.

[3] *Ibid.*, p. 223.

[4] *Ibid.*, p. 227.

platinichloride forms yellow rosettes, M.pt. 287° C.; the *aurichloride* has the composition $C_6H_5.As(C_9H_{11})_2.HAuCl_4$, M.pt. 177° C.

Diphenyl-p-tolylarsine,[1]



This is formed by the interaction of 30 grams of *p*-tolyldichloroarsine, 42 grams of bromobenzene, and 24 grams of sodium in 500 c.c. of ether, the reaction commencing spontaneously, and being completed by heating for three days. From alcohol the arsine is deposited in colourless crystals, M.pt. 50° C.; the *mercurichloride* crystallises from glacial acetic acid with M.pt. 147° C., and the *platinichloride* is a yellow precipitate, M.pt. 233° C.

Dicyclohexylphenylarsine, $(C_6H_{11})_2As.C_6H_5$,[2] is obtained in about 54 per cent. yield from magnesium *cyclo*hexylbromide and phenyldichloroarsine, but in 93 per cent. yield if magnesium *cyclo*hexyl chloride is used.

Treatment with chlorine eliminates a *cyclo*hexyl group, forming *cyclo*hexylphenylchloroarsine.

Compounds of the Type Ar_2AlkAs.

Diphenylmethylarsine, $(C_6H_5)_2As.CH_3$.—This is prepared either by the action of zinc dimethyl on diphenylchloroarsine,[3] or, better, as follows:[4] Methyldi-iodoarsine (34 grams) is gradually added to the reaction product from 34·6 grams of bromobenzene, 5·4 grams of magnesium, and 80 c.c. of ether. The product is worked up in the usual manner and 17·5 grams of the arsine can be obtained.

A third method consists in gently heating 15 grams of phenylmethylchloroarsine, 60 grams of benzene, and 10 grams of aluminium chloride for two hours. Hydrogen chloride is evolved, and the product is decomposed by ice and dilute hydrochloric acid; 7 grams of pure diphenylmethylarsine may be produced.[5]

Diphenylmethylarsine is a colourless, highly refractive oil, B.pt. 306° C., 163° to 170° C. at 15 mm.; it has a pungent, fruity odour, is soluble in alcohol and benzene, insoluble in water. It only possesses to a slight degree the property of forming additive compounds.

p-Bromodiphenylmethylarsine, $(C_6H_4.Br)(C_6H_5)As.CH_3$.[6]—Twenty grams of phenylmethylchloroarsine, 60 grams of bromobenzene, and 20 grams of aluminium chloride are boiled under diminished pressure (bath at about 35° C.) for an hour. The product is cooled, poured into ice and hydrochloric acid, then worked up in the usual manner. From the reaction mixture 5 grams of the required arsine may be isolated, B.pt. 170° to 200° C. at 15 mm. It also results when magnesium phenyl bromide reacts with *p*-bromophenylmethyliodoarsine, the yield being about 60 per cent.

[1] Michaelis, *Annalen*, 1902, 321, 187; Lauterwald, *Inaug. Dissert.*, Rostock, 1897.
[2] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911; compare Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[3] Michaelis and Link, *Annalen*, 1881, 207, 199.
[4] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1381.
[5] Burrows and Turner, *ibid.*, 1921, 119, 430.
[6] Hunt and Turner, *ibid.*, 1925, 127, 2669.

o-Carboxydiphenylmethylarsine, $CO_2H.C_6H_4.As(C_6H_5)CH_3$.[1] — The Grignard solution from 30 grams of bromobenzene is added to 42 grams of *o*-carboxyphenylmethylarsinous anhydride in benzene during thirty minutes, and the mixture heated for four hours. The solvent is removed, the residue decomposed by dilute acid, the aqueous layer drawn off, and the pasty residue recrystallised from alcohol. The yield should be about 20 grams; M.pt. 168° C.

Diphenylethylarsine, $(C_6H_5)_2As.C_2H_5$.—This is obtained in 80 per cent. yield when 33 grams of diphenylchloroarsine in 50 c.c. of ether react with the Grignard solution from 15 grams of ethyl bromide.[2] It also results when zinc diethyl reacts with diphenylchloroarsine.[3] It is a colourless liquid, B.pt. 320° C., or 162° to 163° C. at 10 mm.

Di-o-tolylmethylarsine, $(C_7H_7)_2As.CH_3$,[4] is isolated by the interaction of the Grignard reagent derived from *o*-bromotoluene with methyldi-iodoarsine. It melts at 42° C., giving a very pale, yellow oil, B.pt. 178° to 182° C. at 12 mm.

Di-α-naphthylmethylarsine, $(C_{10}H_7)_2As.CH_3$,[5] is a solid, M.pt. 145° to 146° C.

Compounds of the Type ArAr'AlkAs.

Phenyl-p-tolylmethylarsine, $C_6H_5(C_7H_7)As.CH_3$.[6]—This compound has been prepared by two methods:

(1) The Grignard reagent from 24 grams of *p*-iodotoluene, 2·6 grams of magnesium, and 100 c.c. of ether is slowly treated with 20·4 grams of phenylmethylchloroarsine in 20 c.c of ether, and the reaction product worked up in the usual manner. The yield is 18 grams, or 76 per cent.

(2) By heating under reflux for two and a half hours a mixture of 15 grams of phenylmethylchloroarsine, 60 grams of toluene, and 15 grams of powdered, anhydrous aluminium chloride.

Phenyl-*p*-tolylmethylarsine is a liquid, B.pt. 164° to 165° C. at 12 mm., having an unpleasant, fishy odour, and slowly oxidising on keeping. It forms a white *mercurichloride*, which may be crystallised from glacial acetic acid.

Phenyl-p-tolylethylarsine, $C_6H_5.(C_6H_4.CH_3).As.C_2H_5$,[7] is the product of interaction of zinc diethyl and phenyl-*p*-tolylchloroarsine. It is a colourless oil, B.pt. 210° to 225° C. at 50 mm.

Phenylbenzylmethylarsine, $C_6H_5.(C_6H_5.CH_2).As.CH_3$.[8]—Obtained from phenylmethylchloroarsine and magnesium benzyl chloride, boils at 74° to 1177° C.

Phenylmesitylmethylarsine, $C_6H_5[(CH_3)_3C_6H_2]As.CH_3$.[9] — 15 grams of phenylmethylchloroarsine, 35 grams of mesitylene, and 15 grams of aluminium chloride are gently boiled under reflux at 75° to 80° C. at 45 mm. for several hours. When the evolution of hydrogen chloride slackens, the mixture is poured into ice and hydrochloric acid. The oil

[1] Aeschlimann, *Trans. Chem. Soc.*, 1925, 127, 811.
[2] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2597.
[3] Michaelis and Link, *loc. cit.*; La Coste and Michaelis, *Annalen*, 1880, 201, 184; *Ber.*, 1878, 11, 1883.
[4] Burrows and Turner, *loc. cit.*
[5] Matsumiya and Nakal, *Mem. Coll. Sci. Kyōtō*, 1925, 8, 307.
[6] Hunt and Turner, *Trans. Chem. Soc.*, 1925, 127, 2668.
[7] Michaelis, *Annalen*, 1902, 321, 155; Predari, *Inaug. Dissert.*, Rostock, 1894.
[8] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2597.
[9] Hunt and Turner, *loc. cit.*

thus obtained is extracted with benzene, filtered, shaken with alkali, and worked up in the usual manner, 7 grams (30 per cent. yield) of arsine resulting. It is a colourless, mobile liquid, B.pt. 164° C. at 17 mm., possessing a faint, fishy odour, and oxidising in the air to a white, crystalline solid.

Phenyl-α-naphthylmethylarsine, $C_6H_5(C_{10}H_7)As.CH_3$,[1] is prepared by the Grignard reaction, 117 grams of phenylmethyliodoarsine, 94 grams of α-bromonaphthalene, and 14 grams of magnesium in ether solution giving 102 grams of the arsine. It is a colourless, crystalline solid, M.pt. 58° C., B.pt. 236° to 238° C. at 17 mm., soluble in ether, best recrystallised from alcohol.

cycloHexylphenylmethylarsine, $C_6H_{11}.C_6H_5.As.CH_3$,[2] from magnesium *cyclo*hexyl chloride and phenylmethyliodoarsine, is a highly refractive oil, B.pt. 152° to 153° C. at 12 mm., and shows no marked tendency to oxidise.

Compounds of the Type $ArAlk_2As$.

Phenyldimethylarsine, $C_6H_5.As(CH_3)_2$.—This arsine may be prepared in several ways :

(1) By the interaction of zinc dimethyl and phenyldichloroarsine.[3]

(2) By the action of magnesium methyl iodide on phenyldichloroarsine in the presence of light petroleum.[4] Yield, 75 per cent. Magnesium methyl bromide may also be used in place of the iodide.[5]

(3) To the Grignard reagent from 19 grams of bromobenzene, 2·9 grams of magnesium, and 50 c.c. of ether, 23·2 grams of dimethyliodoarsine in 50 c.c. of ether are slowly added. After the addition, and standing for two hours, the mixture is decomposed by ice and dilute hydrochloric acid, and the ether layer removed and dried over anhydrous sodium sulphate. Removal of the solvent, and distillation under diminished pressure, give the arsine as an oil, B.pt. 85° C. at 14 mm., or 193° to 200° C. in a carbon dioxide atmosphere.[6]

This arsine gives rise to a number of *double compounds*, as follows : With *methyldi-iodoarsine*, $C_6H_5.As(CH_3)_2.CH_3.AsI_2$, lemon-yellow needles, M.pt. 93° to 94° C., the compound being dissociated into its components in benzene solution at concentrations up to 5 per cent.; with *ethyldi-iodoarsine*, $C_6H_5.As(CH_3)_2.C_2H_5.AsI_2$, a yellow solid, M.pt. 44° C.; with *phenyldi-iodoarsine*, $C_6H_5.As(CH_3)_2.C_6H_5.AsI_2$, orange prisms from acetone or alcohol, M.pt. 69° C.; and with *phenyldichloroarsine*, $C_6H_5.As(CH_3)_2.C_6H_5.AsCl_2$, colourless needles, M.pt. 36° C.

A number of *double compounds* may also be obtained between this arsine and *inorganic iodides*. When phenyldimethylarsine (1 mol.) is added to *phosphorus tri-iodide* (1 mol.) in carbon disulphide, heat is evolved, and orange prisms separate. These melt at about 140° C., readily absorb water,[7] and have the following constitution—$C_6H_5(CH_3)_2As.PI_3$. *Arsenious iodide* yields $C_6H_5(CH_3)_2As.AsI_3$, orange-red leaflets, M.pt. 153° C.; *antimony tri-iodide* gives $C_6H_5(CH_3)_2As.SbI_3$, orange

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 432.
[2] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[3] Michaelis and Link, *Annalen*, 1881, 207, 205.
[4] Winmill, *Trans. Chem. Soc.*, 1912, 101, 722.
[5] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[6] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1378.
[7] Burrows and Turner, *ibid.*, 1921, 119, 1448.

prisms, M.pt. 165° C.; *bismuth iodide* gives $C_6H_5(CH_3)_2As.BiI_3$, vermilion prisms, M.pt. 198° to 200° C.; *stannic iodide* gives $C_6H_5(CH_3)_2As.SnI_4$, chocolate-coloured leaflets, M.pt. 140° to 145° C.

Phenyldiethylarsine, $C_6H_5(C_2H_5)_2As$, may be obtained from zinc diethyl and phenyldichloroarsine in ether solution,[1] or in better yield by using light petroleum as solvent.[2] A more recent preparation is as follows:[3] The Grignard reagent from 26·2 grams of ethyl bromide, 5·8 grams of magnesium, and 40 c.c. of ether, is treated with 22·3 grams of phenyldichloroarsine in 100 c.c. of benzene, the mixture boiled for two hours, the ether slowly distilled off, and the residue decomposed with ice and sulphuric acid. The benzene layer is separated, dried, and distilled under reduced pressure, 12 grams of phenyldiethylarsine being obtained as a colourless oil, B.pt. 111° to 115° C. at 14 mm., a further 3 grams of less pure product distilling at 115° to 120° C. at 14 mm.

Phenyldiethylarsine is a colourless, highly refractive liquid, B.pt. 240° C., 111° to 115° C. at 14 mm. It forms a *double compound* with *methyldi-iodoarsine*, $C_6H_5.As(C_2H_5)_2.CH_3.AsI_2$, bright yellow needles from acetone or alcohol, M.pt. 78° to 79° C.

p-Tolyldimethylarsine, $(CH_3.C_6H_4)As(CH_3)_2$,[4] results when zinc dimethyl interacts with *p*-tolyldichloroarsine in dry ether. It is a colourless liquid, B.pt. 220° C. in a carbon dioxide atmosphere.

p-Tolyldiethylarsine is a colourless, strongly refracting, faintly fuming liquid, B.pt. 250° C.

Benzyldimethylarsine, $(C_6H_5.CH_2)As(CH_3)_2$,[5] is obtained by the interaction of benzyl magnesium chloride with one equivalent of dimethyliodoarsine, and working the mixture up in the usual manner. The clear ether solution is dried over sodium sulphate, removal of the solvent and fractionation giving a colourless liquid, B.pt. 110° C. at 8 mm., the yield being about 20 per cent.

α-Naphthyldimethylarsine, $C_{10}H_7.As(CH_3)_2$.[6]—To the Grignard reagent from 50 grams of α-bromonaphthalene, 5·34 grams of magnesium, and 200 c.c. of ether, 46·4 grams of dimethyliodoarsine are added slowly. The reaction is completed by an hour's heating, and the mixture decomposed and worked up in the usual manner. Yield, 37 grams. This arsine is a liquid, B.pt. 163° to 165° C. at 13 mm., and forms a *double compound* with methyldi-iodoarsine, $C_{10}H_7.(CH_3)_2As.CH_3AsI_2$, yellow needles, M.pt. 76° to 77° C.

Cyclohexyldi-n-propylarsine, $C_6H_{11}.As(C_3H_7)_2$.[7]—To an ice-cooled solution from 20 grams of *cyclo*hexyl chloride in 100 c.c. of ether and 4 grams of magnesium, 38 grams of di-*n*-propyliodoarsine (about 80 per cent. of theory) in 50 c.c. of ether are added dropwise. After heating for one hour on the water-bath, the mixture is decomposed with ice and hydrochloric acid and worked up in the usual manner. The arsine is a colourless liquid, B.pt. 126·5° to 129·5° C. at 12 mm., and the yield is about 24·7 grams (60 per cent.).

[1] Michaelis and La Coste, *Annalen*, 1880, 201, 212; see also Michaelis, *Ber.*, 1877, 10, 622.
[2] Winmill, *loc. cit.*
[3] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1378.
[4] Michaelis, *Annalen*, 1902, 320, 304; Klatt, *Inaug. Dissert.*, Rostock, 1893.
[5] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[6] Burrows and Turner, *loc. cit.*
[7] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.

Compounds of the Type ArAlkAlk'As.

Phenylmethylethylarsine, $C_6H_5(CH_3)As.C_2H_5$,[1] is obtained either from phenylmethyliodoarsine and magnesium ethyl bromide, or from methylethyliodoarsine and magnesium phenyl bromide. It is a colourless liquid, B.pt. 97° C. at 12 to 13 mm., or 93° to 99° C. at 11 mm., and forms a *double compound* with *methyldi-iodoarsine*, $C_6H_5.CH_3.As.C_2H_5.CH_3AsI_2$, crystallising from alcohol in yellow needles, M.pt. 84° C. Similarly with *phenyldi-iodoarsine* it gives a compound separating from alcohol in orange-yellow prisms, M.pt. 55° C. It yields a *cyanobromide* when treated with cyanogen bromide in ether solution.

Phenyl-β-phenylethylmethylarsine, $C_6H_5.[C_6H_5(CH_2)_2]CH_3.As$,[2] results when magnesium β-phenylethyl bromide and phenylmethyliodoarsine react in ether solution. The product is a colourless liquid, B.pt. 187° C. at 12 mm., or 190° C. at 15 mm., and the yield is about 82 per cent.

Phenylmethylallylarsine, $C_6H_5(CH_3)As.C_3H_5$,[3] results when magnesium powder is added to a mixture of phenylmethylbromoarsine and allyl iodide in dry ether. It is a colourless liquid, B.pt. 192° C. The scheme worked out for obtaining this arsine is shown by the following equations :

$$C_6H_5.AsCl_2+2CH_3.MgI=C_6H_5.As(CH_3)_2+2MgClI$$
$$C_6H_5.As(CH_3)_2+Br_2=C_6H_5.As(CH_3)_2Br_2$$
$$C_6H_5.As(CH_3)_2Br_2=C_6H_5.As(CH_3)Br+CH_3Br$$
$$C_6H_5.As(CH_3)Br+C_3H_5I+Mg=C_6H_5(CH_3)As.C_3H_5+MgBrI$$

Phenylmethyl-n-propylarsine, $C_6H_5(CH_3)As.C_3H_7$,[4] may be obtained from phenylmethylchloroarsine and magnesium *n*-propyl bromide. It boils at 105° to 106° C. at 12 mm. and forms a non-crystalline *cyanobromide*.

Phenyl-γ-phenylpropylmethylarsine, $C_6H_5.[C_6H_5(CH_2)_3].CH_3As$.[5]—The Grignard reagent from 63 grams of γ-bromopropylbenzene, 10 grams of magnesium, and 300 c.c. of ether is slowly treated with 88·3 grams of phenylmethyliodoarsine. The reaction mixture, worked up in the usual manner, gives 60 grams of arsine as a colourless liquid, B.pt. 208° C. at 17 mm.

Phenylethyl-n-propylarsine,[6] $C_6H_5(C_2H_5)As.C_3H_7$, is prepared by the following reactions :

$$(C_6H_5)_3As+2AsCl_3=3C_6H_5AsCl_2$$
$$C_6H_5AsCl_2+Zn(C_2H_5)_2=C_6H_5As(C_2H_5)_2+ZnCl_2$$
$$C_6H_5As(C_2H_5)_2+Br_2=C_6H_5As(C_2H_5)_2Br_2$$
$$C_6H_5As(C_2H_5)_2Br_2=C_6H_5(C_2H_5)AsBr+C_2H_5Br$$
$$2C_6H_5(C_2H_5)AsBr+Zn(C_3H_7)_2=2C_6H_5(C_2H_5)As.C_3H_7+ZnBr_2$$

The arsine is a colourless liquid, B.pt. 245° C., behaves as a feeble base, is insoluble in concentrated hydrochloric acid, and appears to oxidise slowly in air.

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1380; 1921, 119, 433; see also Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2597.
[2] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[3] Winmill, *Trans. Chem. Soc.*, 1912, 101, 718.
[4] Steinkopf, Donat, and Jaeger, *loc. cit.*
[5] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 426.
[6] Winmill, *loc. cit.*

p - Tolylmethylethylarsine, $(CH_3.C_6H_4)(CH_3)As.C_2H_5$.[1] — The addition of 100 grams of *p*-tolylmethyliodoarsine in 100 c.c. of dry benzene to the Grignard reagent from 31 c.c. of ethyl bromide and 10·4 grams of magnesium in 200 c.c. of ether, gives a yield of 50 grams of this arsine. It is a colourless oil, B.pt. 117° C. at 15 mm.

Compounds of the Type R_4AsX (Arsonium Compounds).

Under the general formula R_4AsX, the following ten types of compounds are included: Ar_4AsX, $Ar_3AlkAsX$, $Ar_2Ar'AlkAsX$, Ar_2Alk_2AsX, $Ar_2AlkAlk'AsX$, $ArAr'Alk_2AsX$, $ArAlk_3AsX$, $ArAr'AlkAlk'AsX$, $ArAlk_2Alk'AsI$, and $ArAlkAlk'Alk''AsX$. The *triarylalkylarsonium iodides* are all obtained by the direct combination of triarylarsines and alkyl iodides, but the ease of combination varies considerably, tri-*m*-tolylarsine and methyl iodide yielding an arsonium compound in the cold, whilst triphenylarsine and the same alkyl halide require prolonged heating to give a good yield of the quaternary derivative:

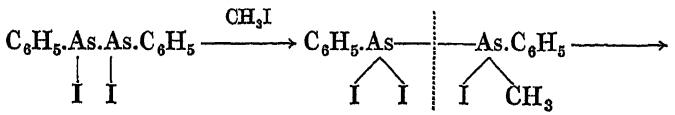
$$Ar_3As+AlkI=Ar_3AlkAsI$$

When the alkyl halide is replaced by methylene iodide or ethylene chlorhydrin, an *iodomethyl* or a *hydroxyethylarsonium compound*, respectively, results. Many arsonium iodides of the above types, and also some bromides, are obtained by the reaction depicted in the above equation.

It has already been shown, on p. 62, that primary arsines and alkyl halides also combine to produce *aryltrialkylarsonium iodides*:

$$ArAsH_2+3AlkX=ArAlk_3AsX+2HX$$

The following interesting series of reactions[2] shows the formation of *phenyltrimethylarsonium tri-iodide* from *sym*-diphenyldi-iododiarsine:

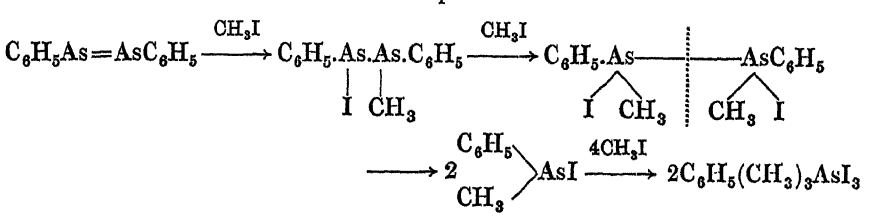


$$C_6H_5.AsI_2+C_6H_5.CH_3.AsI\xrightarrow{2CH_3I}C_6H_5(CH_3)_3AsI_3$$

The tri-iodide thus formed reacts with *sym*-diphenyldi-iodiodiarsine as follows:

$$C_6H_5.(CH_3)_3AsI_3+C_6H_5AsI.AsIC_6H_5=C_6H_5(CH_3)_3AsI+2C_6H_5AsI_2$$

Arsenobenzene may replace *sym*-diphenyldi-iodiodiarsine in the above, when the course of the reaction is represented thus:



[1] Mills and Raper, *Trans. Chem. Soc.*, 1925, 127, 2479.
[2] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1446.

The tri-iodide then reacts with arsenobenzene in a manner similar to that given for *sym*-diphenyldi-iododiarsine:

$$2C_6H_5(CH_3)_3AsI_3+C_6H_5As:AsC_6H_5=2C_6H_5(CH_3)_3AsI+2C_6H_5AsI_2$$

Quaternary arsonium halides may also be obtained from the corresponding hydroxides by treating the latter with halogen acids:

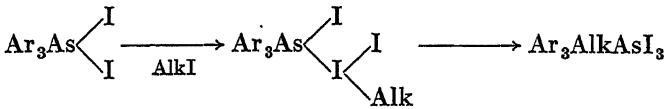
$$R_4As.OH+HX=R_4AsX+H_2O$$

Two methods have been given above for the preparation of *tri-iodides*, and the following are also available:

(*a*) Secondary monohalogenated arsines, cyano- or thiocyano-arsines are treated with alkyl iodides:

$$Ar_2AsI+2AlkI=Ar_2Alk_2AsI_3$$

(*b*) Tertiary arsine dihalides and alkyl iodides react as follows, this probably being an intermediate stage in the reaction shown above:



(*c*) Quaternary arsonium iodides under suitable conditions add on two atoms of halogen directly:

$$R_4AsI+X_2=R_4AsI.X_2$$

The quaternary iodides are crystalline compounds, form *platini-chlorides*, and with chlorine yield *iododichlorides* of the type $R_4AsI.Cl_2$. Some aliphatic-aromatic arsonium iodides combine with metallic salts such as *mercuric halides*, *auric chloride*, and *cadmium iodide*, whilst *iodoform* also forms addition compounds with some derivatives. Treatment of the iodides with a boiling suspension of silver chloride replaces the iodine by chlorine, giving R_4AsCl. The latter also results when hydrochloric acid is added to hydroxides of the type $R_4As.OH$. The hydroxides are derived from the iodides by boiling the latter with a suspension of silver oxide in water or alcohol. It is not always possible to isolate a crystalline product from this reaction, and the syrups often isolated soon absorb carbon dioxide from the air.

Triphenylmethylarsonium chloride [1] results when the iodide is boiled with a suspension of silver chloride in water, or when the hydroxide is neutralised by hydrochloric acid. It crystallises in needles, M.pt. 121° C., readily dissolving in alcohol and water. It forms a *platini-chloride*, consisting of yellowish-red needles, M.pt. 224° to 225° C.

Triphenylmethylarsonium bromide [2] forms colourless crystals, M.pt. 195° C., and yields an *additive compound* with *iodoform*, consisting of pale, brownish-yellow plates, M.pt. 124° C.

Triphenylmethylarsonium iodide, $(C_6H_5)_3As(CH_3)I$.—Triphenylarsine is heated for a long time with an excess of methyl iodide on the water-bath, when addition takes place. The arsonium compound crystallises in yellow plates, M.pt. 176° C., readily soluble in alcohol, less soluble in hot water, insoluble in ether. When treated with chlorine

[1] Michaelis, *Annalen*, 1902, 321, 166; Gimborn, *Inaug. Dissert.*, Rostock, 1891.
[2] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2969.

it yields an *iododichloride*, $(C_6H_5)_3As.CH_3.ICl_2$, M.pt. 144° C., readily dissolving in boiling alcohol, acetone, and acetic acid, insoluble in water and ether.

Triphenylmethylarsonium hydroxide.[1] — The hydroxide is formed when the iodide is digested with silver oxide in aqueous or alcoholic solution. It melts at 125° to 126° C., and prolonged heating at 100° C. converts it into triphenylarsine and methyl alcohol. Spontaneous evaporation in air yields the *hydrogen carbonate*, $(C_6H_5)_3As.HCO_3.H_2O$, which crystallises in transparent plates.

Triphenylmethylarsonium nitrate is prepared by the action of nitric acid on the hydroxide, a stellate mass resulting when the solution is evaporated.

Trinitrotriphenylmethylarsonium nitrate.—The above nitrate or chloride is added to a mixed acid containing 5 parts of concentrated sulphuric acid and 3 parts of fuming nitric acid. The solution is then poured into ice-cold water and the precipitate extracted with warm alcohol. From the resulting solution the trinitro-compound separates as a yellow powder, M.pt. 195° C., soluble in hot alcohol, chloroform, or acetic acid, insoluble in water.

Triphenylethylarsonium iodide, $(C_6H_5)_3As(C_2H_5)I$, results in small yield when triphenylarsine and ethyl iodide are heated under reflux on the water-bath. It crystallises in needles, M.pt. 158° C., readily soluble in alcohol, sparingly soluble in water. Its *platinichloride* melts at 221° C.

Triphenyliodomethylarsonium iodide, $(C_6H_5)_3As(CH_2I)I$. — 15 grams of triphenylarsine and 17 grams of methylene iodide are heated in an oil-bath for thirty minutes at 130° C., when a 12 to 15 grams yield of iodide is obtained. The compound is insoluble in ether, sparingly soluble on heating in dilute alcohol, chloroform, acetic acid, or water. Treatment with chlorine gives the *iododichloride* of the corresponding chloromethyl compound, $(C_6H_5)_3As(CH_2Cl)ICl_2$, an intensely yellow, crystalline compound, M.pt. 138° C.; insoluble in cold alcohol, acetic acid, chloroform, or water, dissolving readily in boiling alcohol.

When heated with aqueous sodium hydroxide the iododichlorides decompose as follows :—

$$(C_6H_5)_3As(CH_2Cl)ICl_2+2NaOH=(C_6H_5)_3As(CH_2Cl)I+NaOCl+NaCl+H_2O$$
$$(C_6H_3)_3As(CH_2Cl)ICl_2+NaOH+NaOCl=CHICl_2+(C_6H_5)_3As(OH)_2+2NaCl$$

Triphenyliodomethylarsonium chloride, obtained by digesting the preceding compound with freshly precipitated silver chloride, crystallises in needles, M.pt. 208° C., readily soluble in alcohol and water.

Triphenylhydroxymethylarsonium chloride, $(C_6H_5)_3As(CH_2OH)Cl$.—The above iodide is shaken with moist silver oxide and the resulting solution treated with hydrochloric acid. The chloride forms deliquescent crystals, M.pt. 112° C. It gives a *platinichloride*, M.pt. 224° C., and an *iodide*, yellow needles, M.pt. 171° C., very soluble in alcohol or water.

Triphenyl-β-hydroxyethylarsonium chloride, $(C_6H_5)_3As(CH_2.CH_2.OH)Cl$, is obtained by heating together triphenylarsine and ethylene chlorhydrin. It crystallises in colourless needles, M.pt. 215° C., and gives a *platinichloride*, M.pt. 223° C.

[1] Michaelis, *loc. cit.*

Tri-o-tolylmethylarsonium iodide crystallises from water in colourless needles, M.pt. 166° C.[1]

Tri-m-tolylmethylarsonium iodide, $(C_7H_7)_3As.CH_3.I$.[2]—The free arsine and methyl iodide combine to give the arsonium compound at the ordinary temperature. It crystallises from water or alcohol in prisms or plates, M.pt. 181° C. The corresponding *chloride* is an oil, yielding a yellow *platinichloride*. The *hydroxide* or *iodide* when heated with aqueous alkali is decomposed into the arsine and methyl alcohol.

Tri-m-tolylethylarsonium iodide crystallises in rhombohedra, M.pt. 130° C.; the corresponding *n-propylarsonium iodide* forms needles, M.pt. 143° C., the *isopropylarsonium iodide* melts at 162° C., and the *benzylarsonium chloride*, formed from its components at 30° to 40° C., melts at 102° C., and is easily soluble in water, sparingly soluble in alcohol.

Tri-p-tolylmethylarsonium iodide, obtained in a similar manner to the phenyl compound, melts at 179° C.; the *chloride* has M.pt. 87° C.; the *platinichloride* separates from dilute alcohol in reddish-brown, refracting prisms, and the *iododichloride* forms reddish-yellow crystals, M.pt. 146° C.

Tri-p-tolyliodomethylarsonium iodide forms colourless crystals, M.pt. 215° C. It is prepared from methylene iodide and tri-*p*-tolylarsine.

Hexamethyltriaminotri-p-tolylmethylarsonium iodide, $[(CH_3)_2N.C_6H_3.CH_3]_3As.CH_3I$, is a white powder, M.pt. 135° C., readily soluble in alcohol, sparingly soluble in water.

Tri-p-tolylethylarsonium iodide crystallises in colourless needles, turning brown and melting at 158° C.

Tri-p-tolylallylarsonium bromide, $(C_7H_7)_3As(C_3H_5)Br$.—Tri-*p*-tolylarsine and allyl bromide are heated together under reflux for five hours. The bromide separates from water in colourless prisms, M.pt. 82° C., soluble in chloroform or alcohol, insoluble in ether.

Tri-p-tolyldibromoallylarsonium bromide, $(C_7H_7)_3As(C_3H_5Br_2)Br$, is prepared by adding bromine to the foregoing bromide in alcoholic solution. It melts at 112° C. and is soluble in the usual solvents. The corresponding *chloride* is an oil, but its *platinichloride* is a red powder, M.pt. 225° C. The *iodide* results when the bromide is treated with potassium iodide; it forms colourless prisms, M.pt. 141° C., sparingly soluble in cold water, easily soluble in alcohol.

Tri-p-ethyl-triphenylmethylarsonium iodide, $(C_6H_4.C_2H_5)_3.As(CH_3)I$, melts at 126° C.

Tribenzylmethylarsonium iodide, $(C_6H_5.CH_2)_3As(CH_3)I$.[3]—This and the following alkylarsonium compounds are prepared by heating the arsine with alkyl iodides in sealed tubes at 100° C. The iodide forms colourless needles or rhombic prisms, M.pt. 143° C. Moist silver oxide transforms it to the *hydroxide*, which absorbs carbon dioxide, and yields toluene on treatment with concentrated sodium hydroxide. The corresponding *chloride* melts at 201° C. and forms a *platinichloride*, M.pt. 173° C.

Tribenzylethylarsonium iodide crystallises in plates, M.pt. 148° C.; **tribenzyl-n-propylarsonium iodide** forms plates, M.pt. 146° C.; **tribenzylisopropylarsonium iodide** forms small tablets, M.pt. 143° C.; **tribenzylisoamylarsonium iodide** melts at 146° C.

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1373. [2] Michaelis, *loc. cit.*
[3] Michaelis and Paetow, *Annalen*, 1886, 233, 60; Paetow, *Inaug. Dissert.*, Rostock, 1885.

Tetrabenzylarsonium chloride, $(C_6H_5.CH_2)_4AsCl$.—This may be isolated by heating benzyl chloride and tribenzylarsine under reflux for a long time, or in quantitative yield by heating the two substances in a sealed tube at 170° to 175° C. for three hours. The temperature should be kept below 180° C., or dibenzylarsine trichloride is formed. Tetrabenzylarsonium chloride forms triclinic crystals, M.pt. 160° C., readily soluble in hot water or alcohol. It is slowly decomposed by concentrated hydrochloric acid at high temperatures and under pressure. The aqueous solution gives precipitates with nitric acid, potassium dichromate, potassium thiocyanate, potassium bromide, potassium iodide, picric acid, and platinic chloride.

Tetrabenzylarsonium bromide crystallises in fine needles, M.pt. 173° C., and the *iodide* in needles or plates, M.pt. 168° C., turning yellow on exposure to light. When an alcoholic solution of the iodide is boiled with iodine in the same solvent, a *periodide* results, $(C_7H_7)_4AsI_3$, consisting of glistening, red plates, M.pt. 149° to 150° C.

Tetrabenzylarsonium hydroxide, $(C_6H_5.CH_2)_4As.OH$, results when the iodide is boiled with an aqueous suspension of silver oxide. Evaporation yields a syrup, having an alkaline reaction and absorbing carbon dioxide from the air. When heated with alkali it decomposes as follows :—

$$(C_7H_7)_4.As.OH = C_6H_5.CH_3 + (C_7H_7)_3As.O$$

It forms the following salts : [1] *mercuri-iodide*, M.pt. 163° C. ; *mercuri-chloride*, transparent needles, M.pt. 176° C. ; *platinichloride*, M.pt. 198° C. ; and *aurichloride*, yellow needles, melting at about 130° C.

Tri-m-xylylmethylarsonium iodide,[2] $(C_8H_9)_3As(CH_3)I$, melts at 179° C., is sparingly soluble in water, but readily dissolves in alcohol or chloroform. The corresponding *chloride* is not crystalline ; it yields a crystalline *platinichloride*, M.pt. 245° C.

Tri-p-xylylmethylarsonium iodide forms tablets, M.pt. 175° C. ; the *platinichloride* separates in pale yellow needles, M.pt. 250° C.

Trimesitylmethylarsonium iodide, $(C_9H_{11})As(CH_3)I$, crystallises in white prisms, M.pt. 186° C., sparingly soluble in hot water, easily soluble in alcohol and chloroform. The corresponding *chloride* melts at 192° C., and the *platinichloride* at 237° C.

Tri-p-cumylmethylarsonium iodide, $(C_6H_4.C_3H_7)_3As(CH_3)I$, forms colourless rosettes, M.pt. 103° C. ; the corresponding *ethiodide* melts at 138° C.

Tri-tertiary-butylphenylmethylarsonium iodide, $[(CH_3)_3C.C_6H_4]_3As(CH_3)I$, melts at 125° C. ; the *hydroxide* melts at 136° C. and crystallises with four molecules of water.

Tricyclohexylmethylarsonium iodide, $(C_6H_{11})_3(CH_3)AsI$,[3] obtained from tri*cyclo*hexylarsine and methyl iodide, crystallises from water in prisms, M.pt. 153° to 154° C. A corresponding **benzobromide** melts with slight decomposition at 197° C.

Diphenyldimethylarsonium iodide,[4] $(C_6H_5)_2As(CH_3)_2I$, is formed by the interaction of methyl iodide and diphenylmethylarsine. It separates in white crystals, M.pt. 190° C., readily soluble in hot water

[1] Mannheim, *Annalen*, 1905, 341, 208.
[2] Michaelis, *ibid.*, 1902, 321, 220.
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[4] Michaelis and Link, *Annalen*, 1881, 207, 199.

and alcohol, insoluble in ether. When heated in a stream of carbon dioxide it is decomposed into its components. The *platinichloride* crystallises in reddish-yellow needles, M.pt. 219° C., with decomposition.

Diphenyldimethylarsonium tri-iodide, $(C_6H_5)_2As(CH_3)_2I_3$,[1] results amongst other products when methyl iodide reacts at 100° C. with any of the following compounds: Diphenylchloroarsine, the corresponding bromide, iodide, cyanide, or thiocyanate. It crystallises in violet needles, M.pt. 69·5° C., insoluble in water or ether, readily dissolving in hot alcohols, chloroform, ethyl acetate, or acetone. When treated with alcoholic potassium hydroxide and the product recrystallised from water, diphenyldimethylarsonium iodide results. An alcoholic solution of iodine transforms the tri-iodide into the *compound*, $(C_6H_5)_2As(CH_3)_2I.I_8$.

p-Bromodiphenyldimethylarsonium iodide,[2] $(C_6H_5)(C_6H_4Br).As(CH_3)_2I$, is obtained by combination of *p*-bromodiphenylmethylarsine and methyl iodide in the cold, two to three weeks being required to complete the reaction. It separates from absolute alcohol in very pale yellow prisms, M.pt. 87° C.

Diphenyldiethylarsonium iodide, $(C_6H_5)_2As(C_2H_5)_2I$.[3] — Diphenylethylarsine and ethyl iodide are heated in a sealed tube at 100° C. The product crystallises in white needles, M.pt. 184° C., sparingly soluble in cold water, readily soluble in hot water or alcohol. The corresponding *chloride* cannot be obtained in crystalline form, but its solution with platinic chloride gives *diphenyldiethylarsonium platinichloride*, $[(C_6H_5)_2As(C_2H_5)_2]_2PtCl_6$, crystallising in golden yellow plates.

Diphenylmethylethylarsonium iodide, $(C_6H_5)_2As(CH_3)(C_2H_5)I$,[4] crystallises in rhombic plates, M.pt. 170° C., soluble in alcohol or hot water, insoluble in ether. It has a bitter taste. When heated in a stream of carbon dioxide, ethyl iodide is split off. The *hydroxide* is a syrupy mass; the *platinichloride* crystallises from boiling water in yellowish-red needles, M.pt. 214° C., whilst the *picrate* forms yellow needles, M.pt. 95° C.

Diphenylmethylbenzylarsonium iodide melts at 193° C.[5]

Diphenyl-p-tolylmethylarsonium iodide, $(C_6H_5)_2As(C_7H_7)(CH_3)I$,[6] melts at 152° C.; the corresponding *chloride* is an oil, and the *platinichloride* forms pale red crystals, M.pt. 209° C.

Diphenyl-p-tolylethylarsonium iodide is an oil, and the *platinichloride* consists of pink crystals, M.pt. 220° C.

Di-o-tolyldimethylarsonium iodide, $(C_7H_7)_2As(CH_3)_2I$,[7] crystallises from water in colourless needles, M.pt. 195° C.

Phenyltrimethylarsonium iodide, $C_6H_5.As(CH_3)_3I$.[8]—In addition to the usual method of preparation, this body results when arsenobenzene and methyl iodide are heated at 100° C.[9] It crystallises in white needles, M.pt. 250° C., fairly soluble in cold water or alcohol, insoluble in ether. It splits up into its components when heated in an atmosphere of carbon dioxide. The *platinichloride* forms red laminæ, M.pt. 219° C. The

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[2] Hunt and Turner, *Trans. Chem. Soc.*, 1925, 127, 2670.
[3] La Coste and Michaelis, *Ber.*, 1878, 11, 1883.
[4] Michaelis and Link, *loc. cit.*
[5] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1381.
[6] Michaelis, *Annalen*, 1902, 321, 141.
[7] Burrows and Turner, *loc. cit.*
[8] Burrows and Turner, *loc. cit.*; see Michaelis and Link, *Annalen*, 1881, 207, 205.
[9] Bertheim, *Ber.*, 1914, 47, 274.

iodide forms an *additive compound* with *iodoform*, $C_6H_5.As(CH_3)_3I \ldots CHI_3$, which crystallises in yellow needles, M.pt. 143° to 145° C.,[1] and also a *compound* with *cadmium iodide*, $[C_6H_5(CH_3)_2As]_2.CdI_4$, M.pt. 194° C.[2]

Phenyltrimethylarsonium tri-iodide, $C_6H_5.As(CH_3)_3I_3$,[3] is formed amongst other products by the interaction of methyl iodide and any of the following arsenicals: Phenylmethylchloro- or iodoarsine, arsenobenzene or *sym.*-diphenyldi-iododiarsine. It forms reddish-brown needles, M.pt. 103° C., which are converted by arsenobenzene or *sym.*-diphenyldi-iododiarsine into phenyltrimethylarsonium iodide and phenyldi-iodoarsine.

p-Iodophenyltrimethylarsonium iodide, $(C_6H_4I)(CH_3)_3AsI$, obtained from methyl iodide and 4 : 4′-di-iodoarsenobenzene, crystallises in plates, M.pt. 300° C. It has a similar solubility to the preceding mono-iodide.[4]

Phenyltrimethylarsonium bromide.[5] — Phenyldimethylarsine (2 grams) and 7·7 grams of methyl bromide are brought together in the cold and allowed to stand for many days, when the bromide separates as a white, microcrystalline mass. It yields large, compact crystals from alcohol, decomposing at 284° C., and dissolving in water, giving a solution with neutral reaction. It is soluble to some extent in most solvents, except ether and pyridine. When heated with methyl iodide the bromide is converted into the corresponding iodide. The corresponding *platinichloride* crystallises from water in brown leaflets, M.pt. 197° to 200° C., and the *picrate* forms orange-yellow needles, M.pt. 145° C.

Benzyltrimethylarsonium iodide, $(C_6H_5.CH_2)(CH_3)_3AsI$,[6] is readily formed from benzyldimethylarsine and methyl iodide. It separates from alcohol in colourless leaflets, M.pt. 195° to 196° C. If ethyl iodide is used in the preparation, *benzyldimethylethylarsonium iodide* is obtained; this separates from alcohol-ether in colourless leaflets, M.pt. 163° to 165° C.

Benzyltrimethylarsonium picrate, $(C_6H_5.CH_2)(CH_3)_3As.C_6H_2N_3O_7$,[7] obtained from the methiodide of benzyldimethylarsine, crystallises from water in yellow prisms, M.pt. 175° to 176° C.

p-Anisyltrimethylarsonium iodide, $(C_6H_4.OCH_3)(CH_3)_3AsI$, is obtained when arseno-*p*-anisole, $CH_3O.C_6H_4As : AsC_6H_4.OCH_3$, is heated at 100° C. with methyl iodide It forms colourless prisms, M.pt. 213° C.[8]

α-Naphthyltrimethylarsonium iodide, $C_{10}H_7(CH_3)_3AsI$,[9] crystallises from alcohol in colourless needles, M.pt. 230° C.

m-Nitrophenyltrimethylarsonium picrate, $(C_6H_4NO_2)(CH_3)_3As.C_6H_2N_3O_7$,[10] results when 4 grams of phenyltrimethylarsonium picrate in 30 grams of nitric acid (density 1·52) are heated at 100° C. for five hours in a sealed tube. It forms orange-yellow needles, M.pt. 180° C.

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2969.
[2] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 1448.
[3] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[4] Bertheim, *loc. cit.* [5] Steinkopf and Schwen, *loc. cit.*
[6] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[7] Ingold, Shaw, and Wilson, *ibid.*, 1928, p. 1282.
[8] Bertheim, *Ber.*, 1914, 47, 276.
[9] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1381.
[10] Ingold, Shaw, and Wilson, *loc. cit.*

p-Nitrobenzyltrimethylarsonium picrate, $(NO_2.C_6H_4.CH_2)(CH_3)_3As.C_6H_2N_3O_7$, from nitration of benzyltrimethylarsonium picrate, crystallises from acetone in orange-yellow needles, M.pt. 166° to 168° C.

Phenyldimethylethylarsonium iodide [1] is obtained from phenylmethylethylarsine and methyl iodide or phenyldimethylarsine and ethyl iodide at water-bath temperatures. It crystallises from alcohol in colourless needles, M.pt. 142° C. *Phenyldimethylethylarsonium mercuri-iodide*, $C_6H_5(CH_3)_2C_2H_5.As.HgI_3$, forms pale yellow prisms, M.pt. 135° C., and the *plumbi-iodide*, $C_6H_5(CH_3)_2C_2H_5AsPbI_3$, melts at 203° C.[2]

Phenyldimethylbenzylarsonium iodide crystallises from acetone-ether in colourless needles, M.pt. 115° to 116° C.

Phenyl-β-phenylethyldimethylarsonium iodide, $C_6H_5[(CH_2)_2.C_6H_5](CH_3)_2AsI$,[3] is prepared from phenyl-β-phenylethylmethylarsine and methyl iodide. It crystallises from water in rhombohedra or prisms, M.pt. 119° C.

Phenylmethyldiethylarsonium iodide,[4] $C_6H_5.As(C_2H_5)_2(CH_3)I$, is a colourless, crystalline solid, M.pt. 75° to 77° C.; the *chloride* is an oil, and the *platinichloride* melts at 190° C.

Phenyltriethylarsonium iodide, $C_6H_5As(C_2H_5)_3I$.[5] — Phenyldiethylarsine and ethyl iodide in a sealed tube at 100° C. combine to give the iodide, or phenylarsine may be heated with ethyl iodide at 120° C.[6] It yields prismatic crystals from water, M.pt. 112° to 113° C., which possess a bitter taste. It decomposes in the usual manner when heated in a carbon dioxide atmosphere. When heated for from two to three hours at 110° C. with water and silver oxide in a sealed tube, it gives the *hydroxide*, a syrupy liquid, which forms an uncrystallisable *chloride* on neutralisation with dilute hydrochloric acid. The *platinichloride* forms golden yellow plates. When an acetic acid solution of the iodide is treated with chlorine, dark yellow crystals of *phenyltriethylarsonium iodod chloride*, $C_6H_5As(C_2H_5)_3ICl_2$, separate, M.pt. 79° C.[7]

Phenyliodomethyldiethylarsonium iodide, $C_6H_5.As(CH_2I)(C_2H_5)_2I$, results when phenyldiethylarsine and methylene iodide are heated together on the water-bath. It crystallises from dilute alcohol in needles, M.pt. 173° C. It dissolves readily in methyl alcohol, and is sparingly soluble in hot ethyl alcohol, acetone, or water.

Phenyltri-isoamylarsonium iodide, $(C_6H_5)(C_5H_{11})_3AsI$, prepared by heating phenylarsine and *iso*amyl iodide at 140° to 150° C., forms white crystals, M.pt. 163° C.[8] It is very soluble in chloroform and alcohol, insoluble in benzene, ether, light petroleum, and cold water.

Phenylethyl-n-propylallylarsonium bromide, $(C_6H_5)(C_2H_5)(C_3H_7)(C_3H_5)AsBr$,[9] obtained from phenylethyl-*n*-propylarsine and allyl bromide, crystallises in colourless plates from acetone, M.pt. 86° C. The corresponding *d-α-bromocamphor-π-sulphonate*, crystallises from alcohol and melts at 123° C.

Phenyl-γ-phenylpropyldimethylarsonium iodide, (C_6H_5)

[1] Burrows and Turner, *loc. cit.*
[2] Burrows and Turner, *ibid.*
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.
[4] See Michaelis, *Annalen*, 1902, 320, 296.
[5] La Coste and Michaelis, *Ber.*, 1878, 11, 1883; Michaelis, *ibid.*, 1877, 10, 622.
[6] Dehn, *Amer. Chem. J.*, 1905, 33, 151.
[7] Michaelis, *loc. cit.*
[8] Dehn, *Amer. Chem. J.*, 1905, 33, 152.
[9] Winmill, *Trans. Chem. Soc.*, 1912, 101, 718.

$[C_6H_5.CH_2.CH_2.CH_2](CH_3)_2.AsI$, crystallises in colourless rhombohedra, M.pt. 102° C.[1]

Phenyl - p - tolyldimethylarsonium iodide, $(C_6H_5)(C_7H_7)As(CH_3)_2I$.[2]—In this case, combination only occurs in the cold after the arsine and methyl iodide have been standing for two to three weeks, but the reaction may be accelerated by heating at 100° C. The iodide crystallises in colourless prisms, M.pt. 93° C.

Phenyl-p-tolylmethylethylarsonium iodide, $(C_6H_5)(C_7H_7)(CH_3)(C_2H_5)AsI$,[3] from phenyl-*p*-tolylethylarsine and methyl iodide, melts at 150° C. when crystallised from alcohol, and at 158° C. when crystallised from water. When once it has been crystallised from water, recrystallisation from either solvent gives M.pt. 158° C. The corresponding *chloride* and *hydroxide* have not been isolated in crystalline form, but the *platinichloride* yields yellowish-red prisms, M.pt. 214° C.

Phenyl-p-tolyldiethylarsonium iodide, $(C_6H_5)(C_7H_7)(C_2H_5)_2AsI$,[4] crystallises from water in needles, M.pt. 148° C. The *n*-propyl and *iso*propyl derivatives are crystalline compounds of indefinite melting-point.

Phenyl-p-tolylethylbenzylarsonium iodide, $(C_6H_5)(C_7H_7)(C_2H_5)(C_6H_5CH_2)AsI$, forms rhombic crystals, M.pt. 150° C., but the corresponding *chloride* is not crystallisable.

Phenylbenzylmethylallylarsonium iodide, $(C_6H_5)(C_6H_5.CH_2)(CH_3)(C_3H_5)AsI$, forms colourless crystals, M.pt. 100° C. Its *d-α-bromocamphor-π-sulphonate* crystallises in prisms, M.pt. 189° C., and cannot be resolved.

Phenylbenzylethyl-n-propylarsonium iodide, $(C_6H_5)(C_6H_5CH_2)(C_2H_5)(C_3H_7)AsI$,[5] is formed from phenylethyl-*n*-propylarsine and benzyl iodide by heating at 40° to 50° C. It separates from dilute alcohol in colourless crystals, M.pt. 128° C. Its *d-camphor-β-sulphonate* shows no signs of resolution into optically active components.

Phenylmesityldimethylarsonium iodide, $(C_6H_5)[C_6H_2(CH_3)_3](CH_3)_2AsI$.[6]—Phenylmesitylmethylarsine readily combines with methyl iodide at 100° C., yielding the iodide, which separates from alcohol in colourless prisms, M.pt. 187° C. **Phenylmesitylbenzylmethylarsonium bromide,** $(C_6H_5)[C_6H_2(CH_3)_3](C_6H_5CH_2)(CH_3)AsBr$, is prepared in a similar manner, and crystallises from alcohol or water in colourless prisms, M.pt. 179° to 180° C.

Phenyl-α-naphthyldimethylarsonium iodide, $(C_6H_5)(C_{10}H_7)(CH_3)_2AsI$,[7] is readily formed on the water-bath, and crystallises from concentrated alcoholic solution in plates, M.pt. 175° C.

Phenyl-α-naphthylmethylallylarsonium bromide, $(C_6H_5)(C_{10}H_7)(CH_3)(C_3H_5)AsBr$,[8] obtained by combination of the arsine and allyl bromide, is a colourless, crystalline compound, melting with decomposition at 140° C.

Phenacylphenyl-α-naphthylmethylarsonium bromide, $(C_6H_5.CO.CH_2)(C_6H_5)(C_{10}H_7)(CH_3)AsBr$. — Phenyl - α - naphthylmethylarsine

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 429.
[2] Hunt and Turner, *ibid.*, 1925, 127, 2668.
[3] See Michaelis, *Annalen*, 1902, 321, 160.
[4] Michaelis, *loc. cit.*
[5] Winmill, *loc. cit.*
[6] Hunt and Turner, *loc. cit.*
[7] Burrows and Turner, *loc. cit.*
[8] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 426.

and ω-bromoacetophenone are warmed together in molecular proportions. The product, when treated with alcohol, gives a white, crystalline solid, M.pt. 189° C. It dissolves readily in hot alcohol, sparingly in cold alcohol, and is insoluble in acetone.

Homopiperonyl-phenyl-α-naphthylmethylarsonium bromide, $[C_6H_2.CH_3(O_2CH_2)](C_6H_5)(C_{10}H_7)(CH_3)AsBr$, crystallises from alcohol in colourless plates, M.pt. 174° to 175° C. It yields a *d-α-bromocamphor-π-sulphonate*, crystallising in stout needles, which cannot be separated into two optically active forms.

Phenyl - α - naphthylbenzylmethylarsonium bromide, $C_6H_5.C_{10}H_7.(C_6H_5CH_2)CH_3AsBr$, forms colourless prisms, M.pt. 185° C. The *bromocamphor-sulphonate* is known; the *d-iodide* forms colourless needles, M.pt. 186° to 187° C., and the *d-bromide* colourless crystals, M.pt. 187° to 188° C.

Phenyldi-p-tolylmethylarsonium iodide, $(C_6H_5)(C_7H_7)_2(CH_3)AsI$,[1] crystallises in needles, M.pt. 84° C.; its *platinichloride* forms golden-yellow needles, M.pt. 222° C. The corresponding *ethylarsonium iodide* forms yellow needles, M.pt. 125° C.

Phenyldi-m-xylylmethylarsonium iodide, $(C_6H_5)[C_6H_3(CH_3)_2]_2(CH_3)AsI$, forms white crystals, M.pt. 184° C., which yield a *hydroxide*, M.pt. 122° C. The corresponding *ethylarsonium compound* melts at 157° C.

Phenyldi-pseudocumylmethylarsonium iodide, $(C_6H_5)[C_6H_2(CH_3)_3]_2(CH_3)AsI$, obtained from the arsine and methyl iodide, melts at 179° C. The corresponding *chloride* melts at 192° C., and the *platinichloride* at 266·5° C. The *hydroxide* crystallises in colourless needles, sintering at 147° and melting at 151° C. Prolonged heating at 130° C. converts the hydroxide into the arsine and methyl alcohol. The *ethylarsonium compound* forms colourless crystals, M.pt. 189° C.

p-Tolyltrimethylarsonium iodide, $(C_7H_7)(CH_3)_3AsI$,[2] is isolated from *p*-tolyldimethylarsine and methyl iodide, or from the latter and *p*-arsenotoluene, $CH_3.C_6H_4As=AsC_6H_4.CH_3$.[3] It crystallises from water in needles or prisms, M.pt. 274° to 275° C. with decomposition. The *platinichloride* melts at 225° C., and separates from very dilute hydrochloric acid in reddish-yellow plates.

p-Tolylmethyldiethylarsonium iodide, $(C_7H_7)(CH_3)(C_2H_5)_2AsI$,[4] from *p*-tolyldiethylarsine and methyl iodide, crystallises in small, colourless plates, M.pt. 120° C.

p-Tolyltriethylarsonium iodide, $(C_7H_7)(C_2H_5)_3AsI$, separates in colourless, prismatic crystals from water, M.pt. 230° C. The *platinichloride* forms reddish-yellow plates, M.pt. 210° C., but the *chloride* is very difficult to crystallise.

***α*-Naphthyldimethylethylarsonium iodide,**[5] $C_{10}H_7(CH_3)_2(C_2H_5)AsI$, produced by treating α-naphthyldimethylarsine with ethyl iodide at 90° to 100° C., crystallises from alcohol in colourless leaflets, M.pt. 218° C.

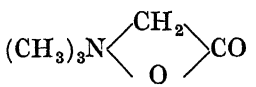
cycloHexylphenylbenzylmethylarsonium bromide, $C_6H_{11}(C_6H_5)(C_6H_5.CH_2)(CH_3)AsBr$.[6]—When *cyclo*hexylphenylmethylarsine is heated at 100° C. with one equivalent of benzyl bromide and a little alcohol,

[1] Michaelis, *Annalen*, 1902, 321, 192.
[2] Michaelis, *ibid.*, 1902, 320, 304.
[3] Bertheim, *Ber.*, 1914, 47, 274.
[4] Michaelis, *loc. cit.*
[5] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1381.
[6] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443.

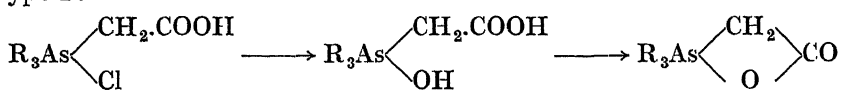
large, colourless crystals appear, but subsequently vanish. On cooling, a little white powder separates, and crystallisation has to be induced by adding an excess of ether. Recrystallisation from alcohol-ether yields rectangular plates, M.pt. 193° C. The corresponding *d-α-bromo-camphor-π-sulphonate* has been isolated, the crude product melting at 109° to 113° C.

Aryl Arsenated Betaines and Ketobetaines.

The method of production of *arylarsenated betaines* is similar to that for betaine itself (trimethyl-glycine),

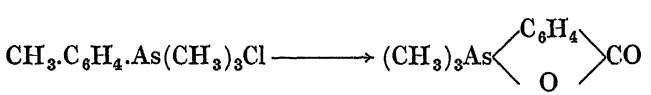


which may be synthesised from trimethylamine and chloracetic acid. The application of this method to the triarylarsines yields products of type I:

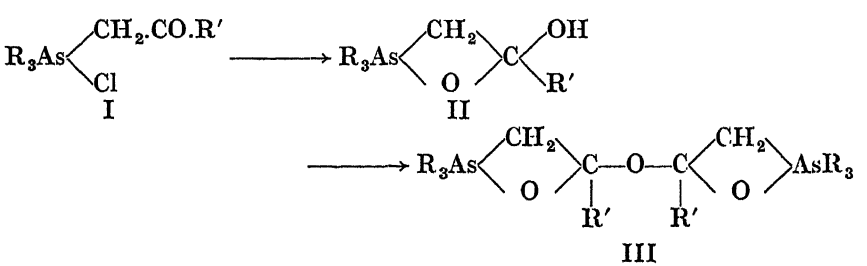


I II III

These products may be transformed by alcoholic alkali to type II, from which the elements of water may be removed to give type III. The compounds used may be either triaryl or alkyl-arylarsines. A ring formation similar to III may also be obtained by oxidising an aryltri-alkylarsonium chloride, in which the aryl group contains a substituted methyl group, by alkaline permanganate:



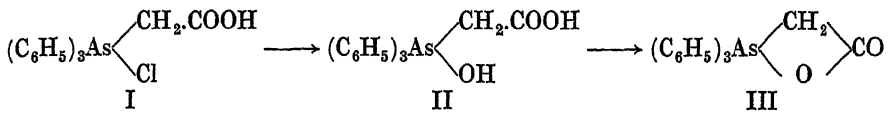
If the chloracetic acid above is replaced by an aliphatic or mixed ketone, such as bromacetophenone, a ketonic group is introduced as in I, and the compounds are known as *ketobetaines*:



I II III

Alkali transforms I to II, which yields the anhydride III on heating. All the above compounds are solids and yield *platinichlorides*, which may be used for their identification.

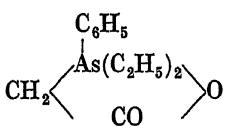
Triphenylarsenibetaine hydrochloride,[1]



I II III

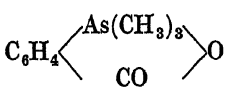
This chloride, I, is prepared by heating equal parts of triphenylarsine and chloracetic acid on the water-bath until a homogeneous mass is formed. When the latter is triturated with ether, then crystallised from alcohol and ether, colourless needles, M.pt. 145° C., are deposited. The chloride is very soluble in alcohol or water, and gives a *platinichloride*, a pale red powder, M.pt. 194° C. When the chloride is heated with alcoholic potassium hydroxide, filtered from potassium chloride, and treated with carbon dioxide to remove excess of alkali, the solution on concentrating over sulphuric acid yields triphenylarsenibetaine (II). The crude product is crystallised from alcohol-ether, small white needles, M.pt. 125° C., being deposited, which are readily soluble in alcohol and water, the solutions being neutral. When heated at 100° C., the betaine is transformed to the anhydride (III).

Phenyldiethylarsenibetaine hydrochloride,[2] $C_6H_5.As(C_2H_5)_2.Cl.CH_2.COOH$, crystallises from alcohol-ether in needles, M.pt. 135° C., and forms a bright red *platinichloride*, M.pt. 161° C. The *free betaine*, obtained as in the preceding preparation, has the composition :



If chloracetic acid is replaced by its ethyl ester, the final product is the *betaine ethyl ester*, $C_6H_5.As(C_2H_5)_2Cl.CH_2.CO.OC_2H_5$, which is an oil. It forms a *platinichloride* consisting of small needles from alcohol, M.pt. 125° C., and also a *picrate*, melting at 90° C.

Trimethylarsenibenzobetaine hydrochloride,



is obtained by oxidising *p*-tolyltrimethylarsonium chloride with alkaline permanganate at 50° C. for about ten days. It separates from water in white, bushy needles, decomposing above 400° C. without melting, sparingly soluble in cold water, readily soluble in hot alcohol. Its *platinichloride* melts at 219° C.

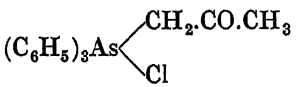
The *free betaine* crystallises from aqueous alcohol in flat plates, containing $2\frac{1}{2}$ molecules of water, stable in air, and melting without decomposition on heating. Prolonged boiling with alcoholic potassium hydroxide converts this compound into trimethylarsine oxide and benzoic acid. It forms the following double salts: *platinichloride*, small, yellow needles, M.pt. 255° C.; *aurichloride*, golden-yellow needles, M.pt. 198° C.; *hydrobromide*, small needles, decomposing at about 270° C. without melting; *nitrate*, plates, M.pt. 230° C.; *sulphate*, flat needles.

[1] Michaelis, *Annalen*, 1902, 321, 174.
[2] Michaelis, *ibid.*, 1902, 320, 297.

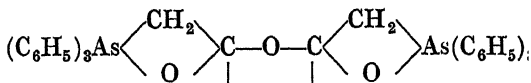
Triethylarsenibenzobetaine hydrochloride is isolated from *p*-tolyltriethylarsonium chloride in a similar manner to the corresponding trimethyl compound. After oxidation, the filtrate is treated with hydrochloric acid, evaporated to dryness and the residue extracted with absolute alcohol. From the solution, hygroscopic star-like crystals separate. The *platinichloride* crystallises from dilute hydrochloric acid in bright yellow plates, M.pt. 225° C.; the *aurichloride* forms golden-yellow needles, M.pt. 165° C.; the *picrate*, golden-yellow plates, M.pt. 155° C.

The *free betaine* is formed from the hydrochloride by treating a solution of the latter with sodium carbonate, evaporating to dryness and extracting the residue with alcohol. It has a bitter taste, forms no salts with alkalis, and is very stable towards concentrated aqueous potassium hydroxide, whereas trimethylphosphorbenzobetaine is easily decomposed by the latter reagent. If, however, alcoholic potassium hydroxide is used, eight hours' boiling yields trimethylarsine oxide and potassium benzoate.

Triphenylmethylarseniketobetaine hydrochloride or **Triphenylacetonylarsonium chloride,**[1]

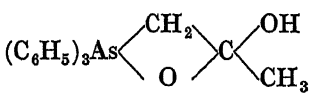


I



II

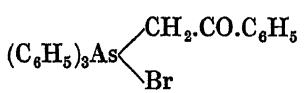
This chloride, I, is prepared by heating triphenylarsine and monochloracetone for some hours under reflux in an oil-bath at 120° C. It melts at 172° C., is soluble in water or alcohol, and forms a *platinichloride*. By treatment with sodium hydroxide it is transformed into free *triphenylmethylarseniketobetaine*,



which melts at 123° C., is insoluble in cold water, but readily dissolves in hot water, alcohol, and benzene; sparingly soluble in ether. At 194° C. it is converted into the anhydride (II), which crystallises unchanged from anhydrous benzene, but reverts to the free betaine in solvents containing water.

Triphenylacetonylarsonium bromide forms colourless crystals, M.pt. 165° C., and the *iodide* melts at 161° C.

Tetraphenylarseniketobetaine hydrobromide or **Triphenylphenacylarsonium bromide,**



results when triphenylarsine and bromoacetophenone are heated for a short time on the water-bath. It forms silky needles from water, M.pt. 178° C., easily soluble in hot water or alcohol, less soluble in cold water. The *free betaine*, obtained by the action of sodium hydroxide or carbonate

[1] Michaelis, *Annalen*, 1902, 321, 176; Weiss, *Inaug. Dissert.*, Rostock, 1899.

on the bromide, forms white needles, M.pt. 176° C., soluble in water, but insoluble in alcohol. It forms the following salts: *hydrochloride*, M.pt. 166° C.; *platinichloride*, M.pt. 191° C.; *hydriodide*, M.pt. 157° C.; *nitrate*, colourless needles, M.pt. 184° C., soluble in cold water, insoluble in alcohol.

Tri-p-tolylarsenibetaine hydrochloride,

$$(C_7H_7)_3As\begin{matrix}CH_2.CO.OH\\Cl\end{matrix}$$

prepared by the general method, melts at 146° C., and forms a *platinichloride*, M.pt. 206° C.

Tri-p-tolylmethylarseniketobetaine hydrochloride,

$$(C_7H_7)_3As\begin{matrix}CH_2.CO.CH_3\\Cl\end{matrix}$$

is formed when tri-*p*-tolylarsine and monochloracetone are heated in a sealed tube at 85° C. It melts at 170° C., is readily soluble in alcohol and water, less soluble in benzene, insoluble in ether. The *free betaine*, obtained from the hydrochloride by the action of alkali, crystallises in fine, glistening needles, M.pt. 113° C. It dissolves in alcohol, benzene, or ether, but is insoluble in water. The *hydrobromide* melts at 159° C., the *hydriodide* at 144° C., and the *platinichloride* forms yellow plates, M.pt. 210° C.

Tri-p-tolylphenylarseniketobetaine hydrochloride,

$$(C_7H_7)_3As\begin{matrix}CH_2.CO.C_6H_5\\Cl\end{matrix}$$

crystallises in white needles, M.pt. 159° C., having a similar solubility to the methyl compound. The *free betaine* forms needles, M.pt. 160° C.; the *platinichloride*, yellowish-red needles, M.pt. 205° C.; and the *hydrobromide* and *hydriodide* melt at 182° C. and 148° C. respectively.

Derivatives of the Type $R_2As.AsR_2$

The first member of this group to be isolated was *tetraphenyldiarsine*, obtained by reducing diphenylarsenoxide with excess of phosphorous acid, the general equation being:

$$(R_2As)_2O+H_3PO_3=R_2As.AsR_2+H_3PO_4$$

This method has been used in several cases, and the oxide has also been replaced by the corresponding acid:

$$2R_2AsO.OH+3H_3PO_3=R_2As.AsR_2+3H_3PO_4+H_2O$$

Reduction of compounds of the type $RAsI_2$ yields *substituted diarsines* of the type RAsI.IAsR. A number of interesting derivatives have recently been obtained as follows:

(1) Interaction of a diarylchloroarsine with a primary arylarsine in ether solution in a carbon dioxide atmosphere yields a *triaryldiarsine*:

$$R_2AsCl+RAsH_2=R_2As.AsHR+HCl$$

(2) Diarylchloroarsine (2 mols.) with a primary arylarsine (1 mol.) in absolute alcohol at about 70° C. in a carbon dioxide atmosphere yields a *penta-aryltriarsine* :

$$2R_2AsCl+RAsH_2=R_2As.AsR.AsR_2+2HCl$$

A similar compound is isolated from a diarylarsine and an aryldiiodoarsine :

$$2R_2AsH+RAsI_2=R_2As.AsR.AsR_2+2HI$$

(3) Interaction of an aryldichloroarsine and a diarylarsine gives a *triarylchlorodiarsine* :

$$RAsCl_2+R_2AsH=R_2As.AsClR+HCl$$

(4) A diaryldi-iododiarsine and a primary arylarsine in alcoholic solution in a carbon dioxide atmosphere at about 70° C. react as follows :

$$RAsI.AsIR+RAsH_2=RAs\begin{array}{l}-As-R\\ \diagdown\ \diagup\\ \ \ As\\ \ \ |\\ \ \ R\end{array}+2HI$$

(5) If the arylarsine is replaced by a diarylarsine (2 mols.) the course of the reaction is :

$$2R_2AsH+RAsI.AsIR=R_2.As.As\begin{array}{l}-As.AsR_2\\ \ \ |\ \ \ \ |\\ R\ \ R\end{array}+2HI$$

Oxidation of these compounds by dilute nitric acid yields arsinic acids, whilst oxidation by air results in arsenoxides. The compounds react with alkyl iodides, the resulting products being fully dealt with in the following pages.

Triphenyldiarsine, $(C_6H_5)_2As.AsH(C_6H_5)$.[1]—The preparation of this compound is carried out in a specially designed apparatus, which ensures the reaction and the filtration being conducted in an atmosphere of carbon dioxide. In such an apparatus 8 grams of diphenylchloroarsine are mixed with 2·3 grams of phenylarsine in ether solution, $C_6H_5.AsH_2+ClAs(C_6H_5)_2=(C_6H_5)_2As.AsH(C_6H_5)+HCl$. The reaction is started by gently warming the reaction flask with water, when hydrogen chloride is evolved and white needles separate. When the diarsine is treated with dilute nitric acid, and the mixture evaporated on the water-bath, complete oxidation ensues, and from the reaction mixture phenyl- and diphenyl-arsinic acids may be isolated. Treatment with iodine, followed by methyl iodide in a sealed tube at 100° C., gives phenyldi-iodoarsine and diphenyliodoarsine as arsonium compounds.

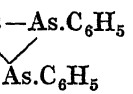
Triphenylchlorodiarsine, $(C_6H_5)_2As.AsCl(C_6H_5)$.—To a solution of 9·2 grams of diphenylarsine in 40 c.c. of ether in an atmosphere of carbon dioxide, 4·5 grams of phenyldichloroarsine in the same solvent are added. After warming to about 30° C., gas evolution takes place, white needles separate, and after about two hours the reaction is complete. The liquor is decanted off and the crystals washed with ether. The diarsine melts to a turbid liquid at 164° C., this becoming clear at 179° C.

[1] Steinkopf and Smie, *Ber.*, 1926, 59, [B], 1453.

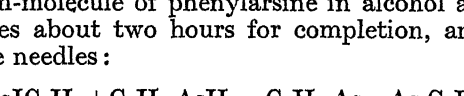
Oxidised by nitric acid the diarsine yields phenyl- and diphenyl-arsinic acids. The preparation may be represented as follows:

$$(C_6H_5)_2AsH+Cl_2AsC_6H_5=(C_6H_5)_2As.AsCl(C_6H_5)+HCl$$

cycloTriphenyltriarsine,



This is formed by the interaction of diphenyldi-iododiarsine and rather more than 1 gram-molecule of phenylarsine in alcohol at about 70° C. The reaction takes about two hours for completion, and the product is obtained in fine needles:



When 3·5 grams of the triarsine are heated with 11 grams of methyl iodide for eight hours at 100° C., the following products are obtained: 1·7 grams of phenyldi-iodoarsine, 1·2 grams of phenyltrimethylarsonium iodide, and 5·2 grams of phenyltrimethylarsonium tri-iodide.

Tetraphenyldiarsine, *Phenylcacodyl,* $(C_6H_5)_2As.As(C_6H_5)_2$.—Diphenylarsenoxide in boiling alcohol solution is reduced by an excess of phosphorous acid to tetraphenyldiarsine.[1] This method of preparation has more recently been repeated,[2] and the product, which is crystalline, introduced into sealed glass tubes without coming into contact with the air. It melts at 130° to 135° C. (corr.),[3] and in moist air is not spontaneously inflammable, but is oxidised to diphenylarsinic acid and *tetraphenyldiarsine oxide*; a benzene solution also gradually absorbs oxygen. Chlorine converts the diarsine to diphenylarsenic chloride, and with iodine, diphenyliodoarsine appears to be formed. The diarsine reacts with methyl iodide, yielding diphenyldimethylarsonium iodide and diphenyliodoarsine. The vapour pressure of tetraphenyldiarsine at 200° C. is about 1 mm., and at 300° C. in a vacuum it decomposes, giving arsenic and triphenylarsine. It does not dissociate at the boiling-point of benzene.[4] The molecular weight, as determined in naphthalene, increases from 500 to 760 with time, and at the latter value the iodine absorption is 40 per cent. The specific conductivity in liquid sulphur dioxide also increases with age of the solution, changing from $13{\cdot}3\times10^{-6}$ to 100×10^{-6} mhos in nineteen days. In the fused state, at 132° C., the specific conductivity is $13{\cdot}3\times10^{-6}$ mhos, and with rise in temperature to 307° or 308° C. the value becomes 880×10^{-6} mhos. From this data it appears that the bond between the arsenic atoms is easily ruptured, but it is doubtful whether bivalent arsenic, which may be present in solution, is present in the stable form.

Tetranitrotetraphenyldiarsine, $(NO_2.C_6H_4)_2As.As(C_6H_4.NO_2)_2$,[5] results when an acetic acid solution of dinitrodiphenylarsinic acid is

[1] Michaelis and Schulte, *Ber.*, 1882, 15, 1952; Michaelis, *Annalen*, 1902, 321, 151.
[2] Porter and Borgstrom, *J. Amer. Chem. Soc.*, 1919, 41, 2048; see Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[3] Borgstrom and Dewar, *J. Amer. Chem. Soc.*, 1922, 44, 2915.
[4] Schlenk, *Annalen*, 1912, 394, 216.
[5] Michaelis, *ibid.*, 1902, 321, 151.

boiled with a moderate excess of phosphorous acid. If too large an excess of the latter is used, reduction of the nitro-groups also occurs. The diarsine crystallises in plates, melting at 200° C. to a yellow liquid, and at higher temperatures explodes. It is insoluble in the usual solvents; it readily combines with chlorine, bromine, and sulphur.

Tetra-aminotetraphenyldiarsine is prepared like the nitro-compound, but using a large excess of phosphorous acid. It is an amorphous powder, yielding a white *acetyl derivative*, M.pt. 162° C.

sym.-Diphenyldimethyldiarsine or *sym.-Phenylmethylcacodyl*, $(CH_3.C_6H_5.As)_2$.[1]—In order to prepare this derivative it is necessary to obtain *sym.-phenylmethylarsenoxide*, $(CH_3.C_6H_5.As)_2O$, in the following manner: Eight grams of phenylmethylbromoarsine in 20 c.c. of alcohol are heated under reflux on the water-bath, and then treated with alcoholic potassium hydroxide until the mixture is alkaline. The potassium bromide is removed, washed with a little alcohol, and the bulk of the alcohol removed from the filtrate by distillation. The oxide is precipitated from the residue by the addition of water, collected in a separating funnel, and dried over calcium chloride. Yield, 5 grams. The oxide may be purified by distillation in a carbon dioxide atmosphere, a colourless, highly refractive oil, B.pt. about 94° C. at 11 mm., being obtained. It is soluble in alcohol, insoluble in water.

Eight grams of the oxide and 6 grams of crystallised phosphorous acid in absolute alcohol solution are boiled under reflux for twenty minutes. An oil separates, which is treated with water after cooling, a solid soon resulting. In air the latter melts with evolution of heat, but does not inflame. When dried in a vacuum in a carbon dioxide atmosphere it melts at about 70° C. When treated with methyl bromide it is converted into phenyltrimethylarsonium bromide and phenylmethylbromoarsine, but phenyltrimethylarsonium iodide results if methyl iodide is used.

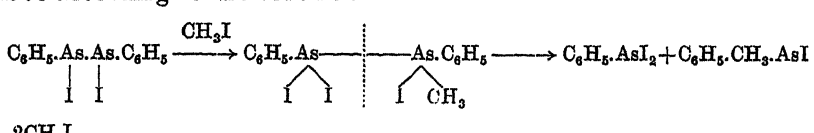
sym.-Diphenyldi-iododiarsine, $C_6H_5.AsI.AsI.C_6H_5$,[2] is obtained in bright yellow needles when phenyldi-iodoarsine in alcohol solution is reduced by phosphorous acid. It oxidises in air:

$$(C_6H_5)_2As_2I_2+O_2+H_2O=C_6H_5.AsI_2+C_6H_5.AsO.(OH)_2$$

Nitric acid decomposes this compound, yielding phenylarsinic acid and iodine, whilst heating causes decomposition as follows:

$$3(C_6H_5)_2As_2I_2=2(C_6H_5)_3As+2AsI_3+2As$$

With methyl iodide, the diarsine gives phenyltrimethylarsonium tri-iodide and mono-iodide, also phenyldi-iodoarsine, the reaction taking place according to the scheme:[3]



The relatively small amount of tri-iodide produced is accounted for by its interaction with *sym.*-diphenyldi-iododiarsine, as shown.

[1] Steinkopf and Schwen, *loc. cit.*; compare Steinkopf and Smie, *loc. cit.*
[2] Michaelis and Schulte, *Ber.*, 1882, 15, 1952. [3] Steinkopf and Schwen, *loc. cit.*

Pentaphenyltriarsine, $(C_6H_5)_2As.As(C_6H_5).As(C_6H_5)_2$.[1]—When 2·5 grams of phenylarsine and 9 grams of diphenylchloroarsine react in 40 c.c. of absolute alcohol in a carbon dioxide atmosphere at 70° C., gas evolution soon takes place and a thick, white, crystalline mass of the triarsine separates. After a short time this is removed and washed with alcohol. The triarsine may also be prepared from diphenylarsine and phenyldi-iodoarsine. It is decomposed by iodine in alcoholic solution into phenyldi-iodoarsine and diphenyliodoarsine:

$$(C_6H_5)_2As.As(C_6H_5).As(C_6H_5)_2+2I_2=2(C_6H_5)_2AsI+C_6H_5AsI_2$$

The reaction product with methyl iodide yields dimethyldiphenylarsonium tri-iodide and phenyldi-iodoarsine in the molecular ratio of 0·95 : 2·08.

Hexaphenyltetra-arsine, $(C_6H_5)_2As.As(C_6H_5).As(C_6H_5).As(C_6H_5)_2$, is prepared according to the equation:

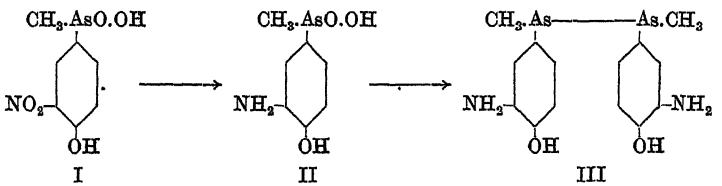
$$2(C_6H_5)_2AsH+(C_6H_5)IAs.AsI(C_6H_5)=(C_6H_5)_2As.As(C_6H_5)As.As(C_6H_5)_2+2HI$$

The reaction is carried out as before in carbon dioxide at about 70° C., using alcohol as solvent, and the product obtained is a white solid, only very sparingly soluble in alcohol, from which it separates in needles on cooling. These react with iodine as follows:

$$(C_6H_5)_2As.As(C_6H_5).As(C_6H_5).As(C_6H_5)_2+3I_2=2C_6H_5AsI_2+2(C_6H_5)_2AsI$$

The reaction mixture from the iodination gives with methyl iodide at 100° C. after fifteen hours' heating, phenyldi-iodoarsine and dimethyldiphenylarsonium tri-iodide in the molecular ratio of 0·88 : 1.

3 : 3′-Diamino-4 : 4′-dihydroxydiphenyldimethyldiarsine.[2]



3-Nitro-4-hydroxyphenylmethylarsinic acid (I) and the corresponding 3-amino compound (II) are described on p. 289. The final stage in the synthesis is carried out as follows: 4·62 grams of the amino-acid (II) are dissolved in 50 c.c. of hypophosphorous acid (density 1·136), containing 0·5 c.c. of hydriodic acid (density 1·7). The reduction is rapid, and after thirty minutes, 50 c.c. of water are added and the solid filtered off in a carbon dioxide atmosphere and washed with much acetone and ether. White, rhombic crystals (5·1 grams) of the hypophosphite of the arsine (III) result. The frec arsine is readily soluble in dilute sodium hydroxide, dilute hydrochloric and sulphuric acids, but insoluble in sodium carbonate solution. With sodium nitrate it forms a yellow diazo-solution. It reduces Fehling's and Tollen's solutions, and explodes in contact with nitric acid (density 1·53).

[1] Steinkopf and Smie, *loc. cit.*
[2] Bertheim, *Ber.*, 1915, 48, 357.

CHAPTER III.

AROMATIC HALOGENATED AND CYANOARSINES.

Compounds of the Type $RAsX_2$.

It has already been pointed out that primary arsines, $RAsH_2$, may have their hydrogen replaced by halogens (p. 62), thus yielding compounds of the type $RAsX_2$. The difficulty of obtaining primary arsines, however, does not permit this method being of practical value. The principal mode of formation consists of heating tertiary arsines with arsenic trichloride under pressure, and at a high temperature, the following reaction taking place :

$$R_3As+2AsCl_3=3RAsCl_2$$

In this method some diphenylchloroarsine results as a by-product. Heating arsenic trichloride with mercury diaryls or with arylmercuric halides also has a wide application :

$$R_2Hg+2AsCl_3=2RAsCl_2+HgCl_2$$
$$RHgCl+AsCl_3=RAsCl_2+HgCl_2$$

Other methods not so extensively used are as follows :—

(1) Arylarsenoxides are allowed to react with halogen acids :

$$RAsO+2HX=RAsX_2+H_2O$$

(2) Phenylarsenic chloride, $C_6H_5.AsCl_4$, is decomposed by acetic acid, losing two chlorine atoms :

$$C_6H_5.AsCl_4+CH_3.COOH=C_6H_5.AsCl_2+CH_2Cl.COOH+HCl$$

(3) Tertiary arsines react with thallic chloride, forming thallous chloride and compounds of the type $RAsX_2$.

(4) Aryldi-iodoarsines may be isolated by treating the corresponding dichloroarsines with sodium iodide in absolute alcohol :

$$RAsCl_2+2NaI=RAsI_2+2NaCl$$

(5) By the interaction of arsenobenzene, or *sym.*-diphenyldi-iodoarsine, with aryltrialkylarsonium tri-iodides, p. 86.

(6) Arylarsinic acids in alcohol solution are treated with concentrated hydrochloric acid and a trace of iodine and the solution saturated with sulphur dioxide whilst hot, when the dichloroarsine separates out. The dichloro-compounds are either highly refractive liquids, evolving pungent odours when heated, or white, low melting solids. They react with dry chlorine, yielding arylarsenic tetrachlorides, $RAsCl_4$, which are decomposed by moisture, forming oxychlorides of the type $RAsOCl_2$, which may be further hydrolysed to the corresponding acids. In some cases the oxychlorides are prepared by treating arylarsenoxides with dry chlorine.

The dichloroarsines may lose their chlorine in two stages when treated with sodium ethoxide, according to the amount of the latter used :

$$RAsCl_2+NaOEt=RAsCl(OEt)+NaCl$$

or

$$RAsCl_2+2NaOEt=RAs(OEt)_2+2NaCl$$

Phenyldichloroarsine, $C_6H_5.AsCl_2$.—This compound has been prepared in a variety of ways :—

(1) Since phosphenyl chloride is readily obtained from phosphorus trichloride and benzene, this method has been applied to the corresponding arsenic compound. Arsenic trichloride (1000 c.c.) and 500 c.c. of benzene are heated together for forty hours and the resulting product fractionated. The fraction between 240° and 260° C. yields fairly pure product. The method, however, is not a particularly good one, and diphenylchloroarsine is formed at the same time.[1]

(2) Triphenylarsine and arsenious chloride are heated in a sealed tube at 250° C., or at ordinary pressures, using a high temperature.[2]

(3) By using mercury diphenyl. Seventy grams of the latter with 800 grams of arsenious chloride (freed from chlorine by shaking with mercury, and from hydrochloric acid by heating slowly to the boiling-point) are quickly raised to 254° C. and maintained at that temperature for about four hours. An 88 gram yield is obtained, but if lower temperatures are used some phenylmercuric chloride is formed:

$$(C_6H_5)_2Hg+2AsCl_3=2C_6H_5AsCl_2+HgCl_2.$$[3]

(4) Using phenylmercuric chloride. Thirty grams of this compound and 100 grams of arsenious chloride are heated together on the water-bath for four to five hours. The product is then filtered off and the filtrate distilled *in vacuo*, excess of arsenious chloride being removed by first distilling at 100° C.[4]

Phenyldichloroarsine is a colourless, strongly refracting liquid, B.pt. 250° to 255° C., non-fuming in air, possessing a pungent odour when hot. Treatment with alkaline hydroxides yields unstable derivatives of the type $C_6H_5.As(OM)_2$. Chlorine combines with it to produce phenylarsenic chloride. With sodium ethoxide it gives *phenylethoxychloroarsine*, $C_6H_5.AsCl.OEt$, a colourless oil, B.pt. 125° to 126° C. at 12 mm.[5] With chlorosulphonic acid the dichloroarsine forms benzenesulphonyl chloride.[6]

Phenylarsenic chloride, $C_6H_5.AsCl_4$,[7] is prepared as described above. It crystallises in yellow needles, M.pt. 45° C., transformed by moist air to the oxychloride, $C_6H_5AsOCl_2$, and finally to phenylarsinic acid. When the chloride is heated in a sealed tube at 150° C. it is

[1] La Coste and Michaelis, *Ber.*, 1878, 11, 1883 ; see La Coste and Michaelis, *Annalen*, 1880, 201, 184 ; La Coste, *Inaug. Dissert.*, Freiburg, 1879.

[2] Michaelis and Reese, *Ber.*, 1882, 15, 2873 ; see British Patent, 142880 (1920) ; see Morgan and Vining, *Trans. Chem. Soc.*, 1920, 117, 780 ; Pope and Turner, *ibid.*, 1920, 117, 1450.

[3] Michaelis, *Ber.*, 1876, 9, 1566 ; La Coste and Michaelis, *Annalen*, 1880, 201, 184.

[4] Roeder and Blasi, *Ber.*, 1914, 47, 2748.

[5] M'Kenzie and Wood, *Trans. Chem. Soc.*, 1920, 117, 406.

[6] Steinkopf, Schubart, and Schmidt, *Ber.*, 1928, 61, [B], 678.

[7] Michaelis, *ibid.*, 1876, 9, 1566 ; 1877, 10, 622 ; see La Coste and Michaelis, *Annalen*, 1880, 201, 184.

decomposed into arsenious chloride and chlorobenzene. It reacts with acetic acid according to the equation :

$$C_6H_5AsCl_4 + CH_3.COOH = C_6H_5AsCl_2 + CH_2Cl.COOH + HCl$$

Phenylarsenic oxychloride, $C_6H_5AsOCl_2$, may be prepared by treating the above tetrachloride with the requisite amount of water, or in quantitative yield by the action of chlorine on phenylarsenoxide. It is a white, crystalline substance, melting at about 100° C., fumes slightly in air, changing to the acid. It is readily soluble in water, the acid crystallising from the solution. Heated at 120° C. it is decomposed into chlorobenzene and arsenious oxychloride. In a similar manner *phenylarsenic oxybromide* is produced by the action of bromine on phenylarsenoxide.

Phenyldibromoarsine, $C_6H_5.AsBr_2$, results when concentrated hydrobromic acid reacts with phenylarsenoxide. It is a transparent, pale yellow liquid, B.pt. 285° C., having a faint odour, and is unchanged by water. Its density at 15° C. is 2·0983.

Phenyldi - iodoarsine, $C_6H_5.AsI_2$.[1] — Phenyldichloroarsine (34 grams), 90 grams of powdered sodium iodide, and 100 c.c. of absolute alcohol are shaken together for three hours. The filtrate is evaporated to dryness under reduced pressure and the residue extracted with chloroform, the extract then being evaporated in a vacuum until free from chloroform. A brownish-red oil results, which is crystallised from alcohol, using solid carbon dioxide for cooling. Another method of preparation is as follows :[2] To an aqueous solution of 10 grams of phenylarsinic acid and 17 grams of potassium iodide, 8 c.c. of concentrated hydrochloric acid are added and sulphur dioxide passed through the warm solution. Phenyldi-iodoarsine separates, is dried in ether solution by calcium chloride, and fractionated. The yield is 8·5 grams, or 42 per cent. The iodide from the first method separates from alcohol in lemon-yellow clusters of needles, M.pt. 15° C., B.pt. 190° C. at 12 mm., with slight decomposition. The boiling-point for the iodide produced in the second method is given as 205·5° C. at 14 mm.

Phenyldicyanoarsine, $C_6H_5As(CN)_2$,[3] results when phenyldichloroarsine and silver cyanide interact in benzene or toluene. It melts at 78·5° to 79·5° C.

o-Tolyldichloroarsine, $C_7H_7.AsCl_2$,[4] is isolated by boiling mercury di-*o*-tolyl with arsenious chloride and fractionating the resulting product. It is a colourless liquid, B.pt. 264° to 265° C., having a faint odour and distilling unchanged in a carbon dioxide atmosphere. When treated with chlorine it yields *o-tolylarsenic chloride,* $C_7H_7.AsCl_4$, a yellow, viscous liquid, which yields *o*-tolylarsinic acid and hydrochloric acid when treated with water. *o*-Tolyldichloroarsine yields the oxide when boiled with aqueous sodium carbonate. The chloride is soluble in benzene, ether, and alcohol.

m-Tolyldichloroarsine [5] is obtained in 40 per cent. yield by

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1920, 117, 1373 ; see also Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.

[2] Steinkopf and Smie, *Ber.*, 1926, 59, [B], 1461.

[3] Grischkievitch-Trochimovski, Mateyak, and Zablotski, *Bull. Soc. chim.*, 1927, [iv.], 41, 1323 ; *Rocz. Chem.*, 1927, 7, 230.

[4] La Coste and Michaelis, *loc. cit.*, also *Ber.*, 1878, 11, 1888.

[5] Michaelis, *Annalen*, 1902, 320, 326 ; Eisenlohr, *Inaug. Dissert.*, Rostock, 1893.

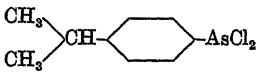
heating tri-*m*-tolylarsine and arsenious chloride in a sealed tube at 300° C. It is a highly refractive liquid, B.pt. 270° C., and yields a crystalline *tetrachloride*, M.pt. 38° C., when chlorinated.

p-Tolyldichloroarsine, prepared by the usual methods, crystallises in colourless plates, M.pt. 31° C., B.pt. 267° C., unchanged in a current of carbon dioxide. It yields *p-tolylarsenic chloride* with chlorine, and possesses a similar solubility and similar properties to the *ortho*-compound.

p-Tolylarsenic oxychloride, $C_7H_7.AsOCl_2$, results when the oxide is treated with dry chlorine. It is a bright yellow compound.[1]

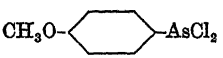
Benzyldichloroarsine, $C_6H_5.CH_2.AsCl_2$, is a liquid, B.pt. 175° C. at 50 mm., decomposed by water yielding benzaldehyde, and by chlorine giving benzyl chloride. This chloride is far less stable than the other compounds mentioned in this section.

p-Cumyldichloroarsine,[2]



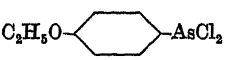
Ten grams of tricumylarsine and 40 grams of arsenious chloride are heated for forty-eight hours at 170° C., the yield of chloride being about 6 grams. It distils at 170° C. at 30 mm. and does not solidify.

p-Anisyldichloroarsine,[3]



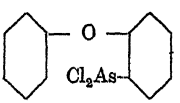
obtained from tri-*p*-anisylarsine and arsenious chloride, is a colourless product, M.pt. 48° C., B.pt. 160° C. at 30 mm., 230° C. at 117 mm. *p-Anisylarsenic chloride*, $CH_3O.C_6H_4.AsCl_4$, is a viscous, yellow liquid.

p-Phenetyldichloroarsine,



is a colourless liquid, B.pt. 198° C. at 28 mm., yielding a solid *tetrachloride* when chlorinated.

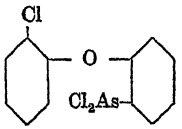
o-Phenoxyphenyldichloroarsine,[4]



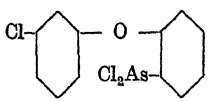
The corresponding arsinic acid (p. 164), suspended in hydrochloric acid, is saturated with sulphur dioxide in the presence of a little iodine. The chloride separates as an orange-red oil, which is isolated by the aid of carbon tetrachloride. Attempts to distil the product at 10 mm. pressure transform it completely into 6-*chlorophenoxyarsine.* Combination of the chloride in alkaline solution with methyl iodide yields *o-phenoxyphenylmethyliodoarsine*, which may be converted into the *oxide*, and then into the *chloride*. The latter is a brownish-yellow, viscous oil.[5]

[1] See La Coste and Michaelis, *Annalen*, 1880, 201, 184.
[2] Michaelis, *ibid.*, 1902, 320, 339.
[3] Michaelis, *ibid.*, p. 298; Michaelis and Weitz, *Ber.*, 1887, 20, 51.
[4] Turner and Sheppard, *Trans. Chem. Soc.*, 1925, 127, 546.
[5] Roberts and Turner, *J. Chem. Soc.*, 1926, p. 1209.

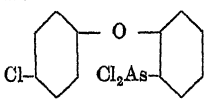
2-o-Chlorophenoxyphenyldichloroarsine,[1]



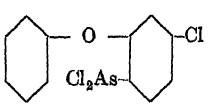
The corresponding arsinic acid is reduced in warm concentrated hydrochloric acid suspension by sulphur dioxide in the presence of a little potassium iodide. The crude chloride is then dissolved in alcoholic sodium hydroxide containing sodium sulphite and the whole poured into dilute sulphuric acid, whereby the chloride is converted into the oxide. The oxide, when warmed with concentrated hydrochloric acid, gives the pure chloride in almost theoretical yield. The chloride is a pale yellow oil, boiling with partial decomposition at 217° C. at 18 mm. In a similar manner *2-m-chlorophenoxyphenyldichloroarsine*



and the *2-p-chloro-* compound



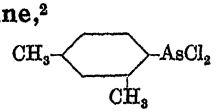
are prepared, the former a pale yellow oil, boiling with decomposition at about 220° C. at 10 mm., and the latter forming pale yellow, prismatic needles, M.pt. 67° to 68° C., and boiling with partial decomposition at about 220° C. at 10 mm. *4-Chloro-2-phenoxyphenyldichloroarsine*



crystallises in yellow cubes or octahedra, M.pt. 91° to 92° C.

o-Phenylthiolphenyldichloroarsine, prepared in the usual way, is a pale, yellowish-brown, viscous oil.

m-Xylyldichloroarsine,[2]

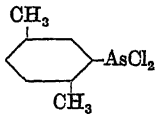


This has been prepared in three ways: (1) Fifty grams of mercury di-*m*-xylyl are added in small portions, with frequent shaking, to 500 grams of arsenious chloride, and after twenty hours' standing the mercuric chloride is removed and the filtrate fractionated. (2) Ten grams of tri-*m*-xylylarsine and 40 grams of arsenious chloride are heated together in a sealed tube at 240° C., and the resulting product fractionated. (3) By the interaction of tri-*m*-xylylarsine and thallic chloride.[3] The chloride crystallises in long, colourless needles, M.pt. 42° to 43° C., B.pt. 278° C. at 760 mm., or 215° C. at 320 mm. The

[1] Roberts and Turner, *Trans. Chem. Soc.*, 1925, 127, 2009.
[2] Michaelis, *Annalen*, 1902, 320, 330; Seeman, *Inaug. Dissert.*, Rostock, 1891.
[3] Goddard, *Trans. Chem. Soc.*, 1923, 123, 1170.

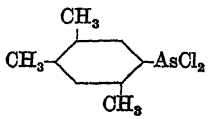
crystals tend to pass into the oxide when exposed to air. *m-Xylylarsenic chloride*, $(CH_3)_2C_6H_3.AsCl_4$, is a white, crystalline mass, gradually changing to the *oxychloride*, $(CH_3)_2C_6H_3.AsOCl_2$, then to the acid, $(CH_3)_2C_6H_3.AsO(OH)_2$.

p-Xylyldichloroarsine,



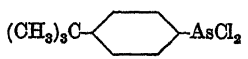
crystallises in tufts of white needles, M.pt. 63° C., B.pt. 285° C. The corresponding *iodide* forms a yellow, crystalline mass, M.pt. 45° C. An *oxychloride* has been prepared, which crystallises from dilute alcohol in long needles, M.pt. 178° C.

Pseudocumyldichloroarsine,



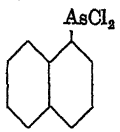
Tri-*pseudo*cumylarsine (5 grams) and 20 grams of arsenious chloride are heated for forty-eight hours at 200° C. in a sealed tube, and the resulting product fractionated at 30 mm., the chloride distilling over at 190° C. It crystallises in small, white needles, M.pt. 82·5° C.

Tert.-butylphenyldichloroarsine,



is a colourless liquid, B.pt. 175° to 180° C. at 20 mm.

α-Naphthyldichloroarsine,[1]



This chloride may be prepared either from mercury di-α-naphthyl and arsenious chloride, or by heating one part of tri-α-naphthylarsine with 20 parts of arsenious chloride at 270° C. for forty hours. The excess of arsenious chloride is removed under reduced pressure and the residue extracted with ether, a grey mass being left when the solvent is distilled off. This, when recrystallised from alcohol or petroleum ether, yields a pure white product, M.pt. 63° C. A more recent investigation gives M.pt. 68° C., and B.pt. 180° C. at 5 mm.[2]

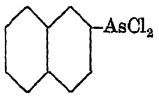
α-Naphthyldicyanoarsine, $C_{10}H_7.As(CN)_2$, is obtained by the interaction of silver cyanide and α-naphthyldichloroarsine.[3] It melts at 159·5° to 160·5° C.

[1] Michaelis, *Annalen*, 1902, 320, 342; Büschler, *Inaug. Dissert.*, Rostock, 1893; Michaelis and Schulte, *Ber.*, 1882, 15, 1954.

[2] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1015.

[3] Grischkievitch-Trochimovski, Mateyak, and Zablotski, *Rocz. Chem.*, 1927, 7, 230; *Bull. Soc. chim.*, 1927, [iv.], 41, 1323.

β-Naphthyldichloroarsine,[1]

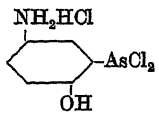


is obtained by the mercury diaryl method as indicated before, and not from tri-β-naphthylarsine, as the latter is difficult to obtain. The chloride crystallises in fine, warty groups of needles, M.pt. 69° C., readily soluble in alcohol, ether, and benzene, sparingly soluble in petroleum ether. It is slowly decomposed by water, forming the oxide.

Cyclohexyldichloroarsine, $C_6H_{11}.AsCl_2$.[2] — When di*cyclo*hexylchloroarsine in petroleum ether is chlorinated, a crystalline *trichloride* results. This decomposes at 80° to 90° C., yielding the dichloroarsine, a transparent liquid, B.pt. 122° to 125° C. at 15 mm.

Halogenated Arsines containing Hydroxyl Groups.

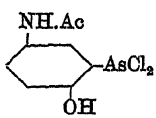
5-Amino-2-hydroxyphenyldichloroarsine hydrochloride,[3]



A solution of 20 grams of 5-amino-2-hydroxyphenylarsinic acid in 60 c.c. of water and 200 c.c. of hydrochloric acid is treated with sulphur dioxide for ninety minutes. The precipitated dichloroarsine hydrochloride is purified by solution in 80 c.c. of water and reprecipitation by 160 c.c. of hydrochloric acid, when 15·5 grams of anhydrous white prisms result. These are soluble in four parts of water, which transforms them to the arsenoxide hydrochloride.

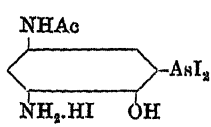
5-Amino-2-hydroxyphenyldi-iodoarsine hydriodide, obtained from the arsenoxide, forms yellow prisms, soluble in water, giving a yellow solution. This solution gradually deposits the arsenoxide hydriodide.

5-Acetamido-2-hydroxyphenyldichloroarsine,



results when the corresponding arsenoxide is triturated with an excess of alcoholic hydrogen chloride and the liquid allowed to evaporate spontaneously. The residue, dissolved in alcohol and precipitated by ether, forms white or pale yellow needles, soluble in cold alcohol or cold water, the latter causing slow hydrolysis to the corresponding arsenoxide.

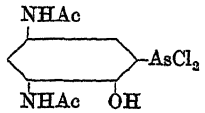
3-Amino-5-acetamido-2-hydroxyphenyldi-iodoarsine hydriodide,



[1] Michaelis, *loc. cit.* [2] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[3] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 2375.

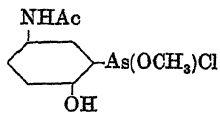
forms yellow, boat-shaped crystals, giving a yellow aqueous solution, which slowly deposits crystals of the arsenoxide hydriodide.

3 : 5-Diacetamido-2-hydroxyphenyldichloroarsine,



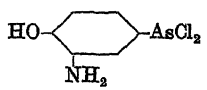
crystallises in clusters of needles, soluble in and slowly hydrolysed by water.

5-Acetamido-2-hydroxyphenylmethoxychloroarsine,



The corresponding arsenoxide in methyl alcohol is treated with methyl alcoholic hydrogen chloride, and after thirty minutes the solution is concentrated under reduced pressure. Yield, about 70 per cent.

3-Amino-4-hydroxyphenyldichloroarsine,

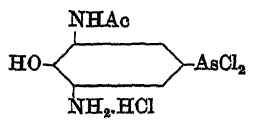


is obtained as the monohydrate by the general methods. Hydrolysis of its hydrochloride by water (3 grams in 10 c.c.) yields the arsenoxide, and the filtrate contains approximately two-thirds of the total chlorine introduced.[1]

3-Amino-4-hydroxyphenyldi-iodoarsine hydriodide, isolated from the preceding compound by treating its aqueous solution with an excess of concentrated hydriodic acid, or by general methods, forms yellow prisms, giving yellow aqueous solutions. When treated with hot 8*N* nitric acid, only one-third of the total iodine is removed.

3-Acetamido-4-hydroxyphenyldichloroarsine is formed in the same way as the 5-acetamido-2-hydroxy derivative, having a similar crystalline form and similar physical properties.

3 - Amino - 5 - acetamido - 4 - hydroxyphenyldichloroarsine hydrochloride,



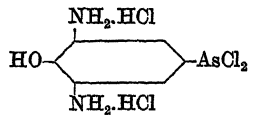
is obtained in 60 per cent. yield by the sulphurous acid reduction of the arsinic acid in hydrochloric acid at room temperature in the presence of a little potassium iodide. It crystallises in white prisms, soluble in dilute alkali hydroxide.

3-Amino-5-acetamido-4-hydroxyphenyldi-iodoarsine hydriodide may be prepared either from the arsenoxide, or by reduction of the arsinic acid with sulphurous acid, using either an acidified solution

[1] For the preparation of 3-amino-4-hydroxyphenyldichloroarsine by treating the aminoaryldichloroarsine hydrochloride with a limited quantity of piperazine or ethylamine, see British Patent, 260382 (1925).

of potassium iodide or hydriodic acid. It crystallises in prisms, in which the acetyl group is remarkably stable towards hot mineral acids, and its yellow aqueous solutions deposit crystals of the arsenoxide.

3 : 5 - Diamino - 4 - hydroxyphenyldichloroarsine dihydrochloride,

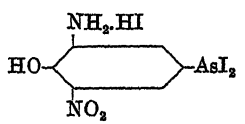


is the hydrolysis product of the foregoing dichloroarsine, using 5*N* hydrochloric acid. The yield is about 50 per cent.; it forms white plates, readily soluble in water.

3 : 5-Diamino-4-hydroxyphenyldi-iodoarsine dihydriodide.—The preceding compound in aqueous solution is treated with hydriodic acid (density 1·7), and the dihydriodide obtained in yellow, water-soluble prisms.

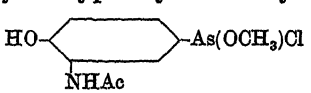
3 : 5-Diacetamido-4-hydroxyphenyldichloroarsine crystallises in clusters of needles, readily soluble in water, by which they are slowly hydrolysed.

3-Nitro-5-amino-4-hydroxyphenyldi-iodoarsine hydriodide,



prepared from the corresponding arsinic acid, consists of yellow prisms, giving a yellow solution in water and a red solution in alkali carbonate or hydroxide.

3-Acetamido-4-hydroxyphenylmethoxychloroarsine,



is isolated under similar conditions to those for the 5-acetamido-2-hydroxy compound. It forms white prisms, converted by warm water to the corresponding *arsenoxide.*

Compounds of the Type R_2AsX.

This type of arsenical came into great prominence during the war, owing to the extensive use of diphenylchloro- and diphenylcyano-arsines for military purposes. The following are the principal methods of preparation for the type R_2AsX, where X=halogen :—

(1) The most successful method for preparing diphenylchloroarsine consists in heating triphenylarsine and arsenious chloride in a rotating autoclave, 93 per cent. of the resulting mixture being the desired product (see p. 115):

$$2R_3As + AsX_3 = 3R_2AsX$$

The by-product in this reaction is phenyldichloroarsine. A modification of the process consists in replacing the arsenious chloride by phenyldichloroarsine:

$$R_3As + RAsX_2 = 2R_2AsX$$

An excellent method has also been devised which uses the same materials as shown in the first equation, but carries out the operation without the use of an autoclave (see p. 115).

(2) The oldest method, and one which gives good results, consists in heating together mercury diaryls and arsenious chloride or aryldichloroarsines. The latter derivatives are useful when mixed arylarsines are desired :

$$R_2Hg+AsX_3=R_2AsX+HgX_2$$
$$Ar_2Hg+2Ar'AsX_2=2ArAr'AsX+HgX_2$$

(3) Tertiary arsine dichlorides, when distilled under reduced pressure, split off aryl chloride. The method is not a very good one :

$$R_3AsX_2=R_2AsX+RX$$

(4) An obvious method of obtaining these halides is to treat the corresponding oxides with halogen acids :

$$(R_2As)_2O+2HX=2R_2AsX+H_2O$$

(5) The addition of magnesium aryl halide to arsenious chloride has been used in the preparation of di-α-naphthylchloroarsine :

$$2RMgX+AsX_3=R_2AsX+2MgX_2$$

(6) Secondary arsines, when treated with iodine, exchange hydrogen for iodine :

$$R_2AsH+I_2=R_2AsI+HI$$

(7) The iodides may also be obtained from diarylchloroarsines by the action of sodium iodide in dry acetone :

$$R_2AsCl+NaI=R_2AsI+NaCl$$

(8) Tetra-aryldiarsines are decomposed by halogen with formation of diarylhalidearsines :

$$R_2As.AsR_2+X_2=2R_2AsX$$

The following methods have been used for the isolation of aliphatic-aromatic halogenated arsines :—

(1) Aryldialkylarsine dihalides, when heated to about 180° C., split off alkyl halide :

$$ArAlk_2AsX_2=ArAlkAsX+AlkX$$

(2) Method (7) above may be used.

(3) Arylalkyliodoarsines are converted by sodium hydroxide to the oxide, which is then treated with hydrochloric acid to convert it to the chloride.

(4) Aryldichloroarsines are methylated by dissolving in alcohol, adding sodium hydroxide and methyl iodide, then neutralising the mixture with hydrochloric acid and allowing it to stand for at least twenty-four hours. Removal of sodium chloride and alcohol yields crude arylalkyliodoarsine.

Cyanoarsines, originally prepared by treating diarylarsenoxides with anhydrous hydrogen cyanide, are better isolated as follows :—

(1) By the interaction of tetra-aryldiarsines or diarylarsenious sulphides and mercuric cyanide :

$$R_2As.AsR_2+Hg(CN)_2=2R_2As.CN+Hg$$
$$R_2As.S.AsR_2+Hg(CN)_2=2R_2As.CN+HgS$$

In the latter reaction silver cyanide may replace mercury cyanide.

(2) By treating diarylchloroarsines with silver cyanide in a rotating autoclave :

$$R_2AsCl+AgCN=R_2As.CN+AgCl$$

(3) The halogen atom in diarylchloroarsines may be replaced by the grouping —OEt by the action of sodium ethoxide, and the product thus obtained transformed to the cyanide by the action of hydrogen cyanide.

(4) Phenyldimethylarsine cyanobromide, or the corresponding ethyl compound, is decomposed by heat, yielding phenylmethylcyanoarsine :

$$RAlk_2As.CNBr=RAlkAs.CN+AlkBr$$

The halogenated aromatic arsines combine additively with dry chlorine or bromine, yielding diarylarsine trihalides :

$$R_2AsX+X_2=R_2AsX_3$$

These trihalides also result when tetra-aryldiarsines are treated with chlorine, or diarylarsines with an excess of halogen :

$$R_2As.AsR_2+3Cl_2=2R_2AsCl_3$$
$$R_2AsH+2Cl_2=R_2AsCl_3+HCl$$

The trihalides are decomposed by water, yielding diarylarsinic acids and halogen acids, and, when distilled, are degraded to aryldihalogenarsines :

$$R_2AsX_3+2H_2O=R_2AsO.OH+3HX$$
$$R_2AsX_3=RAsX_2+RX$$

All compounds of the type $(C_6H_5)_2AsX$, where X=halogen, cyano- or thiocyano-grouping, react with methyl iodide to give diphenyldimethylarsine tri-iodide. Sodium hydrosulphide transforms diarylchloroarsine to the corresponding sulphide. Thionyl chloride forms an interesting addition product with diphenylchloroarsine, $(C_6H_5)_2AsCl.SOCl_2$, from which diphenylarsinic acid or phenyldichloroarsine may be produced, the final product depending upon the conditions.

The cyanoarsines are not so stable as the halogen derivatives, and tend to decompose in moist air with evolution of hydrogen cyanide. They are converted by aqueous or alcoholic alkali to the corresponding oxides, and by oxidising agents to arsinic acids. Chlorine forms an addition product, $R_2AsCN.Cl_2$, which with water yields $R_2AsO.OH$. It is interesting to note that the CN group may be hydrolysed to COOH by the usual methods, giving the compound $R_2As.COOH$.

Diphenylchloroarsine, $(C_6H_5)_2AsCl$.—This compound, which played an important part as a material for chemical warfare, has been the subject of several detailed researches. It was initially obtained by the interaction of mercury diphenyl and arsenious chloride in the following way : 50 grams of mercury diphenyl and 230 grams of arsenious chloride are heated under reflux for several hours at 270° C. The

resulting product consists of a mixture of diphenylchloroarsine, phenyldichloroarsine, and mercuric chloride, and after decantation of the liquor to remove the latter product, the other constituents are separated by fractionation. In order to avoid the formation of triphenylarsine, the mixture should be rapidly heated above 254° C.[1] A second method of preparation consists in distilling triphenylarsine dichloride at 13 to 14 mm. pressure, when the following reaction occurs :[2]

$$(C_6H_5)_3AsCl_2=(C_6H_5)_2AsCl+C_6H_5Cl$$

By this process 8 grams of triphenylarsine can be transformed into 2·5 grams of pure diphenylchloroarsine.

In preparing the compound on a large scale, triphenylarsine and arsenious chloride are heated together and the resulting product fractionated. The more modern methods of preparation are as follows :—

1. *Under atmospheric pressure.*[3]—25·5 c.c. of arsenious chloride are very slowly added, dropwise, to 30·6 grams of triphenylarsine at 350° C., any arsenious chloride which distils over being returned to the reaction vessel. This portion of the experiment occupies about seven hours. The resulting mixture is then fractionated under 12 to 15 mm. pressure, the following fractions being obtained : (*a*) 120° to 160° C., 12 grams of moderately pure phenyldichloroarsine ; (*b*) 160° to 205° C., 31·5 grams of practically pure diphenylchloroarsine ; (*c*) a residue of 7·2 grams of impure triphenylarsine. In another experiment, 15·3 grams of triphenylarsine and 11·2 grams of phenyldichloroarsine, heated for four hours at 300° C. in an open flask, gave a product which yielded 20 grams of diphenylchloroarsine on fractionation. The reactions occurring in these experiments may be represented as follows :

$$(C_6H_5)_3As+2AsCl_3=3C_6H_5AsCl_2$$
$$2(C_6H_5)_3As+AsCl_3=3(C_6H_5)_2AsCl$$
$$C_6H_5AsCl_2+(C_6H_5)_3As=2(C_6H_5)_2AsCl$$

2. *Under increased pressure.*[4]—250 grams of triphenylarsine and 75 grams of arsenious chloride are heated for three hours at 250° to 280° C. in a rotating autoclave, the pressure attained being about 4·2 to 7 kilos. per sq. cm. The resulting mass is then fractionated in a carbon dioxide atmosphere and the following fractions collected : (*a*) 150° to 190° C., 68 grams of phenyldichloroarsine with 32 per cent. of diphenylchloroarsine ; (*b*) 190° to 220° C., 180 grams of diphenylchloroarsine, 93 per cent. ; (*c*) 220° to 250° C., 7 grams of triphenylarsine with 30 per cent. of diphenylchloroarsine ; (*d*) a residue which, when extracted with chloroform, gives 27 grams of unchanged triphenylarsine. Using the rotatory autoclave, triphenylarsine and phenyldichloroarsine, when heated for three hours at 250° to 280° C., give a 60 per cent. yield of diphenylchloroarsine.

Diphenylchloroarsine is a pale yellow oil, having a faint odour, and does not fume in air. It boils at 333° C. without decomposition if distilled in a current of carbon dioxide, and has a density of 1·42231

[1] Michaelis, *Ber.*, 1876, 9, 1566 ; La Coste and Michaelis, *ibid.*, 1878, 11, 1883 ; Michaelis and Link, *Annalen*, 1881, 207, 195.

[2] Michaelis, *Annalen*, 1902, 321, 141.

[3] British Patent, 142880 (1918) ; Pope and Turner, *Trans. Chem. Soc.*, 1920, 117, 1450.

[4] Morgan and Vining, *ibid.*, 1920, 117, 780.

at 15° C. It is insoluble in water, but dissolves in absolute alcohol, ether, or benzene. It reacts with methyl iodide at 100° C., yielding diphenyldimethylarsonium tri-iodide, together with diphenyliodoarsine.[1]

Sodium hydrosulphide (NaSH) transforms the chloride to diphenylarsenious sulphide.[2] The interaction of diphenylchloroarsine and *thionyl chloride* yields a definite crystalline, colourless *addition compound* of composition, $(C_6H_5)_2AsCl.SOCl_2$.[3] Under diminished pressure this compound melts at 188° to 192° C., and begins to decompose at 195° C., the distillate having the odour of chlorobenzene; phenyldichloroarsine has also been proved to be present in the distillate. In some cases sulphur chloride, S_2Cl_2, has been identified in the distillate. Decomposition of the thionyl chloride addition product at 200° to 215° C. at 25 to 30 mm. yields diphenylarsinic acid, but experimental conditions may be so modified that no diphenylarsinic acid is isolated. In the latter case the arsenic appears in the form of phenyldichloroarsine. These changes are represented by the following equations:

$$(C_6H_5)_2AsCl+SOCl_2=(C_6H_5)_2AsCl.SOCl_2$$
$$3(C_6H_5)_2AsCl.SOCl_2=2C_6H_5AsCl_2+C_6H_5AsO+3C_6H_5Cl+SO_2+S_2Cl_2$$
$$(C_6H_5)_2AsCl.SOCl_2=SCl_2+(C_6H_5)_2AsOCl=C_6H_5Cl+C_6H_5AsO$$

Phenyldichloroarsine and chlorosulphonic acid react violently, yielding two products:[4] (*a*) a compound, $2[(C_6H_5)_2AsO(OH)].HCl$, crystallising from acetone-ethyl acetate mixture (1 : 1) in colourless prisms, M.pt. 114° C.; (*b*) a substance, $(C_6H_5)_2AsO(OH).HCl$, melting indefinitely at 110° to 130° C. If fluorosulphonic acid is used in this reaction, benzenesulphonyl fluoride and *diphenylarsinic acid sulphate*, $2[(C_6H_5)_2AsO(OH)].H_2SO_4$, M.pt. 117° C., are isolated.

Diphenylarsenic chloride, $(C_6H_5)_2AsCl_3$.[5]—This substance results when diphenylchloroarsine is treated with dry chlorine. It crystallises from dry benzene in colourless plates, M.pt. 174° C., and is decomposed by water, forming hydrochloric and diphenylarsinic acids. When heated in a sealed tube at about 200° C. it decomposes according to the equation:

$$(C_6H_5)_2AsCl_3=C_6H_5AsCl_2+C_6H_5Cl$$

Diphenylarsenic chlorobromide, $(C_6H_5)_2AsCl.Br_2$, results when dry bromine (1 mol.) is added to cooled diphenylchloroarsine (1 mol.). It is a solid, fumes slightly in air, and is soluble with partial decomposition in benzene or ether on prolonged boiling.

Diphenylarsenic oxychloride, $[(C_6H_5)_2AsCl_2]_2O$,[6] is prepared by treating the arsenoxide with dry chlorine. It is a white powder, M.pt. 117° C.

Diphenylbromoarsine, $(C_6H_5)_2AsBr$.[7]—This may be obtained by two methods: (1) Diphenylarsenoxide and hydrobromic acid are heated together in a sealed tube at 100° C., and on cooling, the bromide

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[2] M'Kenzie and Wood, *Trans. Chem. Soc.*, 1920, 117, 406.
[3] Gibson and Johnson, *J. Chem. Soc.*, 1928, p. 92.
[4] Steinkopf, Schubart, and Schmidt, *Ber.*, 1928, 61, [B], 678.
[5] Michaelis, *ibid.*, 1876, 9, 1566; La Coste and Michaelis, *ibid.*, 1878, 11, 1883; *Annalen*, 1880, 201, 184.
[6] La Coste and Michaelis, *Ber.*, 1878, 11, 1883.
[7] Pope and Turner, *Trans. Chem. Soc.*, 1920, 117, 1451; see La Coste and Michaelis, *Ber.*, 1878, 11, 1883.

separates as a colourless, crystalline mass. (2) Triphenylarsine, 30·6 grams, and 15·8 grams of arsenious bromide are heated together for three hours at 300° to 350° C., and the resulting product distilled under 14 mm. pressure. The fraction distilling at 170° to 205° C. contains 26 grams of crude diphenylbromoarsine, and a residue of 15 grams remains, which consists of the bromide and triphenylarsine.

This bromide forms colourless plates, M.pt. 55° to 56° C.[1] It reacts with methyl iodide in the usual way, yielding diphenyldimethylarsonium tri-iodide.

Diphenyliodoarsine, $(C_6H_5)_2AsI$, is obtained by the two methods used for the bromide, the hydrobromic acid and arsenious bromide being replaced by the corresponding iodine derivatives. Isolated by these methods, it crystallises from benzene in yellow, crystalline scales, M.pt. 45° to 46° C.[2] When prepared by the interaction of iodine and diphenylarsine it is a reddish-brown oil.[3] It may also be isolated as follows: 12·5 grams of diphenylchloroarsine are added to a solution of 14·2 grams of sodium iodide in 100 c.c. of dry acetone, and after twenty-four hours the sodium chloride is filtered off and the acetone evaporated away. The residue is extracted with ether, from which yellow, hexagonal crystals of the iodide are obtained, M.pt. 40·5° C.[4] The iodide is insoluble in water, sparingly soluble in cold alcohol, readily soluble in hot alcohol, very easily soluble in ether, acetone, benzene, carbon disulphide, and carbon tetrachloride. It combines with methyl iodide at 100° C., forming diphenyldimethylarsonium tri-iodide.

Di-p-chlorophenylchloroarsine, $(Cl.C_6H_4)_2AsCl$, is a pale yellow solid, M.pt. 51° C.

Diphenylcyanoarsine, $(C_6H_5)_2AsCN$.[5]—This was originally prepared by treating the corresponding oxide with anhydrous hydrogen cyanide, but the following methods have more recently been devised for eliminating the use of the objectionable hydrogen cyanide:[6]

(1) Tetraphenyldiarsine and mercuric cyanide when heated at 250° C. in a rotating autoclave give a 94 per cent. yield of diphenylcyanoarsine, the proportions used being in accordance with the equation:

$$(C_6H_5)_2As.As(C_6H_5)_2+Hg(CN)_2=2(C_6H_5)_2As.CN+Hg$$

Silver cyanide does not give such satisfactory results in this reaction as mercuric cyanide.

(2) Diphenylarsenious sulphide and mercuric cyanide when heated together as above for two hours at 160° to 200° C. give a 71 per cent. yield of the cyanide:

$$(C_6H_5)_2As.S.As(C_6H_5)_2+Hg(CN)_2=2(C_6H_5)_2As.CN+HgS$$

Replacing mercuric cyanide by silver cyanide in this reaction only decreases the yield by 2 per cent.

(3) Diphenylchloroarsine and 10 per cent. excess of dry silver cyanide are heated together in a glass-lined, rotating autoclave for three

[1] See Steinkopf and Schwen, *loc. cit.*
[2] Pope and Turner, *loc. cit.*
[3] Dehn and Wilcox, *Amer. Chem. J.*, 1906, 35, 48.
[4] Steinkopf and Schwen, *loc. cit.*
[5] Sturniolo and Bellinzoni, *Boll. Chim. Farm.*, 1919, 58, 409; *Gazzetta*, 1919, 49, ii. 326.
[6] Morgan and Vining, *Trans. Chem. Soc.*, 1920, 117, 782.

hours at 150° to 160° C. After cooling to 40° C., the mixture is filtered through a hot filter, and the silver chloride, after draining, is extracted with warm dry benzene. Distillation of the solution gives a 92 per cent. yield of the cyanide.

(4) Diphenylmethylarsine cyanobromide is decomposed by heat into methyl bromide and diphenylcyanoarsine,[1] and a similar decomposition obtains with diphenylethylarsine cyanobromide.[2]

(5) Diphenylchloroarsine is treated with sodium ethoxide and the resulting *ethoxy-compound*, $(C_6H_5)_2As.OC_2H_5$, acted on by hydrogen cyanide.[3]

Diphenylcyanoarsine melts at 28° to 30° C.,[4] 35° C.,[5] 31·5° C.,[6] B.pt. 191° C. at 11 mm., and crystallises in colourless, monoclinic plates, these having an odour of garlic and bitter almonds. Moist air liberates hydrogen cyanide from the compound, whilst aqueous or alcoholic alkali hydroxides convert it into the oxide. Concentrated nitric acid, 2 per cent. hydrogen peroxide or bromine water in the cold, transforms it into diphenylarsinic acid.

When diphenylcyanoarsine is subjected to hydrolysis by the usual methods used for the preparation of carboxylic acids from nitriles, *diphenylarsinecarboxylic acid*, $(C_6H_5)_2As.CO_2H$, is obtained. Hydrogen peroxide, or substances yielding hydrogen peroxide, give *diphenylarsinoformamide*, $(C_6H_5)_2As.CO.NH_2$. Nitrous acid decomposes this compound, giving nitrogen and the foregoing carboxylic acid.[7] The cyanide is converted by methyl iodide into diphenyldimethylarsonium tri-iodide.[8] With chlorine, diphenylcyanoarsine dichloride, $(C_6H_5)_2As(CN)Cl_2$, is obtained, which melts at 130° to 133° C., and is converted into diphenylarsinic acid on boiling with water.[9]

Diphenylthiocyanoarsine, $(C_6H_5)_2As.CNS$.[10] — To a solution of 40 grams of diphenylchloroarsine in 40 c.c. of acetone, a solution of 12·8 grams of sodium thiocyanate in 60 c.c. of the same solvent is added. The thiocyanate is collected after thirty minutes, the yield being 22 grams. It is a pale, brownish oil, B.pt. 230° to 233° C. at 22 to 23 mm., miscible with benzene and acetone in all proportions, but decomposed by water. With methyl iodide at 100° C. it is converted into diphenyldimethylarsonium tri-iodide.[11]

Di-p-tolylchloroarsine, $(CH_3.C_6H_4)_2AsCl$,[12] may be isolated by the methods enumerated under the corresponding phenyl compound. It forms colourless crystals, M.pt. 45° C., B.pt. 340° to 345° C., unaffected by aqueous sodium carbonate, but decomposed by boiling alcoholic potassium hydroxide. When treated with dry chlorine it gives *di-p-tolylarsenic chloride*, $(C_7H_7)_2AsCl_3$, which readily decomposes on addition of water, eventually giving di-*p*-tolylarsinic acid.

Di-p-anisylchloroarsine, $(CH_3O.C_6H_4)_2AsCl$,[13] is obtained by the

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2799.
[2] Steinkopf, Donat, and Jaeger, *ibid.*, 1922, 55, [B], 2579.
[3] M'Kenzie and Wood, *Trans. Chem. Soc.*, 1920, 117, 406.
[4] Morgan and Vining, *loc. cit.* [5] Sturniolo and Bellinzoni, *loc. cit.*
[6] Steinkopf and Schwen, *loc. cit.*
[7] French Patents, 521119, 521469; from *Chem. Zentr.*, 1921, iv. 870.
[8] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1437.
[9] M'Kenzie and Wood, *loc. cit.* [10] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1013.
[11] Steinkopf and Schwen, *loc. cit.*
[12] La Coste, *Annalen*, 1881, 208, 18; Michaelis, *ibid.*, 1902, 321, 160.
[13] Michaelis and Weitz, *Ber.*, 1887, 20, 50.

interaction of the corresponding oxide with concentrated hydrochloric acid. It crystallises from ether in pale yellow needles, M.pt. 79° to 80° C.

Di-α-naphthylchloroarsine, $(C_{10}H_7)_2AsCl$, is prepared by adding magnesium α-naphthyl bromide to arsenious chloride. It melts at 166° to 167° C.[1] With chlorine it yields *di-α-naphthylarsenic chloride*,[2] $(C_{10}H_7)_2AsCl_3$.

Di-α-naphthylcyanoarsine, $(C_{10}H_7)_2As.CN$,[3] is derived by heating di-α-naphthylarsenoxide with anhydrous hydrogen cyanide in a sealed tube at 100° C. It melts at 191·5° to 192·5° C.

Dicyclohexylchloroarsine, $(C_6H_{11})_2AsCl$.[4] — Tri*cyclo*hexylarsine, when chlorinated in carbon tetrachloride solution, yields a crystalline *dichloride*, which decomposes at about 200° C. *in vacuo*, yielding the chloroarsine. The latter boils at 168° to 171° C. at 10 mm., the yield being about 70 per cent.

Phenyl-p-tolylchloroarsine, $C_6H_5(C_7H_7)AsCl$.[5]—Thirty grams of mercury di-*p*-tolyl and 180 grams of phenyldichloroarsine are mixed, and after a time boiled for five hours. The liquor is decanted off and mixed with light petroleum, when a dark oil separates and solidifies. This latter is *p*-tolylmercuric chloride. It is filtered off, distillation of the filtrate giving phenyl-*p*-tolylchloroarsine as a colourless oil, B.pt. 215° to 237° C. at 29 mm., which readily yields a *trichloride* when treated with chlorine.

Phenylcyclohexylchloroarsine, $(C_6H_5)(C_6H_{11})AsCl$.[6]—A solution of 80 grams of di*cyclo*hexylphenylarsine in 600 c.c. of petroleum ether is treated with chlorine. Removal of the solvent yields the *trichloride*, which decomposes at 167° C., and from the decomposition products 50 grams (73 per cent.) of the chloroarsine are isolated on fractionation. It boils at 183° to 184° C. at 15 mm.

Phenylcyclohexylcyanoarsine, $(C_6H_5)(C_6H_{11})AsCN$.—This derivative may be obtained in two ways: (1) Phenyl*cyclo*hexylmethylarsine yields a cyanobromide when treated with cyanogen bromide. This decomposes at 70° to 80° C., and the resultant product by distillation in a stream of carbon dioxide gives the cyanoarsine. It boils at 156·5° C. at about 2 mm., and is a very irritant liquid. (2) Phenyl*cyclo*hexylchloroarsine is transformed to the cyanoarsine when shaken with aqueous potassium cyanide at 60° C. Obtained by this method the product boils at 190° to 192° C. at 14 mm.

p-Tolylmethyliodoarsine, $(C_7H_7)(CH_3)AsI$.[7] — *p*-Tolylarsenoxide (50 grams) is dissolved in a solution containing 27·7 grams of sodium hydroxide, 55 c.c. of water, and 220 c.c. of spirit, the whole being kept cool. The solution is treated in a reflux apparatus with 28 c.c. of methyl iodide, and after twenty-four hours the alcohol is distilled off, the residue acidified with hydrochloric acid, 50 grams of potassium iodide added, and the mixture saturated with sulphur dioxide. The iodide separates

[1] Matsumiya, *Mem. Coll. Sci. Kyōtō*, 1920, 4, 217; *J. Tokyo Chem. Soc.*, 1920, 41, 868.

[2] Matsumiya and Nakai, *Mem. Coll. Sci. Kyōtō*, 1925, 8, 307.

[3] Grischkievitch-Trochimovski, Mateyak, and Zablotski, *Bull. Soc. chim.*, 1927, [iv.], 41, 1323; *Rocz. Chem.*, 1927, 7, 230.

[4] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.

[5] Michaelis, *Annalen*, 1902, 321, 155; Predari, *Inaug. Dissert.*, Rostock, 1894.

[6] Steinkopf, Dudek, and Schmidt, *loc. cit.*

[7] Mills and Raper, *Trans. Chem. Soc.*, 1925, 127, 2479.

as an oil, which is extracted with chloroform, dried and distilled. It is a golden-yellow oil, B.pt. 163° to 165° C. at 12 mm., solidifying on standing to canary-yellow needles, M.pt. 29° C.

Halogen, Hydroxy, Nitro and Amino Nuclear-Substituted Compounds of the Types $RAsX_2$ *and* R_2AsX.

p-Chlorophenyldichloroarsine,[1] $Cl.C_6H_4.AsCl_2$, is a colourless, highly refractive liquid, B.pt. 277° C., or 160° C. at 23 mm.

o-Bromophenyldichloroarsine, $Br.C_6H_4.AsCl_2$.—*o*-Bromophenylarsinic acid in fuming hydrochloric acid is reduced by sulphur dioxide in the presence of potassium iodide at water-bath temperature. The yield is about 73 per cent.[2] It may also be obtained by the reduction of 2-bromo-6′-aminodiphenylarsinic acid, 2-bromo-6′-methylamino- or 2-bromo-6′-dimethylaminodiphenylarsinic acid.[3] It crystallises from petroleum ether in plates, M.pt. 65° to 66° C., readily soluble in indifferent solvents.

p-Bromophenyldichloroarsine[4] results when *p*-bromophenylarsinic acid is reduced with hydrochloric-hydriodic-sulphurous acids. It is a heavy, orange-coloured liquid, B.pt. 168° C. at 18 mm., and when treated with methyl iodide in alcoholic alkali solution for twelve hours, and subsequently with concentrated hydrochloric acid, and reduced by sulphur dioxide in the presence of a little potassium iodide, it yields *p-bromophenylmethyliodoarsine*. This boils at 178° to 180° C. at 23 mm., and forms pale yellow needles, M.pt. 36·5° C.

p-Iodophenyldi-iodoarsine, $I.C_6H_4.AsI_2$,[5] may be prepared by the action of concentrated hydriodic acid on *p*-iodophenylarsinic acid, or together with the latter acid when diazotised atoxyl is treated with potassium iodide, copper sulphate, and sodium thiosulphate in hydrochloric acid solution. It crystallises in golden yellow needles or scales, M.pt. 80° C.

o-Hydroxyphenyldichloroarsine, $HO.C_6H_4.AsCl_2$.—*o*-Hydroxyphenylarsenoxide anhydride (p. 133) is suspended in a large volume of petroleum ether and dry hydrogen chloride passed in with shaking, together with some sulphur dioxide. The product obtained melts at 81° to 82° C., and after standing for six days over soda-lime, the melting-point is 74° to 80° C. The yield is about 73 per cent., and the product is readily soluble in ether, benzene, and carbon disulphide, sparingly soluble in petroleum ether. It is readily hydrolysed by water into hydrogen chloride and the anhydride.[6]

o-Nitrophenyldichloroarsine, $NO_2.C_6H_4.AsCl_2$.[7]—*o*-Nitrophenylarsinic acid, dissolved in concentrated hydrochloric acid, is heated on the water-bath, and saturated for several hours with hydrogen chloride and sulphur dioxide, when an oil separates out. This solidifies, and when recrystallised gives bright yellow prisms, M.pt. 49° to 50° C., readily soluble in alcohol, ether, and benzene, sparingly soluble in petroleum ether. It is easily hydrolysed by water and alkali, the resulting

[1] Hunt and Turner, *Trans. Chem. Soc.*, 1925, 127, 2671.
[2] Kalb, *Annalen*, 1921, 423, 39.
[3] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 459.
[4] Hunt and Turner, *Trans. Chem. Soc.*, 1925, 127, 2667.
[5] Mameli and Patta, *Boll. Soc. Med.-Chirug. Pavia*, 1909.
[6] Kalb, *loc. cit.*
[7] Kalb, *loc. cit.*; see Karrer, *Ber.*, 1914, 47, 1783.

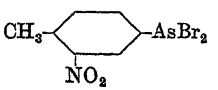
oxide being insoluble in sodium carbonate and ammonium hydroxide, but giving a yellow solution in sodium hydroxide.

m-Nitrophenyldichloroarsine, $NO_2.C_6H_4.AsCl_2$.[1]—Dinitroarsenobenzene in chloroform is treated with chlorine, when *m-nitrophenylarsenic chloride* is produced. This may be isolated, if required, by evaporation of the solvent, long needles being deposited. If the chloroform solution is treated with excess of dinitroarsenobenzene and the solvent removed, an oil remains, which soon solidifies. The reaction may be represented as follows :

$$(NO_2.C_6H_4.As)_2+2NO_2.C_6H_4.AsCl_4=4NO_2.C_6H_4.AsCl_2$$

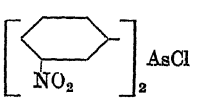
When the chlorine is replaced by bromine, and the solution filtered and concentrated under diminished pressure, *m-nitrophenyldibromoarsine* is obtained as a white, crystalline solid.

3-Nitro-4-tolyldibromoarsine,



obtained from 3 : 3′-dinitroarseno-*p*-toluene suspended in chloroform and bromine, crystallises in brownish-white plates from chloroform; M.pt. 260° C. with decomposition, readily soluble in alcohol, ether, or aqueous alkali.

Di-3-nitrodiphenylchloroarsine,[2]



results when chlorine is passed into a suspension of tetranitrotetraphenyldiarsine, the diarsine being kept in slight excess. It crystallises in golden needles, M.pt. 112° C., readily soluble in benzene and chloroform, sparingly soluble in ether. The corresponding *bromide* crystallises in colourless plates, M.pt. 93° C.

p-Dimethylaminophenyldichloroarsine hydrochloride, HCl. $(CH_3)_2N.C_6H_4.AsCl_2$.[3]—When *p*-dimethylaminophenylarsenoxide is dissolved in dilute hydrochloric acid, and the solution treated with concentrated hydrochloric acid, the required hydrochloride is precipitated. It forms fine, white needles, melting at 116° C. to a bright yellow liquid. In dilute acids and water it dissolves readily, but is sparingly soluble in concentrated acids. The *hydrobromide* is prepared in a similar manner. When potassium iodide is added to an aqueous or alcoholic solution of the hydrochloride, the *hydriodide* is precipitated, $AsI_2.C_6H_4N(CH_3)_2.HI$. This is also obtained by solution of the oxide in hydriodic acid, and is a yellow precipitate, becoming deep red on drying and undergoing decomposition.

p-Diethylaminophenyldichloroarsine hydrochloride, HCl. $(C_2H_5)_2N.C_6H_4.AsCl_2$, forms snow-white needles, M.pt. 139° C., extremely soluble in water, sparingly soluble in hydrochloric acid.

[1] Michaelis and Loesner, *Ber.*, 1894, 27, 269.

[2] Michaelis, *Annalen*, 1902, 321, 141.

[3] Michaelis and Rabinerson, *ibid.*, 1892, 270, 139 : Rabinerson, *Inaug. Dissert.*, Rostock, 1891.

Mixed Halogenated Arsines of the Type ArAlkAsX.

Phenylmethylchloroarsine, $(C_6H_5)(CH_3)AsCl$.[1] — Phenylmethyliodoarsine is treated with the calculated amount of sodium hydroxide, the resulting oily oxide being washed with water, then shaken repeatedly with small quantities of concentrated hydrochloric acid. The oil, after drying over calcium chloride, distils at 113·5° C. at 14 mm. It may also be obtained by heating phenyldimethylarsine dichloride in an oil-bath at 180° C. for thirty minutes. The product thus isolated boils at 229° to 232° C.[2] It combines with methyl iodide at 100° C., forming phenyltrimethylarsonium tri-iodide.[3] The chloroarsine behaves towards thionyl chloride in a similar way to phenylmethylarsinic acid (p. 182).

Phenylmethylbromoarsine, $(C_6H_5)(CH_3)AsBr$,[4] results when phenyldimethylarsine dibromide is heated at 180° C. It is a colourless liquid, B.pt. 250° C. **Phenylethylbromoarsine,** $(C_6H_5)(C_2H_5)AsBr$, obtained in a similar manner, is a colourless liquid, decomposing when distilled under reduced pressure, and the corresponding *chloride* boils with some decomposition at 249° C.

Phenylmethyliodoarsine, $(C_6H_5)(CH_3)AsI$, may be obtained by two methods: (1) A solution containing 365 grams of phenyldichloroarsine, 1200 c.c. of alcohol, 280 grams of sodium hydroxide, and 260 grams of methyl iodide, is neutralised with hydrochloric acid after standing for one day. The sodium chloride and alcohol are removed, the phenylmethyliodoarsine which separates is redissolved by adding water, and the solution, after addition of hydrochloric acid, saturated with sulphur dioxide. A yield of 435 grams of the iodide is obtained as a yellow oil, B.pt. 138° to 140° C. at 12 mm.[5] (2) Sodium iodide in dry acetone is slowly treated with phenylmethylchloroarsine. A 90 per cent. yield of iodide is obtained, B.pt. 143° to 144° C. at 17 to 18 mm.[6] It combines with methyl iodide at 100° C., forming phenyltrimethylarsonium tri-iodide.

Cyclohexyl - n - propylchloroarsine, $(C_6H_{11})(C_3H_7)AsCl$.[7] — The chlorination of di-*n*-propyl*cyclo*hexylarsine yields a dichloride, which decomposes at about 200° C., forming *n*-propyl chloride and the required chloroarsine. It boils at 131° to 132° C. at 16 mm.

Cyclohexyl - n - propylcyanoarsine, $(C_6H_{11})(C_3H_7)AsCN$, results when dipropyl*cyclo*hexylarsine cyanobromide is decomposed by heat. It boils at 108·5° to 110° C. at 1 mm.

Compounds of the Types R_3AsX_2 and $R_3As(OH)X$.

Under the general formulæ R_3AsX_2 and $R_3As(OH)X$ may be included the following types of compounds: Ar_3AsX_2, where X= halogen; $Ar_3As(OH)X$; $ArAr_2'AsX_2$; $ArAr_2'As(OH)X$; $ArAr'AlkAsX_2$; $Ar_2AlkAs(OH)X$; $ArAlk_2AsX_2$; $ArAlk_2As(OH)X$; $ArAlkAlk'As(OH)X$;

[1] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 426; 1920, 117, 1373.
[2] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1017.
[3] Steinkopf and Schwen, *ibid.*, 1921, 54, [B], 1437.
[4] Winmill, *Trans. Chem. Soc.*, 1912, 101, 722.
[5] Burrows and Turner, *loc. cit.*
[6] Steinkopf and Schwen, *loc. cit.*
[7] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.

$Ar_2AlkAsCN.Br$; $ArAlk_2CN.Br$; $ArAlkAlk'AsCN.Br$. The dihalides are prepared by the addition of halogens to tertiary arsines in dry solvents, the dryness of the solvent being of great importance, since the presence of moisture causes the formation of hydroxyhalides. In the case of some substituted tertiary arsines, *e.g.* trinitrotri-*p*-tolylarsine, chlorine not only attaches itself to the arsenic but also enters the ring, the compound mentioned yielding trinitrotrichlorotri-*p*-tolylarsine dichloride. In some cases an excess of halogen gives compounds of the type R_3AsX_4.

The hydroxyhalides, as already mentioned, may be obtained from the dihalides by the action of water:

$$R_3AsX_2+H_2O=R_3As(OH)X+HX$$

The cyanobromides are also decomposed in a similar manner:

$$R_3As(CN)X+H_2O=R_3As(OH)X+HCN$$

In some cases triarylarsine oxides react with halogen acids to give hydroxyhalides, *e.g.* tribenzylarsine hydroxychloride:

$$R_3AsO+HX=R_3As(OH)X$$

The benzyl compound mentioned also occurs as a by-product when tribenzylarsine is prepared from benzyl chloride, arsenious chloride, and metallic sodium in dry ether, using ethyl acetate as a catalyst.

The cyanohalides result when tertiary arsines are treated in perfectly dry solvents with cyanogen bromide, any traces of moisture leading to decomposition, with production of hydroxybromides, as indicated above:

$$R_3As+CNX=R_3As(CN)X$$

Tertiary arsine dihalides react with water, as already shown, yielding hydroxyhalides, and the change may sometimes be effected by alcohol. The halogen is removed if dihalides are treated with sodium carbonate in warm water, oxides resulting:

$$R_3AsX_2+2NaOH=R_3AsO+2NaX+H_2O$$

In some cases a dihydroxide is produced under the above conditions:

$$R_3AsX_2+2NaOH=R_3As(OH)_2+2NaX$$

Heating with alkyl iodides at 100° C. gives arsonium compounds, *e.g.* triphenylarsine di-iodide is converted by methyl iodide into triphenylmethylarsonium tri-iodide. When the dihalides contain aliphatic and aromatic groupings, decomposition may occur as follows on heating:

$$ArAlk_2AsX_2=ArAsX_2+2AlkX$$

Some hydroxyhalides react with platinic chloride in alcohol solution, yielding platinichlorides of the type $[R_3As(OH)X]_3.PtCl_4$. The decomposition of two hydroxybromides in particular deserves mention. When triphenylarsine hydroxybromide is heated in a vacuum at 250° C., decomposition takes place, and from the reaction product the following substances have been isolated: Triphenylarsine, diphenylbromoarsine, bromobenzene, and hydrobromic acid. The decomposition products derived from phenyltrimethylarsine hydroxybromide on heating depend

upon experimental conditions. Heating at 160° to 180° C. in a vacuum gives rise to phenyltrimethylarsonium bromide, phenylmethylarsinic acid, phenyldimethylarsine, phenylmethylbromoarsine, phenyldibromoarsine, methyl alcohol, methyl bromide, and water; whilst distillation under atmospheric pressure at about 195° C. yields phenyltrimethylarsonium bromide, phenyldimethylarsine, phenylmethylbromoarsine, diphenylbromoarsine, methyl bromide, methyl alcohol, hydrobromic acid, and arsenious acid.

Silver oxide in aqueous suspension converts aliphatic-aromatic tertiary arsine hydroxyhalides to dihydroxides, whilst picric acid leads to the formation of hydroxypicrates:

$$ArAlk_2(OH)X+AgOH=ArAlk_2(OH)_2+AgX$$
$$ArAlk_2(OH)X+HO.C_6H_2(NO_2)_3=ArAlk_2(OH)O.C_6H_2(NO_2)_3+HX$$

The elimination of the CN grouping from the cyanobromides by moisture, with formation of hydroxybromides, has already been commented upon. If a mixed cyanobromide containing two similar alkyl groups is subjected to heat, one of the groups is removed as alkyl bromide:

$$ArAlk_2AsCN.Br \longrightarrow ArAlkAsCN+AlkBr$$

Should the two alkyl groups be dissimilar, the one of smaller molecular weight is eliminated:

$$ArAlkAlk'AsCN.Br \longrightarrow ArAlkAsCN+Alk'Br$$

When two aryl groups are present and only one alkyl group, the effect of heat is to remove the alkyl group:

$$Ar_2AlkAsCN.Br \longrightarrow Ar_2AsCN+AlkBr$$

Triphenylarsine dichloride, $(C_6H_5)_3AsCl_2$,[1] crystallises from benzene in colourless plates, sintering at 158° C. and melting at 204° to 205° C. It is converted by moisture into the *hydroxychloride*, a crystalline product melting at 171° C., soluble in alcohol and water. It combines with platinic chloride in alcohol solution, forming a *platinichloride*, $[(C_6H_5)_3As(OH)Cl]_3.PtCl_4$, consisting of yellow needles, M.pt. 180° to 182° C., which are decomposed by concentrated hydrochloric acid.

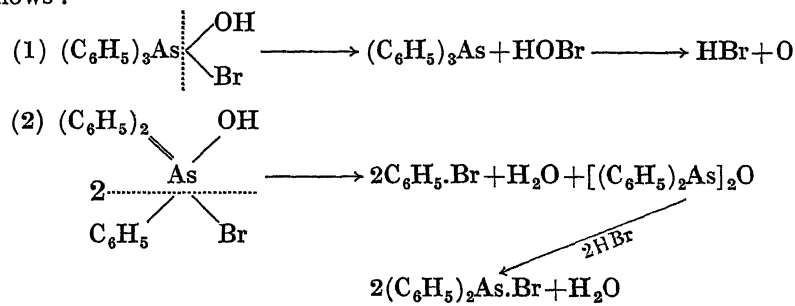
Triphenylarsine cyanobromide, $(C_6H_5)_3As(CN)Br$,[2] results when 1·4 grams of cyanogen bromide and 4·0 grams of triphenylarsine are allowed to react in 40 c.c. of petroleum ether. The product is a colourless, relatively coarsely crystalline powder, sintering at 120° C. and melting indefinitely at 130° to 140° C. Moisture converts it into the *hydroxybromide.*

Triphenylarsine dibromide, $(C_6H_5)_3AsBr_2$, forms colourless crystals, sintering at 165° C. and melting at 215° C.

Triphenylarsine hydroxybromide, $(C_6H_5)_3As(OH)Br$, is produced by the decomposition of the corresponding cyanobromide by moisture. It forms glistening crystals, M.pt. 166° C., soluble in alcohol, chloroform, and acetone, sparingly soluble in water and carbon disulphide, insoluble in ether and petroleum ether.[3] When heated in a

[1] Michaelis, *Annalen*, 1902, 321, 141; see La Coste and Michaelis, *Ber.*, 1878, 11, 1887.
[2] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2791.
[3] Steinkopf and Schwen, *ibid.*

vacuum at 250° C. it undergoes decomposition into the following :[1] (1) A distillate containing bromobenzene, water, and hydrobromic acid. (2) A higher boiling fraction containing bromobenzene, triphenylarsine, and diphenylbromoarsine, this being proved by treating with methyl iodide, when diphenyldimethylarsonium tri-iodide, diphenyldimethylarsonium iodide, and triphenylmethylarsonium tri-iodide are produced. The fission, however, is not quantitative; it may be represented as follows :—



Triphenylarsine hydroxypicrate, $(C_6H_5)_3As(OH)[O.C_6H_2.(NO_2)_3]$, is formed by treating an alcohol solution of the hydroxybromide with a saturated solution of picric acid. It crystallises in yellow needles, M.pt. 162° to 163° C.

Triphenylarsine tetra-iodide, $(C_6H_5)_3AsI_4$.[2]—Direct combination of the arsine and iodine in anhydrous solvents gives a di-iodide, which rapidly changes to a tetra-iodide. It crystallises in steel-blue needles, M.pt. 142° to 144° C. By using the requisite quantities of bromine and iodine in chloroform solution, it is possible to obtain a *bromo-iodide,* $(C_6H_5)_3AsBr_2I_2$, forming yellowish-red needles, M.pt. 120° to 121° C.

Triphenylarsine di-iodide, $(C_6H_5)_3AsI_2$,[3] results when triphenylarsine in dry, light petroleum is treated with iodine in the same solvent. It is an orange-yellow powder, M.pt. 130° to 140° C. With methyl iodide at 100° C. it is converted into triphenylmethylarsonium tri-iodide.

Tri-3-nitrotriphenylarsine dibromide,[4] $(C_6H_4.NO_2)_3AsBr_2$, is prepared by adding bromine to an alcohol-free chloroform solution of the arsine. It is a reddish-yellow product, M.pt. 204° C., very soluble in acetic acid.

Trinitrotrichlorotriphenylarsine dichloride, $(Cl.C_6H_3.NO_2)_3AsCl_2$, results when chlorine acts upon the preceding compound. It crystallises in colourless needles, M.pt. 228° C., soluble in acetic acid but insoluble in chloroform. The corresponding *dibromide* is a yellow, crystalline powder, M.pt. 209° C.

Tri - m - tolylarsine hydroxychloride, $(C_7H_7)_3As(OH)Cl$, is a crystalline compound, M.pt. 205° C., soluble in alcohol, insoluble in ligroin and ether. The *hydroxybromide* forms rhombic crystals, M.pt. 190° C.

Tri-p-tolylarsine dichloride, $(C_7H_7)_3AsCl_2$, is a white, crystalline powder, M.pt. 228° to 230° C., which with hot water gives the *hydroxychloride,* $(C_7H_7)_3As(OH)Cl$. This crystallises from chloroform-ether solutions, yielding feathery crystals, M.pt. 185° C.

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2809.
[2] Michaelis, *loc. cit.*
[3] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 1461.
[4] Michaelis, *loc. cit.*

Tri-p-tolylarsine dibromide, $(C_7H_7)_3AsBr_2$, M.pt. 245° C., changes to the *hydroxybromide* on repeated crystallisation from absolute alcohol.

Tri-p-tolylarsine di-iodide, $(C_7H_7)_3AsI_2$, formed when one molecular equivalent of iodine is used, gives reddish-yellow needles, M.pt. 172° C., but with excess of iodine the *tetra-iodide* results, consisting of steel-grey needles, M.pt. 153° C.

Trinitrotrichlorotri-p-tolylarsine dichloride, $(CH_3.C_6H_2Cl.NO_2)_3AsCl_2$.—A chloroform solution of trinitrotri-*p*-tolylarsine when treated with chlorine, not only gives the dichloride, but the nucleus is also chlorinated, yielding the above compound. It melts at 170° C., is readily soluble in alcohol, sparingly soluble in chloroform. It gives the corresponding *amino-compound* on reduction.

Tri-p-ethylphenylarsine dichloride, $(C_2H_5.C_6H_4)_3AsCl_2$, melts at 246° C., and the *dibromide* at 212° C.

Tribenzylarsine hydroxyhalides.—Tribenzylarsine hydroxychloride, $(C_6H_5.CH_2)_3As(OH)Cl$, results as a by-product in the preparation of tribenzylarsine (p. 77). It is also formed when hydrochloric acid is added to an aqueous solution of tribenzylarsine oxide;[1] it is a colourless, crystalline compound, M.pt. 162° to 163° C. The *hydroxybromide* crystallises in tablets, M.pt. 128° to 129° C., and the *hydroxyiodide* is a body of rather indefinite composition, containing one molecule of water and melting at 78° C. The latter substance is obtained by the action of alcohol on tribenzylarsine di-iodide, which turns red and melts at 95° C.

Tri-p-cumylarsine dichloride, $(C_3H_7.C_6H_4)_3AsCl_2$, M.pt. 276° C., forms a *platinichloride*, consisting of golden-yellow needles from alcohol solution. The *dibromide* crystallises in small needles, M.pt. 142° C.

Tripseudocumylarsine dibromide, $(C_9H_{11})_3AsBr_2$, is a yellow powder, M.pt. 224° to 225° C.; its alcohol solution gives a *hydroxybromide*, M.pt. 108° C., on treatment with water.

Trimesitylarsine hydroxychloride, $(C_9H_{11})_3As(OH)Cl$, crystallises from alcohol in white prisms, M.pt. 100° C., and the *dibromide*, M.pt. 237° C., is soluble in alcohol and chloroform, insoluble in ether.

Tri-α-naphthylarsine dibromide, $(C_{10}H_7)_3AsBr_2$, melts at 180° C., and a *tetrabromo-compound*, M.pt. 144° C., is also known. The dibromide in benzene solution gives a *hydroxybromide*, M.pt. 155° C., on addition of alcohol.

Tri-β-naphthylarsine dibromide has not been obtained in a pure state.

Compounds of the Types $ArAr_2'AsX_2$ *and* $ArAr_2'As(OH)X$.

Phenyldi-p-tolylarsine dichloride, $(C_6H_5)(C_7H_7)_2AsCl_2$, sinters at 186° C. and melts at 194° C. It forms a *platinichloride*, M.pt. 201° C., and in air a *hydroxychloride* is produced, M.pt. 142° to 143° C., soluble in alcohol or hot water, but insoluble in ether.

Phenyldi-m-xylylarsine dichloride, $(C_6H_5)(C_8H_9)_2AsCl_2$, melts at 276° C. and yields a *hydroxychloride*, M.pt. 186° C. The free arsine combines with iodine, forming a *periodide*, $C_6H_5(C_8H_9)_2AsI_4$, reddish-violet crystals, M.pt. 127° C.

[1] Michaelis and Paetow, *Annalen*, 1886, 233, 60.

Phenyldipseudocumylarsine dichloride, $(C_6H_5)(C_9H_{11})_2AsCl_2$, is a crystalline powder, M.pt. 217° C., formed when the free arsine is chlorinated in carbon tetrachloride; if the operation is carried out in ordinary chloroform, the *hydroxychloride* results, M.pt. 173° to 175° C. The *dibromide* is very deliquescent, and the *hydroxybromide* melts at 177° C.; the *di-iodide* forms yellowish-red crystals, M.pt. 163·5° C., which with water yield the bright yellow *hydroxyiodide*, M.pt. 153° C.

Compounds of the Types $ArAlk_2AsX_2$; $ArAlk_2As(OH)X$; $ArAr'AlkAsX_2$; $ArAlkAlk'As(OH)X$; $Ar_2AlkAs(OH)X$.

Phenyldimethylarsine dichloride, $(C_6H_5)(CH_3)_2AsCl_2$,[1] obtained by the chlorination of the arsine in ice-cold petroleum-ether, is a solid, melting with decomposition at 134° C.

Phenyldimethylarsine dibromide, $(C_6H_5)(CH_3)_2AsBr_2$,[2] is a white, crystalline, highly hygroscopic solid, melting with violent decomposition at 128° C. If in this preparation the arsine is not in excess, *phenyldimethylarsine tetrabromide* is formed. This melts at 61° C., but if heated at 160° C. for fifteen minutes, it is quantitatively decomposed into phenyldibromoarsine (1 mol.) and methyl bromide (2 mols.).

Phenyldiethylarsine dichloride, $(C_6H_5)(C_2H_5)_2AsCl_2$, occurs in shining crystals;[3] the *dibromide* melts with decomposition at 85° C.;[4] the *di-iodide* at 95° C., decomposing at 105° C.

Diphenylethylarsine dichloride, $(C_6H_5)_2C_2H_5AsCl_2$, crystallises from benzene in needles, M.pt. 137° C., decomposed by water, evolving hydrogen chloride.[5]

Phenylcyclohexylmethylarsine hydroxybromide, $(C_6H_5)(C_6H_{11})(CH_3)As(OH)Br$,[6] is formed by the action of moisture on the corresponding cyanobromide. It is an oily product, which may be converted into a yellow, crystalline *hydroxypicrate*, M.pt. 132·5° to 133° C., on treatment with aqueous picric acid.

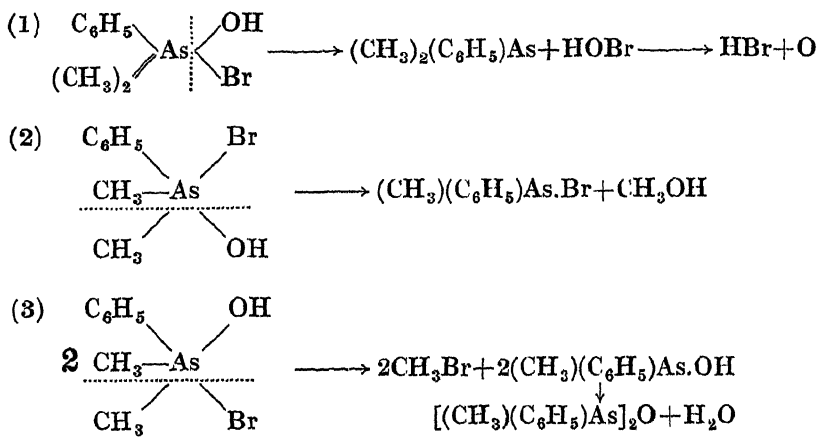
Phenyl-p-tolylethylarsine dichloride, $(C_6H_5)(C_7H_7)(C_2H_5)AsCl_2$,[7] separates in colourless needles, M.pt. 148° C., from benzene.

Phenyldimethylarsine hydroxychloride, $(C_6H)(CH_3)_2As(OH)Cl$,[8] is obtained by treating the dihydroxide in a little alcohol with a little concentrated hydrochloric acid, then adding ether. The chloride separates in fine, white needles, M.pt. 163° C.

Phenyldimethylarsine hydroxybromide, $(C_6H_5)(CH_3)_2As(OH)Br$, is formed by the action of moisture on phenyldimethylarsine cyanobromide. It crystallises in glistening needles, M.pt. 162° C., dissolving in water with an acid reaction, silver nitrate quantitatively precipitating the bromine. The compound dissolves readily in alcohols, pyridine, nitrobenzene, and phenol, is sparingly soluble in cold acetone, benzene, and toluene, insoluble in ether, petroleum ether, and carbon disulphide. When heated in a vacuum at 160° to 180° C., phenyldimethylarsine hydroxybromide is decomposed into the following: (1)

[1] Steinkopf and Mieg, *Ber.*, 1920, 53, [B], 1016.
[2] Winmill, *Trans. Chem. Soc.*, 1912, 101, 722.
[3] La Coste and Michaelis, *Annalen*, 1880, 201, 184; Michaelis, *Ber.*, 1877, 10, 622.
[4] Winmill, *loc. cit.*
[5] Michaelis and Link, *Annalen*, 1881, 207, 199; La Coste and Michaelis, *loc. cit.*; see *Ber.*, 1878, 11, 1883.
[6] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[7] Michaelis, *Annalen*, 1902, 321, 155.
[8] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2791.

Phenyltrimethylarsonium bromide and phenylmethylarsinic acid, which remain as the residue. (2) A high boiling distillate, which is converted by heating with methyl iodide into phenyltrimethylarsonium iodide and phenyltrimethylarsonium tri-iodide, and must therefore originally contain phenyldimethylarsine and phenylmethylbromoarsine. This fraction also appears to contain some phenyldibromoarsine. (3) A low boiling fraction, consisting of methyl alcohol, methyl bromide, and water.[1] If, however, the distillation is carried out at atmospheric pressure at about 195° C., the distillate consists of methyl bromide, methyl alcohol, and aqueous hydrobromic acid. The residue may be divided into ether-soluble and ether-insoluble portions. From the ether-insoluble portion a little arsenious acid and phenyltrimethylarsonium bromide may be isolated. The ether-soluble portion, with methyl iodide, yields phenyltrimethylarsonium iodide, phenyltrimethylarsonium tri-iodide, diphenyldimethylarsonium tri-iodide, and diphenyliodoarsine. It must, therefore, have contained phenyldimethylarsine, phenylmethylbromoarsine, and diphenylbromoarsine. These changes may be represented as follows :



The arsenoxide reacts with the hydrobromic acid from (1) as follows :

$$[(CH_3)(C_6H_5)As]_2O+2HBr=2(CH_3)(C_6H_5)As.Br+H_2O$$

The phenylmethylarsenious acid is oxidised to the arsinic acid by the oxygen from (1).

(4) The phenyltrimethylarsonium bromide is a secondary product, derived from the methyl bromide in (3) and the phenyldimethylarsine in (1).

The changes (1) and (2) are similar to those taking place with trialkylhalogenammonium hydroxides.

Phenyldimethylarsine hydroxyiodide, $C_6H_5(CH_3)_2As(OH)I$, is obtained when the cyano-iodide is exposed to moisture. It crystallises from alcohol-ether in yellow needles, M.pt. 117° C., readily soluble in water, less soluble in alcohol and acetone, sparingly soluble in warm benzene and carbon tetrachloride, and insoluble in petroleum ether.

[1] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2802.

Phenylmethylethylarsine hydroxybromide, $(C_6H_5)(CH_3)(C_2H_5)As(OH)Br$,[1] forms a fine, white, crystalline mass, M.pt. 83° C., and **phenylmethyl - n - propylarsine hydroxybromide,** $(C_6H_5)(CH_3)(C_3H_7)As(OH)Br$, melts at 146° C.

Phenylbenzylmethylarsine hydroxybromide, $(C_6H_5)(C_6H_5.CH_2)(CH_3)As(OH)Br$, is a microcrystalline powder, M.pt. 147° C.; the corresponding *hydroxypicrate* forms yellow needles, M.pt. 119° C.

Diphenylmethylarsine hydroxybromide, $(C_6H_5)_2(CH_3)As(OH)Br$, forms transparent crystals, M.pt. 118° C.[2]

Diphenylethylarsine hydroxybromide, $(C_6H_5)_2C_2H_5.As(OH)Br$,[3] melts at 97·5° C., and the *hydroxypicrate* crystallises in lemon-yellow plates, M.pt. 116° C.

Cyclohexyldipropylarsine hydroxybromide, $(C_6H_{11})(C_3H_7)_2As(OH)Br$,[4] forms a white, crystalline mass, melting at 64° to 67° C., and giving a *hydroxypicrate*, yellow needles, M.pt. 110° to 111° C.

Compounds of the Types $ArAlk_2AsCN.Br$; $Ar_2AlkAsCN.Br$; $ArAlkAlk'AsCN.Br$.

Phenyldimethylarsine cyanobromide, $C_6H_5.As(CH_3)_2Br.CN$,[5] isolated from the interaction of cyanogen bromide and phenyldimethylarsine in petroleum ether, is a microcrystalline powder, M.pt. 94° to 96° C. It is decomposed by heat into phenylmethylcyanoarsine, $C_6H_5.As(CH_3)CN$, B.pt. 127° C. at 11 mm. Moisture converts the cyanobromide to the hydroxybromide. *Phenyldimethylarsine cyanoiodide,* $C_6H_5.As(CH_3)_2CN.I$, is a yellow, crystalline powder, M.pt. 93° C. It is converted to the *hydroxyiodide* by moisture. When the hydroxybromide is treated with moist silver oxide, the hygroscopic *phenyldimethylarsine dihydroxide* results. *Phenyldimethylarsine hydroxypicrate* crystallises in needles, M.pt. 132° C.

Diphenylmethylarsine cyanobromide, $(C_6H_5)_2As(CH_3)Br.CN$, is a voluminous powder, M.pt. 61° to 62° C., changing in air to the *hydroxybromide.* When heated it decomposes, yielding methyl bromide and diphenylcyanoarsine. *Diphenylmethylarsine hydroxypicrate* melts at 137° C.

Diphenylethylarsine cyanobromide, $(C_6H_5)_2As(C_2H_5)Br.CN$,[6] is a white solid, M.pt. 75° C., decomposing into ethyl bromide and diphenylcyanoarsine when heated, and converted by moisture into the *hydroxybromide.*

Phenylmethylethylarsine cyanobromide, $C_6H_5.As(CH_3)(C_2H_5)Br.CN$, has not been obtained in crystalline form; when heated it yields methyl bromide and *phenylethylcyanoarsine,* a colourless liquid, B.pt. 148° to 150° C. at 23 mm. The *hydroxypicrate* melts at 113·5° C.

Phenylmethyl-n-propylarsine cyanobromide, $C_6H_5.As(CH_3)(C_3H_7)Br.CN$, is a non-crystalline product, yielding methyl bromide and *phenyl-n-propylcyanoarsine,* B.pt. 150° to 155° C. at 20 mm., when heated. The *hydroxypicrate* crystallises in brilliant yellow needles, M.pt. 84° C.

[1] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2597.
[2] Steinkopf and Schwen, *loc. cit.* [4] Steinkopf, Donat, and Jaeger, *loc. cit.*
[3] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[5] Steinkopf and Schwen, *Ber.*, 1921, 54, [B], 2791.
[6] Steinkopf, Donat, and Jaeger, *loc. cit.*

CHAPTER IV.

AROMATIC ARSINE OXIDES, HYDROXIDES, AND SULPHIDES.

Compounds of the Types $RAsO$; $(R_2As)_2O$; R_3AsO.

Unsubstituted arylarsenoxides are usually prepared from the corresponding dihalogenated arsines by suspending the latter in warm water and adding sodium carbonate or hydroxide:

$$RAsX_2+Na_2CO_3=RAsO+2NaX+CO_2$$

In some instances hydrogen peroxide will oxidise an arsine to its oxide. Nuclear-substituted oxides of the type under consideration are not generally prepared according to the foregoing equation, although the method has been applied to some halogen substituted derivatives, *e.g.* *p*-bromophenyldichloroarsine. The starting-point usually is the corresponding arsinic acid, which is subjected to mild reduction, this often being carried out by treating the acid in mineral acid solution with sulphur dioxide in the presence of iodine or an iodide, and when reduction is complete, adding concentrated ammonium hydroxide. It is, of course, necessary to modify the details of the process to suit the acid used. The method is applicable to the production of oxides having the following groups or combination of groups substituted in the nucleus: methyl, halogen, nitro, amino, or hydroxyl. Amongst other reducing agents used in the process are phenylhydrazine and phosphorus trichloride. N-Alkylated aminoarylarsenoxides are obtained by treating dialkylated amines with arsenious chloride at 100° C., and mixing the melt with a solution of caustic alkali. In the case of 5-iodo-3-nitro- and 5-iodo-3-acetylamino-4-hydroxyphenylarsenoxides, the corresponding arseno- compound is suspended in ether and treated with iodine, when the di-iodoarsine results, which is then hydrolysed by aqueous sodium bicarbonate.

The diarylarsenoxides may be formed from the corresponding halogenated compounds by the action of alcoholic potassium hydroxide:

$$2R_2AsX+2KOH=(R_2As)_2O+2KX+H_2O$$

In some cases magnesium arylhalides react with arsenious oxide to give diarylarsenoxides:

$$4RMgX+As_2O_3=(R_2As)_2O+2MgO+2MgX_2$$

The triarylarsine oxides, like the preceding oxides, may be prepared from halogenated arsines by the action of caustic alkali:

$$R_3AsX_2+2KOH=R_3AsO+2KX+H_2O$$
$$R_3As(OH)X+KOH=R_3AsO+KX+H_2O$$

In some cases dihydroxides, when heated, eliminate water :

$$R_3As(OH)_2=R_3AsO+H_2O$$

Tertiary arsine oxides containing nitro groups are conveniently isolated by dissolving the arsine in mixed acid and pouring the mixture into a large bulk of water. In this case the nitro group enters the ring in the *meta* position to the arsenic.

In the preparation of triarylarsine dihydroxides it is usually unnecessary to isolate the dihalides, since the arsines in glacial acetic acid may be treated with bromine, and the mixture poured into caustic alkali :

$$R_3As+Br_2=R_3AsBr_2$$
$$R_3AsBr_2+2NaOH=R_3As(OH)_2+2NaBr$$

Hydroxyhalides are also converted by alkali to hydroxides, and sometimes prolonged heating of dihalides or hydroxyhalides with water is sufficient to cause the change. In the case of the phenyl compounds, the mercurichloride, when boiled with aqueous (not alcoholic) potassium hydroxide, yields the oxide :

$$(C_6H_5)_3As.HgCl_2+2KOH=(C_6H_5)_3As(OH)_2+2KCl+Hg$$

The monoarylarsenoxides are amphoteric, dissolving in aqueous caustic alkalis and in concentrated acids. In the former case salts of arsenious acids may be produced, $RAs(ONa)_2$; these do not yield the free acid when treated with mineral acids, but the oxide is regenerated. With methyl iodide the salts react as follows :

$$RAs(ONa)_2+CH_3I=R.CH_3.As.O.ONa+NaI$$

The esters of the unknown phenylarsenious acid, $C_6H_5.As(OH)_2$, are dealt with on p. 180. Reduction of the oxides yields arsenobenzenes, and oxidation gives arsinic acids :

$$2RAsO+2H_2=RAs : AsR+2H_2O$$
$$RAsO+O+H_2O=RAsO(OH)_2$$

Distillation of the oxides produces triarylarsines and arsenious oxide, an exception to this being α-naphthylarsenoxide, which is completely decomposed :

$$3RAsO=R_3As+As_2O_3$$

Halogen acids convert the oxides to dihalogenated arsines, and dry chlorine yields oxychlorides :

$$RAsO+2HX=RAsX_2+H_2O$$
$$RAsO+Cl_2=RAsO.Cl_2$$

Hydrogen sulphide reacts with the oxides, giving sulphides :

$$RAsO+H_2S=RAsS+H_2O$$

The diarylarsenoxides, like the monoaryl compounds, are converted by halogen acids to halogenated arsines, but differ from the monoaryl oxides by their insolubility in alkalis. Chlorine transforms the diaryl oxides to oxychlorides, and hydrogen sulphide converts them to sulphides, $(R_2As)_2S$. The free diarylarsenious hydroxides, $R_2As.OH$, are

unknown, but esters of the type $R_2As.OR'$ are described on p. 181. Strong heating is said to change di-*p*-tolylarsenoxide to tri-*p*-tolylarsine.

Triarylarsenious oxides and dihydroxides possess basic properties, forming hydroxy salts with dilute nitric or picric acid, or with potassium chromate. If concentrated nitric acid is employed, dinitrates are produced. Dihydroxides, when heated, lose water and give oxides. Both types of compounds sometimes yield sulphides when treated with hydrogen sulphide. Reduction of the oxides gives triarylarsines, and in the case of tribenzylarsine oxide, the resulting product depends upon the reducing agent used, zinc and acetic acid yielding tribenzylarsine, whilst hydriodic acid and red phosphorus yield tetrabenzylarsonium iodide. It has already been pointed out that nitration of triarylarsines by mixed acid, and addition of the solution to a large bulk of water, results in the production of triarylarsine oxides. If excess of nitric acid is used, a mixture of oxide, hydroxynitrate and dinitrate is formed, the constituents of which it may be impossible to separate.

Phenylarsenoxide, $C_6H_5.AsO$.[1]—When phenyldichloroarsine is suspended in warm water and treated with sodium carbonate the oxide separates out. It crystallises from alcohol in colourless, crystalline crusts, M.pt. 119° to 120° C., which readily dissolve in cold benzene or hot alcohol, and are volatile in steam. When warmed, the oxide has an irritant effect on the mucous membrane of the nose. Hydrochloric acid reconverts it to the chloride. Aqueous sodium hydroxide converts it into the substance, $C_6H_5.As(ONa)_2$, which yields the oxide when treated with acids. Reduction of the oxide gives rise to arsenobenzene. Heating in a sealed tube at 180° to 200° C. transforms the oxide into triphenylarsine and arsenious oxide, and hydrogen sulphide reacts to form phenylarsenious sulphide.[2] Phenylarsenoxide in alcoholic sodium hydroxide solution reacts with methyl iodide to form phenylmethylarsinic acid, according to the equation :

$$C_6H_5.As(ONa)_2+CH_3I=C_6H_5.CH_3AsO.ONa+NaI$$

This reaction seems to be of general application, and has been carried out using ethyl and *iso*amyl iodides, also benzyl chloride.[3] In the presence of alkali, phenylarsenoxide reacts with chloracetic acid to give *arsinophenylacetic acid*, which melts with decomposition at 145° C.[4]

p-Chlorophenylarsenoxide, $Cl.C_6H_4.AsO$,[5] crystallises from benzene in white needles, M.pt. 198° C.

o-Bromophenylarsenoxide, $Br.C_6H_4.AsO$.[6] — *o*-Bromophenylarsinic acid (14 grams) in 14 c.c. of alcohol and 14 c.c. of concentrated hydrochloric acid containing a trace of iodine, is boiled and treated for thirty minutes with sulphur dioxide. The chloroarsine separates as an oil, which is extracted with benzene after removing the alcohol. The extract is shaken with 14 c.c. of concentrated ammonium hydroxide, cooled and filtered. The solid is washed with water to remove ammonium chloride, and then dried, the yield being 92·5 per cent. The oxide melts at 234° to 238° C. and is insoluble in most neutral solvents.

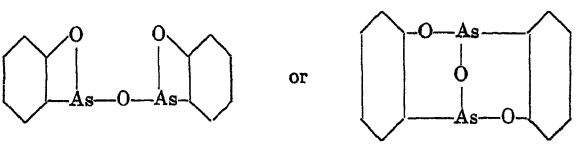
[1] Michaelis, *Ber.*, 1877, 10, 623 ; La Coste and Michaelis, *Ber.*, 1878, 11, 1887.
[2] Schulte, *Ber.*, 1882, 15, 1955. [3] Bertheim, *Ber.*, 1915, 48, 350.
[4] Austrian Patent, 93325, Swiss Patent, 97977 ; from *Chem. Zentr.*, 1923, iv. 721.
[5] Hunt and Turner, *Trans. Chem. Soc.*, 1925, 127, 2667.
[6] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 457.

p-Bromophenylarsenoxide, obtained by the action of sodium carbonate on the corresponding chloride, separates from water in white prisms, M.pt. 259° to 261° C.[1]

p-Iodophenylarsenoxide, $I.C_6H_4.AsO$,[2] results when *p*-iodophenyldi-iodoarsine is treated with alkali.

2 : 4-Dinitrophenylarsenoxide $(NO_2)_2C_6H_3.AsO$.[3]—2 : 4-Dinitrophenylarsinic acid (6 grams) in 100 c.c. of ether, is treated with phosphorus trichloride in small portions, until reaction and evolution of gas cease. The mixture is shaken with 200 c.c. of water, separated, and treated with a further 300 c.c. of water. Spontaneous evaporation of the ether layer yields the oxide in yellowish crusts. It is insoluble in dilute acid and water, but dissolves in an excess of sodium hydroxide, giving a yellow solution.

o-Hydroxyphenylarsenoxide anhydride,[4]



Diazotised *o*-arsanilic acid is treated with cold aqueous sulphurous acid to obtain this anhydride. It crystallises from hot acetic acid in colourless, granular crystals, M.pt. 177° C., readily soluble in benzene, but sparingly soluble in ether. It is hydrolysed by dilute sodium hydroxide.

p-Hydroxyphenylarsenoxide, $HO.C_6H_4.AsO$.[5]—Sodium *p*-hydroxyphenylarsinate (114 grams) is dissolved in 1600 c.c. of water and the solution treated with 20 grams of potassium iodide and 520 c.c. of dilute sulphuric acid (1 : 5), then saturated with sulphur dioxide at 18° C. The solution is saturated with sodium chloride and extracted with ether, the latter solution neutralised with sodium carbonate and the solvent removed. The oxide remains as a white, crystalline mass, which is unchanged at 240° C., readily soluble in alcohols, acetone, and acetic acid, sparingly soluble in benzene, chloroform, or carbon disulphide. The aqueous solution gives a dirty violet coloration with ferric chloride. A neutral solution of hydrosulphite reduces the oxide to 4 : 4′-dihydroxyarsenophenol. The hydroxyphenylarsinic acid may also be reduced to the oxide by using hydriodic acid, phenylhydrazine, phosphorus trichloride, or thionyl chloride as reducing agents.

o-Aminophenylarsenoxide, $NH_2.C_6H_4.AsO$,[6] is formed by the reduction of *o*-arsanilic acid with sulphur dioxide in hydrochloric acid containing hydriodic acid. It is a white powder, readily soluble in dilute acid and sodium hydroxide, insoluble in sodium carbonate and ammonium hydroxide.

p-Aminophenylarsenoxide[7] may be obtained from *p*-arsanilic acid in several ways : (1) 311 grams of sodium *p*-aminophenylarsinate and 520 grams of potassium iodide are dissolved in a mixture consisting of 1800 c.c. of water and 1000 c.c. of dilute sulphuric acid (1 : 5), and

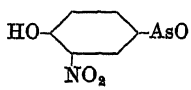
[1] Hunt and Turner, *loc. cit.*
[2] Mameli and Patta, *Giorn. Farm. Chim.*, 1909, 58, 97; *Arch. Farmacol. Sperim.*, 1909, 8, 395.
[3] Karrer, *Ber.*, 1914, 47, 2275.
[4] Kalb, *loc. cit.*
[5] German Patent, 213594.
[6] Kalb, *Annalen*, 1921, 423, 39.
[7] German Patent, 206057.

sulphur dioxide passed in until all the free iodine disappears. Concentrated ammonium hydroxide is then added until the whole is alkaline, the oxide separating in white needles. (2) In this case the sodium salt is reduced by sulphur dioxide in hydrochloric acid solution. The *compound*, $AsCl_2.C_6H_4NH_2.HCl$, appears to be formed as an intermediate, being transformed to the oxide by aqueous sodium hydroxide. (3) *p*-Arsanilic acid is reduced by boiling its solution in methyl alcohol for two hours with phenylhydrazine.

This oxide crystallises in shining, white needles, softening at 80° C., and decomposing with gas evolution at about 100° C. It dissolves readily in sodium hydroxide and dilute acids, alcohol, or acetone, sparingly soluble in ammonium hydroxide, sodium carbonate, ether, chloroform, and benzene. It combines with methyl iodide under suitable conditions to form *p*-aminophenylmethylarsinic acid (p. 183).[1] If *p*-acetylaminophenylarsenoxide is used in the reaction the corresponding acetylated acid is obtained.

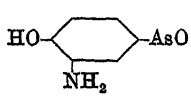
p - Dimethylaminophenylarsenoxide, $(CH_3)_2N.C_6H_4.AsO$.[2]—Dimethylaniline (15 grams) and 25 grams of arsenious chloride are mixed and warmed on the water-bath for fifteen to twenty minutes to complete the reaction. The product is poured into 700 c.c. of water and stirred until all dissolved, then treated with excess of sodium hydroxide and filtered, the filtrate acidified with hydrochloric acid and sodium carbonate added. The oxide is precipitated as a white powder, M.pt. 75° C., soluble in hot alcohol or chloroform, insoluble in water. In a similar manner, *p-diethylaminophenylarsenoxide* is obtained as a yellow powder, M.pt. 58° C., soluble in hot alcohol and dilute mineral acids.

3-Nitro-4-hydroxyphenylarsenoxide,[3]



5 grams of 3-nitro-4-hydroxyphenylarsinic acid in 50 c.c. of 0·38 *N* sodium hydroxide are treated with 6 grams of sodium bisulphite and allowed to stand at room temperature. The oxide separates, 2·5 grams being obtained after standing for three days. It is a yellow powder, only slightly soluble in water, alcohol, and hydrochloric acid, but readily soluble in dilute sodium hydroxide solution. It is reduced in the cold by hypophosphorous acid to dinitrodihydroxyarsenobenzene. The oxide may be condensed with methyl iodide to form 3-nitro-4-hydroxyphenylmethylarsinic acid.[4]

3-Amino-4-hydroxyphenylarsenoxide,[5]

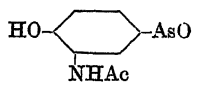


3 Amino-4-hydroxyphenylarsinic acid in hydrochloric acid is treated with a little potassium iodide and the whole saturated with sulphur dioxide. The oxide separates as a white powder in 67 per cent. yield.

[1] Bertheim, *Ber.*, 1915, 48, 356.
[2] Michaelis and Rabinerson, *Annalen*, 1892, 270, 139.
[3] Christiansen, Norton, and Shohan, *J. Amer. Chem. Soc.*, 1925, 47, 2716.
[4] Bertheim, *Ber.*, 1915, 48, 357.
[5] Ehrlich and Bertheim, *Ber.*, 1912, 45, 756; see German Patent, 235391

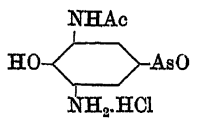
It is very soluble in alcohols, less soluble in caustic alkalis, alkali carbonates and acids, somewhat soluble in water, the solution having a neutral reaction, and insoluble in dry ether.[1] The *hydrochloride* is obtained by treating an alcohol-ether solution of the oxide with alcoholic hydrochloric acid, the product separating as a white powder in 62·7 per cent. yield. It is readily soluble in water and alcohols, slightly soluble in acetic acid, and sparingly soluble in acetone or ether. Its aqueous solution is acid to litmus and neutral to Congo red. It condenses with aldehydes and with β-naphthoquinone sulphonic acid (sodium salt); with sodium hydrosulphite it is reduced to Salvarsan. The hydrochloride reacts with thioglycollic acid at water-bath temperature to give *3-amino-4-hydroxyphenylarsino-bismonothioglycollic acid* in 94·2 per cent. yield.[2] The product is of a gummy nature, and after drying in a vacuum is pulverised.[3]

3-Acetamido-4-hydroxyphenylarsenoxide,[4]



25 grams of 3-amino-4-hydroxyphenyldichloroarsine in 80 c.c. of water are treated with 37·5 c.c. of acetic anhydride, followed at once by sodium acetate, until the mixture no longer reacts acid to Congo red. The whole is then made acid to Congo red by 25 per cent. sulphuric acid, the product collected and purified by means of its alkaline solution. It separates in white prisms containing four molecules of water, these being lost at 100° C. In water, sodium carbonate or bicarbonate solution the oxide is insoluble, but it dissolves in excess of caustic alkali or large excess of ammonium hydroxide.

3-Amino-5-acetamido-4-hydroxyphenylarsenoxide hydrochloride,



5 grams of the corresponding dichloroarsine hydrochloride, suspended in 30 c.c. of water, are stirred for thirty minutes. The resulting solid is filtered off, washed with water, and crystallised by adding concentrated hydrochloric acid to its solution in sodium hydroxide until faintly acid to Congo red. About 2·3 grams of white prisms are isolated, which dissolve in water or dilute caustic alkali.

3-Amino-5-acetamido-4-hydroxyphenylarsenoxide hydriodide forms white prisms, soluble in water after only a few seconds' shaking.

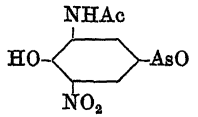
[1] A water-soluble derivative of 3-amino-4-hydroxyphenylarsenoxide has been obtained by condensing the oxide with dextrose at 50° to 55° C. in aqueous solution—see German Patents, 433105, 413147.

[2] Voegtlin, Dyer, and Leonard, *U.S. Pub. Health Reps.*, 1923, 38, 1882.

[3] Solutions of aminoaryldichloroarsine hydrochloride and its derivatives, when treated with piperazine or ethylamine under certain conditions, yield neutral or alkaline solutions containing aminoarylarsenoxides. The preparation of 3-amino-4-hydroxyphenylarsenoxide under these conditions is given in British Patent, 260382 (1925). The substitution of the amino group in the oxide by the acetyl or benzyl radical is dealt with in German Patent 452065.

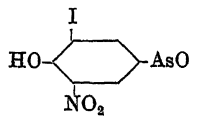
[4] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 2375; see also French Patent, 606238.

3-Nitro-5-acetamido-4-hydroxyphenylarsenoxide,



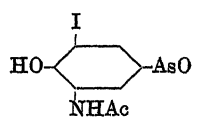
results when the di-iodoarsine hydriodide is acetylated in alkaline solution. It is an amorphous, white solid, insoluble in water but dissolving in caustic alkalis to give deep red solutions.

5-Iodo-3-nitro-4-hydroxyphenylarsenoxide,[1]



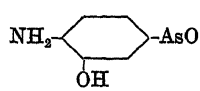
5 : 5′-Di-iodo-3 : 3′-dinitro-4 : 4′-dihydroxyarsenobenzene is suspended in ether and treated with iodine, when the arsine di-iodide is produced. The latter is then hydrolysed with aqueous sodium bicarbonate, the oxide being obtained as an orange-yellow powder, sintering and melting indefinitely between 170° and 210° C. It is sparingly soluble in water, more soluble in alcohol, acetone, ether, benzaldehyde, or pyridine.

5-Iodo-3-acetamido-4-hydroxyphenylarsenoxide,[2]



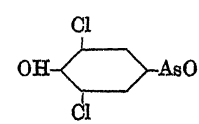
This is prepared in a similar manner to 5-iodo-3-nitro-4-hydroxyphenylarsenoxide, using 5 : 5′-di-iodo-3 : 3′-diacetamido-4 : 4′-dihydroxyarsenobenzene as the starting-point. It is a colourless powder, M.pt. 182° to 183° C., soluble in alcohol or acetone.

4-Amino-3-hydroxyphenylarsenoxide,



is a white powder, obtained by reducing the corresponding arsinic acid in acid solution by sulphur dioxide in the presence of hydriodic acid.[3]

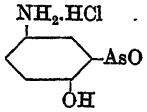
3 : 5-Dichloro-4-hydroxyphenylarsenoxide,[4]



is formed by the mild reduction of the arsinic acid. It crystallises in small prisms, readily soluble in alkalis and alkali carbonates, also in alcohol, but sparingly soluble in water.

[1] Macallum, *J. Chem. Soc.*, 1926, p. 1645.
[2] Macallum, *ibid.*
[3] Benda, *Ber.*, 1911, 44, 3296.
[4] German Patent, 251104.

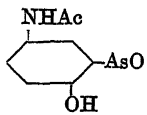
5-Amino-2-hydroxyphenylarsenoxide hydrochloride,[1]



2 grams of the corresponding dichloroarsine hydrochloride in 8 c.c. of water, after standing for some hours, deposit white prisms of the oxide, which are soluble in water.

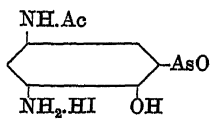
5-Amino-2-hydroxyphenylarsenoxide hydriodide forms stout, white prisms, resembling its isomeride in properties and solubility.

5-Acetamido-2-hydroxyphenylarsenoxide,



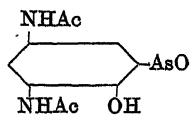
The aminodichloroarsine hydrochloride in water is treated with acetic anhydride, followed by sodium acetate. The acetyl compound separates in white, anhydrous prisms, having similar solubility to its isomeride.

3-Amino-5-acetamido-2-hydroxyphenylarsenoxide hydriodide,



forms white prisms, soluble in water after shaking only for a few seconds.

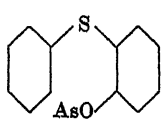
3 : 5-Diacetamido-2-hydroxyphenylarsenoxide,



is obtained by aqueous hydrolysis of the corresponding dichloroarsine. It is an amorphous, white solid, insoluble in water, dilute mineral acids, or sodium bicarbonate solution, but soluble in aqueous solutions of sodium hydroxide or carbonate and in ammonium hydroxide.

Diphenylarsenoxide, $[(C_6H_5)_2As]_2O$, may be obtained either by heating diphenylchloroarsine with alcohol potassium hydroxide,[2] or by the interaction of magnesium phenyl bromide and powdered arsenious oxide in ether solution.[3] It separates from ether in warty crystals, M.pt. 91° to 92° C., and yields *diphenylarsenic oxychloride,* $[(C_6H_5)_2AsCl_2]O$, with dry chlorine.

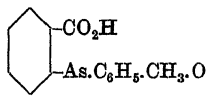
o-Phenylthiolphenylarsenoxide,[4]



[1] Newbery and Phillips, *loc. cit.* [2] La Coste and Michaelis, *Ber.*, 1878, 11, 1883.
[3] Sachs and Kantorowicz, *Ber.*, 1908, 41, 2767.
[4] Roberts and Turner, *J. Chem. Soc.*, 1926, p. 1208.

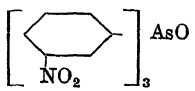
is prepared from the corresponding dichloroarsine in the usual manner. It crystallises from benzene in small, white, irregular rhombohedra, M.pt. 187° to 189° C.

o-Carboxydiphenylmethylarsine oxide,[1]



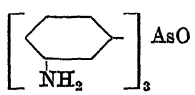
is formed from *o*-carboxydiphenylmethylarsine or its alkaloidal salts by oxidation with hydrogen peroxide. The oxide crystallises from alcohol or acetic acid in colourless needles, M.pt. 142° C.

Tri-3-nitrotriphenylarsine oxide,[2]



20 grams of the arsine are dissolved in a mixture of 40 c.c. of fuming nitric acid and 100 c.c. of concentrated sulphuric acid and the whole poured into water. A yield of 18 grams of oxide is obtained. It is a yellow, crystalline product, M.pt. 254° C., soluble in glacial acetic acid, insoluble in alcohol or ether. Tri-3-nitrotriphenylarsine when treated with chlorine gives tri-3-nitrotrichlorotriphenylarsine dichloride, which is converted by concentrated potassium hydroxide into *trichlorotrinitrotriphenylarsine oxide*, a white, crystalline product, M.pt. 257° C., sparingly soluble in alcohol.

Tri-3-aminotriphenylarsine oxide,[3]



is stated to result when 750 grams of aniline and 150 grams of arsenious chloride in 500 grams of benzene or toluene are boiled for a long time. The yield is very small. A *triacetyl* and a *tribenzoyl* derivative, melting at 140° to 150° C. and 130° to 140° C. respectively, have been obtained.

Hexamethyltri-4-aminotriphenylarsine oxide, $[(CH_3)_2N.C_6H_4]_3AsO$,[4] is obtained from the hydroxide in white crystals, M.pt. 277° C. It dissolves readily in alcohols, is sparingly soluble in ethyl acetate, ether, or benzene, and is insoluble in water.

Triphenylarsine oxide trisulphonic acid, $(C_6H_4.SO_3H)_3AsO$,[5] is isolated as the barium salt after heating triphenylarsine to boiling with sulphuric acid. The salt is a pale pink, water-soluble powder.

o-Tolylarsenoxide, $C_7H_7.AsO$, is obtained from the corresponding di- or tetra-chloride by boiling with aqueous sodium carbonate. It is a white powder, melting at 145° C., and said to decompose above its melting-point, splitting off arsenic and forming the tritolyl compound:

$$3C_7H_7AsO = (C_7H_7)_3As + As_2O_3$$

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[1] Aeschlimann, *Trans. Chem. Soc.*, 1925, 127, 813.
[2] Phillips, *Ber.*, 1886, 19, 1031; Michaelis, *Annalen*, 1902, 321, 180.
[3] Morgan and Micklethwait, *Trans. Chem. Soc.*, 1909, 95, 1474.
[4] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2486.
[5] Michaelis, *loc. cit.*

It is easily soluble in hot alcohol but insoluble in ether. *p-Tolylarsenoxide* melts at 156° C., and has similar properties to the foregoing compound. Dry chlorine converts it to *p-tolylarsenic oxychloride*, $C_7H_7.AsOCl_2$.[1] *m-Tolylarsenoxide* only occurs as a viscous mass.[2]

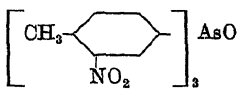
Di-p-tolylarsenoxide, $(C_7H_7)_2AsO$,[3] is formed by boiling di-*p*-tolylchloroarsine with an excess of alcoholic potassium hydroxide. It crystallises in fine, glistening needles, M.pt. 98° C., which on strong heating give tri-*p*-tolylarsine.

Phenyl-p-tolylarsenoxide, $C_6H_5.C_7H_7.AsO$,[4] is a syrupy, yellow liquid, isolated in a similar manner to the preceding compound.

Phenyldi-p-tolylarsine oxide, $C_6H_5.(C_7H_7)_2AsO$, is a white powder, M.pt. 81° C., which gives a *basic nitrate*, M.pt. 94° C., on boiling with dilute nitric acid.

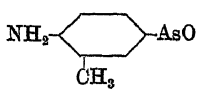
Tri-m-tolylarsine oxide, $(C_7H_7)_3AsO$, is prepared by treating the corresponding arsine with an excess of bromine water, then boiling the product with potassium hydroxide until colourless. It yields white crystals, M.pt. 170° C., readily soluble in alcohol, less soluble in ether.

Tri-3-nitrotri-4-tolylarsine oxide,[5]



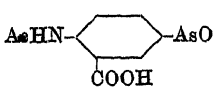
10 grams of tri-*p*-tolylarsine are added to a cool mixture of 20 c.c. of fuming nitric acid and 40 c.c. of concentrated sulphuric acid, and the whole poured into water. The nitro-compound (12 grams) separates out, and is recrystallised. It forms large, yellow, strongly refracting prisms of the monoclinic system, which melt at 212° C., and are readily soluble in acetic acid or hot alcohol, insoluble in ether. Stronger nitration of the arsine yields the *dinitrate* instead of the oxide.

4-Amino-3-methylphenylarsenoxide,[6]



is obtained by reducing the corresponding arsinic acid with sulphur dioxide in the presence of potassium iodide. It is a white, crystalline product, softening at 100° C. and melting at 160° C.; slightly soluble in hot water, moderately soluble in alcohol, acetone, sodium hydroxide, or dilute acids.

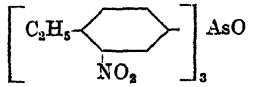
3-Carboxy-4-acetamidophenylarsenoxide,



The corresponding arsinic acid is reduced by boiling with phenylhydrazine for two hours in methyl alcohol solution. The oxide decomposes at about 300° C., is soluble in alkalis and alkali carbonates, hot water, hot hydrochloric acid or acetic acid, insoluble in alcohol or ether.

[1] La Coste and Michaelis, *Ber.*, 1878, 11, 1888; *Annalen*, 1880, 201, 184.
[2] Michaelis, *Annalen*, 1902, 320, 327; Eisenlohr, *Inaug. Dissert.*, Rostock, 1893.
[3] La Coste, *Annalen*, 1881, 208, 1.
[4] Michaelis, *Annalen*, 1902, 321, 141.
[5] Michaelis, *ibid.*, 1902, 320, 334.
[6] German Patent, 212205.

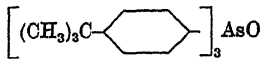
Tri-3-nitrotri-4-ethylphenylarsine oxide,



is a yellow, crystalline compound, M.pt. 232° C.

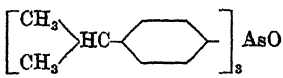
Tribenzylarsine oxide, $(C_6H_5.CH_2)_3AsO$,[1] results when tribenzylarsine hydroxyhalides are boiled with aqueous alkalis. It crystallises in colourless prisms from dilute alcohol, M.pt. 219° to 220° C., soluble in acetic acid, sparingly soluble in cold water, ether, or benzene. When treated with mineral acids it gives hydroxyhalides. Reduction by zinc and acetic acid in the presence of hydrochloric acid yields tribenzylarsine, whilst hydriodic acid and red phosphorus convert the oxide into tetrabenzylarsonium iodide. Hydrogen sulphide reacts with an alcohol solution of the oxide to form the corresponding sulphide.

Tri-tertiary-butylphenylarsine oxide,



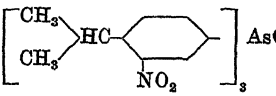
melts above 360° C.[2]

Tri-p-cumylarsine oxide,



forms small white needles, M.pt. 129° C., yielding the *hydroxynitrate* on warming with dilute nitric acid.

Tri-3-nitrotri-4-cumylarsine oxide,



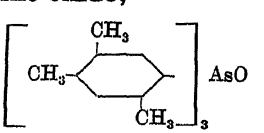
is formed by nitrating the arsine, using mixed acids. It crystallises in small, pale yellow needles, melting at 245° C. with decomposition.

m-Xylylarsenoxide, $C_8H_9.AsO$,[3] is formed when *m*-xylyldichloroarsine is treated with sodium carbonate solution. It crystallises in small granules, M.pt. about 220° C., readily reacting with halogens and hydrogen sulphide, giving *oxyhalides* and a *sulphide* respectively. *p-Xylylarsenoxide* melts at 165° C.

Tri-m-xylylarsine oxide, $(C_8H_9)_3AsO$, is obtained from the bromide by the action of alkali; with aqueous alcohol it yields the hydroxide.

Phenyldi-m-xylylarsine oxide, $C_6H_5(C_8H_9)_2AsO$, results when the hydroxide is heated. It melts at 120° C. Treatment of phenyldi-*m*-xylylarsine with mixed acids yields *trinitrodi-m-xylylphenylarsine oxide*, pale yellow crystals, M.pt. 245° C.

Tripseudocumylarsine oxide,[4]



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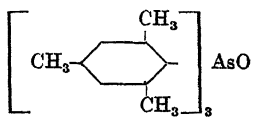
[1] Michaelis and Paetow, *Ber.*, 1885, 18, 41; *Annalen*, 1886, 233, 60.
[2] Michaelis, *Annalen*, 1902, 321, 238.
[3] Michaelis, *ibid.*, 1902, 320, 330; Seemann, *Inaug. Dissert.*, Rostock, 1891.
[4] Michaelis, *Annalen*, 1902, 321, 227.

is formed when the corresponding hydroxide is heated at 120° C. It melts at 227° to 228° C.

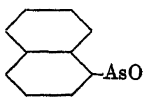
Phenyldipseudocumylarsine oxide, $[C_6H_2(CH)_3]_2C_6H_5.AsO$.—The hydroxide, when heated at 100° C. *in vacuo*, loses water, forming the oxide. This melts at 162·5° C., is readily soluble in alcohol or benzene, less soluble in ether. Nitration of phenyldi*pseudo*cumylarsine yields *trinitrodipseudocumylphenylarsine oxide*, which crystallises in pale yellow crusts, M.pt. 163° C.

Trimesitylarsine oxide,



is isolated by treating the hydroxychloride with potassium hydroxide. It melts at 203° to 204° C., is soluble in alcohol but insoluble in ether.

α-Naphthylarsenoxide,[1]



is a white powder, M.pt. 245° C., formed by treating the corresponding chloride with alkali. It is only sparingly soluble in boiling alcohol, insoluble in water, benzene, or ether. When subjected to dry distillation it gives naphthalene, arsenic, and carbon, not trinaphthylarsine.

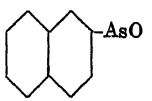
Di-α-naphthylarsenoxide, $(C_{10}H_7)_2AsO$.[2]—The interaction between magnesium α-naphthyl bromide and arsenious oxide is represented as taking place as follows :

$$4RMgBr+As_2O_3=(R_2As)_2O+2MgO+2MgBr_2$$
$$(R_2As)_2O+2RMgBr=2R_3As+MgO+MgBr_2$$

The oxide melts at 240° to 241° C.

Tri-α-naphthylarsine oxide, $(C_{10}H_7)_3AsO$.[3]—The corresponding dihydroxide, $(C_{10}H_7)_3As(OH)_2.2H_2O$, when dried at 110° C., loses three molecules of water, forming the oxide.

β-Naphthylarsenoxide,



is prepared by treating an alcoholic solution of the chloride with alcoholic potassium hydroxide and pouring the mixture into hydrochloric acid. It is a white, granular powder, M.pt. 270° C., sparingly soluble in alcohol, insoluble in other solvents.

Tri-β-naphthylarsine oxide crystallises from alcohol-benzene in fine needles, and is formed from the dibromide by the action of alcoholic potassium hydroxide.

Phenyl-α-naphthylmethylarsine oxide, $(C_6H_5)(C_{10}H_7)(CH_3)AsO$.[4]

[1] Michaelis and Schulte, *Ber.*, 1882, 15, 1952; Michaelis, *Annalen*, 1902, 320, 342; Büschler, *Inaug. Dissert.*, Rostock, 1893.

[2] Matsumiya and Nakal, *Mem. Coll. Sci. Kyōtō*, 1925, 8, 307.

[3] Michaelis, *Annalen*, 1902, 320, 342.

[4] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 432.

—Phenyl-α-naphthylmethylarsine in chloroform solution is treated with bromine (1 mol.) in the same solvent, the mixture being well cooled. The solution is then shaken with a slight excess of aqueous sodium hydroxide and the chloroform layer removed, washed, dried, and evaporated. It may also be prepared from the arsine by oxidation with hydrogen peroxide.[1] The oxide crystallises from toluene in well-defined prisms, M.pt. 175° C. Its *bromocamphorsulphonate* melts at 161° C.

Sulphophenyl-α-naphthylmethylarsine oxide, $(C_6H_4.SO_3H)(C_{10}H_7)(CH_3)AsO$, results when the preceding oxide is treated with oleum (20 per cent. SO_3) and the whole poured into water. The precipitate formed is dissolved in ammonium hydroxide, the solution boiled with charcoal and filtered into hot acetic acid. The sulphonic acid separates on cooling in fine white crystals, M.pt. 249° C.[2]

Dicyclohexylarsenoxide, $[(C_6H_{11})_2As]_2O$,[3] results when the dichloroarsine is shaken with aqueous sodium carbonate. It is a highly viscous, non-distillable product.

Cyclohexylphenylarsenoxide, $[(C_6H_{11})C_6H_5.As]_2O$, is prepared in a similar manner to the preceding oxide, and possesses similar properties.

Triarylarsine Dihydroxides and their Derivatives.

Triphenylarsine dihydroxide, $(C_6H_5)_3As(OH)_2$.—The corresponding dichloride or hydroxychloride is boiled with ammonium hydroxide, or for a long time with water, the dihydroxide resulting.[4] The dihydroxide is also obtained when triphenylarsine in glacial acetic acid solution is treated with bromine and the whole poured into sodium hydroxide solution, or by decomposing the compound $(C_6H_5)_3AsCl.S.S.Cl$ with boiling water.[5] It separates from water in colourless needles, M.pt. 115° to 116° C., sparingly soluble in alcohol or ether. At 189° C. it is converted to the oxide. If the oxide is dissolved in boiling aqueous sodium molybdate solution, and the solution acidified by the gradual addition of hydrochloric acid, a yellow, amorphous substance is isolated, to which the following formula has been assigned :[6]

$$\left[\begin{array}{c}(C_6H_5)_3\\ As\\ Mo_2O_7\end{array}\right]$$

When the dihydroxide is treated with dilute nitric acid it yields *triphenylarsine hydroxynitrate*, consisting of needles, M.pt. 160° to 161° C., but if the hydroxide or oxide is evaporated to dryness with concentrated nitric acid, *triphenylarsine dinitrate*, M.pt. 99° to 100° C., results. Interaction of the hydroxychloride and potassium chromate gives a yellowish-red precipitate of *triphenylarsine hydroxychromate*, $(C_6H_5)_3As(OH)O.HCrO_3$.

Tri-p-tolylarsine dihydroxide, $(C_7H_7)_3As(OH)_2$, crystallises in needles, M.pt. 96° C., and is obtained by the action of alkali on the dichloride or hydroxychloride.[7]

[1] Aeschlimann, *Trans. Chem. Soc.*, 1925, 127, 813. [2] Aeschlimann, *ibid.*
[3] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1911.
[4] Michaelis, *Annalen*, 1902, 321, 141; La Coste and Michaelis, *Ber.*, 1878, 11, 1887.
[5] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2479.
[6] Michaelis, *loc. cit.* [7] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.

Tri-p-ethylphenylarsine dihydroxide, $(C_6H_4.C_2H_5)_3As(OH)_2$, melts at 180° C.

Tri-p-cumylarsine forms a *hydroxynitrate,* $(C_9H_{11})_3As(OH).NO_3$, M.pt. 147° C., and *tripseudocumylarsine,* a *dihydroxide,* $(C_9H_{11})_3As(OH)_2.4H_2O$, which crystallises in white needles, M.pt. 120° C.

Tri-α-naphthylarsine dihydroxide, $(C_{10}H_7)_3As(OH)_2$, crystallises with two molecules of water, and does not melt below 300° C. In addition to the usual method of preparation it may be obtained by decomposing the compound $(C_{10}H_7)_3As.S_2Cl_2$ with warm dilute potassium hydroxide solution.[1]

Phenyldi-m-xylylarsine dihydroxide, $C_6H_5(C_8H_9)_2As(OH)_2$,[2] melts at 112° C., and the *hydroxynitrate* forms transparent crystals, M.pt. 126° C.

Phenyldipseudocumylarsine dihydroxide, $C_6H_5[C_6H_2(CH_3)_3]_2As(OH)_2$, crystallises in colourless prisms, M.pt. 113° to 114° C.

Diphenyl-p-tolylarsine dihydroxide, $(C_6H_5)_2(C_7H_7)As(OH)_2$, is obtained by treating the corresponding arsine with bromine in hot glacial acetic acid solution, then pouring the mixture into an excess of potassium hydroxide and boiling for thirty minutes. It melts at 68° C., and is very soluble in alcohol. When heated with dilute nitric acid, a *hydroxynitrate* is formed, $(C_6H_5)_2(C_7H_7)As(OH)(NO_3)$, which crystallises in needles, M.pt. 125° C.

Hexamethyltri-4-aminotriphenylarsine dihydroxide, $[C_6H_4N(CH_3)_2]_3As(OH)_2$, results when the arsine-sulphur monochloride addition product, $[C_6H_4N(CH_3)_2]_3As.S_2Cl_2$, is dissolved in hydrochloric acid and potassium hydroxide added. It forms warty crystals, M.pt. 257° C., readily soluble in ethyl acetate, sparingly soluble in alcohols, benzene, ether, or carbon disulphide, insoluble in water.[3]

Compounds of the Types $RAsS$; $RAsS_2$; $(RAs)_2S_3$.

Hydrogen sulphide readily reacts with halogenated aryl arsines or arylarsenoxides, the corresponding sulphides resulting:

$$RAsX_2+H_2S=RAsS+2HX$$
$$RAsO+H_2S=RAsS+H_2O$$

Treatment of an arseno-compound with sulphur may also lead to the formation of sulphides:

$$RAs:AsR+S_2=2RAsS$$

Substituted aryl arsenious sulphides are produced by the reduction of the corresponding arsinic acids in ammoniacal solution with hydrogen sulphide:

$$RAsO(OH)_2+2H_2S=RAsS+3H_2O+S$$

Reduction of ammoniacal solutions of arylarsinic acids by hydrogen sulphide is not always such a simple process as indicated by the above equation. The process is capable of producing sulphides of the types $RAsS_2$ and $(RAs)_2S_3$ when the reaction mixture is treated with mineral acids. The final product depends upon the stability of the disulphide

[1] Zuckerkandl and Sinai, *loc. cit.*
[2] Michaelis, *loc. cit.*
[3] Zuckerkandl and Sinai, *loc. cit.*

towards acid, for instability leads to a loss of sulphur and formation of a sesquisulphide :

$$RAsO(ONH_4)_2+3H_2S=RAsS(SNH_4)_2+3H_2O$$
$$RAsS(SNH_4)_2+2HX=RAsS_2+2NH_4X+H_2S$$
$$2RAsS(SNH_4)_2+4HX=(RAs)_2S_3+4NH_4X+2H_2S+S$$

The reduction of 3-nitro-4-tolylarsinic acid by ammoniacal hydrogen sulphide is interesting, the resulting compound being 3-amino-4-tolyl-thioarsinic acid, $NH_2.C_7H_6.AsS(SH)_2$.

In addition to the foregoing method, disulphides are obtained by treating arseno-compounds with sulphur, or by the action of hydrogen sulphide on aqueous solutions of arsinic acids :

$$RAs:AsR+2S_2=2RAsS_2$$
$$RAsO(OH)_2+2H_2S=RAsS_2+3H_2O$$

Some of the foregoing general methods may be applied to the preparation of diarylarsenious sulphides. Halogenated secondary arsines or their oxides yield sulphides when treated with hydrogen sulphide :

$$2R_2AsX+H_2S=(R_2As)_2S+2HX$$
$$(R_2As)_2O+H_2S=(R_2As)_2S+H_2O$$

Substituted diarylarsenious sulphides result when the corresponding arsinic acids in concentrated ammonium hydroxide are treated with hydrogen sulphide and the resulting products treated with dilute hydrochloric acid :

$$(NO_2.C_6H_4)_2AsO(ONH_4)+8(NH_4)_2S=(NH_2.C_6H_4)_2AsS.SNH_4+6H_2O+6S+16NH_3$$
$$2(NH_2.C_6H_4)_2AsS.SNH_4+6HCl=[(NH_2.C_6H_4)_2As]_2S.4HCl+2NH_4Cl+H_2S+S_2$$

Tetra-aryldiarsines when boiled with a suspension of sulphur in benzene solution yield diarylarsenious sulphides, but an excess of sulphur may result in the formation of an arylarsenious sesquisulphide,

$$R_2As.AsR_2+S=(R_2As)_2S$$
$$R_2As.AsR_2+2S_2=(R_2As)_2S_3+R_2S$$

Diarylarsenious sulphides may result as by-products when magnesium aryl halides interact with arsenic trisulphide.

Triarylarsine sulphides are formed when triarylarsine dihalides, hydroxyhalides or oxides in alcohol solution are treated with hydrogen sulphide :

$$R_3AsCl_2+H_2S=R_3AsS+2HCl$$

Dihalides also give sulphides when boiled with yellow ammonium sulphide. Triarylarsines in suitable solvents, such as carbon disulphide, combine directly with sulphur to yield sulphides, and a similar result is obtained when the arsines are melted with powdered sulphur :

$$R_3As+S=R_3AsS$$

The addition product formed from triarylarsines and sulphur chloride is converted to the sulphide by hydrogen sulphide :

$$R_3AsCl.S.S.Cl+H_2S=R_3AsS+2HCl+S_2$$

The interaction of magnesium aryl halides and arsenic trisulphide yields tertiary arsine sulphides amongst other products.

The mono- and diarylarsenious sulphides are oxidised by nitric acid to the corresponding arsinic acids. Distillation in dry carbon dioxide converts phenylarsenious sulphide into the tertiary arsine :

$$3RAsS = R_3As + As_2S_3$$

Zinc or mercury dialkyls are also capable of converting this sulphide into a mixed tertiary arsine :

$$RAsS + HgAlk_2 = RAsAlk_2 + HgS$$

Hydrochloric acid, in many cases, transforms sulphides into chlorides :

$$RAsS + 2HCl = RAsCl_2 + H_2S$$
$$(R_2As)_2S + 2HCl = 2R_2AsCl + H_2S$$

When tri-β-naphthylarsine sulphide in benzene solution is heated with mercury, pure tri-β-naphthylarsine is isolated :

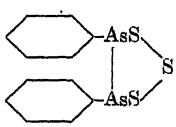
$$R_3AsS + Hg = R_3As + HgS$$

Phenylarsenious sulphide, $C_6H_5.AsS$.[1]—When an alcohol solution of phenylarsenoxide or chloride is saturated with hydrogen sulphide, a slight evolution of heat is noticed, and the sulphide separates as a yellow powder. Arsenobenzene combines directly with sulphur to give phenylarsenious sulphide. The sulphide crystallises from benzene in fine, white needles, M.pt. 152° C., sparingly soluble in cold benzene, alcohol, and ether, readily soluble in hot benzene and cold carbon disulphide. It is oxidised by nitric acid to phenylarsinic acid, and when distilled in dry carbon dioxide reacts as follows :

$$3C_6H_5.AsS = (C_6H_5)_3As + As_2S_3$$

It reacts with zinc or mercury diethyl to form phenyldiethylarsine.

Phenylarsenic sesquisulphide,



When phenylarsinic acid in ammoniacal solution is saturated with hydrogen sulphide and then treated with hydrochloric acid, the following reactions take place :

$$C_6H_5.AsO\begin{matrix}ONH_4\\ONH_4\end{matrix} + 3H_2S = C_6H_5.AsS\begin{matrix}SNH_4\\SNH_4\end{matrix} + 3H_2O$$

$$2C_6H_5.AsS\begin{matrix}SNH_4\\SNH_4\end{matrix} + 4HCl = (C_6H_5.As)_2S_3 + 4NH_4Cl + 2H_2S + S$$

Some sesquisulphide is also formed when arsenobenzene, sulphur and ammonium sulphide are heated together in a sealed tube.[2] It crystallises

[1] Schulte, *Ber.*, 1882, 15, 1955.
[2] Michaelis and Schulte, *ibid.*, 1882, 15, 1952.

in pale yellow prisms from benzene, and from acetic acid in plates, M.pt. 130° C. It is oxidised to the acid by nitric acid, is insoluble in ammonium hydroxide, but dissolves readily in sodium hydroxide. It dissolves readily in sodium sulphide to form *disodium phenylthioarsinate*, $C_6H_5.AsS(SNa)_2.6H_2O$, which crystallises in shining needles, readily soluble in water, less soluble in alcohol. It is decomposed by acids, the sesquisulphide being obtained.

m-Nitrophenylarsenic sulphide, $NO_2.C_6H_4.AsS_2$,[1] results when *m*-dinitroarsenobenzene in aqueous suspension is boiled with flowers of sulphur (4 atoms) for one hour, the mixture rendered ammoniacal by ammonium hydroxide, filtered, and the filtrate treated with mineral acid. The sulphide separates as a white powder, sparingly soluble in alcohol or benzene, insoluble in ether or chloroform. It melts at about 80° C.

m-Nitrophenylarsenic sesquisulphide, $(NO_2.C_6H_4.As)_2S_3$.—Ten grams of the corresponding nitro-acid in 200 c.c. of water are treated with hydrogen sulphide at 50° to 60° C. and allowed to stand for twelve hours. The product is then treated with ammonium hydroxide and precipitated as above. It forms small, yellow crystals, M.pt. 119° C., soluble in benzene, sparingly soluble in chloroform and carbon disulphide, insoluble in petroleum ether, ether, and water. Oxidising agents convert it into nitrophenylarsinic acid.

m-Aminophenylarsenious sulphide, $NH_2.C_6H_4.AsS$.—A rapid stream of hydrogen sulphide is passed into 20 grams of *m*-nitrophenylarsinic acid dissolved in concentrated ammonium hydroxide, and the solution warmed for twelve hours on the water-bath, the ammonium hydroxide being replenished from time to time. The solution is evaporated to dryness, the residue extracted with water and the extract treated with dilute hydrochloric acid. The sulphur is filtered off and the amine precipitated by ammonium hydroxide. Yield, 11 grams or 69 per cent. It is a white powder, sintering at 182° C. and melting at 188° C., readily soluble in hydrochloric acid, concentrated acid precipitating the *hydrochloride*, $(NH_2.C_6H_4.AsS)_3.2HCl$. When the sulphide is boiled with hydrochloric acid, hydrogen sulphide is evolved and *m-aminophenyldichloroarsine* formed, $NH_2.C_6H_4.AsCl_2$.

p-Aminophenylarsenious sulphide, $NH_2.C_6H_4.AsS$.[2]—This may be prepared either by saturating a solution of *p*-aminophenylarsinic acid in hydrochloric acid (density 1·19) with hydrogen sulphide, or by allowing the latter to react with *p*-aminophenylarsenoxide in cold methyl alcohol solution.[3] The sulphide is a yellowish-white powder, sintering at 165° C. and melting at about 180° C. It dissolves readily in aniline and pyridine, is somewhat soluble in acetone, sparingly soluble in alcohol, insoluble in acetic acid, benzene, carbon disulphide, and chloroform.

p-Acetylaminophenylarsenic sesquisulphide,[4] $(CH_3.CO.NH.C_6H_4.As)_2S_3$.—Acetyl-*p*-arsanilic acid (80 grams) in 800 c.c. of 25 per cent. ammonium hydroxide is saturated with hydrogen sulphide. The liquor is diluted to 8000 c.c. with water and acidified with hydrochloric acid, the sulphide separating in snow-white flocks. It crystallises from alcohol in glistening needles, M.pt. 208° C., readily soluble in aniline or pyridine, less soluble in alcohol and acetic acid, and sparingly soluble in toluene and chloroform.

[1] Michaelis and Loesner, *Ber.*, 1894, *27*, 263.
[2] German Patent, 205617.
[3] English Patent, 17619 (1907).
[4] German Patent, 205617.

Thiolacetylaminophenyl-4-arsenic sulphide, $AsS_2.C_6H_4.NH.S.COCH_3$.[1]—To a solution of 20 grams of formaldehyde sulphoxylate in 20 c.c. of water, 30 grams of atoxyl are added. At 70° C. a brownish-yellow solution is obtained, which is diluted to 100 c.c. This is cooled and treated with 30 c.c. of thioacetic acid in small quantities, then heated to about 45° C. and allowed to stand overnight. The liquor is decanted off, and the solid which has separated is washed with acetone, methyl alcohol, and ether, then dissolved in pyridine, the solution filtered, and the sulphide reprecipitated by the addition of methyl alcohol. Yield about 11 grams; M.pt. 183° C., with decomposition. The sulphide and its solution in pyridine are both red.

Bisthiolacetylaminophenyl-p-p′-arsenic sesquisulphide, $(CH_3.CO.S.NH.C_6H_4.As)_2S_3$.—The liquid which is decanted off in the previous preparation is treated with an excess of dilute hydrochloric acid and allowed to stand for several hours. A yellow precipitate separates, which is filtered off, washed with water, methyl alcohol, and ether, extracted with carbon disulphide, and dried in a vacuum. The yield is about 20 grams. The sulphide is purified by solution in pyridine and reprecipitation with methyl alcohol. It sinters at 150° C. and melts with decomposition at 159° C.

The interaction of atoxyl and formaldehyde sulphoxylate in aqueous solution gives rise to the following magnesium product:

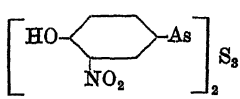
$$MgO_3As.C_6H_4.NH.CH_2.O.S.ONa.2H_2O$$

This is converted by thioacetic acid into a mixture of the foregoing disulphide and sesquisulphide.

Phenylglycine-p-arsenic sulphide, $CO_2H.CH_2.NH.C_6H_4.AsS_2$.[2]—A solution of 20 grams of phenylglycine-*p*-arsinic acid in 1000 c.c. of water is saturated with hydrogen sulphide. The disulphide separates as a pale yellow powder, sintering at 70° C. and decomposing at 142° C. It becomes yellow in the light, and is sparingly soluble in the usual organic solvents.

p-Dimethylaminophenylarsenious sulphide, $N(CH_3)_2.C_6H_4.AsS$,[3] is obtained when hydrogen sulphide is passed into an alcohol solution of the corresponding oxide or a neutral solution of *p*-dimethylamino-phenyldichloroarsine hydrochloride. It crystallises from chloroform in white needles, M.pt. 187° C., which are stable in cold hydrochloric acid, but on heating, hydrogen sulphide is evolved and the sulphide converted into the hydrochloride. The sulphide is insoluble in alkali and hot water. The corresponding *p-diethylaminophenylarsenious sulphide* forms white needles, M.pt. 155° C., very soluble in chloroform, insoluble in alcohol.

3-Nitro-4-hydroxyphenylarsenic sesquisulphide,[4]



[1] Binz and Holzapfel, *Ber.*, 1920, 53, [B], 2026.
[2] German Patent, 205617.
[3] Michaelis and Rabinerson, *Annalen*, 1892, 270, 139.
[4] German Patent, 253757.

3-Nitro-4-hydroxyphenylarsinic acid (26·3 grams) in 50 c.c. of 2*N* sodium hydroxide and 300 c.c. of water, is saturated at the ordinary temperature with hydrogen sulphide. The mixture is then acidified with dilute hydrochloric acid, and after standing for a short time is filtered and the solid washed with water, then digested with 150 c.c. of acetone, completely reprecipitated by water, and crystallised from boiling xylene. It forms warty aggregates of hard, yellow crystals, melting and decomposing at about 160° C. Its solutions in alkalis are reddish-brown. When the above reduction is carried out by the use of sodium mono- or di-sulphide, the resulting product is a pale brown powder, which yields sulphur when dissolved in alkali or mineral acids. When its hydrochloric acid solution is treated with dilute sulphuric acid, a sparingly soluble *sulphate* is produced.

3-Amino-4-hydroxyphenylarsinic acid yields a *sulphide* when reduced by hydrogen sulphide, but the composition of the sulphide does not appear to have been determined with certainty. The sulphide is soluble in acids and alkalis, solutions in the latter on boiling with lead acetate giving a black precipitate. A sparingly soluble *sulphate* has been obtained. The *hydrochloride* of the amino-acid also gives a sulphur derivative.[1]

Diphenylarsenious sulphide, $[(C_6H_5)_2As]_2S$,[2] is obtained by passing hydrogen sulphide into alcohol solutions of the corresponding oxide or chloride, or by treating the latter with sodium hydrosulphide.[3] It crystallises in glistening needles, M.pt. 67° C., readily soluble in benzene, carbon disulphide, and chloroform, less soluble in alcohol, ether, and acetic acid, insoluble in alkalis and alkali sulphides. With hydrochloric acid it gives hydrogen sulphide and diphenylchloroarsine.

3 : 3′-Dinitrodiphenylarsenious sulphide, $[(NO_2.C_6H_4)_2As]_2S$, results when a slight excess of tetranitrotetraphenyldiarsine is boiled with a suspension of sulphur in benzene. It forms warty aggregates of yellow needles, M.pt. 156° C. When an excess of sulphur is used, *tetranitrotetraphenyldiarsenious trisulphide*, $[(C_6H_4NO_2)_2]_2As_2S_3$, is formed as a yellow powder, M.pt. 69° C.

3 : 3′-Diaminodiphenylarsenious sulphide, $[(NH_2.C_6H_4)_2As]_2S$. —Hydrogen sulphide is passed into a solution of 3 : 3′-dinitrodiphenylarsinic acid in concentrated ammonium hydroxide, when the following reaction takes place :

$$(NO_2.C_6H_4)_2AsO.ONH_4+8(NH_4)_2S=(NH_2.C_6H_4)_2AsS.SNH_4+6H_2O+6S+16NH_3$$

Treatment of this product with dilute hydrochloric acid, avoiding rise of temperature, gives the sulphide in the form of its hydrochloride :

$$2(NH_2.C_6H_4)_2AsS.SNH_4+6HCl=[(NH_2.C_6H_4)_2As]_2S.4HCl+2NH_4Cl+H_2S+S_2$$

The sulphur is filtered off and the sulphide precipitated by adding ammonium hydroxide, a white, amorphous powder, M.pt. 110° C.,

[1] Co-ordination compounds between palladium chloride and 3-amino-4-hydroxyphenylarsenious sulphide, 3-amino-4-hydroxyphenyldichloroarsine hydrochloride and cupric chloride, 3-carboxy-4-aminophenylarsenoxide and auric chloride, are dealt with in German Patent, 281101.

[2] Michaelis, *Annalen*, 1902, 321, 141.

[3] M'Kenzie and Wood, *Trans. Chem. Soc.*, 1920, 117, 406.

being isolated. Its salts are readily soluble in water. the *sulphate* crystallising in needles and the *acetyl derivative* melting at 175° C.

Triphenylarsine sulphide, $(C_6H_5)_3AsS$.—This sulphide may be obtained in several ways: (1) By passing hydrogen sulphide into an alcohol solution of triphenylarsine hydroxide.[1] (2) By boiling the corresponding dichloride with yellow ammonium sulphide.[2] (3) By boiling triphenylarsine with sulphur in carbon disulphide solution. (4) By melting triphenylarsine with powdered sulphur. (5) By treating the addition compound of triphenylarsine and sulphur monochloride with hydrogen sulphide.[3] It crystallises from alcohol in glistening needles, M.pt. 162° C., insoluble in sodium sulphide, acids, and ether. It yields a *mercurichloride*, M.pt. 239° to 241° C.[4]

Tetraphenylarsenic disulphide, $[(C_6H_5)_2As]_2S_2$, is prepared by treating a strongly ammoniacal solution of diphenylarsinic acid for two hours with hydrogen sulphide and then acidifying with hydrochloric acid.[5] It crystallises from alcohol in plates, sintering at 60° C. and melting at 110° C. It is soluble in ammonium sulphide.

Hexamethyltri-4-aminotriphenylarsine sulphide, $[(CH_3)_2N.C_6H_4]_3AsS$.[6]—The addition compound of the arsine with sulphur monochloride when treated with ammonium pentasulphide, $(NH_4)_2S_5$, yields this sulphide. It crystallises in plates, M.pt. 269° to 270° C., readily soluble in chloroform, sparingly soluble in other solvents.

p-Tolylarsenious sulphide, $CH_3.C_6H_4.AsS$.[7]—Hydrogen sulphide is passed into an alcohol solution of *p*-tolylarsenoxide and the resulting product recrystallised from benzene-ether. The sulphide forms white, glistening crystals, M.pt. 146° C., readily soluble in chloroform and benzene, very sparingly soluble in alcohol and ether.

p-Tolylarsenic sesquisulphide, $(CH_3.C_6H_4.As)_2S_3$, is prepared in a similar way to the corresponding phenyl compound. It melts at 119° to 120° C., is readily soluble in benzene and carbon disulphide, sparingly soluble in acetic acid, alcohol, or ether.

3-Nitro-4-tolylarsenious sulphide, $NO_2.C_7H_6.AsS$.—5 grams of the corresponding acid in 200 c.c. of water are treated at 70° C. with a rapid stream of hydrogen sulphide for two hours, then allowed to stand for twelve hours. The process is then repeated, and after treatment with ammonium hydroxide the mixture is filtered to remove the sulphur. The filtrate yields the sulphide on acidification with hydrochloric acid. The product is dissolved in benzene, alcohol added until the solution is turbid, and after standing for twenty-four hours the sulphide separates in small yellow needles, M.pt. 141° to 142° C., readily soluble in benzene, sparingly soluble in ether and water. When strongly heated it explodes.

3-Amino-4-tolylthioarsinic acid, $NH_2.C_7H_6.S(SH)_2$, is the reduction product of 3-nitro-4-tolylarsinic acid, using hydrogen sulphide in ammoniacal solution. It yields a *sulphate*, decomposing at 155° C., readily soluble in dilute alkali and reprecipitated by sulphuric acid. With concentrated hydrochloric acid it gives a sparingly soluble hydrochloride.

[1] Phillips, *Ber.*, 1886, 19, 1031.
[2] La Coste and Michaelis, *Ber.*, 1878, 11, 1887.
[3] Zuckerkandl and Sinai, *Ber.*, 1921, 54, [B], 2479.
[4] Matsumiya and Nakai, *Mem. Coll. Sci. Kyōtō*, 1926, 10, 57.
[5] Michaelis, *Annalen*, 1902, 321, 141.
[6] Zuckerkandl and Sinai, *loc. cit.*
[7] Michaelis, *Annalen*, 1902, 320, 302.

Phenyl-p-tolylarsenious sulphide, $[C_6H_5(C_7H_7)As]_2S$,[1] is an oily substance, rapidly oxidising to the arsinic acid.

Di-p-tolylarsenious sulphide, $(C_7H_7)_2AsS$, results, amongst other products, when magnesium *p*-tolyl bromide reacts with arsenic trisulphide.[2]

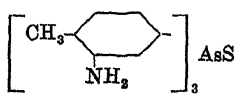
Phenyldi-p-tolylarsine sulphide,[3] $C_6H_5.(C_7H_7)_2.AsS$, prepared from the oxide in the usual manner, melts at 144° C., and is soluble in the usual organic solvents.

Diphenyl-p-tolylarsine sulphide, $(C_6H_5)_2.C_7H_7.AsS$, forms granular crystals from hot alcohol, M.pt. 135° C., and is obtained from the hydroxide.

Tri-p-tolylarsine sulphide, $(C_7H_7)_3.AsS$, is not obtained directly by the interaction of sulphur and the arsine, but by passing hydrogen sulphide through an aqueous solution of the oxychloride. It also results, along with tri-*p*-tolylarsine and di-*p*-tolylarsenious sulphide, when magnesium-*p*-tolyl bromide reacts with arsenic trisulphide. It forms glistening plates, M.pt. 170° to 171° C., and yields a *mercurichloride*, M.pt. 227° to 229° C.[4]

Tri-m-tolylarsine sulphide[5] forms silvery, glistening needles, M.pt. 186° C., and is formed by direct combination of the arsine and sulphur.

Tri-3-amino-tri-4-tolylarsine sulphide,



An alcohol solution of the arsine is treated first with ammonia, then with hydrogen sulphide, and warmed. The sulphide is insoluble in organic solvents, but dissolves in most dilute acids. It forms a *sulphate*, $2(C_7H_6.NH_2)_3AsS.3H_2SO_4$, which is insoluble in water but readily dissolves in hot dilute hydrochloric acid.

Tri-p-ethylphenylarsine sulphide,[6] $(C_2H_5.C_6H_4)_3AsS$, is a crystalline product, M.pt. 123° C.

Benzylarsenic sulphide, $C_6H_5.CH_2.AsS_2$,[7] is prepared by treating an aqueous solution of benzylarsinic acid with hydrogen sulphide. It is a heavy, bright yellow oil, dissolving rapidly in nitric acid, with liberation of sulphur and oxides of nitrogen. When heated alone it yields hydrogen sulphide, arsenious oxide, and stilbene, probably according to the equation:

$$2C_6H_5.CH_2.AsS_2+3O=C_6H_5.CH:CH.C_6H_5+As_2O_3+H_2S+3S$$

Tribenzylarsine sulphide, $(C_6H_5.CH_2)_3AsS$, may be obtained either by direct combination of the arsine and sulphur in glacial acetic acid,[8] or by passing hydrogen sulphide into an alcohol solution of the oxide. It crystallises in prisms, M.pt. 212° to 214° C., sparingly soluble

[1] Michaelis, *Annalen*, 1902, 321, 155.
[2] Matsumiya and Nakai, *Mem. Coll. Sci. Kyōtō*, 1926, 10, 57.
[3] Michaelis, *loc. cit.*
[4] Matsumiya and Nakai, *loc. cit.*
[5] Michaelis, *Annalen*, 1902, 321, 216.
[6] Michaelis, *ibid.*, p. 226.
[7] Dehn and M'Grath, *J. Amer. Chem. Soc.*, 1906, 28, 347.
[8] Michaelis and Paetow, *Annalen*, 1886, 233, 60; Paetow, *Inaug. Dissert.*, Rostock, 1885.

in hot chloroform and acetic acid, insoluble in alcohol, ether, benzene, and carbon disulphide.

m-Xylylarsenious sulphide, $(CH_3)_2C_6H_3.AsS$, crystallises from warm ether or alcohol-benzene in fine, white needles, M.pt. 169° C.[1]

Tri-m-xylylarsine sulphide, $(C_8H_9)_3AsS$,[2] is obtained from its components and crystallises in prisms, M.pt. 145° C.

p-Xylylarsenious sulphide, $(CH_3)_2C_6H_3.AsS$, crystallises from ether in long, yellow needles, M.pt. 188° C. A *disulphide* is also known, $(C_8H_9)_3AsS_2$, being obtained by the action of hydrogen sulphide on an ammoniacal solution of the acid and precipitation of the product by hydrochloric acid. It forms white crystals from benzene, M.pt. 95° C.

Trinitrotri-p-cumylarsine sulphide, $(C_9H_{10}.NO_2)_3AsS$, forms white crystals, M.pt. 149·5° C., and *phenyldipseudocumylarsine sulphide*, obtained by heating the arsine with an excess of yellow ammonium sulphide at 110° C. in a sealed tube, melts at 135° C.

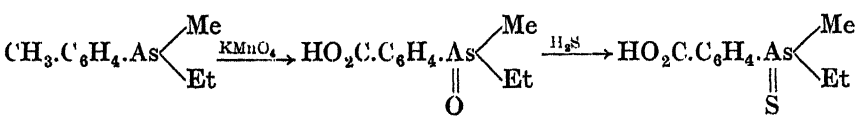
Di-α-naphthylarsenious sulphide, $(C_{10}H_7)_2AsS$,[3] is formed either by the interaction of magnesium α-naphthyl bromide and arsenic trisulphide, or by treating the corresponding oxide or chloride with hydrogen sulphide in the usual way. The sulphide melts at 185° to 186° C.

Tri-α-naphthylarsine sulphide, $(C_{10}H_7)_3AsS$,[4]—The addition product from tri-α-naphthylarsine and sulphur monochloride, when heated with ammonium pentasulphide, yields this sulphide. It crystallises in white plates, M.pt. 285° C., sparingly soluble in benzene and carbon disulphide, insoluble in water, easily soluble in chloroform or ethyl acetate.

Tri-β-naphthylarsine sulphide.[5]—The corresponding bromide in alcoholic solution is treated with hydrogen sulphide. The sulphide crystallises in plates, M.pt. 162° C., soluble in benzene and carbon disulphide, less soluble in ether or alcohol. When its benzene solution is heated under reflux with mercury, mercuric sulphide is precipitated and pure tri-β-naphthylarsine remains.

An Asymmetric Arsenic Compound.

dl-p-Carboxyphenylmethylethylarsine sulphide,[6]



p-Tolylmethylethylarsine, 25 grams, is gradually treated with 50 grams of potassium permanganate in 2000 c.c. of water, the mixture being well shaken during the addition. It is then placed in a thermostat at 35° C. until the oxidation is complete, this taking seven to ten days. Alcohol is then added, the filtrate from the manganese dioxide evaporated to dryness, the residue taken up in 400 c.c. of water, and the solution

[1] Michaelis, *Annalen*, 1902, 320, 330.
[2] Michaelis, *ibid.*, 321, 220.
[3] Matsumiya and Nakai, *Mem. Coll. Sci. Kyōtō*, 1926, 10, 57.
[4] Zuckerkandl and Sinai, *loc. cit.*
[5] Michaelis, *loc. cit.*
[6] Mills and Raper, *Trans. Chem. Soc.*, 1925, 127, 2479.

saturated with hydrogen sulphide. The sulphide is precipitated, and crystallises from water in lustrous needles, M.pt. 183° C., the yield being 10 to 12 grams. The *brucine* salt is prepared and fractionally crystallised fourteen times from water, the rotation in chloroform solution then remaining constant and having the value $[\alpha]^{20°\,C.}_{5461} = -19{\cdot}6°$. The final fraction is shaken with an excess of sodium hydroxide solution and chloroform, and the aqueous layer extracted four times with chloroform to remove the brucine completely. The solution of the sodium salt is kept at 0° C., and acidified with hydrochloric acid, when *l-p-carboxyphenylmethylethylarsine sulphide* is precipitated; this is washed with water and dried. Recrystallisation from chloroform-light petroleum gives a product of M.pt. 175° to 177° C. The following measurements made in a 6-dm. tube at 20° C. are obtained from a solution of 0·5753 gram of the salt in 50 c.c. of absolute alcohol:

$$\alpha^{20°}_{5780} = -1{\cdot}31\,; \quad [\alpha]^{20°}_{5780} = -19{\cdot}1°\,; \quad [M]^{20°}_{5780} = -52°$$
$$\alpha^{20°}_{5461} = -1{\cdot}49\,; \quad [\alpha]^{20°}_{5461} = -21{\cdot}6°\,; \quad [M]^{20°}_{5461} = -59°$$

The *d-p-carboxyphenylmethylethylarsine sulphide* is obtained from the *morphine* salt of the *dl*-acid, which is fractionally crystallised by dissolving in absolute alcohol, filtering, adding ether until the solution becomes turbid, warming and allowing to stand. After ten crystallisations the value for $[\alpha]^{20°}_{5461} = -51{\cdot}1°$, and the final fraction is shaken with chloroform and successive quantities of dilute sulphuric acid, until the latter extracts no more morphine. The chloroform solution, after drying with anhydrous sodium sulphate, is treated with light petroleum to precipitate the *d*-acid. A further crystallisation from chloroform-light petroleum gives a product of M.pt. 175° to 176° C. For measurements, 0·2560 gram of salt in 15 c.c. of absolute alcohol is used in a 2-dm. tube at 20° C., the following values being obtained:-

$$\alpha^{20°}_{5780} = +0{\cdot}64°\,; \quad [\alpha]^{20°}_{5780} = +18{\cdot}7°\,; \quad [M]^{20°}_{5780} = +51°$$
$$\alpha^{20°}_{5461} = +0{\cdot}76°\,; \quad [\alpha]^{20°}_{5461} = +22{\cdot}2°\,; \quad [M]^{20°}_{5461} = +60°$$
$$\alpha^{20°}_{4359} = +1{\cdot}33°\,; \quad [\alpha]^{20°}_{4359} = +39{\cdot}4°\,; \quad [M]^{20°}_{4359} = +107°$$

CHAPTER V.

ARYLARSINIC ACIDS.

Acids of the Types $RAsO(OH)_2$; $R_2AsO.OH$.

The phenyl derivatives of these acids were known as early as 1876, owing to the fact that they are obtainable from halogenated arsines when the latter are treated with water. The older methods for isolating arylarsinic acids consist in decomposing aryl or diarylarsine halides, tetrahalides, or oxyhalides by water:

$$RAsX_4+3H_2O=RAsO(OH)_2+4HX$$
$$RAsOX_2+2H_2O=RAsO(OH)_2+2HX$$
$$R_2AsX_3+2H_2O=R_2AsO.OH+3HX$$
$$(R_2AsX_2)_2O+3H_2O=2R_2AsO.OH+4HX$$

Primary arsines are oxidised by nitric acid, yielding arsinic acids as one of the oxidation products:

$$2RAsH_2+3O_2=2RAsO(OH)_2$$

Arsenoxides and cyanides give rise to acids on oxidation, and aryldichloroarsines may also be converted to acids by the action of hydrogen peroxide in glacial acetic acid, or by oxidation with Chloramine-T. The latter process appears to be likely to have a wide application in the future, since it can be used for mono- and diarylarsinic acids:

$$RAsO+H_2O+O=RAsO(OH)_2$$
$$R_2AsCN+H_2O+O=R_2AsO.OH+HCN$$
$$RAsX_2+H_2O+H_2O_2=RAsO(OH)_2+2HX$$

The preparation of benzylarsinic acid by Meyer's reaction (p. 165) is only possible on account of the benzyl radical really being aliphatic in structure. Another specialised method of preparation in the case of alkoxy-compounds consists in alkylating arylhydroxyarsinic acids, *e.g.* methylation of *p*-hydroxyphenylarsinic acid by methyl sulphate yields *p*-anisylarsinic acid.

Only one method for direct arsenation of the benzene nucleus with the production of arsinic acids is known, and this has not yet been proved to be of general application. It consists in heating bromobenzene, potassium arsenite, and a little copper sulphate at 180° to 200° C. for six hours, when some phenylarsinic acid results.

The most satisfactory general method so far devised for the preparation of these acids employs the diazo reaction, and is known under the name of the Bart method.[1] The following equations show the applicability of the method:

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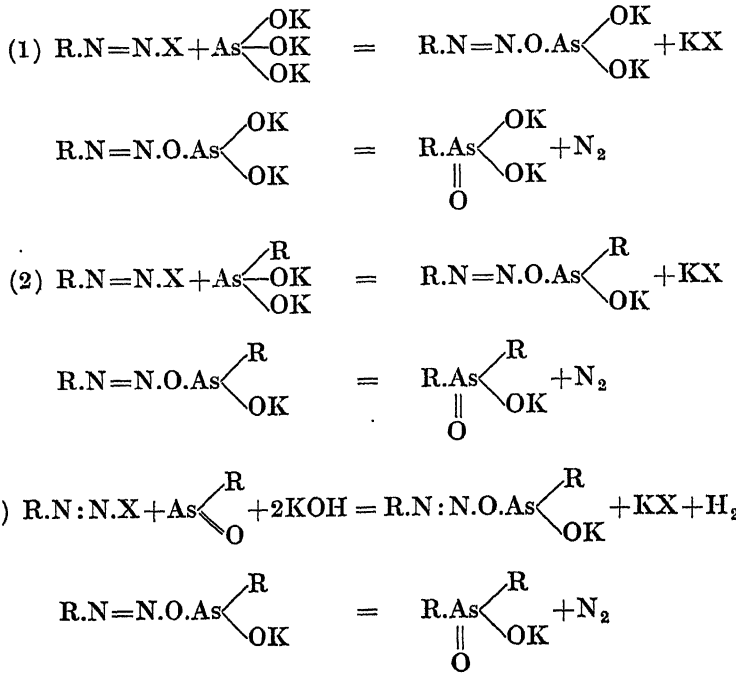
[1] Bart, German Patent, 250264.



Potassium benzene *iso*diazo-oxide gives a better yield than benzene normal diazo-salts, since the latter are less reactive than the former. In the case of nuclear-substituted arylamines, the normal diazonium compounds are sufficiently reactive to render unnecessary the preparation of the *iso*diazo-derivatives. Bart improved his yields when using normal diazonium compounds by adding copper powder, copper oxide, cuprous salts or silver powder in neutral solution as catalyst, and by employing magnesium salts in the reaction he really transformed his sodium arsenite to magnesium arsenite.[1] After the evolution of the diazo nitrogen, the mixture was filtered and the crude acid reduced to the arseno-compound by sodium hydrosulphite, the resulting product being oxidised again to the arsinic acid by nitric acid or hydrogen peroxide in alkaline solution. Cobalt and nickel in the finely divided state have also been used as catalysts.[2] The results of further investigations on this method were published in 1919 by Mouneyrat.[3] This investigator modified Bart's method, producing aromatic arsinic acids by the interaction of diazonium compounds with cold or warm aqueous or dilute alcoholic solutions of arsenious acid in an acid, neutral, or alkaline medium, in the presence of a copper salt and a reducing agent specially chosen for the acid or alkaline medium used. Examples of such reducing agents are hypophosphorous acid or cuprous hydroxide for an acid medium, sodium hydrosulphite, sodium formaldehyde-sulphoxylate, or an excess of alkaline arsenite for neutral or alkaline media. The method is capable of numerous modifications in detail. Subsequently, in 1920, Schmidt[4] stated that the most favourable con-

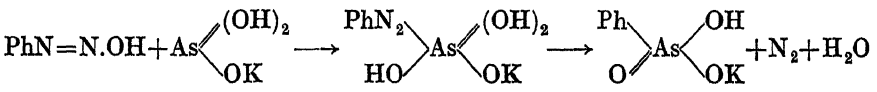
[1] German Patent, 254092.
[2] German Patent, 268172.
[3] British Patent, 142947 (1919).
[4] Schmidt, *Annalen*, 1920, 421, 159.

ditions for the production of many arsinic acids occur when the alkalinity of the solution is maintained so that the reaction may take place in accordance with the equation :

$$RN_2X+K_2HAsO_3=R.AsO_3HK+N_2+KX$$

Under these conditions the investigator states that reaction occurs spontaneously, and the diazo-compound is rapidly destroyed. If the solution is more alkaline than indicated by the above equation, the yield is lowered, owing to the reduction of some arsinic acid. Moreover, unless strongly acidic groups are present in the arylamines, it is not advisable to carry out the operation in an acid medium.

The arsenic in these reactions passes from the tervalent to the pentavalent state, and arsenious acid has been considered to react in the form $O=AsH(OH)_2$, instead of as $As(OH)_3$. Schmidt considers that H_3AsO_3 can exist in such a form that one hydrogen is in a labile form, and this labile hydrogen is stabilised when an organic radical replaces it. The following scheme illustrates the formation of phenylarsinic acid :



It has already been stated that Bart used catalysts in his reaction, in order to eliminate the diazo-nitrogen at low temperatures and thus decrease the formation of by-products. In Schmidt's method, in addition to non-arsenated aromatic derivatives, arsenated derivatives may also occur as by-products. In the case of the preparation of phenylarsinic acid, the by-product is diphenylyl-4-arsinic acid, $C_6H_4.Ph.AsO(OH)_2$, and the presence of such a derivative can only be accounted for on the assumption that one of the hydrogen atoms of the benzene nucleus becomes labile at the moment when the replacement of the diazo-group by the arsinic acid grouping takes place.

Arylarsinic acids containing halogen substituted in the nucleus are prepared from halogenated arylamines by employing the diazo-reaction in one of the ways indicated in the foregoing. Should the corresponding aminoarylarsinic acid be known, the amino group may be replaced by halogen in the usual way. Direct halogenation is unknown, except in the case of *m*-xylyl compounds. Passing chlorine into an aqueous suspension of *m*-xylyldichloroarsine does not yield *m*-xylylarsinic acid, but chloro-*m*-xylylarsinic acid, $(CH_3)_2C_6H_2Cl.AsO(OH)_2$, whilst chlorination in acetic acid solution yields a dichloro-*m*-xylylarsinic acid.

All the arsinic acids dealt with in the following pages are crystalline solids. Some of the primary acids, when heated above their melting-points, eliminate water and form anhydrides. The acids are very stable but may be reduced by amalgamated zinc dust and hydrochloric acid, or by electrolysis in aqueous alcoholic hydrochloric acid, to arylarsines, $RAsH_2$. An exception to the above-mentioned stability is the case of benzylarsinic acid, which is decomposed by mineral acids, and differs from all other members of this series in its reactions. The salts formed with alkali and alkaline earth metals show that the acids are dibasic. Esters may be formed by heating the silver salts of the acids in ethereal solution under reflux with the calculated amount of alkyl iodide, but excess of the latter must be avoided or alkyl-arylarsenites are formed :

$$Ar.AsO(OAg)_2+2AlkI=Ar.AsO(OAlk)_2+2AgI$$
$$Ar.AsO(OAg)_2+4AlkI=Ar.As(OAlk)_2+2AgI+I_2+Alk_2O$$

Sodium alkyloxides react with arylarsenic oxyhalides to yield arsinates:

$$Ar.AsOCl_2+2NaOAlk=Ar.AsO(OAlk)_2+2NaCl$$

These esters are liquids, readily hydrolysed by moisture into acid and alcohol.

p-Iodophenylarsinic acid resembles iodobenzene and its homologues in readily combining with chlorine to form a dichloride, which is decomposed by sodium hydroxide, yielding the iodoso-derivative:

$$I.C_6H_4.AsO(OH)_2+Cl_2=Cl_2:I.C_6H_4.AsO(OH)_2$$
$$Cl_2:I.C_6H_4.AsO(OH)_2+H_2O=O:I.C_6H_4.AsO(OH)_2+2HCl$$

Oxidation of *p*-iodophenylarsinic acid, or the iodoso-compound by chlorine in cooled sodium hydroxide solution, gives the iodoxy-derivative:

$$I.C_6H_4\,AsO(OH)_2+2NaOCl=O_2I.C_6H_4.AsO(OH)_2+2NaCl$$
$$O:I.C_6H_4.AsO(OH)_2+NaOCl=O_2I.C_6H_4.AsO(OH)_2+NaCl$$

The iodoso- and iodoxy-compounds explode when heated.

The diarylarsinic acids are stable compounds and are amphoteric. The structure of their salts indicates that they are monobasic. The scheme on p. 157 shows the principal arsinic acids dealt with in this section, $[X=AsO(OH)_2]$.

Phenylarsinic acid, $C_6H_5.AsO(OH)_2$.—This acid has been prepared by several methods:—

(1) By the action of water on phenylarsenic chloride.[1]

(2) By the action of water on phenylarsenic oxychloride or phenyldichloroarsine.[2]

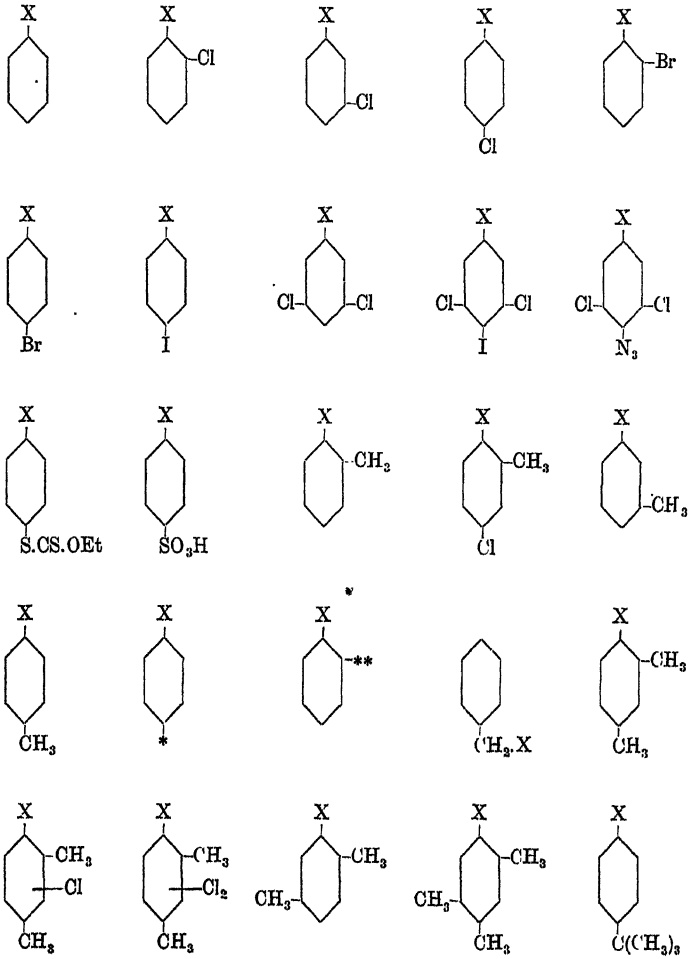
(3) By the interaction of diazotised aniline and sodium arsenite, as follows:[3] 2000 grams of anhydrous sodium carbonate, 1000 grams of technical arsenious oxide (about 20 per cent. excess), and 45 grams of crystallised copper sulphate are dissolved in 4000 c.c. of water in a twenty-five litre cylindrical copper tank, by the aid of heat. The mixture is mechanically stirred, and when the temperature falls to 15° C. the addition of the diazo-solution is begun, the temperature being maintained at 15° C. during the operation. The diazo-solution is made up in four quantities, each containing the following materials: 186 grams of aniline, 400 c.c. of concentrated hydrochloric acid, 1000 c.c. of water, and sufficient ice to bring the volume to 3000 c.c., this mixture being diazotised with 140 grams of sodium nitrite. If excessive frothing occurs, 10 c.c. of benzene are added, and the whole is stirred for one hour after the addition of the diazo-solution. The mass is filtered, the filtrate concentrated, and the arsinic acid precipitated by adding concentrated hydrochloric acid, avoiding excess, or some of the arsinic acid redissolves. Some 800 grams (50 per cent. yield) of a white or cream product are thus obtained, which may be purified by crystallisation from water.

(4) From potassium arsenite and potassium benzene *iso*diazo-oxide:

[1] Michaelis, *Ber.*, 1877, 10, 622.

[2] La Coste and Michaelis, *Ber.*, 1878, 11, 1883; *Annalen*, 1880, 201, 184.

[3] Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356; see German Patents, 264924, 254092; Bart, *Annalen*, 1922, 429, 75, 110; Schmidt, *Annalen*, 1920, 421, 159.



* May be C_3H_7, OCH_3, or OC_2H_5.

** May be OC_6H_5, SC_6H_5, or OC_6H_4Cl.

1·61 parts of the latter compound in 6 parts of water are treated with 2 parts of potassium arsenite, the mixture well stirred and heated until the nitrogen evolution ceases. The liquor is then neutralised with acid, filtered, the filtrate evaporated to dryness, and the residue extracted with alcohol. The extract contains the *potassium salt* of the arsinic acid, from which the free acid is liberated by hydrochloric acid.[1]

(5) From *p*-aminophenylarsinic acid : 217 grams of this acid in 1000 c.c. of water and 260 c.c. of concentrated hydrochloric acid (density 1·12) are diazotised by the addition of 335 c.c. of 3*N* sodium nitrate. The filtered solution is poured into 530 grams of technical sodium hypophosphite in 650 c.c. of hydrochloric acid (density 1·12) and 1000 c.c. of water, the temperature being maintained below 2° C. Nitrogen is evolved, and after completion of the operation the liquor is allowed to stand about eighteen hours at 2° to 5° C. It is then filtered and the filtrate treated with 1250 c.c. of 20 per cent. ammonium hydroxide, after which 500 grams of crystallised barium chloride in 1500 c.c. of water are added. The filtrate from the precipitated barium salts is neutralised with acetic acid, and the addition of zinc acetate precipitates the *zinc salt* of phenylarsinic acid. This is washed with 3500 c.c. of water and boiled with 2000 c.c. of a solution containing 212 grams of sodium carbonate, the precipitated zinc carbonate being filtered off and the filtrate treated with 218 c.c. of concentrated sulphuric acid. The liquor, when boiled with charcoal and evaporated to crystallising point, gives a 50 per cent. yield of phenylarsinic acid.[2]

(6) From bromobenzene : 3 grams of bromobenzene, 3 grams of potassium arsenite in 5 c.c. of water, and some copper sulphate are heated at 180° to 200° C. for six hours. The contents of the tube are then washed out, any unchanged bromobenzene removed, and the liquor extracted with ether, from which solution the acid crystallises on evaporation.[3]

Phenylarsinic acid crystallises in long, colourless prisms from water, and sinters at 158° C.[4] (158° to 162° C.[5]), passing to the anhydride, which decomposes when strongly heated. The acid is soluble in alcohol and very stable towards concentrated nitric acid or boiling chromic acid. When reduced by amalgamated zinc dust and hydrochloric acid it gives a 40 to 70 per cent. yield of phenylarsine.[6] Electrolytic reduction of the acid in aqueous alcoholic hydrochloric acid also yields phenylarsine.[7]

Phenylarsinic acid reacts vigorously with thionyl chloride in a manner indicated by the following equations : [8]

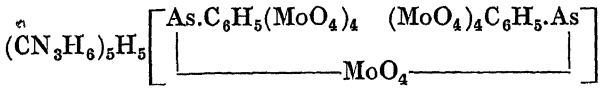
$$R.AsO(OH)_2+2SOCl_2=R.AsCl_2+SO_2Cl_2+SO_2+H_2O$$
or $$R.AsO(OH)_2+2SOCl_2=R.Cl+AsCl_3+2SO_2+H_2O$$

The following salts of phenylarsinic acid have been described : *Ammonium salt*, not stable ; *potassium salt* ; *barium salt* ; *acid calcium salt* $(C_6H_5.AsO_3H)_2Ca$, colourless needles ; *normal calcium salt*, containing two molecules of water of crystallisation ; *copper* and *lead salts*,

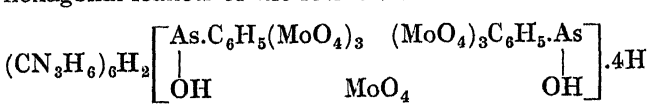
[1] German Patent, 250264.
[2] Bertheim, *Ber.*, 1908, 41, 1853.
[3] Rosenmund, *Ber.*, 1921, 54, [B], 438.
[4] La Coste and Michaelis, *loc. cit.*
[5] Bertheim, *loc. cit.*
[6] Adams and Palmer, *J. Amer. Chem. Soc.*, 1920, 42, 2375 ; see Palmer and Dehn, *Ber.*, 1901, 34, 3594 ; Kahn, *Chem. Zeit.*, 1912, 36, 1099.
[7] Fichter and Elkind, *Ber.*, 1916, 49, 239.
[8] Steinkopf and Schmidt, *Ber.*, 1928, 61, [B], 675.

bluish-green and white respectively, and both insoluble in water. *Yohimbine phenylarsinate* is known, and melts at about 140° C.[1]

When a boiling aqueous solution of sodium phenylarsinate is treated with molybdic acid, filtered and mixed with *guanidinium chloride*, two crystalline *salts* are produced. One of these is not very soluble in water and does not yield a neutral salt when boiled with an excess of guanidinium carbonate; the formula proposed for it is $(CN_3H_6)H[As.C_6H_5(MoO_4)_3].H_2O$.[2] It crystallises from water in white leaflets. The more soluble salt crystallises in long, white needles, and appears to be exclusively formed in faintly alkaline solution. Its conductivity indicates that it behaves as the salt of a normal pentabasic substance, and the following constitution is assigned to it:



If this compound is heated with *guanidinium carbonate* it yields microscopic, hexagonal leaflets of the formula:



The esters of phenylarsinic acid are obtained by heating under reflux the alkyl iodide and the silver salt of the acid in ether solution, taking care that the calculated amount of alkyl iodide is used, since excess only forms alkyl phenylarsinites.

Methyl phenylarsinate, $C_6H_5.AsO(OCH_3)_2$, is a colourless liquid, B.pt. 188° C. at 95 mm., density 1·3946 at 23° C.; it is readily decomposed by water to the acid and methyl alcohol. The *ethyl ester* boils at 168° to 170° C. at 15 mm., density 1·318 at 15° C. When treated with chlorine it yields phenylhydroxychloroarsine, chloral, and hydrogen chloride.[3]

o-Chlorophenylarsinic acid, $Cl.C_6H_4.AsO(OH)_2$.[4] — *o*-Chloroaniline, 12·7 grams, is stirred into 300 c.c. of water and 35 c.c. of hydrochloric acid (density 1·126), then diazotised and run into alkaline arsenite solution, as in the case of *o*-tolylarsinic acid, p. 162. The acid crystallises from water in shining white needles, M.pt. 181° C.,[5] soluble in alcohols, insoluble in ether, benzene, or chloroform.

m-Chlorophenylarsinic acid has similar properties to the foregoing acid and melts at 175° C.

p-Chlorophenylarsinic acid is obtained from *p*-chloro-aniline, 12·7 grams giving an 11 gram yield of the acid.[6] It has also been prepared from *p*-aminophenylarsinic acid by diazotisation in hydrochloric acid solution and treatment with copper powder.[7] The *acid barium salt* crystallises in plates, having the constitution $(C_6H_4Cl.AsO_3H)_2Ba$, the free acid yielding colourless crystals, decomposing at about 348° C.

[1] American Patent, 1305462. For the manufacture of basic bismuth salts of arylarsinic acids, see British Patent, 266820 (1925).
[2] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.
[3] Michaelis, *Annalen*, 1902, 320, 294.
[4] Bart, *Annalen*, 1922, 429, 85.
[5] Palmer and Adams give the M.pt. of this acid as 186° to 187° C.
[6] Bart, *loc. cit.*; see Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356.
[7] Bertheim, *Ber.*, 1908, 41, 1853.

o-Bromophenylarsinic acid, $Br.C_6H_4.AsO(OH)_2$, may be obtained by two methods: (1) *o*-Bromo-aniline hydrochloride (89 grams), suspended in a mixture of 1500 c.c. of water and 75 grams of fuming hydrochloric acid, is diazotised with a solution of 35 grams of sodium nitrite. A solution prepared as follows is then stirred into the diazo-solution: 60 grams of arsenious oxide in 120 c.c. of 5*N* sodium hydroxide, 500 c.c. of normal sodium carbonate, 2000 c.c. of ice water, 10 c.c. of concentrated ammonium hydroxide, and 10 per cent. copper sulphate solution. Ether is added to minimise frothing and the reaction mixture is stirred with charcoal, filtered, and the filtrate evaporated to 1500 c.c. Hot hydrochloric acid is added until Congo red paper becomes blue, grey flocks separating, which, after adding charcoal, are filtered whilst hot. The bromo-acid crystallises from the filtrate in white plates, the yield being about 37 per cent.[1] (2) *o*-Aminophenylarsinic acid (36 grams) in 126 c.c. of hydrobromic acid (density 1·265) and 63 c.c. of water is diazotised at 0° C. by 12·6 grams of sodium nitrite in 25 c.c. of water. The diazo-solution is then gradually stirred into a solution of cuprous bromide at 30° to 40° C. The latter solution is prepared by boiling 16·5 grams of copper carbonate with 165 c.c. of hydrobromic acid and a suspension of metallic copper, until the solution is clear. When the reaction is complete, the mixture is filtered, the residue extracted with alcohol, the extract evaporated to dryness, and the residue boiled with sodium carbonate and filtered. Acidification of the filtrate with concentrated hydrochloric acid should yield 27 grams of the bromo-acid. It crystallises from aqueous alcohol in colourless prisms, M.pt. 201° C.[2]

p-Bromophenylarsinic acid.[3]—This acid is prepared in a similar manner to the preceding one, using *p*-bromoaniline as the starting-point. It crystallises in white needles, soluble in alcohols, sparingly soluble in water.

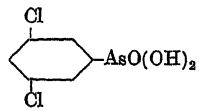
p-Iodophenylarsinic acid, $I.C_6H_4.AsO(OH)_2$,[4] results, together with *p*-iodophenyldi-iodoarsine, when diazotised atoxyl is treated with a hydrochloric acid solution containing potassium iodide, copper sulphate, and sodium thiosulphate. It crystallises from alcohol, acetone, or acetic acid in shining white needles.

Phenylarsinic acid iododichloride, $ICl_2.C_6H_4.AsO(OH)_2$.[5] *p*-Iodophenylarsinic acid is dissolved in glacial acetic acid and chlorine passed through the water-cooled solution. The iodochloride is a yellow powder having an odour of chlorine. When made into a paste with water, treated with sodium hydroxide solution dropwise until faintly alkaline, then precipitated with dilute hydrochloric acid, *p-iodosophenylarsinic acid,* $IO.C_6H_4.AsO(OH)_2$, is obtained. This is a white, microcrystalline precipitate, which liberates iodine from acidified potassium iodide, bleaches indigo, and decomposes litmus. When heated it explodes. It is soluble in alkalis or sodium acetate, sparingly soluble in water, alcohol, or acetic acid. When *p*-iodophenylarsinic acid, or the above iodoso-compound, in normal sodium hydroxide solution, is cooled in ice and saturated with chlorine, *p-iodoxyphenylarsinic acid,* $IO_2.C_6H_4$.

[1] Kalb, *Annalen*, 1921, 423, 39.
[2] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 456.
[3] German Patent, 250264.
[4] Mameli and Patta, *Giorn. Farm. Chim.*, 1909, 58, 97; *Arch. Farmacol. sperim.*, 1909, 8, 395; *Bull. Soc. Med.-Chirurg. Pavia*, 1909.
[5] Karrer, *Ber.*, 1914, 47, 96.

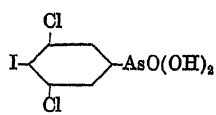
$AsO(OH)_2$, is obtained. The iodoxy compound is precipitated by dilute sulphuric acid, and the product filtered, washed, and dried. It crystallises in needles, which explode sharply on heating, and are insoluble in the usual solvents.

3 : 5-Dichlorophenylarsinic acid,[1]



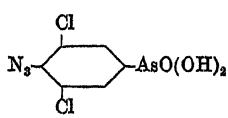
may be prepared as follows : 2·7 grams of dichloroarsanilic acid mixed with 3 grams of potassium pyrosulphite are added in small portions, with ice cooling, to 20 c.c. of nitric acid (density 1·49), and the whole poured upon 100 grams of ice. In a short time the diazo-derivative separates out as shining crystals. To its solution 100 grams of ice, 70 c.c. of alcohol, and 2 grams of finely divided copper are added. Nitrogen evolution commences immediately, and is completed by warming on the water-bath. When the copper has all dissolved, the solution is filtered hot, and then slowly cooled. The acid separates in snow-white plates, readily soluble in hot water or alcohols.

3 : 5-Dichloro-4-iodophenylarsinic acid,



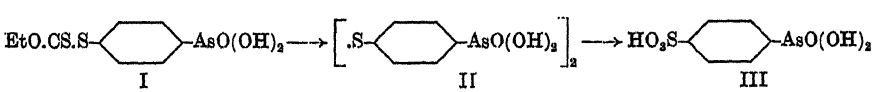
Dichloroarsanilic acid is diazotised as before, and an aqueous solution of the crystalline diazo-derivative treated with 10 per cent. potassium iodide solution. The precipitated product is recrystallised from 50 per cent. acetic acid, fine, white needles being deposited, which are sparingly soluble in hot or cold water.

3 : 5-Dichloro-4-diazoimidophenylarsinic acid,



is a colourless, crystalline compound, resulting when the foregoing crystalline diazo-derivative is treated with sodium azide in aqueous solution.

p-Xanthylphenylarsinic acid,[2]

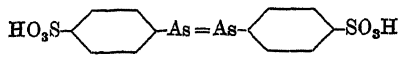


I II III

Sodium *p*-aminophenylarsinate pentahydrate, $NH_2.C_6H_4.AsO(ONa)_2.5H_2O$ (82·9 grams), in 200 c.c. of water and 30 grams of concentrated hydrochloric acid is diazotised at 0° C. and the product slowly poured into a rapidly stirred solution of 20 grams of potassium xanthate, $KS.CS.OC_2H_5$, in 420 c.c. of a 10 per cent. solution of hydrated sodium

[1] Karrer, *Ber.*, 1914, 47, 1779.
[2] Hewitt, King, and Murch, *J. Chem. Soc.*, 1926, p. 1369.

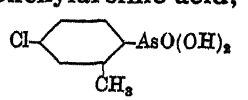
carbonate at 80° C. The mixture is then stirred for one hour, cooled and acidified. The precipitated resin solidifies on standing, and is partially purified by dissolving in aqueous sodium carbonate, filtering, and reprecipitating by acids. The yield of crude product (I) is about 62 per cent. When 5 grams of the acid are heated for two hours on the water-bath with 100 c.c. of 3*N* nitric acid, and then boiled for thirty minutes, the solution on cooling gives an 82 per cent. yield of *diphenyldisulphide-p-p'-diarsinic acid* (II). This acid crystallises from boiling water in narrow plates or needles, and gives a *barium salt*, crystallising in needles. From the mother-liquors of this oxidation, *p-sulphophenylarsinic acid* (III) is obtained, but this is better prepared by boiling 5 grams of the disulphide with 50 c.c. of 6*N* nitric acid for four hours. Evaporation of the solution leaves 6 grams of crude sulphoarsinic acid. This sulpho-acid is sometimes obtained in hexagonal plates. When reduced at 50° to 55° C. by hypophosphorous acid in the presence of a trace of iodide, it yields *p-sulphophenylarsenobenzene*,



a yellow, gelatinous product. Reduction of the disulphide (II) under similar conditions gives a compound which probably is *thiolarsenobenzene*.

o-Tolylarsinic acid, $CH_3.C_6H_4.AsO(OH)_2$. — This acid was originally prepared by the action of water on *o*-tolylarsenic chloride or *o*-tolyloxyhalides,[1] but it has more recently been obtained from *o*-toluidine, using the diazo-reaction.[2] *o*-Toluidine (10·7 grams) in 300 c.c. of water and 35 c.c. of hydrochloric acid (density 1·126) is cooled to about −5° C. and diazotised by 100 c.c. of normal sodium nitrite solution. This diazo-solution is then stirred into a solution containing 200 c.c. of normal sodium arsenite, 30 c.c. of 5*N* sodium hydroxide, and 1400 c.c. of water. Nitrogen is evolved and the reaction is complete after about an hour's stirring. The whole is filtered, the filtrate evaporated to about 400 c.c. on the water-bath, treated with hydrochloric acid until faintly acid, charcoal added, the liquid boiled, filtered hot and evaporated to crystallising point. The liquor is then cooled and made acid to Congo red, about 10 c.c. of hydrochloric acid (density 1·126) being required, the acid being thus precipitated in crystalline form. The crude acid is triturated with cold ethyl acetate, then recrystallised from hot water, the total yield being about 11 grams.[3] It may also be obtained by the action of Chloramine-T on the corresponding chloroarsine, the yield being quantitative.[4] The acid crystallises from water in centimetre long needles, M.pt. 160° C.; prolonged heating at 105° to 110° C. appears to give the anhydride as a pale yellow, crystalline mass. The *calcium* and *barium* salts form white crystals, and the *silver* salt is deposited from dilute alcohol in spur-like crystals.

4-Chloro-2-methylphenylarsinic acid,[5]

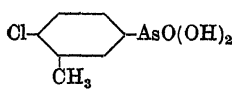


[1] La Coste and Michaelis, *Ber.*, 1878, 11, 1888; *ibid.*, *Annalen*, 1880, 201, 184.
[2] Karrer, *Ber.*, 1915, 48, 310; Bart, *Annalen*, 1922, 429, 80; Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356. [3] Bart, *loc. cit.*
[4] Burton and Gibson, *Trans. Chem. Soc.*, 1924, 125, 2276. By this method the acid is said to be obtained in long needles, M.pt. 163° to 164° C.
[5] Karrer, *Ber.*, 1915, 48, 314.

This acid is obtained by means of the diazo-reaction from *p*-chloro-*o*-toluidine, 45 grams of this giving about 8 grams of the *magnesium salt* of the arsinic acid. The free acid is obtained from the salt by heating with 30 c.c. of concentrated hydrochloric acid in 200 c.c. of water. After filtering and cooling, the acid separates in white needles, sintering at 195° C. and melting at 199° C.

m-Tolylarsinic acid may be prepared from *m*-tolylarsenic chloride by hydrolysis with water,[1] or from *m*-toluidine, using the diazo reaction.[2] It crystallises in bushy groups of needles, M.pt. 150° C., and on heating alone, or with water, to 220°–230° C., it passes into the *anhydride*, $C_7H_7.AsO_2$. The following salts have been described : *acid ammonium salt*, $C_7H_7.AsO(OH).ONH_4$, crystalline crusts ; *acid phenylhydrazine salt*, $C_7H_7.AsO(OH).O.NH_3.NH.C_6H_5$, glistening plates from alcohol ; *calcium salt*, crystallising in plates ; *copper salt*, a bright blue precipitate ; *silver salt*, a white precipitate ; *salts* of *lead*, *zinc*, and *cobalt*, insoluble in water ; *iron salt*, soluble in excess of ferric chloride.

4-Chloro-3-methylphenylarsinic acid,[3]



results when 4-amino-3-methylphenylarsinic acid is diazotised and the diazo-compound decomposed in the presence of cuprous chloride. It crystallises from alcohol in needles, M.pt. 180° C.

p-Tolylarsinic acid is prepared similarly to the *m*-tolyl compound.[4] It crystallises from water in needles, 2 to 3 cm. long, which remain unmelted at 300° C. The following salts are known : *acid calcium salt*, $(C_7H_7.AsO_3H)_2Ca$, and *acid barium salt*, both crystallising in needles from water ; *silver salt*, $C_7H_7.AsO(OAg)_2$, a white precipitate ; *copper salt*, $C_7H_7.AsO_3Cu$, bluish-green, and a similar type of *lead salt*, which is white.

p-Cumylarsinic acid, $C_3H_7.C_6H_4AsO(OH)_2$, crystallises in snow-white needles, M.pt. 152° C., readily soluble in warm alcohol or hot water, sparingly soluble in cold solvents. Oxidation with alkaline permanganate converts the propyl group to the carboxyl group, yielding *p*-carboxyphenylarsinic acid, $CO_2H.C_6H_4AsO(OH)_2$.

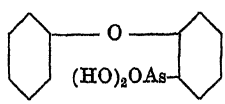
p-Anisylarsinic acid, $CH_3O.C_6H_4.AsO(OH)_2$, may be isolated in several ways : (1) *p*-Anisylarsenic chloride is treated with water, when a compound of M.pt. 159° to 160° C. is obtained.[5] (2) The pure acid is formed when *p*-anisyldichloroarsine in acetic acid solution is oxidised by hydrogen peroxide, the melting-point of the product being given as 203° C. (3) A more recent method consists of methylating *p*-hydroxyphenylarsinic acid (sodium salt) as follows :[6] 96 grams of the hydroxy acid in 140 c.c. of water and 80 c.c. of 10*N* sodium hydroxide are treated with 60 c.c. of dimethyl sulphate, and when the latter has disappeared, 60 c.c. more of 10*N* sodium hydroxide and 60 c.c. of dimethyl sulphate

[1] Michaelis, *Annalen*, 1902, 320, 326 ; Eisenlohr, *Inaug. Dissert.*, Rostock, 1893.
[2] Bart, *Annalen*, 1922, 429, 82.
[3] German Patent, 245536.
[4] La Coste and Michaelis, *Ber.*, 1878, 11, 1888 ; *Annalen*, 1880, 201, 256 ; Bart, *Annalen*, 1922, 429, 82 ; German Patent, 250264 ; Palmer and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 1356.
[5] Michaelis and Weitz, *Ber.*, 1887, 20, 48.
[6] Bertheim, *Ber.*, 1914, 47, 274.

are added, this operation being repeated several times. The mixture is finally acidified with 78 c.c. of hydrochloric acid (density 1·12), when the *p*-anisylarsinic acid is precipitated. The yield is about 78 grams, and the melting-point is given as 170° to 180° C. The acid is sparingly soluble in cold water and moderately soluble in alcohol. When heated for several hours at 190° to 200° C. it is converted to the *anhydride*, $CH_3.O.C_6H_4.AsO_2$. The *silver salt* is a white precipitate of normal constitution.

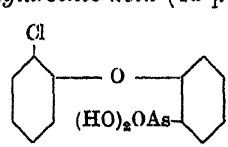
p-Phenetylarsinic acid, $C_2H_5O.C_6H_4.AsO(OH)_2$, is prepared by suspending *p*-phenetyldichloroarsine in warm water and passing in chlorine,[1] or from *p*-arsanilic acid as follows: [2] 130 grams of *p*-aminophenylarsinic acid in 1300 c.c. of absolute alcohol are treated with hydrogen chloride until a clear solution is obtained, the mixture being shaken during the operation. With ice-cooling, 60 c.c. of ethyl nitrite are added in small portions, the diazo-compound separating in small crystals, and after standing for about one hour, the whole is heated until the action is complete. About 1230 c.c. of liquid are distilled off. 120 c.c. of water are added to the residue, which solidifies to a reddish, crystalline mass. This is filtered and pressed, about 96 grams (65 per cent.) of crude product being isolated. The latter is recrystallised from water, with the addition of animal charcoal, the melting-point of the pure acid being 209° to 210° C., the rate of heating affecting the melting-point. The *silver*, *copper*, and *calcium salts* are only slightly soluble in water.

o-Phenoxyphenylarsinic acid,[3]



This and the following substituted phenoxyphenylarsinic acids are obtained by a general process: The diazo-solution, prepared from the corresponding aminodiphenyl ether (1 mol.) in hydrochloric acid (1·5 mols.), is neutralised with sodium hydrogen carbonate (0·5 mol.) and treated with a little copper sulphate solution. The resulting solution is slowly added to a solution containing arsenious oxide (0·75 mol.), sodium hydroxide (2 mols.), sodium carbonate (0·7 mol.), water (7 mols.), and a little copper sulphate, at 50° to 60° C. After completion of the reaction the liquor is filtered, acidification of the filtrate precipitating the pure arsinic acid. *o*-Phenoxyphenylarsinic acid is obtained by this method in 32 per cent. yield, and separates from alcohol in needles, M.pt. 167° to 168° C. The following have also been prepared:

2-*o*-*Chlorophenoxyphenylarsinic acid* (18 per cent. yield),



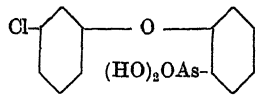
crystallising from alcohol or water in needles, M.pt. 195° to 195·5° C.

2-*m*-*Chlorophenoxyphenylarsinic acid* (18 per cent. yield),

[1] Michaelis, *Annalen*, 1902, 320, 299.

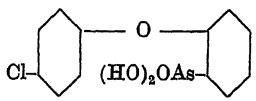
[2] Bertheim, *Ber.*, 1908, 41, 1853.

[3] Roberts and Turner, *Trans. Chem. Soc.*, 1925, 127, 2009; see Turner and Sheppard, *ibid.*, p. 544.



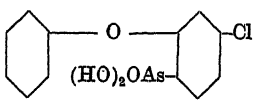
separating from dilute alcohol in rounded, hexagonal plates, M.pt. 177° to 179° C.

2-*p*-*Chlorophenoxyphenylarsinic acid* (24 per cent. yield),



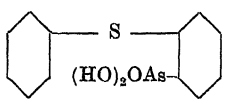
giving cubes from alcohol, M.pt. 187° to 188° C.

4-*Chloro*-2-*phenoxyphenylarsinic acid* (25 per cent. yield),



forming colourless, hairy tufts of needles from dilute alcohol, M.pt. 182° C.

o-Phenylthiolphenylarsinic acid,



results when the aminodiphenyl ether of the preceding preparations is replaced by *o*-aminodiphenyl sulphide. It is obtained in 12 per cent. yield, and crystallises from alcohol in irregular plates, M.pt. 192° to 194° C., sparingly soluble in water.[1]

Benzylarsinic acid, $C_6H_5.CH_2.AsO(OH)_2$.[2]—When benzyl iodide, arsenious oxide, and potassium hydroxide react in dilute alcohol solution, the following changes take place :

$$2C_6H_5.CH_2I+As_2O_3+6KOH=2C_6H_5.CH_2.AsO(OK)_2+2KI+3H_2O$$

The alcohol is distilled off, the solution neutralised, filtered, and treated with hydrochloric acid, when a 60 per cent. yield of benzylarsinic acid is obtained. It forms white, glistening needles, M.pt. 167° C., decomposed by strong mineral acids, hydrochloric acid yielding benzyl chloride, arsenious oxide, and water, sulphuric acid giving dibenzyl, benzaldehyde, and arsenious oxide. When strongly heated it decomposes into benzaldehyde, benzyl alcohol, stilbene, arsenious oxide, and water.

m-Xylylarsinic acid, $(CH_3)_2C_6H_3.AsO(OH)_2$,[3] may be prepared either by hydrolysis of *m*-xylylarsenic chloride, by oxidising the chloroarsine or oxide by air, or by adding hydrogen peroxide to an acetic acid solution of the chloroarsine or oxide. It crystallises from dilute alcohol in quadratic crystals, M.pt. 210° C. ; it yields an *acid ammonium salt*, M.pt. 136° C., and its *silver*, *copper*, *lead*, *cobalt*, and *iron salts* have been prepared. By the action of potassium permanganate a methyl group may be oxidised to a carboxyl group, the acid formed changing

[1] Roberts and Turner, *J. Chem. Soc.*, 1926, p. 1208.

[2] Dehn and M'Grath, *J. Amer. Chem. Soc.*, 1906, 28, 354 ; see Quick and Adams, *ibid.*, 1922, 44, 805.

[3] Michaelis, *Annalen*, 1902, 320, 330 ; Seeman, *Inaug. Dissert.*, Rostock, 1891.

to its *anhydride*, $(CO_2H)(CH_3)C_6H_3AsO_2$, at 190° C.; if twice the amount of permanganate is used both methyl groups are oxidised, the *dicarboxylic acid*, $(CO_2H)_2.C_6H_3.AsO(OH)_2$, forming colourless crystals.

Chloro-m-xylylarsinic acid, $(CH_3)_2C_6H_2Cl.AsO(OH)_2$, results when chlorine is passed into an aqueous suspension of *m*-xylyldichloroarsine. It crystallises in fine needles, M.pt. 165° C. It is noteworthy how easily this chlorination takes place; phenyl and tolylarsinic acids remain unchanged when subjected to the same treatment. When an acetic acid solution of the dichloride is chlorinated, *dichloro-m-xylylarsinic acid*, $(CH_3)_2C_6HCl_2.AsO(OH)_2$, M.pt. 193° C., is produced.

p-Xylylarsinic acid.—*p*-Xylyldichloroarsine is suspended in water and chlorine passed through the heated mixture until all the solid goes into solution. On cooling, the arsinic acid crystallises in needles, M.pt. 223° C., sparingly soluble in cold water, easily soluble in hot water or alcohol. The *silver*, *lead*, *copper*, and *iron salts* are insoluble in water.

Pseudocumylarsinic acid, $C_9H_{11}.AsO(OH)_2$, [$CH_3 : CH_3 : CH_3 : AsO(OH)_2 = 1 : 2 : 4 : 5$], crystallises from warm water or alcohol in white needles, M.pt. 224° C., and yields a *silver salt* of the constitution $C_9H_{11}.AsO(\Theta Ag)_2$.

Tert.-butylphenylarsinic acid, $(CH_3)_3C.C_6H_4.AsO(OH)_2$, results when an acetic acid solution of the corresponding dichloroarsine is oxidised by hydrogen peroxide. It crystallises in small, white, bushy groups of needles, M.pt. 193° C., sparingly soluble in hot water, readily soluble in alcohol. The *silver salt* is a white, amorphous powder of normal constitution.

α-Naphthylarsinic acid, $C_{10}H_7.AsO(OH)_2$.—This acid may be prepared by dissolving mercury di-α-naphthyl in arsenious chloride, the reaction being completed by heating under reflux. The mass is then diluted with benzene and filtered to remove the mercuric chloride which separates. The benzene is distilled off and chlorine passed into the residue, after which the latter is treated with water, when shining colourless needles of the arsinic acid separate. The reaction is represented by the following equations:

$$2AsCl_3+(C_{10}H_7)_2Hg=2C_{10}H_7AsCl_2+HgCl_2$$
$$C_{10}H_7AsCl_2+Cl_2=C_{10}H_7AsCl_4$$
$$C_{10}H_7AsCl_4+3H_2O=C_{10}H_7.AsO(OH)_2+4HCl$$ [1]

The acid has more recently been obtained by adding diazotised α-naphthylamine to an aqueous solution of sodium arsenite and allowing the mixture to decompose at room temperature.[2] It crystallises in creamy-white needles, M.pt. 197° C., not affected by dilute or concentrated sulphuric acid. With 20 per cent. fuming acid it yields a *monosulphonic acid*, which is unchanged at 250° C., and crystallises in glistening plates. Three *potassium salts* of the sulpho-acid have been obtained, but the position of the sulphonic acid group in the molecule has not been determined.

β-Naphthylarsinic acid[3] is obtained by hydrolysis of β-naphthylarsenic chloride; it crystallises from a large bulk of hot water in fine needles, M.pt. 155° C. It resembles the *α-iso*meride, is easily soluble in alcohol and hot water, sparingly soluble in cold water.

[1] Kelbe, *Ber.*, 1878, 11, 1499; see Michaelis, *Annalen*, 1902, 320, 342; Büschler, *Inaug. Dissert.*, Rostock, 1893.

[2] Hill and Balls, *J. Amer. Chem. Soc.*, 1922, 44, 2051. [3] Michaelis, *loc. cit.*

Diphenylarsinic acid, $(C_6H_5)_2AsO.OH$, may be obtained by hydrolysis of diphenylarsenic oxychloride, $[(C_6H_5)_2AsCl_2]_2O$, or diphenylarsenic chloride, $(C_6H_5)_2AsCl_3$.[1] It has also been obtained by the interaction of phenylarsenoxide and benzene diazonium chloride,[2] and by the action of Chloramine-T on diphenylchloroarsine.[3] The following method of preparation from diaminodiphenylarsinic acid, a waste by-product in the manufacture of arsanilic acid, is of interest.[4] The process consists in the diazotisation of diaminodiphenylarsinic acid and subsequent reduction. For the latter process an excess of hypophosphite is used, and if a small amount of 10 per cent. copper sulphate solution is added, the rate of reduction is increased, and the yield is about 60 per cent. Diphenylarsinic acid crystallises in fine needles, 2 to 3 cm. long, melting at 178° C. and showing a tendency to sublime at 190° to 200° C.[5] It crystallises from alcohol in short prisms, and is somewhat soluble in ether and benzene. It is unattacked by boiling nitric acid or chromic acid. When heated with thionyl chloride it yields the compound $(C_6H_5)_2AsCl.SOCl_2$,[6] although more recent investigators[7] claim that the reaction may take the following course when the operation is conducted in a carbon dioxide atmosphere :

$$(C_6H_5)_2AsO.OH+2SOCl_2=(C_6H_5)_2AsCl_3+2SO_2+HCl$$

The following salts have been described: *Ammonium salt*, losing all its ammonia when dried over sulphuric acid ; *silver salt*, $(C_6H_5)_2AsO.OAg$, a white precipitate, readily soluble in ammonium hydroxide ; *lead salt*, small, glistening crystals ; *barium salt*, $[(C_6H_5)_2AsO.O]_2Ba$, a crystalline mass from alcohol; *copper salt*, $[(C_6H_5)_2AsO.O]_2Cu$, a light blue precipitate.

Treatment of sodium diphenylarsinate with *molybdic acid* and subsequently with *guanidinium chloride*, as in the case of sodium phenylarsinate, yields a *salt* crystallising in hexagonal plates, having the constitution [8]

$$(CN_3H_6)_2H\left[\begin{matrix}As.C_6H_5(Mo_2O_7)_3\\(OH)_2\end{matrix}\right].H_2O$$

Di-p-tolylarsinic acid, $(C_7H_7)_2AsO.OH$,[9] results when di-*p*-tolylchloroarsine is treated with dry chlorine, this producing di-*p*-tolylarsenic chloride, $(C_7H_7)_2AsCl_3$, which is decomposed by adding water, giving the required acid. It crystallises from alcohol, melts at 167° C., and yields a *silver* and a *sodium* salt.

Dibenzylarsinic acid, $(C_6H_5.CH_2)_2AsO.OH$.[10]—The interaction of sodium, arsenic trichloride, and benzyl chloride in dry ether gives rise principally to tribenzylarsine and dibenzylarsine trichloride. The latter compound is converted by dilute alkali to dibenzylarsinic acid. This

[1] Michaelis, *Ber.*, 1876, 9, 1566; La Coste and Michaelis, *ibid.*, 1878, 11, 1883; *Annalen*, 1880, 201, 184; La Coste, *Inaug. Dissert. Freiburg*, 1879; Michaelis, *Annalen*, 1902, 321, 15.
[2] Bart, *Annalen*, 1922, 429, 100.
[3] Burton and Gibson, *Trans. Chem. Soc.*, 1924, 125, 2276.
[4] Nekrassov, *J. Russ. Phys. Chem. Soc.*, 1927, 59, 877.
[5] Michaelis, *loc. cit.*; La Coste and Michaelis, *loc. cit.*
[6] Gibson and Johnson, *J. Chem. Soc.*, 1928, p. 99.
[7] Steinkopf and Schmidt, *Ber.*, 1928, 61, [B], 675.
[8] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539.
[9] La Coste, *Annalen*, 1881, 208, 18; Michaelis, *ibid.*, 1902, 320, 26.
[10] Michaelis and Paetow, *Ber.*, 1885, 18, 41.

crystallises from alcohol in white, pearly, glistening plates, M.pt. 210° C., which have a bitter taste and irritant odour. It dissolves readily in hot alcohol, sparingly in boiling water, benzene, ether, and acetone. When heated above its melting-point it decomposes as follows :

$$2(C_7H_7)_2AsO.OH = 2C_6H_5.CHO + (C_6H_5.CH_2)_2 + 2As + 2H_2O$$

Boiling under reflux with concentrated hydrochloric acid also causes decomposition :

$$(C_7H_7)_2AsO.OH + 4HCl = C_6H_5.CH_2.Cl + C_6H_5.CH_3 + AsCl_3 + 2H_2O$$

Boiling with nitric acid (density 1·3) yields benzoic and arsenic acids, and the arsinic acid is also oxidised by alkaline permanganate. The following salts are known : *Barium salt*, plates, $[(C_7H_7)_2AsO_2]_2Ba.8H_2O$; *calcium salt*, $[(C_7H_7)_2AsO_2]_2Ca.6H_2O$; *silver salt*, $(C_7H_7)_2AsO.OAg$.

When an alkaline solution of the acid is treated with hydrogen sulphide, it yields *dibenzylthioarsinic acid*, $(C_6H_5.CH_2)_2AsS.SH$, consisting of white, glistening plates, M.pt. 197° to 199° C., soluble in alcohol, benzene, and acetic acid.

When powdered dibenzylarsinic acid is boiled with dilute hydrochloric acid, it yields *dibenzylarsinic acid hydrochloride*, $(C_6H_5.CH_2)_2As(OH)_2Cl$, white needles, M.pt. 128° C. The corresponding *hydrobromide* is also known, and both compounds on decomposition yield benzyl halide. The *nitrate*, $(C_6H_5.CH_2)_2As(OH)_2NO_3$, crystallises in needles, M.pt. 128° to 129° C.

Di-α-naphthylarsinic acid, $(C_{10}H_7)_2AsO.OH$, is a white solid, M.pt. 228° to 229° C.[1]

Phenyl-p-tolylarsinic acid, $C_6H_5.(C_6H_4.CH_3).AsO.OH$,[2] crystallises in colourless needles, M.pt. 158° to 160° C., soluble in hot water, benzene, and concentrated nitric acid, less soluble in alcohol, sparingly soluble in cold water and ether. The *silver salt* is a white precipitate.

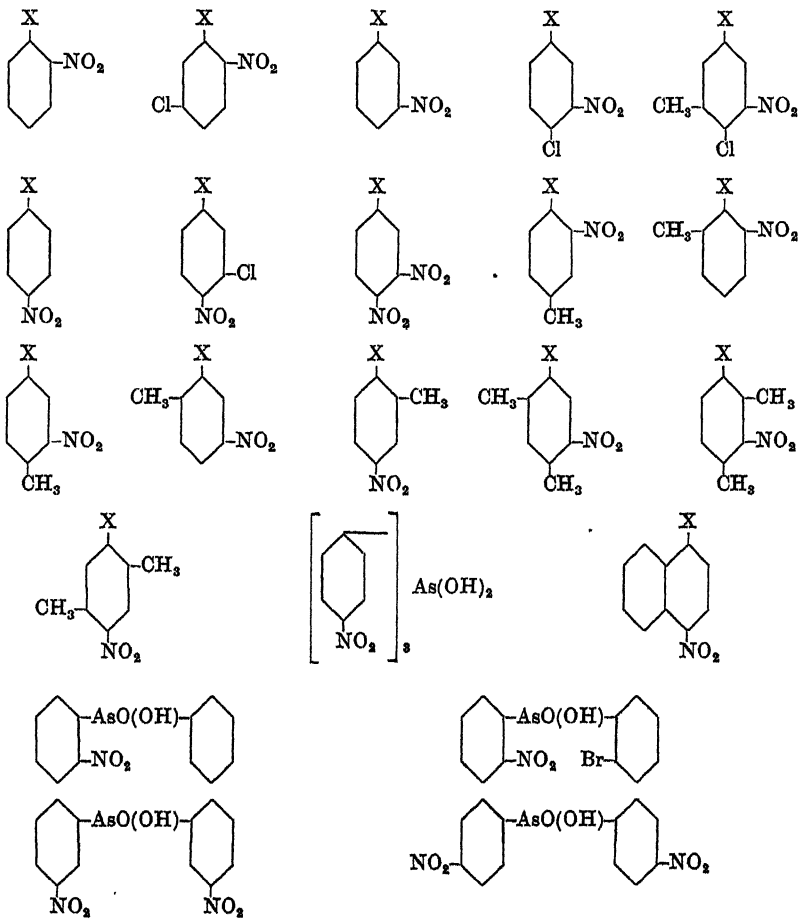
Phenylbenzylarsinic acid, $C_6H_5.(C_6H_5.CH_2).AsO.OH$.[3]—Phenylarsenoxide, 75 grams, in 150 c.c. of spirit, is treated with a solution of 36 grams of sodium hydroxide in 52 c.c. of water. The solution is heated and 60 grams of benzyl chloride gradually added, regulating the reaction so that it remains vigorous. After cooling, the alcohol is distilled off, the residue acidified, and the precipitate washed with water and ether. The acid crystallises in pure white, glistening needles, M.pt. 206° to 207° C., soluble in methyl alcohol and acetic acid, sparingly soluble in water, acetone, and ether. When heated with concentrated hydrochloric acid it yields benzyl chloride and phenyldichloroarsine. The *strychnine salt* crystallises in needles, $[\alpha]_D - 31.2$ at 20° C. in 50 per cent. aqueous acetone.

Nitroarylarsinic Acids.

These acids are important, since they form starting materials for the preparation of aminoarylarsinic acids. The nitro-acids may be obtained by the general methods indicated for arsinic acids in the preceding section : (1) Sodium arsenite reacting with nitroaryl-*iso*diazo-oxides.

[1] Matsumiya and Nakai, *Mem. Coll. Sci. Kyōtō*, 1925, 8, 307.
[2] Michaelis, *Annalen*, 1902, 321, 155.
[3] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1443 ; compare Bertheim, *Ber.*, 1915, 48, 350.

(2) By the interaction of diazotised nitroarylamines with sodium arsenite or arylchloroarsines or oxides. In the case of acids containing halogen in the nucleus the halogen is present in the arylamine and is not substituted in the ring after arsenation. Using Schmidt's method, an approximately 90 per cent. yield of *o*-nitrophenylarsinic acid may be isolated from *o*-benzene diazonium chloride. By-products are also obtained, as in the case of unsubstituted acids; *e.g.* in the preparation of *m*-nitrophenylarsinic acid, 2 : 3′-dinitrodiphenylyl-4-arsinic acid, $NO_2.C_6H_4.C_6H_3.(NO_2).AsO(OH)_2$, occurs; whilst in the formation of *o*-nitrophenylarsinic acid, the by-product is diphenylyl-4-arsinic acid, $C_6H_4.C_6H_5.AsO(OH)_2$, no nitro by-product resulting. Many nitroarylarsinic acids have also been isolated by the direct nitration of the arsinic acids. In these cases the nitro group always enters the ring in the *meta* position to the arsenic, similar results being noted with phosphorus and antimony organic derivatives.

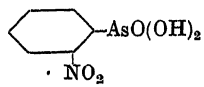


All the nitroarylarsinic acids are solids, usually of good crystalline form, and salts of the alkaline earth metals and heavy metals are known

in many cases. α-Nitronaphthalene-4-arsinic acid is interesting owing to the apparently loose attachment of the arsinic acid grouping, which may be removed by concentrated hydrochloric acid, α-nitronaphthalene being formed. The chlorine of 3-nitro-4-chlorophenylarsinic acid may be replaced by the hydroxyl group by boiling the compound with aqueous potassium hydroxide, and by the piperidino grouping on boiling with excess of alcoholic piperidine. Reduction of *o*-nitrophenylarsinic acid electrolytically, under suitable conditions, yields hydrazobenzene-*o*-*o*′-diarsinic acid, $(HO)_2OAs.C_6H_4NH.NH.C_6H_4.AsO(OH)_2$.

The principal nitroarylarsinic acids, excluding condensation products, are shown in the scheme on p. 169, where $X=AsO(OH)_2$.

o-Nitrophenylarsinic acid,



This acid may be obtained by heating 1·8 parts of sodium *o*-nitrobenzene-*iso*diazo-oxide with 2 parts of sodium arsenite in 4 parts of water until no further evolution of nitrogen occurs. The solution is then evaporated to dryness, the residue extracted with alcohol, the *sodium salt* of the acid being obtained, this in aqueous solution giving the free acid on treatment with hydrochloric acid.[1] The acid has more recently been obtained as follows:[2] 13·8 grams of *o*-nitroaniline are boiled with 80 c.c. of hydrochloric acid (density 1·126) until complete solution occurs, when 50 c.c. of boiling water are added and the whole cooled to 5° C., whereby the hydrochloride is deposited in slender, pale yellow needles. The hydrochloride is diazotised with 115 c.c. of normal sodium nitrite solution, then 175 c.c. of normal sodium hydroxide solution are run in at about 10° C. until the acid is neutralised and the Congo red reaction immediately disappears. During these operations the mixture should be vigorously stirred. A little ether is added to avoid foaming, and 200 c.c. of 10 per cent. sodium arsenite solution run in with stirring. To complete the reaction, 275 c.c. of normal sodium hydroxide solution are added dropwise and the whole stirred.

Too large an excess of alkali must not be present, as it would influence the mechanism of the reaction. The mixture is evaporated to half bulk and 16 c.c. of hydrochloric acid (density 1·126) added until the Congo red reaction is strongly produced, when the *o*-nitrophenylarsinic acid separates in pale yellow needles. After standing for several hours, these are filtered off and washed, about 23 grams of crude product being isolated. This is recrystallised from boiling water and decolorised by charcoal. It melts with decomposition at 233° C., and is more sparingly soluble in water than the corresponding *meta*-compound. With magnesia mixture it yields an insoluble *magnesium salt* which crystallises in woolly needles.[3]

Electrolytic reduction of *o*-nitrophenylarsinic acid in a 2*N* sodium acetate solution, using a water-cooled platinum cathode, yields **hydrazobenzene-o-o′-diarsinic acid,** $(HO)_2OAs.C_6H_4.NH.NH.C_6H_4.AsO(OH)_2$,

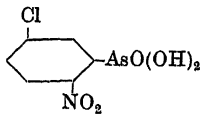
[1] German Patent, 250264.

[2] Bart, *Annalen*, 1922, 429, 92, 106; see Schmidt, *Annalen*, 1920, 421, 159; Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580; Kalb, *Annalen*, 1921, 423, 39; Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307.

[3] In the preparation, *phenylphenylenearsinic acid*, $C_6H_5.C_6H_4.AsO(OH)_2$, occurs as a by-product (Schmidt, *loc. cit.*). When reduced, this acid gives the corresponding *chloride*, M.pt. 78° to 80° C. (Compare, Letterman, *Inaug. Dissert.*, Rostock, 1911.)

as a pale brown powder, whilst both the nitro- and arsinic groups are completely reduced in acid solution at a lead cathode.[1]

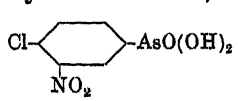
5-Chloro-2-nitrophenylarsinic acid,[2]



This acid is isolated from 5-chloro-2-nitroaniline by the Bart-Schmidt reaction, a yield of 64 per cent. being obtained. It crystallises in anhydrous rods, sintering at 240° C. and melting at 250° C.; it is very sparingly soluble in glacial acetic acid, from which it is deposited in long, colourless, rectangular prisms, soluble in alcohol. Its *magnesium salt* is amorphous. When reduced with ferrous sulphate the acid is quantitatively converted into 5-chloro-2-aminophenylarsinic acid (p. 203).

m-Nitrophenylarsinic acid may be prepared from *m*-nitroaniline by the foregoing process, but the yield is only 7 grams.[3] It may also be obtained by direct nitration of phenylarsinic acid.[4] 3-Nitro-4-aminophenylarsinic acid and 5-nitro-2-aminophenylarsinic acid have been used as starting-points for producing *m*-nitrophenylarsinic acid.[5] Three grams of phenylarsinic acid when treated with 6 grams of fuming nitric acid and 9 grams of concentrated sulphuric acid yield 3·4 grams of the *m*-nitro acid. A similar result is obtained if the former acid is heated in a sealed tube with 7 parts of concentrated sulphuric acid and 5 parts of concentrated nitric acid at 155° to 165° C. for three hours, an insoluble isomeride also being produced. The nitro-acid crystallises in glistening plates, melting at about 200° C. when rapidly heated, and changing to an *anhydride* on solidification. The following salts are known: *calcium salt*, $NO_2.C_6H_4.AsO(OH).OCa.OH$; *acid barium salt*, $[NO_2.C_6H_4.AsO(OH).O]_2Ba$, crystalline crusts; *copper salt*, from copper sulphate and the acid, $NO_2.C_6H_4.AsO(OH).OCu.OH$, a blue, crystalline substance; *silver salt*, $NO_2.C_6H_4.AsO(OAg)_2$, a white, amorphous precipitate; *magnesium salt*, small needles.

4-Chloro-3-nitrophenylarsinic acid,



is obtained by the nitration of 4-chlorophenylarsinic acid, using mixed acid. It crystallises in white plates from dilute alcohol, and when boiled with 5 parts of aqueous potassium hydroxide (density 1·32) for several hours its chlorine is evolved and replaced by the hydroxyl group. When boiled with an excess of alcoholic piperidine for three hours it yields *3-nitro-4-piperidinophenylarsinic acid*, which forms leaflets from boiling water.[6]

[1] Fichter and Elkind, *Ber.*, 1916, 49, 239.

[2] Balaban, *J. Chem. Soc.*, 1928, p. 812.

[3] In this preparation, 2 : 3′-dinitrodiphenylyl-4-arsinic acid, $NO_2.C_6H_4.C_6H_3(NO_2).AsO(OH)_2$, has been isolated as a by-product. (Schmidt, *Annalen*, 1920, 421, 159; Bart, *loc. cit.*):

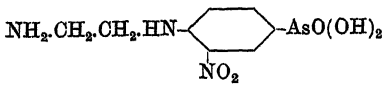
[4] Michaelis and Loesner, *Ber.*, 1894, 27, 265; Michaelis, *Annalen*, 1902, 320, 294; Hamilton and Sly, *J. Amer. Chem. Soc.*, 1925, 47, 435.

[5] Bertheim and Benda, *Ber.*, 1911, 44, 3297.

[6] King, *J. Chem. Soc.*, 1927, p. 1053.

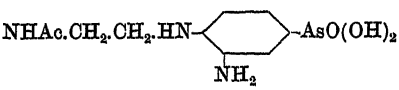
Condensation of 4-Chloro-3-nitrophenylarsinic Acid with Amines.[1]

3-Nitro-4-β-aminoethylaminophenylarsinic acid,



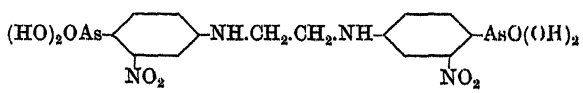
is prepared by heating 5 grams of 4-chloro-3-nitrophenylarsinic acid with 10 grams of ethylene diamine for one and a half hours at 135° to 140° C. in the presence of anhydrous sodium acetate. A yellow mass results, which is dissolved in dilute sodium carbonate and precipitated by addition of hydrochloric acid. On treating the arsinic acid in aqueous suspension with 30 per cent. excess of acetic anhydride, the *acetyl derivative* is formed.

3-Amino-4-β-acetamidoethylaminophenylarsinic acid,



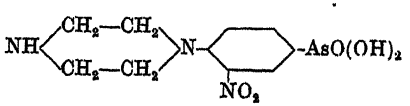
The previous acetyl derivative, 11·5 grams, is dissolved in a solution containing 15 c.c. of 10*N* sodium hydroxide and 10 c.c. of water. The solution is poured little by little with 35 c.c. of 10*N* sodium hydroxide into 30 grams of water containing 65 grams of ferrous sulphate, $FeSO_4.7H_2O$. The temperature is kept below 50° C. for thirty minutes, then solution cooled to 3° C., when most of the sodium sulphate separates. This is removed and the filtrate neutralised, when a 50 per cent. yield of the amino-acid is obtained.

NN′-Di-o-nitrophenylethylenediamine-4 : 4′-diarsinic acid,



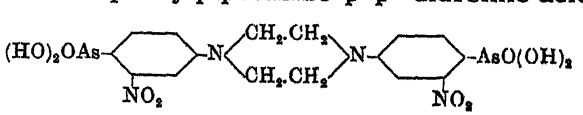
is obtained in 80 per cent. yield when the previous condensation with ethylene diamine is carried out in 50 per cent. aqueous solution. When this acid is reduced by ferrous hydroxide, a 20 to 25 per cent. yield of the *aminophenyl-derivative* is isolated.

3-Nitro-4-piperazinophenylarsinic acid,



This is formed by condensing 4-chloro-3-nitrophenylarsinic acid (1 mol.) with piperazine hydrochloride (2·5 mols.) in 1200 c.c. of 10*N* sodium hydroxide. The mixture, after heating for thirty minutes, is precipitated by adding hydrochloric acid, a 65 per cent. yield being obtained.

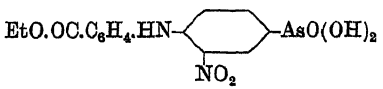
1 : 4-Di-o-nitrophenylpiperazine-p-p′-diarsinic acid,



[1] Fourneau and Funke, *Bull. Soc. chim.*, 1928, [iv], 43, 889.

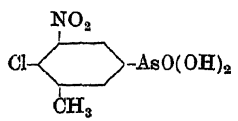
results when the preceding condensation is carried out using piperazine hydrate in the presence of sodium acetate, the temperature of reaction being 110° C.

3-Nitro-4-p-carbethoxyphenylaminophenylarsinic acid,



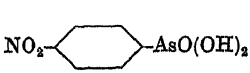
is the condensation product of 4-chloro-3-nitrophenylarsinic acid and ethyl *p*-aminobenzoate; ferrous sulphate reduction converts it to the *amino-acid.*

3-Methyl-4-chloro-5-nitrophenylarsinic acid,[1]



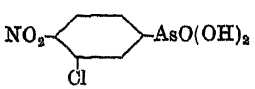
results when 4-chloro-3-methylphenylarsinic acid is nitrated by mixed acid. It crystallises in yellow needles, melting at about 310° C., and giving a colourless solution in dilute sodium hydroxide. By the action of alkali the chlorine may be removed and *5-nitro-4-hydroxy-3-methylphenylarsinic acid* isolated.

p-Nitrophenylarsinic acid,[2]



The methods of preparation for this acid are identical with those for the *ortho* isomeride, 13·8 grams of *p*-nitroaniline giving an 11 grams yield of the *p*-nitro acid. The latter is readily soluble in hot water and methyl alcohol, sparingly soluble in cold water and ethyl alcohol. It melts above 300° C. with decomposition.

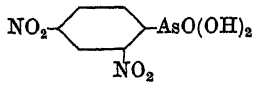
3-Chloro-4-nitrophenylarsinic acid,[3]



3-Chloro-4-nitroaniline, 51·75 grams, is triturated with 103·5 c.c. of concentrated hydrochloric acid and an equal volume of water, diazotised at 0° C. with 21 grams of sodium nitrite in 63 c.c. of water, and the solution added to copper arsenite solution. After stirring for thirty minutes, and heating for thirty minutes at 60° C., the filtered liquor is acidified with concentrated hydrochloric acid until acid to Congo red paper. The yield is 37·5 grams (45 per cent.). The acid crystallises from 2*N* acetic acid in long, irregular, pale yellow, anhydrous prisms, decomposing at 200° C. It is soluble in alcohol, sparingly soluble in cold water. The *barium salt* crystallises in prismatic rods, whilst the *magnesium* and *calcium salts* are amorphous.

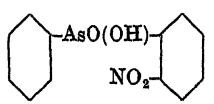
[1] German Patent, 245536.
[2] German Patent, 250264; Bart, *Annalen*, 1922, 429, 95, 110.
[3] Balaban, *J. Chem. Soc.*, 1928, p. 810.

2 : 4-Dinitrophenylarsinic acid,[1]



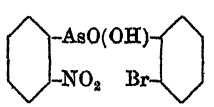
This acid has been prepared by two methods: (1) 2 : 4-Dinitrophenyl *syn*-diazo-hydroxide in acid solution is treated with sodium arsenite. (2) 18·5 grams of 2-4-dinitroaniline are added to a mixture of 30 grams of sulphuric acid and 23 grams of sulphuric acid containing 59 per cent. of nitrosyl sulphuric acid and maintained below 25° C. After treatment with 250 grams of ice, 25 grams of sodium arsenite in 50 c.c. of water are quickly stirred in, a vigorous evolution of nitrogen resulting, the reaction being completed by passing in steam. As soon as the diazo-reaction is complete, animal charcoal is added and the solution filtered whilst hot. The arsinic acid is precipitated from the filtrate by the addition of sodium chloride. It crystallises in felted needles, M.pt. 199° to 200° C., very soluble in hot water, fairly soluble in alkali, sodium carbonate, ethyl acetate, acetic acid, or alcohols, insoluble in ether. Its aqueous solution turns Congo red to violet.

2-Nitrodiphenylarsinic acid,[2]



results when diazotised *o*-nitroaniline is treated with phenyldichloroarsine in alkaline solution. The yield is about 54 per cent., but it is asserted that it may be increased to 87 per cent. if the phenyldichloroarsine is replaced by phenylarsenoxide in sodium hydroxide and sodium acetate solution.[3] The product crystallises from water in pale yellow rhomboids, M.pt. 197° to 198° C., readily soluble in hot alcohol, moderately soluble in acetic acid, insoluble in ether and benzene. Reduction with ferrous sulphate and iron powder gives the corresponding amino compound.

2-Bromo-6′-nitrodiphenylarsinic acid,[4]

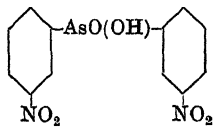


A suspension of 13·8 grams of *o*-nitroaniline in 80 c.c. of concentrated hydrochloric acid and 250 c.c. of water is diazotised at 0° C. with a solution of 7·6 grams of sodium nitrite. After filtering, the diazo solution is stirred into a solution prepared as follows and warmed to 20° C.: 27·2 grams of *o*-bromophenylarsenoxide are dissolved in 174 c.c. of 5*N* sodium hydroxide, the solution diluted to 500 c.c. with water, and 10 c.c. of 10 per cent. aqueous copper sulphate containing ammonium hydroxide to form the soluble complex added. The mixture is stirred for two hours, made faintly alkaline to litmus, filtered, and the filtrate treated

[1] Bart, *Annalen*, 1922, 429, 96; German Patent, 266944; American Patents, 1075537, 1075538; British Patent, 24667 (1912).
[2] Kalb, *Annalen*, 1921, 423, 39.
[3] Sakellarios, *Ber.*, 1924, 57, [B], 1514.
[4] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 457

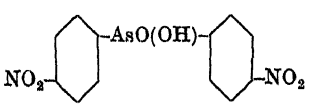
with concentrated hydrochloric acid until Congo paper turns blue. The arsinic acid (19·6 grams) is precipitated, and is recrystallised from dilute alcohol, yielding pale yellow prisms, M.pt. 254° to 255° C. with decomposition.

3 : 3′-Dinitrodiphenylarsinic acid



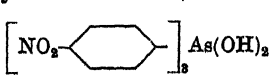
is obtained in quantitative yield by nitrating diphenylarsinic acid as follows:[1] 10 grams of diphenylarsinic acid are dissolved in a mixture of 20 grams of nitric acid (density 1·4), 10 grams of fuming nitric acid, and 60 grams of concentrated sulphuric acid. The temperature is gradually raised to 100° C. on the water-bath, and the mixture then cooled and poured upon 1000 grams of ice. The acid separates, and is filtered off and crystallised from acetic acid, a yellow powder resulting, M.pt. 256° C. It is only sparingly soluble in water or alcohol, insoluble in benzene, chloroform, or ether. It yields the following salts: *Barium salt*, $[(NO_2.C_6H_4)_2AsO_2]_2Ba$, yellowish-white; *neutral silver salt*, $(NO_2.C_6H_4)_2AsO_2Ag$, a white precipitate; *copper salt*, $(NO_2.C_6H_4)_2AsO.OCu.OH$, a bluish-white precipitate. The alkali and alkaline earth salts are readily soluble. Mild reduction of the acid by hydriodic acid in acetic acid solution yields 3 : 3′-*dinitrodiphenylarsenious acid*, $NO_2.C_6H_4.As(OH).C_6H_4.NO_2$. This may be crystallised from acetic acid; it is insoluble in water, alcohol, and sodium carbonate solution, but yields a yellow solution in sodium hydroxide. It explodes on heating.

4 : 4′-Dinitrodiphenylarsinic acid,



is obtained by the action of a normal sodium hydroxide solution of *p*-nitrophenylarsenious acid, $(HO)_2As.C_6H_4.NO_2$, on diazotised *p*-nitroaniline.[2] The acid, M.pt. 278° C., is sparingly soluble in water and alcohol, but insoluble in ether, benzene, or chloroform; it is best recrystallised from 50 per cent. alcohol or acetic acid. Its alkali and alkaline earth salts are easily soluble in water.

Tri-p-nitrotriphenylarsinic acid,[3]



Sodium *p*-nitrobenzene-*iso*diazo-oxide (1000 grams) in 10,000 c.c. of water is treated with a solution of 1860 grams of di-*p*-nitrodiphenylarsenious acid (p. 181) in 40,000 c.c. of water and the equivalent of sodium hydroxide, the mixture being slowly heated up to 75° or 80° C. until the evolution of nitrogen ceases. The product is then filtered and the filtrate acidified with hydrochloric acid, when a brown precipitate

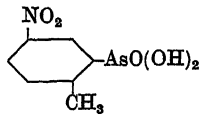
[1] Wieland and Rheinheimer, *Annalen*, 1921, 423, 1; see Michaelis, *Annalen*, 1902, 321, 151.

[2] German Patent, 250264; Bart, *Annalen*, 1922, 429, 102.

[3] German Patent, 254345.

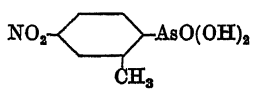
is thrown down, which is boiled with barium carbonate in water. After filtration, the residue is freed from carbonate by treatment with hydrochloric acid and crystallised from glacial acetic acid-alcohol mixture. It is insoluble in water, alcohol, and sodium carbonate, but gives a brownish-yellow solution in sodium hydroxide. It explodes on heating.

5-Nitro-2-methylphenylarsinic acid,[1]



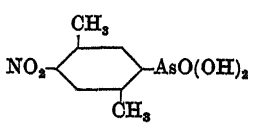
o-Tolylarsinic acid (5 grams) is added to a mixture of 25 grams of concentrated sulphuric acid and 20 grams of nitric acid (density 1·49), maintained at 20° to 35° C., and after fifteen minutes the mixture is poured into six volumes of water. The sulphuric acid is neutralised by concentrated sodium hydroxide solution, and on cooling, the nitro-acid separates in shining, felted needles. It may also be obtained from 4-nitro-*o*-toluidine.[2] At 230° C. it becomes brown, and melts at 261° C.; it is fairly soluble in hot water, but sparingly soluble in cold water.

4-Nitro-2-methylphenylarsinic acid,[2]



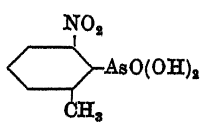
is obtained from 5-nitro-*o*-toluidine. It forms colourless needles, melting with decomposition at 235° to 240° C. It is sparingly soluble in cold water, alcohol, or acetic acid, but soluble on boiling; practically insoluble in acetone or chloroform.

4-Nitro-2 : 5-dimethylphenylarsinic acid,[2]



This acid is isolated from 2 : 5-dimethyl-*p*-nitroaniline, and crystallises in needles, M.pt. 290° C., sparingly soluble in boiling water or cold glacial acetic acid, more soluble on heating.

6-Nitro-2-methylphenylarsinic acid,

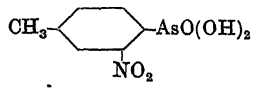


The starting-point in this preparation is 3-nitro-*o*-toluidine. The acid crystallises in star-like aggregates of pale yellow needles, decomposing with preliminary softening and darkening at 228° to 230° C. It dissolves readily in hot ethyl alcohol and in methyl alcohol at room temperature;

[1] Karrer, *Ber.*, 1915, 48, 311.
[2] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

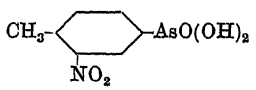
it is practically insoluble in cold glacial acetic acid, but somewhat more soluble in the boiling acid.

2-Nitro-4-methylphenylarsinic acid,



3-Nitro-4-toluidine (22 grams) is powdered under 100 c.c. of 20 per cent. hydrochloric acid and diazotised at 10° C. with 11 grams of sodium nitrite. When solution is nearly complete, the diazo solution is poured into 355 grams of 10 per cent. aqueous sodium hydroxide at 0° C., a concentrated solution of 27 grams of sodium arsenite added at once, and the mixture heated at 60° to 70° C. for one and a half to two hours. The liquor is then acidified with acetic acid, treated with charcoal, filtered, and the filtrate made acid to Congo red by hydrochloric acid, when about 22 grams of the arsinic acid separate. This is dissolved in hot sodium acetate and reprecipitated by hydrochloric acid, when the nitro acid separates in minute rods, melting with decomposition at about 255° to 260° C. A more recent preparation [1] states that the acid may be recrystallised from water and melts with decomposition at 241° to 242° C. It is sparingly soluble in cold water, alcohol, or acetic acid, but appreciably soluble on boiling.

3-Nitro-4-methylphenylarsinic acid,[2]



is either obtained by nitrating *p*-tolylarsinic acid or from 2-nitro-4-toluidine. It crystallises from hot water in glistening crystals of the rhombic system, which do not melt at 300° C. It is soluble in alcohol, sparingly soluble in benzene and chloroform, and insoluble in ether and ligroin. The following salts have been isolated: *Alkali salts*, not crystallisable; *silver salt*, a white, amorphous powder; *barium salt*, white needles; *calcium salt*, small, glistening plates; *copper* and *cobalt salts* have also been described. The latter, when heated to 100° C., becomes ultramarine-blue, and has been assigned the following constitution: $NO_2.C_7H_6.AsO(OH).O.Co.OH$. In air, the violet colour is gradually regenerated.

Nitro-m-xylylarsinic acid, $NO_2.C_8H_8.AsO(OH)_2$,[3] is formed by dissolving *m*-xylylarsinic acid in cold, fuming nitric acid, pouring the mixture into water and evaporating. It crystallises in short, white needles, M.pt. 207° C., decomposing with explosion at 306° C., readily soluble in water, sparingly soluble in alcohol or ether. The *neutral silver salt* is known, $NO_2.C_8H_8.AsO(OAg)_2$.

Nitro-p-xylylarsinic acid crystallises in pale yellow needles, M.pt. 205° C., readily soluble in alcohol, sparingly soluble in water. When strongly heated it explodes.[4]

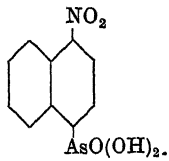
[1] Maschmann, *Ber.*, 1924, 57, [B], 1759.

[2] Michaelis, *Annalen*, 1902, 320, 321; see Jacobs, Heidelberger, and Rolf, *loc. cit.*

[3] Michaelis, *Annalen*, 1902, 320, 334.

[4] Since the acid is formed by nitrating *p*-xylylarsinic acid it is probably 3-nitro-2 : 5-dimethylphenylarsinic acid, and the preceding acid, 5-nitro-2 : 4-dimethylphenylarsinic acid.—AUTHOR.

1-Nitronaphthyl-4-arsinic acid,[1]



This acid is obtained when α-naphthylarsinic acid is nitrated ; it crystallises in pale yellow needles. The arsinic grouping is so firmly attached that it is not replaced by iodine, and only slightly by bromine. Concentrated hydrochloric acid at 120° C. converts the acid into α-nitronaphthalene, fusion with potassium hydroxide into α-naphthol, phosphorus pentachloride into 4-chloro-α-nitronaphthalene. Reduction to the corresponding amine is rendered difficult by the case with which the arsinic grouping undergoes reduction.

The Electrical Conductivity of Arsinic Acids and their Salts.

The conductivities of the sodium salts of certain substituted phenylarsinic acids have been measured [2] at dilutions of from 23 to 1024, and the limiting conductivities at infinite dilution calculated from the two Kohlrausch extrapolation formulæ $\mu_\alpha-\mu=a[S_0]^{\frac{1}{2}}$ and $\mu_\alpha-\mu=b[S_0]^{\frac{1}{4}}$. From the results obtained, the acids investigated may be divided into groups. The first consists of acids where $\mu_\alpha=75$ to 100, and comprises the neutral monosodium salts of amino-substituted arsinic acids, *e.g.* sodium *p*-aminophenylarsinate, sodium *o*-aminotolylarsinate, sodium *o*-*o*′-diaminodiphenylarsinate and sodium dimethylaminophenylarsinate, together with mono-acid salts of dibasic acids, dichloro- and dibromohydroxyphenylarsinic acids, *m*-dihydroxyphenylarsinic acid, and the di-acid salt of 3-nitro-4-hydroxyphenylarsinic acid. The second group, $\mu_\alpha=100$ to 200, comprises neutral salts of dibasic acids and mono-acid salts of tribasic acids. The third group contains those salts showing still higher conductivities. It consists of neutral salts of tribasic acids, 3-nitro-4-hydroxyphenylarsinic acid (329), dinitrohydroxyphenylarsinic acid (330), the mono-acid salt of phenylene-1 : 4-diarsinic acid (287), and its neutral salt (392).

A few conductivities at infinite dilution are : [3] *p*-Aminophenylarsinic acid, 370·0 ; *o*-aminotolylarsinic acid, 369·0 ; diaminophenylarsinic acid, 369·0 ; *m*-dihydroxyphenylarsinic acid, 371·0 ; 3-nitro-4-aminophenylarsinic acid, 369·0 ; dichlorophenylarsinic acid, 371·0 ; 3-nitro-4-hydroxyphenylarsinic acid, 370·0 ; phenylene-1 : 4-diarsinic acid, 369·0 ; *m*-dinitrophenylarsinic acid, 369·0. Another set of measurements [4] gives the values at infinite dilution, and the mean values of K are shown in brackets, the experiments being conducted at 25° C. : *e.g.* p-Aminophenylarsinic acid, 370 ; phenylarsinic acid, 372 (0·025) ; *o*-nitrophenylarsinic acid, 370 (0·035).

In the following cases [5] the constant K is calculated from the formula :

[1] Andreev, *J. Russ. Phys. Chem. Soc.*, 1913, 45, 1980.
[2] Lorenz and Schmidt, *Zeitsch. anorg. Chem.*, 1920, 112, 209.
[3] Lorenz and Schmidt, *ibid.*, 1920, 111, 175.
[4] Fichter, *Ber.*, 1921, 54, [B], 1280.
[5] Lorenz and Brehmer, *Zeitsch. anorg. Chem.*, 1923, 128, 76.

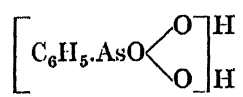
$$\frac{\alpha^2}{1-10^{-3}\alpha C}$$

and is therefore related to Kohlrausch's constant c, which is given in C.G.S. units, thus $10^5c=K$. The following values for K are at the molar concentration 1/256: Phenylarsinic acid, 0·027; *p*-hydroxyphenylarsinic acid, 0·015; *p*-amino-*o*-tolylarsinic acid, 0·014; *m*-methoxy-*p*-acetamidophenylarsinic acid, 0·029; *p*-nitrophenylarsinic acid, 0·137; *o*-nitrophenylarsinic acid, 0·037; 2-nitro-4-aminophenylarsinic acid, 0·0086; 3-hydroxy-4-aminophenylarsinic acid (at 1/512), 0·0067.

From the dissociation constants of the substituted phenylarsinic acids shown in the Appendix, Table I., the following factors for the mathematical expression of the influence of various groups in differing positions in the molecule have been calculated.[1] Wegscheider's factors for the carboxylic acids are shown in the brackets: *o*-Nitro, 1·41, 1·51*(103); *m*-nitro, 5, 5·5(5·75); *p*-nitro, 5·3(6·6); *o*-hydroxy, 0·42(17·0); *m*-hydroxy, about 1·45*(1·45); *p*-hydroxy, 0·55(0·48); *o*-methyl, 2·4*(2·00); *m*-methyl, 0·85*(0·86). The factors marked thus * are based on experiments with acids containing an amino group. The most marked divergences are shown in the two sets of figures where the substituent is in the *ortho* position to the carboxyl or arsinic group. The conductivity of a substituted arsinic acid depends, therefore, on three factors: (1) The conductivity of the parent substance. (2) The nature and position of the substituent, the effect being the same on the arsinic as on the carboxyl group, provided that the groups are not too close together, in which case a new factor enters. (3) The immediate mutual influence between the acid radical and the substituent, this being more marked with the arsinic acids than with the carboxylic acids.

Molecular Weight of Arsinic Acids.[2]

The molecular weights of a number of arsinic acids have been determined by the ebullioscopic method, and generally the acids appear to have the simple, non-polymerised structure of the type



o-Phenylenediarsinic acid is polymerised, and may even show twice the normal molecular weight, different preparations giving different values.

Arsanilic acid, $(C_6H_4.NH_2.AsO_3)H_2$, is strictly monobasic, and may be represented as an internal salt, $[C_6H_4(NH_3).O.AsO.O]H$, and similarly with *o*-toluidinoarsinic acid, *p*-dimethylaminophenylarsinic acid, and *o*-phenylenediamine arsinic acid. The following behave normally with regard to electrical conductivity and exhibit normal molecular weights: Resorcino-, 3-nitro-4-aminophenyl-, dichlorophenyl-, dibromophenyl-, 3-nitro-4-hydroxyphenyl-, and *p*-iodophenyl- arsinic acids, and 4-amino-3-carboxyphenylarsenoxide. For the densities of arsinic acids, see Table II., Appendix.

[1] Lorenz and Brehmer, *Ber.*, 1923, 56, [B], 742.
[2] Lorenz and Brehmer, *Ber.*, 1923, 56, [B], 174.

Arsenicals of the Types $RAs(OR)_2$; $R_2As.OR$.

Phenylarsenious acid, although unknown in the free state, is represented by a number of esters, as indicated below :[1]

Methyl phenylarsenite, $C_6H_5.As(OCH_3)_2$, is obtained by the prolonged action of sodium methoxide on phenyldichloroarsine in ether solution. It is a colourless, fuming liquid, B.pt. 116° C. at 18 mm., density 1·343 at 20° C. Treatment with water or alkali converts it into phenylarsenoxide and methyl alcohol. Chlorine combines with it, forming a *dichloro-compound,* $C_6H_5.AsCl_2(OCH_3)_2$, which melts at 90° C., and is decomposed by water or alcohol according to the equation :

$$C_6H_5.AsCl_2(OCH_3)_2+3H_2O=C_6H_5.AsO(OH)_2+2CH_3.OH+2HCl.$$

Methyl phenylarsenite does not interact with methyl iodide and is decomposed by bromine.

Ethyl phenylarsenite, $C_6H_5.As(OC_2H_5)_2$, is a colourless liquid, B.pt. 122° C. at 15° C., the *chlorine addition compound* forming warty aggregates, M.pt. 95° C.

isoAmyl phenylarsenite, $C_6H_5.As(OC_5H_{11})_2$,[2] is a colourless liquid, B.pt. 173° to 176° C. at 11 mm.

Phenyl phenylarsenite,[1] $C_6H_5.As(OC_6H_5)_2$, may be obtained either by replacing the alkyl oxides in the above by sodium phenolate, or by heating phenyldichloroarsine with phenol at 200° C. The arsenite is a colourless liquid, B.pt. 245° C. at 15 mm., density 1·32 at 20° C. It is decomposed by moisture and reacts with chlorine as follows, a similar result being obtained with bromine :

$$C_6H_5.As(OC_6H_5)_2+8Cl_2=C_6H_5.AsCl_4+2C_6H_2Cl_3OH+6HCl.$$

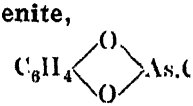
p-Cresyl phenylarsenite, $C_6H_5.As(O.C_6H_4.CH_3)_2$.—*p*-Cresol (10·8 grams) in dry xylene is treated with 2·3 grams of sodium and heated to boiling to form the sodium salt. To this, 7·3 grams of phenyldichloroarsine are added, and the whole boiled for a short time to complete the reaction. The liquor is filtered, and the filtrate distilled in carbon dioxide at 12 mm., a yellowish oil resulting, B.pt. 285° C., density 1·2989 at 13° C.

Benzyl phenylarsenite, $C_6H_5.As(O.CH_2C_6H_5)_2$, is a bright yellow, fuming oil, B.pt. 296° C. at 30 mm., density 1.2853 at 13° C., decomposed by chlorine or bromine in the following manner :

$$C_6H_5.As(O.CH_2C_6H_5)_2+5Cl_2=C_6H_4Cl_2+C_6H_4Cl.COOH+C_6H_5.CH_2Cl+3HCl+AsCl_3$$

β-Naphthyl phenylarsenite, $C_6H_5.As(OC_{10}H_7)_2$, results when sodium β-naphthoxide is used in the general method. It separates in colourless needles from benzene-petroleum, M.pt. 113° to 114° C., and is decomposed by water.

Catechyl phenylarsenite,



[1] Michaelis, *Annalen*, 1902, 320, 271.

[2] Steinkopf, Schubart, and Schmidt, *Ber.*, 1928, 61, [B], 682.

In this preparation the dry lead salt of catechol is used. The product forms a white, star-like mass, M.pt. 83° C., B.pt. 197° to 198° C. at 15 mm., decomposed in the usual manner by water. If the sodium salt is used instead of the lead salt in this preparation, a product is isolated, M.pt. 63° C.

Phenylarsenimide, $C_6H_5.As{=}NH$.—Phenyldichloroarsine in dry benzene is treated with ammonia, the heat of reaction being sufficient to boil the benzene. The compound crystallises in plates from alcohol, sintering at 265° C. and melting at 270° C., readily soluble in benzene and xylene, sparingly soluble in ether, hydrolysed by water and dilute acids.

m-Nitrophenylarsenious acid, $NO_2.C_6H_4.As(OH)_2$.[1]—*m*-Nitrophenyldichloro- or dibromo-arsine is dissolved in aqueous alkali and treated with carbon dioxide, then with hydrochloric acid. The acid separates in white flocks, soluble in alkali and alcohol, sparingly soluble in carbonate solutions and insoluble in water.

p-Nitrophenylarsenious acid.[2]—This acid is prepared by reducing *p*-nitrophenylarsinic acid in dilute sulphuric acid solution with sulphur dioxide at 15° C. The arsenious acid is a yellow, microcrystalline powder, exploding without melting when heated, sparingly soluble in alkali carbonates, readily dissolving in caustic alkali.

Phenyl diphenylarsenite, $(C_6H_5)_2As.OC_6H_5$.[3]—This is the phenyl ester of the unknown diphenylarsenious acid, and is formed by treating a xylene solution of diphenylchloroarsine with sodium phenoxide. It is a colourless liquid, B.pt. 230° to 231° C. at 15 mm., density 1·3113 at 11° C. It is isomeric with triphenylarsine oxide. It combines only with the halogens, whereas the corresponding phosphorous acid derivative combines with oxygen, sulphur, selenium, and methyl iodide. The *chloride*, $(C_6H_5)_2AsCl_2.OC_6H_5$, forms fine needles, M.pt. 121° to 122° C., readily decomposed by moisture, and the corresponding *bromide* gives yellowish-red crystals, M.pt. 100° C.

Di-p-nitrodiphenylarsenious acid, $(C_6H_4.NO_2)_2As.OH$, results when the corresponding chloride is treated with alkali, or the arsinic acid reduced with hydriodic acid in glacial acetic acid. It crystallises from alcohol in white needles, M.pt. 149° C., and yields unstable salts.

iso-Amyl diphenylarsenite, $(C_6H_5)_2As.OC_5H_{11}$.[4]—This derivative is formed by treating the alcoholate from 9 grams of *iso*amyl alcohol and 2·3 grams of sodium in 150 c.c. of benzene, with 26·5 grams of diphenylchloroarsine in 100 c.c. of benzene. The yield is about 50 per cent., and the boiling-point of the ester 188° to 189° C. at 11 mm. It is pale green in colour, and has an odour resembling that of amyl alcohol.

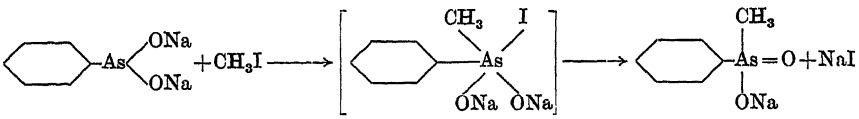
iso-Amyl diphenylthioarsenite, $(C_6H_5)_2As.SC_5H_{11}$, results when the alcohol used in the preceding preparation is replaced by *iso*amylmercaptan and the reaction carried out in xylene solution. It is a greenish-yellow liquid, B.pt. 215° to 220° C. at 11 mm.

Allyl diphenylarsenite, $(C_6H_5)_2As.OC_3H_5$, is a pale green liquid, obtained by using allyl alcohol in the foregoing reactions. The yield is some 39 per cent., and the product boils at 180·5° to 181·5° C. at 11 mm.

[1] Michaelis and Loesner, *Ber.*, 1894, *27*, 263.
[2] Bart, *Annalen*, 1922, *429*, 101; see German Patent, 250264.
[3] Michaelis, *Annalen*, 1902, *321*, 143.
[4] Steinkopf, Schubart, and Schmidt, *Ber.*, 1928, *61*, [B], 682.

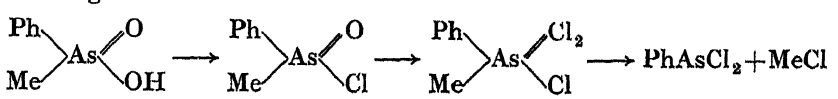
Mixed Aromatic-Aliphatic Arsinic Acids.

Acids of the aromatic-aliphatic type are prepared by the reaction represented in the following scheme : [1]



Phenylmethylarsinic acid, $C_6H_5.As(CH_3)O.OH$.—Phenylarsenoxide (16·8 grams), in 80 c.c. of alcohol and 20 c.c. of 10*N* sodium hydroxide, is treated with 8 c.c. of methyl iodide, when a vigorous reaction takes place. After standing overnight, the mixture is poured into 300 c.c. of water and 25 grams of silver nitrate in 50 c.c. of water and 50 c.c. of nitric acid (density 1·12) added. The silver iodide is filtered off and the filtrate boiled with a little charcoal, filtered through a fluted filter, and treated with 25 grams of silver nitrate in 50 c.c. of water. Addition of 17 c.c. of concentrated ammonium hydroxide precipitates 22·1 grams of the *silver salt* of the arsinic acid. The free acid is isolated by taking 20·85 grams of the salt in 200 c.c. of water, adding 35 c.c. of 2*N* hydrochloric acid, and heating for a long time, the mixture being well stirred. The silver chloride is filtered off and the filtrate evaporated to the crystallising point on the water-bath. In this way 9·3 grams of acid, M.pt. 179·5° C., are obtained, and a further 3·3 grams may be isolated from the mother liquors.

The acid has more recently been prepared as follows : [2] Phenylmethyliodoarsine is converted to phenylmethylchloroarsine through the oxide, and 8·55 grams of the chloroarsine in 170 c.c. of acetone boiled under reflux with 23·4 grams of Chloramine-T in 230 c.c. of water for one hour. The acetone is distilled off, the *p*-toluenesulphonamide filtered from the cooled solution, and the filtrate evaporated to dryness. Extraction of the residue with two quantities of warm acetone, leaves a 96·5 per cent. yield of phenylmethylarsinic acid, M.pt. 176° to 177° C. The acid may also be prepared from phenylmethyliodoarsine by oxidation with Chloramine-T or hydrogen peroxide, but the iodine liberated during the process renders the separation of the acid difficult. The arsinic acid crystallises in white, silky needles,[1] very soluble in water, alcohol, and acetic acid, less soluble in acetone and ether. Its aqueous solution is neutral to methyl orange but can be titrated with barium hydroxide, using litmus as indicator. The *barium salt* is a white, hygroscopic powder, the aqueous solution being faintly acid to litmus ; the *lead salt* is a water-soluble powder, and the *mercury salt* a white precipitate. A *hydrochloride* and a *nitrate* are also known. When the free acid is heated on the water-bath with thionyl chloride it is decomposed, yielding phenyldichloroarsine and probably methyl chloride, the reaction according to experimental evidence presumably taking the following course : [2]



[1] Bertheim, *Ber.*, 1915, 48, 350. [2] Gibson and Johnson, *J. Chem. Soc.*, 1928, p. 92.

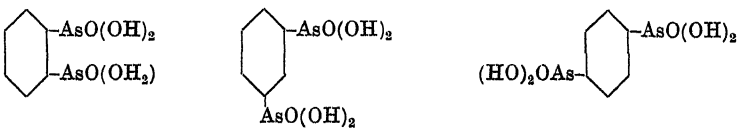
Phenylethylarsinic acid,[1] $C_6H_5.As(C_2H_5)O.OH$, is obtained when ethyl iodide replaces methyl iodide in the preceding preparation, 8·4 grams of the oxide yielding 7·8 grams of the acid. It crystallises in four-sided prisms, M.pt. 108° C., having a similar solubility to the methyl compound.

Phenylisoamylarsinic acid, $C_6H_5.As(C_5H_{11})O.OH$, crystallises in stellate groups of prisms, M.pt. 108° C.

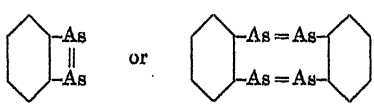
p-Aminophenylmethylarsinic acid, $NH_2.C_6H_4As(CH_3)O.OH$, is prepared from *p*-aminophenylarsenoxide and methyl iodide. It is a crystalline powder, M.pt. 201° C. On replacing the foregoing oxide by its acetyl derivative, *acetyl-p-aminophenylmethylarsinic acid* results. This product melts at 260° C.

Aromatic Diarsinic Acids and their Reduction Products.

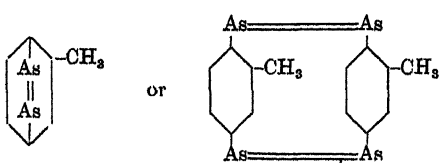
When diazotised arsanilic acids are treated with sodium arsenite in alkaline solution they yield diarsinic acids of the following types :



The nitrophenylenediarsinic acids are obtained in a similar manner, 5-nitro-2-aminophenylarsinic acid and 3-nitro-4-aminophenylarsinic acid giving 4-nitrophenylene-1 : 2-diarsinic acid and 2(3)-nitrophenylene-1 : 4-diarsinic acid respectively. 3-Methyl-4-aminophenylarsinic acid under the foregoing treatment forms 2(3)-methylphenylene-1 : 4-diarsinic acid. It is possible to reduce the nitro-groups in the nitrophenylenediarsinic acids without affecting the arsinic acid residue if suitable reducing agents are chosen (*e.g.* ferrous chloride or sodium amalgam and methyl alcohol). The aminophenylenediarsinic acids thus obtained may be diazotised and the amino group replaced by halogens or hydroxyl in the usual manner. If reduction is carried out using an excess of hypophosphorous acid, an arseno-compound is produced. These arseno-compounds may be formulated in two ways—*e.g.* *o*-arsenophenylene or *o*-diarsenodibenzene is represented as follows :



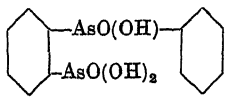
whilst 2-methyl-1 : 4-arsenobenzene or 2 : 2′-dimethyl-1 : 4 : 1′ : 4′-diarsenodibenzene is assigned the constitution,



Diazotised *o*-arsanilic acid coupled with phenylarsenoxide, or diazotised

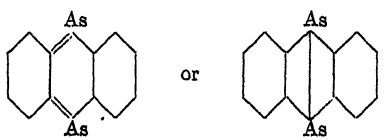
[1] Bertheim, *loc. cit.*

o-aminodiphenylarsinic acid treated with alkaline sodium arsenite, yields *phenylarsinophenyl-o-arsinic acid,*

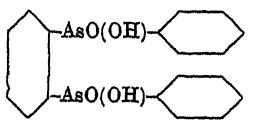


Reduction of this acid in concentrated hydrochloric acid solution by sulphur dioxide in the presence of potassium iodide yields *arsanthrene chloride,* which is oxidised by nitric acid to *arsanthrenic acid* or *diphenylene-o-diarsinic acid,*

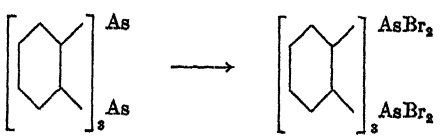
Reduction of arsanthrene chloride by fuming hydrochloric acid and zinc, or the corresponding oxide by phenylhydrazine, yields *arsanthrene* or *diphenylenediarsine,* which may be represented as follows :



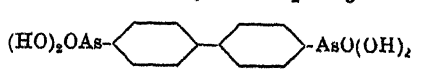
Nitration of phenylarsinophenyl-*o*-arsinic acid yields a *meta-nitro compound* in accordance with the general rule, and this derivative can undergo similar reactions to those described for the unsubstituted acid. Diazotised *o*-aminodiphenylarsinic acid reacts with phenyldichloroarsine to give *phenylene*-1 : 2-*diphenyldiarsinic acid,*



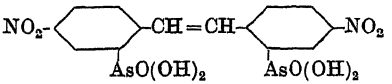
Reduction of this acid with phosphorus trichloride, or heating arsanthrene oxide in carbon dioxide under reduced pressure, forms *tri-o-phenylenediarsine.* This is a crystalline product, forming a *mercurichloride* and yielding a *tetrabromide* with bromine,



A different type of diarsinic acid is formed by treating diazotised benzidine or its derivatives with sodium arsenite in the presence of copper sulphate. Benzidine itself yields *diphenyl*-4 : 4′-*diarsinic acid,*

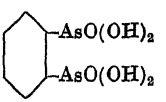


5-Nitro-2-methylphenylarsinic acid is transformed by sodium hypochlorite in alkaline solution to 5 : 5′-*dinitro*-2 : 2′-*stilbene*-1 : 1′-*diarsinic acid*,

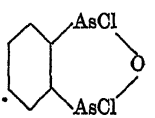


If 5-nitro-2-methylphenylarsinic acid is heated with alkali at 90° C., subsequent treatment with acid yields a mixture of stilbenediarsinic acids, as detailed on p. 194. Reduction with sodium hydrosulphite transforms these into 5 : 5′-diamino-2 : 2′-stilbene-1 : 1′-diarsinic acid. Further reduction yields the corresponding arseno-compound. 4-Nitro-5-chlorotolyl-2-arsinic acid undergoes a similar series of reactions.

o-Phenylenediarsinic acid,[1]



When *o*-arsanilic acid is diazotised in the usual manner and the amino-group replaced by the arsenic residue, a 43·6 per cent. yield of the diarsinic acid results. It forms white, microscopic needles, containing 1 molecule of water, which remain unmelted at 360° C., and on strong heating explode. It is sparingly soluble in water, practically insoluble in the usual solvents, and is not precipitated from its alkaline solutions by acetic acid. On warming with dilute copper sulphate solution, a very pale, insoluble *copper salt* is deposited. Boiling with bisulphite solution yields the oxide. In the above preparation, *o*-hydroxyphenylarsinic acid is formed as a by-product. When the diarsinic acid in fuming hydrochloric acid is treated with a little potassium iodide and saturated with sulphur dioxide at water-bath temperature, *o-phenylenediarsine oxychloride* is formed in 55 per cent. yield,

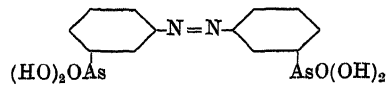


It forms colourless, quadrilateral plates, M.pt. 148° C., easily soluble in hot ether, benzene, and carbon disulphide.

m-Phenylenediarsinic acid[2] is prepared from *m*-arsanilic acid as follows : 5 grams of *m*-arsanilic acid in 250 c.c. of water and 15 c.c. of 5*N* sulphuric acid are cooled to 7° or 8° C. and diazotised by 2 grams of sodium nitrite. The diazo solution at 3° C. is neutralised by 15 c.c. of 5*N* potassium hydroxide solution, the whole cooled to 0° C. and treated with 14 c.c. of alkaline arsenite solution. Nitrogen is evolved and the liquor becomes yellowish-brown. After several hours it is acidified with hydrochloric acid, when the colour changes to red, any small quantities of reddish-brown product (soluble in alkali and reprecipitated by acids) being filtered off. The filtrate is evaporated to dryness, the residue extracted several times with boiling alcohol and the solution evaporated to 10 c.c. After long standing, this syrup solidifies, and on trituration with a little aqueous alcohol, reddish-yellow crystals are formed, which contain traces of a red dye in addition to the diarsinic acid. Treatment

[1] Kalb, *Annalen*, 1921, 423, 39. [2] Lieb, *Ber.*, 1921, 54, 1511.

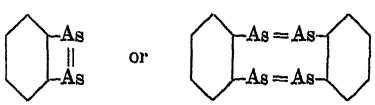
with ethyl acetate removes the acid, and after evaporating the solvent, the residue is dissolved in water and decolorised by charcoal. The aqueous solution, on evaporation to small bulk, deposits the acid in colourless plates. These have no melting-point, but decompose with explosion when heated to a high temperature. The *sodium salt* crystallises with 10 molecules of water. Heating the acid with phosphorous acid at 200° to 235° C. gives a yellow, amorphous substance, probably of the type obtained from *o*-phenylenediarsinic acid. If, however, the foregoing preparation is adjusted so that the solution remains faintly acid after coupling, and the mixture is heated at 50° to 60° C., nitrogen is only slowly evolved and the main product is *azobenzene-3 : 3'-diarsinic acid,*



This acid crystallises in dark, orange-yellow needles, which darken and feebly evolve gas at 240° C. The *tri-* and *tetra-sodium salts* form orange-yellow needles containing 11 molecules of water.

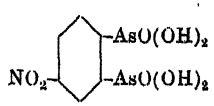
p-Phenylenediarsinic acid [1] results when *p*-arsanilic acid is diazotised and to its faintly acid solution alkaline sodium arsenite added. Nitrogen evolution takes place at the ordinary temperature, and is completed by warming to 50°–60° C. The resulting diarsinic acid crystallises in colourless leaflets, soluble in water, sparingly soluble in alcohol, insoluble in ether, acetone, and benzene. The yield is rather poor, only 1·5 grams being obtained from 5 grams of atoxyl. The *sodium salt* crystallises in needles containing 14 molecules of water.

o-Arsenophenylene or **o-Diarsenodibenzene,** [2]



o-Phenylenediarsinic acid (1·5 grams) is treated with an excess of hypophosphorous acid (density 1·28) and the mixture heated at 100° C. for fifteen minutes, then boiled. The arseno-compound separates as an egg-yellow, amorphous precipitate, practically insoluble in the usual solvents. The yield is about 0·9 gram.

4-Nitrophenylene-1 : 2-diarsinic acid, [3]

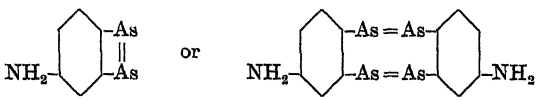


5-Nitro-2-aminophenylarsinic acid is diazotised and treated in alkaline solution with sodium arsenite in the presence of copper powder. The diarsinic acid thus obtained is purified by means of its *zinc salt*, a pale yellow, crystalline powder. The acid crystallises in large, prismatic rosettes of needles, containing 1 molecule of water. It is sparingly soluble in cold water, readily soluble in hot water, moderately soluble in alcohols, fairly soluble in acetone and acetic acid, insoluble in benzene and chloroform. When heated above 100° C. it passes into the *anhydride.*

[1] Lieb, *Ber.*, 1921, 54, 1511; see German Patent, 250264; Bart, *Annalen*, 1922, 429, 89.
[2] Lieb and Wintersteiner, *Ber.*, 1923, 56, [B], 425.
[3] Lieb and Wintersteiner, *ibid.*, 1923, 56, [B], 1283.

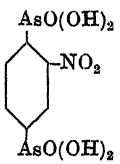
4-Aminophenylene-1 : 2-diarsinic acid is obtained when the above nitro-acid is reduced by ferrous chloride. It is best purified through its *zinc salt*. It crystallises with 1 molecule of water. Heating above 100° C. converts it into the *anhydride*, and above 300° C. it suddenly darkens. It is less soluble in alcohols than the nitro-acid and insoluble in amyl alcohol, acetone, toluene, and chloroform. Diazotised and coupled with β-naphthol it forms a red dye.

4-Amino-1 : 2-arsenobenzene or **4 : 4′-Diamino-1 : 2 : 1′ : 2′-diarsenodibenzene,**



When the preceding compound is heated on the water-bath with hypophosphorous acid, reduction rapidly takes place and the arseno-compound is obtained by diluting the reaction mixture with water. It is a yellow, amorphous substance, insoluble in water, alkalis, alcohol, acetone, chloroform, and benzene, but soluble in hot acetic acid. In amyl alcohol it gives a colourless solution and is readily soluble in pyridine. Dilute sulphuric acid does not dissolve it, but it is readily soluble in the concentrated acid. Concentrated hydrochloric acid forms the *hydrochloride*, which is precipitated by excess of acid.

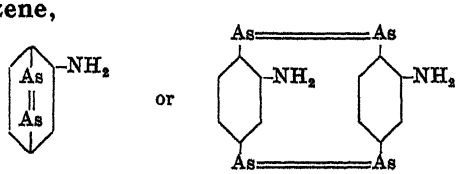
2(3)-Nitrophenylene-1 : 4-diarsinic acid,



is prepared from 3-nitro-4-aminophenylarsinic acid by diazotisation and treatment with sodium arsenite in the presence of a little ammoniacal copper sulphate solution. The acid is purified through its *zinc salt*. The free acid crystallises from water in colourless prisms, which decompose with gas evolution at 239° to 243° C. The yield is about 70 per cent. The acid is sparingly soluble in hot alcohols and insoluble in acetone, ether, benzene, and acetic acid.

2(3)-Aminophenylene-1 : 4-diarsinic acid is formed by reducing the preceding nitro-acid in the presence of methyl alcohol with 4 per cent. sodium amalgam at 40° to 50° C. The process takes from ten to fourteen hours. The acid is purified through the *zinc salt* in the usual way. The yield is 85 to 90 per cent. The free acid crystallises from water in long prisms, having a similar solubility to the nitro-acid.

2-Amino-1 : 4-arsenobenzene or **2 : 2′-Diamino-1 : 4 : 1′ : 4′-diarsenodibenzene,**



The foregoing 2-nitrophenylene-1 : 4-diarsinic acid, when reduced at 100° C. with a large excess of hypophosphorous acid, yields this arseno-

compound. It is an ochre-yellow to brownish-red, amorphous powder, darkening at 205° C. and melting at 217° to 220° C. It is insoluble in the usual solvents, very sparingly soluble in pyridine, and appears to undergo oxidation in boiling amyl alcohol. It is soluble in dilute hydrochloric acid, the concentrated acid precipitating the *hydrochloride*, which is a brick-red, amorphous powder, darkening above 220° C. The arseno-compound dissolves in concentrated sulphuric acid, giving a dark red solution.

2(3)-Methylphenylene-1 : 4-diarsinic acid.—3-Methyl-4-aminophenylarsinic acid is diazotised, the solution treated with sodium arsenite and worked up in the usual manner. The diarsinic acid crystallises in colourless plates, which darken above 280° C. and decompose with explosion above 330° C. In the pure state it is very sparingly soluble in all solvents, but traces of brown organic by-products and inorganic salts increase the solubility. When the crude acid is heated with magnesia mixture in faintly ammoniacal solution, the *magnesium salt* is precipitated as a white, amorphous powder. This salt may be used as a means of purifying the acid. The *sodium salt* crystallises with 9 molecules of water, and the *barium salt* is a white, amorphous precipitate. A hot aqueous solution of the diarsinic acid when treated for two hours with hydrogen sulphide gives the sulphide, $C_6H_3.CH_3(AsS)_2$, a pale yellow, amorphous precipitate, soluble in ammonium hydroxide, but insoluble in the usual solvents.

2-Methyl-1 : 4-arsenobenzene or **2 : 2′-Dimethyl-1 : 4 : 1′ : 4′-diarsenodibenzene** is obtained in the usual way by reducing the foregoing diarsinic acid. The acid is heated for three to four hours in a sealed tube with hypophosphorous acid at 190° C. The arseno-compound is an egg-yellow to orange coloured powder, insoluble in all solvents, and readily oxidised to the diarsinic acid by nitric acid or hydrogen peroxide.

2-Chlorophenylene-1 : 4-diarsinic acid.—This acid is best prepared by diazotising 2-aminophenylene-1 : 4-diarsinic acid and treating the solution with copper bronze in the presence of hydrochloric acid. Another method for preparing it consists of diazotising 3-chloro-4-aminophenylarsinic acid and treating the solution with sodium arsenite, but the yield is very poor. The acid is best purified by means of its *zinc salt*, and crystallises in colourless, rhombic plates, which become reddish at 210° C. but remain unchanged below 315° C. The air-dried product contains 0·5 molecule of water, which is removed on drying *in vacuo* at 120° C.

In a similar manner *2-bromophenylene-1 : 4-diarsinic acid* may be prepared, which possesses similar properties to the chloro-derivative.

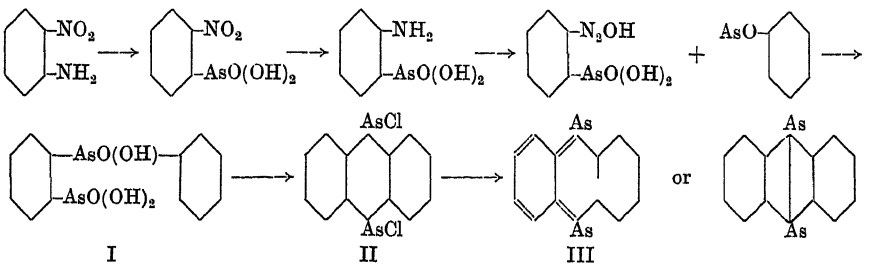
2-Chloro-1 : 4-arsenobenzene or **2 : 2′-dichloro-1 : 4 : 1′ : 4′-diarsenodibenzene** results when the previous chloro-diarsinic acid is reduced by hypophosphorous acid. It is an amorphous, citron-yellow powder, insoluble in all solvents. On boiling with concentrated hydrochloric or sulphuric acid, or with amyl alcohol, it loses its colour.

2-Hydroxyphenylene-1 : 4-diarsinic acid, obtained by the diazotisation of 2-aminophenylene-1 : 4-diarsinic acid and heating the product with water, crystallises in pale pink leaflets, which become reddish at 220° C. but do not melt at 315° C. It is sparingly soluble in all solvents.

2-Hydroxy-1 : 4-arsenobenzene or **2 : 2′-dihydroxy-**

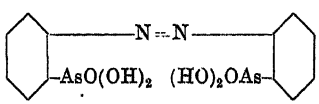
1 : 4 : 1′ : 4′-diarsenodibenzene is formed by reduction of the preceding compound. The arseno-compound is an amorphous, reddish-brown substance, readily soluble in alkali, alcohol, acetone, pyridine, and concentrated sulphuric acid, insoluble in water, carbonates, and concentrated hydrochloric acid. Its solutions are rapidly oxidised in air, an amorphous yellow precipitate being deposited.

Arsanthrene or **Diphenylenediarsine.**[1]—The complete synthesis of this compound (III) is shown by the following scheme :



The compounds I, II, and III are described in the following:

Phenylarsinophenyl-o-arsinic acid.—This compound (I) may be obtained in two ways : (1) Diazotised *o*-arsanilic acid is coupled with phenylarsenoxide (from the dichloride and 5*N* sodium hydroxide). The acid crystallises from hot dilute alkaline solution on treatment with hydrochloric acid in microscopic, long, quadrilateral plates, which melt with decomposition at 350° or 360° C. on rapid heating. It is sparingly soluble in acetic acid and very difficultly soluble in water and the usual organic solvents. From its ammoniacal solution barium hydroxide precipitates the *barium salt* as a white, insoluble powder. The *copper salt* is insoluble in water and dilute acetic acid. *Azobenzene-o-o′-diarsinic acid,*



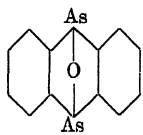
occurs as a by-product in the preceding preparation, to the extent of 2 per cent. on the weight of the starting material. It forms yellow to orange-yellow needles, M.pt. 272° C., insoluble in most solvents, but giving an orange-yellow solution in alkalis and a yellow solution in concentrated sulphuric acid. It also occurs as a by-product in the preparation of *o*-phenylenediarsinic acid by the reduction of *o*-diazophenylarsinic acid, but may be obtained in larger quantities by reduction of *o*-nitrophenylarsinic acid in alkaline solution with zinc dust and ammonium hydroxide in the presence of ammonium chloride.

(2) In this synthesis of phenylarsinophenyl-*o*-arsinic acid, the starting material is *o*-nitroaniline, which, when diazotised and coupled with phenyldichloroarsine, gives *o*-nitrodiphenylarsinic acid. Reduction of the latter gives the amino-acid, which is diazotised and the arsinic residue introduced in the usual way.

Arsanthrene chloride (II). - The preceding acid is reduced by sulphur dioxide in the presence of potassium iodide in concentrated hydrochloric acid solution. The arsanthrene chloride obtained crystal-

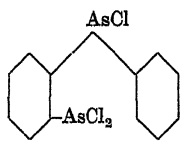
[1] Kalb, *Annalen*, 1921, 423, 39.

lises from hot carbon tetrachloride in lanceolate crystals, a centimetre long, M.pt. 182° to 183° C., readily soluble in benzene, chloroform, and carbon disulphide, sparingly soluble in ether. It is easily hydrolysed by water or alcohol. When shaken for several hours with a mixture of sodium carbonate and ether, it yields *arsanthrene oxide*,



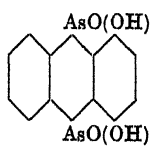
which crystallises in quadrilateral plates or bushy needles, M.pt. 196° C., readily dissolving in benzene, chloroform, and carbon disulphide, sparingly soluble in alcohol and ether, and insoluble in sodium hydroxide. It decomposes with feeble explosion on rapid heating to a high temperature.

As by-products in the preparation of arsanthrene chloride, phenyldichloroarsine and *phenylchloroarsinophenyl-o-arsine dichloride* are formed. The latter forms fine, white needles, M.pt. 153° to 155° C., readily soluble in benzene, chloroform, and carbon tetrachloride, and having the constitution,



Arsanthrene (III) may be obtained from arsanthrene chloride or oxide. (1) The chloride, in boiling alcohol solution, is treated with fuming hydrochloric acid and zinc turnings in small portions. (2) An alcoholic solution of the oxide and phenylhydrazine are boiled over a free flame for two minutes. Arsanthrene crystallises in orange-yellow, rhombic plates, which become orange-red at about 170° C., greenish-yellow at 290° C., partially liquefy at 340° C., and completely liquefy and become dark brown at 350° C. It is sparingly soluble in boiling acetic acid, pyridine, and phenylhydrazine, the first two solutions slowly decomposing on boiling.

Arsanthrenic acid or **Diphenylene-o-diarsinic acid.**[1]



Arsanthrene chloride in ten times its weight of warm nitric acid (density 1·38) is heated until no more nitrous fumes escape. An equal volume of water is then added and the product obtained recrystallised from hot dilute nitric acid (density 1·2). Large, colourless prisms separate (probably a *dinitrate*), which fall to a chalky powder on washing with water. The acid does not melt at 360° C., and is sparingly soluble in all solvents.

m - Nitrophenylarsinophenyl - o - arsinic acid. - 40 grams of

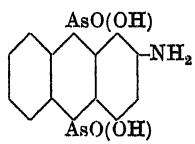
[1] Wieland and Rheinheimer, *Annalen*, 1921, 423, 1.

phenylarsinophenyl-*o*-arsinic acid (p. 189) are stirred into a mixture of 200 c.c. of fuming nitric acid (density 1·52), 150 c.c. of concentrated sulphuric acid, and 100 c.c. of 20 per cent. oleum at 20° C. The yellow solution is kept below 25° C., and on completion of the reaction the whole is poured upon 2000 grams of ice, and filtered. The moist solid is dissolved in dilute sodium carbonate solution and boiled with 3000 c.c. of the same solution, then treated with hydrochloric acid. The solid separating out is recrystallised from 5*N* nitric acid or 50 per cent. acetic acid. The acid forms colourless crystals, which give yellow solutions in alkalis, and the yield is nearly quantitative.

m-Aminophenylarsinophenyl-o-arsinic acid, obtained from the foregoing nitro-acid by reduction with ferrous sulphate in alkaline solution, crystallises in faintly pink, stellate needles, which yield a water-soluble *hydrochloride.*

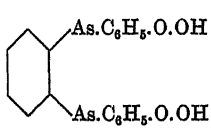
m-Aminoarsanthrene chloride hydrochloride is obtained when the previous amino-acid is dissolved in an excess of concentrated hydrochloric acid, a little potassium iodide added and sulphur dioxide passed in at 60° to 70° C. It forms colourless crystals.

Aminoarsanthrenic acid,



The colourless aqueous solution of the preceding hydrochloride yields the oxide on treatment with alkali, which dissolves on addition of hydrogen peroxide and warming. The mixture is acidified with hydrochloric acid, excess being removed by sodium acetate, when the arsanthrenic acid separates as a brownish, non-crystalline powder. It is purified by boiling with charcoal, when colourless needles are obtained.

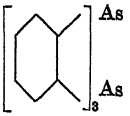
Phenylene-1 : 2-diphenyldiarsinic acid,[1]



A solution containing 20 grams of *o*-aminodiphenylarsinic acid, 58 c.c. of concentrated hydrochloric acid, 700 c.c. of water, and 500 grams of ice is diazotised, and with brisk stirring is treated with a solution of 18 grams of phenyldichloroarsine in 64 c.c. of 5*N* sodium hydroxide solution to which 58 grams of sodium acetate in 450 c.c. of ice-water have been added just previously. The mixture is made alkaline with sodium hydroxide, boiled with charcoal, and filtered. Acidification of the filtrate yields a yellowish-brown pasty precipitate, which is boiled with alcohol and the residue dissolved in a large bulk of dilute ammonium hydroxide. The solution is neutralised with acetic acid, boiled with charcoal, and an excess of dilute acetic acid added to the boiling filtered solution. The arsinic acid slowly separates in pale yellow, microscopic crystals, unmelted at 310° C., insoluble in water and the usual solvents. The yield is 9 grams.

[1] M'Cleland and Whitworth, *Trans. Chem. Soc.*, 1927, p. 2753.

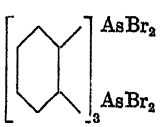
Tri-o-phenylenediarsine,



This derivative may be prepared in several ways: (1) 9 grams of the preceding compound suspended in 100 c.c. of chloroform are treated with an excess of phosphorus trichloride (25 grams). Heat is evolved and most of the acid dissolves, the reaction being completed by heating for three hours on the water-bath. The solution is then filtered and the filtrate heated under reduced pressure. At 120° to 130° C. frothing occurs, and at 320° to 340° C. the diarsine gradually sublimes into the upper parts of the distilling flask, but no distillate is obtained. The product is collected and the charred residue extracted with hot benzene, the combined yield being about 2·5 grams. (2) Arsanthrene oxide is distilled under slightly reduced pressure in a current of carbon dioxide. Arsenious oxide sublimes into the receiver and the triphenylene diarsine sublimes on the distilling flask. (3) It results to some extent during the distillation of arsanthrene chloride.

Tri-*o*-phenylenediarsine crystallises from benzene in small, almost colourless plates, M.pt. 295° to 296° C., soluble in acetone, light petroleum, and chloroform, sparingly soluble in alcohol or ether, insoluble in water. It can be sublimed without decomposition. Its crystallographic constants are as follows—System, monoclinic (holohedral); $a:b:c = 1{\cdot}589:1:-$; $\beta = 113°\ 15'$; forms present: *a*(100), *c*(001), *m*(110); angles observed: *am* 55° 35′, *ac* 66° 45′. It yields a *mercurichloride*, consisting of short, colourless needles, M.pt. 285° to 286° C., readily decomposed by dilute sodium hydroxide. When the diarsine is boiled with concentrated nitric acid and the solution poured into water, the oxide is precipitated. This separates from dilute alcohol in short, thin, colourless needles, unmelted below 360° C.

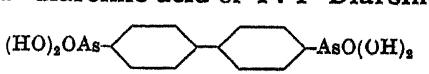
Tri-o-phenylenediarsine tetrabromide,



results when the diarsine is treated with a small excess of bromine in dry chloroform solution. It is an orange-red, crystalline substance, M.pt. 255° to 256° C., readily soluble in acetone, alcohol, or hot glacial acetic acid (with decomposition), sparingly soluble in chloroform, insoluble in ether, benzene, or light petroleum. Water decomposes the tetrabromide, giving the oxide. When it is heated under reduced pressure, it is decomposed, yielding bromine, triphenylenediarsine, *o*-dibromobenzene, and arsanthrene bromide.

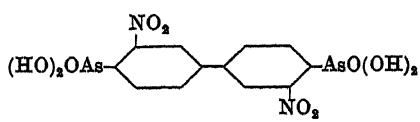
Diphenyl-4 : 4′-diarsinic Acid and its Derivatives.

Diphenyl-4 : 4′-diarsinic acid or 4 : 4′-Diarsinodiphenyl,



Benzidine, 18·4 grams, is dissolved in a mixture of 250 c.c. of 2*N* hydrochloric acid and 150 c.c. of water by heating to 70° C. The solution, after filtering and cooling to 0° C., is diazotised by 100 c.c. of 2*N* sodium nitrite, excess of nitrite being maintained for thirty minutes. The clear solution is then made neutral to Congo red by adding 50 c.c. of 2*N* sodium carbonate solution diluted to 100 c.c. The diazotised solution is then added during fifteen to twenty minutes to an arsenite solution of the following composition: 30 grams of arsenious oxide dissolved in 300 c.c. of 2*N* sodium carbonate solution, containing 2 grams of copper sulphate, the whole being cooled to 0° C. The resulting brown solution is stirred for two to three hours, the temperature allowed to rise gradually to about 20° C., and when a solution of R-salt no longer couples with a test portion, the temperature is raised to 50° C. and the stirring continued until the evolution of nitrogen ceases. After filtration, the liquor is made slightly acid to litmus by dilute hydrochloric acid, when a brown precipitate separates. The latter is removed, dissolved in alkali, and again precipitated, this process being repeated until the filtrate from the brown solid no longer gives a precipitate when acidified with dilute hydrochloric acid. The filtrates are finally combined and acidified with hydrochloric acid, the diarsinic acid separating as a yellowish-white precipitate. This is removed, washed, and dried, a neutral solution of the diarsinic acid being prepared by dissolving 25 grams in 250 c.c. of water and 12·4 c.c. of 10*N* sodium hydroxide and treating with bone black at 90° C. for one hour. The pale yellow solution obtained on acidification with hydrochloric acid gives a white, gelatinous precipitate, which, when removed and dried, is a white powder.[1] The yield is about 23 grams of pure diarsinic acid, *i.e.* about 55 per cent. The acid is a white, microcrystalline powder, composed of masses of branching needles. It is only soluble to the extent of 1 part in 1000 of boiling water; hot sulphuric acid and hot glycerol dissolve it apparently without change, but it is neither dissolved nor acted upon by the other mineral acids, nor attacked by bromine or iodine. It is insoluble in the common organic solvents. All attempts to sulphonate it have failed. By titration of its aqueous suspension with sodium hydroxide the acid can be shown to be tetrabasic, and the titration also furnishes evidence that the acid differs from diphenylarsinic-*o*-arsinic acid. The *tetra-sodium salt* crystallises from very concentrated solutions in white columnar crystals.[2]

3 : 5′-Dinitrodiphenyl-4 : 4′-diarsinic acid,[3]



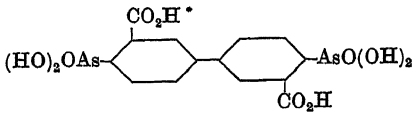
is not prepared by direct nitration, but by using 3 : 3′-dinitrobenzidine as the starting material. It is isolated in 65 per cent. yield as a light yellow solid, soluble in glacial acetic acid to the extent of about 3 grams per 1000 c.c.

3 : 5′-Diaminodiphenyl-4 : 4′-diarsinic acid results when the preceding compound is reduced by means of alkaline ferrous hydroxide.

[1] Bauer and Adams, *J. Amer. Chem. Soc.*, 1924, 46, 1925.
[2] Hill, *J. Amer. Chem. Soc.*, 1924, 46, 1855. [3] Bauer and Adams, *loc. cit.*

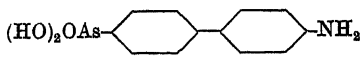
The yield is 79 per cent., and the product is pale yellow. The *diacetyl derivative* is a white solid. When the acid is tetrazotised and coupled with H-acid it forms a dye of the Trypan Blue type. This dye is a bronze-coloured solid, dissolving in water to give a bluish-red solution.

3 : 5′-Dimethyldiphenyl-4 : 4′-diarsinic acid is obtained when toluidine replaces dinitrobenzidine in the foregoing preparation. The acid is isolated in 44 per cent. yield, does not melt up to 310° C., and is insoluble in water and organic solvents, but its alkali salts are readily soluble in water. Oxidation with potassium permanganate in alkaline solution gives 3 : 5′-*dicarboxydiphenyl*-4 : 4′-*diarsinic acid*,



in 67 per cent. yield, as a white, crystalline compound, insoluble in water.

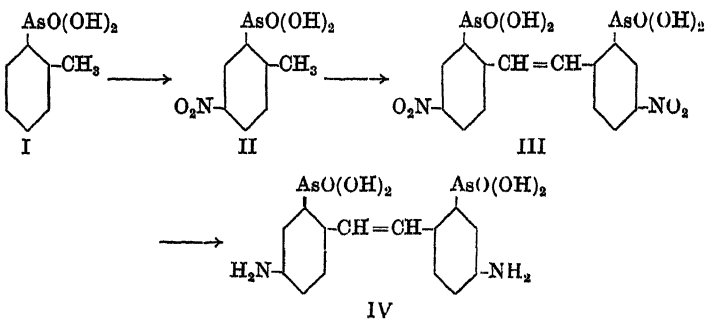
4-Aminodiphenyl-4′-arsinic acid,



The method adopted in the preparation of this type of compound is to tetrazotise benzidine, couple one diazonium group with a component which can be reduced to give an amino-group (*e.g.* H-acid), and replace the second diazonium group by the arsinic acid radical. The acid gives a white *hydrochloride* and a white, crystalline *acetyl derivative*.

Stilbene Derivatives.

5 : 5′-Diamino-2 : 2′-stilbene-1 : 1′-diarsinic acid[1] may be isolated by the following series of reactions :

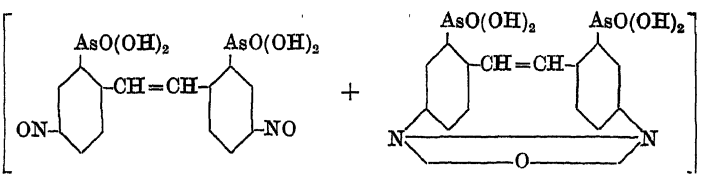


o-Tolylarsinic acid (I) and 5-nitro-2-methylphenylarsinic acid (II) are described on pp. 162 and 176. The 5 : 5′-*dinitro*-2 : 2′-*stilbene*-1 : 1′-*diarsinic acid* (III) is prepared as follows : 5 grams of the nitro-compound (II) are warmed for five minutes at 90° C. with a mixture of 50 c.c. of 10*N* sodium hydroxide solution, 50 c.c. of water, and 35 c.c. of sodium hypochlorite (chlorine content = 5·5 per cent.). Concentrated hydrochloric acid then precipitates the acid from the hot solution in a thick mass of white crystals, very sparingly soluble in water and alcohol. The solution in alkali, when warmed with a little acetone, yields a

[1] Karrer, *Ber.*, 1915, 48, 305.

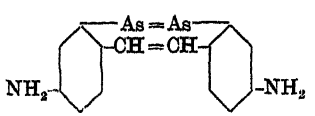
reddish-brown condensation product, and heating with phenylhydrazine produces a red coloration.

Instead of isolating the dinitro-compound just described, another method may be adopted: 30 grams of 5-nitro-2-methylphenylarsinic acid are dissolved in 150 c.c. of 10*N* sodium hydroxide solution and 50 c.c. of water and the solution heated at 90° C. for about fifteen minutes, until the melt becomes deep brown. Dilution with seven volumes of water and acidification with concentrated hydrochloric acid precipitates a reddish-brown dyestuff. The mixture is heated to boiling, filtered, washed with hot water, and dried. The product consists of a mixture of arsenical stilbene dyes of the Mikado Brown type, dinitroso-, azoxy- and azo-stilbenediarsinic acids such as the following being present:



The reduction is carried out as follows: 20 grams of the mixed product previously described are dissolved in 200 c.c. of 10*N* sodium hydroxide solution and 400 c.c. of water and boiled under reflux for twelve hours, 50 grams of zinc dust being added in small quantities. The boiling with zinc dust is maintained until the decolorised solution no longer turns brown on exposure to air, this requiring about twelve hours. About 30 grams of sodium hydrosulphite are then added and the hot solution poured into an excess of dilute hydrochloric acid, when a brown, amorphous product separates, which is filtered off and washed with water. It is dissolved in 50 to 80 c.c. of hot 10 per cent. sodium carbonate solution, and the solution boiled with about 20 grams of sodium hydrosulphite until completely decolorised, then filtered whilst hot. On cooling, the filtrate deposits yellowish-brown plates of the *disodium salt* of 5 : 5′-diamino-2 : 2′-stilbene-1 : 1′-diarsinic acid. This product is washed with ice-water, alcohol, and ether, and recrystallised from dilute alcohol. It is not very soluble in cold water, and dried *in vacuo* it contains 4 molecules of water of crystallisation. When dried slowly at 110° to 120° C., the anhydrous salt is formed, but it is very hygroscopic. The free base (IV) is precipitated in yellow flocks when the sodium salt is treated with mineral acid. It is easily soluble in alkali and also in excess of mineral acid. Its hydrochloric acid solution with dimethylaminobenzaldehyde gives a red precipitate of a Schiff's base.

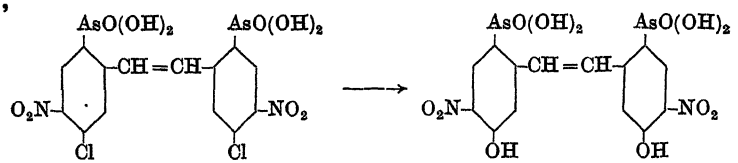
5 : 5′-Diamino-1 : 1′-arseno-2 : 2′-stilbene,



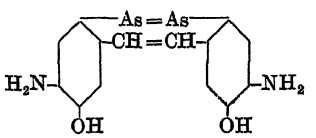
results when 3 grams of the preceding disodium salt in 100 c.c. of warm water are treated with 20 grams of sodium hydrosulphite in 100 c.c. of water and the whole heated for a short time at 50° to 60° C. The product separates in yellow flakes, which are filtered and washed with

hot water. It is insoluble in alkali and only very slightly soluble in excess of mineral acid.

4 : 4′-Dichloro-5 : 5′-dinitro-2 : 2′-stilbene-1 : 1′-diarsinic acid,



I II



III

This acid (I) is prepared from 4-nitro-5-chlorotolyl-2-arsinic acid by heating with sodium hypochlorite and 10*N* sodium hydroxide solution. It is a white, crystalline powder, sparingly soluble in hot water.

5 : 5′-Diamino-4 : 4′-dihydroxy-1 : 1′-arseno-2 : 2′-stilbene.—5 grams of the preceding acid are warmed for three hours with 50 c.c. of 10*N* sodium hydroxide solution and 10 c.c. of sodium hypochlorite solution (chlorine content = 5·5 per cent.), then diluted with 50 c.c. of water and acidified with concentrated hydrochloric acid. Yellowish-brown flocks of 5 : 5′-*dinitro*-4 : 4′-*dihydroxy*-2 : 2′-*stilbene*-1 : 1′-*diarsinic acid* (II) are precipitated. These are removed, well washed with water, dissolved in dilute sodium hydroxide solution and reduced by hydrosulphite or stannous chloride containing potassium iodide. The arseno-compound (III) thus obtained is readily soluble in sodium hydroxide, insoluble in acids.

CHAPTER VI.

ARYLARSINIC ACIDS (*continued*).

Aminoarylarsinic Acids and their Derivatives.

These acids are of great importance owing to the therapeutic value of certain of them, and also on account of their utility in the preparation of other arsenated derivatives. The group contains the first aromatic organic arsenic compound to be isolated, namely, *p*-aminophenylarsinic acid (*p*-arsanilic acid). Its discovery in 1863 [1] was due to Béchamp, who showed that aniline, when heated with arsenic acid, condensed to give a colourless monobasic acid, capable of forming well-defined salts, and not hydrolysed by aqueous caustic alkali. The reaction between arylamines and arsenic acids is now known as the *Béchamp reaction.* Béchamp failed to realise the importance of his discovery, and it was not until 1907 that Ehrlich and Bertheim [2] showed the actual constitution of *Atoxyl,* the sodium salt of the acid. Arsenation by the Béchamp reaction yields products in which the arsenic grouping enters the ring in the *para* position to the amino-group, should this be vacant. If this position is occupied, the arsenic group takes up the *ortho* position if possible; failing this no arsenation occurs:

$$C_6H_5NH_2+AsO(OH)_3 \longrightarrow NH_2.C_6H_5.AsO(OH)_3 \longrightarrow NH_2.C_6H_4.AsO(OH)_2+H_2O$$

The Béchamp reaction has been applied to the following arylamines: Aniline, *o*- and *p*-chloroanilines, *o*-, *m*- and *p*-toluidines, *m*- and *p*-xylidines, and α-naphthylamine.

In addition to the foregoing direct method of arsenation, the following indirect methods are available:

(1) Reduction of the corresponding nitroarylarsinic acid by the aid of ferrous salts and alkali, sodium amalgam and methyl alcohol, or ammonium sulphide.

(2) An aminonitroarylarsinic acid is converted to its oxalyl or similar derivative, the nitro-group then reduced to the amino-group, the latter replaced by hydrogen by aid of the diazo-reaction, and the resulting compound hydrolysed to remove the oxalyl grouping.

(3) A diaminoarsinic acid is diazotised with 1 molecular equivalent of sodium nitrite and the solution treated with alcohol and copper powder, when one amino-group is removed.

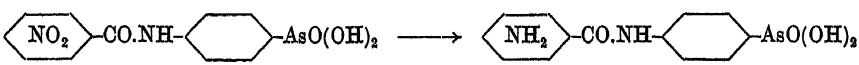
Halogenated aminoarylarsinic acids are usually prepared by the Béchamp reaction or by Method (1), and direct halogenation has only been applied in the case of *p*-aminophenylarsinic acid. Chlorination of the acetyl derivative of this acid yields a monochloro-acid, whilst the free amino-acid under the same conditions gives a dichloro-acid.

[1] Béchamp, *Bull. Soc. chim.*, 1863, 5, 518.
[2] Ehrlich and Bertheim, *Ber.*, 1907, 40, 3292.

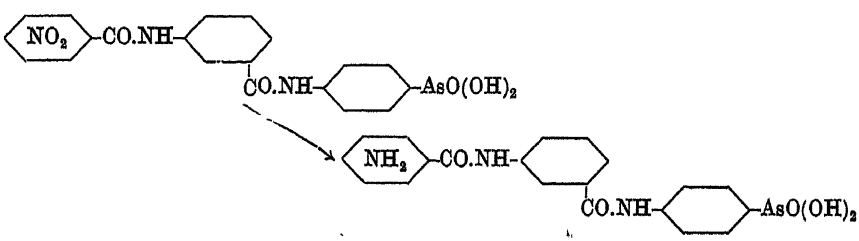
The aminoarylarsinic acids are colourless, crystalline solids, soluble in dilute acids and alkalis, and except for moderate solubility in water, alcohols and glacial acetic acid, show a general tendency to be insoluble in most organic solvents. In some cases heating with potassium iodide and dilute sulphuric acid splits off the arsinic acid grouping and replaces it by iodine. The amino-group may be diazotised and coupled with various components in the usual way. The halogenated amino-acids are less basic than the unsubstituted compounds, and their diazonium derivatives are more stable.

The N-acyl and N-alkyl derivatives of aminoarylarsinic acids are prepared by the usual methods. Acetyl-*p*-aminophenylarsinic acid, in addition to the usual method of acetylation of the arsinic acid, may be formed by subjecting *p*-aminoacetanilide to the Bart-Schmidt reaction. An interesting series of N-aryl derivatives of *p*-aminophenylarsinic acid has been obtained by King and his co-workers in the course of seeking organic arsenicals of therapeutic value.[1]

Benzoyl-*p*-aminophenylarsinic acid was first described in 1906,[2] and prepared by the benzoylation of sodium *p*-aminophenylarsinate, using benzoyl chloride and aqueous sodium hydroxide. Replacing the benzoyl chloride by *o*-, *m*- or *p*-nitrobenzoyl chloride, King isolated *o'*-, *m'*-, and *p'*-mononitrobenzoyl-*p*-aminophenylarsinic acids respectively, which in turn were reduced to the corresponding amino-compounds in yields of 60 to 85 per cent.:



By repeating this process of nitro-benzoylation, the following types were produced:



The average yields were 50 to 80 per cent. in the case of *m*-amino derivatives, and 30 to 50 per cent. in the case of *o*- and *p*-compounds. These structures were later modified by replacing the nitrobenzoyl chlorides by *para*-substituted *m*-nitrobenzoyl chlorides, in which the group R in the *para*-position was one of the following: CH_3, OCH_3, OC_2H_5, $O.CO_2.C_2H_5$ or Cl. This led to the production of compounds of the types indicated in the following scheme:

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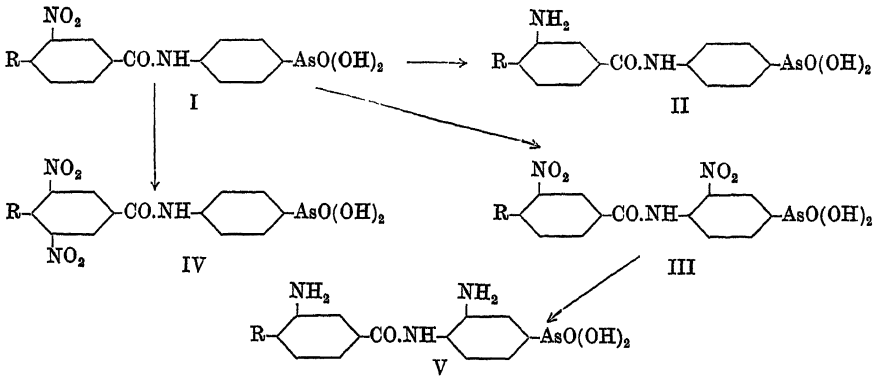
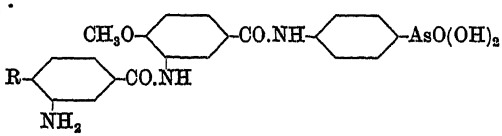
[1] King and Murch, *Trans. Chem. Soc.*, 1924, 125, 2595; 1925, 127, 2632; Balaban and King, *ibid.*, 1925, 127, 271.

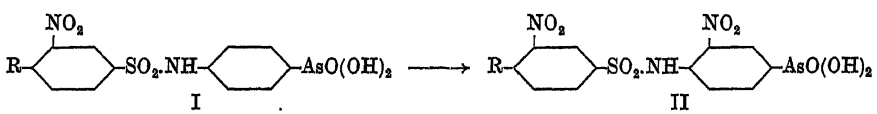
[2] German Patent, 191548.



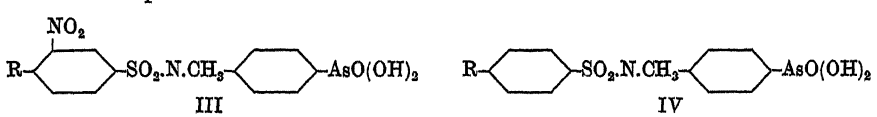
When product I was nitrated, type III was exclusively obtained when R was H, CH_3, or Cl, but when R was OCH_3 or OC_2H_5, a mixture of the two isomeric dinitro-acids III and IV resulted. The amino-acids II were isolated by reduction of I by ferrous chloride and alkali, yields of 55 to 95 per cent. being obtained. The following complex has been isolated from 3′-amino-4-anisoyl-4-aminophenylarsinic acid, where R is H or OCH_3:



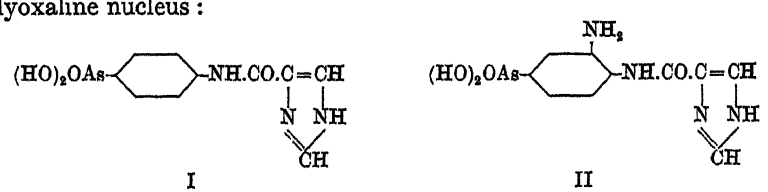
By the condensation of *p*-aminophenylarsinic acid with *m*-nitrobenzenesulphonyl chloride or *m*-nitro-*p*-toluenesulphonyl chloride, compounds of type I are obtained, where R is H or CH_3. These on further nitration yield type II:



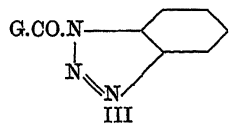
The methylation product of I ($R=CH_3$) is only obtained by the action of methyl sulphate at 100° C. (III); IV is formed by methylation at room temperature:



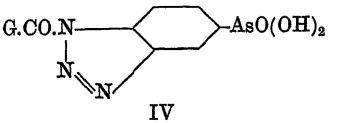
By applying the Bart-Schmidt reaction to glyoxaline-4 (or 5)-carboxy-*p*-aminoanilide, it is possible to obtain arsinic acids containing the glyoxaline nucleus:



The compound II may also be obtained from I by nitration and subsequent reduction. The Bart-Schmidt reaction applied to glyoxaline-4 (or 5)-carboxy-*o*-aminoanilide does not give a substance analogous to I, but a diazoimide (III), whilst the aminoarsinic acid II gives the crystalline diazoimide IV:



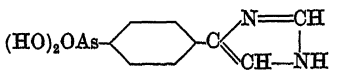
III



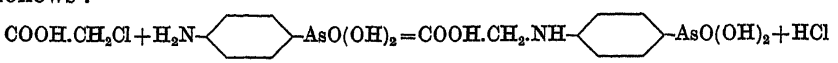
IV

(G = glyoxalinyl.)

4-*p*-Aminophenylglyoxaline under similar conditions yields a very small amount of 4-phenylglyoxaline-*p*-arsinic acid:



A considerable amount of work has been done on condensations between aminoarylarsinic acids and chloracetic acid and its derivatives. The reaction, which produces glycine derivatives, may be represented as follows:



Substituting the amide or alkyl amides of chloracetic acid for the acid itself, the following type of compound is produced:

$$R'RN.CO.CH_2.NH.C_6H_4.AsO(OH)_2$$

(where R and R′ may be any of the groups: hydrogen, alkyl, benzyl or substituted benzyl). Using an aromatic amide of chloracetic acid, the derivatives are of the type

$$ArNH.CO.CH_2.NH.C_6H_4.AsO(OH)_2$$

Replacing the amides by carbamide or its β-alkyl or aryl derivatives, the general formula of the products becomes

$$R.NH.CO.NH.CO.CH_2.NH.C_6H_4.AsO(OH)_2$$

(where R is hydrogen, alkyl, or aryl).

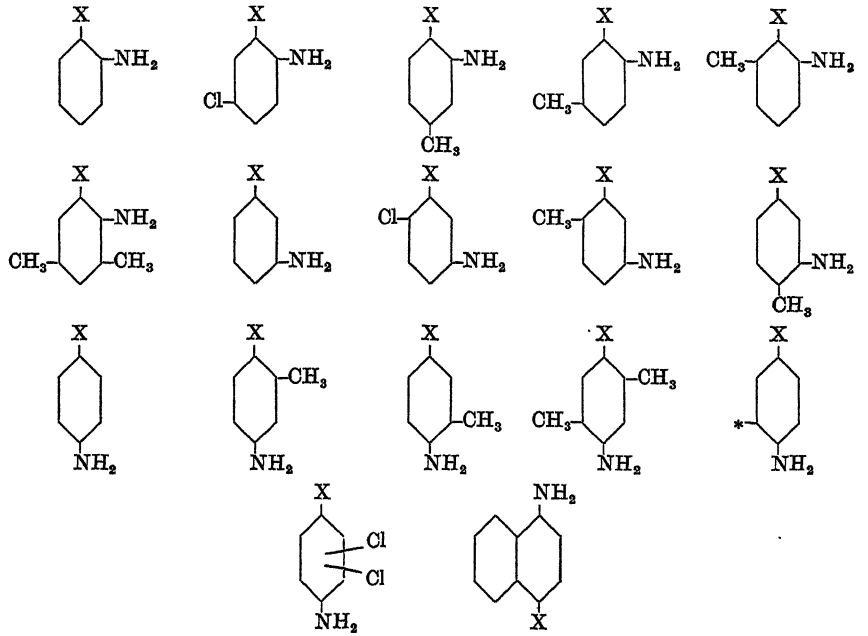
By using as starting materials chloracetyl-*p*-arsanilic acid and arylamines, it is possible to reverse the glycine side chain, the arsinic acid radical then being a substituent on the anilide nucleus:

$$XC_6H_4.NH.CH_2.CO.NH.C_6H_4.AsO(OH)_2$$

Other interesting condensation products are those between sodium *p*-arsanilic acid and substituted benzyl chlorides, phenoxyethyl bromide, and phenacyl halides, which lead, respectively, to the following types of compounds:

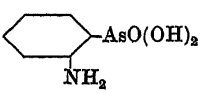
$$XC_6H_4.CH_2.NH.C_6H_4.AsO(OH)_2;\ XC_6H_4.OCH_2.CH_2.NH.C_6H_4.AsO(OH)_2;$$
$$XC_6H_4.CO.CH_2.NH.C_6H_4.AsO(OH)_2$$

The principal aminoarylarsinic acids are given in the following scheme, where X is $AsO(OH)_2$. The list only contains acids with free amino-groups, N-acyl and N-alkyl derivatives, condensation products of these amino-acids being dealt with in separate sections.

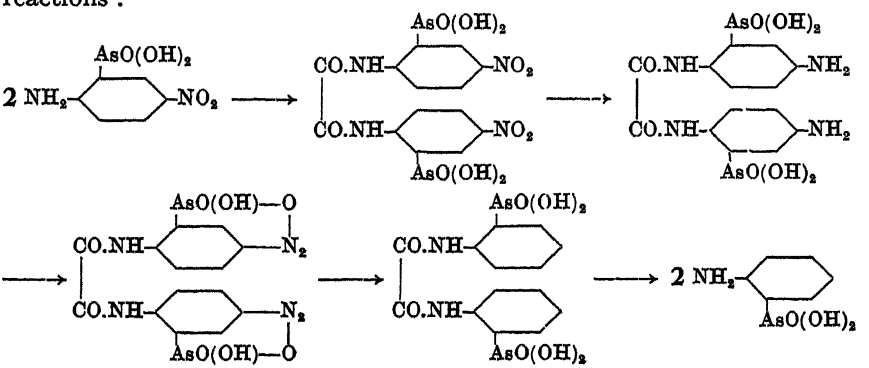


* May be Cl, Br, or I.

2-Aminophenylarsinic acid, o-Arsanilic acid,



This acid may be obtained from 2-nitrophenylarsinic acid by reduction with ferrous chloride or sulphate, an 80 per cent. yield resulting ; [1] or, reduction may be effected by 4 per cent. sodium amalgam and methyl alcohol.[2] It was originally synthesised by Benda [3] from 2-amino-5-nitrophenyl-1-arsinic acid by the following series of reactions : [4]



[1] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580 ; see Kalb, *Annalen*, 1921, 423, 39.
[2] Kashima, *J. Amer. Chem. Soc.*, 1925, 47, 2207.
[3] Benda, *Ber.*, 1911, 44, 3304.
[4] Compare Morgan, *Organic Compounds of Arsenic and Antimony* (Longmans).

The practical details involved in the carrying out of the foregoing scheme are as follows: 104 grams of 2-amino-5-nitrophenyl-1-arsinic acid and 200 grams of finely powdered oxalic acid are triturated with 40 c.c. of 10*N* sodium hydroxide. The mixture is then heated in an oil-bath, water being driven off at 110° to 130° C., and at 175° C. the mass finally solidifies. It is then stirred with 2400 c.c. of water, allowed to settle, filtered, and made into a paste.

Reduction.—A mixture containing 600 grams of iron powder, 40 c.c. of 50 per cent. acetic acid, and 500 c.c. of water, is heated to boiling and the paste added in small quantities. The heating is maintained and the mixture mechanically stirred for a period of two hours, then filtered. The solid residue is treated with hot 2*N* sodium hydroxide until a test portion of the filtrate on diazotising no longer couples with R-salt. The filtrate is then acidified with hydrochloric acid (test by Congo red), the precipitate filtered off, washed, and dried.

Diazotisation.—15 grams of the foregoing product are dissolved in 85 c.c. of 2*N* sodium hydroxide and 115 c.c. of water, and the solution mixed with 50 c.c. of normal sodium nitrite solution. When this mixture is poured into 560 c.c. of 2*N* sulphuric acid, the diazo compound separates as a grey mud. This is suspended in 375 c.c. of alcohol in the presence of 1·5 grams of copper powder and the whole warmed at 55° to 60° C. until the evolution of gas ceases and no further reaction occurs with R-salt. The liquor is filtered hot, and on cooling, the oxanilide diarsinic acid separates out as a sandy powder. It is purified by solution in 2*N* acetic acid, adding a little normal hydrochloric acid until flocks separate, then filtering rapidly and adding an excess of hydrochloric acid to the filtrate, when the compound separates in glistening silver plates.

Hydrolysis.—9 grams of the preceding compound are boiled with 360 c.c. of 2*N* sulphuric acid for several hours, when practically all goes into solution. The reaction is complete when 12 c.c. of the solution use up 11 c.c. of normal sodium nitrite when titrated. The solution is filtered and barium hydroxide added, the barium sulphate filtered off, the filtrate evaporated down on the water-bath and alcohol added, when the *barium salt* of *o*-arsanilic acid is precipitated in glistening crystals. These are filtered off, washed with alcohol, then with ether, and dried. The salt is made into a paste with a little water, and 2*N* sulphuric acid added until a test portion shows the absence of barium. The barium sulphate is removed and the filtrate evaporated to small bulk; when crystals appear a little charcoal is added and the whole boiled and filtered. On standing, the acid separates in needles, melting at about 153° C., very easily soluble in water, fairly soluble in acids and alkalis, alcohols, and acetic acid, sparingly soluble in ether. Ammoniacal solutions of the acid give a precipitate when heated with magnesia mixture. The *silver salt* shows a characteristic reaction. A neutral solution of the *sodium salt* with silver nitrate yields at once a white precipitate, which after a few seconds suddenly changes to glistening needles. An aqueous solution of the acid colours Congo red paper violet. When 1·1 grams of the acid in 10 c.c. of normal sodium hydroxide solution are heated at 80° to 85° C. with 2·59 grams of potassium iodide and 15 c.c. of 2*N* sulphuric acid, *o*-iodoaniline is obtained.

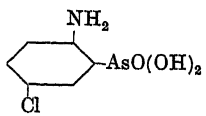
Acetyl-o-arsanilic acid.—*o*-Arsanilic acid may be acetylated by

warming on the water-bath with an excess of acetic anhydride, from which mixture the *acetyl derivative* separates.[1]

Benzylidene-o-arsanilic acid, $C_6H_5.CH{=}N.C_6H_4.AsO(OH)_2$, obtained from *o*-arsanilic acid, benzaldehyde and pyruvic acid, or the aldehyde in alcohol, melts with decomposition at 227° to 229° C.[2]

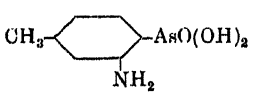
o-Ethylaminophenylarsinic acid, $NH(C_2H_5).C_6H_4.AsO(OH)_2$,[3] is obtained by the interaction of ethyl sulphate and *o*-aminophenylarsinic acid. It crystallises from water in colourless needles, M.pt. 128° to 129° C., and yields a *nitroso-derivative*, consisting of colourless needles, melting with decomposition at 160° C. The *acetyl derivative* melts at 187° to 188° C. A *silver salt* of the acid is known. Reduction of the acid or its acetyl derivative by sulphur dioxide in alcoholic hydrochloric acid in the presence of iodine causes elimination of the arsenic grouping from the molecule.

3-Chloro-6-aminophenylarsinic acid,[4]



This results when the corresponding nitro-acid is reduced by ferrous sulphate. It has also been prepared by the direct arsenation of *p*-chloroaniline, using arsenic acid, the details of the method being similar to those given for 2-amino-5-methylphenylarsinic acid (p. 204).[5] It crystallises from water in long, colourless, rectangular, anhydrous prisms, soluble in cold concentrated hydrochloric acid. The solution becomes bright red on diazotisation and treatment with sodium β-naphthoxide. The acid dissolves in 80 per cent. formic acid, but is sparingly soluble in glacial acetic acid or alcohol. From acetic acid it crystallises in clusters of needles, M.pt. 207° C., on rapid heating. The *calcium salt* forms rosettes of needles and the *barium salt* is amorphous. The *acetyl derivative* crystallises in long, colourless, rectangular prisms, and forms a microcrystalline *magnesium salt*. When the acid, dissolved in 2*N* sodium hydroxide, is heated with chloracetamide, the 6-*glycineamide* is produced, which crystallises in needles and melts with decomposition at 195° C. This yields a microcrystalline *magnesium salt* and a *calcium salt* crystallising in plates.

2-Amino-4-methylphenylarsinic acid,[6]

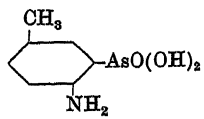


2-Nitro-4-methylphenylarsinic acid (14·5 grams) is reduced with 120 grams of ferrous sulphate and the acidified filtrate treated with barium chloride, the barium sulphate filtered off, the filtrate made slightly alkaline and concentrated *in vacuo*. The sodium chloride which separates is filtered off and the amino-acid precipitated by careful addition

[1] Wintersteiner and Lieb, *Ber.*, 1928, 61, [B], 1130.
[2] Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307.
[3] Burton and Gibson, *J. Chem. Soc.*, 1927, p. 2387.
[4] Balaban, *J. Chem. Soc.*, 1928, p. 812; see Benda, *Ber.*, 1909, 42, 3622.
[5] Benda, *loc. cit.*
[6] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

of hydrochloric acid. Yield, 10 grams. The product is purified by crystallisation from a little hot water, colourless needles, M.pt. 180° C., being deposited. The nitro-acid in methyl alcohol may also be reduced by 4 per cent. sodium amalgam, the resulting amino-acid decomposing at 185° C.[1] The acid is readily soluble in water, alcohols, and acetic acid, sparingly soluble in acetone and ether. Its solution in dilute hydrochloric acid when diazotised and coupled with R-salt forms a weak, orange-red dye.

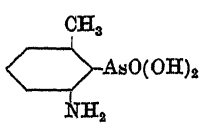
2-Amino-5-methylphenylarsinic acid,[2]



p-Toluidine (240 grams) is melted in a 1-litre flask, warmed to 60° or 70° C., and 60 grams of finely powdered arsenic acid introduced with vigorous shaking. A thick mass of toluidine arsenate results, which is placed in an oil-bath and raised to a temperature of 195° to 200° C. within half an hour. The contents of the flask darken and toluidine and water distil off. The hot melt is mixed with water and made alkaline with sodium hydroxide. Unchanged toluidine is removed by extraction with ether and arsenious and arsenic acids precipitated by the addition of barium hydroxide. The filtrate is saturated with sodium chloride, filtered several times, and the clear solution just neutralised with pure hydrochloric acid, using methyl orange as indicator, the arsinic acid separating in fine needles. After twenty-four hours the crystals are filtered off, washed with cold water, dried, and recrystallised from 50 per cent. alcohol.

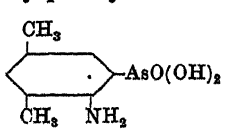
The acid crystallises in fine needles, M.pt. 176° C., sparingly soluble in cold water, readily soluble in hot water and alcohol, insoluble in benzene.

2-Amino-6-methylphenylarsinic acid,[3]



results when the corresponding nitro-acid is reduced. It crystallises in rosettes or plates, decomposing at 175° to 180° C., somewhat soluble in alcohols or glacial acetic acid, less soluble in acetone or water.

2-Amino-3 : 5-dimethylphenylarsinic acid,

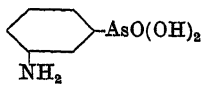


is obtained from *m*-xylidine and arsenic acid in the foregoing manner. It is a microcrystalline powder, melting at 199° to 200° C., soluble in alcohols, insoluble in benzene. When heated with potassium iodide and

[1] Maschmann, *Ber.*, 1924, 57, [B], 1759.
[2] Benda, *loc. cit.*
[3] Jacobs, Heidelberger, and Rolf, *loc. cit.*

2*N* sulphuric acid at 100° C. for thirty minutes it yields 5-iodo-4-amino-1 : 3-xylene.

3-Aminophenylarsinic acid, m-Arsanilic acid,



This acid is usually obtained by the reduction of *m*-nitrophenylarsinic acid, the process being conducted in a number of ways :

(1) *Reduction by means of ferrous sulphate.*—63 grams of the nitro-acid, when treated with 500 grams of ferrous sulphate, yield 47·5 grams of the amino-acid.[1]

(2) *Reduction with sodium amalgam.*[2]—30 grams of *m*-nitrophenyl-arsinic acid in 600 c.c. of methyl alcohol are treated with 840 grams of 4 per cent. sodium amalgam and warmed at 50° to 60° C. until the amalgam is exhausted, the operation requiring about twenty hours. The alcohol is removed and the residue dissolved in 2500 c.c. of water, the solution neutralised with acetic acid, and the zinc salt obtained by adding excess of zinc acetate. The process is carried forward from this stage as detailed below in method (3), the yield obtained being from 70 to 80 per cent.

(3) *Reduction by ammonium sulphide.*[3]—25 grams of *m*-nitro-phenylarsinic acid are dissolved in 140 c.c. of 25 per cent. ammonium hydroxide, the solution saturated with hydrogen sulphide and heated under reflux for twelve hours. A further 50 c.c. of ammonium hydroxide are then added, the liquor again saturated with hydrogen sulphide and heated, this process being repeated several times, after which the whole is evaporated to dryness. The residue is extracted with dilute hydro-chloric acid, the solution treated with 140 c.c. of 7*N* sodium hydroxide and heated to boiling. *N*/10 copper sulphate solution is then added until a test portion on boiling gives no lead sulphide when tested with lead acetate. The reactions taking place are as follows :

$$RAsS_2+2Cu(OH)_2=RAsO(OH)_2+2CuS+H_2O$$
$$RAsS\ +2Cu(OH)_2=RAsO(OH)_2+Cu_2S+H_2O$$

The copper sulphide is filtered off and zinc acetate added to the filtrate, the zinc salt of *m*-arsanilic acid separating out. After filtering and washing, this is boiled with 275 c.c. of water and 160 c.c. of 10 per cent. sodium carbonate solution, the zinc carbonate filtered off, and the solution nearly neutralised with concentrated hydrochloric acid. 13·5 c.c. of glacial acetic acid are added to acidify the solution, and the amino compound is precipitated as a faintly red, crystalline powder. Yield, 65 per cent. It may be purified by dissolving in dilute ammonium hydroxide, boiling with animal charcoal, and reprecipitating with acetic acid.

(4) The *m*-nitrophenylarsinic acid may also be reduced by *palladous oxide* in a hydrogen atmosphere.[4]

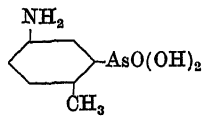
(5) The acid may also be prepared from *p*-phenylenediaminearsinic acid [5] by diazotising with 1 molecular equivalent of sodium nitrite and

[1] Jacobs, Heidelberger, and Rolf, *loc. cit.*
[2] Bertheim, *Ber.*, 1908, 41, 1655; Bertheim and Benda, *Ber.*, 1911, 44, 3297.
[3] Bertheim, *loc. cit.*; German Patent, 206344.
[4] German Patent, 286547. [5] Benda, *Ber.*, 1911, 44, 3300.

treating the solution with alcohol and copper powder, when *m*-arsanilic acid results. This is purified by diazotisation and coupling with alkaline β-naphthol, the red dyestuff obtained being reduced with sodium hydrosulphite.

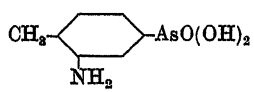
m-Aminophenylarsinic acid crystallises in colourless prisms, M.pt. 213° to 215° C., soluble in ammonia and alkalis, sparingly soluble in hot water. Its ammoniacal solutions give a white precipitate of the *magnesium salt* when treated with magnesia mixture. The acid may be diazotised and coupled to form azo dyes, and it couples with *p*-nitrodiazobenzene, but not with diazobenzene or diazotised sulphanilic acid.

5-Amino-2-methylphenylarsinic acid,



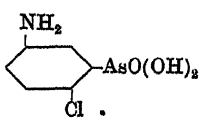
5-Nitro-2-methylphenylarsinic acid is dissolved in 100 c.c. of 10*N* sodium hydroxide and 200 c.c. of water, the solution heated to 80° C. and 86 grams of ferrous sulphate in 200 c.c. of water slowly added, the mixture being well stirred. After thirty minutes 500 c.c. of hot water are added, the whole filtered, and the residue washed with boiling water. The filtrate is evaporated to crystallising point and strongly acidified with concentrated hydrochloric acid (density 1·19). The mixture is left overnight in ice and the orange flocks which separate are then removed, the filtrate neutralised with 10*N* sodium hydroxide, and 6 c.c. of glacial acetic acid added. The arsinic acid separates as a yellow precipitate, crystallising from water in bushy needles, which begin to discolour at 200° C. and melt with decomposition at 235° to 236° C. The yield is about 8 grams, or 70 per cent. The acid is somewhat soluble in hot water, sparingly soluble in cold water.[1]

3-Amino-4-methylphenylarsinic acid,



This acid, prepared by reducing the corresponding nitro-acid, crystallises from a small volume of hot water in woolly masses of delicate, microscopic needles, which soften and melt at 172° to 175° C. It is somewhat soluble in water and dissolves readily in warm alcohols.

2-Chloro-5-aminophenylarsinic acid,[2]



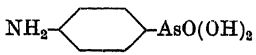
o-Chloroaniline is diazotised and treated with sodium arsenite in the usual manner, and the resulting product, *o*-chlorophenylarsinic acid, on being nitrated yields 2-chloro-5-nitrophenylarsinic acid. The latter (5·6 grams) is dissolved in 150 c.c. of water and 20 c.c. of 2*N* sodium

[1] Maschmann, *Ber.*, 1924, 57, [B], 1759; see Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

[2] German Patent, 286547.

hydroxide. To the solution 1·5 grams of reduced nickel are added and hydrogen passed in at 2 to 3 atmospheres pressure. After the absorption of about 440 c.c. of gas, the reduction is complete. The mixture is filtered and rendered faintly acid by the addition of about 30 c.c. of dilute hydrochloric acid. The required acid separates in white needles, sparingly soluble in water, readily soluble in alcohol. On heating it decomposes without melting.

4-Aminophenylarsinic acid or **p-Arsanilic acid,**



This acid has a special interest for two reasons: firstly, it was the first aromatic arsenical to be produced,[1] although it was not recognised as such at the time; secondly, its sodium salt, *Atoxyl*, has proved of great value in medicine. Consequently, many attempts have been made to prepare this arsinic acid, but none seem to have been very successful as far as the yield is concerned.[2] The following preparation is that due to Cheetham and Schmidt:[3]

47 grams of dry arsenic acid ($\frac{1}{3}$ mol.) are placed in a 300 c.c. Kjeldhal flask, 152 c.c. ($\frac{5}{3}$ mol.) of aniline (previously distilled over caustic alkali) added, and the mixture heated in a paraffin-bath for twelve hours at 150° to 160° C. At about 110° C. the mass solidifies, then slowly melts and remains liquid. After the heating the whole is poured into an 800 c.c. beaker and the flask rinsed out with 200 c.c. of hot water, the washings being added to the main solution. When the product has cooled to room temperature, 60 c.c. of 6*N* sodium hydroxide solution are vigorously stirred in, two layers of solution being obtained. The upper layer consists mainly of aniline; the lower layer, containing sodium arsanilate, is withdrawn. 15 to 20 grams of kieselguhr are added to this latter solution, which is filtered by suction, the kieselguhr removing the suspended aniline. To the filtrate, 50 c.c. of 6*N* hydrochloric acid are added, the arsanilic acid soon separating as a colourless, crystalline precipitate. It may be recrystallised from a little hot water, containing charcoal if necessary. Yield, about 26 per cent.

The acid has also been prepared by reducing *p*-nitrophenylarsinic acid with ferrous salt[4] or palladous oxide.[5]

It is known that *p*-arsanilic acid prepared by direct arsenation of aniline contains diphenylarsinic acid as impurity, and recently it has been pointed out that a fairly large quantity of *o*-arsanilic acid is present.[6] Unless this is removed, *Arsphenamine* obtained from arsanilic acid will also contain *o*-Arsphenamine, and, since little is known of this latter substance, its presence in the drug might be injurious. The following method is used to separate *o*- and *p*-arsanilic acids, being based on the fact that the *ortho*-compound has the greater solubility in water:[7] 100 grams of triturated technical arsanilic acid (84 per cent.) are stirred in a mixer with 900 c.c. of water for six hours at

[1] Béchamp, *Bull. Soc. chim.*, 1863, 5, 518.

[2] Benda and Kahn, *Ber.*, 1908, 41, 1672; German Patent, 15723 (1910); Fichter and Elkind, *Ber.*, 1916, 49, 239; Kober and Davis, *Proc. Soc. exp. Biol. Med., New York*, 1918, 16, 13; *J. Amer. Chem. Soc.*, 1919, 41, 451.

[3] Cheetham and Schmidt, *J. Amer. Chem. Soc.*, 1920, 42, 828.

[4] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

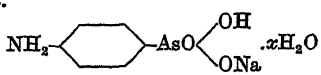
[5] German Patent, 286547. [6] Pozdnyakov, *J. Chem. Ind.* (Moscow), 1928, 5, 530.

[7] 100 grams of water at 16·5° C. dissolve 2·861 to 2·875 grams of *o*-arsanilic acid; 100 grams of water at 15·5° C. dissolve 0·390 gram of *p*-arsanilic acid.

15° to 17° C. The undissolved *p*-arsanilic acid is removed and the filtrate evaporated to 100 c.c. on a steam-bath. The *para*-acid separates on cooling and is removed; the filtrate is concentrated to 40 or 50 c.c. to precipitate the *o*-arsanilic acid.

The acid may be derived from atoxyl in the following manner:[1] Commercial atoxyl (155 grams) is dissolved by gentle heating in 600 c.c. of water and 65 c.c. of hydrochloric acid (density 1·12) added. After several hours, the precipitate is filtered off and washed with cold water until free from hydrochloric acid, then washed with alcohol and ether and dried in the air. The yield is quantitative. The acid thus obtained is readily soluble in methyl alcohol, sparingly soluble in ethyl alcohol and acetic acid, insoluble in ether, acetone, chloroform, and benzene. It shows feebly basic properties, and when evaporated to dryness with hydrochloric acid forms a hydrochloride, which does not give a clear solution in water and may be precipitated from its solution by alcohols.[2]

Sodium p-arsanilate, *Atoxyl.* Synonyms: *Soamin, Arsamin, Natrium, Arsanilicum.*



This salt is a white, crystalline powder, readily soluble in water, the solution having a neutral reaction. Its water content is variable, commercial samples containing from 3 to 5 molecules of water, although it may be obtained under suitable conditions with 2 and 6 molecules of water. It has been shown that solutions of atoxyl cannot be sterilised without some decomposition taking place.[3]

The measurements of crystals of *p*-aminophenylarsinic acid and its salts are as follows:

p-Aminophenylarsinic acid: Monoclinic; $a:b:c=1{\cdot}393499:1:1{\cdot}162276$; $\beta=101°\ 20'$.[4]

Sodium salt ($5H_2O$): Monoclinic; $a:b:c=2{\cdot}181215:1:0{\cdot}960163$; $\beta=91°\ 4'$.

Sodium salt ($4H_2O$): Monoclinic; $a:b:c=0{\cdot}986590:1:1{\cdot}251538$; $\beta=82°\ 30'$.[5]

Sodium salt ($?H_2O$): Monoclinic; $a:b:c=2{\cdot}481:1:0{\cdot}963$; $\beta=97°\ 40'$.[6]

Potassium salt, anhydrous: Orthorhombic; $a:b:c=0{\cdot}778011:1:0{\cdot}758124$; conchoidal fracture.[7]

Lithium salt, anhydrous: Monoclinic; $a:b:c=0{\cdot}944731:1:0{\cdot}830419$; $\beta=91°\ 16'$.

Ammonium salt ($2H_2O$): Orthorhombic; $a:b:c=1{\cdot}037944:1:0{\cdot}657969$; conchoidal fracture.

Mercuric p-arsanilate, $[NH_2.C_6H_4.AsO(OH)O]_2Hg$,[8] is prepared by triturating the arsanilic acid (2 mols.) with mercuric oxide (1 mol.).

[1] Ehrlich and Bertheim, *Ber.*, 1907, 40, 3292.

[2] For the condensation of the acid with arabinose, see German Patent, 433105, addition to 413147.

[3] Schmitz, *Ber.*, 1914, 47, 363.

[4] Gilta, *Bull. Soc. chim. Belg.*, 1923, 32, 19.

[5] Mélon, *Bull. Acad. roy. Belg.*, 1922, [v], 8, 150.

[6] Gilta, *Bull. Soc. chim. Belg.*, 1922, 31, 211.

[7] Gilta, *ibid.*, 1924, 33, 532.

[8] German Patent, 237787; British Patents, 8959, 24428 (1908); French Patent, 396192; American Patent, 938939.

By treating 1 molecular equivalent of the arsanilic acid with mercuric chloride (1 mol.) in the presence of alkali (2 mols.), a basic salt is produced, $NH_2.C_6H_4.AsO(OH).OHg.OH$. The mercuric salt goes under the name of *Asyphil*, and is sparingly soluble in water, but readily dissolves in sodium chloride solution.

The *quinine salt* of *p*-arsanilic acid forms white needles, M.pt. 202° C., and the *cinchonidine salt* small prisms, decomposing at 180° C., both compounds being soluble in alcohol.[1]

N-Acyl and N-Alkyl Derivatives of p-Arsanilic Acid.

Formyl-p-arsanilic acid, $HCO.NH.C_6H_4.AsO(OH)_2$,[2] results when dry atoxyl and excess of formic acid are boiled together for two hours. It crystallises from hot water or methyl alcohol in fine needles.

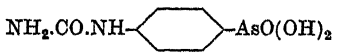
Acetyl-p-arsanilic acid may be prepared by the usual methods of acetylation,[3] or by diazotising *p*-aminoacetanilide and introducing the arsenic residue in the usual way.[4] It forms glistening, white plates from water, soluble in sodium carbonate solution, sparingly soluble in dilute hydrochloric acid. Its *sodium salt* commercially goes under the names of *Arsacetin* and *Acetylatoxyl*. This salt crystallises from methyl alcohol in needles,[5] and occurs associated with 3 to 5 molecules of water of crystallisation. *Oximinoacetyl-p-arsanilic acid* is also known.[6]

Chloracetyl-p-arsanilic acid is prepared by the interaction of chloracetyl chloride and *p*-arsanilic acid, whilst the corresponding *iodoacetyl* derivative (M.pt. 196° C.) and the *iodopropionyl* derivative (M.pt. 224° C.) are formed by treating sodium hydroxide solutions of the acid with the respective acid chloride.[7]

p-β-Carbamido-β-acetoxy-n-propylaminophenylarsinic acid, $NH_2.CO.C.CH_3(OAc).CH_2.NH.C_6H_4.AsO(OH)_2$,[8] is obtained by the interaction of sodium *p*-aminophenylarsinate and β-chloro-α-acetoxy-α-methylpropionamide, and subsequent acidification.

Butyryl, *malonyl*, and *phthalyl-p-arsanilic acids* are known.

Carbamino-p-arsanilic acid or **p-Carbaminophenylarsinic acid,**[9]



Sodium *p*-arsanilate (620 grams) is dissolved in 3600 c.c. of cold water and 480 grams of potassium cyanate dissolved in the solution. Glacial acetic acid (480 c.c.) is added and the whole allowed to stand at room temperature for twenty-four hours. 1560 c.c. of hydrochloric acid (density 1·124) are then added, when crystallisation takes place. After several hours the product is filtered off, washed free from hydrochloric

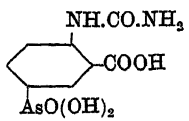
[1] German Patent, 203081.
[2] German Patent, 191548.
[3] Ehrlich and Bertheim, *Ber.*, 1907, 40, 3292.
[4] Schmidt, *Annalen*, 1920, 421, 159.
[5] German Patent, 250264.
[6] Karrer, Diechmann, and Haebler, *Helv. Chim. Acta*, 1924, 1, 1031.
[7] German Patent, 268983.
[8] French Patent, 543112, from *Chem. Zentr.*, 1924, ii. 1632.
[9] German Patent, 213155, addition to 191548; French Patent, 392857; British Patent, 17139 (1908); American Patent, 937929; see also French Patent, 401586.

acid and dried. The preparation has more recently been carried out [1] using the following reaction :

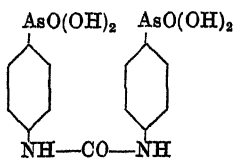
$$NH_2.C_6H_4.AsO(OH).ONa+CNBr+H_2O = NH_2.CO.NH.C_6H_4.AsO(OH)_2+NaBr$$

p-Arsanilic acid, 108 grams, is dissolved in 500 c.c. of water containing 20 grams of sodium hydroxide, and to this solution a freshly prepared suspension of 106 grams of cyanogen bromide in 300 c.c. of water is added. After standing overnight the mixture is acidified to Congo red by concentrated hydrochloric acid, the precipitate filtered off, dissolved in aqueous sodium hydroxide, the solution treated with charcoal, and the acid reprecipitated by hydrochloric acid. A yield of about 89 grams is obtained, the substance crystallising from hot water in glistening needles, sparingly soluble in organic solvents, readily soluble in caustic alkalis or alkali carbonate solutions, insoluble in dilute mineral acids. When heated with sodium hydroxide solution, ammonia is evolved, and the solution on acidification with acetic acid gives carbon dioxide and *p*-arsanilic acid.

If in the first method given in the foregoing [2] the potassium cyanate is replaced by the thiocyanate, *thiocarbamino-p-arsanilic acid* is formed. In a similar manner *methylcarbamino-* and *phenylcarbamino-p-arsanilic acids* are prepared, and using the methyl derivative of atoxyl in place of atoxyl itself, 2-*carbaminomethyl*-5-*arsinic acid* is isolated, the oxidation product of which is 2-*carbamino*-1 : 5-*benzarsinic acid*,



Sym.-Diphenylcarbamide-4 : 4′-diarsinic acid,[3]



p-Aminophenylarsinic acid, 4·3 grams, is neutralised with 10 c.c. of 2*N* sodium hydroxide solution, and 100 c.c. of half-saturated sodium acetate solution are added. The liquid is then treated with two successive portions each of 20 c.c. of a 12·5 per cent. solution of carbonyl chloride in toluene, the mixture being vigorously shaken. After thirty minutes the toluene is removed by extraction with ether and the aqueous layer made acid to Congo red paper. The free acid separates, and is freed from diazotisable matter by washing with *N*/2 hydrochloric acid. The diarsinic acid is very sparingly soluble in boiling 90 per cent. formic acid, from which it separates in microscopic needles.

Allylthiocarbamino-p-arsanilic acid, $C_3H_5.NH.CS.NH.C_6H_4.AsO(OH)_2$.[4]—*p*-Arsanilic acid in methyl alcohol solution is condensed with allylthiocarbimide, the resulting product melting with decomposi-

[1] Sticklings, *J. Chem. Soc.*, 1928, p. 3131. [2] German Patent, 213155.
[3] King and Murch, *Trans. Chem. Soc.*, 1924, 125, 2609; compare German Patents, 271548, 268983. [4] German Patent, 294632.

tion at 185° C. It is almost insoluble in water and alcohol, sparingly soluble in methyl alcohol. A similar *methyl compound* is derived from methyl-*p*-arsanilic acid, decomposing without melting at 170° C.

p - Sulphomethylaminophenylarsinic acid, $SO_3H.CH_2.NH.C_6H_4.AsO(OH)_2$,[1] is prepared from atoxyl by the action of formaldehyde and sodium bisulphite, addition of hydrochloric acid to the reaction mixture precipitating the free acid. It crystallises in needles, decomposing at 148° C.

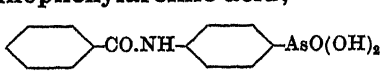
Benzenesulphonyl - p - arsanilic acid, $C_6H_5.SO_2.NH.C_6H_4.AsO(OH)_2$.—This acid may be obtained either from *p*-arsanilic acid and benzene sulphonic chloride by the Schotten-Baumann reaction,[2] or from benzenesulphonyl-*p*-aminophenylamine by Bart's reaction.[3] The sodium salt goes under the name of *Hectine* and the mercury salt is *Hectargyre*.

Benzylidene - p - arsanilic acid, $C_6H_5.CH{=}N.C_6H_4.AsO(OH)_2$, formed by the condensation of benzaldehyde and *p*-arsanilic acid, is a heavy, white, crystalline precipitate, M.pt. 225° C., with decomposition.[4] *p-Hydroxybenzylidene-p-arsanilic acid,* formed by using *p*-hydroxybenzaldehyde and conducting the condensation at 140° to 150° C., is a yellow, crystalline powder, sparingly soluble in the usual solvents. It dissolves in aqueous sodium carbonate, but is hydrolysed by concentrated sodium hydroxide. Similar compounds have been isolated using dimethyl-*p*-aminobenzaldehyde and resorcinyl aldehyde.[5]

Gluconyl - p - arsanilic acid, $CH_2.OH[CH.OH]_4.CO.NH.C_6H_4.AsO(OH)_2$,[6] is obtained by the condensation of gluconic acid and *p*-arsanilic acid in hot methyl alcohol solution. The product is slightly pink, sparingly soluble in cold methyl alcohol and insoluble in glacial acetic acid. It is readily hydrolysed by heating with dilute alkalis.

Oxalyl - p - aminophenylarsinic acid, $CO_2H.CO.NH.C_6H_4AsO(OH)_2$.[7]—A mixture of 347 grams of sodium *p*-arsanilate and 378 grams of crystallised oxalic acid are heated at a temperature of 120° to 130° C. until the bulk of the water is driven off, the temperature then being slowly raised to 160° C., until the mass becomes pulverulent. After cooling, it is mixed with 3000 c.c. of water, 390 c.c. of hydrochloric acid (density 1·12) are added and the mixture stirred for thirty minutes. The crude product is dissolved in 700 c.c. of cold water and 200 c.c. of 7*N* sodium hydroxide, the filtered solution being treated with 390 c.c. of hydrochloric acid (density 1·12) to precipitate the oxalyl derivative. The latter is a white powder, unmelted at 360° C., soluble in hot water, alkali hydroxide and carbonate, insoluble in acids and sparingly soluble in methyl alcohol.

Benzoyl-p-aminophenylarsinic acid,[8]

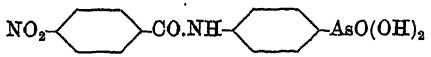


Benzoyl chloride (2 mols.) is slowly added to a vigorously stirred solution

[1] Abelin, *Biochem. Zeitsch.*, 1916, 78, 191.
[2] French Patent, 401586.
[3] English Patent, 142947 (1919).
[4] Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307.
[5] German Patent, 193542.
[6] Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1923, 45, 761.
[7] German Patents, 206057, 231969.
[8] German Patent, 191548; King and Murch, *Trans. Chem. Soc.*, 1924, 125, 2601; see Hamilton and Major, *J. Amer. Chem. Soc.*, 1925, 47, 1128.

of 25 grams of hydrated atoxyl in 250 c.c. of water and 150 c.c of 10 per cent. sodium hydroxide solution. The product obtained after acidification is dissolved in 2*N* ammonium hydroxide, magnesium chloride is added and the whole heated on the water-bath. The magnesium salt of the arsinic acid is then decomposed by acid, 21·2 grams of benzoyl-*p*-aminophenylarsinic acid being obtained. This acid crystallises from glacial acetic acid and from formic acid in small prisms. Its *ammonium salt* forms hydrated, long needles, containing 2 molecules of water, and is sparingly soluble.

p′-Nitrobenzoyl-p-aminophenylarsinic acid,



This compound is prepared in the foregoing manner, the benzoyl chloride being replaced by *p*-nitrobenzoyl chloride dissolved in benzene. It is sparingly soluble in boiling glacial acetic acid, more readily soluble in boiling formic acid, and separates in clusters of fine needles. In boiling alcohol it is much more soluble than the unsubstituted benzoyl-*p*-aminophenylarsinic acid. The *sodium* and *ammonium salts* crystallise in sparingly soluble needles. *m′-Nitrobenzoyl-p-aminophenylarsinic acid* crystallises in long needles, and *o′-nitrobenzoyl-p-aminophenylarsinic acid* in plates. These acids have a similar solubility to the *p′*-nitrobenzoyl compound.

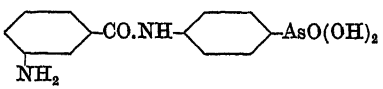
p′-Aminobenzoyl-p-aminophenylarsinic acid.—To a solution of 14·6 grams of the corresponding nitro-compound in 43 c.c. of 2*N* sodium hydroxide and 80 c.c. of water, cooled to 0° C., 28 grams of sodium hyposulphite are added in four portions, the temperature being kept below 2° C. The resulting solid is dissolved in *N*/2 ammonium hydroxide, the solution filtered, and the filtrate neutralised with concentrated hydrochloric acid. The precipitate is removed, ground with 100 c.c. of 40 per cent. sulphuric acid, filtered, and the residue extracted with 40 per cent. sulphuric acid until all diazotisable product is removed. The acid solution is then poured into water, the hydrolysed base collected and washed with 6 per cent. acetic acid until free from sulphate. Yield, about 70 per cent. The acid is a white powder, soluble in dilute ammonium hydroxide, giving a colourless solution. When isolated from *p′*-carbethoxyaminobenzoyl-*p*-aminophenylarsinic acid (see below) it is a purer product than when obtained from the nitro-compound. The product from the latter compound may give a yellow coloration in alkali, due to impurities. Whilst the acid dissolves readily in cold 90 per cent. formic acid, it is very sparingly soluble in boiling 25 per cent. formic acid or glacial acetic acid. It is feebly basic and forms the following crystalline salts: *Hydrochloride, hydrobromide, nitrate, sulphate, phosphate,* and *perchlorate.* Its *diazonium chloride* forms pale yellow needles, and couples with *β*-naphthol, giving a crimson-red, soluble azo-compound.

p′-Carbethoxyaminobenzoyl-p-aminophenylarsinic acid,

2·7 grams of *p*-aminophenylarsinic acid are dissolved in a mixture containing 25 c.c. of water, 6·5 c.c. of 2*N* sodium hydroxide, and 25 c.c. of saturated sodium acetate solution, the whole being made faintly alkaline to phenolphthalein by adding a further 3 c.c. of the sodium hydroxide solution. A solution of 2 molecular equivalents of *p*-carbethoxyamino-

benzoyl chloride in 50 c.c. of anhydrous ether is then added and the mixture shaken for thirty minutes, after which 29 c.c. of 2*N* sodium hydroxide are added and the shaking continued. This process is repeated until the phenolphthalein is no longer decolorised, about 37 c.c. of the sodium hydroxide solution being required. The ether is removed *in vacuo*, the solution made acid to Congo red paper, the precipitate dried and extracted with ether, when the arsinic acid is left behind in 50 per cent. yield. The acid is very sparingly soluble in the usual solvents, but crystallises from 90 per cent. formic acid in minute needles. Partial hydrolysis of the acid by sodium hydroxide gives an 80 per cent. yield of the sodium salt of *p'*-aminobenzoyl-*p*-aminophenylarsinic acid.

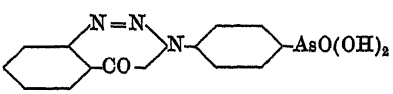
m'-Aminobenzoyl-p-aminophenylarsinic acid,



may be prepared by reduction of the corresponding nitro-compound with sodium hyposulphite or ferrous chloride. The latter is the only method of practical value, and is carried out as follows: 22 grams of the corresponding nitro-compound in 220 c.c. of 2*N* sodium hydroxide at 0° C. are treated with 73 grams of ferrous chloride (10 per cent. excess) in 100 c.c. of water, with vigorous stirring; then 250 c.c. of 2*N* sodium hydroxide solution are added, the temperature being maintained below 0° C. throughout the process. The ferric hydroxide is removed and extracted twice with 250 c.c. of 0·4*N* sodium hydroxide, the combined filtrates being made neutral to Congo red paper. The precipitated amino-acid is extracted with normal hydrochloric acid, then reprecipitated by adding saturated sodium acetate solution. Yield, 15·3 grams. The arsinic acid crystallises in minute, matted needles, readily soluble in dilute acids.

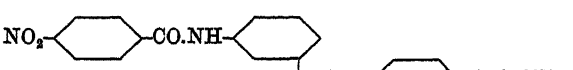
o'-Aminobenzoyl-p-aminophenylarsinic acid is obtained in a similar way to the preceding derivative, the nitro-compound being reduced with ferrous chloride. The acid crystallises in glistening leaflets, which are very sparingly soluble, and form a crystalline *hydrochloride*, *sulphate*, and *nitrate*.

1 : 2 : 3-Benztriazone-3-phenyl-p-arsinic acid,



This is formed in quantitative yield when *o'*-aminobenzoyl-*p*-aminophenylarsinic acid is diazotised in nitric acid solution. It crystallises in leaflets, insoluble in dilute acids, but crystallising from 90 per cent. formic acid in diamond-shaped plates.

p''-Nitrobenzoyl-m'-aminobenzoyl-p-aminophenylarsinic acid,



This is prepared in a similar manner to the nitrobenzoyl compounds (p. 212). It is soluble in 0·2*N* ammonium hydroxide, from which the *ammonium salt* crystallises in plates.

m″-Nitrobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid crystallises in plates from boiling 85 per cent. formic acid. Its *ammonium salt* is very soluble in water.

o″-Nitrobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid occurs in plates containing $1\frac{1}{2}$ or 2 molecules of water of crystallisation. It is very sparingly soluble in glacial acetic acid, and its *ammonium salt* separates in microscopic needles, sparingly soluble in water.

p″-Aminobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid.—The corresponding *p″*-nitrobenzoyl-compound, 9·7 grams, in 73 c.c. of 2*N* sodium hydroxide at −5° C., is slowly treated with 24 grams of ferrous chloride in 34 c.c. of water, then 83 c.c. of 2*N* sodium hydroxide are added. The ferric hydroxide is filtered off and extracted thrice with 83 c.c. of 0·4*N* sodium hydroxide. The combined filtrates are neutralised to Congo red paper, the solids collected, washed, made into a paste with water and added to 4000 c.c. of 2*N* nitric acid, which is vigorously stirred at 50° C. The solution is rapidly filtered, then refiltered after adding charcoal, the acidity to Congo red paper being removed by the addition of saturated sodium acetate solution. The amino-acid separates as a microcrystalline, white powder; yield, about 4·5 grams. It gives a series of insoluble, crystalline salts with mineral acids.

m″-Aminobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid crystallises in leaflets. The *sulphate* occurs in leaflets, and the *hydrochloride*, *nitrate*, and *ammonium salt* in needles.

o″-Aminobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid is deposited in fine needles when liberated from its dilute acid solutions by sodium acetate. Its salts crystallise in needles. When diazotised it is rapidly transformed into an insoluble product, which is probably 1 : 2 : 3-*benztriazone-3-m′-benzoyl-p-aminophenylarsinic acid.*

p″-Nitrobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid crystallises from 37 parts of boiling 90 per cent. formic acid in short needles.

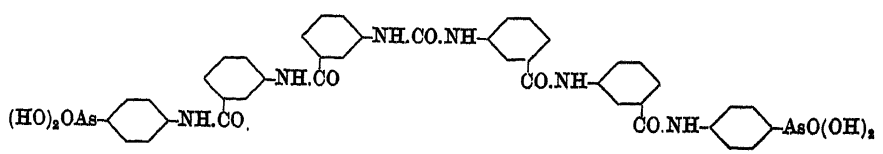
m″-Nitrobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid forms rhombic leaflets, from which a crystalline *ammonium salt* may be isolated.

o″-Nitrobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid is obtained in soft, glistening needles, and its *ammonium salt* crystallises from water in leaflets.

p″-Aminobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid is obtained in fine needles by the usual method of reduction of the nitro-compound. Its *sulphate* and *hydrochloride* form needles, and its *nitrate*, short rods.

m″-Aminobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid and **o″-aminobenzoyl-o′-aminobenzoyl-p-aminophenylarsinic acid** have also been obtained, and have similar properties to the preceding compound.

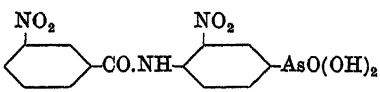
sym.-Carbamide of m″-Aminobenzoyl-m′-aminobenzoyl-p-aminophenylarsinic acid,



This carbamide is prepared as follows: To 3·55 grams of the corresponding amino-acid in 50 c.c. of water and 7·4 c.c. of 2*N* sodium hydroxide, 50 c.c. of saturated sodium acetate are added, the whole cooled to 0° C., and 40 c.c. of a 12·5 per cent. solution of carbonyl chloride in toluene added in 10 c.c. portions, with vigorous shaking, during a period of thirty minutes. The solution is made faintly acid to Congo red paper, the precipitate collected, washed with water and ether, then made into a thin paste, added to 1000 c.c. of normal nitric acid, and stirred at 50° C. After filtering, the acid is precipitated by the addition of saturated sodium acetate solution, and purified by dissolving in dilute ammonium hydroxide and adding charcoal. Filtration and acidification yield the carbamide (2·5 grams) as a gelatinous product which has marked colloidal properties.

The *sym.-carbamides* of the following arsinic acids have also been prepared: *m"-aminobenzoyl-o'-aminobenzoyl-p-aminophenylarsinic acid, o"-aminobenzoyl-m'-aminobenzoyl-p-aminophenylarsinic acid,* and *o"-aminobenzoyl-o'-aminobenzoyl-p-aminophenylarsinic acid.*

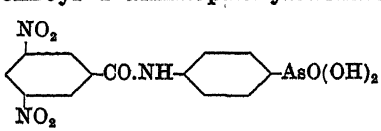
3'-Nitrobenzoyl-3-nitro-4-aminophenylarsinic acid,[1]



Benzoyl-*p*-aminophenylarsinic acid (19·3 grams) in 45 c.c. of sulphuric acid at 0° C. is treated with mixed acid, containing 8·5 c.c. of nitric acid (density 1·4) and 11·4 c.c. of sulphuric acid. The mixture is then poured upon ice, the precipitate air-dried and digested with 100 c.c. of glacial acetic acid. A crystalline product is obtained in 92 per cent. yield. The acid crystallises from 170 parts of boiling glacial acetic acid in fine, silky needles, containing 1 molecule of water of crystallisation. Its *sodium* and *potassium salts* are sparingly soluble. When hydrolysed by alkali it gives almost quantitative yields of *m*-nitrobenzoic acid and 3-nitro-4-aminophenylarsinic acid, but acid hydrolysis has little effect upon it.

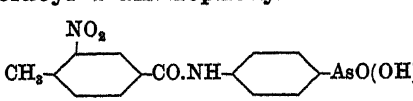
3'-Aminobenzoyl-3 : 4-diaminophenylarsinic acid is obtained from the preceding compound by reduction with ferrous chloride in alkaline solution, the temperature being maintained below 0° C. during the operation. It crystallises in clusters of leaflets.

3' : 5'-Dinitrobenzoyl-4-aminophenylarsinic acid,



This acid is obtained in 84 per cent. yield by the interaction of sodium *p*-aminophenylarsinate pentahydrate and 3 : 5-dinitrobenzoyl chloride at −3° C. It crystallises from 80 parts of boiling 90 per cent. formic acid in fine needles.

3'-Nitro-4'-toluoyl-4-aminophenylarsinic acid,

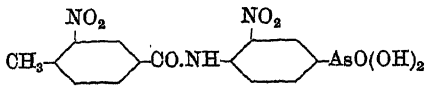


[1] King and Murch, *Trans. Chem. Soc.*, 1925, 127, 2632.

This acid, which is obtained in 55 per cent. yield, is sparingly soluble in boiling formic or acetic acid, and crystallises in small needles.

3′-Amino-4′-toluoyl-4-aminophenylarsinic acid occurs in fan-shaped clusters of small white needles. It yields the following salts: *hydrochloride*, small needles; *nitrate*, minute needles; *sulphate*, square plates.

3′-Nitro-4′-toluoyl-3-nitro-4-aminophenylarsinic acid,

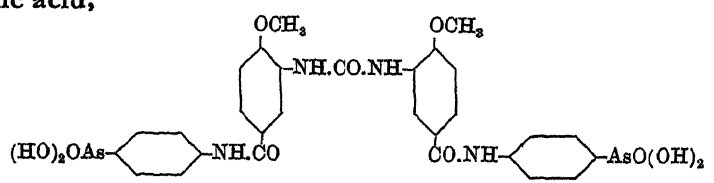


The preceding mononitro-acid is dissolved in sulphuric acid and nitrated at 0° C. by mixed acid. The resulting dinitro-acid crystallises in needles, which are sparingly soluble in boiling formic or acetic acid. Hydrolysis of the acid by normal sodium hydroxide yields 2-nitro-*p*-toluic acid and 3-nitro-4-aminophenylarsinic acid. Reduction of the dinitro-acid by ferrous chloride gives the corresponding *diamino-acid*, which separates in sphæro-crystals when liberated from the *magnesium salt* by adding saturated sodium acetate. When diazotised and coupled with alkaline β-naphthol, a brownish-red compound results.

3′-Nitro-4′-anisoyl-4-aminophenylarsinic acid results in 48 per cent. yield. It crystallises in woolly needles from boiling acetic acid. Reduction in the usual manner gives a 95 per cent. yield of the *amino-acid*, which forms the following salts: *hydrochloride*, wedge-shaped crystals; *sulphate*, sphæro-crystals; *nitrate*, woolly needles. The *acetyl derivative* is prepared by dissolving the amino-acid in normal sodium hydroxide and adding an excess of acetic anhydride. From dilute formic acid it separates in anisotropic sphæro-crystals.

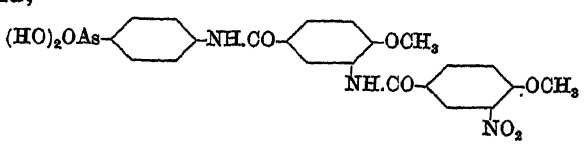
3′-Carbethoxyamino-4′-anisoyl-4-aminophenylarsinic acid is isolated by the interaction of the corresponding amino-acid and ethyl chloroformate in normal sodium hydroxide solution. It crystallises from boiling 90 per cent. formic acid in microscopic leaflets, which are practically insoluble in boiling acetic acid.

sym.-Carbamide of 3′-Amino-4′-anisoyl-4-aminophenylarsinic acid,



This crystallises in microscopic needles from boiling 90 per cent. formic acid.

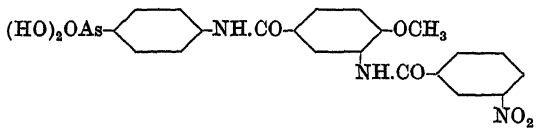
3″-Nitro-4″-anisoyl-3′-amino-4′-anisoyl-4-aminophenylarsinic acid,



3′-Amino-4′-anisoyl-4-aminophenylarsinic acid (7·3 grams) in 15 c.c. of 10 per cent. sodium hydroxide at −5° C. is treated with 8·3 grams of

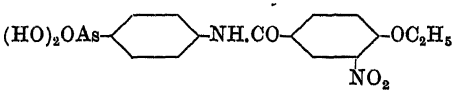
3-nitro-*p*-anisoyl chloride in 15 c.c. of toluene. After vigorous stirring for four and a half hours, the toluene is removed and the aqueous solution acidified, when the arsinic acid is precipitated. The latter is extracted with normal hydrochloric acid to remove any unchanged amino-acid, and dried. The product is then extracted with ether to remove nitroanisic acid, and reprecipitated from dilute ammonia. It separates from boiling glacial acetic acid in clusters of needles. Reduction of the acid in the usual way leads to the formation of the corresponding 3″-*amino-acid*, which has rather an indefinite crystalline form; it yields a *sulphate*, crystallising in microscopic needles, and a *nitrate*, forming balls of needles.

3″-Nitrobenzoyl-3′-amino-4′-anisoyl-4-aminophenylarsinic acid,



is obtained in a similar manner to the preceding nitro-acid, and crystallises from boiling acetic acid in pointed needles, or from 90 per cent. formic acid in square tablets.. The corresponding 3″-*aminobenzoyl acid* forms a *hydrochloride* crystallising in microscopic rods, a *sulphate* forming woolly needles, and a crystalline *nitrate*.

3′-Nitro-4′-ethoxybenzoyl-4-aminophenylarsinic acid,

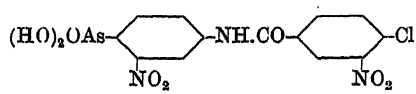


occurs in fine needles, and its *amino-derivative* in woolly needles, the latter giving a *hydrochloride*, forming small tablets, a *sulphate*, consisting of pointed prisms, and a *nitrate*, fine needles.

Nitration of the 3′-nitro acid yields a mixture of 3′-*nitro*-4′-*ethoxybenzoyl*-3-*nitro*-4-*aminophenylarsinic acid* and 3′ : 5′-*dinitro*-4′-*ethoxybenzoyl*-4-*aminophenylarsinic acid* in the ratio of 5 : 3 parts.

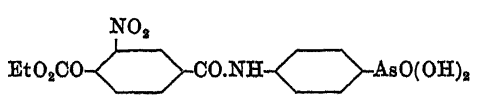
4′-Chloro-3′-nitrobenzoyl-4-aminophenylarsinic acid crystallises from boiling 90 per cent. formic acid in needles. The 3′-*amino-acid* separates in leaflets, and gives a crystalline *hydrochloride* and *sulphate*.

4′-Chloro-3′-nitrobenzoyl-3-nitro-4-aminophenylarsinic acid,



isolated by nitration of the corresponding mononitro-acid with mixed acid, crystallises in needles. The *diamino-acid* crystallises in rosettes of pointed plates.

3′-Nitro-4′-ethylcarbonatobenzoyl-4-aminophenylarsinic acid,



3-Nitro-4-ethylcarbonatobenzoic acid (25·5 grams) is shaken with 21·0 grams of phosphorus pentachloride, and after completion of the reaction

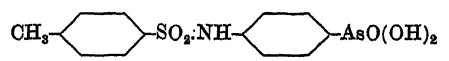
the phosphorus oxychloride is removed by warming *in vacuo*. The residue is crystallised in a freezing mixture; it consists of the nitro-ethylcarbonatobenzoyl chloride. This is added in three portions to 15·5 grams of sodium 4-aminophenylarsinate pentahydrate in 300 c.c. of half-saturated sodium acetate solution, the whole mixture being vigorously stirred. When the solution is made acid to Congo red paper, a solid is obtained, from which ether extraction gives 18·1 grams or an 80 per cent. yield of the 3′-nitro-acid. The latter crystallises from 90 per cent. formic acid in needles.

3′-Nitro-4′-hydroxybenzoyl-4-aminophenylarsinic acid.—When the preceding compound is heated with normal sodium hydroxide solution, the ethylcarbonato grouping is replaced by hydroxyl. The acid is primrose yellow, crystallising in long, silky needles from boiling 90 per cent. formic acid. Reduction of this nitro-acid may be brought about by sodium hyposulphite or by ferrous chloride, a 93 per cent. yield being obtained in the latter case. The *amino-acid* is readily soluble in warm normal mineral acids, and on being diazotised and coupled with alkaline β-naphthol produces a cherry-red colour. When reduced by hypophosphorous acid, the amino-acid gives an *arseno-compound.*

3′-Acetylamino-4′-acetoxylbenzoyl-4-aminophenylarsinic acid is produced by acetylation of the aminohydroxy-acid. It crystallises in fine, soft needles; which yield *3′-acetylamino-4′-hydroxybenzoyl-4-aminophenylarsinic acid* when treated with normal sodium hydroxide solution.

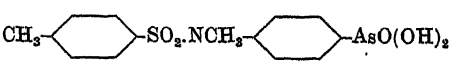
Arylsulphonamides of p-Aminophenylarsinic Acids.[1]

4′-Toluenesulphonyl-4-aminophenylarsinic acid,[2]



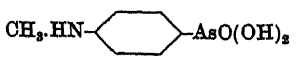
This acid is obtained in 74 per cent. yield by the arylsulphonylation of sodium *p*-aminophenylarsinate pentahydrate. It crystallises from water in microscopic rectangular plates, and from 90 per cent. formic acid in needles and diamond-shaped plates.

4′-Toluenesulphonyl-4-methylaminophenylarsinic acid,



One molecular equivalent of the preceding acid in 2*N* sodium hydroxide (2 mols.) is heated on the water-bath and methyl sulphate (16 mols.) and an equivalent quantity of 2*N* sodium hydroxide run in simultaneously, with vigorous stirring. The liquor reacts faintly alkaline throughout, and when acidified, a 90 per cent. yield of the methylated acid is obtained. It is readily soluble in boiling water and crystallises in needles, which are unstable and readily pass into large, hexagonal plates. From 90 per cent. formic acid, microscopic, rectangular plates are deposited.

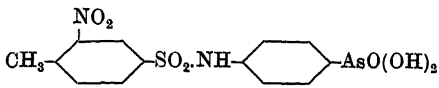
4-Methylaminophenylarsinic acid,



[1] Hewitt, King, and Murch, *Trans. Chem. Soc.*, 1926, p. 1360.
[2] See also Little, Cahen, and Morgan, *ibid.*, 1909, 95, 1482.

This acid is prepared from the foregoing acid by dissolving in 3·5 volumes of concentrated sulphuric acid at room temperature and pouring upon ice after thirty minutes. The yield is about 80 per cent.; the corresponding *nitroso-compound* separates in fine needles, which rapidly change to six-sided plates on dilution of the solution.

3′-Nitro-4′-toluenesulphonyl-4-aminophenylarsinic acid,



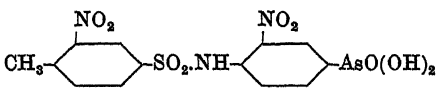
obtained in 77 per cent. yield from *m*-nitro-*p*-toluenesulphonyl chloride, crystallises from boiling water in minute, rectangular plates.

3′-Nitro-4′-toluenesulphonyl-4-methylaminophenylarsinic acid occurs in feathery crystals from hot water, hexagonal plates from alcohol, and diamond-shaped plates from 90 per cent. formic acid. It is obtained in 93 per cent. yield.

3′-Amino-4′-toluenesulphonyl-4-aminophenylarsinic acid is isolated when the corresponding nitro-acid is reduced with ferrous chloride and alkali. It crystallises in prismatic needles. The *hydrochloride* forms oblique rhomboids; a *magnesium salt* has been described. The corresponding oxide, formed by reducing the acid in hydrochloric acid solution with hydriodic acid, is a white powder, which on further reduction yields *3′-amino-4′-toluenesulphonyl-4-aminoarsenobenzene*, a pale cream or white powder.

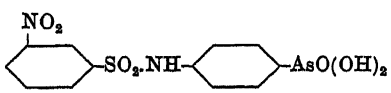
3′-Amino-4′-toluenesulphonyl-4-methylaminophenylarsinic acid crystallises from boiling water in clusters of thin plates. The *hydrochloride* crystallises in prisms, the *sulphate* and *nitrate* in fine needles.

3′-Nitro-4′-toluenesulphonyl-3-nitro-4-aminophenylarsinic acid,



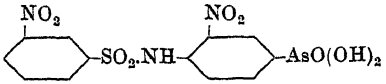
When the mononitro-acid is nitrated, using mixed acid, a 73 per cent. yield of this acid results. It crystallises from boiling water in very small needles, and from glacial acetic acid in bunches of small, prismatic needles. Reduction in the usual way yields the *diamino-acid*, which separates in small, rhomb-shaped plates. The diamino-acid may be reduced to the oxide.

3′-Nitrobenzenesulphonyl-4-aminophenylarsinic acid,



results when sodium *p*-aminophenylarsinate is treated with nitrobenzenesulphonyl chloride. The yield is 69 per cent., and the acid crystallises from 90 per cent. formic acid in short prisms. When reduced it yields the *amino-acid* in the form of narrow plates with sloping ends. The *hydrochloride* of the latter occurs as rhomb-shaped plates. When reduced by hypophosphorous acid in the usual way at 40° to 50° C., the amino-acid yields *3′-aminobenzenesulphonyl-4-aminoarsenobenzene*, a white, or creamy white, amorphous powder.

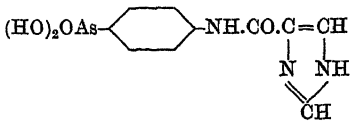
3′-Nitrobenzenesulphonyl-3-nitro-4-aminophenylarsinic acid,



crystallises from boiling water in short needles. The corresponding *diamino-acid* forms diamond-shaped plates.

Arsinic Acids containing the Glyoxaline Nucleus.

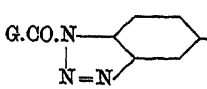
Glyoxaline-4′ (or 5′)-carboxy-p-aminophenylarsinic acid,[1]



Glyoxaline-4-carboxy-*p*-aminoanilide dihydrochloride (27·3 grams), in five batches, is dissolved in 150 c.c. of water and treated with 100 c.c. of 10 per cent. sodium nitrite solution at 0° C. To the diazotised solution 9·0 grams of arsenious oxide in 70 c.c. of 2*N* sodium hydroxide are added to produce slight alkalinity. After standing overnight the solution is warmed on the water-bath and filtered, the filtrate being fractionally precipitated by concentrated hydrochloric acid. From this operation 11·2 grams of crude arsinic acid are obtained (a 36 per cent. yield), which, after crystallisation from 75 per cent. acetic acid, yields pale yellow, glistening, triangular leaflets, darkening at 280° C. The product crystallises from 25 per cent. formic acid in needles consisting of a stable monohydrate. The *magnesium*, *calcium* and *sodium salts* have been isolated, also the *hydrochloride*.

Glyoxaline-4′ (or 5′)-carboxy-3-nitro-p-aminophenylarsinic acid.—The preceding acid (9·9 grams) in 30 c.c. of sulphuric acid at 0° C. is treated with 3 grams of nitric acid (density 1·42) in a few c.c. of sulphuric acid. When poured upon ice, 10·5 grams of crude product are obtained. It crystallises from 25 per cent. formic acid in clusters of yellow plates, melting at about 327° C., with decomposition. It forms a stable monohydrate, and the following salts, crystallising in needles, are known: *lithium*, *magnesium*, *calcium* and *barium salts*. Hydrolysis of the nitro-acid by normal sodium hydroxide gives an 86 per cent. theoretical yield of 3-nitro-4-aminophenylarsinic acid, and an 83 per cent. theoretical yield of glyoxalinecarboxylic acid.

Glyoxaline-4′ (or 5′)-carboxy-3-4-diaminophenylarsinic acid.—Reduction of the nitro-acid by ferrous chloride in the usual manner gives the amino-acid in 86 per cent. yield. It crystallises in fine, long, colourless prisms, containing half a molecule of water, and remaining unmelted at 320° C. When its hydrochloric acid solution is treated with sodium nitrite, a *diazoimide*, having the following constitution, is precipitated:

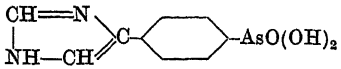


(G=glyoxalinyl)

This separates from dilute solutions in microscopic leaflets.

[1] Balaban and King, *Trans. Chem. Soc.*, 1925, 127, 2708.

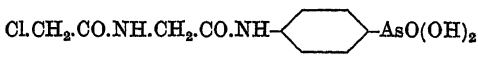
Glyoxaline-4′ (or 5′)-phenyl-p-arsinic acid,



Sodium nitrite solution is added to 10 grams of 4-*p*-aminophenylglyoxaline dihydrochloride at 0° C., and 6·6 grams of arsenious oxide in 36 c.c. of 2*N* sodium hydroxide subsequently added. When evolution of nitrogen ceases the mixture is warmed on the water-bath, filtered, and the solution made neutral to Congo red paper. After removal of amorphous material the liquor is concentrated, when 0·5 gram of the arsinic acid separates in reddish-yellow plates, unmelted at 310° C. It crystallises from glacial acetic acid in yellowish-brown prisms. The *magnesium* and *calcium salts* are insoluble, the *barium* and *lithium salts* soluble.

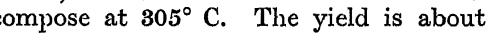
Derivatives of p-Arsanilic Acid resembling Polypeptides.[1]

Chloracetylglycyl-p-arsanilic acid,



Glycyl-*p*-arsanilic acid (8·1 grams) is dissolved in 60 c.c. of normal sodium hydroxide and diluted with 100 to 150 c.c. of water. To this solution 4 grams of chloracetyl chloride in 30 c.c. of ether are added alternately with 40 c.c. of normal sodium hydroxide, the mixture being well shaken and cooled after each addition and the additions being completed in about thirty minutes. The ether layer is then separated, filtered, and acidified. After standing in the ice-chest, the crystals which separate are washed with cold water until free from hydrochloric acid, and then recrystallised from hot water. Microscopic, bushy needles are obtained, which are insoluble in the usual organic solvents, and slowly decompose at 305° C. The yield is about 8·2 grams, or 80 per cent.

Carbethoxyglycyl-p-arsanilic acid,



is obtained in a similar manner from glycyl-*p*-arsanilic acid and ethyl chloroformate, the product decomposing at about 275° C. When hydrolysed with a slight excess of normal sodium hydroxide it yields *carboxyglycyl-p-arsanilic acid*, $HOOC.NH.CH_2.CO.NH.C_6H_4.AsO(OH)_2$, decomposing at 205° C.

By adopting similar methods to the foregoing, the following derivatives have been obtained: *p-Anisoylglycyl-p-arsanilic acid*, decomposing at 300° to 302° C.; *diglycyl-p-arsanilic acid*, decomposing at 275° to 280° C.; *chloracetyldiglycyl-p-arsanilic acid*, decomposing at 222° to 224° C.; *carbethoxydiglycyl-p-arsanilic acid*, decomposing at 295° to 299° C.; *carboxydiglycyl-p-arsanilic acid*; *triglycyl-p-arsanilic acid*, decomposing at 220° C.; *chloracetyltriglycyl-p-arsanilic acid*, decomposing at 286° to 289° C.; *carbethoxytriglycyl-p-arsanilic acid*, decomposing at 259° to 261° C.; *tetraglycyl-p-arsanilic acid*, decomposing at 222° to 224° C.; *α-bromopropionyl-p-arsanilic acid*, decom-

[1] Giemsa and Tropp, *Ber.*, 1926, 59, [B], 1776.

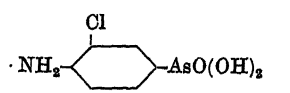
posing at 245° C.; *alanyl-p-arsanilic acid*, decomposing above 300° C.; *α-bromopropionylglycyl-p-arsanilic acid*, decomposing at 205° C.; *alanylglycyl-p-arsanilic acid*, decomposing above 300° C.; *α-bromoisohexoyl-p-arsanilic acid*, decomposing at 240° to 243° C.; *leucyl-p-arsanilic acid*, decomposing at 272° to 275° C.; *α-bromoisohexoylglycyl-p-arsanilic acid*, decomposing at 240° to 243° C.; *leucylglycyl-p-arsanilic acid* (*calcium salt*).

p-Dimethylaminophenylarsinic acid,

This acid has been isolated by several methods: (1) *p*-Dimethylaminophenylarsenoxide is suspended in water, treated with a slight excess of red mercuric oxide, heated for a short time, and filtered. The acid crystallises from the filtrate.[1] (2) *p*-Dimethylaminophenylarsenoxide (5 grams) is covered with 100 c.c. of water, 20 c.c. of 15 per cent. sodium hydroxide added, then 6 c.c. of 30 per cent. hydrogen peroxide. The acid is precipitated by the addition of acetic acid, the yield being about 5 grams.[2] (3) *p*-Aminophenylarsinic acid is heated with an excess of methyl sulphate, the product dissolved in warm water, treated with sodium hydroxide, and the acid precipitated by acetic acid. The yield in this case is small.[3] The acid does not melt, but blackens on heating, is sparingly soluble in water or cold alcohol, readily soluble in warm alcohol. The *sodium salt* crystallises in glistening plates containing 5 molecules of water. When the acid is nitrated it yields either *3-nitro-4-dimethylaminophenylarsinic acid* or a mixture of this with *4-methylnitrosoaminophenylarsinic acid*, according to the conditions of the process.[4] The 3-nitro acid on treatment with alkali and subsequent reduction yields *Salvarsan*.

Halogenated p-Arsanilic Acids.

5-Chloro-4-aminophenylarsinic acid,



was originally obtained by the interaction of arsenic acid and *o*-chloroaniline[5] and stated to form white crystals, M.pt. 305° C. It has since been obtained by the chlorination of acetyl-*p*-arsanilic acid by two methods:[6] (*a*) Into a suspension of 13 grams of acetyl-*p*-arsanilic acid (0·05 mol.) in 50 c.c. of glacial acetic acid, 7·1 grams of chlorine (0·1 mol.) are passed during one hour. After two hours' standing the solid is filtered off, washed with acetic acid, then with ether. By evaporation of the filtrate, 6·9 grams of the acetylchloroarsanilic acid are obtained, from which the acetyl group is removed by boiling under reflux for one hour with 21 c.c. of 7*N* sodium hydroxide and 42 c.c. of water. The filtered liquor is treated with 42 c.c. of hydrochloric acid (density 1·12), and after twelve hours the precipitate is filtered off, washed with water, and dried. The yield is about 4·5 grams, or

[1] Michaelis, *Annalen*, 1902, 320, 295.
[2] German Patent, 200065.
[3] Michaelis, *Ber.*, 1908, 41, 1514.
[4] British Patent, 22521 (1914).
[5] Benda and Kahn, *Ber.*, 1908, 41, 1672.
[6] Bertheim, *Ber.*, 1910, 43, 530.

36 per cent. of the theoretical. (*b*) 15·5 grams of acetyl-*p*-arsanilic acid (0·06 mol.), suspended in 180 c.c. of water and 36 c.c. of acetic acid, are treated with 126 c.c. of sodium hypochlorite solution (containing 8·52 grams=0·12 mol. of active chlorine), the mixture being vigorously stirred and cooled. The liquor is extracted with ether to remove unchanged acetyl compound and the clear aqueous liquor cooled in a freezing mixture, then treated with 63 c.c. of hydrochloric acid (density 1·12). After twenty-four hours, fine white needles of the *acetylchloroarsanilic acid* separate in 12·5 grams yield, or 71 per cent.

The chloroarsanilic acid crystallises in fine, white needles, stated to melt with decomposition at 240° C. It is sparingly soluble in hot water, aqueous mineral acids and acetic acid, readily soluble in alkalis or alcohols, insoluble in acetone or ether.

5-Bromo-4-aminophenylarsinic acid results when *p*-arsanilic acid is brominated in glacial acetic acid, using half the theoretical quantity of bromine :

$$2NH_2.C_6H_4.AsO(OH)_2+Br_2=NH_2.C_6H_3Br.AsO(OH)_2 + NH_2.C_6H_4.AsO(OH)_2.HBr$$

It crystallises in white needles, unchanged at 255° C.

5-Iodo-4-aminophenylarsinic acid.—*p*-Arsanilic acid is iodinated by iodine in methyl alcohol solution in the presence of mercuric oxide, 21·7 grams of the acid yielding 23·5 grams, or 68·5 per cent., of the iodo-compound. It crystallises from methyl alcohol in colourless needles on the addition of water, is sparingly soluble in hot water, soluble with difficulty in ethyl alcohol, readily soluble in methyl alcohol and in alkali. It is unchanged at 255° C., but strong heating decomposes it with blackening and liberation of iodine.

2-Chloro-4-dimethylaminophenylarsinic acid.[1]—*m*-Chlorodimethylaniline (155 grams) is heated with 186 grams of arsenious chloride for ten minutes on the water-bath, and the melt poured into 500 c.c. of water. Since some *2-chloro-4-dimethylaminophenylarsenoxide* separates out, 500 c.c. of 7*N* sodium hydroxide are added to effect solution and the liquid filtered, any unchanged *m*-chlorodimethylaniline being removed by shaking the filtrate with ether. If hydrochloric acid is added until the solution is only faintly alkaline, the oxide separates in white flocks. This is removed, washed with water and dried, a white powder being obtained, M.pt. 88° C., dissolving in chloroform, benzene, and dilute acids, but insoluble in alcohol and ether. The oxide is converted by concentrated hydrochloric acid into *2-chloro-4-dimethylaminophenyldichloroarsine*, M.pt. 116° C., soluble in acetone, alcohol, and water. Aqueous alkali transforms the arsine into the oxide. The oxide is converted into the acid by suspending 10 grams in 100 c.c. of water, adding 15 c.c. of 7*N* sodium hydroxide solution, followed by 50 c.c. of hydrogen peroxide (20 vols.). The arsinic acid is precipitated by acidifying with acetic acid. It is a white powder, unmelted at 300° C., soluble in hot alcohol, concentrated hydrochloric acid, glacial acetic acid, and aqueous alkali, insoluble in cold water and alcohol.[2]

Dichloro-p-arsanilic acid, $NH_2.C_6H_2Cl_2.AsO(OH)_2$, is produced by direct chlorination of *p*-arsanilic acid in glacial acetic acid. It crystallises in glistening needles. The corresponding *dibromo-compound*

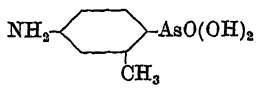
[1] German Patent, 286546.

[2] See American Patent, 1156045; German Patent, 286669.

is obtained from aqueous sodium hypobromite and *p*-arsanilic acid and crystallises in pale red needles. The *iodo-compound* results when a hot solution of the arsanilic acid, potassium iodate and dilute sulphuric acid is treated with 4 per cent. potassium iodide solution. Above 250° C. it commences to decompose, evolving iodine vapour.

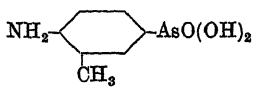
Homologues of p-Arsanilic Acid.

4-Amino-2-methylphenylarsinic acid,



This acid may be obtained either by the direct arsenation of *m*-toluidine at 170° to 190° C.,[1] or by reducing 4-nitro-2-methylphenylarsinic acid.[2] It crystallises from hot water in flat, microscopic needles and pointed prisms, which darken and decompose at 222° to 224° C. The *acetyl derivative* crystallises from water in prisms, which darken at 240° C., but are not completely decomposed at 350° C.

4-Amino-3-methylphenylarsinic acid,



o-Toluidine arsenate (250 grams) and 100 grams of *o*-toluidine, or 200 grams of *o*-toluidine with 140 grams of arsenic acid, are heated at about 200° C. until the greater part of the excess of *o*-toluidine is removed. The dark melt is extracted with an excess of sodium hydroxide solution, and the acid precipitated from the extract by acidification with hydrochloric acid.[3] The arsinic acid crystallises in needles or prisms, M.pt. 198° to 200° C., soluble in excess of dilute mineral acids, alkali or alkali carbonates, sparingly soluble in alcohol, insoluble in benzene and ether. The constitution of the acid is shown by boiling it with dilute sulphuric acid and potassium iodide, when a good yield of 5-iodo-*o*-toluidine results. When concentrated solutions of the sodium salt are mixed with 3 volumes of alcohol, tabular crystals separate, containing 3·5 molecules of water, but the *sodium salt*, when crystallised from water, contains 5 molecules of water of crystallisation. This salt is sold under the name of *Kharsin*. *Sodium 4-acetylamino-3-methylphenylarsinate* crystallises from 50 per cent. alcohol in glistening tabular crystals, containing 5 molecules of water, and from water with 7 molecules of water; it goes under the name of *Orsudan*. When the acetyl-compound is oxidised by alkaline permanganate the methyl group is converted to the carboxyl group.

The *oxalyl derivative* is formed by heating the sodium salt of the acid with oxalic acid, first at 140° C., then at 160° C. It crystallises from 50 per cent. acetic acid in elongated, rhombic prisms. When nitrated with mixed acid it is converted into 5-nitro-4-amino-3-methylphenylarsinic acid (p. 263).[4]

[1] Benda and Kahn, *Ber.*, 1908, 41, 1672; see German Patent, 219210.

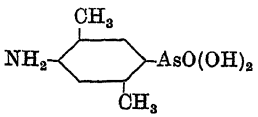
[2] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

[3] Adler and Adler, *Ber.*, 1908, 41, 931; see German Patent, 219210; English Patents, 855, 14937 (1908); American Patent, 913940; Pyman and Reynolds, *Trans. Chem. Soc.*, 1908, 93, 1180; Benda and Kahn, *Ber.*, 1908, 41, 1672.

[4] Fargher, *Trans. Chem. Soc.*, 1919, 115, 989.

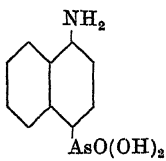
Condensation of the original acid with benzaldehyde in the presence of pyruvic acid yields 4-*benzalamino*-3-*methylphenylarsinic acid*, $C_6H_5CH.N.C_6H_3.CH_3.AsO(OH)_2$, a cream-coloured solid from alcohol, melting with decomposition at 202° to 205° C.; and condensation with *p*-chlorobenzaldehyde gives 4-(4′-*chlorobenzal*) *amino*-3-*methylphenylarsinic acid*, $Cl.C_6H_4CH.N.C_6H_3.CH_3.AsO(OH)_2$, a pale yellow powder from alcohol, M.pt. 255° to 260° C., with decomposition.[1]

4-Amino-2 : 5-dimethylphenylarsinic acid,



may be obtained by reduction of the corresponding nitro-acid,[2] or by the direct arsenation of *p*-xylidine.[3] It crystallises from water in six-sided plates containing 1 molecule of water; it melts at 210° C., or at 213° to 214° C. when anhydrous. The *acetyl derivative* separates from water in prisms, darkening at 240° C., and decomposing with frothing at 278° C.[4]

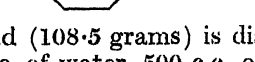
1-Aminonaphthyl-4-arsinic acid,



is best prepared by fusing α-naphthylamine arsenate or heating a mixture of α-naphthylamine and arsenic acid gradually to 175° C. The yield is greatly diminished if traces of moisture are present.[5] When an intimate mixture of equal parts of arsenic acid and α-naphthylamine is crystallised from hot water, *α-naphthylamine hydrogen arsenate*, $C_{10}H_7.NH_2.H_3AsO_4$, is produced, M.pt. 176° C. This arsenate, heated with four-ninths of its weight of α-naphthylamine at 200° C., soon changes to the arsinic acid, together with an amorphous, purple substance containing no arsenic.[6] The acid melts at 175° C., and crystallises in prisms, soluble in water and alcohol, insoluble in chloroform and petroleum.

Triazo- and Nitroso-phenylarsinic Acids and their Derivatives.

4-Triazophenylarsinic acid,[7]



p-Aminophenylarsinic acid (108·5 grams) is dissolved in 175 c.c. of 2*N* sulphuric acid and 500 c.c. of water, 500 c.c. of 2*N* sulphuric acid then

[1] Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307.
[2] Jacobs, Heidelberger, and Rolf, *ibid.*, 1918, 40, 1580.
[3] German Patent, 219210; see Benda and Kahn, *Ber.*, 1908, 41, 1672.
[4] *p*-Dimethylaminomethylphenylarsinic acid, $(CH_3)_2N.C_6H_4.CH_2.AsO(OH)_2$ (French Patent, 541612, from *Chem. Zentr.*, 1924, 95, ii. 1511), is prepared from *p*-aminodimethylbenzylamine by applying Bart's reaction.
[5] Andreev, *J. Russ. Phys. Chem. Soc.*, 1913, 45, 1980; see German Patent, 205775; Adler and Adler, *Ber.*, 1908, 41, 931; Benda and Kahn, *loc. cit.*
[6] Boon and Ogilvie, *Pharm. J.*, 1918, 101, 129. [7] Karrer, *Ber.*, 1913, 46, 249.

added, and the solution diazotised with 255 c.c. of 2*N* sodium nitrite solution, the mixture being cooled during the operation. 35 grams of sodium azide in 100 c.c. of water are added, nitrogen is evolved, and the triazo-compound separates as a pure white precipitate, which is filtered off, washed with cold water, alcohol, and ether, the yield being about 108 grams. It may be recrystallised from dilute alcohol or dilute sulphuric acid. The *monosodium salt* is a white powder, readily soluble in water, and obtained in white flocks when a hot alcoholic solution of the acid and sodium ethoxide (1 mol.) in alcohol are boiled together. For 3 : 5-dichloro-4-triazophenylarsinic acid, see p. 161.

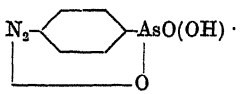
3-Iodo-4-triazophenylarsinic acid results when 3-iodo-4-aminophenylarsinic acid replaces *p*-aminophenylarsinic acid in the foregoing preparation. It is a white product, sparingly soluble in cold water, readily soluble in alkali and alcohols.

2-Nitro-3-triazophenylarsinic acid, obtained from 2-nitro-3-aminophenylarsinic acid, is a pale yellow, granular powder.

3-Nitro-4-triazophenylarsinic acid is a yellowish powder, losing nitrogen at 75° C., but may be heated in a sealed tube to 230° C. without decomposition.

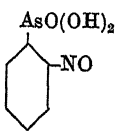
3-Nitro-4-triazophenylarsenoxide is prepared from 3-nitro-4-aminophenyldichloroarsine and not by reduction of the arsinic acid, since the triazo-group also undergoes reduction in the latter case. The oxide is a colourless powder, easily soluble in alkalis and alcohols.

Benzenediazonium-4-arsinate,[1]

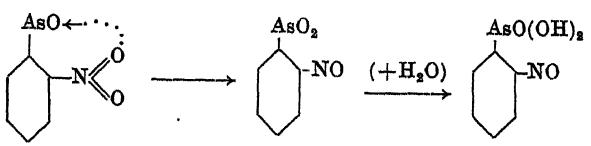


results when 311 grams of sodium *p*-aminophenylarsinate in 2500 c.c. of water and 520 c.c. of hydrochloric acid (density 1·12) are diazotised with 75 grams of sodium nitrite in 20 per cent. solution. It is precipitated as a white double salt by the aid of phosphotungstic acid. It couples with 2 : 4-tolylenediamine to give a dark red *azo dye*.

2-Nitrosophenylarsinic acid,[2]



When an ether solution of 2-nitrophenyldichloroarsine is exposed to sunlight, a yellowish-brown, crystalline deposit is obtained. 2-Nitrosophenylarsinic acid represents a constitution which fits in with the analysis of the product but not with its reactions. The formation is explained by the supposition that one oxygen atom of the nitro-group migrates to the arsenic residue, and in the presence of water the nitroso-acid is formed:

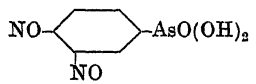


[1] German Patent, 205449.

[2] Karrer, *Ber.*, 1914, 47, 1783.

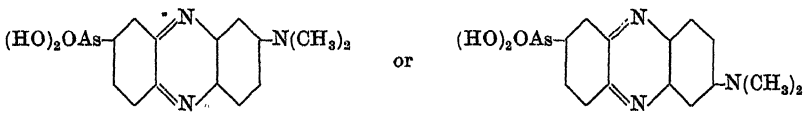
4-Nitrosophenylarsinic acid.[1]—10 grams of *atoxyl* are added to an ice-cold solution of neutralised permonosulphuric acid (200 c.c. $\equiv 1{\cdot}67$ O_2), and the whole treated with sodium carbonate until faintly alkaline. After thirty minutes the liquid is filtered and the filtrate acidified, when 3 to 3·5 grams (40 to 50 per cent.) of product separate. It is yellow and readily soluble in hot water, sparingly soluble in cold water, fairly soluble in alkali, alkali carbonates, and acetic acid. In alcohols, ether, chloroform, and pyridine, it is practically insoluble. It gives all the typical nitroso reactions, and when reduced by alkaline hydrosulphite yields 4 : 4′-diaminoarsenobenzene.

3 : 4-Dinitrosophenylarsinic acid,[2]



3-Nitro-4-triazophenylarsinic acid (5 grams) is heated at 75° C., when nitrogen is evolved and the mass solidifies. After one hour the product is dissolved in sodium carbonate, reprecipitated by hydrochloric acid and recrystallised from dilute alcohol.

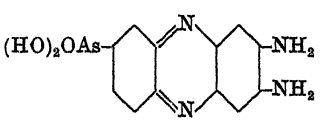
2 (or 3)-Dimethylaminophenazine-7-arsinic acid,



The preceding compound (5 grams) is warmed with 12 grams of dimethylaniline; a blue condensation product separates out. This is dissolved in 20 c.c. of hot acetic acid, the solution filtered and the filtrate treated with ether, when the required dye separates in blue flocks. If the dinitroso-compound is replaced by 3-nitro-4-triazophenylarsinic acid, the same product is obtained. The dye is very sparingly soluble in water, ether, and benzene, moderately soluble in sodium carbonate, readily soluble in alcohol, acetic acid, and sodium hydroxide.

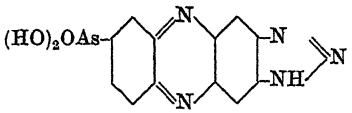
2 (or 3)-Dimethylaminophenazine-8-arsinic acid is obtained when 2-nitro-3-triazophenylarsinic acid is condensed with dimethylaniline. The dye has a reddish colour, is soluble in alcohol and acetic acid, insoluble in sodium carbonate.

2 : 3-Diaminophenazine-7-arsinic acid,



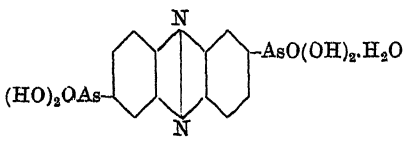
This acid is the condensation product of 3-nitro-4-triazophenylarsinic acid and *o*-phenylenediamine in warm acetic acid solution. It is a brick-red powder, readily soluble in dilute acetic acid and dilute hydrochloric acid, sparingly soluble in alcohol and insoluble in alkali. When boiled with acetic anhydride it yields a *diacetyl derivative*, an alkali-soluble, yellowish-brown powder. Treatment with nitrous acid gives the *azimido compound*,

[1] Karrer, *Ber.*, 1912, 45, 2065; German Patent, 256963.
[2] Karrer, *Ber.*, 1913, 46, 248.

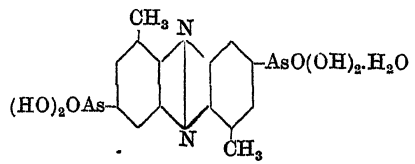


a brown powder, insoluble in alkali.

Phenazine-2 : 7-bis-arsinic acid (I) ; **4 : 9-Dimethylphenazine-2 : 7-bis-arsinic acid** (II) :



I



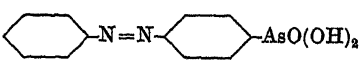
II

Phenazine-2 : 7-*bis*-arsinic acid (I) [1] is prepared as follows : *p*-Aminophenylarsinic acid (20 grams), suspended in 100 c.c. of water, is dissolved by the addition of 15 c.c. of concentrated sulphuric acid. To the warm solution, 23 grams of finely powdered ammonium persulphate are added in small quantities during one hour, and the mixture well stirred. The light brown liquor is then gently heated on the water-bath, when it darkens and leafy crystals are deposited. When the reaction is complete the liquor is cooled for ninety minutes and the crystals collected. The yield is about 35 per cent. The product may be purified by means of the sodium salt. It does not melt below 300° C., is sparingly soluble in alcohol and acetic acid, insoluble in water and the usual organic solvents. With concentrated sulphuric acid it gives a blood-red coloration. It crystallises with 1 molecule of water, which is not lost at 120° C., but it loses 2 molecules of water at 150° C., forming an *internal anhydride*. The *tetrasodium salt* is a buff-coloured, crystalline powder, containing 11 molecules of water, and soluble in one and a half times its weight of water, but insoluble in alcohol.

The dimethyl acid (II) is formed by oxidising 2-aminotolyl-5-arsinic acid as described in the foregoing. It is a buff powder, unmelted at 300° C., and has similar properties to the preceding compound.[2]

Azo-Compounds.

Azobenzene-4-arsinic acid,[3]



p-Nitrosophenylarsinic acid (4·6 grams) and 1·83 grams of aniline in 50 c.c. of acetic acid are boiled under reflux for ninety minutes. On cooling and adding ether, the azo-compound separates as a brown, amorphous powder, readily soluble in alkali, alkali carbonates, and ammonium hydroxide, sparingly soluble in water and dilute acids.

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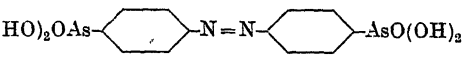
[1] Barrowcliff, Pyman, and Remfry, *Trans. Chem. Soc.*, 1908, 93, 1893.

[2] When 3 : 6-diamino-10-methylacridinium chloride is diazotised and treated with sodium arsenite, a reddish-brown powder results, which may be an arsenical acridine compound—American Patent, 1408974.

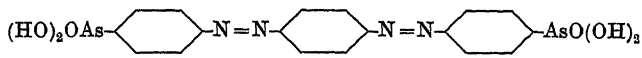
[3] Karrer, *Ber.*, 1912, 45, 2359.

Azobenzene-4 : 4′-diarsinic acid,



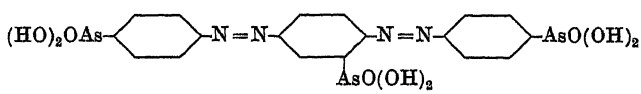
is the condensation product of *p*-nitrosophenylarsinic acid and *p*-aminophenylarsinic acid in boiling acetic acid solution. It is a dark brown powder, giving yellowish-green solutions in alkali. It is sparingly soluble in cold water, dilute mineral acids, and the usual organic solvents, moderately soluble in hot water and acetic acid. In concentrated mineral acids its solutions are purple-red.

Disazobenzene-4 : 4′-diarsinic acid,



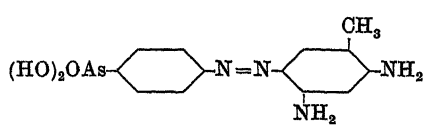
This is obtained by condensing *p*-nitrosophenylarsinic acid with *p*-phenylenediamine. It is a black powder, having a metallic reflex; it gives reddish-brown solutions in alkali and red solutions in concentrated mineral acids.

Disazobenzene-triarsinic acid,



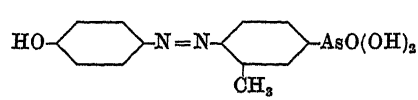
results when the *p*-phenylenediamine in the preceding condensation is replaced by *p*-phenylenediamine arsinic acid. It is a black powder, having a dark green reflex, and gives dark brown solutions in alkali, purple-red in concentrated mineral acids.

Benzeneazo-2 : 4-tolylenediamino-4′-arsinic acid,[1]



This is prepared either by condensing *p*-nitrosophenylarsinic acid with *m*-tolylenediamine and hydroxylamine in alkaline solution, or by coupling *p*-diazobenzenearsinic acid with *m*-tolylenediamine. The product is dark red.

4-Hydroxy-2′-benzeneazotoluene-5′-arsinic acid,[2]

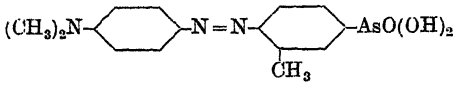


is isolated when diazotised 2-aminotolyl-5-arsinic acid is coupled with phenol. It is a light red, crystalline powder, readily soluble in alkalis but very sparingly soluble in boiling water and the usual organic solvents. The *monosodium salt* crystallises from water in red leaflets containing $2\frac{1}{2}$ molecules of water, and the *disodium salt* is a red powder containing $4\frac{1}{2}$ molecules of water.

[1] See German Patent, 205449; English Patent, 3929 (1907).

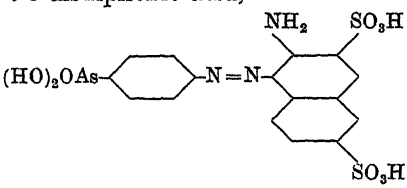
[2] Barrowcliff, Pyman, and Remfry, *Trans. Chem. Soc.*, 1908, 93, 1893.

4-Dimethylamino-2′-benzeneazotoluene-5′-arsinic acid,

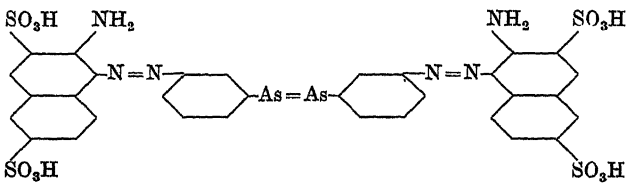


To produce this acid, the phenol in the preceding preparation is replaced by dimethylaniline, and the coupling conducted in acid solution. The *monosodium salt* is a red crystalline powder containing 5 molecules of water, and the *disodium salt* a red powder containing 4 molecules of water.

Azo-dyes containing the arsinic acid or arsenoxide group can be reduced by hypophosphorous acid without affecting the azo-group, as in the following cases: [1] (1) The dye obtained by coupling diazotised 3-amino-4-hydroxyphenylarsinic acid with phloroglucinol gives a red dye when boiled with 35 per cent. hypophosphorous acid. (2) Under the same treatment the dye formed from *m*-aminophenylarsinic acid and 2-naphthylamine-3 : 6-disulphonic acid,



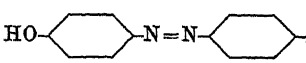
yields



which is a brown powder, soluble in alkali. (3) The dye from diazoatoxyl and 1-amino-8-naphthol-3 : 6-disulphonic acid gives on reduction a dark, metallic, glistening powder, forming violet solutions in alkalis.

Many azo-dyes have been prepared from *p*-aminophenylarsinic acid by diazotisation and coupling with phenols; for example, with alkaline β-naphthol,[2] a red powder is formed; with β-naphthol-3 : 6-disulphonic acid (R salt), a red powder is given; 8-amino-α-naphthol-3 : 6-disulphonic acid (H acid) gives a blackish-brown powder; naphthionic acid also gives a blackish-brown powder.[3]

4-Hydroxyazobenzene-4′-arsinic acid,[4]



is the product of coupling phenol with diazotised *p*-aminophenylarsinic acid. It is a light red powder, insoluble in water and the usual organic media, but gives deep red solutions in alkalis. The *monosodium salt* contains 2½ molecules of water, and crystallises in glistening yellow

[1] German Patent, 271271; English Patent, 2090 (1914).

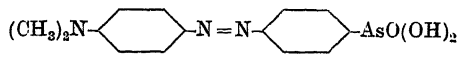
[2] German Patent, 212018; see Barrowcliff, Pyman, and Remfry, *Trans. Chem. Soc.*, 1908, 93, 1899; compare Noelting, *Bull. Soc. chim.*, 1916, [iv.], 19, 341.

[3] See German Patent, 216223.

[4] Barrowcliff, Pyman, and Remfry, *loc. cit.*

plates, almost insoluble in water. The *disodium salt* contains 8 molecules of water and is a red, water-soluble powder.

4-Dimethylaminoazobenzene-4′-arsinic acid,



results when the coupler is dimethylaniline. It is a red powder, having a similar solubility to the preceding compound. The *monosodium salt* forms glistening scarlet plates from hot water, which contain 5½ molecules of water; the *disodium* salt contains 6 molecules of water.

A number of azo-dyes have been prepared recently,[1] and these are given in Table III. of the Appendix; diazoamino derivatives of *p*-aminophenylarsinic acid are given in Table IV. Derivatives obtained from diazotised arsanilic acid and hydroxy- and amino-quinolines are given in Table V.[2]

Azo-dyes may also be obtained by coupling diazotised 3 : 5-dinitro-4-aminophenylarsinic acid with *p*-nitroaniline, diazotised aniline with the hydrochloride of 3 : 5 : 3′ : 5′-tetramino-4 : 4′-dihydroxyarsenobenzene, and diazotised sulphanilic acid with 3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene hydrochloride.[3] When atoxyl is diazotised and 1-benzyldihydroberberine in 50 per cent. acetic acid slowly added, the mixture on saturation with ammonia yields *4-p-arsinobenzeneazo-1-benzyldihydroberberine*, $CH_2.C_6H_5.C_{20}H_{17}O_4N.N{=}N.C_6H_4.AsO(OH)_2$.[4]

Polyazo-dyes.[5]—Examples of these are obtained as follows:

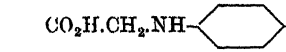
(1) Diazotised benzidine is coupled with 8-amino-α-naphthol-3 : 6-disulphonic acid (H acid) in acid solution and the resulting dyestuff in sodium carbonate solution added to diazotised *p*-aminophenylarsinic acid. The resulting *trisazo-dyestuff* is a brownish-black powder, soluble in water, giving a blue solution, which dyes cotton directly in blue tones.

(2) The foregoing trisazo-dyestuff may be again treated with diazotised *p*-aminophenylarsinic acid, yielding a *tetrakisazo-dyestuff*, which is a brownish-black powder, giving a dark blue solution in water, which dyes cotton directly in dark blue shades.

(3) Diazotised *p*-aminophenylarsinic acid is coupled with H acid in alkaline solution and the brownish-violet product cooled and stirred with diazotised dichlorobenzidine, The resultant dyestuff is a glistening dark brown powder, giving a deep blue solution in water. In place of benzidine or dichlorobenzidine the following may be used: tolidine, dianisidine, or diaminophenyl urea. Instead of H acid, 2-amino-5-naphthol-7-sulphonic acid (J acid), 1 : 8-aminonaphthol-4-sulphonic acid (S acid) or 1 : 8-dihydroxynaphthalene-3 : 6-disulphonic acid (chromotrope acid) may be employed.

Arylglycinearsinic Acids and Derivatives.

Phenylglycine-p-arsinic acid or **Phenyl-(4-arsinic acid) glycine,**[6]



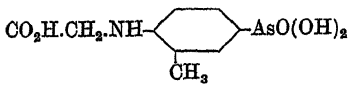
[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1921, 43, 1646.
[2] Berlingozzi, *Annali Chim. Appl.*, 1928, 18, 31, 333.
[3] German Patent, 278421.
[4] Freund and Fleischer, *Annalen*, 1916, 411, 1.
[5] German Patents, 212304, 222063.
[6] German Patent, 204664.

This acid may be prepared in two ways: (1) Sodium *p*-aminophenylarsinate, 27·5 parts, is dissolved in 80 parts of hot water, a solution of 16 parts of monochloracetic acid in 20 parts of water added, and the whole heated under reflux for six to eight hours. The glycine derivative which crystallises on cooling is removed and washed with dilute hydrochloric acid.

(2) *p*-Aminophenylarsinic acid (7 parts), 2 parts of sodium cyanide, and 2·2 parts of 40 per cent. formalin solution are dissolved in 35 parts of water and the solution heated in an autoclave at 100° C. for one to two hours. On cooling, and neutralising with dilute hydrochloric acid, the *nitrile*, $CN.CH_2.NH.C_6H_4.AsO(OH)_2$, separates. This is boiled with sodium hydroxide solution, and subsequent acidification with dilute hydrochloric acid precipitates phenylglycine-*p*-arsinic acid. This acid is readily soluble in hot water, alkalis, alkali acetates, and concentrated hydrochloric acid.

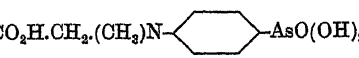
Derivatives are obtained in a similar manner from *2-aminotolyl-5-arsinic acid*, *5-aminotolyl-2-arsinic acid* and *2-amino-p-xylyl-5-arsinic acid*.

o-Tolylglycine-p-arsinic acid,



melts with decomposition at 220° C., and has similar properties to the preceding phenyl compound.

Phenylmethylglycine-p-arsinic acid,[1]



is obtained by hydrolysing its propyl or amyl ester. It is a white, crystalline powder, which decomposes at a high temperature, evolving carbon dioxide and forming *p*-dimethylaminophenylarsinic acid.

According to Öchslin [2] it decomposes at 180° C., and when warmed for three hours at 50° to 55° C. with normal sodium hydroxide and sodium hydrosulphite it is converted into *arsenophenylmethylglycine*, $[C_6H_4.N(CH_3).CH_2.CO_2H]_2As_2$ (p. 359).

The *amyl ester* of the acid is prepared as follows: 150 grams of arsenious chloride, 200 grams of amyl phenylmethylaminoacetate, and 70 grams of pyridine are heated for two and a half hours at 100° to 112° C., and the product whilst still liquid is poured upon ice. An oil separates, which is washed with water, dissolved in ether, and the solution shaken with sodium carbonate solution and some hydrogen peroxide. The *amyl ester* of *phenylmethylglycinearsenoxide*, $AsO.C_6H_4.N(CH_3).CH_2.CO_2.C_5H_{11}$, crystallises out; it melts at 133° to 134° C. Addition of hydrochloric acid to a sodium carbonate solution of the oxide causes the separation of an oil, which slowly crystallises. This is a mixture of the *amyl ester* of *phenylmethylglycinearsinic acid*, $(HO)_2OAs.C_6H_4.N(CH_3).CH_2.CO_2.C_5H_{11}$, M.pt. 118° C., and the *ester* of *diphenylmethylglycinearsinic acid*, $(HO)OAs[C_6H_4.N(CH_3).CH_2.CO_2.C_5H_{11}]_2$. The mixture is separated by the action of warm acetic acid.

Saponification of the foregoing ester yields *diphenylmethylglycinearsinic acid*, melting with decomposition at 180° to 190° C. In a similar

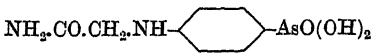
[1] French Patents, 462276, 450214. [2] Öchslin, *Ann. Chim.*, 1914, [ix.], 1, 239.

manner the following derivatives may be isolated: *Ethyl* and *propyl esters* of *phenylmethylglycinearsinic acid*, M.pt. 169° C. and 154° C. respectively, and the *amyl ester* of the corresponding *di-o-tolyl acid*, M.pt. 107° C.

Phenylethylglycinearsinic acid decomposes at 178° C., and *phenylamylglycinearsinic acid* at 180° C.

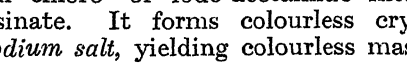
A series of aminoarsinic acids may be obtained by the condensation of α-halogenacylamides of the composition $X.CHR.CO.NR_1R_2$ (where X=halogen, R=alkyl, aryl, or hydrogen, R_1, R_2=alkyl, aryl, substituted aryl, or hydrogen) with *p*-aminophenylarsinic acid, its homologues, substituted derivatives or salts of these acids.[1]

Phenylglycylamido-p-arsinic acid, *Tryparsamide,*



is obtained when chloro- or iodo-acetamide interacts with sodium *p*-aminophenylarsinate. It forms colourless crystals, M.pt. above 280° C., and a *sodium salt*, yielding colourless masses of crystals (see p. 234).

Phenylglycylcarbamido-p-arsinic acid,



is prepared by treating an alkaline solution of *p*-aminophenylarsinic acid with chloracetylcarbamide. When hydrolysed it gives phenylglycine-*p*-arsinic acid. If α-chloracetylmethylcarbamide is used in the preparation, *phenylglycylmethylcarbamido-p-arsinic acid* is formed, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CO.NH.CH_3$, consisting of colourless crystals, M.pt. 232° C.

Phenylglycylanilino-p-arsinic acid, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.C_6H_5$, is obtained as a crystalline mass when iodoacetanilide is used in the preceding preparation.

Phenylglycyl-m′-aminophenol-p-arsinic acid, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.C_6H_4.OH$, is prepared from 3N-chloracetylamino-1-hydroxybenzene and *p*-aminophenylarsinic acid. It crystallises in small plates, M.pt. above 200° C. When reduced by hypophosphorous acid and hydriodic acid[2] it gives the corresponding *arseno-compound*, a yellow powder, M.pt. 180° to 190° C., the *dihydrochloride* of which forms a yellow powder, M.pt. about 130° C. If, however, the acid is reduced with sulphur dioxide and hydriodic acid, it yields *phenylglycyl-m′-aminophenol-p-arsenoxide*, a white powder, softening at 130° C. and melting above 200° C. In a similar manner, *phenylglycylanthranilic acid-p-arsenoxide*, $AsO.C_6H_4.NH.CH_2.CO.NH.C_6H_4.CO_2H$, is obtained.

Alkylamides of N-Arylglycinearsinic Acids.[3]

These compounds are obtained by the condensation of sodium *p*-aminophenylarsinate or similar substances with the amide or alkyl amides of chloracetic acid. The general formula for these derivatives is:

$$AsO(OH)_2.C_6H_4.NH.CH_2.CO.NRR',$$

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[1] Dutch Patent, 6581; from *Chem. Zentr.*, 1922, ii. 873.
[2] Dutch Patent, 6352; from *Chem. Zentr.*, 1922, ii. 573.
[3] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1587.

where R and R′ may be hydrogen, alkyl, benzyl, or substituted benzyl radicals. (The benzyl radical is included because in most of its reactions it behaves like the alkyl radicals.)

All the glycineamidearsinic acids are colourless, crystalline substances, possessing high melting- or decomposition-points, and are sparingly soluble in the usual solvents. They form neutral salts when dissolved in alkalis, from which they are displaced even by acetic acid. Their hydrochlorides are only stable in the presence of concentrated hydrochloric acid, so that they are less basic than arsanilic acid. When boiled with excess of alkali or mineral acid they are hydrolysed, forming glycine arsinic acid and the amine.

Derivatives of p-Aminophenylarsinic Acid (p-Arsanilic Acid).

N-(Phenyl-p-arsinic acid)-glycineamide or *N-Phenylglycineamide-p-arsinic acid, Tryparsamide,* $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH_2$. —Arsanilic acid (434 grams) is dissolved in 2000 c.c. of normal sodium hydroxide solution and 375 grams of chloracetamide added. The mixture is heated under reflux for forty-five minutes, a clear solution being obtained, which solidifies on cooling. Concentrated hydrochloric acid, 75 c.c., is then added, the whole filtered, and the solid washed with water. The product is purified by solution in 25 per cent. sodium hydroxide and precipitation with acetic acid. Yield, 300 grams. It is very sparingly soluble in cold water, but from hot water it crystallises in aggregates of long, thin plates, which soften and darken at 280° C. when rapidly heated, but do not melt. It is soluble in boiling acetic acid, but only sparingly soluble in other organic solvents. When boiled with sodium hydroxide, ammonia is evolved.

This substance has also been prepared by the action of cold concentrated ammonium hydroxide on N-(phenyl-*p*-arsinic acid)-glycine methyl ester, an 80 per cent. yield being obtained.

N-(Phenyl-*p*-arsinic acid)-glycineamide gives the following salts: *Sodium salt,* forming thin, nacreous plates containing 0·5 molecule of water of crystallisation, extremely soluble in cold water, the solution being neutral to litmus; *potassium* and *ammonium salts,* forming thin, glistening, hexagonal, microscopic platelets; *calcium salt,* separating in anhydrous, microscopic, wedge-shaped prisms; *magnesium salt,* a microcrystalline powder; *heavy metal salts,* immediately precipitated; *silver salt,* forming aggregates of thin, microscopic needles.

N-(Phenyl-p-arsinic acid)-glycine methyl ester, $AsO(OH)_2.C_6H_4.NH.CH_2.CO_2CH_3$.—40 grams of N-phenylglycine-*p*-arsinic acid are treated with 120 grams of dry methyl alcohol and 12 grams of concentrated sulphuric acid, the mixture being heated under reflux for two hours, then cooled, when addition of water causes separation of the ester. Yield, 38 grams. The product is recrystallised from hot water or 95 per cent. alcohol, microscopic needles and thin plates being deposited, which soften and darken above 200° C., and decompose at about 285° C. The compound is readily soluble in boiling methyl alcohol, but sparingly soluble in cold water, alcohol, or boiling acetone. With concentrated ammonium hydroxide it yields the preceding compound.

N-(Phenyl-p-arsinic acid)-glycine ethyl ester forms delicate needles from 50 per cent. alcohol, melting with decomposition at about 270° C.

N-(Phenyl-p-arsinic acid)-nitrosoglycineamide, $AsO(OH)_2.C_6H_4.N(NO).CH_2.CO.NH_2$, is obtained from the sodium salt of N-(phenyl-*p*-arsinic acid)-glycineamide by the action of sodium nitrite and hydrochloric acid. It crystallises in rosettes and sheaves of silky needles, becoming yellow at 180° C. and melting at 182° to 183° C. It is readily soluble in hot acetic acid, and dissolves to an almost colourless solution in sulphuric acid, which solution gives a brownish-red Liebermann test.

N-(Phenyl-p-arsinic acid)-glycinemethylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NHCH_3$.—44 grams of *p*-arsanilic acid in 200 c.c. of normal sodium hydroxide solution are heated under reflux for one hour with 25 grams of chloracetyl-methylamine. It crystallises in thin, microscopic plates, darkening above 240° C., and decomposing at 285° C.

N-(Phenyl-p-arsinic acid)-glycine-ethylamide occurs in crusts of platelets, darkening above 250° C., and decomposing at 278° to 280° C. It is soluble in warm alcohol.

N-(Phenyl-p-arsinic acid)-glycine-n-propylamide crystallises in sheaves of microscopic needles, which do not melt below 280° C. It is sparingly soluble in boiling water, but readily soluble in 50 per cent. boiling alcohol.

N-(Phenyl-p-arsinic acid)-glycinedimethylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.N(CH_3)_2$, obtained from chloracetyl-dimethylamine and *p*-arsanilic acid, occurs in microscopic needles, decomposing at about 241° to 242° C. Its *sodium salt* may be precipitated by alcohol, and contains 4 molecules of water of crystallisation.

N-(Phenyl-p-arsinic acid)-glycinediethylamide forms microscopic aggregates of short needles, darkening above 195° C., and melting at 199° to 201° C. with gas evolution. It is sparingly soluble in boiling water, but soluble in boiling methyl alcohol or 50 per cent. ethyl alcohol.

N-(Phenyl-p-arsinic acid)-glycinepiperidide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NC_5H_{10}$, occurs in thin, microscopic needles, darkening above 200° C., and decomposing at 218° to 221° C. It is obtained by using chloracetyl-piperidine in the condensation.

N-(Phenyl-p-arsinic acid)-glycinebenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_5$, obtained by using chloracetyl-benzylamine in the condensation, forms microscopic needles, decomposing at 282° to 284° C.

N-(Phenyl-p-arsinic acid)-glycine-3′-carboxylamidobenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_4.CO.NH_2$, is formed when *m*-carboxylamido-chloracetyl-benzylamine is used in the condensation. It crystallises in thick aggregates of microscopic needles, decomposing at 237° to 239° C. It is sparingly soluble in boiling water or boiling acetic acid, practically insoluble in boiling alcohol; when washed with much water it tends to become colloidal. The *sodium salt* forms rosettes and sheaves of delicate needles, containing 5 molecules of water of crystallisation, and may be salted out by means of sodium acetate.

N-(Phenyl-p-arsinic acid)-glycine-4′-acetylaminobenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_4.NH.CO.CH_3$, occurs in flat, microscopic needles, which remain unmelted at 280° C. From 50 per cent. alcohol it deposits diamond-shaped plates. It forms a *sodium salt*, crystallising in microscopic needles, containing $4\frac{1}{2}$ molecules of water of crystallisation.

N-(Phenyl-p-arsinic acid)-glycine-3′-carboxylcarbamidobenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_4.CO.NH.CO.NH_2$.—This is obtained in poor yield by the condensation of *p*-arsanilic acid with *m*-(ω-chloracetylaminomethyl)-benzoyl urea. It forms glistening microscopic aggregates of delicate needles, decomposing at 239° to 240° C.

N-(Phenyl-p-arsinic acid)-glycine-4′-carbamidobenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_4.NH.CO.NH_2$, has only been obtained in very poor yield.

N-(Phenyl-p-arsinic acid)-glycine-3′-methyl-4′-acetylaminobenzylamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH.CH_2.C_6H_3(CH_3)(NH.CO.CH_3)$, is deposited in flat minute needles from 50 per cent. alcohol. When rapidly heated it decomposes at 278° C. The *sodium salt* yields microscopic needles from 85 per cent. alcohol.

N-(Phenyl-p-arsinic acid)-glycine-α-aminopropionamide, $AsO(OH)_2.C_6H_4.NH.CH(CH_3).CO.NH_2$, is obtained by employing α-bromopropionamide in the condensation. From water or hot 50 per cent. alcohol, thin hexagonal plates are deposited, darkening at 255° C. and decomposing at 262° to 263·5° C. The *sodium salt* forms flat, microscopic needles, containing about 2½ molecules of water.

Oxanilamide-p-arsinic acid, $AsO(OH)_2.C_6H_4.NH.CO.CO.NH_2$, occurs in felted masses of minute needles, remaining unmelted below 280° C., soluble in dilute sodium hydroxide solution, the solution evolving ammonia on boiling.

Derivatives of o- and m-Aminophenylarsinic Acids.

N-(Phenyl-o-arsinic acid)-glycineamide, $AsO(OH)_2.C_6H_4.NH.CH_2.CO.NH_2$, obtained from *o*-arsanilic acid and chloracetamide, crystallises from hydrochloric acid solution in flat, microscopic needles, decomposing at 198° to 199° C. From boiling water or 50 per cent. alcohol it crystallises in narrow plates.

N-(Phenyl-3-arsinic acid)-glycineamide.—*m*-Arsanilic acid is used in the preparation of this substance. The product yields prismatic needles, M.pt. 175° to 177° C., soluble in water, alcohols, or glacial acetic acid, but very sparingly soluble in hot acetone.

N-(Phenyl-3-arsinic acid)-glycinemethylamide yields sparingly soluble needles or platelets, darkening and melting at 193° to 194·5° C.

Derivatives of Aminotolylarsinic Acids.

N-(2-Methylphenyl-5-arsinic acid)-glycineamide, $AsO(OH)_2.C_6H_3(CH_3)NH.CH_2.CO.NH_2$.—This is formed by the condensation of chloracetamide and 3-amino-4-methylphenylarsinic acid. It crystallises in delicate, interlaced needles, which do not melt below 285° C., and are sparingly soluble in water, alcohol, and acetic acid, soluble in methyl alcohol. The corresponding *4-arsinic acid* yields a *glycineamide* which forms diamond-shaped platelets, M.pt. 203° to 205° C.

N-(2:5-Dimethylphenyl-4-arsinic acid)-glycineamide gives brownish plates and prisms, which decompose on rapid heating at 236° to 237° C. It is sparingly soluble in cold water, acetic acid, and 50 per cent. alcohol.

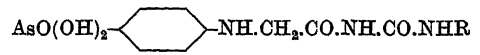
o-Chloro-p-aminoglycineamidephenylarsinic acid [1] is prepared

[1] British Patent, 279379 (1926).

by diazotising *o*-chloro-*p*-nitroaniline and treating the product with sodium arsenite. The resulting *o*-chloro-*p*-nitrophenylarsinic acid is then reduced, and the amino-acid treated with chloracetamide.

Carbamides and β-Substituted Carbamides of N-Arylglycinearsinic Acids.[1]

By replacing the amides of chloracetic acid by carbamide or its β-alkyl or aryl derivatives in the reaction described in the preceding section, the carbamides and substituted carbamides of the arylglycinearsinic acids may be obtained; these have the general formula:



(where R=hydrogen, alkyl, or aryl).

These compounds closely resemble the amides, and form stable and neutral salts with the alkali metals. The carbamide linking is easily ruptured, this often occurring at ordinary temperatures in the presence of an excess of alkali hydroxide. A list of the compounds is given in the Appendix, Table VI.

Aromatic Amides of N-Arylglycinearsinic Acids.[2]

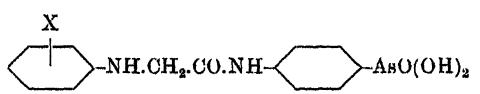
These derivatives are prepared in accordance with the scheme:

$$AsO(OH)(ONa)C_6H_4.NH_2+Cl.CH_2.CO.NHAr = AsO(OH)_2.C_6H_4.NH.CH_2.CO.NHAr+NaCl$$

The reaction may be carried out in 50 per cent. alcohol in the presence of sodium iodide, except in the case of more reactive chloracetyl derivatives, where condensation takes place in boiling aqueous solution. Of the three arsanilic acids the *meta* compound condenses the most readily. The derivatives generally have weakly basic and acidic properties. The free arsinic acids do not, as a rule, possess sharp melting or decomposition points, the values varying with the rate of heating. Taken on the whole the acids are not very soluble in the usual solvents. The sodium salts are fairly soluble in water. A list of these compounds is given in the Appendix, Table VII.

N-Substituted Glycyl-arsanilic Acids.[3]

These compounds are closely related to those described in the last two sections, but differ in the fact that the glycine side chain is reversed, the arsinic acid radical becoming a substituent on the anilide nucleus:



The compounds are readily prepared by boiling the sodium salt of chloracetylarsanilic acid with the aromatic amino-compound, the condensation occurring within fifteen to thirty minutes. The products

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1600.
[2] Jacobs and Heidelberger, *ibid.*, p. 1610.
[3] Jacobs and Heidelberger, *ibid.*, p. 1809.

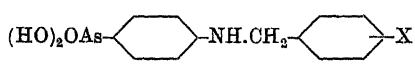
resemble in general properties the isomeric anilides of phenylglycine-*p*-arsinic acids, functioning both as acids and as feeble bases. They are sparingly soluble in the usual solvents, and all have high melting or decomposition points, the values depending on the rate of heating. In general the sodium salts are readily soluble in water. A list of these compounds is given in the Appendix, Table VIII.

N-(Phenyl-*p*-arsinic acid)-α-phenylglycine and its Amides.[1]

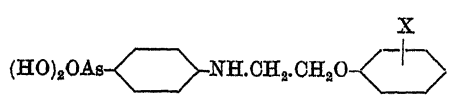
As a special extension of the general type of substances represented by the substituted amides, carbamides, and anilides of the phenylglycine-arsinic acids, N-(phenyl-*p*-arsinic acid)-α-phenylglycine, $AsO(OH)_2.C_6H_4.NH.CH.C_6H_5.CO_2H$, its amide, carbamide, and certain substituted anilides, have been prepared. The glycine itself, prepared by hydrolysis of the amide, crystallises in lustrous rhombic plates, decomposing at 202° to 203° C. after darkening and softening. The other derivatives are prepared from sodium arsanilate and the phenylchloracetylamino-compounds. It is necessary to use sodium iodide and 50 per cent. alcoholic solutions in these condensations, since the chloro-compounds alone show little tendency to react. The general properties of these compounds are similar to those of the simpler glycine derivatives, and a list of the compounds is given in Table IX. of the Appendix.

Substituted Benzyl-, Phenoxyethyl-, and Phenacyl-arsanilic Acids.[2]

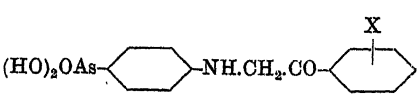
The benzyl- and substituted benzyl-arsanilic acids are of the type



They are obtained by condensing benzyl chloride or its substitution products with sodium *p*-arsanilate. Using phenoxyethyl bromide or its derivatives, the condensation products are of the type



The reaction between sodium *p*-arsanilate and halogen acetyl compounds, such as phenacyl halides, yields phenacyl-*p*-arsanilic acids :

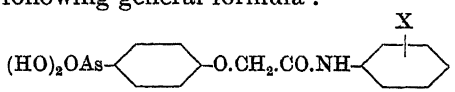


These compounds are yellow in colour and yield yellow solutions. All the derivatives function as acids and as feeble bases, forming salts with alkalis and with strong mineral acids. With the exception of the negatively substituted benzyl derivatives, they are readily displaced from their alkali salts by a slight excess of acetic acid. A complete list of the compounds is given in Table X. of the Appendix.

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1822.
[2] Jacobs and Heidelberger, *ibid.*, p. 1826.

The Amides of (*p*-Arsinic acid)-phenoxyacetic Acid and the Isomeric Phenoxyacetylarsanilic Acids.[1]

Chloracetylamino-compounds react with sodium *p*-hydroxyphenylarsinate [2] to give substituted amides of phenylglycollic acid *p*-arsinic acid, having the following general formula :



A condition of success in the condensation is the use of an extra molecular equivalent of sodium hydroxide in order to form the sodium phenolate, as in the preparation of phenyl ethers with alkyl halides in general. When the chloracetyl-compounds are sufficiently stable in alkaline solution the yields are good, but in cases where the halide is readily decomposed the yields suffer accordingly.

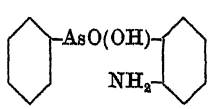
When the acids are pure they possess high decomposition points and are sparingly soluble in the usual solvents. They are stronger acids than the amides of phenylglycinearsinic acid, since only mineral acids or a large excess of acetic acid displaces them completely from their salts. Similarly, the sodium salt of chloracetylarsanilic acid condenses with phenolic compounds to form derivatives of the type

These crystallise readily, are sparingly soluble in the usual solvents, but yield easily soluble sodium salts. They are stronger acids than the glycylarsanilic acids, and are completely displaced from their salts only by mineral acids or by a large excess of acetic acid.

On reduction, both the above types of substances yield *arsenoxides* and *arseno-compounds*. A list of the acids is given in Table XI. of the Appendix.

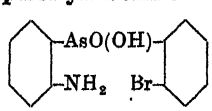
The Aminodiphenylarsinic Acids.

o-Aminodiphenylarsinic acid,[3]



is obtained in 84 per cent. yield by reducing the corresponding nitro-acid with ferrous sulphate and iron powder. It forms snow-white, granular crystals, M.pt. 129° to 130° C., the turbid liquid clearing again at 135° C. It is somewhat readily soluble in hot dilute acetic acid, very soluble in hot alcohol. By diazotisation and treatment in the usual way, the arsenic residue may be made to replace the amino-group, giving phenylarsinophenyl-*o*-arsinic acid (p. 189).

2-Bromo-6′-aminodiphenylarsinic acid,



[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1834.
[2] See German Patent, 216270.
[3] Kalb, *Annalen*, 1921, 423, 39.

Ferrous hydroxide is precipitated from a hot solution of 50 grams of ferrous sulphate in 150 c.c. of water by the addition of an excess of 25 per cent. sodium hydroxide solution. The resulting suspension is heated to 100° C. and treated slowly with 11·5 grams of 2-bromo-6′-methylaminodiphenylarsinic acid dissolved in dilute sodium hydroxide solution, the mixture being well stirred during the operation. After boiling for fifteen minutes the mixture is filtered, the filtrate acidified to Congo red paper with concentrated hydrochloric acid and the precipitated amino-acid (9·8 grams) filtered off. It crystallises from dilute alcohol in colourless prisms, M.pt. 213° to 214° C., with decomposition.

2-Bromo-6′-methylaminodiphenylarsinic acid.—The preceding amino-acid (21·4 grams) is suspended in 150 c.c. of water and mixed with 7·6 grams of methyl sulphate. A solution of 5 grams of sodium hydroxide in 20 c.c. of water is added in five portions at intervals of thirty minutes, the mixture being well shaken after each addition. The acid is then precipitated by acidification with hydrochloric acid. The crude product, after fractional crystallisation from alcohol, gives about 10·8 grams of the pure arsinic acid, M.pt. 193° to 194° C.

2-Bromo-6′-dimethylaminodiphenylarsinic acid.—A mixture of 4·3 grams of 2-bromo-6′-aminodiphenylarsinic acid and 10 c.c. of methyl sulphate is heated on the steam-bath for three hours. The solution is then decomposed by sodium carbonate solution and the acid precipitated by hydrochloric acid. It crystallises from aqueous alcohol in clusters of colourless needles, M.pt. 220° to 221° C.

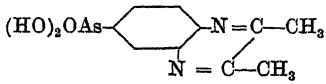
Di- and Tri-aminoarylarsinic Acids.

The diaminomonoarylarsinic acids are all obtained from the corresponding nitroaminoarylarsinic acids by reducing the nitro group with a ferrous salt in alkaline solution or with alkaline hydrosulphite at a low temperature. The diaminodiarylarsinic acids, in addition to being produced from dinitrodiarylarsinic acids by the previous reduction methods, sometimes occur as by-products in the application of the Béchamp reaction to arylamines. Triaminoarylarsinic acids are the reduction products of dinitroaminoarylarsinic acids. In the case of 3-nitro-4-aminophenylarsinic acid, larger yields of the diamino-acid result if ferrous hydroxide and not hydrosulphite is used as the reducing agent, and whilst 3 : 3-diaminodiphenylarsinic acid is the sole reduction product of the corresponding dinitro-compound using ferrous hydroxide, the use of iron powder for reduction gives principally an oxide.

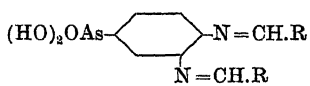
The foregoing aminoarsinic acids as a class are not so stable as the mono-amino acids, some decomposing on exposure to air and light. All are crystalline solids, soluble to some extent in water, alkali, dilute mineral acids and acetic acid. They are practically insoluble in ether, benzene, chloroform, and petroleum. 3 : 4-Diaminophenylarsinic acid and 4 : 5-diamino-3-methylphenylarsinic acid in dilute hydrochloric acid solution give violet colorations when treated with a drop of dilute potassium dichromate solution. The arsenic is eliminated from 4 : 4′-diaminodiphenylarsinic acid, and 2 : 2′-diaminoditolyl-5-arsinic acid, on boiling with potassium iodide and dilute sulphuric acid, *p*-iodoaniline and 5-iodo-*o*-toluidine respectively, being produced. Diazotisation of the diamino-acids and subsequent coupling yields *azo-derivatives* in the usual manner, except in the case of ortho-substituted diamines, when

azoimides result. 2 : 5-Diaminophenylarsinic acid, when diazotised with one molecular equivalent of sodium nitrite, and then treated with alcohol and copper powder, yields *m*-arsanilic acid.

The chief interest in this group of acids centres around 3 : 4-diaminophenylarsinic acid. When diazotised this acid yields an *azoimide*, and condensation with gluconic acid, phosgene, and phenanthraquinone, yields, respectively, a *digluconyl derivative*, a *carbamide*, and an *azine*. Condensation with 1 : 2-diketones [1] such as diacetyl, benzil and its *m*-nitro-, *p*-methoxy-, *p*-ethoxy-, and *p*-dimethylamino-derivatives, also piperil and furil, yields *arsenated quinoxalines*, *e.g.*

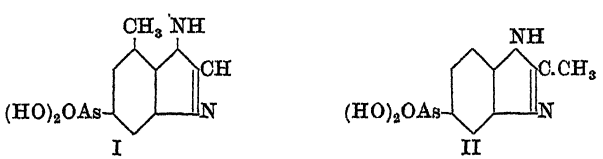


Cyanogen and ω-bromoacetophenone give *di-imino-dihydroquinoxaline* and a *phenyl-dihydroquinoxaline* respectively. If the diketones are replaced by monocarbonyl compounds such as aldol, crotonic aldehyde, benzaldehyde, *o*- and *p*-anisaldehydes or piperonal, *arsenated Schiff's bases* result, *e.g.*

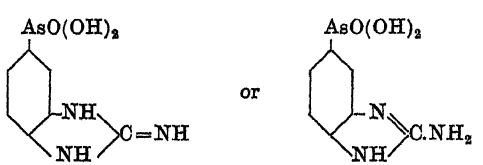


an exception to this occurring with ethyl acetoacetate.

Another interesting condensation applicable to 3 : 4-diaminophenylarsinic acid and 4 : 5-diamino-3-methylphenylarsinic acid takes place when the acids are boiled with *glacial formic acid*,[2] the resulting products being of the type shown in formula I. By suitable adjustment of experimental conditions, type II is obtained, which is the corresponding *acetic acid condensation product*:



3 : 4-Diaminophenylarsinic acid reacts with acyl chlorides in the usual manner,[3] but its interaction with chloracetamide has led to a discussion as to whether one or both of the amino-groups react with the amide.[4] By the interaction of *cyanogen bromide* and 3 : 4-diaminophenylarsinic acid the following type of compound is produced :

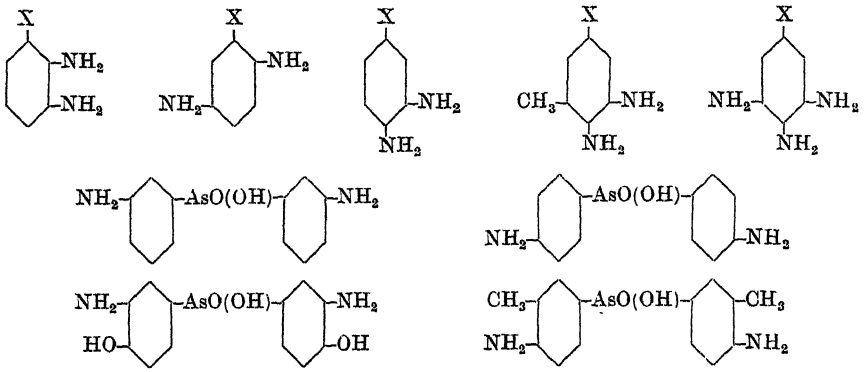


Condensation between dibasic acids and 2 : 3- or 3 : 4-diaminophenyl-

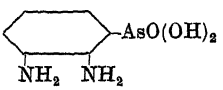
[1] Lewis, Cramer, and Bly, *J. Amer. Chem. Soc.*, 1924, 46, 2058.
[2] Baxter and Fargher, *Trans. Chem. Soc.*, 1919, 115, 1372.
[3] Lewis and Bent, *J. Amer. Chem. Soc.*, 1926, 48, 949.
[4] Ewins, Newbery, and Sticklings, *J. Chem. Soc.*, 1927, p. 851.

arsinic acid yields quinoxaline derivatives. The 2 : 3-diamino-acid reacts with formic acid in a similar manner to the 3 : 4-diamino-acid.

The chief acids dealt with in this section are as follows, where X represents $AsO(OH)_2$. Condensation products and N-substituted products are not shown.

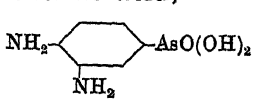


2 : 3-Diaminophenylarsinic acid,



This acid may be prepared by reducing 2-nitro-3-aminophenylarsinic acid (p. 261) with sodium hydrosulphite at the ordinary temperature,[1] or as follows :[2] 5 grams of 2-nitro-3-carbethoxyaminophenylarsinic acid are dissolved in 25 c.c. of water containing 5 grams of sodium hydroxide, and 4 grams of glucose are added immediately. When the reaction subsides, the liquid is boiled for five minutes, acidified strongly to Congo red, treated with charcoal, and filtered. On neutralisation to Congo red, using 10*N* sodium hydroxide, and cooling, the required acid separates out in about 45 per cent. yield (1·5 grams). When purified it is obtained in colourless plates, melting with decomposition at 198° C.,[3] sparingly soluble in water. It yields an *azoimide* when treated with nitrous acid. The *barium*, *calcium* and *magnesium salts* are fairly soluble, and the acid gives a rich red colour with acidified dichromate solution. It differs from the isomeric 3 : 4-diaminophenylarsinic acid (*vide infra*) in yielding a characteristic calcium salt crystallising in plates, decomposing at 158° C. The 3 : 4-acid also gives a purple colour with acidified dichromate solution, and is considerably more basic than the 2 : 3-acid.

3 : 4-Diaminophenylarsinic acid,



This acid is best prepared as follows :[4] 61·5 grams of 3-nitro-4-aminophenylarsinic acid in 250 c.c. of 12 per cent. sodium hydroxide solution

[1] German Patent, 256343. [2] Phillips, *J. Chem. Soc.*, 1928, p. 3134.

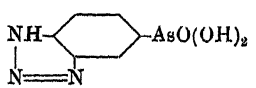
[3] The Patent Specification gives the melting and decomposition point as 205° to 208° C.

[4] Lewis, Cramer, and Bly, *J. Amer. Chem. Soc.*, 1924, 46, 2058; see Bertheim, *Ber.*, 1911, 44, 3093; Baxter and Fargher, *Trans. Chem. Soc.*, 1919, 115, 1372.

are poured into an alkaline solution of ferrous hydroxide prepared in the following manner: Hydrated ferrous chloride ($FeCl_2.4H_2O$), 340 grams, in 1250 c.c. of water, is treated with a 25 per cent. solution of sodium hydroxide, in small portions, until a strongly alkaline reaction is obtained after shaking for several minutes. The mixed solutions are shaken for ten to fifteen minutes, filtered, the filtrate nearly neutralised with hydrochloric acid and evaporated in a vacuum to about 250 c.c. It is then filtered from sodium chloride, and acidified to Congo red with hydrochloric acid; on scratching the sides of the vessel, the arsinic acid separates as a dark brown, crystalline powder. If the mud of ferrous and ferric hydroxides is again extracted with 500 c.c. of 25 per cent. sodium hydroxide solution and treated as described in the foregoing, the united yield consists of about 41 grams of crude product. This is dissolved in 350 c.c. of water, treated with charcoal, and filtered hot, the filtrate yielding tufts of brown crystals, melting with decomposition at 159° to 160° C., the yield being about 33 grams, or 60·7 per cent. When sodium hydrosulphite is used as the reducing agent in the preparation, the yields are very poor. The reduction may also be accomplished by using palladous oxide in alkaline solution in an atmosphere of hydrogen.[1] The acid is soluble in alcohols and acetic acid, insoluble in acetone and ether. Its alkaline solutions become brown in air, and in dilute hydrochloric acid a deep violet coloration is produced on the addition of a drop of potassium dichromate solution. The *diacetyl derivative*[2] is obtained by dissolving the acid in methyl alcohol, adding a mixture of acetic acid and acetic anhydride, removing the methyl alcohol on the water-bath and boiling the residue for four hours; it crystallises from water in a felted mass of fine needles, which retain 2 to 2·5 per cent. of solvent. The product is only slightly decomposed when heated at 250° C. at 20 mm. pressure. This derivative has more recently been obtained as follows:[3] A diazotised solution containing 8 grams of 4-amino-1 : 2-diacetamidobenzene, 60 c.c. of ice-water, 8 c.c. of hydrochloric acid (density 1·16), and 2·8 grams of sodium nitrite, is decomposed at 50° C. by adding a copper arsenite suspension prepared from 5 grams of arsenious oxide, 6 grams of sodium hydroxide in 50 c.c. of water, and 8 c.c. of 2*N* copper sulphate solution. The solution is then acidified to litmus, filtered, acidified to Congo red, and concentrated to 50 c.c. The product crystallises from concentrated aqueous solution in colourless needles, which melt with decomposition at 320° C.

3 : 4-Digluconyl-3 : 4-diaminophenylarsinic acid, $[CH_2OH(CHOH)_4CO.NH]_2C_6H_3.AsO(OH)_2$.[4]—Condensation occurs between the diamino-arsinic acid and gluconic acid in absolute methyl alcohol if the mixture is well shaken and allowed to stand for a few hours. The digluconyl acid is cream-coloured, soluble in cold water and dilute alkalis, and readily hydrolysed by hot water. The yield is about 70 per cent.

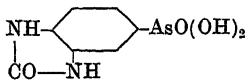
Azimidophenylarsinic acid,[5]



[1] German Patent, 286547.
[2] Baxter and Fargher, *loc. cit.*
[3] Phillips, *J. Chem. Soc.*, 1928, p. 3134.
[4] Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1923, 45, 761.
[5] Bertheim, *loc. cit.*

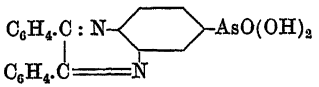
results when 3 : 4-diaminophenylarsinic acid in hydrochloric acid is diazotised with sodium nitrite at 0° C. It forms colourless prisms, decomposing above 300° C., readily soluble in water and alcohols, sparingly soluble in acetic acid, acetone, and ether.

When 3 : 4-diaminophenylarsinic acid in alkaline solution is treated with phosgene in toluene, with ice cooling and stirring, a *carbamide* is formed :



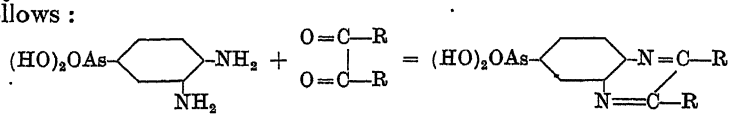
which crystallises in plates or prisms. It is unmelted at 300° C., and sparingly soluble in the usual solvents.

The diaminoarsinic acid and phenanthraquinone yield an *azine*, an amorphous yellow compound unmelted at 300° C. :

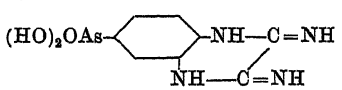


Condensation Products of 3 : 4-*Diaminophenylarsinic Acid.*

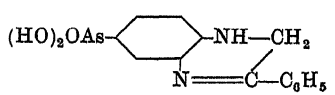
The first group of compounds to be considered under this heading are the *arsenated quinoxalines* derived by condensation of 3 : 4-diamino-phenylarsinic acid with *o*-diketones. The reaction may be formulated as follows :



The addition of cyanogen to 3 : 4-diaminophenylarsinic acid leads to the production of a *di-imino-dihydroquinoxaline* (I), and the addition of ω-bromoacetophenone leads to a *phenyl-dihydroquinoxaline* (II). No method has been found which will decide the position of the phenyl group in the quinoxaline ring.[1]

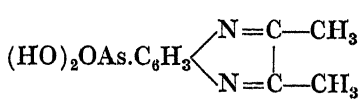


I



II

2 : 3-Dimethylquinoxaline-6-arsinic acid,



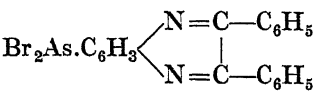
5 grams of the 3 : 4-diamino-acid, 100 c.c. of ethyl alcohol and 2 grams of diacetyl are boiled for four hours under reflux, then concentrated to a small bulk and two volumes of water added. The precipitate is removed, recrystallised twice from hot water containing charcoal, 2 grams (42 per cent. yield) of shining, pink flakes being isolated. The substance melts with decomposition at 212° to 215° C., is readily soluble in methyl alcohol, sparingly soluble in water.

2 : 3-Diphenylquinoxaline-6-arsinic acid results when the

[1] Lewis, Cramer, and Bly, *J. Amer. Chem. Soc.*, 1924, 46, 2058.

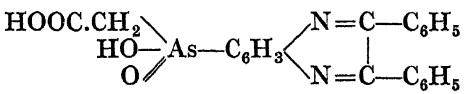
diacetyl of the preceding preparation is replaced by an equimolecular quantity of benzil. A 64 per cent. yield is obtained, the compound being slightly soluble in acetic acid, but insoluble in alcohol and ether.

2 : 3-Diphenylquinoxaline-6-dibromoarsine,



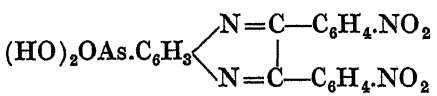
When 8·5 grams of the preceding acid in 100 c.c. of acetic acid are boiled and an excess of 50 per cent. hydrobromic acid added, the dibromoarsine separates after a few minutes in shining, yellow plates, M.pt. 232° C.; yield, 8·8 grams (83 per cent.). It is slightly soluble in benzene and acetic acid, readily soluble in alcohol. The corresponding *dichloroarsine* melts at 185° to 187° C., and the *dihydroxide* is a white product isolated from the bromide by the addition of 10 per cent. sodium carbonate solution.

2 : 3-Diphenylquinoxaline-6-arsinoacetic acid,



2 grams of the foregoing hydroxide in 25 c.c. of 12*N* sodium hydroxide solution and just sufficient alcohol to effect solution, are treated with 1 gram of chloracetic acid in 5 c.c. of 6*N* sodium hydroxide. After standing overnight the mixture is acidified to phenolphthalein by hydrochloric acid, filtered, and the filtrate made acid to Congo red. The bulky precipitate is removed, dried, and crystallised from 50 per cent. acetic acid; yield, 1 gram, or 45 per cent., of small white needles, melting at 122° to 125° C., with decomposition.

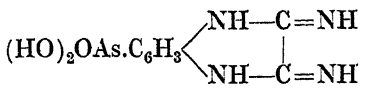
2 : 3-Di-m-nitrophenylquinoxaline-6-arsinic acid,



results when dinitrobenzil is used in the condensation. It is obtained in 75 per cent. yield as a white powder, unmelted below 230° C., insoluble in water, but giving a red solution in alkali.

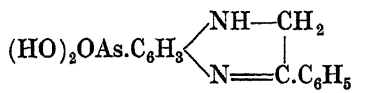
2 : 3-Di-p-methoxyphenylquinoxaline-6-arsinic acid is obtained in 61 per cent. yield when anisil is used in the condensation. It crystallises from hot acetic acid in light yellow needles, sparingly soluble in alcohol. Replacing the anisil by phenetil gives 2 : 3-*di-p-ethoxyphenylquinoxaline*-6-*arsinic acid* in 84 per cent. yield, consisting of yellow, needle-like crystals, soluble in hot acetic acid and in methyl alcohol. Furil and piperil give 2 : 3-*difurylquinoxaline*-6-*arsinic acid* and 2 : 3-*di*-3 : 4-*methylenedioxyphenylquinoxaline*-6-*arsinic acid*, respectively, the former being a light brown product and the latter a yellow, crystalline powder. Tetramethyldiaminobenzil produces 2 : 3-*di-p-dimethylaminophenylquinoxaline*-6-*arsinic acid* in 45 per cent. yield; this is a yellow powder, soluble in dilute alkali, sparingly soluble in methyl alcohol, and insoluble in water.

2 : 3-Di-imino-1 : 4-dihydroquinoxaline-6-arsinic acid,



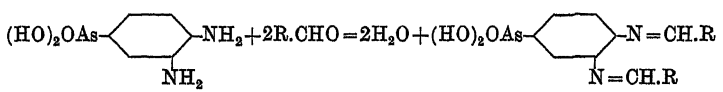
Cyanogen is slowly passed for two hours through a warm solution of 5 grams of 3 : 4-diaminophenylarsinic acid in 60 c.c. of absolute methyl alcohol. The liquor is evaporated and the oily residue treated with absolute ethyl alcohol until it is converted to an orange-coloured powder. The product is then crystallised from ethyl alcohol and dried at 85° C. The yield is 2·1 grams, or 36 per cent. It melts with decomposition at 200° to 205° C., is quite soluble in water or methyl alcohol, sparingly soluble in ethyl alcohol.

3 (?)-Phenyl-1 : 2-dihydroquinoxaline-6-arsinic acid,

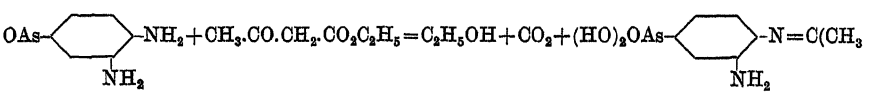


is obtained from ω-bromoacetophenone and 3 : 4-diaminophenylarsinic acid. A 38 per cent. yield of orange-coloured product is isolated, which does not melt below 250° C. It is soluble in alcohols and dilute alkali, but sparingly soluble in water.

The second group of compounds is formed by the condensation of monocarbonyl compounds with 3 : 4-diaminophenylarsinic acid, *arsenated Schiff's bases* being formed, the reaction being as follows :



The reaction with ethyl acetoacetate is exceptional, a condensation product of amino-acid (1 mol.) with acetone (1 mol.) resulting. This product cannot be obtained directly from acetone.



Details of its preparation are as follows :

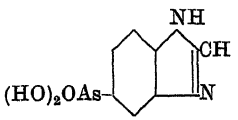
4 - Dimethylmethyleneamino - 3 - aminophenylarsinic acid.— One gram of the 3 : 4-diamino-acid in 30 c.c. of absolute methyl alcohol is mixed with 1 c.c. of acetoacetic ester and the whole boiled for four hours under reflux, then allowed to stand overnight. The precipitate, 1 gram or 88 per cent. yield, does not melt below 260° C.

3 : 4-Di-γ-hydroxybutylene-aminophenylarsinic acid, $(HO)_2OAs.C_6H_3[N:CH.CH_2.CH(CH_3)(OH)]_2$, results in 36 per cent. yield when aldol is used in the condensation. It is a crystalline product melting below 260° C., soluble in the usual organic solvents. Crotonic aldehyde similarly reacts to give 3 : 4-*dicrotonylidene-aminophenylarsinic acid,* $(HO)_2OAs.C_6H_3(N:CH.CH:CH.CH_3)_2$; benzaldehyde and *o*-methoxybenzaldehyde form 3 : 4-*dibenzylideneaminophenylarsinic acid,* $(HO)_2OAs.C_6H_3(N:CH.C_6H_5)_2$, and 4-*o-methoxybenzylideneamino-3-aminophenylarsinic acid,* $(HO)_2OAs.C_6H_3(NH_2)(N:CH.C_6H_4.OCH_3)$, respectively; none of these compounds melts below 250° C. With

anisaldehyde, 4-*p-methoxybenzylideneamino*-3-*aminophenylarsinic acid* is obtained, which differs from the benzaldehyde condensation product in being light brown instead of white. The condensation product from chloracetamide, using sodium hydroxide solution, is 4 (?)-*acetamido-amino* - 3 - *aminophenylarsinic acid*, $(HO)_2OAs.C_6H_3(NH.CH_2.CO.NH_2)(NH_2)$, crystallising from hot water in needles, decomposing at 220° to 232° C. Condensation with piperonal yields 4-*piperonalamino*-3-*aminophenylarsinic acid*, $(HO)_2OAs.C_6H_3(NH_2)_2(N:CH.C_6H_3.O_2CH_2)$.

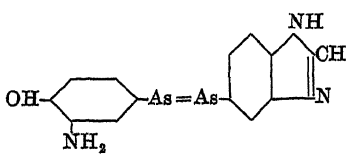
The third group of condensation products takes account of the fact that *o*-diamines react with formic or acetic acid to give acyl derivatives, which then lose one molecule of water if a monoacyl derivative, or a molecule of acid if a diacyl derivative, with consequent closing of the ring.[1] In some cases diaminotolylarsinic acids are used in this condensation.

1 : 3-Benzodiazole-5-arsinic acid or **Benziminazole-5(6)-arsinic acid,**



10 grams of 3 : 4-diaminophenylarsinic acid and 100 c.c. of glacial formic acid are boiled for six hours, the excess of formic acid then distilled off, and water added, whereby 7·5 grams of crystalline product separate. To remove traces of colouring matter the product, in dilute alkaline solution, is treated with charcoal. The solution is then made neutral to methyl orange, when the pure product separates. The acid crystallises from water in clusters of minute, flattened prisms, which are anhydrous. These gradually darken above 250° C., and decompose rapidly about 297° C.

3′-Amino-4′-hydroxy-1 : 3-diazole-5 : 1′-arsenobenzene,[2]



is obtained when 3-amino-4-hydroxyphenylarsinic acid and 1 : 3-benzodiazole-5-arsinic acid are mixed in molecular proportions and reduced with sodium hydrosulphite as in the next preparation. The product, dissolved in methyl alcohol containing hydrogen chloride, yields the *hydrochloride*, which may be precipitated by ether. The hydrochloride is a pale yellow powder, readily soluble in water or methyl alcohol, less soluble in ethyl alcohol, and very sparingly soluble in acetone or ether. It contains three molecules of water, one of which is lost at 60° C., and a second at 100° C. when heated *in vacuo*. The base dissolves completely in sodium hydroxide solution or methyl alcohol containing hydrogen chloride.

5 : 5′-Arseno-1 : 3 : 1′ : 3′-benzodiazole or **5 : 5′-Arsenobenziminazole,**[3]

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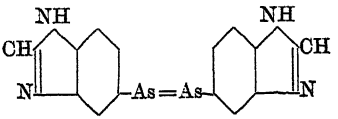
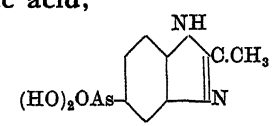
[1] Baxter and Fargher, *Trans. Chem. Soc.*, 1919, 115, 1372.
[2] Fargher, *ibid.*, 1920, 117, 875. [3] Baxter and Fargher, *loc. cit.*



5 grams of the preceding acid and 1·2 grams of sodium hydroxide in 100 c.c. of water are treated with a solution of 50 grams of sodium hydrosulphite and 11·5 grams of magnesium chloride in 300 c.c. of water. The mixture is heated to 60° C. and stirred for two hours in an atmosphere of nitrogen. After cooling, the precipitate is collected, washed with water, suspended in 90 c.c. of water and dissolved by the addition of hydrochloric acid. The solution is filtered and poured into an equal volume of concentrated hydrochloric acid, when the arseno-compound separates in the form of its hydrochloride. Yield, 3·9 grams. The free base is a bright yellow powder, fairly soluble in 50 per cent. acetic acid, sparingly soluble in methyl alcohol containing hydrochloric acid, and insoluble in water and the usual organic solvents. The *dihydrochloride* is pale yellow, soluble in water, sparingly soluble in alcohols and insoluble in acetone or ether. Its aqueous solution is neutral to methyl orange but acid to litmus. It contains two molecules of water of crystallisation.

2-Methyl-1 : 3-benzodiazole-5-arsinic acid or **2-Methylbenziminazole-5(6)-arsinic acid,**



results when 3 : 4-diacetamidophenylarsinic acid is heated with ten times its weight of water in a sealed tube for four hours at 130° C. It crystallises from water in minute needles containing 2½ molecules of water of crystallisation, and darkens when heated above 250° C., decomposing at about 270° C.

A more recent investigation of this acid carried out by Phillips [1] showed that, in addition to the foregoing method of preparation, the following methods may be used: (*a*) 4 grams of 3 : 4-diacetamidophenylarsinic acid, when refluxed with 20 c.c. of 5*N* hydrochloric acid for forty minutes, and the solution filtered and neutralised to Congo red, give 2·5 grams (78 per cent.) of the required acid. (*b*) 4 grams of 3 : 4-diaminophenylarsinic acid are boiled under reflux with 30 c.c. of 5*N* hydrochloric acid and 2 c.c. of acetic acid or acetic anhydride for forty minutes. Working up the product as before gives 2 grams (40 per cent.) of the acid. (*c*) A diazotised solution (7 grams sodium nitrite) of 22 grams of 5-amino-2-methylbenziminazole dihydrochloride in 100 c.c. of water is decomposed at 50° C. by a copper arsenite suspension prepared from 15 grams of arsenious oxide, 15 grams of sodium hydroxide, 6 c.c. of 2*N* copper sulphate solution, and 100 c.c. of water. A 30 per cent. yield of the required acid is obtained. According to this investigator, the acid, when anhydrous, melts with decomposition at 275° C., and is obtained in all cases as a monohydrate. This loses half its water at 100° C., and the remainder is slowly evolved at 120° C. It consists of colourless prisms, sparingly soluble in cold water, but readily soluble in

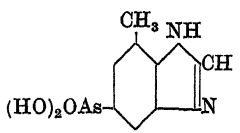
[1] Phillips, *J. Chem. Soc.*, 1928, p. 3134.

mineral acids and in alkalis. The *calcium* and *magnesium salts* are amorphous. Boiling 10 per cent. nitric acid converts the arsinic acid to the *nitrate*, which crystallises in white needles. When reduced by sodium hydrosulphite the arsinic acid yields 2 : 2′-*dimethyl*-5 : 5′-*arseno*-1 : 3 : 1′ : 3′-*benzodiazole*-(2 : 2′-*dimethyl*-5 : 5′-*arsenobenziminazole*), the *hydrochloride* of which has similar properties to that of the preceding arseno-compound;[1] on desiccation in a vacuum it retains 4 molecules of water, one of which is removed with difficulty at 90° C.

2-Ethyl-1 : 3-benzodiazole-5-arsinic acid or **2-Ethylbenziminazole-5(6)-arsinic acid**[2] is the condensation product from propionic acid and 3 : 4-diaminophenylarsinic acid when the two are refluxed for one hour, the solution treated with charcoal and neutralised to Congo red or litmus. It forms clusters of needles, fairly soluble in cold water or alcohol, readily soluble in dilute mineral acids and alkalis. The *calcium salt* crystallises from hot aqueous solution in clusters of prisms, soluble in cold water; the *magnesium salt* is amorphous.

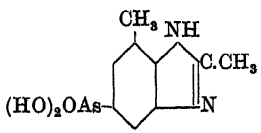
2-α-Hydroxyethyl-1 : 3-benzodiazole-5-arsinic acid or **2-α-Hydroxyethylbenziminazole-5(6)-arsinic acid** is obtained when the propionic acid in the preceding preparation is replaced by *l*-lactic acid, or when 3 : 4-diaminophenylarsinic acid is heated with *l*-lactic acid in a boiling water-bath for one hour and the solution then diluted with water. It crystallises in colourless needles, sparingly soluble in boiling water, insoluble in cold water. It forms an amorphous *magnesium salt*.

7-Methyl-1 : 3-benzodiazole-5-arsinic acid,[3]



is the result of the interaction of 3 : 4-diamino-*m*-tolylarsinic acid and glacial acetic acid. It crystallises from water in minute, prismatic needles, which melt with decomposition at about 300° C. Its reduction product is 7 : 7′-*dimethyl*-5 : 5′-*arseno*-1 : 3 : 1′ : 3′-*benzodiazole*, a pale yellow powder, yielding a *hydrochloride* which is a pale yellow, granular powder.

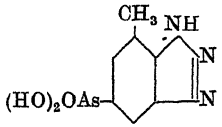
2 : 7-Dimethyl-1 : 3-benzodiazole-5-arsinic acid,



obtained from 5 : 6-diamino-*m*-tolylarsinic acid and acetic acid, crystallises in minute, prismatic needles, containing 2 molecules of water of crystallisation. Its arseno-derivative, 2 : 7 : 2′ : 7′-*tetramethyl*-5 : 5′-*arseno*-1 : 3 : 1′ : 3′-*benzodiazole*, yields a hydrochloride containing 2 molecules of water of crystallisation.

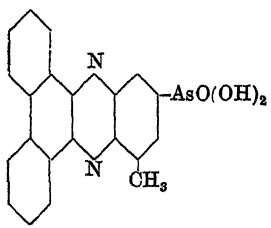
[1] Baxter and Fargher, *loc. cit.*; Phillips, *loc. cit.*
[2] Phillips, *loc. cit.*
[3] Baxter and Fargher, *loc. cit.*

7-Methyl-1 : 2 : 3-benzotriazole-5-arsinic acid,



results when 3 : 4-diamino-*m*-tolylarsinic acid in dilute hydrochloric acid is treated with one molecular proportion of sodium nitrite. It is a crystalline powder, sparingly soluble in water, but more soluble in alcohol. From 50 per cent. alcohol it crystallises in minute, colourless, glistening needles, which gradually decompose above 280° C.

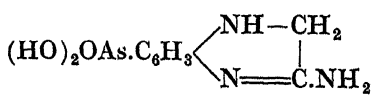
4-Methylphenanthraphenazine-2-arsinic acid,



is the condensation product of equimolecular proportions of phenanthraquinone and 3 : 4-diamino-*m*-tolylarsinic acid in acetic acid solution. It is a yellow, amorphous powder, sparingly soluble in water and organic solvents. With concentrated sulphuric acid it gives an eosin-red coloration, with nitric acid a cherry-red colour, and with hydrochloric acid an insoluble red compound, all these colours being discharged on dilution with water. It dissolves in sodium hydroxide or carbonate solution, but gives a precipitate of the *sodium salt* with excess of reagent.

By treating 3 : 4-diaminophenylarsinic acid with the appropriate acyl chlorides the following derivatives can be obtained : [1] 3-*Amino*-4-*acetylaminophenylarsinic acid*, M.pt. 265° to 267° C. ; 3-*amino*-4-*propionylaminophenylarsinic acid*, M.pt. 230° to 235° C. ; 3 : 4-*divaleryl-aminophenylarsinic acid* ; 3 : 4-*dichloroacetylaminophenylarsinic acid* ; 3 : 4-*diphenylacetylaminophenylarsinic acid* ; 3 : 4-*dibenzoylaminophenyl-arsinic acid* ; 3 : 4-*diphthalylaminophenylarsinic acid* ; 3 : 4-*dicarbethoxy-aminophenylarsinic acid*, M.pt. 192° to 192·5° C. ; 3 : 4-*dicarbopropoxy-aminophenylarsinic acid*, M.pt. 249° to 253° C. ; 3 : 4-*dicarbobutoxy-aminophenylarsinic acid*, decomposing at 185° to 187° C.

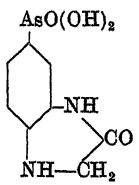
N-(Phenyl-1-amino-4-arsinic acid)-glycine-amide, $(HO)_2OAs.C_6H_3(NH_2).NH.CH_2.CO.NH_2$, is obtained when 3 : 4-diaminophenylarsinic acid in alkaline solution is treated with chloracetamide. It begins to darken at 215° C. and melts with decomposition at 234° to 241° C. If about 25 per cent. more alkali is used in the preparation, 3-*amino*-6-*arsino*-1 : 2-*dihydroquinoxaline* results :



[1] Lewis and Bent, *J. Amer. Chem. Soc.*, 1926, 48, 949.

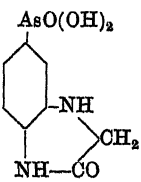
This melts at 226° C., forms an *ammonium salt*, decomposing at 200° C., and a *benzoyl derivative*, M.pt. 234° C. In the preparation of the glycine-amide, longer heating, or recrystallisation from an excess of alkali, causes it to change to the quinoxaline. If the latter in sodium hydroxide solution is allowed to stand for several days at 30° C. with an excess of ethylene oxide, the mixture being occasionally shaken, *3-hydroxyethyl-amino-6-arsino-1 : 2-dihydroquinoxaline* is formed.

This interaction of chloracetamide and 3 : 4-diaminophenylarsinic acid has recently been criticised,[1] and it is claimed that both amino-groups of the acid react with the chloracetamide and that two isomeric hydroxy-1 : 4-dihydroquinoxaline-6-arsinic acids result. The details of the condensation are as follows : 25 grams of 3 : 4-diaminophenylarsinic acid in 105 c.c. of water containing 4·1 grams of sodium hydroxide are treated with 19·4 grams of chloracetamide and the mixture boiled for forty-five minutes. The addition of 7·8 c.c. of concentrated hydrochloric acid to the cooled solution precipitates a crystalline solid, purified by reprecipitation from dilute sodium carbonate solution after treatment with charcoal. The product (12 grams) is boiled with successive quantities (50, 25, 25, and 25 c.c.) of water, the hot extracts combined, and the crystalline product obtained on cooling repeatedly crystallised from water. The final product consists of long, nearly white, prismatic needles, undecomposed at 260° C., which on analysis prove to be **3-hydroxy-1 : 4-dihydroquinoxaline-6-arsinic acid,**



This yields a *monobenzoyl derivative*, crystallising from 50 per cent. alcohol in lustrous, hexagonal plates, undecomposed below 290° C. The free acid is identical with that prepared by nitrating phenylarsinic acid 4-glycine-amide and reducing the nitro-acid with ferrous hydroxide.

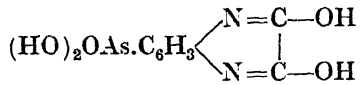
Purification of the less soluble fraction (about 6·8 grams) from the foregoing interaction gives **2-hydroxy-1 : 4-dihydroquinoxaline-6-arsinic acid,**



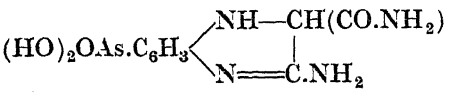
This is very insoluble in neutral solvents ; it is purified by means of its *sodium salt*. The acid crystallises in diamond-shaped plates, melting with decomposition at 258° C. The *monobenzoyl derivative* separates from water in stout, hexagonal plates, M.pt. 251° to 252° C.

[1] Ewins, Newbery, and Sticklings, *J. Chem. Soc.*, 1927, p. 851.

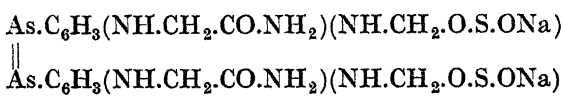
2 : 3-Dihydroxy-6-arsinoquinoxaline,[1]



results when 3 : 4-diaminophenylarsinic acid is condensed with oxalyl chloride; replacement of the latter by bromomalonamide affords *3-amino-2-carbamido-6-arsino-1 : 2-dihydroquinoxaline,*



The compound



results when amino-tryparsamide is boiled under reflux with sodium formaldehyde-sulphoxylate. During the first thirty minutes a precipitate forms, which may be filtered off in an atmosphere of carbon dioxide. Its composition appears to be $C_{17}H_{21}O_4N_6SAs_2Na$, that is, it is an arseno-compound with one amino group condensed with the sulphoxylate. As the heating is continued the solution becomes clear again, and after fifteen hours is cooled and added dropwise and with stirring to 300 c.c. of alcohol. The arseno-derivative separates as a fine, light yellow powder, which is filtered off and dried in air. The yield is about 75 per cent. theoretical. The product is unchanged when heated to 260° C., is readily soluble in water, and gives the indigo-carmine test for the sulphinic acid group.

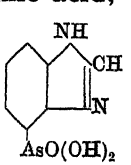
N - 4 - Arsinophenylaminomalonamide, $(HO)_2OAs.C_6H_4.NH.CH(CONH_2)_2$, is obtained when bromomalonamide is used in the general condensation; using phthalic anhydride, the product is *3-amino-4-phthalylaminophenylarsinic acid,* $(HO)_2OAs.C_6H_3(NH_2)NH.CO.C_6H_4.COOH$.

3 : 4-Di-(N-N'-dimethylamino)-phenylarsinic acid, $(HO)_2OAs.C_6H_3[N(CH_3)_2]_2$, is prepared by boiling the amino-acid with methyl alcohol in the presence of hydrochloric acid.

Malonylamino - arsanilic oxide, $O_2AsC_6H_3<(NHCO)_2>CH_2$, results when malonic ester is refluxed with amino-arsanilic acid. It is a bright red powder.

Condensation Products of 2 : 3-*Diaminophenylarsinic Acid.*

Benziminazole-4(7)-arsinic acid,[2]

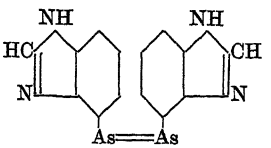


2 : 3-Diaminophenylarsinic acid interacts with formic acid to produce the above compound in the same way that benziminazole-5(6)-arsinic

[1] Lewis and Bent, *loc. cit.* [2] Phillips, *J. Chem. Soc.*, 1928, p. 3138.

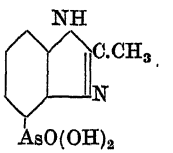
acid is formed from 3 : 4-diaminophenylarsinic acid. It crystallises from boiling water in colourless prisms, melting with decomposition at 277° C. It is decidedly amphoteric, and appears to be less basic than the 5(6)-arsinic acid. The *calcium salt* is amorphous, and the *magnesium salt* forms clusters of colourless prisms.

4 : 4′-Arsenobenziminazole,



the reduction product of the preceding arsinic acid, is a yellow, amorphous solid, insoluble in water, alkalis, or organic solvents ; it yields a *hydrochloride*, which may be precipitated by excess of the mineral acid.

2-Methylbenziminazole-4(7)-arsinic acid,



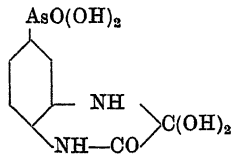
is obtained in 50 per cent. yield when the formic acid in the foregoing preparation is replaced by acetic anhydride, the reaction taking place in the presence of boiling 4*N* hydrochloric acid. It crystallises from boiling water in anhydrous needles, M.pt. 280° to 282° C., readily soluble in alkalis and dilute mineral acids, and forming amorphous *calcium* and *magnesium salts*. Reduction of the acid gives 2 : 2′-*dimethyl*-4 : 4′-*arsenobenziminazole*, a yellow, amorphous solid, resembling the preceding arseno-compound in properties.

2-α-Hydroxyethylbenziminazole-4(7)-arsinic acid is obtained in poor yield when *l*-lactic acid is used in the foregoing preparation, the reaction taking place in the presence of 4*N* hydrochloric acid. It crystallises in colourless needles from boiling water, is amphoteric, and forms an amorphous *magnesium salt*.

The Condensation of Dibasic Acids with 2 : 3- *and* 3 : 4-*Diaminophenylarsinic Acids.*[1]

(1) *Oxalic Acid.*—2 grams of 3 : 4-diaminophenylarsinic acid, 14 c.c. of 4*N* hydrochloric acid, and 1·2 grams of crystallised oxalic acid are boiled under reflux for forty minutes. Cooling the mixture causes the separation of 1·5 grams (60 per cent. yield) of 2 : 3-*dihydroxyquinoxaline*-6(7)-*arsinic acid*. This appears to be identical with the product obtained by reducing 3-nitro-4-oxalylaminophenylarsinic acid or by treating 3 : 4-diaminophenylarsinic acid with oxalyl chloride. It crystallises from boiling water in colourless, hexagonal plates, containing one molecule of water, not eliminated at 100° C.; it is unmelted at 300° C. The following formula has been suggested as representing its structure :

[1] Phillips, *loc. cit.*



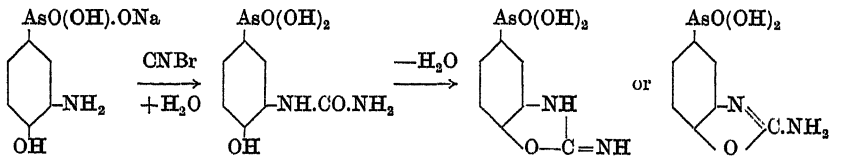
It is insoluble in dilute mineral acids, but readily soluble in alkalis, yielding *mono-* and *disodium salts* with sodium hydroxide. It yields sparingly soluble *barium*, *calcium* and *magnesium salts*.

Replacement of the 3 : 4- acid by 2 : 3-diaminophenylarsinic acid gives a 75 per cent. yield of 2 : 3-*dihydroxyquinoxaline*-5(8)-*arsinic acid*, crystallising in prisms, unmelted at 300° C. This has similar properties to its isomeride.

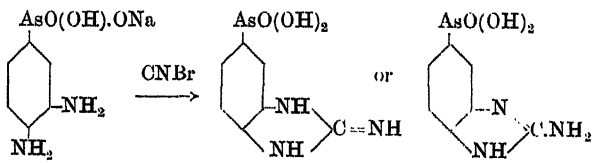
(2) *Malonic Acid.*—Using the free acid, under the same conditions as oxalic acid, only results in traces of a red compound being formed, whilst ethyl malonate in methyl alcohol apparently yields *malon-o-phenyleneamide-4-arsinic acid.*

Carbamido-derivatives of Arylarsinic Acids.[1]

1 - Aminobenzoxazole - 4 - arsinic acid.—3-Amino-4-hydroxyphenylarsinic acid, 117 grams, in 500 c.c. of water containing 20 grams of sodium hydroxide, is treated with 120 grams (excess) of cyanogen bromide, the reaction being complete in about one hour. 10 c.c. of glacial acetic acid are then added, the precipitate dissolved in 20 per cent. sodium hydroxide, the solution cooled, and then treated with an excess of sodium chloride. After standing overnight, the mass of crystals is washed with brine and decolorised in 400 c.c. of hot water with charcoal. Acidification with excess of acetic acid gives 88 grams of white prismatic needles of the constitution shown below, soluble in dilute mineral acids and alkalis, but sparingly soluble in water. The acid is only slowly decomposed by boiling concentrated aqueous caustic alkali. The course of the reaction is probably represented by the following scheme :

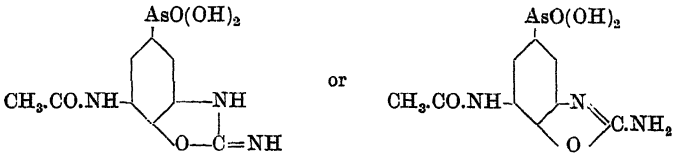


2-Aminobenziminazole-5-arsinic acid.—This acid is prepared in the same way as the preceding one, the 3-amino-acid above being replaced by 3 : 4-diaminophenylarsinic acid. The product forms slender needles, fairly soluble in hot water, readily dissolving in dilute mineral acids and alkalis. The reaction is as follows :



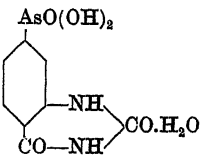
[1] Sticklings, *J. Chem. Soc.*, 1928, p. 3131.

1-Amino-6-acetamidobenzoxazole-4-arsinic acid,



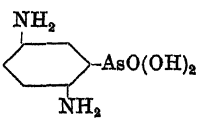
A neutral solution of 28 grams of 3-amino-5-acetamido-4-hydroxyphenylarsinic acid (p. 309) in dilute aqueous sodium hydroxide is diluted to 150 c.c. and rapidly added to an aqueous suspension of cyanogen bromide (freshly prepared from 18 grams of bromine) and the whole well stirred. After standing for about an hour the product is acidified with acetic acid, the brown precipitate treated in alkaline solution with charcoal, and reprecipitated. White, prismatic needles result (20 grams yield), readily soluble in alkalis and dilute mineral acids.

2 : 4-Diketo-1 : 2 : 3 : 4-tetrahydro-1 : 3-quinazoline-7-arsinic acid,



3-Amino-4-carboxyphenylarsinic acid (26 grams) in neutral solution is treated in the manner described above with the cyanogen bromide obtained from 15 grams of bromine. After standing for one hour, acidification to Congo red, using hydrochloric acid, gives a crystalline precipitate. Purification in the usual manner yields 18 grams of the required acid in the form of white prisms.[1]

2 : 5-Diaminophenylarsinic acid or **p-Phenylenediaminearsinic acid,**[2]



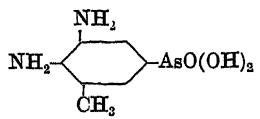
5-Nitro-2-aminophenylarsinic acid (78 grams), in 900 c.c. of water and 480 c.c. of 10*N* sodium hydroxide solution, is well stirred and slowly treated with 20·6 per cent. ferrous chloride solution (about 500 c.c.), the mixture being kept alkaline towards turmeric. After filtering and

[1] Benzimidazolone-5-arsinic acids—English Patent, 256243 (1926)—are obtained from *o*-phenylenediamine-4-arsinic acids, where one amino-group has an alkyl, aralkyl, or alkylenyl substituent, by treatment with carbonyl chloride in the presence of aqueous sodium acetate. In this way 1-*methyl*-, 3-*methyl*-, 1-*propyl*-, 1-*allyl*- and 1-*benzyl*-*benzimidazolone-5-arsinic acids* are produced, all melting above 280° C. When these N-substituted benzimidazolonearsinic acids are reduced with hyposulphite, N-substituted arsenobenzimidazolones are obtained—British Patent, 281690 (1926); the following derivatives are known: *Benzethyl, benzpropyl* and *benzallylimidazolones.* By diazotising 1-amino-3 : 4-benz-(3-N-methyl-)-imidazolone and treating the resulting product with sodium arsenite in alkaline solution, 3 : 4-*benz*-(3-*N*-*methyl*)-*imidazolonearsinic acid* is produced. Taking the suitable amino-compounds, 3 : 4-*benz*-(4-*N*-*ethyl* or *propyl*)-*imidazolonearsinic acid* may be isolated in a similar manner—British Patent, 281703 (1926).

[2] Benda, *Ber.*, 1911, 44, 3300; German Patent, 248047 (1911).

washing with hot water, the filtrate is treated with sulphuric acid (66° Bé.) until Congo red paper turns brown. On standing, the arsinic acid separates in fine needles. It decomposes at 210° to 215° C., and when exposed to air and light becomes violet. It dissolves in hot water, alkali, dilute acid, and sodium acetate, but is sparingly soluble in alcohol. After diazotising with one molecular equivalent of sodium nitrite, the solution couples with R-salt (reddish-violet product), resorcinol (orange-yellow product), and β-naphthol (red product). When the diamine is diazotised and the solution treated with alcohol and copper powder in the cold, it is decomposed, yielding *m*-arsanilic acid (p. 205).

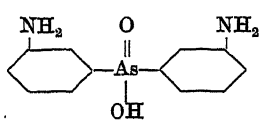
5 : 6-Diamino-m-tolylarsinic acid,[1]



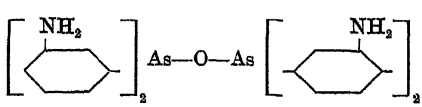
A solution of 8·6 grams of 5-nitro-6-amino-*m*-tolylarsinic acid in 75 c.c. of water and 6·2 c.c. of 10*N* sodium hydroxide solution is cooled to −1° C. and 20·4 grams of sodium hydrosulphite added in one operation. When the reaction is complete the solution is filtered and 8·1 c.c. of hydrochloric acid (density 1·12) added. The arsinic acid separates and is recrystallised from water. It forms colourless needles, containing 1½ to 2 mols. of water of crystallisation. It is soluble in methyl alcohol and acetic acid, sparingly soluble in ether, benzene, and petroleum. Its solution in dilute hydrochloric acid gives a characteristic deep violet coloration with a drop of dilute solution of potassium dichromate.

Diaminodiarylarsinic Acids.

3 : 3′-Diaminodiphenylarsinic acid,[2]



3 : 3′-Dinitrodiphenylarsinic acid (p. 175) yields the diamino-acid when reduced with hot ferrous hydroxide solution, 15 grams of the dinitro-acid giving 6 to 7 grams of the free diamine. It crystallises in pale, reddish plates, soluble in dilute hydrochloric acid, the addition of concentrated acid precipitating the hydrochloride in crystalline form. If the reduction is effected with iron powder, the principal product is not the diamino-acid, but an *oxide*,

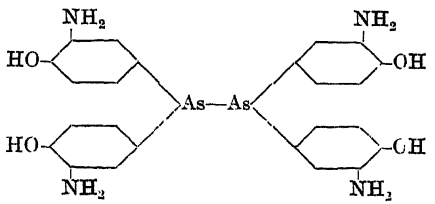


This is insoluble in alkali, but with concentrated hydrochloric acid yields colourless matted needles of $C_{12}H_{12}N_2AsCl.2HCl$, *i.e.* the *chloroarsine dihydrochloride*. This salt is readily soluble in water; alkali reprecipitates the oxide, and warming with hydrogen peroxide gives the acid.

[1] Baxter and Fargher, *Trans. Chem. Soc.*, 1919, 115, 1372.
[2] Wieland and Rheinheimer, *Annalen*, 1921, 423, 1.

3 : 3′-Diamino-4 : 4′-dihydroxydiphenylarsinic acid.[1]—3 : 3′-Dinitro-4 : 4′-dihydroxydiphenylarsinic acid (5·1 grams) in 80 c.c. of water and 24 c.c. of 2*N* sodium hydroxide solution is cooled to 0° C. and treated in one operation with 17·6 grams of sodium hydrosulphite. The temperature rises to about 30° C., and after completion of the reaction the solution is cooled, treated with 20 c.c. of 2*N* hydrochloric acid, and the arsinic acid salted out. It forms a sandy, crystalline precipitate, fairly soluble in water or methyl alcohol, sparingly soluble in ethyl acetate. The yield is 46 per cent.

3 : 3′ : 3″ : 3‴ - Tetramino - 4 : 4′ : 4″ : 4‴ - tetrahydroxytetraphenyldiarsine tetrahydrochloride,



2 grams of the preceding acid are heated with 20 c.c. of hypophosphorous acid (density 1·15) and a trace of hydriodic acid for one hour at 60° C. in an atmosphere of carbon dioxide. The mixture is then poured into 150 c.c. of hydrochloric acid, the precipitate collected, washed with a few drops of glacial acetic acid and a little dry ether, and dried in a vacuum. It is readily soluble in water or methyl alcohol.

4 : 4′-Diaminodiphenylarsinic acid.—This acid is a by-product of the Béchamp reaction between aniline and arsenic acid at 180° C. The crude aminophenylarsinic acid from the reaction is dissolved in hot sodium hydroxide solution, a little charcoal added, then 2 volumes of alcohol, and the whole filtered. From the filtrate the sodium salt of the primary acid separates out, which is removed and the filtrate evaporated. Alcohol is then added, the solid removed, and the alcohol evaporated off from the filtrate, which on neutralisation with hydrochloric acid gives the secondary acid as a resinous mass. This is dissolved in sodium hydroxide, filtered, and neutralised with dilute hydrochloric acid, when the product is precipitated as a powder. It is filtered off, washed, dried, and recrystallised from 50 per cent. acetic acid.[2] The yield is 2 to 3 per cent.[3]

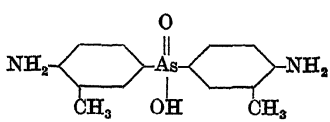
The following method of preparation of the acid is said to give a 20 to 30 per cent. yield in a fairly pure state :[4] 56·4 c.c. of commercial arsenic acid (density 1·88) are added to 1500 c.c. of aniline in a 2000 c.c. flask placed in an oil-bath. The mixture is aerated when the temperature reaches 100° C., and the bath maintained at 230° C. until about 1200 c.c. of aniline have distilled over. The mass is then cooled and 200 c.c. of 3*N* sodium hydroxide added, the whole well shaken, allowed to settle, and the aqueous layer drawn off. The extraction is repeated using a further 100 c.c. of alkali and the combined extract shaken with 5 to 10 grams of infusorial earth, then filtered through hardened filter-paper. The acid is precipitated as a gummy mass by acidification

[1] Fargher, *Trans. Chem. Soc.*, 1919, 115, 987. [2] Benda, *Ber.*, 1908, 41, 2367.
[3] Pyman and Reynolds, *Trans. Chem. Soc.*, 1908, 93, 1180.
[4] Kober and Davis, *J. Amer. Chem. Soc.*, 1919, 41, 451.

with 3*N* acetic acid, the mother-liquors being kept for a further crop of substances. The product is purified by dissolving in 3*N* sodium hydroxide and steam distilling or aerating whilst boiling to remove the aniline. The residue is extracted with water and the solution acidified with 3*N* acetic acid until a permanent precipitate is produced (this, containing impurities, is filtered and discarded), then the acid is completely precipitated. After standing for twelve hours it is filtered off and extracted with hot acetone, the extract after twelve hours' standing giving fairly pure acid.

4 : 4′-Diaminodiphenylarsinic acid melts with decomposition at 248° to 249° C., and crystallises in needles, soluble in hot water, excess of mineral acids, caustic alkali or alkali carbonates, hot alcohols and warm acetic acid, insoluble in ether, acetone, benzene, and chloroform. When silver nitrate is added to the neutral solution, white flocks separate, which are soluble in nitric acid and ammonium hydroxide. Barium chloride gives no precipitate, neither does magnesia mixture even on warming. When boiled with potassium iodide and sulphuric acid the arsinic acid gives a good yield of *p*-iodoaniline. The *sodium salt* crystallises from water in large monoclinic plates, melting in their water of crystallisation at 83° C., water being lost on further heating and the product resolidifying but not melting at 250° C. The crystals contain 5 to 6 molecules of water. The *barium salt* forms large, hard prisms, containing 7½ molecules of water, soluble in twice their weight of cold water, sparingly soluble in alcohol. The *diacetyl derivative* crystallises in rosettes of needles, M.pt. 275° C., readily soluble in boiling water, sparingly soluble in the usual organic solvents. When crystallised from water it retains 3 molecules of solvent; the *sodium salt* of this derivative contains 9 molecules of water and crystallises in prismatic needles. The *dioxalyl derivative* forms slender needles containing 4 molecules of water, and when nitrated with mixed acid gives rise to 3 : 3′-*dinitro*-4 : 4′-*diaminodiphenylarsinic acid*, a yellow, crystalline powder.[1]

2 : 2′-Diaminoditolyl-5-arsinic acid,

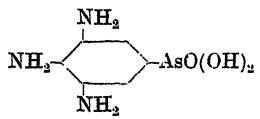


o-Toluidine arsenate (200 grams) and 400 grams of *o*-toluidine are shaken together and heated over a naked flame until liquid, then boiled gently under reflux for one hour, the temperature of the liquid being maintained at 180° to 185° C. The melt is cooled and extracted with 10 per cent. sodium carbonate solution until effervescence ceases; the aqueous solution is then evaporated to crystallising-point. 2-Aminotolyl-5-arsinic acid (sodium salt) separates and is removed. Evaporation of the mother-liquors and addition of alcohol give a further crop of the same product. The final liquors and alcohol washings are evaporated to remove alcohol and hydrochloric acid added, when 15 grams of a purple tar are obtained. This is dissolved in sodium hydroxide and evaporated, the *sodium salt* of the diaminoditolylarsinic acid separating in large, hard, prismatic needles, containing 7½ molecules

[1] Fargher, *loc. cit.*

of water, 5 of which are lost at 100° C. and the remainder at 130° C. Treatment with mineral acid yields the free arsinic acid, which crystallises from boiling water in highly refractive, pointed, microscopic needles, M.pt. 247° to 249° C. with decomposition. It is practically insoluble in cold water and the usual organic solvents, but dissolves readily in glacial acetic acid, dilute alkali, and mineral acids. When boiled with potassium iodide and dilute sulphuric acid it gives a good yield of 5-iodo-*o*-toluidine. The *diacetyl derivative* crystallises from boiling water in highly refractive, microscopic prisms, M.pt. 242° to 244° C., containing $\frac{2}{3}$ molecule of water of crystallisation. Its *sodium salt* contains 6 molecules of water and crystallises in radial clusters of silky needles, readily soluble in alcohol.

3 : 4 : 5-Triaminophenylarsinic acid,[1]



Dinitro-4-aminophenylarsinic acid (92·4 grams) is dissolved in 1400 c.c. of water and 200 c.c. of 10*N* sodium hydroxide at the ordinary temperature. An acid ferrous chloride solution, 3050 c.c. (prepared by diluting 1050 c.c. of ferrous chloride solution containing 19·6 per cent. by volume of iron with 2000 c.c. of water), is then stirred in. The mixture is acidified by adding an excess of sulphuric acid (1 : 1), filtered, and the iron sludge washed with warm water, acidification of the filtrate precipitating black flocks. These are removed and the filtrate treated with sodium hydroxide, using Congo red as indicator, the acid separating in brown needles. The yield is 46 grams, or 62 per cent.; the mother-liquors on evaporation yield a further 10 per cent. On recrystallisation the acid yields colourless needles, melting with decomposition at 170° to 175° C., sparingly soluble in cold water, more soluble in hot water, slightly soluble in hot alcohol, dilute acid, caustic alkali and alkali carbonates, readily soluble in warm sodium acetate and 50 per cent. acetic acid. It forms a yellowish *diazo-compound* which gives an orange *azo derivative* with resorcinol and a bluish-red derivative with R-salt. Alkaline solutions of the acid give transient red colorations with ferric cyanide and hypochlorite, and the ammoniacal solution slowly reduces silver nitrate. The solution in concentrated sulphuric acid is first coloured brown by a drop of nitric acid, then changes to olive green and finally becomes pure blue. Reduction of the amino-acid gives 3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene (p. 352).

Nitroaminoarylarsinic Acids.

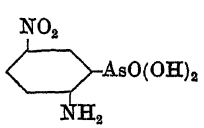
These acids occupy an intermediate position between the monoaminoarylarsinic acids on the one hand and the di- and tri-aminoarylarsinic acids on the other, since the latter are the reduction products of the nitroamino compounds. Where the amino-group is not substituted, the acids have been prepared by four methods: (1) By direct arsenation of nitroarylamines. (2) The aminoarylarsinic acid is converted to its

[1] Benda, *Ber.*, 1914, 47, 1316.

oxalyl or urethane derivative, which is nitrated, and then hydrolysed to restore the free amino-group. (3) Halogenated nitroarylarsinic acids are heated in an autoclave with ammonium hydroxide. (4) Nitro-aryldiamines are subjected to the Bart reaction. In method (1), by-products occur as usual, arsenation of *o*-nitroaniline yielding *bis*-(3-nitro-4-aminophenyl)-arsinic acid in addition to the main product, 3-nitro-4-aminophenylarsinic acid. Method (2) may give two isomers; *e.g.* nitration of the oxalyl derivative of 3-aminophenylarsinic acid produces 5-nitro-3-aminophenylarsinic acid, together with a small quantity of 2-nitro-3-aminophenylarsinic acid. The N-substituted acids are prepared by treating halogenated nitroarylarsinic acids with mono- or dialkylamines, arylsulphonamides, aminoacetic acid, etc., at ordinary pressures or in an autoclave, according to the reacting substances. In the cases of 3 : 5-dinitro-4-methylnitraminophenylarsinic acid, 3-nitro- and 2-nitro-4-phenylmethylglycinearsinic acids, the acids are prepared by direct nitration of the N-substituted derivative.

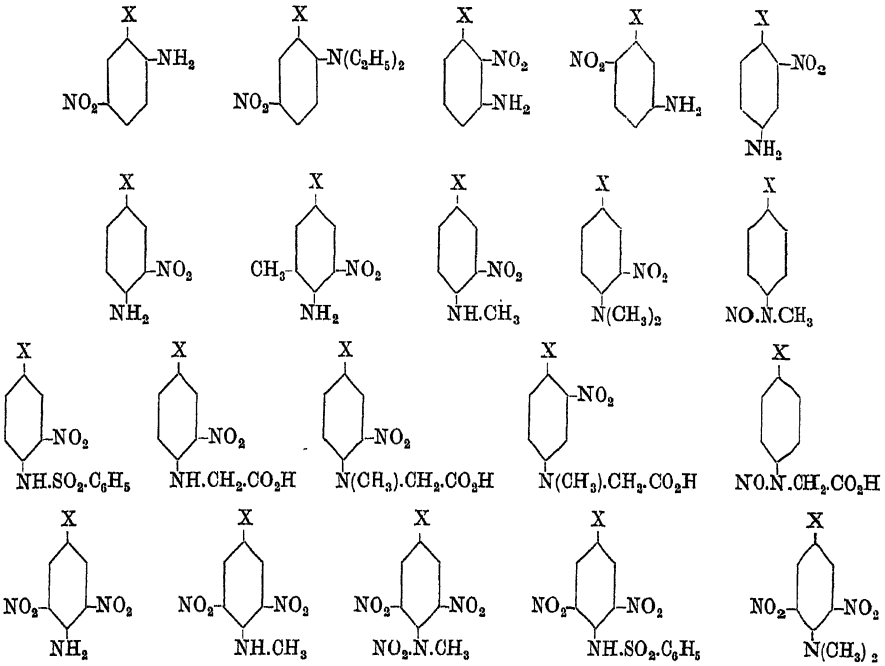
The nitroaminoarylarsinic acids are yellow or colourless solids, often soluble in hot water and alkali, but sparingly soluble in cold dilute mineral acids. The amino-group may be acetylated, diazotised, and coupled in the usual way. Mild reduction yields di- and triaminoaryl derivatives. When the sodium salts of 5-nitro-2-amino- and 3-nitro-4-aminophenylarsinic acids are boiled with potassium iodide and dilute sulphuric acid, the arsinic acid grouping is replaced by iodine, whilst bromine in alkali converts 3 : 5-dinitro-4-aminophenylarsinic acid to 4-bromo-2 : 6-dinitroaniline. This latter arsinic acid with 10 per cent. potassium hydroxide solution at 90° C. gives 3 : 5-dinitro-4-hydroxyphenylarsinic acid, and 6-nitro-3-aminophenylarsinic acid with concentrated potassium hydroxide solution yields 6-nitro-3-hydroxyphenylarsinic acid. The nitroaminoarylarsinic acids in the scheme on the opposite page are known, where $X = AsO(OH)_2$.

5-Nitro-2-aminophenylarsinic acid,[1]



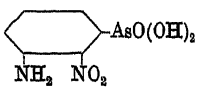
This acid is best obtained as follows :[2] 200 grams of arsenic acid are mixed with 700 grams of *p*-nitroaniline, and heated in an oil-bath at 210° C. until no more water is given off. The mass is then cooled to about 200° C. and 200 grams of sodium carbonate in 2500 c.c. of water stirred in, until the whole is strongly alkaline. The product is filtered off and the filtrate acidified by hydrochloric acid, when the arsinic acid is precipitated. It is filtered off, washed with cold water and recrystallised from boiling water. It separates in orange-yellow prisms, M.pt. 235° to 236° C., with decomposition. It is soluble in alkali, alkali carbonates, ammonium hydroxide, and alcohol, but only sparingly soluble in cold dilute acids. The amino-group can be acetylated, and it is readily diazotised and coupled to form azo-derivatives. When an alkali solution of the acid is treated with potassium iodide and sulphuric acid and boiled, the arsinic acid grouping is replaced by iodine.

[1] German Patent, 243693; British Patent, 29196 (1911).
[2] Benda, *Ber.*, 1911, 44, 3293.



5 - Nitro - 2 - diethylaminophenylarsinic acid results when 4-nitro-2-aminodiethylaniline is diazotised and the arsinic acid group introduced in the usual way. It crystallises from water in glistening, yellow needles, M.pt. 195° to 196° C., with decomposition. Reduction in alcoholic hydrochloric acid solution by sulphur dioxide in the presence of a trace of iodine yields *5-nitro-2-diethylaminophenyldichloroarsine*, consisting of deep yellow prisms from benzene, M.pt. 143° to 144° C.[1]

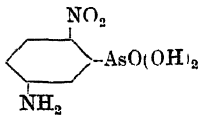
2-Nitro-3-aminophenylarsinic acid,[2]



3-Aminophenylarsinic acid is converted into its *urethane derivative* by means of ethyl chlorocarbonate, which derivative crystallises from hot water in shining needles, melting with decomposition at about 180° C. 289 grams of the urethane in about 5 parts of concentrated sulphuric acid are treated with 245 grams of nitric acid (26 per cent.) at 0° to 5° C., and the mixture stirred for thirty to sixty minutes at 15° C., then poured upon ice. The nitro-compound separates as a pale yellow, crystalline powder, which is saponified by heating with 8 to 10 parts of sulphuric acid (66° Bé.) at 70° to 80° C. until evolution of carbon dioxide ceases. The liquid is then poured upon ice, when the 2-nitro-3-aminophenylarsinic acid separates. It is purified by dissolving in alkali and reprecipitating with acid. It forms orange-yellow needles, sparingly soluble in hot water and dilute mineral acids, readily soluble in alkalis. Gentle reduction yields the corresponding *diamino-acid.*

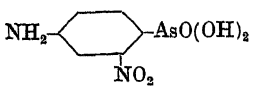
[1] Burton and Gibson, *J. Chem. Soc.*, 1927, p. 2387.
[2] German Patent, 256343.

6-Nitro-3-aminophenylarsinic acid,[1]



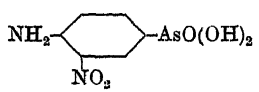
3-Aminophenylarsinic acid is converted into its *oxalyl derivative*, which crystallises from water in needles. This product, in 3 parts of concentrated sulphuric acid at 0° to 5° C., is treated with the requisite amount of nitric acid (26 per cent.), stirred at the ordinary temperature, and the liquid poured upon ice. The precipitated nitro-compound is boiled with 10 parts of 2*N* hydrochloric acid, the required arsinic acid separating in yellow needles on cooling. Boiling with concentrated potassium hydroxide converts the acid into 6-nitro-3-hydroxyphenylarsinic acid. In the mother-liquors of the foregoing nitration a very small quantity of 2-nitro-3-aminophenylarsinic acid is present.[2]

2-Nitro-4-aminophenylarsinic acid,[3]



4000 grams of 2-nitro-4-acetyl-*p*-phenylenediamine in 10 litres of concentrated hydrochloric acid and 15 litres of water are diazotised in the usual way. 5000 grams of sodium arsenite in 10 litres of water are added and the mixture gradually heated by blowing in steam. As soon as the diazo-reaction has finished, the solution is filtered, and the filtrate boiled under reflux for several hours. On cooling, the arsinic acid separates out in orange-yellow needles, darkening at 240° C., and melting with decomposition at about 258° C. It is sparingly soluble in cold water, dilute mineral acids, and alcohol, more soluble in methyl alcohol and acetic acid, readily soluble in alkalis and sodium acetate. The *acetyl derivative* forms microcrystalline needles, readily soluble in hot water, alcohol, acetic acid, and alkali, sparingly soluble in dilute mineral acids.

3-Nitro-4-aminophenylarsinic acid,



This acid may be prepared in several ways: (1) 281 grams of 4-chloro-3-nitrophenylarsinic acid and 500 c.c. of 15 per cent. ammonium hydroxide are heated together in an autoclave for two hours at 120° C.[4] The arsinic acid is precipitated from the red solution by the addition of concentrated hydrochloric acid. (2) By heating 4-aminophenylarsinic acid with crystallised oxalic acid in an oil-bath at from 130° to 140° C., and finally at 160° C., *oxalyl-4-aminophenylarsinic acid* is produced (see p. 211). 116 grams of the latter in 300 c.c. of concentrated sulphuric acid are well stirred, and a mixture of 26 c.c. of nitric acid (density 1·4) and

[1] German Patent, 261643.

[2] For the determination of the amino-group in nitroarsanilic acid, see Semiganovsky, *Zeitsch. anal. Chem.*, 1927, *72*, 295.

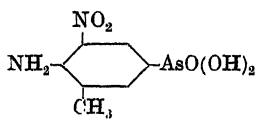
[3] German Patent, 267307; British Patent, 24668 (1912).

[4] German Patent, 285604.

26 c.c. of concentrated sulphuric acid slowly run in. The temperature is then allowed to rise to 15° or 20° C., and after stirring for thirty minutes, the whole is poured into 1500 c.c. of water. The nitro-oxalyl compound separates, and the oxalyl residue is split off by boiling the mixture for one hour. The yield is about 86 per cent.[1] (3) Instead of nitrating the oxalyl derivative as above, the urethane derivative may be used.[2] (4) *o*-Nitroaniline and arsenic acid are heated at 200° to 210° C. for ten minutes and the melt extracted with 10 per cent. sodium hydroxide solution, from which extract the arsinic acid is precipitated by acid.[3] In this preparation *bis-(3-nitro-4-aminophenyl)-arsinic acid* results in small yield as a by-product.

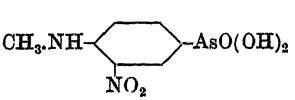
3-Nitro-4-aminophenylarsinic acid crystallises from hot 50 per cent. acetic acid in yellow needles, decomposing above 300° C. It is readily soluble in boiling water, alcohols, alkalis, and concentrated mineral acids, insoluble in acetone, ether, hydrocarbons, and dilute mineral acids. With concentrated hydriodic acid it yields *3-nitro-4-aminophenyldi-iodoarsine*, $NH_2.C_6H_3NO_2.AsI_2$. The *sodium salt* of the acid with potassium iodide and sulphuric acid gives 4-iodo-3-nitroaniline.[4]

5-Nitro-4-amino-3-methylphenylarsinic acid,[5]



6 grams of 4-oxalylamino-3-methylphenylarsinic acid in 20 c.c. of sulphuric acid are gradually treated with a mixture of 1·2 c.c. of nitric acid (density 1·4) and 1·2 c.c. of sulphuric acid, the temperature being kept below 15° C. When the reaction is complete, the liquid is poured into 100 c.c. of water, boiled under reflux for two hours, then cooled. About 4·6 grams of acid separate. It crystallises in slender needles consisting of a mixture of the yellow anhydrous form and the orange hydrated form. The mass gradually changes completely into the latter variety, which contains 1½ molecules of water of crystallisation.

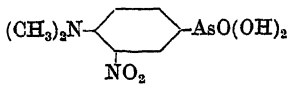
3-Nitro-4-methylaminophenylarsinic acid,[6]



281 grams of 4-chloro-3-nitrophenylarsinic acid in 680 c.c. of 5*N* sodium hydroxide are treated with 160 grams of methylamine hydrochloride and the solution heated in an autoclave for three hours at about 100° C. The dark red solution is acidified with hydrochloric acid, when the arsinic acid separates as a yellow powder. It explodes on heating, is soluble in alkali, sodium acetate, and hot alcohol, sparingly soluble in cold alcohol, and insoluble in acetone, ether, water, and dilute acids.

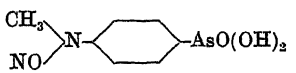
[1] Bertheim, *Ber.*, 1911, 44, 3093; see German Patent, 231969.
[2] German Patent, 232879.
[3] Mameli, *Boll. Chim. Farm.*, 1909, 48, 682; see Lieb and Winterstein, *Ber.*, 1923, 56, [B], 428.
[4] Mameli, *loc. cit.*
[5] Fargher, *Trans. Chem. Soc.*, 1919, 115, 989.
[6] German Patent, 285604.

3-Nitro-4-dimethylaminophenylarsinic acid,



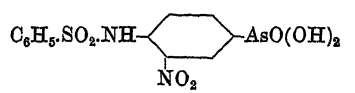
4-Chloro-3-nitrophenylarsinic acid (141 grams) is dissolved in 500 c.c. of hot alcohol, treated with 150 grams of a 33 per cent. alcoholic solution of dimethylamine, and the whole heated for a time on the water-bath. The alcohol is removed in a vacuum, and on cooling, the arsinic acid separates out[1]. This acid may also be obtained by direct nitration of *p*-dimethylaminophenylarsinic acid (p. 222).[2] Prepared by the former method it is said to explode on heating, and is readily soluble in water and acids, but the product from the latter method is stated to have a melting-point of 204° C., and is sparingly soluble in hot water and alcohol. It crystallises in yellow needles.[3]

4-Methylnitrosoaminophenylarsinic acid,[4]



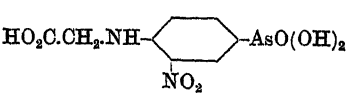
The requisite amount of *p*-dimethylaminophenylarsinic acid in 300 c.c. of 60 per cent. sulphuric acid at 0° C. is treated with 84 grams of sodium nitrite in 500 c.c. of 60 per cent. sulphuric acid and the whole poured upon ice. The required acid separates in practically colourless, spear-shaped crystals. It has also been prepared by nitrating *p*-dimethyl-aminophenylarsinic acid in dilute solution.

3-Nitro-4-benzenesulphamidophenylarsinic acid,[5]



is obtained when 4-chloro-3-nitrophenylarsinic acid and benzene sul-phonamide in 5*N* sodium hydroxide solution are heated in an autoclave for two hours at 120° C., and then for nine hours at 150° C. The product is precipitated by acid and extracted with ether. It is pale brown, and gives a yellow solution in alkali. It dissolves in hot water and hot alcohol, is moderately soluble in acetone, sparingly soluble in ether.

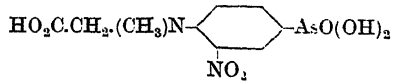
3-Nitro-4-phenylglycine-1-arsinic acid,



results when 4-chloro-3-nitrophenylarsinic acid and aminoacetic acid in 5*N* sodium hydroxide are heated under reflux for thirty hours at 50° C. The product is precipitated by dilute sulphuric acid. It is yellow in colour and is soluble in hot alcohol, hot water, and alkali, insoluble in acetone, ether, and acetic acid. It explodes feebly on heating.

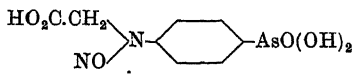
[1] German Patent, 285604.
[2] French Patent, 474056; Karrer, *Ber.*, 1913, 46, 515.
[3] See French Patents, 449373, 451078; British Patent, 22521 (1914).
[4] French Patents, 474056, 479646; British Patent, 22521 (1914).
[5] German Patent, 285604.

3-Nitro-4-phenylmethylglycine-1-arsinic acid,[1]



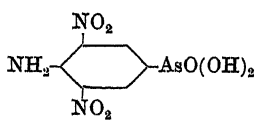
The C-amyl ester of phenylmethylglycine arsinic acid (50 grams), in 300 grams of sulphuric acid and 100 grams of water, is nitrated by adding one molecular equivalent of nitric acid in 30 grams of sulphuric acid (1 : 3). The free acid is then obtained by hydrolysing the nitrated ester with sodium hydroxide. If, however, the same amount of C-amyl ester is dissolved in 228 grams of concentrated sulphuric acid and 152 grams of water and nitrated by adding one molecular equivalent of nitric acid in 30 grams of sulphuric acid (3 : 2), the nitro-group enters the *ortho* position to the arsenic, yielding *2-nitro-4-phenylmethylglycine-1-arsinic acid.*

4-N-Nitrosophenylglycine-1-arsinic acid,[2]



This compound is obtained as the *amyl ester* by adding sodium nitrite to the amyl ester of phenylmethylglycine-4-arsinic acid in dilute sulphuric acid. It separates from acetic acid in colourless crystals, decomposing at 150° C. The nitroso-group is eliminated on heating with concentrated hydrochloric acid, the N-alkyl acid being produced.

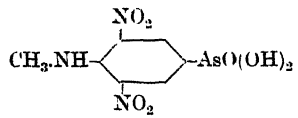
3 : 5-Dinitro-4-aminophenylarsinic acid,[3]



4-Aminophenylarsinic acid (44 grams) is stirred into 120 c.c. of concentrated sulphuric acid at 5° to 10° C. and nitrated by adding 56 grams of mixed acid, containing 44·7 per cent. of nitric acid, the temperature being kept below 15° C. After stirring for three hours, the mixture is poured upon 500 grams of ice, and the crude product which separates is filtered off. This consists of 3 : 5-dinitro-4-aminophenylarsinic acid and 2 : 4 : 6-trinitroaniline, the latter being removed by dissolving the mixture in 2*N* sodium hydroxide and shaking the solution with ether, in which the nitrated aniline dissolves. The alkaline solution is separated and treated with 2*N* sulphuric acid, the dinitroaminophenylarsinic acid being precipitated in golden yellow plates. It is purified by dissolving in sodium hydroxide, reprecipitating with acetic acid, and recrystallising from 50 per cent. acetic acid. It separates in brownish-yellow, glistening needles, readily soluble in alkali, alkali carbonates, and sodium acetate, sparingly soluble in water, alcohol, and dilute acids. Treatment with bromine in alkaline solution gives 4-bromo-2 : 6-dinitroaniline. When heated with 10 per cent. potassium hydroxide at 90° C. until evolution of ammonia ceases, the dinitro-compound is converted into 3 : 5-dinitro-4-hydroxyphenylarsinic acid (p. 291).

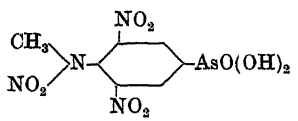
[1] French Patent, 473705.
[2] British Patent, 22522 (1914); French Patent, 479646.
[3] Benda, *Ber.*, 1912, 45, 53.

3 : 5-Dinitro-4-methylaminophenylarsinic acid,[1]



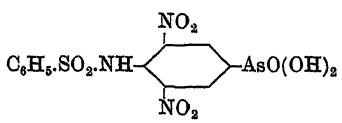
4-Chloro-3-nitrophenylarsinic acid is nitrated in sulphuric acid solution, when *4-chloro-3 : 5-dinitrophenylarsinic acid* is formed. The latter is a white, crystalline compound, readily soluble in alcohol, hot water, and concentrated hydrochloric acid, and explodes on heating. The 4-chloro-3 : 5-dinitrophenylarsinic acid obtained from 163 grams of the mononitro-compound is dissolved in 500 c.c. of alcohol, 225 c.c. of 15 per cent. alcoholic methylamine solution added, and the whole gently warmed for a short time on the water-bath. The greater part of the alcohol is then removed in a vacuum and the residue treated with hydrochloric acid, the 4-methylamino-derivative separating as a yellow, crystalline powder. It is readily soluble in hot alcohol, acetic acid, and sodium acetate, insoluble in acetone, ether, and mineral acids. It explodes on heating.

3 : 5-Dinitro-4-methylnitroaminophenylarsinic acid,[1]



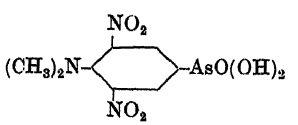
This may be prepared in two ways : (1) 3-Nitro-4-methylaminophenylarsinic acid (148 grams) is warmed on the water-bath for two hours with 550 grams of fuming nitric acid. (2) Dimethylanilinearsenoxide is nitrated by mixed acid.[2] For the 2-chloro- and 2-bromo-derivatives of this acid, see p. 355.

3 : 5-Dinitro-4-benzenesulphamidophenylarsinic acid,[1]



326 grams of 4-chloro-3 : 5-dinitrophenylarsinic acid, 168 grams of benzene sulphonamide, and 620 c.c. of *5N* sodium hydroxide solution are heated for two hours in an autoclave at 120° C., then for six hours at 150° C. The product is precipitated by acid and extracted with ether. It is a brownish compound, exploding when heated, soluble in hot water, alcohol, and acetic acid, insoluble in ether and dilute acids.

3 : 5-Dinitro-4-dimethylaminophenylarsinic acids,



[1] German Patent, 285604.
[2] German Patent, 285572; also 293842.

Two isomeric dinitro-compounds may be obtained by nitrating *p*-dimethylaminophenylarsinic acid. One forms yellow, prismatic crystals, melting at 161° C. with decomposition, and appears to be the 3 : 5-dinitro acid; the second crystallises in red, four-sided plates, melting with decomposition at 158° C. The latter is less soluble in hot water than the former.[1]

[1] French Patent, 479646; British Patent, 22522 (1914). For the nitration of methylarsanilic acid, acetylmethylarsanilic acid, and nitrosomethylaniline-*p*-arsinic acid, see German Patent, 294731. The diazotisation of nitroaminoarylarsinic acid and coupling of the product with the usual compounds is dealt with in German Patent, 243648; British Patent, 15438 (1911).

CHAPTER VII.

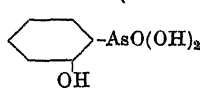
ARYLARSINIC ACIDS (*continued*).

Hydroxyarylarsinic Acids.

Application of the Béchamp reaction to phenols yields hydroxy-acids, in which the arsenic enters the nucleus in the *para* position to the hydroxyl group. The process is not so simple as it appears at first sight, for, in addition to these *para*-substituted acids, a number of by-products always occur—*e.g.* the arsenation of phenol yields *p*-hydroxyphenylarsinic acid as the main product, and *o*-hydroxyphenylarsinic acid, 4 : 4′-dihydroxydiphenylarsinic acid, and 2 : 4′-dihydroxydiphenylarsinic acid as by-products. Direct arsenation of resorcinol yields *m*-dihydroxy-acids, but 3 : 4-dihydroxyphenylarsinic acid is obtained by treating *p*-hydroxyphenylarsinic acid in sodium hydroxide with potassium persulphate. The acids may be more conveniently prepared by applying Bart's reaction to aminophenols, or replacing the amino-group by the hydroxyl-group in aminoarylarsinic acids by the aid of the diazo reaction. Unlike the aminoarylarsinic acids, the hydroxyaryl acids may be directly halogenated; free halogens, however, are not employed, but halogenated salts.

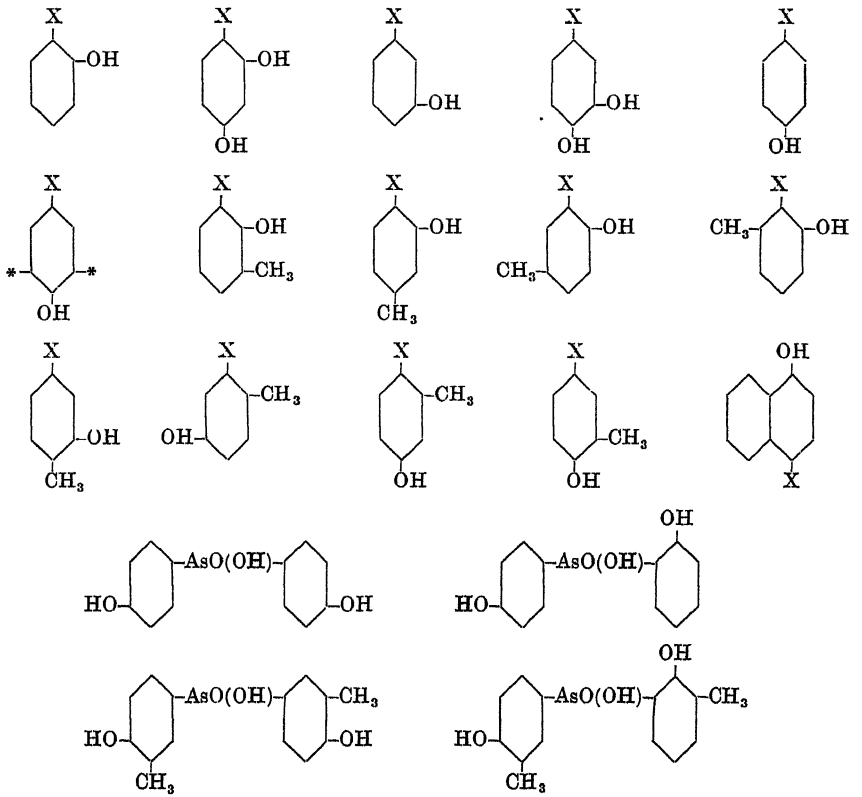
Many of the acids, their sodium salts and acetyl derivatives, crystallise well from aqueous solution, and some couple with diazotised sulphanilic acid. Those containing the hydroxyl group in the *ortho* position to the arsinic acid group give reddish colorations with ferric chloride solution. *p*-Hydroxyphenylarsinic acid, when treated with bromine water, is decomposed, forming tribromophenol. The methoxyarylarsinic acids are dealt with in a separate section (p. 278). The principal hydroxyarylarsinic acids are given in the scheme on the opposite page, where $X=AsO(OH)_2$.

o-Hydroxyphenylarsinic acid (*Phenol-o-arsinic acid*),



o-Aminophenol (10·9 grams) is suspended in 400 c.c. of water and dissolved by stirring in 35 c.c. of hydrochloric acid. The solution is diazotised and introduced into a mixture containing 60 c.c. of 4*N* sodium arsenite solution, 100 c.c. of 10*N* sodium hydroxide solution, and 250 c.c. of water, the whole being well stirred during the operation. The mass becomes reddish-brown and nitrogen is evolved. To separate the by-products the liquid is concentrated to 250 c.c., acidified with hydrochloric acid, and filtered. The filtrate is neutralised with sodium hydroxide and allowed to remain on the water-bath until the *sodium salt* commences to crystallise, further crops being obtained after standing for twenty-four hours in the cold. Yield, 22 grams. This sodium salt may be recrystallised from dilute acid. It is readily soluble in

water and is more difficult to salt out with sodium chloride than the *p*-isomeride. In alcohol it is sparingly soluble and in ether insoluble. To isolate the free acid, the solution of the sodium salt is made acid to Congo red, boiled with charcoal, and evaporated to dryness *in vacuo*. The acid is extracted from the residue by alcohol or acetone.[1]



o-Hydroxyphenylarsinic acid is formed as a by-product in the direct arsenation of phenol, and the following process has been devised for recovering it.[2] The alcoholic mother-liquors from the sodium salt of *p*-hydroxyphenylarsinic acid are concentrated to remove the alcohol, then diluted to 750 c.c., and treated with sodium hydroxide until the solution is strongly alkaline to phenolphthalein. An excess of concentrated barium hydroxide solution is added, and on rubbing the vessel the *barium salt* of the *o*-hydroxyphenylarsinic acid separates as a heavy powder. This salt is suspended in water and the free acid liberated by sulphuric acid, the mixture filtered, and the filtrate concentrated to crystallising-point and cooled. By this method a 14-gram yield is obtained, together with 40 grams of the *p*-isomeride, when 200 grams of phenol are arsenated with 480 grams of 80 per cent. aqueous arsenic acid.

[1] Bart, *Annalen*, 1922, 429, 90.

[2] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1440.

A third method of preparation uses *o*-aminophenylarsinic acid (*o*-arsanilic acid) as the starting-point. 11 grams of this acid in 100 c.c. of normal hydrochloric acid are cooled and diazotised with 50 c.c. of normal sodium nitrite solution. Most of the nitrogen is allowed to come off at room temperature and the reaction completed by gently heating the mixture for an hour on the water-bath. The filtrate is boiled with charcoal, treated with 50 c.c. of normal sodium hydroxide solution, and concentrated. The acid crystallises out and is filtered off and washed with ice water. Yield, 9·5 grams.[1]

The acid also occurs as a by-product in the preparation of *o*-phenylenediarsinic acid from *o*-arsanilic acid.[2]

o-Hydroxyphenylarsinic acid crystallises from water in rosettes of colourless needles, softening at 185° C. and melting at 196° C.[3] (191° C.[4]). It is soluble in alcohols or hot glacial acetic acid, sparingly soluble in hot acetone and chloroform, insoluble in ether. It gives a wine-red colour even with dilute solutions of ferric chloride; the *meta*- and *para*-acids give no such coloration. Its alcoholic solution couples with diazotised sulphanilic acid, giving a bright orange solution. The acid is precipitated from concentrated solutions of its salts by hydrochloric acid, but redissolves if excess of acid is used; acetic acid, however, does not readily displace it from its salts. The *sodium salt* is precipitated from aqueous solution by alcohol; it crystallises in hexagonal plates, containing 4 molecules of water. A *basic barium salt* has been described, which separates as rosettes of colourless, microscopic needles.

m-Hydroxyphenylarsinic acid [5] is prepared in a similar way to the *ortho*-acid, except that sulphuric acid is used instead of hydrochloric acid. 11 grams of *m*-arsanilic acid give 8 grams of the hydroxy-acid. It crystallises in aggregates of rhombic crystals, melting slowly at 159° to 173° C. It is soluble in water and alcohols at ordinary temperatures, somewhat soluble in hot acetone, soluble in boiling acetic acid, and practically insoluble in chloroform or benzene. The *sodium salt* separates in rosettes of flat needles, yielding insoluble precipitates with salts of the heavy metals.[6]

p-Hydroxyphenylarsinic acid has been prepared (1) by direct arsenation of phenol, (2) by the diazotisation of *p*-aminophenol or *p*-arsanilic acid. The details are as follows:

(1) 150 grams of phenol, 300 grams of arsenic acid (B.pt. 150° C.), and 600 grams of xylene, are placed in a 1·5-litre flask, fitted with stirring gear and a return hot-water condenser, and heated to boiling on an oil-bath for eight hours. The mixture is then diluted with 1·5 litres of water and finely ground barium hydroxide added until slight alkalinity is produced, then filtered. The xylene is separated off and washed with a little water, the washings being added to the aqueous extract, which is freed from barium and sulphate ions and evaporated to about 1·5 litres on the steam-bath. The extract is then neutralised to litmus with sodium hydroxide and filtered, the filtrate being evaporated to crystallising-point; 2·5 volumes of alcohol are then added. The crystals are removed and washed with a little alcohol. The yield of anhydrous salt is about 126 grams. The free acid is released from the sodium salt

[1] Jacobs and Heidelberger, *loc. cit.*
[2] Kalb, *Annalen*, 1921, 423, 39.
[3] Jacobs and Heidelberger, *loc. cit.*
[4] Bart, *loc. cit.*
[5] Jacobs and Heidelberger, *loc. cit.*
[6] See Hamilton and Johnson, *J. Amer. Chem. Soc.*, 1926, 48, 1406.

by sulphuric acid, the mixture evaporated, and the residue extracted with acetone to take out the arsinic acid.[1]

(2) The preparation from *p*-aminophenol is carried out in a similar manner to that for *o*-hydroxyphenylarsinic acid from *o*-aminophenol, 20 grams of crude sodium salt being obtained from 10·9 grams of *p*-aminophenol.[2]

The method of preparation of the acid from *p*-aminophenylarsinic acid is as follows: 217 grams of the latter acid in 2500 c.c. of water and 81·6 c.c. of concentrated sulphuric acid are diazotised at 0° C. with 70 grams of sodium nitrite in 350 c.c. of water. The filtered diazo-solution is heated to about 70° C., then boiled and treated with barium carbonate until free from sulphuric acid. The barium sulphate is removed, the filtrate treated with 20 grams of anhydrous sodium sulphate and evaporated to crystallising-point. The yield of sodium salt is about 75 per cent.[3]

p-Hydroxyphenylarsinic acid crystallises from glacial acetic acid in small, yellow prisms, decomposing at 170° to 174° C.; it is readily soluble in water or alcohols, sparingly soluble in acetone, ethyl acetate, or ether. The acid itself, its 3-*nitro-derivative*, and its *barium salt*, all occur in two different crystalline forms,[4] which are regarded as possessing the benzenoid and quinonoid structures respectively. In the case of the 3 : 5-dinitro-derivative only one crystalline form is obtainable. A similar isomerism exists in the case of 4-hydroxy-3-methylphenylarsinic acid. The two isomeric forms of *p*-hydroxyphenylarsinic acid have the following properties: (*a*), obtained by diazotising *p*-arsanilic acid, forms pinkish, monoclinic crystals, the parameters of which are $a : b : c = 0{\cdot}4483 : 1 : 0{\cdot}4936$; (*b*), obtained by direct arsenation of phenol with arsenic acid,[5] forms yellowish, monoclinic crystals, $a : b : c = 2{\cdot}465 : 1 : 0{\cdot}7968$. In aqueous solution (*b*) is slowly converted into (*a*); the change occurs more quickly on boiling and seeding with a crystal of (*a*). The *sodium* and *barium salts* from (*b*) are more stable than the corresponding isomeric salts from (*a*). With ferric chloride the acid gives no coloration; with bromine water it is decomposed, yielding tribromophenol. Gentle boiling with acetic anhydride gives the *acetyl derivative*, separating from acetone in matted clusters of fine needles, unmelted at 250° C., soluble in cold water but sparingly soluble in cold alcohol or acetone. The *sodium salt* of the acetyl derivative crystallises in clusters of silky needles, containing 3 molecules of water.[6] This salt, when treated with molybdic acid and then with guanidinium chloride, gives a *guanidinium salt*, $(CN_3H_6)_2\left[As\begin{matrix}C_6H_4.OH\\(MoO_4)_3\end{matrix}\right].2H_2O$, consisting of white needles, and a more soluble salt crystallising in plates.[7]

[1] Hamilton and Johnson, *loc. cit.*; see German Patent, 205616; British Patents, 3087, 6322 (1915); Conant, *J. Amer. Chem. Soc.*, 1919, 41, 431; Jacobs and Heidelberger, *ibid.*, p. 1440; Christiansen and Norton, *ibid.*, 1923, 45, 2188; *Organic Syntheses*, vol. iv. p. 65 (Wiley & Sons).

[2] Bart, *Annalen*, 1922, 429, 91; see German Patents, 250264, 268172.

[3] Bertheim, *Ber.*, 1908, 41, 1853; Barrowcliff, Pyman, and Remfry, *Trans. Chem. Soc.*, 1908, 93, 1893; German Patents, 205616, 223796.

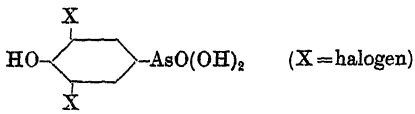
[4] Gilta, *Compt. rend.*, 1927, 184, 1073.

[5] Gilta, *Bull. Soc. chim. Belg.*, 1928, 37, 253.

[6] Barrowcliff, Pyman, and Remfry, *loc. cit.*

[7] Rosenheim and Bilecki, *Ber.*, 1913, 46, 539. For *quinine salts* of hydroxyphenylarsinic acids, see British Patent, 259153 (1926).

3 : 5-Dichloro- and **dibromo-p-hydroxyphenylarsinic acids,**[1]

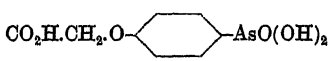


(X = halogen)

To obtain these acids, sodium *p*-hydroxyphenylarsinate (285 grams) in 2850 grams of water is poured into sodium hypochlorite or hypobromite solution containing 142 grams of chlorine or 320 grams of bromine. After twelve hours the mixture is cooled in ice, stirred, and acidified with concentrated hydrochloric acid. The dihalogen-substituted acid separates, is filtered off, and extracted with ether to remove trihalogenated phenol. The compounds do not decompose at 260° C., are crystalline, and sparingly soluble in cold water. They readily dissolve in alcohols or acetone, but are insoluble in ether or chloroform.

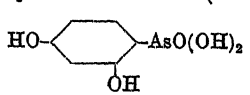
3 : 5-Di-iodo-p-hydroxyphenylarsinic acid is isolated as follows: 285 grams of sodium *p*-hydroxyphenylarsinate and 220 grams of potassium iodate in 6000 c.c. of water are treated with 3300 c.c. of 25 per cent. sulphuric acid and the mixture heated to 80° C. The whole is rapidly stirred and 220 grams of potassium iodide in 2500 c.c. of water slowly added until no more iodine vapour is evolved. On cooling, the di-iodo-compound separates out. It has similar properties to the preceding dihalogen derivatives.

p-Arsinophenoxyacetic acid,[2]



To prepare this acid, *p*-hydroxyphenylarsinic acid (218 grams) is treated with 375 c.c. of water in a two-litre round-bottom flask, and a solution of 180 grams of sodium hydroxide in 375 c.c. of water added. The mixture is shaken until homogeneous, cooled to 40° or 50° C., treated cautiously with 189 grams of chloracetic acid, and the solution boiled for four hours under reflux. It is then cooled to 20° C., filtered, and the required acid precipitated by adding 200 c.c. of hydrochloric acid (density 1·19), crystallisation being induced, if necessary, by rubbing the vessel with a glass-rod. The precipitate is filtered off on a 10-cm. Büchner funnel, washed with three successive portions of cold water and recrystallised from 2000 c.c. of hot water, using charcoal as a decoloriser, if necessary. The crystals are twice washed with 100 c.c. of cold water, then with 25 c.c. of acetone, and finally with 25 c.c. of ether. After drying at 110° C. for one hour, a pure white, anhydrous product is obtained. The yield is 110 to 120 grams (40 to 43 per cent.), and the purity is about 99 per cent.

2 : 4-Dihydroxyphenylarsinic acid (Resorcinol arsinic acid),[3]

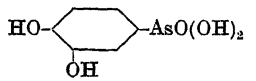


Resorcinol, 110 grams, and 171 grams of commercial arsenic acid (75° Bé., or about 83 per cent.), are heated on the water-bath for several

[1] German Patent, 235430.
[2] *Organic Syntheses*, vol. vii. p. 4 (Wiley & Sons); compare German Patent, 216270.
[3] Bauer, *Ber.*, 1915, 48, 509; see German Patent, 272690.

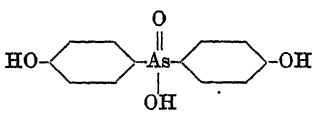
hours, when a thick, crystalline mass results, which is heated for two days. The product is triturated with acetic acid, filtered, and washed with acetic acid until free from impurities. Yield, 145 grams. It melts at 191° C., is very soluble in water and alcohols, sparingly soluble in acetic acid or acetone, and insoluble in ether, benzene, and ligroin. With ferric chloride solution a dark red colour is produced; when the acid is warmed with ammoniacal silver nitrate, no reduction of the latter takes place.

3 : 4-Dihydroxyphenylarsinic acid,[1]



p-Hydroxyphenylarsinic acid (120 grams) in 1800 c.c. of water is treated with 200 c.c. of 10*N* sodium hydroxide solution, then with 135 grams of powdered potassium persulphate, and the whole stirred for forty-eight hours. The product is diluted with 650 c.c. of hydrochloric acid (density 1·12) and boiled for fifteen minutes. To the mixture 500 c.c. of concentrated ammonium hydroxide are added and an excess of magnesia mixture. The whole is stirred in the presence of animal charcoal, filtered, heated to boiling, then cooled, when the *magnesium salt* of the dihydroxy-acid separates as a microcrystalline powder. The free acid is liberated by hydrochloric acid (density 1·12), using 13 c.c. of acid to 11 grams of salt. It is very soluble in water, gives a green coloration with ferric chloride and reduces cold ammoniacal silver nitrate solution, this distinguishing it from *p*-hydroxyphenylarsinic acid.

4 : 4′-Dihydroxydiphenylarsinic acid,



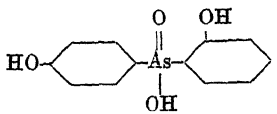
This has been obtained by two methods: (1) 10 grams of diaminodiphenylarsinic acid are dissolved in 200 c.c. of water containing 25 c.c. of 10*N* hydrochloric acid (or the equivalent amount of sulphuric acid), and the whole diazotised with normal sodium nitrite solution. The mixture is heated to boiling by passing in steam, then saturated with sodium chloride and sodium acetate, when the dihydroxy-acid is precipitated.[2] (2) The mother-liquors obtained from the barium salt of *o*-hydroxyphenylarsinic acid (p. 269) are treated with hydrochloric acid until only a faint alkalinity persists, then concentrated to about 1000 c.c. bulk. The cool solution is treated with hydrochloric acid (1 : 1) until definitely acid to Congo red, an oil separating out. On rubbing the sides of the vessel the oil solidifies, and after four hours the product is filtered off and washed with water. It is dissolved in 50 per cent. acetic acid, colourless, prismatic crystals separating on cooling.[3]

The product obtained by method (1) melts at 239° C. (Benda), 259° C. (Fargher), but that from method (2) is said to melt at 250° to 251° C. The acid is readily soluble in alcohols, sparingly soluble in

[1] German Patent, 271892.
[2] Benda, *Ber.*, 1908, 41, 2367; see Fargher, *Trans. Chem. Soc.*, 1919, 115, 986.
[3] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1440.

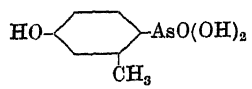
ether, and insoluble in benzene and chloroform. Its alcohol solutions couple with diazotised sulphanilic acid to give orange solutions. The pure compound does not give a red coloration with ferric chloride. Magnesia mixture gives no precipitate.

2 : 4′-Dihydroxydiphenylarsinic acid,



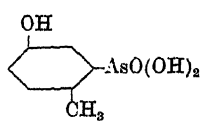
The mother-liquors obtained from 4 : 4′-dihydroxydiphenylarsinic acid by method (2) in the foregoing, after standing for about four hours, deposit heavy aggregates of stout, glistening prisms. These are filtered off after forty-eight hours and washed with water. The product separates from 50 per cent. acetic acid in prisms, M.pt. 215° to 217° C. with gas evolution, and gives a wine-red colour with ferric chloride.

2-Methyl-4-hydroxyphenylarsinic acid,



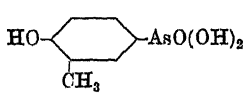
The preparation of this acid is carried out on the same lines as the arsenation of *o*-cresol (see preparation of the 3-methyl acid), the *o*-cresol being replaced by *m*-cresol and the temperature of the mixture maintained at 140° to 146° C. for seven hours. From 720 grams of syrupy arsenic acid and 300 grams of *m*-cresol, a yield of 138·8 grams of the arsinic acid is obtained in the form of its *sodium salt*. The free acid is obtained from the sodium salt by the aid of hydrochloric acid. The arsinic acid crystallises from hot water in white needles, which gradually melt at 194° to 195° C.

5-Hydroxy-2-methylphenylarsinic acid,[1]



is prepared from 5-amino-2-methylphenylarsinic acid. It melts at 184° to 185° C., and gives no coloration with ferric chloride.

3-Methyl-4-hydroxyphenylarsinic acid,



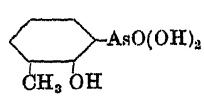
This acid is obtained in the usual manner by the diazotisation of 3-methyl-4-aminophenylarsinic acid.[2] It is also isolated amongst other products by the direct arsenation of *o*-cresol, the operations being carried out as follows :[3] Syrupy arsenic acid (540 grams) is heated in a beaker until the temperature reaches 150° C., then added to 224 grams of *o*-cresol (M.pt. 31·2° C.) and the whole heated under reflux in an oil-bath at

[1] Finzi, *Atti II Cong. Naz. Chim. Pura. Appl.*, 1926, p. 1302.
[2] Benda and Kahn, *Ber.*, 1908, 41, 1672 ; see German Patent, 206456.
[3] Christiansen, *J. Amer. Chem. Soc.*, 1923, 45, 800 ; see also German Patent, 205616.

155° to 160° C. for five and a half hours. The mixture is then diluted with 2000 c.c. of water, and after standing for some hours is filtered from tar, the red filtrate being mechanically stirred whilst solid barium hydroxide is added until the liquid is faintly alkaline to litmus. The barium arsenate is filtered off and the filtrate treated with sulphuric acid until free from barium and sulphate ions. The barium sulphate is removed and the filtrate added to the extract obtained by boiling the tar formed during the reaction with aqueous sodium hydroxide and acidifying with hydrochloric acid. The solution is evaporated as far as possible on a steam-bath, extracted with acetone, and the solvent removed. A red syrup remains which contains several arsinic acids. The syrup is diluted with water and treated with sodium hydroxide until slightly alkaline to litmus, any precipitate which may appear being removed. The red solution is then evaporated to crystallising-point, three volumes of alcohol added and the mixture allowed to stand overnight in ice. The crystals are then collected and washed with alcohol, the alcohol being removed from the main filtrate, which is again evaporated to crystallising-point and treated as before. The combined crops from the two crystallisations are dried at 80° C. overnight; yield, 41 grams. The product, which is a white powder, is the *monosodium salt* of the required acid. The foregoing method has recently been slightly modified, and it is claimed that the yield of sodium salt is doubled. The preliminary distillation of the *o*-cresol-arsenic acid mixture is continued until half a molecule of water has been removed, and the residual mixture then refluxed, with mechanical agitation, for four hours, then worked up as already indicated.[1] The free acid is isolated in the following manner:[2] An aqueous solution of 4 grams of the crude sodium salt, after acidification with hydrochloric acid and addition of a little charcoal, is boiled, filtered, and evaporated to dryness. The residue is extracted with acetone and the solvent removed, the syrup remaining becoming crystalline when rubbed with a glass rod. Yield, 2·3 grams.

The acid is slightly pink, and softens at 146° C., melting at 170° C. It is soluble in alcohol, aqueous alkalis or mineral acids, sparingly soluble in cold water, insoluble in benzene. In aqueous solution it gives no coloration with ferric chloride. The *sodium salt* crystallises from water in plates containing 2 molecules of solvent, and the *acetyl derivative* forms clusters of fine needles, M.pt. 164° to 166° C., yielding a *sodium salt* crystallising with 4 molecules of water.[3]

2-Hydroxy-3-methylphenylarsinic acid,[4]



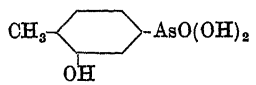
This acid occurs amongst other by-products in the preceding preparation. The alcohol is distilled off from the filtrate from the second crop of sodium salt in the foregoing, the residue treated with 650 c.c. of water and made distinctly alkaline to phenolphthalein with sodium hydroxide. The mixture is boiled, aqueous barium chloride added, the whole allowed

[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3061.
[2] Christiansen, *loc. cit.*
[3] Barrowcliff, Pyman, and Remfry, *Trans. Chem. Soc.*, 1908, 93, 1893.
[4] Christiansen, *loc. cit.*

to cool overnight in ice, and the precipitate filtered off, washed, and dried in air. Boiling the filtrate causes the precipitation of a further quantity of substance. The total yield of crude barium salt is 11·8 grams. The free acid is liberated by means of sulphuric acid; the yield is only 1·3 grams.

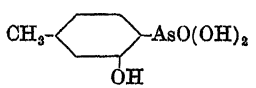
The compound may also be obtained as follows:[1] 2-Methyl-6-aminophenol hydrochloride (6·4 grams) is diazotised and added to a solution prepared from 3·96 grams of arsenious oxide, 11·25 grams of sodium hydroxide and 750 to 800 c.c. of water, and the mixture allowed to stand overnight. It is then heated at 60° to 70° C., concentrated, and the excess of arsenite oxidised with hydrogen peroxide. The arsenate is then precipitated with barium chloride, filtered off, and the excess of barium chloride removed by sodium sulphate. The solution is concentrated until sodium chloride commences to separate, then acidified with hydrochloric acid, when the crude arsinic acid separates. The latter is repeatedly recrystallised from boiling water, coloration being removed by treatment with charcoal. Prepared by the first method the acid forms stout, white needles, M.pt. 198° to 200° C., but the product of method (2) is stated to have a melting-point of 205° C. Both products give a deep purple coloration with aqueous ferric chloride.

3-Hydroxy-4-methylphenylarsinic acid,[1]



5 grams of 3-amino-4-methylphenylarsinic acid in 25 c.c. of normal sulphuric acid, are diazotised and warmed at 50° to 60° C., then diluted with water. The sulphuric acid is removed by barium hydroxide, the filtered solution made alkaline with sodium carbonate, then acidified with hydrochloric acid. The precipitated acid is purified by crystallisation from boiling water; it melts at 174° to 175° C. It gives no coloration with ferric chloride.

2-Hydroxy-4-methylphenylarsinic acid,

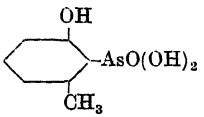


This is obtained in the usual way from 2-amino-4-methylphenylarsinic acid. It crystallises with one molecule of water, softens at 125° C., then solidifies; the anhydrous acid melts at 173° C. It gives an intensely red coloration with ferric chloride. Christiansen,[2] on working up the mother-liquors from 4-hydroxy-2-methylphenylarsinic acid in the manner described under 2-hydroxy-3-methylphenylarsinic acid, obtained an acid, M.pt. 165° to 167° C., slightly soluble in cold water, readily soluble in alkalis and hot water. This gave a very deep red coloration with ferric chloride, a property characteristic of compounds containing the hydroxyl and arsinic acid groups in *ortho* positions to each other. Christiansen therefore considered his compound to be either 2-hydroxy-4-methylphenylarsinic acid or **6-hydroxy-2-methylphenylarsinic**

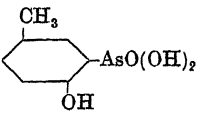
[1] Finzi, *loc. cit.*

[2] Christiansen, *loc. cit.*

acid. Finzi[1] considers Christiansen's compound to be the 6-hydroxy-derivative:

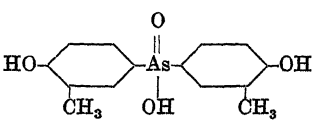


2-Hydroxy-5-methylphenylarsinic acid,[1]



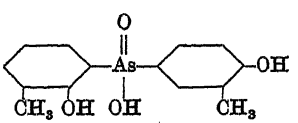
is obtained when the Bart reaction is applied to 4-hydroxy-*m*-toluidine. It crystallises with $1\frac{1}{2}$ molecules of water, softens at 90° to 100° C., and solidifies at higher temperatures. The anhydrous acid melts at about 218° C., and gives a colour reaction with ferric chloride.

3 : 3′-Dimethyl-4 : 4′-dihydroxydiphenylarsinic acid,



is found in the mother-liquors from the preparation of 2-hydroxy-3-methylphenylarsinic acid when *o*-cresol is arsenated (p. 275). The filtrate from the crude barium salt of this acid on acidification gives a reddish-brown, flocculent precipitate. This is filtered off and extracted with 50 per cent. acetic acid, the residue being the required acid.[2] It has also been obtained from 4 : 4′-diamino-3 : 3′-dimethyldiphenylarsinic acid by the diazo reaction.[3] It is a light brown solid, M.pt. 249° C. It is moderately soluble in normal sodium hydroxide solution or in ammonium hydroxide, and dissolves readily in warm alcohol, hot acetic and hydrochloric acids, is sparingly soluble in cold hydrochloric acid, insoluble in benzene, ether, and ligroin. With magnesia mixture in ammoniacal solution it gives no precipitate.

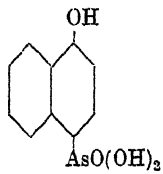
3 : 3′-Dimethyl-4: 2 ′-dihydroxydiphenylarsinic acid,[2]



The mother-liquors from the preceding compound when prepared by the first method deposit a precipitate after standing in an ice-bath for three hours. This is extracted with 50 per cent. acetic acid, the extracts depositing the arsinic acid as a white solid, M.pt. 208° to 210° C. It gives a pale purple coloration with ferric chloride, which increases in intensity on heating.

[1] Finzi, *loc. cit.*
[2] Christiansen, *loc. cit.*
[3] Benda, *Ber.*, 1908, 41, 2372.

α-Naphthol-4-arsinic acid,[1]



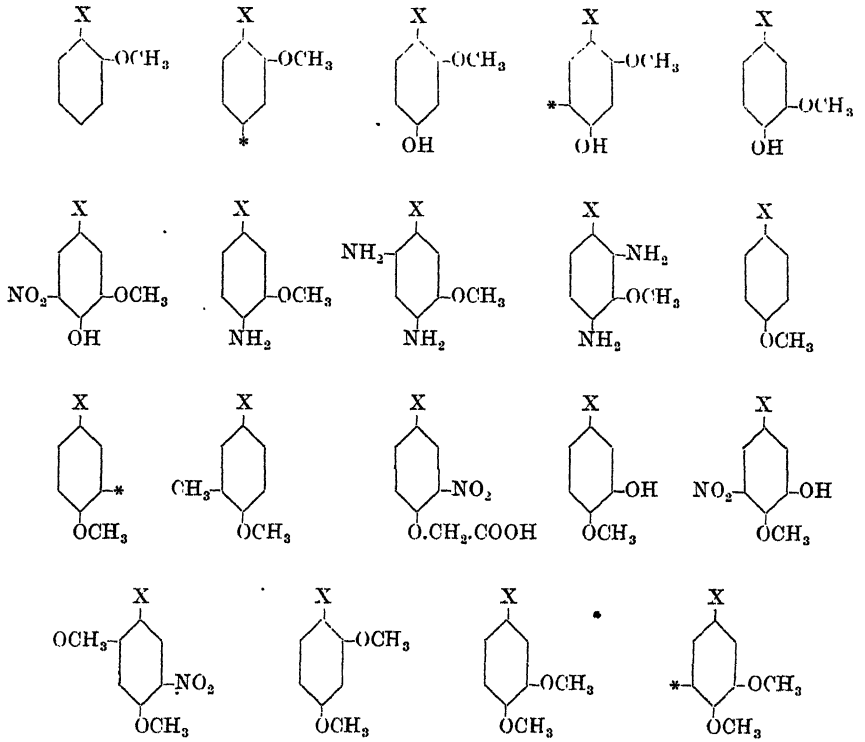
1-Aminonaphthalene-4-arsinic acid (1000 grams) is suspended in 10,000 c.c. of 15 per cent. sulphuric acid, the mixture cooled to 5° C., and diazotised with 250 grams of sodium nitrite. Steam is then blown in and the red product converted to the sodium salt. The latter is purified by solution in water and precipitation by alcohol, mineral acid then transforming it to the free acid. This crystallises in colourless needles or plates, sparingly soluble in cold water and ether, fairly soluble in alcohol, insoluble in chloroform, petroleum, and ligroin. Its salts with the heavy metals are insoluble in water.

Methoxyarylarsinic Acids and their Derivatives.

The unsubstituted methoxyarylarsinic acids are isolated (1) By the diazotisation of methoxyarylamines and subsequent treatment with sodium arsenite. (2) By methylation of hydroxyarylarsinic acids, using dimethyl sulphate in alkaline solution. 4-Methoxyphenylarsinic acid may also be prepared by the hydrolysis of *p*-anisylarsenic chloride, and 2 : 4-dimethoxyphenylarsinic acid by direct arsenation of resorcinol dimethyl ether, using arsenic acid, the latter also being used to arsenate resorcinol monomethyl ether. The nitromethoxyarylarsinic acids are prepared by direct nitration of the corresponding methoxyaryl acids, the only exception being 4-nitro-2-methoxyphenylarsinic acid, which results when 2-methoxy-4-nitroaniline is diazotised and treated with sodium arsenite. The corresponding amino-acids are obtained by reducing the nitro-acids with (*a*) ferrous salts in the presence of alkali, (*b*) sodium hydrosulphite, (*c*) sodium amalgam in boiling methyl alcohol. 4-Amino-3-methoxyphenylarsinic acid is isolated from 3-nitro-4-aminophenylarsinic acid by an interesting series of reactions detailed on p. 281. In all cases of methoxyhydroxyphenylarsinic acids, the hydroxyl group is already in the nucleus of the starting material before arsenation takes place.

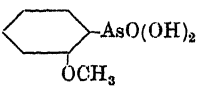
All the foregoing types of methoxyarylarsinic acids are crystalline compounds, many of them separating in a pure state from hot water. Vigorous reduction of the compounds leads to the formation of methoxyarseno-derivatives, described on pp. 347–349. The principal arsinic acids of the foregoing types are shown in the following scheme, the arsinic acid grouping, $AsO(OH)_2$, being represented by X :

[1] Adler and Adler, *Ber.*, 1908, 41, 931; German Patent, 205775.



* These positions may be occupied by NO_2 or NH_2 groups.

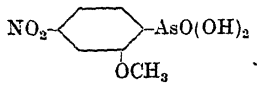
2-Methoxyphenylarsinic acid,[1]



One molecular equivalent of *o*-anisidine in 600 c.c. of 5*N* hydrochloric acid (3 molecular equivalents) is cooled and diazotised, filtered, and the filtrate transferred to a 12,000 c.c. flask, well cooled, and 200 c.c. of 5*N* sodium hydroxide (one molecular equivalent) stirred in, followed at once by a mixture containing 750 c.c. of 2*N* disodium monohydrogen arsenite solution (prepared by dissolving 198 grams of arsenious oxide in 800 c.c. of 5*N* sodium hydroxide and making up to one litre), 60 c.c. of 5*N* hydrochloric acid, 650 c.c. of water, 650 grams of ice, and 200 c.c. of 20 per cent. copper sulphate solution. Nitrogen is rapidly evolved, and a few c.c. of ethyl acetate are added to prevent excessive foaming. After standing for one hour the whole is warmed to 40° or 50° C., and filtered. The filtrate is acidified to litmus by acetic acid, concentrated on a steam-bath, and filtered hot. The filtrate on acidification to Congo red with hydrochloric acid yields the arsinic acid, 12·3 grams of pure *o*-anisidine yielding 13·5 grams of 2-methoxyphenylarsinic acid. This compound crystallises from alcohol in white needles, M.pt. 193° to 194° C.

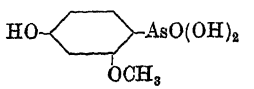
[1] Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307.

4-Nitro-2-methoxyphenylarsinic acid,



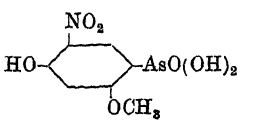
is obtained when 2-methoxy-4-nitroaniline is diazotised and treated with sodium arsenite, as described in the preceding preparation. It crystallises from 90 per cent. alcohol in pale yellow needles, which do not melt below 250° C. Reduction of this acid by ferrous chloride gives a 60 per cent. yield of **2-methoxy-4-aminophenylarsinic acid,** which crystallises from water in white needles, M.pt. 203° to 204° C., with decomposition, on slow heating, or 208° to 209° C. if heated rapidly.

2-Methoxy-4-hydroxyphenylarsinic acid,[1]



100 grams of resorcinol monomethyl ether and 160 grams of arsenic acid (75° Bé.) are heated on the water-bath for fifty hours. The melt is triturated with acetic acid, then recrystallised from water, the product melting at 209° C. Yield, 63 grams. It is soluble in water, alcohols, and acetic acid, sparingly soluble in acetone, insoluble in ether.

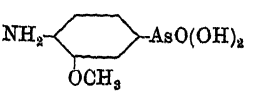
5-Nitro-2-methoxy-4-hydroxyphenylarsinic acid,



is isolated from the preceding acid (15 grams) by nitration with 30 c.c. of nitric acid (density 1·4) in 30 c.c. of acetic acid solution, at a temperature not above 35° C. After two days the mixture is diluted with water, the precipitate filtered off, washed and dried, the yield being about 8 grams. It gives pale yellow crystals, M.pt. about 237° C., sparingly soluble in water, alcohols, acetic acid, and ether.

5-Amino-2-methoxy-4-hydroxyphenylarsinic acid is obtained when the preceding nitro-acid is reduced with sodium hydrosulphite. It crystallises in needles containing 2 molecules of water of crystallisation, which darken at 120° C., and decompose at higher temperatures without appearing to melt. On reduction it yields the corresponding arseno-compound (p. 347).

4-Amino-3-methoxyphenylarsinic acid or o-Anisidine-4-arsinic acid,[2]



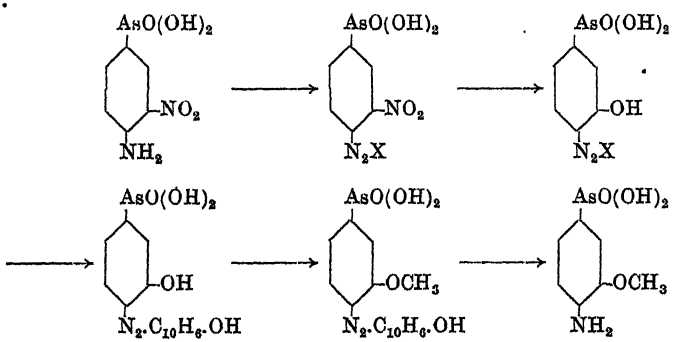
3-Nitro-4-aminophenylarsinic acid (260 grams) is dissolved in 800 c.c. of 2*N* sodium carbonate solution and 800 c.c. of water, and the solution mixed with 200 c.c. of 5*N* sodium nitrite. The liquid is poured into a mixture of 3000 c.c. of water, 535 grams of concentrated sulphuric acid, and 1500 grams of ice. After completion of the reaction, 2800 grams of sodium acetate are stirred in, the temperature being maintained at

[1] Bauer, *Ber.*, 1915, 48, 509. [2] Benda, *Ber.* 1914, 47, 995.

about 18° C. until a test portion no longer couples with R-salt, but yields a red azo compound with resorcinol instead of a yellow one, this change arising from the elimination of the nitro-group. The solution from 160 grams of β-naphthol, 4500 c.c. of water, 930 c.c. of sodium hydroxide (40° Bé.), and 2000 c.c. of 2*N* sodium carbonate solution, is then stirred in, the dye precipitating in glistening copper crystals of the *sodium salt*. The latter is filtered off, washed with cold water, and dried. Yield, 230 grams.

Methylation of the dyestuff.—The foregoing product is boiled with 200 grams of anhydrous sodium carbonate and 200 grams of methyl toluene-*p*-sulphonate in 2000 c.c. of spirit, the alkylation being complete when a test portion on dilution with water remains red, the process taking about eight hours. The alcohol is then distilled off and the residue dissolved in 5000 c.c. of hot water, filtered, and the dye precipitated by the addition of hydrochloric acid. The mixture is boiled, filtered, and washed with hot water.

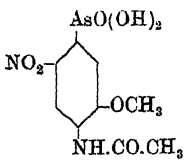
Reduction of the dyestuff.—The alkylated dyestuff is dissolved in a mixture of 1000 c.c. of hot water and 250 c.c. of 10*N* sodium hydroxide, cooled to about 25° C., and treated with 250 grams of sodium hydrosulphite, whereby, with a temperature rise to 40° C., the azo dyestuff is broken down. The mixture is cooled to room temperature and carbon dioxide passed in until a portion of the filtrate is no longer rendered turbid by the gas. The mixture is then filtered and the residue washed, the filtrate containing the anisidine arsinic acid and hydrosulphite, the latter being destroyed by blowing air through the solution until a test portion no longer decolorises indigo carmine solution. The liquid is then evaporated to about 1000 c.c., after the addition of animal charcoal, filtered, and at a temperature of 35° C. about 190 c.c. of sulphuric acid (1 part of acid, 66° Bé., to 1 part of water) added until the solution gives a red coloration with methyl orange. A thick, crystalline mass results, which is filtered off, washed with a little water, then with alcohol, and finally with ether. The yield of crude product is about 75 grams. The reactions taking place in this preparation are shown in the following scheme:



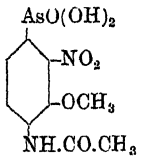
o-Anisidine arsinic acid forms colourless, glistening needles, several centimetres in length, easily soluble in hot water, alkalis, and sodium acetate solution. The *acetyl compound* is formed when the acid in sodium hydroxide solution is treated with acetic anhydride. It crystallises in fine needles, dissolving readily in warm water, and partially saponified by solution in alkalis, completely saponified when boiled with

normal sodium hydroxide solution. At 275° C. it darkens, and decomposes at 285° to 287° C.

The foregoing acetyl derivative may be nitrated as follows: 29 grams of product are dissolved in 200 grams of sulphuric acid (66° Bé.) at 20° C., the solution cooled to 5° C., and 13 c.c. of nitric acid (128 c.c.=1 gm.-mol. HNO_3) added dropwise. After stirring for one hour the mixture is poured upon 500 grams of ice, a bright yellow precipitate being obtained, which is allowed to stand for several hours, then filtered off, washed, and dried. Yield, 28 grams, or 80 per cent. This crude product contains two isomers:

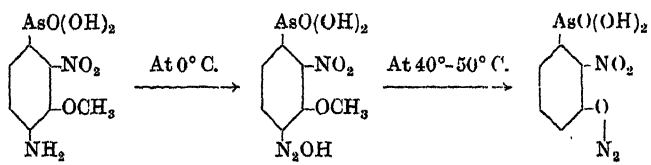


A.

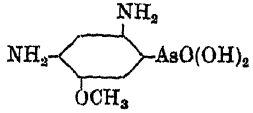


B.

The separation of the isomers is effected as follows: The crude product is dried, and then heated with potassium hydroxide solution on the water-bath for one and a half hours. The liquid is then cooled to 40° C. and treated with sulphuric acid until it gives a brown coloration to Congo red paper, at which stage product A is precipitated; this is filtered off, washed, and dried. Crystallisation from boiling water gives glistening orange needles, soluble in alkali to give an intensely orange-yellow solution, but sparingly soluble in alcohols. When diazotised it couples with R-salt and with resorcinol, and on reduction it gives 4:6-diamino-3-methoxyphenylarsinic acid. To obtain product B, the filtrate from A is treated with hydrochloric acid until the solution yields a blue colour with Congo red, then allowed to stand for ten to twelve hours. Bright orange-yellow needles separate out, similar to the A compound, but much more soluble. They give a bright yellow solution in alkali, and when diazotised at 0° C. and quickly warmed, the solution becomes intensely orange in colour, this distinguishing the B compound from the A compound. When B is reduced, 2:4-diamino-3-methoxyphenylarsinic acid is formed. The reaction taking place on diazotisation is represented as follows:



4:6-Diamino-3-methoxyphenylarsinic acid,

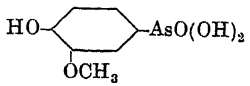


5·8 grams of the nitro-acid A in the foregoing preparation in 60 c.c. of water and 32 c.c. of 10*N* sodium hydroxide are treated dropwise with 35 c.c. of ferrous chloride solution (19·65 per cent. by volume Fe) and

diluted with 100 c.c. of water. The product is somewhat soluble in cold water, the solution turning Congo red paper brown, and it easily dissolves in alkali, sodium acetate, dilute mineral acid, 50 per cent. acetic acid and alcohols.

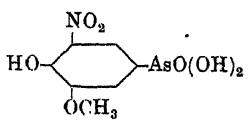
2 : 4-Diamino-3-methoxyphenylarsinic acid is the reduction product of nitro-acid B (p. 282), and it has similar properties to the preceding arsinic acid.

4-Hydroxy-3-methoxyphenylarsinic acid,[1]



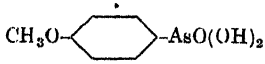
A suspension of 25·2 grams of 4-nitroguaiacol in 90 c.c. of concentrated hydrochloric acid is reduced by the gradual addition of 42 grams of tin, and the resulting solution, after removal of tin, diazotised with 12 grams of sodium nitrite. The diazo solution is added to an ice-cold solution of 27 grams of arsenious acid in 210 c.c. of 10 per cent. sodium hydroxide, the mixture being maintained alkaline. When the reaction ceases, the mixture is heated for thirty minutes on the water-bath, acidified to methyl orange, using hydrochloric acid, treated with charcoal, evaporated to dryness under diminished pressure, and extracted with alcohol. A yield of 12·5 grams of product is obtained, which crystallises from hot water in stout, glistening, rhombic prisms, containing 1 molecule of water, and melting at 190° C. It gives an *arseno-compound* on reduction (p. 348).

5-Nitro-4-hydroxy-3-methoxyphenylarsinic acid,



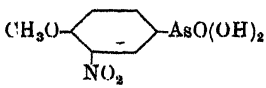
is isolated from the preceding acid when the nitration is carried out as in the case of 3-nitro-4-methoxyphenylarsinic acid. It forms glistening leaflets from water, which gradually decompose above 260° C., without melting.

4-Methoxyphenylarsinic acid,



This acid is readily prepared by the method described for the corresponding *ortho*-compound ;[2] it may also be obtained by the methylation of *p*-hydroxyphenylarsinic acid[3] or by the hydrolysis of *p*-anisylarsenic chloride.[4] The most recent investigators state that, after purification by crystallisation from water, it melts at 176° to 177° C.

3-Nitro-4-methoxyphenylarsinic acid,[5]



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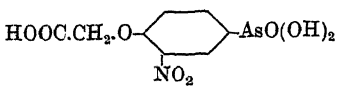
[1] Fargher, *Trans. Chem. Soc.*, 1920, 117, 872.
[2] Johnson and Adams, *loc. cit.*
[3] Bertheim, *Ber.*, 1914, 47, 276.
[4] Michaelis, *Ber.*, 1887, 20, 2051 ; *Annalen*, 1902, 320, 299.
[5] Fargher, *Trans. Chem. Soc.*, 1920, 117, 865.

A solution of 4·6 grams of 4-methoxyphenylarsinic acid in 15 c.c. of sulphuric acid at -10° C. is treated with a mixture of 1·4 c.c. of nitric acid (density 1·4) and 1·4 c.c. of sulphuric acid, the temperature being maintained at about -8° C. After standing for twenty-four hours in ice, the whole is poured upon 100 grams of powdered ice, when a 95 per cent. yield of the nitro-acid separates. It crystallises from hot water in minute needles, which begin to decompose above 290° C. The *monosodium salt* crystallises in pale yellow needles containing 2 molecules of water of crystallisation.

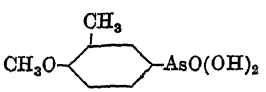
3-Amino-4-methoxyphenylarsinic acid is obtained when the preceding nitro-acid is reduced with 5 per cent. sodium amalgam in boiling methyl alcohol. It separates from water in clusters of colourless needles, melting with decomposition at 193° C., and can be acetylated.

3-Nitro-4-carbomethoxyphenylarsinic acid or **2-Nitrophenoxyacetic acid 4-arsinic acid,**[1]



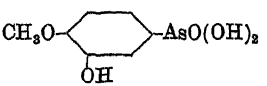
This acid is obtained by the direct nitration of *p*-carbomethoxyphenylarsinic acid at 0° C. by mixed acid, then allowing the temperature to rise to 20° C. The yield is about 75 per cent., and the product crystallises from water in coarse yellow prisms. When reduced by ferrous hydroxide, the acid yields 3-hydroxy-1 : 4-benz*iso*xazine-6-arsinic acid (p. 429). When the nitro-acid is reduced by sulphur dioxide and potassium iodide in hydrochloric acid solution, a 70 per cent. yield of the *dichloroarsine* is obtained in rosettes of plates, very resistant to aqueous hydrolysis; attempts to reduce this by stannous chloride or sodium hyposulphite have been unsuccessful. Ferrous hydroxide gives a small yield of 3-hydroxy-1 : 4-benz*iso*xazine-6-arsenoxide.

4-Methoxy-5-methylphenylarsinic acid,



When monosodium 4-hydroxy-5-methylphenylarsinate is methylated in alkaline solution with dimethyl sulphate, a 75 per cent. yield of the crude methoxy-compound is obtained. It separates from water in white, feathery needles, unmelted below 260° C. Nitration yields 3-*nitro*-4-*methoxy*-5-*methylphenylarsinic acid* as pale yellow needles.

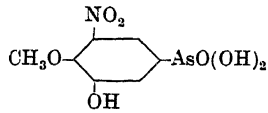
3-Hydroxy-4-methoxyphenylarsinic acid,[2]



is prepared from 5-nitroguaiacol in the same manner as 4-hydroxy-3-methoxyphenylarsinic acid is obtained from 4-nitroguaiacol (p. 283). It crystallises from water in stout, flattened prisms, containing one molecule of water, and melting at 189° C. It is sparingly soluble in alcohol and the usual organic solvents. Its reduction product is 3 : 3′-dihydroxy-4 : 4′-dimethoxyarsenobenzene (p. 348).

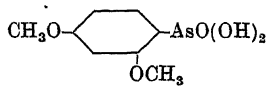
[1] Christiansen, *J. Amer. Chem. Soc.*, 1922, 44, 2334.
[2] Fargher, *loc. cit.*

5-Nitro-3-hydroxy-4-methoxyphenylarsinic acid,



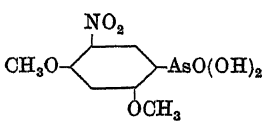
formed by nitration of the preceding acid or by the hydrolysis of 5-nitro-3 : 4-dimethoxyphenylarsinic acid, crystallises from water in stellate clusters of prismatic needles, which gradually darken above 220° C. and melt at 252° C.

2 : 4-Dimethoxyphenylarsinic acid,[1]



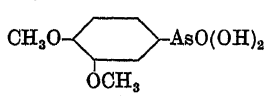
Resorcinol dimethyl ether, 28 grams, and 50 grams of arsenic acid (75° Bé.) are heated together on a water-bath, with occasional stirring, for eight days. After trituration with acetic acid the product is recrystallised from water containing charcoal. It may also be obtained by heating resorcinol-4-arsinic acid in sodium hydroxide solution with a large excess of dimethyl sulphate for one day on the water-bath. It crystallises from water in silky needles, M.pt. 242° to 243° C.[2]

5-Nitro-2 : 4-dimethoxyphenylarsinic acid,[3]



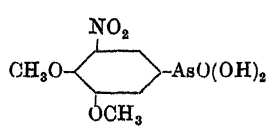
is obtained in 77 per cent. yield, when the preceding dimethoxy-acid is nitrated. It crystallises in feathery needles, having a slight greenish-yellow colour.

3 : 4-Dimethoxyphenylarsinic acid,[4]



A diazotised solution of aminoveratrole is added to a solution of arsenious oxide in sodium hydroxide. After the reaction is complete, the mixture is allowed to stand for several hours, warmed for thirty minutes on the water-bath, treated with charcoal, and acidified, the arsinic acid separating out. It crystallises from hot water in colourless, anhydrous rhombic prisms, sintering at 187° C., and melting at 192° C. when first placed in a bath at 170° C. When slowly heated it sinters, but does not melt, between 180° and 190° C.

5-Nitro-3 : 4-dimethoxyphenylarsinic acid,



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[1] Bauer, *loc. cit.* [2] Christiansen (*loc. cit.*) gives this M.pt. as 238° to 239° C.
[3] Christiansen, *loc. cit.* [4] Fargher, *loc. cit.*

when prepared by the method described for 3-nitro-4-methoxyphenylarsinic acid (p. 283), is obtained in 85 per cent. yield. It separates from water in clusters of minute needles, M.pt. 236° C., with decomposition. The *monosodium salt* crystallises in glistening, flattened prisms, containing 6 molecules of water, and the *acid barium salt* forms faint yellow needles containing 3 molecules of water. At 130° C. the acid is slowly hydrolysed by concentrated hydrochloric acid, forming *5-nitro-3-hydroxy-4-methoxyphenylarsinic acid.*

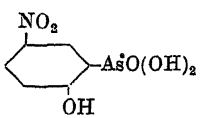
5-Amino-3 : 4-dimethoxyphenylarsinic acid, prepared by reducing the foregoing acid with ferrous hydroxide in alkaline solution, crystallises in needles, M.pt. 173° C., with decomposition. It is sparingly soluble in cold water or alcohol, but dissolves in dilute mineral acids or hot water.

Nitrohydroxyarylarsinic Acids.

These acids can be obtained in many instances by nitration of the hydroxyarylarsinic acids. Another general method is to apply the Bart reaction to nitroaminophenols. If a nitroaminoarylarsinic acid contains the nitro- and amino-groups in the *ortho* positions, the amino-group may be converted to hydroxyl by heating with aqueous potassium hydroxide. 5-Nitro-2-aminophenylarsinic acid and 3-chloro-4-nitrophenylarsinic acid also yield hydroxy-acids on treatment with potassium hydroxide. The foregoing methods apply equally well to the preparation of dinitrohydroxyarylarsinic acids. The nitrohydroxyarylarsinic acids are yellow, crystalline products, many of which may be crystallised from water; their alkaline solutions are intensely yellow. Bromine converts alcohol solutions of 5-nitro-2 : 4-dihydroxyphenylarsinic acid and 3 : 5-dinitro-2 : 4-dihydroxyphenylarsinic acid to 2 : 6-dibromo-4-nitroresorcinol and 2 : 4-dinitro-6-bromoresorcinol, respectively.

The scheme on the opposite page shows the principal nitrohydroxyarylarsinic acids known at present, X signifying the position of the $AsO(OH)_2$ grouping.

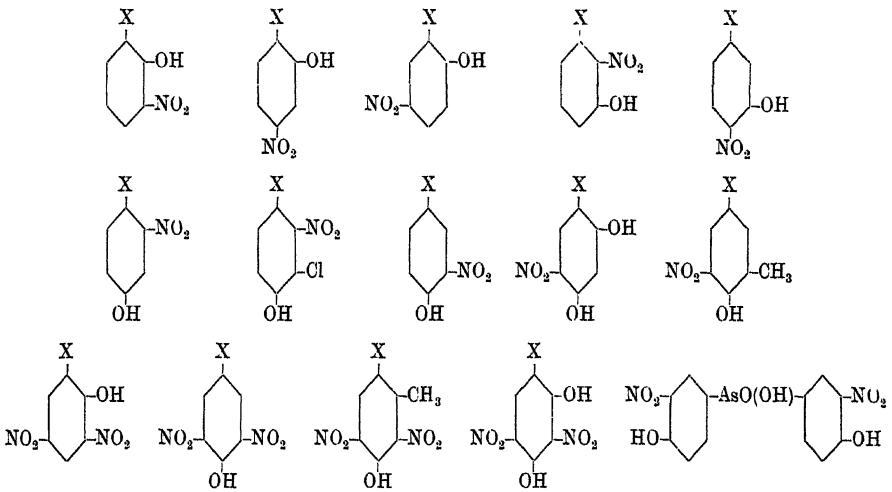
5-Nitro-2-hydroxyphenylarsinic acid,



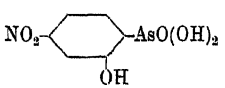
When 15·4 grams of 5-nitro-2-aminophenol are diazotised and treated with alkaline sodium arsenite, 12 grams of the required nitro-acid are obtained.[1] Another method of preparation consists in boiling 5-nitro-2-aminophenylarsinic acid with potassium hydroxide solution (36° Bé.), when ammonia is eliminated owing to the displacement of the amino-group by the hydroxyl-group. The reaction is complete when a diazotised test portion no longer couples with R-salt. The acid may also be obtained by nitration of 2-hydroxyphenylarsinic acid.[2] The *mono-* and *dipotassium salts* are both known,[3] the latter being precipitated by alcohol from its aqueous solution in the form of fine needles. Excess of mineral acid precipitates the free acid from its salt solutions as a sandy,

[1] Bart, *Annalen*, 1922, 429, 97.
[2] Keimatsu and Kakinuma, *J. Pharm. Soc.*, Japan, 1925, No. 520, 2.
[3] Benda, *Ber.*, 1911, 44, 3293.

crystalline powder. The acid commences to decompose at 250° C., is soluble in acetic acid and hot water, sparingly soluble in cold water, insoluble in ether. Its solutions in alkali are intensely yellow.



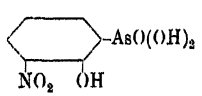
4-Nitro-2-hydroxyphenylarsinic acid,[1]



4-Nitro-2-aminophenol is diazotised in hydrochloric acid solution, treated with alkaline sodium nitrite, and warmed until the evolution of nitrogen ceases. The product is neutralised, filtered, and the filtrate evaporated to dryness in the presence of excess of hydrochloric acid. The residue is extracted with alcohol, boiled with charcoal and filtered. Yellowish crystals of the nitro-acid separate out on cooling. It is decomposed on rapid heating, is soluble in alcohol, acetone, acetic acid, and hot water, sparingly soluble in cold water. The aqueous solutions of the alkali salts are yellow.

2-Hydroxy-4-methylnitrophenylarsinic acid,[2] $(HO)_2OAs.C_6H_2(CH_3)(OH)(NO_2)$.—4 grams of 2-hydroxy-4-methylphenylarsinic acid are nitrated with 7 or 8 c.c. of mixed acid (2 parts HNO_3, density 1·40, and 3 parts concentrated H_2SO_4) and the whole poured into water. The nitro-acid crystallises from water with 2 molecules of solvent; it sinters at 120° C.; the anhydrous acid melts at 193° C., and gives a purplish colour with ferric chloride solution.

3-Nitro-2-hydroxyphenylarsinic acid,[3]



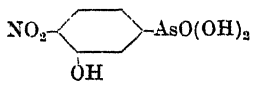
[1] German Patent, 250264.

[2] Finzi, *Atti II Cong. Naz. Chim. Pura. Appl.*, 1926, p. 1302.

[3] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3064; compare Fourneau, Tréfouel, and Bénoit, *Bull. Soc. chim.*, 1927, 41, 499.

This is formed by the application of a modified Bart reaction to 6-nitro-2-aminophenol, the yield of arsinic acid being about 50 per cent. It forms characteristic yellow nodules, which melt with decomposition at 252° to 254° C. The *barium*, *calcium* and *magnesium salts* are yellow, amorphous solids.

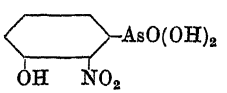
4-Nitro-3-hydroxyphenylarsinic acid,[1]



A solution of 28·2 grams of 3-chloro-4-nitrophenylarsinic acid in 300 c.c. of 4*N* potassium hydroxide solution is boiled for three hours, filtered, and acidified to Congo red paper, when 19 grams (73 per cent. yield) of crystalline product are deposited. Recrystallisation from glacial acetic acid yields pale yellow, anhydrous needles, soluble in alcohol, sparingly soluble in water. The *magnesium salt* is microcrystalline and the *barium salt* crystallises in minute rods.

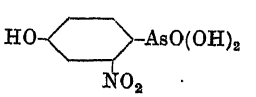
3-Hydroxy-4-methylnitrophenylarsinic acid,[2] $(HO)_2OAs.C_6H_2(CH_3)(OH)(NO_2)$.—2 grams of 3-hydroxy-4-methylphenylarsinic acid are dissolved in 5 or 6 c.c. of mixed acid, containing 2 parts of nitric acid (density 1·40) and 3 parts of concentrated sulphuric acid, the solution cooled in ice, then allowed to stand at room temperature. The nitro-acid is precipitated by pouring the mixture into 20 or 25 c.c. of ice-water, and recrystallised from boiling water. It forms yellowish crystals, melting with decomposition at about 237° C., and giving no colour with ferric chloride solution.

2-Nitro-3-hydroxyphenylarsinic acid,[3]



This acid is isolated when 2-nitro-3-aminophenylarsinic acid is heated with concentrated potassium hydroxide; also in 50 per cent. yield when 2-nitro-3-carbethoxyaminophenylarsinic acid is refluxed with 5*N* sodium hydroxide solution, and the reaction mixture made acid to Congo red. It crystallises in rich yellow, hexagonal plates, melting with decomposition at 208° C.[4]

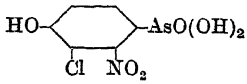
2-Nitro-4-hydroxyphenylarsinic acid,[5]



When 15·4 grams of 2-nitro-4-aminophenol are diazotised and treated with alkaline sodium arsenite in the usual way, a 14 grams yield of this acid is obtained. It is soluble in acetone, alcohols, and hot water, sparingly soluble in cold water; it forms shining yellow needles, M.pt. 228° C.

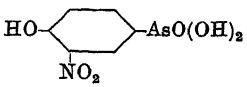
[1] Balaban, *J. Chem. Soc.*, 1928, p. 809.
[2] Finzi, *loc. cit.*
[3] German Patent, 256343.
[4] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3053.
[5] Bart, *Annalen*, 1922, 429, 98.

3-Chloro-2-nitro-4-hydroxyphenylarsinic acid,[1]



is obtained when 3-chloro-4-hydroxyphenylarsinic acid is nitrated in sulphuric acid at 5° to 12° C. It may be reduced to the corresponding *amino-compound*, which crystallises in long needles, its *acetyl derivative* crystallising from hot water in small white needles.

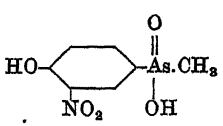
3-Nitro-4-hydroxyphenylarsinic acid,



This acid may be prepared in several ways: (1) 144 grams of sodium phenolarsinate, $HO.C_6H_4.As(OH).ONa$, dried at 80° C., are added in small portions to 450 c.c. of concentrated sulphuric acid at 0° C. To this solution a mixture of 39 c.c. of nitric acid (density 1·4) and 39 c.c. of concentrated sulphuric acid is added dropwise, the whole being well stirred and maintained at 0° C. The temperature is then allowed to rise to 10° C., the solution poured into 2250 c.c. of water, and filtered after twelve hours' standing. The nitro-acid is thus obtained as a yellowish powder. Yield, 75 per cent.[2] (2) 3-Nitro-4-aminophenol is diazotised and treated with alkaline sodium nitrite in the usual way,[3] 15·4 grams of amino-compound yielding 10 grams of the hydroxy-acid. (3) 3-Nitro-4-aminophenylarsinic acid is warmed at 80° C. with potassium hydroxide solution (density 1·324) until the solution can no longer be diazotised.[4] (4) 4-Dimethylaminophenylarsinic acid is nitrated, giving 4-dimethylamino-3-nitrophenylarsinic acid, which on heating with potassium hydroxide solution is converted into 3-nitro-4-hydroxyphenylarsinic acid.[5] (5) One part of 3-nitro-4-chlorophenylarsinic acid in 5 parts of potassium hydroxide solution (36° Bé.) is heated for several hours on the water-bath. The solution becomes dark yellowish-red, and when acidified yields 3-nitro-4-hydroxyphenylarsinic acid.[6]

The acid crystallises in pale yellow prisms, which do not melt on heating, but explode. It is soluble in alcohol, acetone, acetic acid, and ethyl acetate, fairly soluble in hot water, sparingly soluble in cold water. The *disodium* salt is orange and has a neutral reaction in water, whilst the *trisodium* salt is alkaline to litmus and neutral to phenolphthalein. The acid condenses with *p*-toluene sulphonic chloride in alkaline solution, yielding glistening plates, M.pt. 171° C.

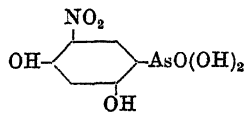
3-Nitro-4-hydroxyphenylmethylarsinic acid,[7]



[1] British Patent, 230487 (1925).
[2] German Patent, 224953; see Benda and Bertheim, *Ber.*, 1911, 44, 3445; Conant, *J. Amer. Chem. Soc.*, 1919, 41, 431.
[3] Bart, *Annalen*, 1922, 429, 98; see German Patent, 250264.
[4] German Patent, 235141; see Benda, *Ber.*, 1911, 44, 3449.
[5] French Patent, 451078; see Karrer, *Ber.*, 1913, 46, 515.
[6] German Patent, 245536.
[7] Bertheim, *Ber.*, 1915, 48, 357.

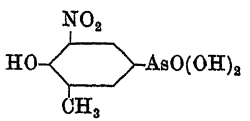
3-Nitro-4-hydroxyphenylarsenoxide (45·8 grams), 160 c.c. of methyl alcohol, 60 c.c. of 10*N* sodium hydroxide solution, and 16 c.c. of methyl iodide are mixed together and allowed to stand for a day. The mixture is then diluted with 600 c.c. of water, filtered, and acidified with 75 c.c. of acetic acid. The nitro-acid crystallises out (48 grams yield), and is recrystallised from 50 per cent. acetic acid. It crystallises in prisms, M.pt. 232° to 233° C., with decomposition, easily soluble in methyl alcohol containing hydrochloric acid, sparingly soluble in water, insoluble in acetone, chloroform, benzene, and ether.

5-Nitro-2 : 4-dihydroxyphenylarsinic acid,[1]



2 : 4-Dihydroxyphenylarsinic acid (46·8 grams) in 50 c.c. of concentrated sulphuric acid is nitrated, using 14 c.c. of nitric acid (density 1·4) and an equal volume of concentrated sulphuric acid, the operation being conducted at 0° C., with brisk stirring. After standing overnight the mixture is poured upon ice, the nitro-compound removed, washed with water, and dried on the water-bath, the yield being about 42 grams of crude product. This is purified by crystallisation from water containing charcoal, yellowish needles separating, which contain two molecules of water and melt with decomposition at 223° C. It is soluble in alcohol and acetic acid, insoluble in ether and benzene ; it gives a red coloration with ferric chloride solution. When treated with bromine, an alcoholic solution of the acid yields 2 : 6-dibromo-4-nitroresorcinol.

5-Nitro-4-hydroxy-3-methylphenylarsinic acid,[2]



is prepared by nitrating the corresponding methylhydroxyphenylarsinic acid. The yield is 90 per cent. It may be obtained also in almost theoretical yield when 5-nitro-4-amino-3-methylphenylarsinic acid is heated on the water-bath with 40 per cent. potassium hydroxide solution until a test portion no longer shows the presence of an amino-group, the acid then being precipitated by acidifying the mixture with hydrochloric acid. It crystallises in pale yellow needles or plates, decomposing explosively at 310° C. It is not so soluble in water as 3-nitro-4-hydroxyphenylarsinic acid. The *acetyl derivative* crystallises in colourless, spherical nodules, soluble in alcohols or boiling water.

Nitrohydroxyacetylphenylarsinic acid, $CH_3.CO.C_6H_2(OH)(NO_2).AsO(OH)_2$.[3]—Nitroaminohydroxyacetophenone is diazotised and treated in alkaline solution with sodium arsenite, when this arsinic acid is obtained as needles, M.pt. about 200° C. In a similar manner, *p*-aminobenzophenone yields *p-benzoylphenylarsinic acid*, M.pt. 195° to

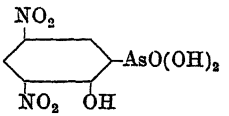
[1] Bauer, *Ber.*, 1915, 48, 515.

[2] Benda and Bertheim, *ibid.*, 1911, 44, 3445 ; Fargher, *Trans. Chem. Soc.*, 1919, 115, 990 ; German Patents, 235141, 245536.

[3] American Patent, 1472778.

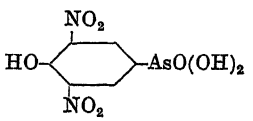
197° C., diaminobenzophenone yields a *diarsinic acid* of M.pt. 260° C., and *p*-aminobenzaldehyde yields *p-aldehydophenylarsinic acid.*[1]

3 : 5-Dinitro-2-hydroxyphenylarsinic acid,[2]



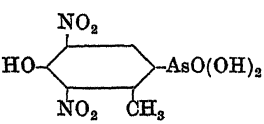
13 grams of 5-nitro-2-hydroxyphenylarsinic acid in 60 c.c. of sulphuric acid are stirred and maintained at 0° to 5° C. Without rise of temperature, 7·3 grams of mixed acid containing 44·7 per cent. of nitric acid are added dropwise, and after two hours' stirring, the product is poured upon 200 grams of ice. The acid separates in pale yellow needles, M.pt. 237° C. It may also be obtained by application of the Bart-Schmidt reaction to picramic acid.[3] Its solution in alkali is intensely yellowish-orange.

3 : 5-Dinitro-4-hydroxyphenylarsinic acid,[4]



4-Hydroxyphenylarsinic acid is nitrated in concentrated sulphuric acid solution at 15° to 20° C., using an excess of nitric acid (density 1·52). The acid has also been prepared by heating 3 : 5-dinitro-*p*-arsanilic acid with 10 per cent. potassium hydroxide solution at 90° C., the amino-group being substituted by the hydroxyl-group.[5] The dinitro-acid separates in pale yellow plates, sparingly soluble in cold water, readily soluble in hot water and methyl alcohol. It explodes on heating. De-arsenation of this acid occurs when it is boiled with aqueous sodium bisulphite, 2 : 6-dinitrophenol resulting.[6]

3 : 5-Dinitro-2-methyl-4-hydroxyphenylarsinic acid,[7]



To a solution of 9 grams of 2-methyl-4-hydroxyphenylarsinic acid in 30 c.c. of concentrated sulphuric acid, a mixture of 7 grams of nitric acid (density 1·4) and 10 c.c. of concentrated sulphuric acid is added dropwise, the temperature being maintained at about −5° C. during the operation.

[1] The electrolytic reduction of the following compounds is dealt with in German Patent, 270568 : 3-Nitro-4-hydroxyphenylarsenious acid, 2-nitro-4-hydroxyphenylarsenious acid, *o*-carboxyphenylarsenious acid, 3-nitro-4-hydroxyphenylarsinic acid, carboxyethylamino-hydroxyphenylarsinic acid, *p*-hydroxyphenylarsenoxide, and 3-amino-4-hydroxyphenyl-arsenoxide.

[2] Benda, *Ber.*, 1911, 44, 3293.

[3] King, *J. Chem. Soc.*, 1927, p. 1057. The melting-point of the product obtained by this second method is given as 244° to 246° C.

[4] German Patent, 224953 ; Benda and Bertheim, *Ber.*, 1911, 44, 3445.

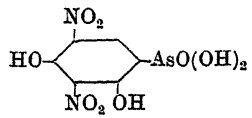
[5] Benda, *Ber.*, 1912, 45, 53.

[6] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 3050.

[7] Karrer, *Ber.*, 1915, 48, 313.

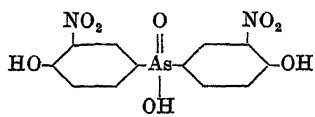
The temperature is then allowed to rise to 18° C., and after standing for thirty minutes the mixture is poured upon ice, the product separating as a thick, crystalline mass. It crystallises from water in long yellow needles, from which the water of crystallisation may be removed by drying at 75° C.

3 : 5-Dinitro-2 : 4-dihydroxyphenylarsinic acid,[1]

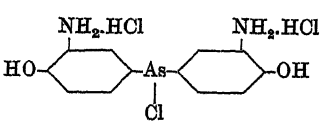


2 : 4-Dihydroxyphenylarsinic acid in 50 c.c. of concentrated sulphuric acid is well stirred and cooled, and a mixture of 30 c.c. of nitric acid (density 1·4) and 30 c.c. of sulphuric acid added. The temperature is maintained at about 20° C. during this operation, and afterwards the whole is warmed on the water-bath at 60° C. for an hour. The nitro-acid is separated by pouring the solution upon ice, the precipitate being washed with water, and dried ; yield, about 50 grams. The product is recrystallised from water and thus obtained as a white powder, melting with decomposition at 206° C. When treated with bromine in alcohol solution it yields 2 : 4-dinitro-6-bromoresorcinol.

3 : 3′-Dinitro-4 : 4′-dihydroxydiphenylarsinic acid,[2]



4 : 4′-Dihydroxydiphenylarsinic acid (6·3 grams) in 35 c.c. of concentrated sulphuric acid is treated with a mixture of 2·5 c.c. of nitric acid (density 1·44) and 2·5 c.c. of sulphuric acid, the temperature being maintained at −5° to −3° C. After a time the mixture is poured upon 250 grams of crushed ice, the required acid being precipitated in 94 per cent. yield. It is fairly soluble in glacial acetic acid, sparingly soluble in 50 per cent. acetic acid, from which it separates in minute rhomboidal prisms, melting with decomposition at 230° C. It is almost insoluble in boiling water. Complete reduction with sodium hydrosulphite leads to 3 : 3′-*diamino*-4 : 4′-*dihydroxydiphenylarsenious hydroxide*, which, dissolved in methyl alcoholic hydrochloric acid and treated with concentrated hydrochloric acid, gives rise to 3 : 3′-*diamino*-4 : 4′-*dihydroxydiphenylchloroarsine dihydrochloride*,

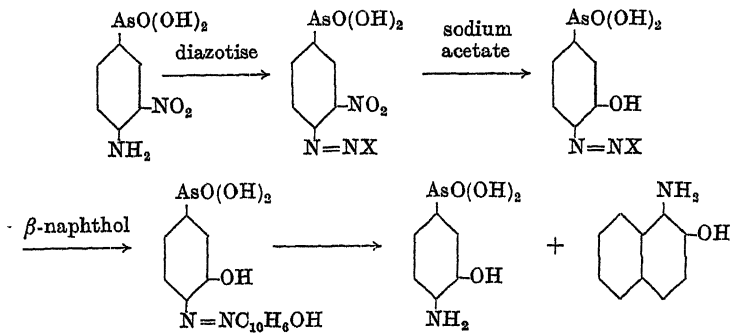


This forms glistening leaflets, darkening above 170° C. and melting at 215° C., soluble in water or methyl alcohol.

[1] Bauer, *Ber.*, 1915, 48, 516.
[2] Fargher, *Trans. Chem. Soc.*, 1919, 115, 986.

Aminohydroxyarylarsinic and Nitroaminohydroxyarylarsinic Acids.

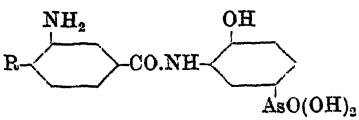
These acids may be prepared (1) by the reduction of nitrohydroxyarylarsinic acids using (*a*) sodium hydrosulphite at low temperatures, (*b*) electrolysis, (*c*) sodium amalgam, (*d*) ferrous sulphate in alkaline solution, or (*e*) glucose; (2) by application of the Bart reaction to nitroaminophenols, then reducing the resulting nitro-acids; (3) by the nitration of acetylaminohydroxyarsinic acids. Diaminohydroxyarylarsinic acids are produced by the reduction of dinitro- or nitroaminohydroxy-acids with alkaline hydrosulphite. 5-Nitro-4-amino-2-hydroxyphenylarsinic acid is formed when 3′:5-dinitrobenzoyl-4-amino-2-hydroxyphenylarsinic acid is hydrolysed by normal sodium hydroxide solution; 4-acetylamino-3-hydroxy-2-nitrophenylarsinic acid is produced by the nitration of the corresponding acetylaminohydroxyphenylarsinic acid. The production of 4-amino-3-hydroxyphenylarsinic acid from 3-nitro-4-aminophenylarsinic acid is of interest, and takes place in accordance with the following scheme:

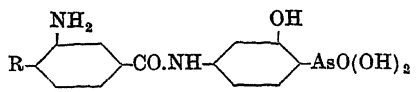


The preparation of this arsinic acid from *m*-chloracetanilide is dealt with in the scheme on p. 305. Two halogenated aminohydroxyarylarsinic acids are dealt with in this section: 3-chloro-5-amino-4-hydroxyphenylarsinic acid, and 3-iodo-5-amino-4-hydroxyphenylarsinic acid, which is obtained by reduction of the corresponding iodonitrohydroxy-acid, using titanous or ferrous oxide.

The foregoing acids are crystalline solids, and in some cases may be crystallised from water. 5-Amino-2:4-dihydroxy-, 3:5-diamino-2-hydroxy-, and 4:5-diamino-2-hydroxyphenylarsinic acids reduce ammoniacal silver nitrate solution, the reaction being instantaneous with the latter two acids. 4-Acetylamino-3-hydroxy-2-nitrophenylarsinic acid, boiled with 2*N* sulphuric acid, yields 2:6-nitroaminophenol, but with potassium hydroxide the acetyl group is merely hydrolysed; reduction of the acid with ferrous chloride produces the corresponding diamine. 3-Amino-4-hydroxyphenylarsinic acid tends to oxidise when recrystallised from water, and when a cooled solution of the acid in 5 per cent. sodium hydroxide solution is treated with carbonyl chloride, it gives 1:2-dihydrobenzoxazolone-4-arsinic acid. 3-Amino-4-hydroxyphenylarsinic acid also yields a number of N-acyl derivatives (see details on p. 296), the most important of which is the 3-acetylamino-compound,

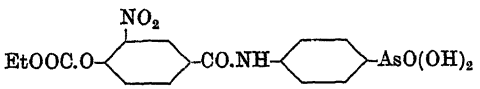
known commercially as *Stovarsal.* Arylamides of the 3-amino-4-hydroxy- and 4-amino-2-hydroxy-acids have been obtained, the general structures of the derivatives being:

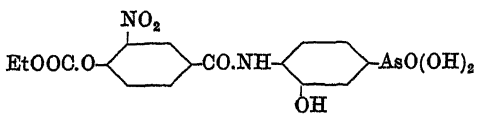




where R is H, OCH_3, or OH.

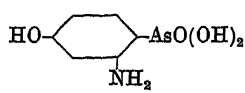
In the case of 3'-nitro-4'-ethylcarbonatobenzoyl-4-aminophenylarsinic acid, hydrolysis readily occurs with negligible fission at the amide linkage when the compound is boiled for a short time with normal alkali, but in the case of the corresponding derivative of 3-amino-4-hydroxyphenylarsinic acid, hydrolysis with cold normal alkali causes appreciable fission of the amide linkage. The two compounds are represented by the structures:





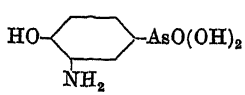
The unsubstituted acids are given in the scheme on the opposite page, where $X=AsO(OH)_2$.

2-Amino-4-hydroxyphenylarsinic acid,



3-Nitro-4-aminophenol gives 2-nitro-4-hydroxyphenylarsinic acid in 50 per cent. yield by the Bart reaction, and the nitro-acid when reduced by alkaline ferrous sulphate gives an 80 per cent. yield of the amino-acid.[1]

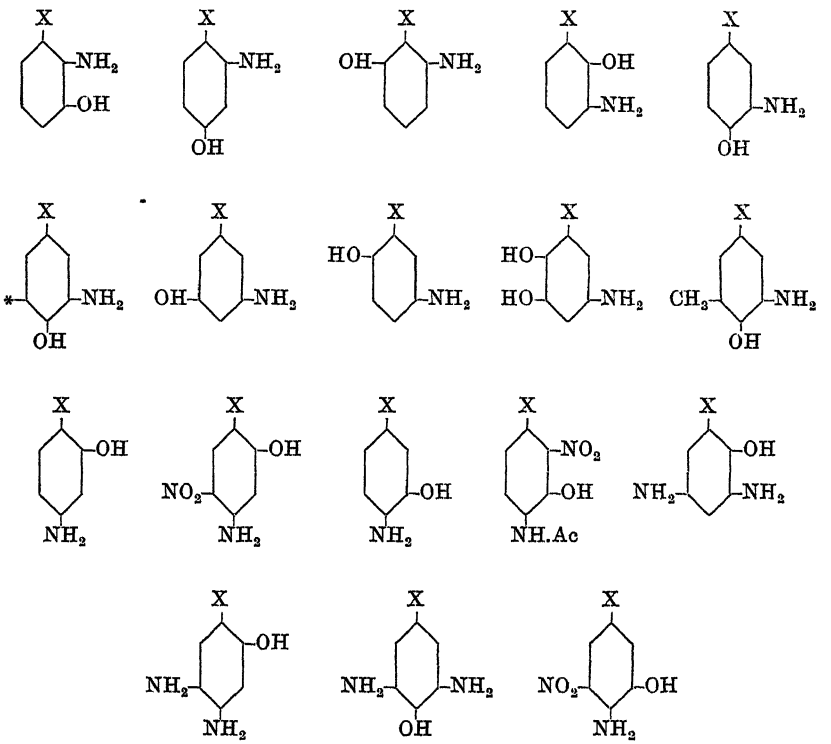
3-Amino-4-hydroxyphenylarsinic acid,



This is obtained by the reduction of the corresponding nitro-acid, which operation may be conducted in several ways: (1) Twenty-six grams of 3-nitro-4-hydroxyphenylarsinic acid in 200 c.c. of normal sodium hydroxide solution are cooled to −2° C. and 65 grams of sodium hydrosulphite (80 per cent.) added in one operation, with brisk stirring. The solution becomes colourless and the temperature rises to 25° C., whilst the amino-acid commences to be deposited. The remainder is precipitated by adding 23 c.c. of hydrochloric acid (density 1·12), the product

[1] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 123; Fourneau, *Ann. Inst. Pasteur*, 1923, 37, 576.

filtered off and washed with water. The yield varies from 65 to 80 per cent.[1] (2) The nitro-acid is reduced in a double cell with a mercury cathode and a nickel anode in sodium hydroxide in the inner cell. The nitro-acid in a large excess of sodium hydroxide is placed over the mercury in the outer cell. A current of 2 ampères at 3·5 to 4 volts is used.[2] (3) The nitro-acid (31·6 grams) in 600 c.c. of methyl alcohol is boiled on the water-bath with 840 grams of 4 per cent. sodium amalgam



* May be Cl or I.

until evolution of gas ceases. The alcohol is distilled off, the residue treated with 120 c.c. of water, separated from the mercury, and 150 c.c. of hydrochloric acid added (density 1·19). After twelve hours the solution is filtered, the filtrate boiled with charcoal, and the clear solution treated with 25 c.c. of acetic acid and 52 c.c. of 10*N* sodium hydroxide, when the amino-acid crystallises out in about 87 per cent. yield.[3] (4) 3-Nitro-4-hydroxyphenylarsinic acid may also be reduced by ferrous sulphate.[4]

Since this acid is difficult to recrystallise from water without oxidation occurring, the following method has been devised to overcome the

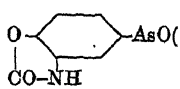
[1] Fargher, *Trans. Chem. Soc.*, 1919, 115, 990; see German Patent, 224953; American Patent, 986148. [2] British Patent, 3087 (1915).

[3] Ehrlich and Bertheim, *Ber.*, 1912, 45, 756; see German Patent, 224953; American Patent, 986148.

[4] Jacobs, Heidelberger, and Rolf, *J. Amer. Chem. Soc.*, 1918, 40, 1580.

difficulty :[1] 10 grams of the amino-acid are dissolved in 500 c.c. of boiling water in a nitrogen atmosphere, 2 grams of charcoal added, and the solution filtered. The filtrate is cooled in a nitrogen atmosphere, the crystals filtered off, washed with methyl alcohol, then with ether. The pure product forms very light brown short prisms of the monoclinic system. Yield, about 8 grams. The acid decomposes with melting at about 170° C. It is sparingly soluble in water and organic solvents, but readily dissolves in alkalis, ammonium hydroxide, sodium bicarbonate, and dilute mineral acids. The alkali solution gives a deep olive-green coloration with sodium hypochlorite, and the acid solution develops an intense red coloration with a drop of potassium dichromate solution. The *sodium salt* crystallises with one or two molecules of water. The *urethane derivative* is prepared from 5-amino-2-hydroxyphenylurethane, which is diazotised and treated with alkaline sodium arsenite and copper paste. The product crystallises from water, is soluble in sodium carbonate and alcohols, insoluble in acids, ether, and benzene.[2]

When 3-amino-4-hydroxyphenylarsinic acid in 5 per cent. sodium hydroxide is cooled in ice and treated with 6·5 per cent. carbonyl chloride, 1 : 2-*dihydrobenzoxazolone-4-arsinic acid* is produced,[3]



This crystallises from boiling water in colourless, prismatic needles, decomposing above 250° C. without melting. When reduced by sodium hydrosulphite in 2*N* sodium hydroxide at 60° C. in the presence of magnesium chloride and in a carbon dioxide atmosphere, it yields the corresponding arseno-compound, 1 : 2 : 1′ : 2′-*tetrahydro-4-arsenobenzodioxazolone*. This is a pale yellow powder, insoluble in water and the usual organic solvents, but dissolving readily in sodium hydroxide.[4]

N-Acyl Derivatives of 3-*Amino-4-hydroxyphenylarsinic Acid.*[5]

In the preparation of these compounds it is found that a better yield and a purer product results by working in a neutral or slightly acid solution. Condensation is effected by heating the reactants for a few hours at a moderate temperature. For the formyl compound, formic acid may replace water as solvent, and for the butyryl and propionyl derivatives the addition of copper turnings shortens the time of heating. With the exception of the latter derivative, these compounds do not contain water of crystallisation, but their salts do contain varying amounts of water.

3-Formylamino-4-hydroxyphenylarsinic acid, $HCO.NH(OH)C_6H_3AsO(OH)_2$, crystallises from water in long colourless prisms of the monoclinic system, which do not melt at 275° C. It decomposes on prolonged boiling with water or dilute sodium hydroxide solution. It is soluble in dilute alkali and ammonium hydroxide, sparingly soluble in boiling water, practically insoluble in cold water, insoluble in acids and

[1] Raiziss and Fisher, *J. Amer. Chem. Soc.*, 1926, 48, 1323.
[2] German Patent, 268172.
[3] Fargher, *loc. cit.*
[4] For the condensation of 3-amino-4-hydroxyphenylarsinic acid with dextrose, see German Patent, 433105, addition to 413147.
[5] Raiziss and Fisher, *loc. cit.*

the usual organic solvents. Its *sodium salt* contains 7 molecules of water of crystallisation and crystallises in prisms, which slowly decompose but do not melt when heated to 275° C.

3 - Acetamido - 4 - hydroxyphenylarsinic acid (*Stovarsol*), $CH_3CO.NH(OH)C_6H_3AsO(OH)_2$.[1]—A mixture of 10 grams of 3-amino-4-hydroxyphenylarsinic acid, 40 c.c. of water and 9 c.c. of acetic anhydride is mechanically stirred for two hours and maintained at 50° to 55° C. The solid is filtered off, suspended in 100 c.c. of 10 per cent. hydrochloric acid, stirred for fifteen minutes, then collected and washed with a little 10 per cent. hydrochloric acid. The product is purified by suspending in 100 c.c. of water and dissolving by the addition of 10 per cent. aqueous sodium hydroxide. 5 grams of Nuchar "W" (a form of carbon with very high decolorising power) are then added, and after thirty minutes' stirring the mixture is treated in the cold with glacial acetic acid in slight excess. Crystals separate and are washed with water until free from sodium chloride, acetate, and acetic acid, finally being washed with a little methyl alcohol and ether. About 9·7 grams of substance are isolated, which can be recrystallised from boiling water. It crystallises from water in short, colourless prisms of the monoclinic system, which slowly decompose on prolonged boiling with water or dilute alkalis. It is soluble in cold dilute alkalis but insoluble in dilute acids and the usual organic solvents. It melts with decomposition between 240° and 250° C., and forms colourless, crystalline, water-soluble *sodium, potassium, lithium, ammonium*[2] and *strontium salts*, and sparingly soluble *salts* of *calcium* and *barium*. The sodium salt crystallises in short, colourless prisms, containing 4 molecules of water. When heated, it effervesces at about 113° C., again at 150° C., and apparently melts with decomposition at about 210° C.[3]

3-Chloracetamido-4-hydroxyphenylarsinic acid, $CH_2Cl.CO.NH(OH)C_6H_3AsO(OH)_2$, forms colourless prisms, darkening at 230° C., and melting sharply with decomposition at 238° to 239° C. It is readily soluble in dilute alkalis, methyl alcohol, and boiling 30 per cent. acetic acid, sparingly soluble in boiling water. The *sodium salt* contains 8 molecules of water, and forms clumps of colourless, twisted, hair-like needles, unmelted at 275° C.

3-Propionylamino-4-hydroxyphenylarsinic acid, $CH_3.CH_2.CO.NH(OH)C_6H_3AsO(OH)_2$, crystallises in colourless, diamond- and hexagonal-shaped plates containing 1 molecule of water, melting with considerable decomposition at 228° to 229° C. The *sodium salt* forms needles containing 1 molecule of water.

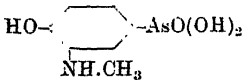
3-Butyrylamino-4-hydroxyphenylarsinic acid, $CH_3.CH_2.CH_2.CO.NH(OH)C_6H_3AsO(OH)_2$, yields microscopic hexahedrons of the isometric system, melting with decomposition at 218° to 219° C.; its *sodium salt* crystallises in clumps of colourless needles containing 10 molecules of water of crystallisation.

[1] See American Patent, 1077462; Raiziss and Gavron, *J. Amer. Chem. Soc.*, 1921, 43, 583; Christiansen, *ibid.*, 1922, 44, 2340; Fourneau, Tréfouel, and Bénoit, *Bull. Soc. chim.*, 1927, [iv.], 41, 499. Stable solutions of *bismuth salts* of this derivative or similar arylarsinic acids are prepared by the addition of a base such as piperazine, or sodium or ammonium hydroxide, to a suspension of the salt, to render it soluble, and of a salt of an aliphatic hydroxypolybasic acid, such as potassium tartrate or citrate—British Patent, 277774 (1926); French Patent, 632834.

[2] See British Patent, 264797 (1926).

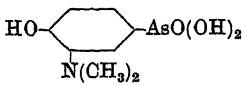
[3] For alkaloidal salts of acetylaminohydroxyphenylarsinic acids, see American Patent, 1643692; British Patent, 249849 (1926).

3-Methylamino-4-hydroxyphenylarsinic acid,[1]



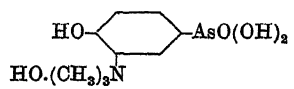
is obtained when 3-amino-4-hydroxyphenylarsinic acid is methylated in alkaline solution by dimethyl sulphate. It crystallises with 0·5 of a molecule of water, and is very soluble in water, alcohols, acetic acid, alkalis, and mineral acids. It melts with decomposition at 263° to 263·5° C., and the aqueous solution readily oxidises in air.

3-Dimethylamino-4-hydroxyphenylarsinic acid,



3-Amino-4-hydroxyphenylarsinic acid (46·6 grams) in 300 c.c. of water and 21·2 c.c. of 10*N* sodium hydroxide is treated with 20 c.c. of dimethyl sulphate at room temperature. When the reaction ceases, the mixture is cooled, crystallisation commencing. At this stage a further 20 c.c. of alkali and 20 c.c. of dimethyl sulphate are added. When no further crystallisation takes place, 12 c.c. of glacial acetic acid are added and the solution is seeded with a little of the starting material. After two days, 3-amino-4-hydroxyphenylarsinic acid separates, and the filtrate from these crystals is concentrated in a vacuum. The dimethylated acid separates in transparent prisms, the yield being 54 per cent. The acid decomposes at 119° to 121° C., is soluble in water, alcohols, or acetic acid, but sparingly soluble in acetone, and insoluble in ether.

3-Trimethylammonium-4-hydroxyphenylarsinic acid,

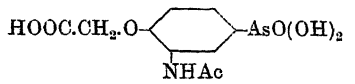


3-Amino-4-hydroxyphenylarsinic acid (21 grams) is shaken with 210 c.c. of methyl alcohol, 9 c.c. of 10*N* sodium hydroxide solution, and 6 c.c. of methyl iodide. After several hours similar quantities of alkali and iodide are added, the process again being repeated after standing for a day. From the solution, 25·3 grams of product separate, this being a mixture of quaternary iodide and quaternary base. These are separated by fractional crystallisation from water, in which the iodide is the more soluble. The quaternary base loses water at 110° to 114° C., yielding an *inner anhydride*. The hydroxide is soluble in water, the solution having an acid reaction; it is less soluble in alcohols and acetone, but readily soluble in aqueous alkalis and acids. It yields no red coloration with a drop of acid dichromate solution, which distinguishes it from the mono-, di-, and un-methylated arsinic acids.

3-Oximinoacetamido-4-hydroxyphenylarsinic acid is obtained by Sandmeyer's method from 3-amino-4-hydroxyphenylarsinic acid. Reduction by stannous chloride in the presence of potassium iodide gives 3 : 3′-*diglycylamido*-4 : 4′-*dihydroxyarsenobenzene*, which yields a *hydrochloride*.[2]

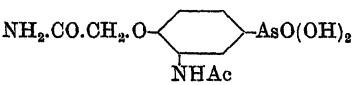
[1] Bertheim, *Ber.*, 1912, 45, 2130.
[2] Karrer, Diechmann, and Haebler, *Helv. Chim. Acta*, 1924, 7, 1031.

2-Acetamidophenoxyacetic acid 4-arsinic acid,[1]



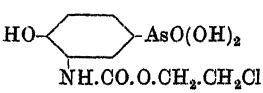
3-Acetamido-4-hydroxyphenylarsinic acid (45·5 grams) is suspended in 130 c.c. of water containing 20 grams of sodium hydroxide, treated with 16 grams of chloracetic acid, and the whole refluxed until the solution is acid to litmus, this operation requiring about forty-five minutes. A further 7 grams of sodium hydroxide in 7 c.c. of water and 8 grams of chloracetic acid are added and the boiling continued until acidity again develops. The mixture is then acidified to Congo red, and, after cooling, the arsinic acid is filtered off, dissolved in alkali, acetic acid added, the solution filtered, and the filtrate made acid to Congo red. The arsinic acid crystallises out in long, pointed needles, unmelted at 280° C., the yield being about 66 per cent. The *magnesium salt* is amorphous. The acid, when heated with 5*N* sodium hydroxide or 4*N* hydrochloric acid, yields 3-hydroxy-1 : 4-benz*iso*xazine-6-arsinic acid (p. 429).

2-Acetamidophenoxyacetamide 4-arsinic acid,



This acid is the product of the interaction of 3-acetamido-4-hydroxyphenylarsinic acid and chloracetamide in alkaline solution. It crystallises from water in colourless hexagonal plates, melting with decomposition at 236° C., and forming an insoluble, amorphous *magnesium salt.* Hydrolysis of the amide gives similar results to those obtained with the preceding acid.

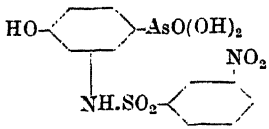
3-ω-Chlorocarbethoxyamino-4-hydroxyphenylarsinic acid,



10 grams of 3-amino-4-hydroxyphenylarsinic acid in 30 c.c. of 2*N* sodium hydroxide at 30° C. are treated alternately with β-chloroethyl chlorocarbonate (7 c.c.) and 10*N* sodium hydroxide, the temperature being maintained between 35° and 40° C., and the mixture being kept alkaline to litmus, but not to phenolphthalein. After filtration the solution is acidified to Congo red and the precipitated arsinic acid purified by acidification of its warm solution in sodium carbonate. The yield is about 9·5 grams, or 63 per cent. The product forms colourless, rhombic crystals, melting with decomposition at 209° C., insoluble in cold water, alcohols, and dilute mineral acids, but readily soluble in alkalis. The *magnesium salt* is amorphous. When the acid is refluxed with 4*N* sodium hydroxide it is converted into 2 : 3-dihydro-1 : 4-benz*iso*xazine-6-arsinic acid (p. 434).

[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3054.

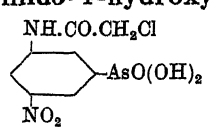
3'-Nitrobenzenesulphonyl-3-amino-4-hydroxyphenylarsinic acid,[1]



3-Amino-4-hydroxyphenylarsinic acid (11·6 grams) is dissolved in 60 c.c. of water containing 3·85 grams of anhydrous sodium carbonate and 22 grams (2 mols.) of nitrobenzenesulphonyl chloride and a few drops of ether added. The mixture is shaken for thirty minutes, then three successive portions of normal sodium carbonate (1 mol.) are added at thirty-minute intervals with intermediate shaking. The solution, on acidification to Congo red paper, deposits a pale-coloured gum and, after twelve hours in the cold, a crystalline powder. These substances are stirred with 75 c.c. of normal hydrochloric acid on a boiling water-bath until the non-soluble portion crystallises. The latter is dissolved in 20 volumes of 0·5*N* sodium hydroxide, boiled for thirty minutes, and the solution treated while hot with concentrated hydrochloric acid so long as an oily turbidity is produced. The liquor is filtered, the required nitro-acid separating. This product, plus that which may be recovered from the mother-liquors, brings the yield to 33 per cent. The acid crystallises from 20 volumes of boiling water as the *dihydrate*, consisting of large, straw-coloured prisms or rhombs. In sodium hydrogen carbonate solution it gives an intense purple coloration when treated with a drop of ferric chloride, the colour being redder on addition of caustic alkali, finally disappearing if excess of the latter is used, with separation of ferric hydroxide.

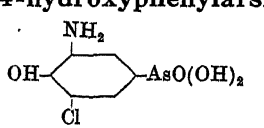
Reduction of the nitro-acid by ferrous chloride and alkali gives *3'-aminobenzenesulphonyl-3-amino-4-hydroxyphenylarsinic acid* in 76 per cent. yield. This crystallises from boiling water in glistening prisms; its *hydrochloride* forms rectangular tablets, the *sulphate*, short needles, and the *nitrate*, prisms. Its sodium hydrogen carbonate solution gives colour reactions with ferric chloride, cobalt and nickel nitrates, and with copper salts.

3-Nitro-5-chloracetamido-4-hydroxyphenylarsinic acid,[2]



is the chloracetylation product of 3-nitro-5-amino-4-hydroxyphenylarsinic acid. It crystallises from water in yellow prisms, melting with decomposition at 200° C., and yields an amorphous *magnesium salt*. Sodium hydroxide converts the acid into 8-nitro-3-hydroxy-1 : 4-benz*iso*xazine-6-arsinic acid (p. 432).

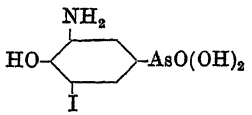
3-Chloro-5-amino-4-hydroxyphenylarsinic acid,[3]



[1] Hewitt, King, and Murch, *J. Chem. Soc.*, 1926, p. 1365.
[2] Newbery, Phillips, and Sticklings, *ibid.*, 1928, p. 3059.
[3] American Patent, 1595498.

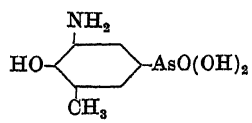
In the nitration of 3-chloro-4-hydroxyphenylarsinic acid, the nitro-group enters the 5-position in the nucleus. This 5-nitro-compound is reduced and treated with acetic anhydride to form the acetamido-derivative, which on hydrolysis with 16 per cent. aqueous sodium hydroxide at 100° C. yields the required acid.[1]

3-Iodo-5-amino-4-hydroxyphenylarsinic acid,[2]



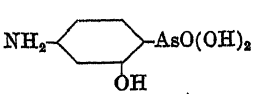
results when the corresponding nitro-acid is reduced in cold alkaline solution by an excess of freshly precipitated titanous or ferrous oxide. The acid itself is comparatively unstable ; treatment with zinc or lead acetate yields the corresponding *zinc* and *lead salts*, which, when dry, are colourless powders. A solution of the zinc salt in cold sulphuric acid (1 : 20), when partly neutralised, yields the amino-acid as yellow needles which darken at about 95° C. The *acetyl compound* is obtained by treating 3-iodo-5-nitro-4-hydroxyphenylarsinic acid with hydrosulphite in alkaline solution, then with acetic anhydride. It crystallises from dilute acetic acid (1 : 1) in prisms, M.pt. 190° to 191° C. If the acetic anhydride in this preparation is replaced by ethyl chloroformate, *5-iodo-3-carbethoxyamino-4-hydroxyphenylarsinic acid* is formed. This is a powder, M.pt. 182° to 183° C. with decomposition, soluble in methyl alcohol, acetone, or pyridine.

3-Methyl-5-amino-4-hydroxyphenylarsinic acid,[3]



formed by reduction of the corresponding nitro-acid, is more soluble in water than the aminophenolarsinic acid, and has to be salted out from its aqueous solutions. It has recently[4] been purified by solution in hydrochloric acid and reprecipitation by sodium acetate, when it separates in colourless prisms, insoluble in water, but readily soluble in alkalis. The *monosodium salt* crystallises in white needles, sparingly soluble in cold water.

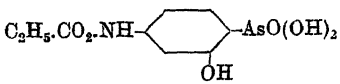
4-Amino-2-hydroxyphenylarsinic acid,[5]



This acid may be prepared in several ways : (1) *m*-Aminophenol in ethyl acetate solution is treated with ethyl chlorocarbonate, whereby it is converted into carbethoxy-*m*-aminophenol (M.pt. 97° C.). This

[1] For N-acyl derivatives of this acid, see American Patent, 1588382 ; British Patent, 230847 (1925).
[2] Macallum, *J. Chem. Soc.*, 1926, p. 1645.
[3] German Patent, 224953 ; American Patent, 986148.
[4] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3061.
[5] Bauer, *Ber.*, 1915, 48, 1579.

product (90 grams) is heated on a water-bath for one week with 100 grams of arsenic acid (about 83 per cent.). The melt is triturated with water and washed to remove arsenic acid, then dissolved in ammonium hydroxide and the solution saturated with ammonia gas. The *ammonium salt* separates, and is converted into the free acid by treatment with mineral acid. The product thus obtained is *4-carbethoxyamino-2-hydroxyphenylarsinic acid*,



It is soluble in hot water, alcohols, and acetic acid, sparingly soluble in acetone, insoluble in benzene and ether. It is transformed into the required 4-amino-acid by boiling 15 grams with 30 c.c. of 10*N* sodium hydroxide and 60 c.c. of water for two hours under reflux. The product is precipitated by the addition of 150 c.c. of 2*N* sulphuric acid, the yield being about 9 grams.

(2) The starting-point in this case is 3-nitro-6-aminophenol. 77 grams of this in 170 c.c. of hydrochloric acid (density 1·12) and 350 c.c. of water are treated with ice and diazotised with 36 grams of sodium nitrite. An aqueous solution of 65 grams of sodium arsenite is stirred in and the whole gradually made alkaline by the addition of 2*N* sodium hydroxide solution. Nitrogen is evolved and the dark solution acidified with hydrochloric acid, which precipitates a small quantity of impurity. The filtrate is rendered ammoniacal, magnesia mixture added, and the whole boiled, when the yellow *magnesium salt* separates out and is removed.[1] Treatment with hydrochloric acid converts this salt to the free 4-nitro-2-hydroxyphenylarsinic acid. Recrystallising from water, with the addition of charcoal, gives a yield of 72 grams. The acid sinters at 212° C. and decomposes at 250° C., is soluble in acetone and acetic acid, very soluble in alcohols. It is reduced to the amino-acid by boiling with dilute acetic acid and iron filings,[2] or by using ferrous chloride.[3]

4-Amino-2-hydroxyphenylarsinic acid, when crystallised from water, melts at 173° C.; it is very soluble in alcohols, sparingly soluble in acetone, and insoluble in ether and hydrocarbons. The *hydrochloride*, *nitrate* and *sulphate* all crystallise from the corresponding normal acids in acicular crystals. When treated with potassium cyanate the acid yields *4-carbamido-2-hydroxyphenylarsinic acid*.[4]

4-Amino-2-hydroxyphenylarsinic acid, when boiled for three hours with 98 per cent. formic acid, yields *4-formamido-2-hydroxyphenylarsinic acid*.[5]

4-Dimethylamino-2-hydroxyphenylarsinic acid[6] is obtained when 1 part of 2-nitro-4-dimethylaminophenylarsinic acid is added to 0·5 part of carbamide in 10 parts of 60 per cent. sulphuric acid.

[1] Instead of proceeding through the magnesium salt, the main bulk of the arsinic acid may be precipitated by neutralisation to Congo red paper (Hewitt and King, *J. Chem. Soc.*, 1926, p. 824; see also Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 121).

[2] Bauer, *loc. cit.*

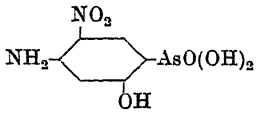
[3] Hewitt and King, *loc. cit.*; compare Newbery and Phillips, *loc. cit.*

[4] King, *J. Chem. Soc.*, 1927, p. 1056.

[5] British Patent, 277586 (1926).

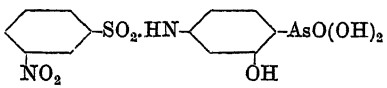
[6] French Patent, 474056.

5-Nitro-4-amino-2-hydroxyphenylarsinic acid,[1]



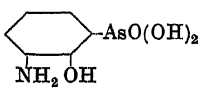
When 3′ : 5-dinitrobenzoyl-4-amino-2-hydroxyphenylarsinic acid is hydrolysed by boiling with 15 volumes of normal sodium hydroxide for forty minutes, it yields pure *m*-nitrobenzoic acid and the required 5-nitro-acid. The latter crystallises from hot water in short, yellow prisms, which are readily soluble in concentrated hydrochloric acid but only sparingly soluble in the 3*N* acid.

3′-Nitrobenzenesulphonyl-4-amino-2-hydroxyphenylarsinic acid,[2]



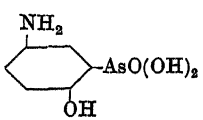
crystallises in colourless needles, which are rapidly transformed to plates. It also exists as a *dihydrate*. When reduced with ferrous chloride and alkali it gives a 63 per cent. yield of the *3′-aminobenzenesulphonyl-compound*, which crystallises from boiling water in tufts of fine needles. When dissolved in sodium hydrogen carbonate solution it gives a clear, deep yellowish-brown colour with ferric chloride, and a bright emerald-green colour with copper sulphate, whereas the preceding nitro-compound under the same conditions gives a clear, reddish-brown solution with ferric chloride, and an olive-green colour with copper salts.

3-Amino-2-hydroxyphenylarsinic acid,[3]



This acid is formed in 62 per cent. yield by reducing the corresponding nitro-compound with glucose and alkali. Its melting-point is over 300° C.; it forms amorphous *calcium* and *magnesium salts*. The *acetyl derivative* crystallises from water in stout plates, melting with decomposition at 205° C.; it forms a microcrystalline *barium salt* and an amorphous *calcium salt*.

5-Amino-2-hydroxyphenylarsinic acid,[4]



This is obtained by reducing 5-nitro-2-hydroxyphenylarsinic acid (p. 286) as follows: To 100 grams of the nitro-acid in 250 c.c. of water and 200 c.c. of 2*N* sodium hydroxide solution, 200 grams of ice are added, followed by 240 grams of sodium hyposulphite, the temperature being maintained below 10° C. The whole is mechanically stirred for thirty

[1] Hewitt and King, *loc. cit.*

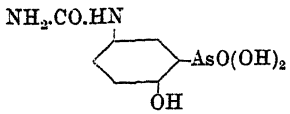
[2] Hewitt, King, and Murch, *J. Chem. Soc.*, 1926, p. 1367.

[3] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3065; compare Fourneau, Tréfouel, and Bénoit, *Bull. Soc. chim.*, 1927, 41, 499.

[4] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 122.

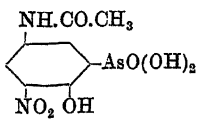
minutes, the solid then removed, washed and purified, a yield of about 50 grams (60 per cent.) being obtained.

5-Carbamido-2-hydroxyphenylarsinic acid,[1]



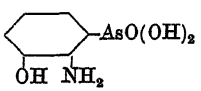
This results when 5-amino-2-hydroxyphenylarsinic acid is treated with cyanogen bromide (see conditions given for *p*-carbamidophenylarsinic acid, p. 209). It forms needle-shaped crystals, soluble in hot water or alkalis, insoluble in mineral acids.

3-Nitro-5-acetamido-2-hydroxyphenylarsinic acid,[2]



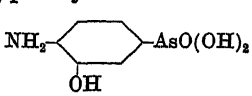
5-Acetamido-2-hydroxyphenylarsinic acid, 100 grams, in 300 c.c. of sulphuric acid at 20° C., is nitrated at 10° to 20° C. by a mixture of 35 c.c. of nitric acid (density 1·42) and 35 c.c. of sulphuric acid, and the whole poured into ice-water. Pure nitro-acid separates in 80 per cent. yield as yellow prisms, giving red solutions in caustic alkali and alkali carbonates.

2-Amino-3-hydroxyphenylarsinic acid,[3]



This may be obtained in 52 per cent. yield by reducing 55 grams of the corresponding nitrohydroxy-acid in 330 c.c. of hot water containing 58 grams of sodium hydroxide with 44 grams of glucose. The mixture is gently boiled for five minutes, and then after standing for an hour is strongly acidified to Congo red. After treating with charcoal, filtering, and neutralising to Congo red with 10*N* sodium hydroxide solution, the amino-acid separates. It crystallises on purification in characteristic wedge-shaped crystals. The *calcium salt* forms hexagonal plates and the *acetyl derivative* crystallises in rectangular plates, melting with decomposition at 207° to 210° C.

4-Amino-3-hydroxyphenylarsinic acid,

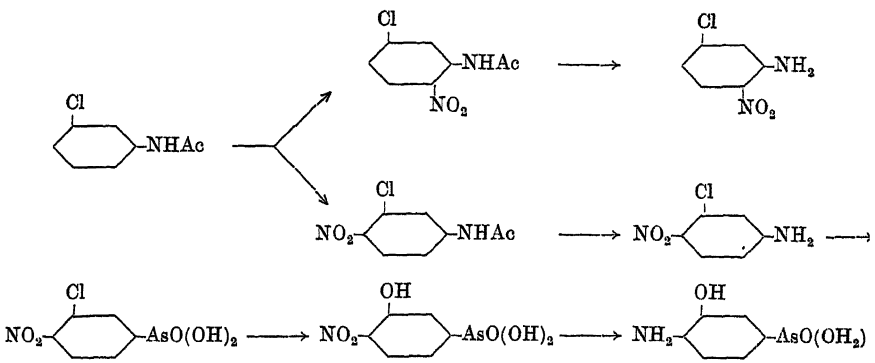


3-Nitro-4-aminophenylarsinic acid is diazotised and coupled with β-naphthol, and the azo-compound produced (p. 394) reduced as follows :[4] 160 grams of the dyestuff are dissolved in a mixture of 2400 c.c. of water and 320 c.c. of 10*N* sodium hydroxide at 60° C., and the

[1] Sticklings, *J. Chem. Soc.*, 1928, p. 3131.
[2] Newbery and Phillips, *ibid.*, p. 2375.
[3] Fourneau, Tréfouel, and Bénoit, *Bull. Soc. chim.*, 1927, 41, 499; Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3054.
[4] Benda, *Ber.*, 1911, 44, 3578; see German Patent, 244166.

solution cooled at 25° C. Sodium hydrosulphite (320 grams) is stirred in, the temperature rising to 38° or 40° C. whilst the mixture decolorises. After cooling to 10° C., the 1-amino-2-naphthol is filtered off and the filtrate saturated with carbon dioxide, when the remainder of the aminonaphthol separates. After several filtrations, air is blown through the yellow solution to destroy the hydrosulphite and the whole then evaporated to 200 c.c. At a temperature of 35° C., 250 c.c. of sulphuric acid (1 : 1) are added, the aminohydroxy-acid separating after several hours. The foregoing reduction may also be accomplished using aluminium powder and sodium hydroxide.

The most recent synthesis of 4-amino-3-hydroxyphenylarsinic acid is carried out by the following series of reactions : [1]



4-Nitro-3-hydroxyphenylarsinic acid (p. 288), 49 grams, is dissolved in 175 c.c. of water containing 52·5 grams of sodium hydroxide. This mixture on reduction with 42 grams of glucose in 140 c.c. of hot water gives 38 grams (68 per cent.) of 4-amino-3-hydroxyphenylarsinic acid after acidification, heating with charcoal, filtering, and adding solid sodium acetate. The acid is deposited in small, hexagonal, anhydrous prisms from 2*N* acetic acid.

The acid is soluble in hot water and the usual solvents, insoluble in ether. Its *diazo-compound* is citron-yellow and gives a red dye with alkaline resorcinol. The *sodium salt* forms glistening groups of silver crystals containing 5 molecules of water. When carbonyl chloride is passed into a solution of the arsinic acid in aqueous sodium acetate, a white crystalline product is obtained.[2]

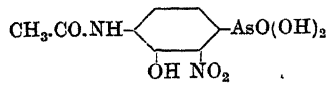
The *acetyl derivative* forms colourless needles, readily soluble in water ; [3] it separates as diamond-shaped plates when an alkaline solution of the acid is acidified.[4] It is almost insoluble in hot water and alcohol, sparingly soluble in 50 per cent. acetic acid, readily soluble in cold 80 per cent. formic acid. The *magnesium salt* is amorphous, and the *sodium salt* is deposited from alcohol in fine needles. It is possible to obtain 4-acetamido-3-hydroxyphenylarsinic acid from 5-aminoethenyl-*o*-aminophenol by the Bart method,[5] but the yield is only 10 per cent. Hydrolysis of the acetyl derivative with hot 20 per

[1] Balaban, *J. Chem. Soc.*, 1928, p. 809.
[2] British Patent, 214628 (1924).
[3] Benda, *Ber.*, 1914, 47, 995.
[4] Balaban, *J. Chem. Soc.*, 1928, p. 811.
[5] Newbery and Phillips, *ibid.*, 1928, p. 122.

cent. sodium hydroxide solution, followed by acidification with acetic acid, gives the free amino-acid in 90 per cent. yield. The latter gives a green coloration with chromic acid; 3-amino-4-hydroxyphenylarsinic acid gives a red colour.

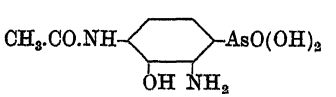
The following isomeric aminohydroxyphenylarsinic acids have recently been obtained:[1] 3-*Amino*-2-*hydroxyphenylarsinic acid*, prepared from 6-nitro-2-aminophenol by diazotisation and introduction of the arsinic acid group, then reducing the nitro-acid by hydrosulphite or alkali and ferrous sulphate, 3-*amino*-5-*hydroxy*- and 2-*amino*-6-*hydroxyphenylarsinic acids*, prepared in a similar manner.[2]

2-Nitro-4-acetamido-3-hydroxyphenylarsinic acid,[3]



4-Acetylamino-3-hydroxyphenylarsinic acid (16·5 grams) is dissolved at the ordinary temperature in 50 c.c. of sulphuric acid (66° Bé.) and treated dropwise with 8 c.c. of mixed acid (100 c.c. = 49·2 grams HNO_3) at 5° to 10° C., the mixture being well stirred during the operation. The temperature is then allowed to rise to 15° or 20° C. and the stirring continued for thirty minutes, when the whole is poured upon ice. An orange-yellow precipitate separates, which is filtered off, washed, and dried. The yield is 15·5 grams, or 80 per cent. The acid crystallises from large quantities of boiling water in long, red, glistening, hexagonal, anhydrous prisms, and from glacial acetic acid in rods,[4] which do not yield ammonia or the *o*-nitro-amino compound on heating with potassium hydroxide. The melting-point is rather indefinite, the acid blackening and frothing at about 220° C. The acid is soluble in methyl and ethyl alcohols, and when boiled with 2*N* sulphuric acid, 2 : 6-nitroaminophenol results. The *calcium salt* of the acetamido-acid crystallises in bunches of needles; the *barium* and *magnesium salts* are amorphous. Boiling the acid with potassium hydroxide gives 2-*nitro*-4-*amino*-3-*hydroxyphenylarsinic acid*, consisting of long, red, glistening, boat-shaped plates, which change to a brown *monohydrate* when dried at 100° C. but do not lose their water at 110° C. This acid is soluble in alcohol, and moderately soluble in glacial acetic acid, from which it separates in prisms, whilst its *magnesium salt* is amorphous when precipitated from an ammoniacal solution of the acid.[5] It forms a yellow *diazo-compound*, which gives a bluish-red *azo-derivative* with R-salt, this changing to bluish-violet. Reduction with ferrous chloride yields the diamino-compound.

2-Amino-4-acetamido-3-hydroxyphenylarsinic acid,[6]



This is isolated by reducing the corresponding nitro-compound at 30° C. with ferrous sulphate, a 74 per cent. yield resulting. It crystallises

[1] Fourneau, Tréfouel, and Bénoit, *Bull. Soc. chim.*, 1927, [iv.], 41, 499.

[2] When the arsinic acids of *o*-aminophenols are benzylated in alkali solution the monobenzamido compounds are exclusively formed, no substitution occurring in the amino-group (American Patent, 1588381).

[3] Benda, *loc. cit.*

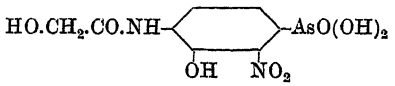
[4] Balaban, *J. Chem. Soc.*, 1928, p. 811.

[5] Balaban, *ibid.*

[6] Balaban, *ibid.*

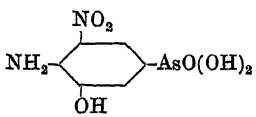
from water in long, colourless, rectangular, anhydrous prisms, soluble in excess of 2*N* hydrochloric acid, cold 90 per cent. formic acid, and glacial acetic acid, but almost insoluble in alcohol. With nitrous acid it yields an insoluble *diazo-oxide*, consisting of yellow quadrilateral plates, which do not couple with sodium β-naphthoxide. The *calcium salt* is microcrystalline, the *magnesium salt* amorphous. Acetylation leads to the formation of 2 : 4-*diacetamido*-3-*hydroxyphenylarsinic acid*, which forms colourless, silky, anhydrous needles from 2*N* acetic acid.

2 - Nitro - 4 - ω - hydroxyacetamido - 3 - hydroxyphenylarsinic acid,[1]



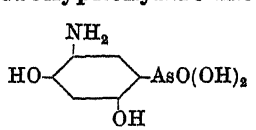
This acid is prepared by the chloracetylation of 2-nitro-4-amino-3-hydroxyphenylarsinic acid; it crystallises from water in golden-brown anhydrous plates, which decompose with effervescence at 210° C. It dissolves sparingly in alcohol and glacial acetic acid, from which it crystallises in plates; it forms a rich red solution in aqueous sodium hydroxide. When the acid is heated with 16 per cent. hydrochloric acid, the arsenic is removed and 2-nitro-6-aminophenol results. Reduction of the acid gives the corresponding *amino-acid*, which crystallises from water in almost colourless clusters of stout, anhydrous prisms. This amino-acid is soluble in excess of 2*N* hydrochloric acid, moderately soluble in glacial acetic acid, sparingly soluble in alcohol, and readily soluble in 80 per cent. formic acid. The *calcium*, *barium* and *magnesium salts* of the nitro-acid are amorphous. De-arsenation of the amino-acid yields, after acetylation, the triacetyl derivative of 2 : 6-diaminophenol. The *acetyl derivative* of the amino-acid crystallises from water in fine, colourless, silky, anhydrous needles, moderately soluble in glacial acetic acid, insoluble in alcohol. The *magnesium salt* is amorphous.

5-Nitro-4-amino-3-hydroxyphenylarsinic acid,



This acid is obtained when 3-nitrobenzoxazolone-5-arsinic acid (p. 437) is heated with 2*N* sodium hydroxide solution. It crystallises from water in bright yellow spikes containing 1 molecule of water, almost insoluble in glacial acetic acid or alcohol, soluble in concentrated hydrochloric acid and in formic acid. The *calcium salt* crystallises in laminæ.

5-Amino-2 : 4-dihydroxyphenylarsinic acid,[2]

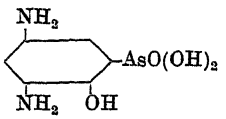


This acid is prepared from the nitro-acid by reduction with alkaline hydrosulphite. It crystallises in bushy needles, decomposing at 150° C. and containing 1 molecule of water. It is sparingly soluble in the usual solvents; sodium acetate precipitates it from solution in mineral acids.

[1] Balaban, *J. Chem. Soc.*, 1928, p. 3069. [2] Bauer, *Ber.*, 1915, 48, 517.

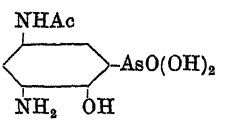
The acid reduces ammoniacal silver nitrate solution, and with sodium nitrite gives a yellow *diazo-compound*, which couples with resorcinol to give a bluish-red dye. When dissolved in sodium hydroxide and treated with acetic anhydride, the amino-acid yields an *acetyl derivative*, which separates in colourless prisms from water, and yields amorphous *calcium* and *magnesium salts*.[1]

3 : 5-Diamino-2-hydroxyphenylarsinic acid,[2]



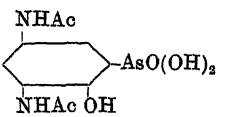
results when the corresponding dinitro-acid is reduced by alkaline hyposulphite. It crystallises in long needles, which instantly reduce ammoniacal silver nitrate solution, and give a port wine coloration with potassium dichromate solution.

3-Amino-5-acetamido-2-hydroxyphenylarsinic acid,[3]



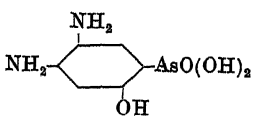
is prepared by reducing the corresponding nitro-acid, a 60 per cent. yield being obtained. This acid is only soluble in excess of dilute mineral acids.

3 : 5-Diacetamido-2-hydroxyphenylarsinic acid,



is isolated by dissolving 30 grams of the preceding acid in 2*N* sodium hydroxide solution and slowly adding 54 grams of sodium hyposulphite, the mixture being stirred and the temperature maintained at 10° C. After half an hour, 10*N* sodium hydroxide is added, the solution filtered, 30 c.c. of acetic anhydride run in, and the mixture allowed to stand for one hour. It is then acidified to Congo red and the precipitated arsinic acid purified through its alkaline solution, the yield varying from 10 to 15 grams. The acid crystallises in white needles, readily soluble in alkalis; it is converted into 2 : 4-diaminophenol (isolated as the diacetyl derivative) by boiling with 5 parts of 15 per cent. hydrochloric acid.

4 : 5-Diamino-2-hydroxyphenylarsinic acid,[4]



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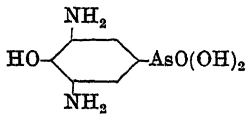
[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3058.
[2] King, *ibid.*, 1927, p. 1057.
[3] Newbery and Phillips, *ibid.*, 1928, p. 2375.
[4] Hewitt and King, *ibid.*, 1926, p. 824.

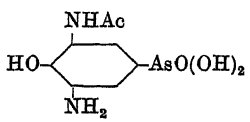
results when 5-nitro-4-amino-2-hydroxyphenylarsinic acid (p. 303) is reduced with sodium hydrosulphite. It crystallises from boiling water in fine needles. It dissolves readily in normal hydrochloric acid, addition of nitrite solution giving a red coloration, followed by the separation of a *diazoimine*, in rectangular leaflets. The diamino-acid instantly reduces ammoniacal silver nitrate solution, and gives a port-wine colour with potassium dichromate in acid solution.

3 : 5-Diamino-4-hydroxyphenylarsinic acid,[1]



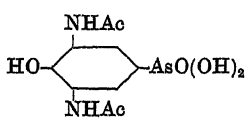
is obtained by reducing the corresponding dinitro-acid with sodium hydrosulphite or sodium amalgam. It crystallises in silver-grey needles, decomposing at 170° C., readily soluble in aqueous alkalis and dilute acids. Its solution in sulphuric acid gives a dark olive-green coloration with potassium dichromate solution.

3-Amino-5-acetamido-4-hydroxyphenylarsinic acid,[2]



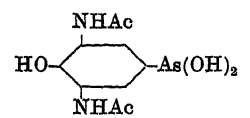
consists of stout, white prisms, formed by reducing the corresponding nitro-acid. It readily dissolves in dilute mineral acids, and in alkali hydroxide and carbonate solutions.

3 : 5-Diacetamido-4-hydroxyphenylarsinic acid,[3]



is best prepared from the preceding arsinic acid under the conditions described for 3 : 5-diacetamido-2-hydroxyphenylarsinic acid (p. 308).

3 : 5-Diacetamido-4-hydroxyphenylarsinous acid,

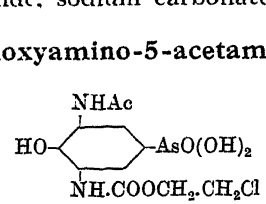


may be prepared by three methods: (1) By hydrolysis of the corresponding dichloroarsine, p. 112; (2) by acetylation of 3-amino-5-acetamido-4-hydroxyphenyldichloroarsine hydrochloride (see 5-acetamido-2-hydroxyphenylarsenoxide, p. 137); (3) by acetylation of 3 : 5-diamino-4-hydroxyphenyldichloroarsine dihydrochloride. It is purified by solution in caustic alkali and acidification to Congo red by hydrochloric acid. It forms white plates or needles, insoluble in water,

[1] German Patent, 224953.
[2] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 2375.
[3] Newbery and Phillips, *ibid.*; compare Raiziss and Gavron, *J. Amer. Chem. Soc.*, 1921, 43, 582.

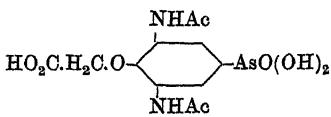
dilute mineral acids, or sodium bicarbonate solution, but soluble in aqueous sodium hydroxide, sodium carbonate, and dilute ammonium hydroxide.

3-ω-Chlorocarbethoxyamino-5-acetamido-4-hydroxyphenylarsinic acid,[1]



results when 3-amino-5-acetamido-4-hydroxyphenylarsinic acid and β-chloroethylchlorocarbonate react in sodium hydroxide solution (for conditions, see 3-ω-chlorocarbethoxyamino-4-hydroxyphenylarsinic acid, p. 299). It crystallises from 30 per cent. acetic acid in long needles, melting with decomposition at 189° C. Its *magnesium salt* is amorphous. When reduced it yields 3 : 3'-*di*(β-*hydroxyethylamino*)-5 : 5'-*diacetamido*-4 : 4'-*dihydroxyarsenobenzene.*

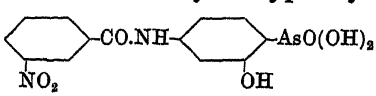
2 : 6-Diacetamidophenoxyacetic acid 4-arsinic acid,



is formed by the interaction of monochloracetic acid and sodium 3 : 5-diacetamido-4-hydroxyphenylarsinate. It crystallises from water in colourless prisms, melting with decomposition at 212° C., and gives an amorphous *magnesium salt.* When boiled with 5*N* sodium hydroxide or 5*N* hydrochloric acid, it yields 8-amino-3-hydroxy-1 : 4-benz*iso*xazine-6-arsinic acid (p. 432).[2]

Arylamides of Aminohydroxyphenylarsinic Acids.[3]

3'-Nitrobenzoyl-4-amino-2-hydroxyphenylarsinic acid,



A solution containing 7·4 grams of 4-amino-2-hydroxyphenylarsinic acid, 25 c.c. of 2*N* sodium hydroxide solution, and 200 c.c. of half-saturated sodium acetate solution, is treated with 11·8 grams of 3-nitrobenzoyl chloride in ether. The whole is vigorously shaken, and sodium hydroxide solution added from time to time in sufficient quantity to maintain a slight alkalinity to phenolphthalein. When the reaction is complete the mixture is made neutral to Congo red paper, and the precipitate washed, dried, and extracted with ether. It is then dissolved in alkali, reprecipitated by acid, dried, and again extracted with ether, an 89 per cent. yield being obtained. The product is almost insoluble in hot glacial acetic acid, and only slightly soluble in hot 90 per cent. formic acid, from which it crystallises in bunches of needles. Its *sodium salt* crystallises in fine needles.

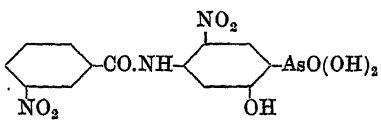
[1] Newbery, Phillips, and Sticklings, *loc. cit.*

[2] For the preparation of 3-amino-4-ω-hydroxyalkylaminophenylarsinic acid and its derivatives, see Canadian Patent, 282284.

[3] Hewitt and King, *J. Chem. Soc.*, 1926, p. 817.

3′-Aminobenzoyl-4-amino-2-hydroxyphenylarsinic acid.—To a solution of 7·6 grams of the preceding nitro-acid in 72 c.c. of 2*N* sodium hydroxide at 0° C., 28 grams of ferrous chloride in 40 c.c. of water are slowly added with vigorous stirring. Then 72 c.c. of 2*N* sodium hydroxide solution are added in the same manner. The stirring is maintained for ninety minutes, the ferric hydroxide removed and extracted twice with 150 c.c. quantities of 0·5*N* sodium hydroxide solution. The combined alkaline filtrates are neutralised to Congo red paper, the precipitate filtered off, dissolved in 150 c.c. of normal hydrochloric acid, and reprecipitated by adding saturated sodium acetate solution, a 72 per cent. yield being obtained. The *sodium salt* crystallises in platelets, the *ammonium salt* in felted needles, the *hydrochloride*, *nitrate*, and *sulphate*, in needles. Attempts to prepare the arseno-derivative by the action of hypophosphorous acid at 60° C., give a product consisting mainly of polyarsenides.

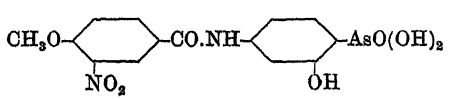
3′ : 5 - Dinitrobenzoyl-4-amino-2-hydroxyphenylarsinic acid,



results when the foregoing mononitro-acid is nitrated with mixed acid at 0° C. A 95 per cent. yield is obtained as a yellow, microcrystalline precipitate. It is sparingly soluble in boiling acetic acid, crystallising in microscopic needles, more soluble in formic acid. When hydrolysed by boiling with 15 volumes of normal sodium hydroxide solution for forty minutes it yields pure *m*-nitrobenzoic acid and 5-nitro-4-amino-2-hydroxyphenylarsinic acid (p. 303).

3′ : 5-Diaminobenzoyl-4-amino-2-hydroxyphenylarsinic acid is obtained in 71 per cent. yield by reduction of the preceding compound with ferrous chloride and alkali. It crystallises in fine needles. The *hydrochloride* forms narrow leaflets with domed ends, the *sulphate*, minute needles, and the *nitrate*, needles and lenticular prisms.

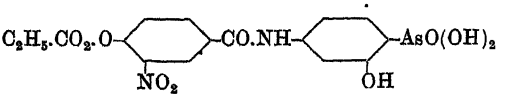
3′-Nitroanisoyl-4-amino-2-hydroxyphenylarsinic acid,



crystallises in spear-shaped needles; its *sodium salt* forms silky needles, and the *ammonium salt*, diamond-shaped plates.

3′-Aminoanisoyl-4-amino-2-hydroxyphenylarsinic acid forms silky needles, the *sodium salt*, prisms, the *hydrochloride*, spiked leaflets, the *sulphate*, white needles and stout prisms, and the *nitrate*, woolly needles. Reduction of this acid gives a mixture of polyarsenides.

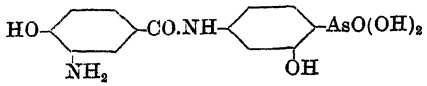
3′ - Nitro - 4′ - ethylcarbonatobenzoyl - 4 - amino - 2 - hydroxyphenylarsinic acid,



crystallises in microscopic, fluffy needles; hydrolysis at room temperature gives 3′-*nitro*-4′-*hydroxybenzoyl*-4-*amino*-2-*hydroxyphenylarsinic*

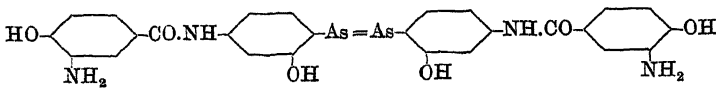
acid, which crystallises from 90 per cent. formic acid in microscopic needles.

3′-Amino-4′-hydroxybenzoyl-4-amino-2-hydroxyphenylarsinic acid,



forms elongated leaflets. Its salts have the following crystalline form: *Hydrochloride*, small needles; *nitrate*, diamond-shaped plates; *sulphate*, needles; *diazo-oxide*, yellow precipitate.

3′-Amino-4′-hydroxybenzoyl-4-amino-2-hydroxyarsenobenzene,



3 grams of the preceding acid suspended in 15 c.c. of hypophosphorous acid (density 1·14) diluted with 15 c.c. of water are treated with a crystal of potassium iodide and stirred at 45° C. for two and a half hours. A yield of one gram of arseno-compound is obtained, which contains polyarsenide, the proportion of the latter increasing when the reduction is carried out at 55° C.[1]

The following derivatives of 3-amino-4-hydroxyphenylarsinic acid may be obtained by methods similar to those used for the foregoing 4-amino-2-hydroxyphenylarsinic acid derivatives: **3′-Nitrobenzoyl-3-amino-4-hydroxyphenylarsinic acid,** forming silky needles; the corresponding *3′-aminobenzoyl-acid* forms microscopic platelets, yielding a *hydrochloride* consisting of narrow leaflets, a *sulphate* consisting of rectangular leaflets, and a *nitrate* forming microscopic plates. The corresponding *arseno-compound* is an orange-yellow solid. **3′-Nitroanisoyl-3-amino-4-hydroxyphenylarsinic acid,** forming square leaflets; the *amino-compound* forms colourless plates, giving a *hydrochloride* as rosettes of needles, a *sulphate* consisting of microscopic, square leaflets, and a *nitrate* forming silky needles. The *arseno-compound* is a yellow powder. **3′-Nitro-4′-ethylcarbonatobenzoyl-3-amino-4-hydroxyphenylarsinic acid,** forming needles or rectangular leaflets, yielding the *3′-nitro-4′-hydroxybenzoyl-compound* in diamond-shaped crystals on hydrolysis, which on reduction gives the *3′-amino-derivative*. The latter forms a *hydrochloride* consisting of microscopic needles, a *sulphate* forming leaflets, a *nitrate* consisting of microscopic needles, an *azoxy-compound* forming pale brown, truncate, diamond-shaped plates, and an *arseno-compound* which is a yellow powder, giving an amorphous *diazo-oxide*.

[1] Compare this compound with the corresponding 4-aminoarsenobenzene (p. 344).

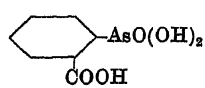
CHAPTER VIII.

ARSENICAL COMPOUNDS CONTAINING CARBOXYL GROUPS.

MUCH of the work to be described in this section has been carried out within the last ten years. The original method of producing these carboxyl derivatives consisted in oxidising nuclear-substituted methyl groups by means of alkaline permanganate or dilute nitric acid (density 1·2) in sealed tubes at a fairly high temperature. The permanganate process is often a very lengthy one, but by varying the proportion of oxidising agent present, both methods can be used to oxidise two or more methyl groups separately or simultaneously. The acids also result when the Bart reaction is applied to aminoarylcarboxylic acids or when aminoarylarsinic acids are diazotised, the amino-group replaced by the cyano-group, and the latter hydrolysed to the carboxyl-group. *o*-Carboxyphenylarsinic acid has also been prepared by an unusual method, namely, heating together *o*-bromobenzoic acid, alkaline potassium arsenite, and copper powder. The combination of an arylarsenious oxide and a diazotised aminoarylcarboxylic acid yields a carboxylated diarylarsinic acid, having a carboxyl-group in one nucleus only.

Many of the carboxylated arylarsinic acids are soluble in water, and they are of particular interest as they all contain at least two acidic groupings, the carboxyl-group being capable of undergoing the usual reactions. Treatment with phosphorus trichloride yields acid chlorides of the type $Cl_2AsC_6H_4.COCl$. Reduction of the acids leads to the formation of arsines, arsenoxides, or arseno compounds, the product depending upon the reducing agent employed. Reduction in aqueous solution by amorphous phosphorus and concentrated hydriodic acid gives the corresponding carboxylated aryldi-iodoarsines, which dissolve in aqueous sodium carbonate; addition of hydrochloric acid precipitates the carboxylated arylarsenious acids. The latter yield dichloroarsines on treatment with phosphorus trichloride, and the same products are isolated when the di-iodoarsines interact with silver chloride. When the carboxyl and arsinic acid radicals are in the *ortho* position, the elements of water are eliminated between them and an anhydride formed. Heating the acids with methyl iodide converts them into the corresponding methyl esters.

o-Carboxyphenylarsinic acid,



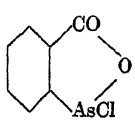
Anthranilic acid (150 grams) in 2000 c.c. of water and 225 c.c. of concentrated hydrochloric acid is diazotised with 80 grams of sodium nitrite, keeping the temperature below 5° C. An arsenite solution is prepared

from 140 grams of arsenious oxide in 1200 c.c. of water and 162 grams of sodium hydroxide, 40 c.c. of 6N copper sulphate solution added, and the diazo-solution poured in with stirring, the temperature being maintained at 20° C. The mixture is then warmed on the water-bath to 60° C., until the evolution of nitrogen ceases, when it is acidified with hydrochloric acid, concentrated to about 1000 c.c., and filtered hot; the acid separates on cooling in 50 to 60 per cent. yield.[1]

The acid has also been obtained by heating *o*-bromobenzoic acid in 10 per cent. potassium hydroxide with a 50 per cent. aqueous solution of potassium arsenite, 20 c.c. of alcohol and a little copper powder, in a reflux apparatus for ten to twelve hours at about 90° C. 20 grams of *o*-bromobenzoic acid yield about 12 grams of carboxylated acid.[2]

The acid crystallises from water in colourless, glistening plates, unmelted below 320° C., soluble in alcohol, sparingly soluble in cold water, and insoluble in ether or chloroform. It forms a salt neutral to phenolphthalein with two equivalents of alkali. When the acid is reduced by red phosphorus and hydriodic acid and the solution made alkaline and boiled with phosphorous acid, *o-arsenobenzoic acid* is formed.[3] When the acid, in aqueous solution, is reduced with sulphur dioxide and a little hydriodic acid at 60° C., the corresponding *oxide* is formed. This crystallises from water, melts at 89° C., resolidifies at about 140° C., and remelts at 225° to 231° C. Heating with alkali at 100° C. for five hours hydrolyses the oxide to benzoic acid and arsenious oxide; about 15 per cent. is converted into *monosodium dicarboxydiphenylarsenite.*

o-Carboxyphenyldichloroarsine, $CO.OH.C_6H_4.AsCl_2$.[4] — *o*-Carboxyphenylarsinic acid is dissolved in hydrochloric acid and reduced with sulphur dioxide in the presence of a trace of an iodide, a mixture of oxide and chloride resulting, which is completely transformed to chloride by solution in benzene or chloroform and treatment with hydrogen chloride. When this chloride is distilled in a vacuum it yields the *anhydride,*



which distils at about 220° C. at 15 mm., and forms colourless crystals, M.pt. 145° C. It is fairly soluble in warm benzene, chloroform, and ether, more soluble in alcohol and warm sodium carbonate.

Dichloro-o-arsinobenzoyl chloride, $Cl_2As.C_6H_4.COCl$.[5]—25 grams of *o*-carboxyphenylarsinic acid, suspended in 100 c.c. of cold chloroform, are slowly treated with 20 c.c. of phosphorus trichloride in 20 c.c. of chloroform. When the evolution of hydrogen chloride ceases, 20 grams of phosphorus pentachloride are added in one lot, and the mixture is heated on the water-bath to complete the reaction. The solution is decanted from the sludge of phosphoric acid and impurities, and the chloroform and chlorides of phosphorus are removed under diminished

[1] Lewis and Cheetham, *J. Amer. Chem. Soc.*, 1923, 45, 510; see Bart, *Annalen*, 1922, 429, 86, 111; German Patent, 250264; Aeschlimann and McCleland, *Trans. Chem. Soc.*, 1924, 125, 2025.

[2] Rosenmund, *Ber.*, 1921, 54, [B], 438.

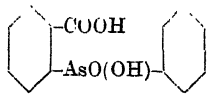
[3] Michaelis, *ibid.*, 1915, 48, 870.

[4] Aeschlimann and McCleland, *loc. cit.*

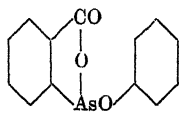
[5] Lewis and Cheetham, *loc. cit.*

pressure up to 110° C. The residue, which contains the dichloro-compound, cannot be distilled under any conditions without decomposition. Its condensation products are dealt with on p. 332.

o-Carboxydiphenylarsinic acid,[1]

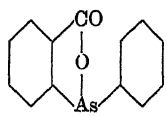


Phenylarsenoxide (67·2 grams) is dissolved in 160 c.c. of 5*N* sodium hydroxide and 266·5 c.c. of *N* sodium carbonate solution, and 1000 grams of ice with 800 c.c. of water added. A diazo solution, prepared from 56 grams of anthranilic acid, 400 c.c. of water, 144 c.c. of hydrochloric acid, 28·4 grams of sodium nitrite, and 1500 grams of ice, is then added. Nitrogen is evolved, and when the reaction is complete the mixture is evaporated to 3000 c.c. and faintly acidified to Congo red paper with hydrochloric acid. The mixture is filtered at 45° C., and on cooling, benzoic acid separates. This is removed and the liquor evaporated to 1000 c.c., when more benzoic acid and a little *azobenzene-o-o'-dicarboxylic acid* crystallise out. The filtrate is strongly acidified to Congo red by hydrochloric acid and allowed to stand overnight in ice, when about 44·5 grams of *o*-carboxydiphenylarsinic acid separate. The product is washed with cold ethyl acetate and dried in a vacuum. After several crystallisations from hot water it melts with gas evolution at 166° C. Attempted preparation of the acid from diazotised aniline and sodium benzarsinite lead to the production of the *anhydride*,[2]



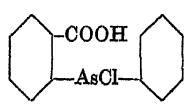
This anhydride is a white, crystalline solid, which remains unmelted below 300° C.

o-Carboxydiphenylarsenious acid anhydride,



is produced by reducing the foregoing acid, either with sodium bisulphite (20 per cent. solution) at 80° C., or with sulphur dioxide in hot aqueous solution. It is a crystalline product, M.pt. 133° C., sparingly soluble in hot water, more soluble in hot benzene, readily soluble in alcohol.

o-Carboxydiphenylchloroarsine,[3]

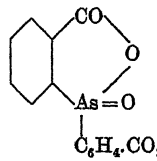


results when phenyldichloroarsine in alkaline solution is condensed with diazotised anthranilic acid, the product reduced with sulphur

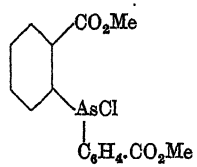
[1] Sakellarios, *Ber.*, 1926, 59, [B], 2552.
[2] Aeschlimann and McCleland, *loc. cit.*
[3] Aeschlimann and McCleland, *loc. cit.*

dioxide at 80° C., and the reduction product treated with hydrogen chloride in benzene solution. The chloroarsine is a white, crystalline compound, M.pt. 163° C., readily soluble in alcohol, moderately soluble in hot benzene. When suspended in chloroform and treated with phosphorus pentachloride, the *acid chloride* results, which can be distilled at low pressure without much decomposition.

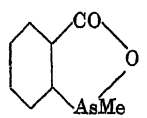
o-o'-Dicarboxydiphenylarsinic acid anhydride,



Diazotised anthranilic acid is condensed with an alkaline solution of *o*-carboxyphenylarsenoxide and the product recrystallised from methyl alcohol and finally from water. It melts at 255° C., and when reduced gives *o-o'-dicarboxydiphenylarsenious anhydride*, M.pt. 251° to 255° C. The latter compound is insoluble in ether, benzene, chloroform, or carbon tetrachloride, but dissolves in methyl alcohol. When its solution in this solvent is treated with hydrogen chloride it gives *o-o'-dicarbomethoxydiphenylchloroarsine*, M.pt. 184° C. :

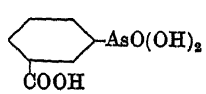


o-Carboxyphenylmethylarsenious anhydride,

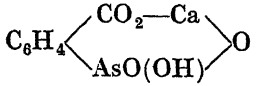


o-Carboxyphenylarsenoxide in 20 per cent. sodium hydroxide is shaken for forty hours with the requisite amount of methyl iodide, filtered, acidified with hydrochloric acid, and sulphur dioxide passed in. The resulting oil, consisting of the required anhydride, is dissolved in alkali, reprecipitated by sulphur dioxide, then distilled in a vacuum or recrystallised from water. It boils at 220° C. at 15 mm., melts at 106° C., and is readily soluble in alcohol or hot benzene. When oxidised by hydrogen peroxide it gives *o-carboxyphenylmethylarsinic acid.* This gives crystals from a little hot water, M.pt. 310° C., which on reduction and treatment of the reduction product with hydrogen chloride in benzene, yield *o-carboxyphenylmethylchloroarsine*, M.pt. 141° C., dissolving in most organic solvents and in alkalis. It loses hydrogen chloride on distillation in a vacuum.

m-Carboxyphenylarsinic acid,

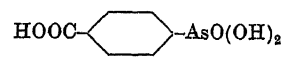


may be obtained by diazotising *m*-aminobenzoic acid and treating the solution with sodium arsenite,[1] or by the oxidation of *m*-tolylarsinic acid with alkaline permanganate.[2] It crystallises from water or acetic acid in glistening plates or needles, its solubility in water being somewhat greater than that of the *ortho* and *para* isomerides. It does not melt, but passes into an *anhydride*, $AsO_2.C_6H_4.COOH$, at about 250° C. The *calcium salt* forms small, rectangular plates, readily soluble in water, and having the composition



A neutral *silver salt* is known, $CO_2Ag.C_6H_4.AsO(OAg)_2$.

p-Carboxyphenylarsinic acid,



is best prepared as follows: 50 grams of *p*-aminobenzoic acid in 750 c.c. of water and 70 c.c. of concentrated hydrochloric acid are diazotised with 26 grams of sodium nitrite. The arsenite solution prepared by dissolving 46 grams of arsenious oxide in 400 c.c. of water containing 54 grams of sodium hydroxide is treated with 20 c.c. of 6*N* copper sulphate solution. The diazo solution is slowly added to the arsenite solution, with vigorous stirring, the temperature being kept at 20° C. The whole is then warmed to 60° C. until the evolution of nitrogen ceases, when the mixture is acidified with hydrochloric acid and the precipitate which separates is discarded. The filtrate is concentrated to 500 c.c. and cooled, when a yield of 50 to 60 per cent. of the carboxylated arsinic acid separates.[3] The acid may also be obtained in quantitative yield by heating *p*-tolylarsinic acid in a sealed tube with nitric acid (density 1·2) for three hours at 170° C.[4] Instead of using nitric acid as the oxidising agent, alkaline permanganate may be used, but this makes the process rather lengthy. It is carried out as follows: 10 grams of *p*-tolylarsinic acid and 6 grams of potassium hydroxide in 250 c.c. of water are slowly treated with 14 grams of potassium permanganate in 750 c.c. of water. The reaction is conducted at 60° C. and requires several days for completion, about 10 grams of the potassium salt of the acid being isolated by treating the filtrate from the reaction mixture with an excess of acetic acid, evaporating to dryness, and removing the potassium acetate by extraction with alcohol. The free acid is liberated from the potassium salt by treatment with hydrochloric acid.[5] Another method of preparation consists of diazotising *p*-aminophenylarsinic acid and treating the solution with cuprous cyanide, when *p-cyanophenylarsinic acid* results. This is then hydrolysed by aqueous potassium hydroxide, and the potassium salt of the acid so obtained treated with hydrochloric acid.[6]

p-Carboxyphenylarsinic acid crystallises from water in pearly plates,

[1] Bart, *Annalen*, 1922, 429, 87. [2] Michaelis, *Annalen*, 1902, 320, 329.

[3] Lewis and Cheetham, *J. Amer. Chem. Soc.*, 1921, 43, 2117; see Bart, *Annalen*, 1922, 429, 88, 112.

[4] Sieburg, *Arch. Pharm.*, 1916, 254, 224; *Zeitsch. physiol. Chem.*, 1916, 97, 53; Michaelis, *Annalen*, 1902, 320, 303; *Ber.*, 1915, 48, 870.

[5] La Coste, *Annalen*, 1881, 208, 1.

[6] Bertheim, *Ber.*, 1908, 41, 1853.

or from dilute hydrochloric acid in needles.[1] It is soluble in hot alcohol or alkali, sparingly soluble in water; it decomposes without melting when heated to about 232° C. At 210° C. the acid loses water and passes into an *oxy-derivative*, $CO_2H.C_6H_4.AsO_2$, which is a pale yellow powder. A solution of the *potassium salt* of the acid when spontaneously evaporated at 50° to 60° C. gives crystals of the composition $CO_2K.C_6H_4.AsO(OH)_2.CO_2H.C_6H_4.AsO(OH)_2$, which yield an unstable chloride when treated with phosphorus pentachloride. The *calcium salt* has a similar composition to that of the corresponding *meta* acid (p. 317), and crystallises with 1 molecule of water in pearly plates, sparingly soluble in water. The *silver salt*, $CO_2Ag.C_6H_4.AsO(OAg)_2$, is a white, amorphous precipitate, completely soluble in nitric acid and ammonia; when heated in a sealed tube at 100° C. with methyl iodide it is transformed into the *methyl ester*, $CO_2Me.C_6H_4.AsO(OH)_2$, which crystallises from ether in colourless needles; it does not melt, is readily attacked by alkali and decomposes on prolonged boiling with water.

Phenylarsine-p-carboxylic acid, $CO_2H.C_6H_4.AsH_2$.[2]—A methyl alcohol solution of *p*-carboxyphenylarsinic acid is reduced by zinc dust and hydrochloric acid and the product removed by steam distillation. In the moist state it is very sensitive to atmospheric oxygen, becoming yellow and apparently changing to *p*-arsenobenzoic acid.

Dichloro-p-arsinobenzoyl chloride, $Cl_2As.C_6H_4.COCl$, is prepared in the same way as the corresponding *ortho*-compound (p. 314). The yield is 75 to 80 per cent.[3] The compound is a liquid, B.pt. 189° to 190° C. at 19 mm., or 190° to 195° C. at 20 to 25 mm. Its condensation products are dealt with on p. 328.

p-Carboxyphenylarsenious acid, $CO_2H.C_6H_4.As(OH)_2$.[4]—The corresponding iodoarsine is dissolved in sodium carbonate solution and treated with dilute hydrochloric acid, when the carboxylated acid separates out in crystalline form. When heated to 145°–160° C., water is eliminated and the *oxide* produced, $CO_2H.C_6H_4.AsO$. By boiling the free acid with calcium carbonate, the *calcium salt* is obtained in pearly plates, $[As(OH)_2.C_6H_4.CO_2]_2Ca$, which lose water at 200° C., forming $(AsO.C_6H_4.CO_2)_2Ca$. The latter calcium salt is decomposed by silver nitrate solution, yielding the *silver salt*, $CO_2Ag.C_6H_4.AsO$, as a white powder. When the acid is dissolved in a minimum quantity of boiling water and the solution mixed with an excess of solid phosphorous acid, *p*-arsenobenzoic acid separates as an insoluble pale yellow powder.

p-Carboxyphenyldichloroarsine, $CO_2H.C_6H_4.AsCl_2$.[5]—This compound may be obtained by the action of silver chloride on the corresponding iodide at 100° C. in a sealed tube, or by the following process: The corresponding arsinic acid is treated with phosphorus trichloride, and after distilling off the excess of trichloride, benzene is added and the mixture treated, dropwise, with water. The benzene layer is dried and evaporated, the chloride crystallising in colourless needles, M.pt. 157° to 158° C. It is decomposed on boiling with water.

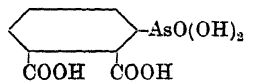
p-Carboxyphenyldi-iodoarsine.—*p*-Carboxyphenylarsinic acid (3 grams) in 70 c.c. of boiling water is treated with 2 grams of amorphous

[1] La Coste, *loc. cit.* [2] Sieburg, *Arch. Pharm.*, 1916, 254, 224.
[3] Lewis and Cheetham, *J. Amer. Chem. Soc.*, 1921, 43, 2117; see French Patent, 441215; La Coste, *Annalen*, 1881, 208, 1; Fourneau and Öchslin, *Bull. Soc. chim.*, 1912, [iv.], 11, 909.
[4] Michaelis, *Ber.*, 1915, 48, 871; see La Coste, *loc. cit.* [5] Michaelis, *loc. cit.*

phosphorus and 12 to 13 c.c. of concentrated hydriodic acid (density 1·96). The iodide separates out, and crystallises from chloroform in yellowish-red needles, M.pt. 153° C. Sodium hydroxide transforms it into the acid.

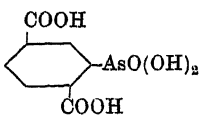
p-Carboxyphenylarsine oxide, $CO_2H.C_6H_4.AsO$.[1]—The preceding iodide in aqueous sodium carbonate, when acidified, yields this oxide as an amorphous powder. The oxide is converted into *p*-carboxyphenylarsenious acid when boiled with water. The *ethyl ester* of this oxide results when dichloro-*p*-arsinobenzoyl chloride in alcoholic solution is treated with water. It is a white powder, M.pt. 277° C., insoluble in water, sparingly soluble in alcohol. If the chloride is oxidised by alkaline hydrogen peroxide, and hydrochloric acid then added, *p-carbethoxyphenylarsinic acid,* $C_2H_5.CO_2.C_6H_4.AsO(OH)_2$, is formed. This crystallises in spangles, decomposing at 260° C.[2]

2 : 3-Dicarboxyphenylarsinic acid,[3]



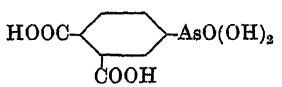
is obtained from 3-amino-*o*-phthalic acid by diazotisation and introduction of the arsenic residue by Bart's method.[4] The yield is 50 to 55 per cent. The acid crystallises from hydrochloric acid in colourless needles, which decompose without melting when heated. It is only sparingly soluble in hot or cold alcohol, insoluble in ether, but readily soluble in water. The neutral *trisodium salt* is known, and likewise the *anhydride,* obtained by heating the free acid at 200° C. for a week. The latter body yields a fluorescent compound resembling fluorescein, when condensed with resorcinol. The condensation product with phenol is colourless in acid solution and pink in alkaline solution, thus resembling phenolphthalein.

2 : 5-Dicarboxyphenylarsinic acid,[5]



5-Carboxy-2-tolylarsinic acid is oxidised by alkaline permanganate and the dicarboxylic acid precipitated by acidification. The acid has no definite decomposition point ; it is readily soluble in water and alcohol.

3 : 4-Dicarboxyphenylarsinic acid,[6]

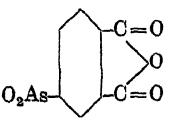


This acid is isolated in the form of its *dimethyl ester* by the arsenation of dimethyl-4-aminophthalate according to Bart's method. The ester on hydrolysis gives the *sodium salt,* which is converted to the *silver salt* and the latter treated with concentrated hydrochloric acid to obtain the free acid. The free acid separates in clusters of pale yellow crystals

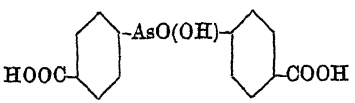
[1] Sieburg, *loc. cit.* [2] Fourneau and Öchslin, *Bull. Soc. chim.*, 1912, [iv.], 11, 909.
[3] Hamilton and Frazier, *J. Amer. Chem. Soc.*, 1926, 48, 2415.
[4] German Patent, 250264 ; Bart, *Annalen*, 1922, 429, 55.
[5] Maschmann, *Ber.*, 1924, 57, [B], 1759.
[6] Hamilton and Jelinek, *J. Amer. Chem. Soc.*, 1927, 49, 3165.

from concentrated solutions, melting with decomposition at 180° C. It is very soluble in water and methyl alcohol, insoluble in ether, benzene, and chloroform.

The *diethyl ester* is known, and neutral *trisodium* and *tetrasodium salts*. When the free acid is heated for three days at 100° C. under reduced pressure in the presence of phosphorus pentoxide, water is eliminated and the *anhydride* formed :



Di-p-carboxydiphenylarsinic acid,[1]

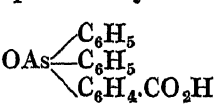


is prepared by oxidising di-*p*-tolylarsinic acid with alkaline permanganate at 50° to 60° C. The acid crystallises in colourless plates, which decompose at a high temperature without melting, and are sparingly soluble in water, slightly soluble in alcohol or hot concentrated hydrochloric acid. The *calcium*, *barium*, and *silver salts* appear to be mixtures of neutral and acid salts. When the di-silver salt is heated at 100° C. with methyl iodide in a sealed tube, the *methyl ester* is formed, $(CO_2CH_3.C_6H_4)_2AsO(OH)$, which crystallises in yellow crusts from alcohol. When the acid is heated with concentrated hydriodic acid and red phosphorus, *di-p-carboxydiphenyliodoarsine* results, $(CO_2H.C_6H_4)_2AsI$. This is a yellow powder, readily soluble in alcohol, ether, or chloroform, and on boiling with water yields hydriodic acid. When treated with sodium carbonate solution the iodide dissolves, and the addition of hydrochloric acid precipitates *di-p-carboxydiphenylarsenious acid*, $(CO_2H.C_6H_4)_2As.OH$, which is somewhat soluble in alcohol. Its *calcium salt* contains 2 molecules of water of crystallisation.

Triphenylarsinedihydroxide-tri-p-carboxylic acid, $(CO_2H.C_6H_4)_3As(OH)_2$,[2] is produced by oxidising tri-*p*-tolylarsine with alkaline permanganate. It crystallises from alcohol in crusts, and forms a *silver salt*, $HO.(OAg)As.(C_6H_4.CO_2Ag)_3$, a *potassium salt*, $O:As(C_6H_4.CO_2K)_3$, and a *calcium salt*, $[O:As(C_6H_4.CO_2)_3]Ca_3.xH_2O$.

Triphenylarsine-tri-p-carboxylic acid, $As(C_6H_4.CO_2H)_3$.—The preceding acid is reduced with concentrated hydriodic acid and red phosphorus and the product purified by solution in aqueous sodium carbonate, treating the solution with charcoal and reprecipitating by acidification with hydrochloric acid. It forms fine, colourless needles from ether, and gives a *sodium salt*, $As(C_6H_4.CO_2Na)_3.2H_2O$, which crystallises from hot water in fine, short needles, and also a *silver salt*, $As(C_6H_4.CO_2Ag)_3$, a pale yellow precipitate.

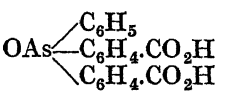
Triphenylarsineoxide-p-carboxylic acid,[3]



[1] La Coste, *Annalen*, 1881, 208, 23.
[2] La Coste, *loc. cit.*
[3] Michaelis, *Annalen*, 1902, 321, 192.

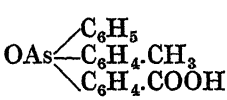
10 grams of diphenyl-*p*-tolylarsine and 13 grams of potassium permanganate are maintained at about 60° C. for four to five weeks; the liquid is then filtered and the filtrate treated with hydrochloric acid to precipitate the carboxylic acid. The acid melts at 253° to 254° C., is insoluble in ether or water, but dissolves in alcohol, alkali, or excess of mineral acid. The *silver salt*, $OAs(C_6H_5)_2.C_6H_4.CO_2Ag$, is a white powder, affected by light; the *barium salt* is an amorphous powder, soluble in water. By saturating an alcohol solution of the acid with hydrogen chloride, *triphenylarsinedichloride-p-carboxylic acid ethyl ester* is produced, $Cl_2As(C_6H_5)_2.C_6H_4.CO_2C_2H_5$. This crystallises in white needles, M.pt. 133° C. A similar solution, when saturated with hydrogen sulphide, gives *triphenylarsinesulphide-p-carboxylic acid*, $SAs(C_6H_5)_2.C_6H_4.CO_2H$, white crystals, M.pt. 178° C.

Triphenylarsineoxide-di-p-carboxylic acid,[1]



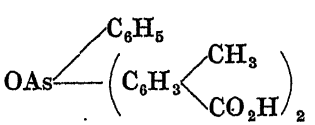
is obtained by oxidation of the corresponding arsine with alkaline permanganate, the reaction taking about eight weeks for completion at 50° to 60° C. It is a white, crystalline powder, unmelted at 300° C., soluble in hot alcohol or acetic acid, insoluble in water, benzene, or chloroform. The *silver salt* is a white powder, $OAs.C_6H_5(C_6H_4.CO_2Ag)_2$; the *copper salt*, $OAs.C_6H_5(C_6H_4.CO_2)_2Cu.H_2O$, loses its water of crystallisation at 105° C.; the *barium salt*, $[OAs.C_6H_5(C_6H_4.CO_2H)(C_6H_4CO_2)]_2Ba$, is readily soluble in water. Hydrogen chloride acting on an alcoholic solution of the acid produces *triphenylarsinedichloride-di-p-carboxylic acid ethyl ester*, $Cl_2As.C_6H_5(C_6H_4.CO_2C_2H_5)_2$, crystallising in needles, M.pt. 176° C.

Diphenyl-p-tolylarsineoxide-p-carboxylic acid,

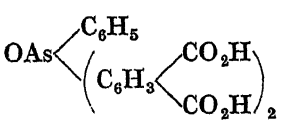


results when only half the permanganate is used in the preceding preparation. It is always contaminated with the dicarboxylic acid, and is separated from the latter by solution in alcohol, in which solvent the monocarboxylic acid is more soluble. The *silver salt*, $OAs.C_6H_5(C_6H_4.CH_3)(C_6H_4.CO_2Ag)$, crystallises in needles, which discolour on exposure to light. It yields *diphenyl-p-tolylarsinedichloride-p-carboxylic acid ethyl ester* in the usual manner, which is a hygroscopic substance, M.pt. 94° C., readily soluble in alcohol.

Phenylditolylarsineoxide-dicarboxylic acid,[2]



I



II

This acid (I) is formed when di-*m*-xylylphenylarsine is heated in a sealed tube at 110° to 170° C. with the calculated amount of nitric acid

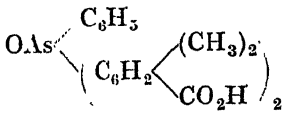
[1] Michaelis, *Annalen*, 1902, 321, 196.

[2] Michaelis, *ibid.*, p. 226.

(density 1·2). It is a pale yellow powder, M.pt. 196° C., sparingly soluble in water, readily soluble in alcohol.

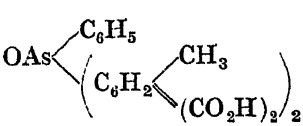
Triphenylarsineoxide-tetracarboxylic acid is produced when twice the amount of nitric acid is used in the preceding preparation. It melts at 213° C., and is soluble in hot water or warm alcohol. It has the structure II.

Phenyldixylylarsineoxide-dicarboxylic acid,

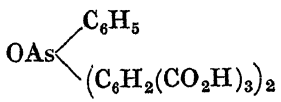


The corresponding arsine is heated for twelve hours at 120° to 180° C. with the requisite amount of nitric acid (density 1·2). It is a faintly yellow powder, M.pt. 199° C., readily soluble in alcohol, insoluble in water, ether, or benzene.

Phenylditolylarsineoxide-tetracarboxylic acid,



I



II

This tetracarboxylic acid (I) results when twice the amount of nitric acid is used in the previous preparation.

Triphenylarsineoxide-hexacarboxylic acid is produced when 16 grams of nitric acid are used to oxidise 2 grams of arsine, the heating being from 110° to 150° C. for thirteen hours. It has the constitution II. It forms white crystals, M.pt. 275° C., yields a *silver salt*, and an *ethyl ester* consisting of silky needles, M.pt. 193° C.

Diethylphenylarsinehydroxychloride - p - carboxylic acid,[1] $CO_2H.C_6H_4.As(C_2H_5)_2(OH)Cl$. — *p*-Tolyldiethylarsine is oxidised by twice its weight of potassium permanganate at 30° to 40° C. and the liquid filtered. The filtrate is evaporated to dryness after treating with hydrochloric acid, and the residue extracted with absolute alcohol. The solvent is partially removed and ether added, when the carboxylic acid separates in white crystals, M.pt. 162° C. It is readily soluble in alcohol and water, insoluble in ether. Its aqueous solution gives a *mercurichloride*, $CO_2H.C_6H_4.As(C_2H_5)_2(OH)Cl.HgCl_2$, M.pt. 182° C., sparingly soluble in water, more soluble in hot alcohol. When an aqueous solution of the carboxylic acid is treated with hydrogen sulphide, *diethylphenylarsinesulphide-p-carboxylic acid*, $CO_2H.C_6H_4.AsS(C_2H_5)_2$, is obtained as colourless needles, M.pt. 184° C.

Diethylphenylarsine-p-carboxylic acid, $CO_2H.C_6H_4.As(C_2H_5)_2$, occurs in small yield when the foregoing hydroxychloride is reduced with tin and hydrochloric acid. The smallness of the yield is accounted for on the assumption that the following side-reaction occurs :

$$COOH.C_6H_4.As(C_2H_5)_2+H_2=C_6H_5.COOH+(C_2H_5)_2AsH$$

The acid crystallises in fine, white needles, M.pt. 58° C., very soluble in ether, alcohol, and chloroform, insoluble in water and petroleum ether.

[1] Michaelis, *Annalen*, 1902, 320, 305.

The *mercurichloride* crystallises in white, glistening plates, M.pt. 171° to 172° C., sparingly soluble in water, insoluble in ether. The *barium*, *ammonium* and *lead salts* of the acid have been prepared. The *hydrobromide* crystallises in white needles, M.pt. 144° to 145° C., the *hydriodide* in brown plates, M.pt. 84° C., and the *methiodide* as white needles, M.pt. 131° C., which are affected by light.

Carboxymethyleneoxyphenyl-4-arsinic acid,[1] $CO_2H.CH_2.O.C_6H_4.AsO(OH)_2$.—Sodium *p*-hydroxyphenylarsinate in water is treated with chloracetic acid, then with 35 per cent. sodium hydroxide, and the mixture heated under reflux for three hours. The acid crystallises from the cooled solution on acidification with hydrochloric acid. It is soluble in water or alcohol, insoluble in ether or benzene.

Arsenobenzene-bis-4-oxymethylene-carboxylic acid,

$$\begin{matrix} As.C_6H_4.O.CH_2.CO_2H \\ \| \\ As.C_6H_4.O.CH_2.CO_2H \end{matrix}$$

results when the preceding compound is reduced with alkaline hydrosulphite at 45° C. It is a voluminous yellow precipitate, which reduces ammoniacal silver nitrate in the cold. Its *sodium salt* is yellow, readily soluble in water, sparingly soluble in alcohol.

Carboxymethylenethiophenyl-4-arsinic acid, $CO_2H.CH_2.S.C_6H_4.AsO(OH)_2$.—A diazotised solution of *p*-aminophenylarsinic acid is added to a solution of potassium xanthate in sodium carbonate at 80° C. Sodium hydroxide is then added, and after several hours' warming at 90° to 100° C., chloracetic acid and 35 per cent. sodium hydroxide are introduced and the solution evaporated to small bulk. The arsinic acid separates on addition of hydrochloric acid. It crystallises from water in pale yellow needles, sintering at 170° C. and melting with decomposition at 187° C.

Arsenobenzene-bis-4-thiomethylene-carboxylic acid,

$$\begin{matrix} As.C_6H_4.S.CH_2.COOH \\ \| \\ As.C_6H_4.S.CH_2.COOH \end{matrix}$$

is the reduction product of the preceding compound. The reduction process may be carried out in one stage, using hydrosulphite, or in two stages—first reducing to the oxide with phenylhydrazine, then reducing the oxide with 4 per cent. sodium amalgam. The acid is a yellow powder, and forms a *sodium salt*, the properties being similar to those of the corresponding oxymethylene acid and its sodium salt.

Nitro-, Amino- and Hydroxy-carboxyarylarsinic Acids.

The nitrocarboxylarylarsinic acids may be prepared by four methods: (1) By treating diazotised nitrocarboxyarylamines with sodium arsenite (Bart's reaction).

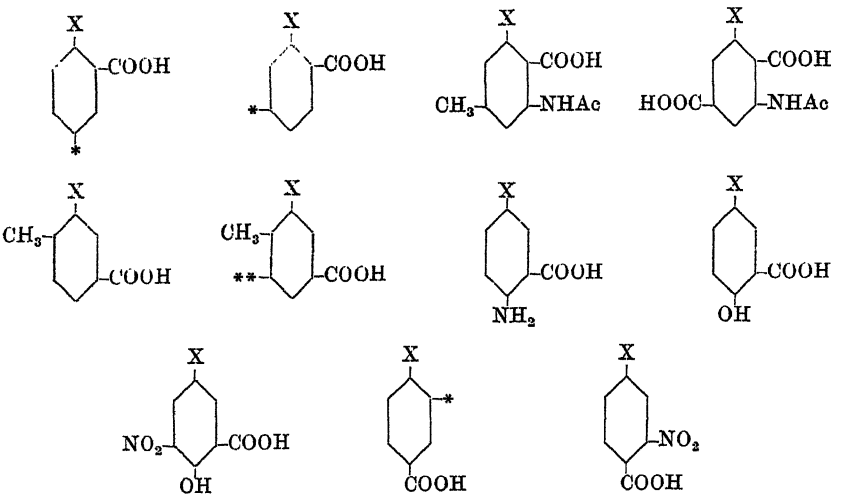
(2) By the conversion of nitroaminoarylarsinic acids to the corresponding nitriles by means of the diazo reaction, and subsequent hydrolysis of the CN grouping.

[1] German Patent, 216270; British Patent, 4246 (1908).

(3) By the oxidation of the methyl group of nitrotolylarsinic acids with alkaline permanganate.

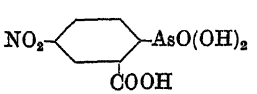
(4) By direct nitration of carboxyarylarsinic acids.

Reduction of these nitro-acids gives the amino-acids, the usual reducing agent being ferrous sulphate in alkaline solution, but in one case sodium amalgam in methyl alcohol has been used. The hydroxy-acids are isolated from the amino-acids by the aid of the diazo reaction. The acids are crystalline solids, usually soluble in water. The following scheme shows the compounds known :



* Groups may be NO_2, NH_2, or OH.
** Groups may be NO_2 or NH_2.

4-Nitro-2-carboxyphenylarsinic acid,[1]



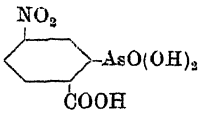
5-Nitroanthranilic acid (18 grams), suspended in 100 c.c. of concentrated hydrochloric acid (density 1·12) and 50 c.c. of water, is diazotised at 5° C. with 50 c.c. of 2*N* sodium nitrite solution. The solution is filtered, and treated with 26 grams of sodium arsenite in 50 c.c. of water, a violent evolution of nitrogen resulting. To complete the reaction 10*N* sodium hydroxide is added, dropwise, until the acid reaction to Congo red disappears, when the carboxy-acid separates in about 22 grams yield. It crystallises from water in snow-white needles.

4-Amino-2-carboxyphenylarsinic acid is the reduction product of the preceding nitro-acid, using ferrous sulphate in alkaline solution. It is an intermediate in the preparation of 2 : 2′-dicarboxy-4 : 4′-dihydroxyarsenobenzene, but is not isolated in the solid state (p. 355).

4-Hydroxy-2-carboxyphenylarsinic acid and **5-Nitro-4-hydroxy-2-carboxyphenylarsinic acid** are dealt with in the synthesis of 5 : 5′-diamino-4 : 4′-dihydroxy-2 : 2′-dicarboxyarsenobenzene (p. 356).

[1] Karrer, *Ber.*, 1915, 48, 1058.

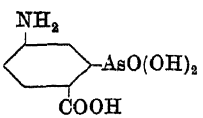
5-Nitro-2-carboxyphenylarsinic acid,[1]



5-Nitro-*o*-tolylarsinic acid (26·1 grams) in 100 c.c. of *N* sodium hydroxide and 400 c.c. of water is heated to 75°–80° C. and treated with 35 grams of potassium permanganate in small portions. The oxidation proceeds rapidly, and the mixture is gradually heated to boiling and maintained at 100° C. until decolorised. Hot water (500 c.c.) is then added and the whole filtered, the filtrate boiled with charcoal, filtered, and acidified to Congo red, using hydrochloric acid. The arsinic acid separates in about 70 per cent. yield, or 25 grams, consisting of fine needles, decomposing at 264° to 265° C. The acid is soluble in alcohols, moderately soluble in water.

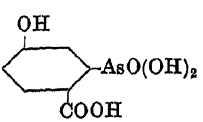
For 3-*nitro-* and 5-*nitro*-2-*carboxy*-4-*hydroxyphenylarsinic acids,* see pp. 357 and 356, respectively.

5-Amino-2-carboxyphenylarsinic acid,



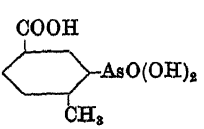
is obtained by dissolving the preceding acid (14·5 grams) in 300 c.c. of methyl alcohol and heating it on the water-bath with 400 grams of 4 per cent. sodium amalgam, the reduction taking from five to six hours. The alcohol is distilled off and 75 c.c. of water added to the residue. The liquor is separated from the mercury and treated with 75 c.c. of hydrochloric acid (density 1·19). After long standing in the cold, any inorganic products which separate are removed, the filtrate is neutralised with concentrated sodium hydroxide, and a little acetic acid added. The acid separates out completely; yield, 9 grams, or about 70 per cent. It crystallises from water in needles, melting with decomposition at 219° to 220° C., readily soluble in water.

5-Hydroxy-2-carboxyphenylarsinic acid,



is prepared by boiling the diazo solution obtained from the above amino-acid. The compound has an indefinite decomposition point, is soluble in water and methyl alcohol, less soluble in ethyl alcohol.

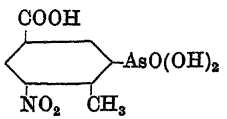
5-Carboxy-2-methylphenylarsinic acid,



[1] Maschmann, *Ber.*, 1924, 57, [B], 1759.

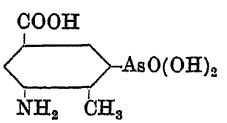
5-Amino-*o*-tolylarsinic acid is diazotised and the diazonium solution treated with cuprous cyanide, the resulting nitrile being hydrolysed by potassium hydroxide to the carboxylated acid. When crystallised from hydrochloric acid, and then from water, it appears in needles, 1 cm. in length, which do not melt below 300° C. The acid is very soluble in warm hydrochloric acid, readily soluble in water, moderately soluble in methyl alcohol, and sparingly soluble in ethyl alcohol. On oxidation with alkaline permanganate it yields 2 : 5-dicarboxyphenylarsinic acid (p. 319).

3-Nitro-5-carboxy-2-methylphenylarsinic acid,



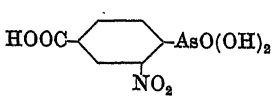
5-Carboxy-*o*-tolylarsinic acid (5·2 grams) in 25 c.c. of concentrated sulphuric acid at 0° C. is stirred and treated dropwise with 1·8 grams of nitric acid (density 1·4). The temperature is allowed to rise to 10° C. and the stirring continued for one hour. The mixture is then poured upon ice, and the precipitate recrystallised from water, fine needles being obtained, which are unmelted below 300° C.

3-Amino-5-carboxy-2-methylphenylarsinic acid,



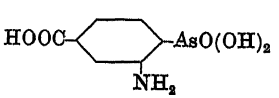
The nitro-acid (6·1 grams) in 40 c.c. of 10*N* sodium hydroxide and 80 c.c. of water is well stirred and treated at 80° C. with 35 grams of ferrous sulphate in 80 c.c. of water. The mixture is filtered, the residue well washed with hot water and the filtrate evaporated to crystallising-point, then made strongly acid to Congo red, using hydrochloric acid, and allowed to stand for a long time. Any precipitate is removed, the solution neutralised with concentrated sodium hydroxide and acidified with acetic acid. On rubbing the vessel with a glass rod, the acid separates as a pale yellow, crystalline precipitate. It crystallises from water in fine needles, soluble in methyl alcohol.

2-Nitro-4-carboxyphenylarsinic acid,



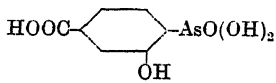
is prepared by oxidising 2-nitro-4-tolylarsinic acid with alkaline permanganate at 75° to 80° C. The acid is obtained in 62 per cent. yield, and crystallises in needles, M.pt. 226° to 227° C., soluble in hot water or methyl alcohol, sparingly soluble in ethyl alcohol.

2-Amino-4-carboxyphenylarsinic acid,



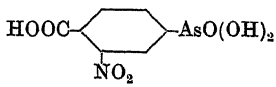
is obtained by reducing the preceding nitro-acid with ferrous sulphate in the usual manner. It crystallises in colourless needles, decomposing at 225° to 226° C., and forms a crystalline *acetyl derivative.*

2-Hydroxy-4-carboxyphenylarsinic acid,



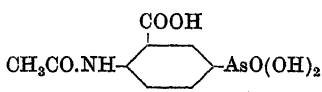
is formed by boiling the diazonium solution derived from the foregoing amino-acid. It crystallises in colourless needles having no definite decomposition-point, and is readily soluble in water.

3-Nitro-4-carboxyphenylarsinic acid,[1]



3-Nitro-4-tolylarsinic acid is oxidised with alkaline permanganate in the usual manner at 60° to 70° C. The carboxylated acid crystallises in fine, white needles, remaining unchanged at 300° C., and easily soluble in water, less soluble in alcohol, and insoluble in ether or chloroform.

4-Acetylamino-5-carboxyphenylarsinic acid,[2]

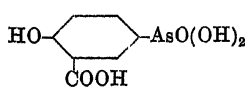


4-Acetylamino-*m*-tolylarsinic acid yields this acid when oxidised with aqueous permanganate. The product decomposes at about 230° C., and by acid or alkaline hydrolysis gives *4-amino-5-carboxyphenylarsinic acid,* decomposing at about 245° C.

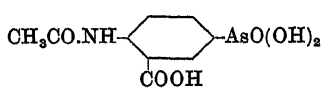
In a similar manner *4-acetylamino-6-carboxyphenylarsinic acid,* decomposing at about 260° C., is obtained from the corresponding amino-tolylarsinic acid.

The acetyl derivative of *3-amino-2 : 5-dimethylphenylarsinic acid* yields *3-acetylamino-5-methyl-2-carboxyphenylarsinic acid,* decomposing at about 255° C., and *3-acetylamino-2 : 5-dicarboxyphenylarsinic acid,* decomposing at 340° C., when oxidised with permanganate, the final product depending on the amount of oxidising agent used.

3-Carboxy-4-hydroxyphenylarsinic acid,[3]



3-Carboxy-4-acetylaminophenylarsinic acid,



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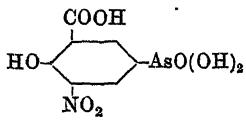
[1] Michaelis, *Annalen,* 1902, 320, 321.

[2] Adler and Adler, *Ber.,* 1908, 41, 931; German Patent, 203717; American Patent, 907016 (1908).

[3] Adler and Adler, *loc. cit.*; German Patent, 215251.

is saponified, then diazotised, and the diazo-compound heated on the water-bath or treated with steam. The free acid crystallises in white needles, melting at above 300° C. It is fairly soluble in cold water, methyl alcohol, or acetone, readily soluble in hot solvents. The following salts are known, all of which are decomposed by mineral acids: *silver* and *barium salts*, white; *copper salt*, yellowish-green; *iron salt*, brownish-red. The mercuric salt is known as *Enesol*.

3-Nitro-4-hydroxy-5-carboxyphenylarsinic acid,[1]



20 grams of 4-hydroxy-3-carboxyphenylarsinic acid and 7·7 grams of potassium nitrate are added to 100 c.c. of sulphuric acid at 5° C., and the whole poured into 500 c.c. of ice-water. The resulting solid (16 grams) crystallises from boiling water in rich yellow plates containing 1 molecule of water of crystallisation. The anhydrous compound melts with decomposition at 282° to 284° C., is fairly soluble in cold water, readily soluble in alkalis, forming a deep red solution with an excess of sodium hydroxide. Its *barium*, *calcium* and *magnesium salts* are amorphous. Reduction of the nitro-acid by glucose and alkali yields the corresponding *amino-acid*, white rhombs from water, unmelted at 300° C. The *barium*, *calcium* and *magnesium salts* of the amino-acid are also amorphous; with sodium hydroxide the amino-acid forms a *monosodium salt*, which crystallises in needles and is less soluble in water than the *disodium salt*. The amino-acid is only soluble in an excess of mineral acid. The *acetylamino-acid*, formed by acetylation in alkaline solution, crystallises from boiling water in long, colourless needles, melting with decomposition at 250° to 254° C. It forms amorphous *calcium* and *magnesium salts*.

Condensation Products of Dichloro-*p*-arsinobenzoyl Chloride with Amino-acids and Higher Alcohols.[2]

Dichloro-*p*-arsinobenzoyl chloride condenses with amino-acids in aqueous sodium hydrogen carbonate, and acidification of the resulting solutions yields arsenoxides. These are all white, amorphous powders, having no definite melting-points, are readily soluble in alcohols, alkali hydroxides, carbonates, or hydrogen carbonates, but insoluble in dilute hydrochloric acid, and the oxygen of the AsO-group cannot be replaced by sulphur or halogens.

Alanine condenses to give *benzoylalanine-p-arsenoxide*, $CO_2H.CH(CH_3).NH.CO.C_6H_4.AsO$, and phenylalanine forms *benzoylphenylalanine-p-arsenoxide*, $CO_2H.CH(CH_2.C_6H_5).NH.CO.C_6H_4.AsO$. *Benzoyltyrosine-p-arsenoxide*, $CO_2H.CH(CH_2.C_6H_4OH)NH.CO.C_6H_4.AsO$, is isolated from tyrosine when the condensation is carried out in 2*N* sodium hydroxide solution. Leucine yields *benzoylleucine-p-arsenoxide*, $CO_2H.CH[CH_2CH(CH_3)_2]NH.CO.C_6H_4.AsO$; aspartic acid, *benzoylaspartic*

[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3062.
[2] Sieburg, *Arch. Pharm.*, 1916, *254*, 224.

acid-p-arsenoxide, $CO_2H.CH(CH_2.CO_2H)NH.CO.C_6H_4.AsO$; glutamic acid, *benzoylglutamic acid-p-arsenoxide*, $CO_2H.CH(CH_2.CH_2.CO_2H)NH.CO.C_6H_4.AsO$; and pentamethylenediamine, *dibenzoylpentamethylenediamine-pp'-diarsenoxide*, $CH_2[(CH_2)_2.NH.CO.C_6H_4.AsO]_2$.

These oxides may be oxidised by hydrogen peroxide in alkaline solution to the corresponding arsinic acids, which are crystalline. Reduction of the oxides by sodium amalgam affords the arseno-compounds, $As_2(C_6H_4.CO.NH.CHR.CO_2H)_2$. The acids are as follows: *benzoylalanine-p-arsinic acid*, $CO_2H.CH(CH_3).NH.CO.C_6H_4.AsO(OH)_2$, cubic crystals; *benzoylphenylalanine-p-arsinic acid*, $CO_2H.CH(CH_2.C_6H_5)NH.CO.C_6H_4.AsO(OH)_2$, needles; *benzoyltyrosine-p-arsinic acid*, $CO_2H.CH(CH_2.C_6H_4.OH).NH.CO.C_6H_4.AsO(OH)_2$, long, pointed plates; *benzoylleucine-p-arsinic acid*, $CO_2H.CH[CH_2.CH(CH_3)_2]NH.CO.C_6H_4.AsO(OH)_2$, needles; *benzoylaspartic acid-p-arsinic acid*, $CO_2H.CH(CH_2.CO_2H)NH.CO.C_6H_4.AsO(OH)_2$, cone-shaped crystals; and *benzoylglutamic acid-p-arsinic acid*, $CO_2H.CH(CH_2.CH_2.CO_2H)NH.CO.C_6H_4.AsO(OH)_2$, cubic crystals.

In the case of the higher alcohols, the condensation is effected in benzene solution, using pyridine as a catalyst, and the reaction completed by finally heating the mixtures on the water-bath. The following compounds are known: From myricyl alcohol, *myricyl benzoate p-arsenoxide*, $C_{30}H_{61}.O.CO.C_6H_4.AsO$, which in acetone solution is transformed by hydrogen peroxide into the *arsinic acid*, $C_{30}H_{61}.O.CO.C_6H_4.AsO(OH)_2$, which crystallises in plates. Reduction of the oxide by phosphorous acid gives the *arseno-compound*, $As_2(C_6H_4.CO.OC_{30}H_{61})_2$, a yellow powder. In a similar manner, cholesterol yields *cholesteryl benzoate p-arsenoxide*, $C_{27}H_{45}O.CO.C_6H_4.AsO$, a colourless powder which forms an *arsinic acid*, $C_{27}H_{45}O.CO.C_6H_4.AsO(OH)_2$, pointed needles, and an *arseno-compound*, $As_2(C_6H_4.CO.OC_{27}H_{45})_2$, a yellow powder.

Arsenated Benzanilide and its Derivatives.[1]

These derivatives are obtained by the condensation of dichloro-*p*-arsinobenzoyl chloride, $Cl_2AsC_6H_4.COCl$, with primary and secondary arylamines, the resulting compounds being of the general type,

$$(HO)_2OAs.C_6H_4.CO.NRR'$$

The general procedure for preparing the arsino-compounds of the type $AsO(OH)_2.C_6H_4.CO.NHR$, is as follows: The primary amine (0·2 mol.) in 200 to 300 c.c. of dry benzene is treated with crude dichloro-*p*-arsinobenzoyl chloride (0·1 mol.) in 50 c.c. of benzene, the latter solution being added in small quantities and with vigorous shaking. The precipitate is allowed to stand for several hours, then filtered off, washed with benzene, and finally with ether. It is then triturated with water to remove the hydrochloride formed during the reaction. The crude product is dissolved in hot glacial acetic acid and an excess of 3 per cent. hydrogen peroxide added. The arsinic acid separates on cooling, and may be obtained in colourless crystals by recrystallising from glacial acetic acid.

The following compounds have been isolated, all being of high melting-point and insoluble in cold water or benzene, but soluble in

[1] Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1923, 45, 757.

alcohol or dilute alkali: *p-arsinobenzanilide*, $C_6H_5.NH.CO.C_6H_4.AsO(OH)_2$; *p-arsinobenzanthranilide*, $CO_2H.C_6H_4.NH.CO.C_6H_4.AsO(OH)_2$; *p-arsinobenzo-p-anisidide*, $C_6H_4(OCH_3).NH.CO.C_6H_4.AsO(OH)_2$; *p-arsinobenzo-p-phenetidide*, $C_6H_4(OC_2H_5).NH.CO.C_6H_4.AsO(OH)_2$; *p-arsinobenzo-o-anisidide*, $C_6H_4(OCH_3).NH.CO.C_6H_4.AsO(OH)_2$; *p-arsinobenzoyl-arsanilide*, $(HO)_2OAs.C_6H_4.CO.NH.C_6H_4.AsO(OH)_2$, formed by the action of alkaline hydrogen peroxide on hydrated *p-arsinosobenzoylarsanilide*, $(HO)_2OAs.C_6H_4.NH.CO.C_6H_4.As(OH)_2$, which is prepared by condensing dichloro-*p*-arsinobenzoyl chloride with arsanilic acid.

$$Cl_2As.C_6H_4.CO.Cl + NH_2.C_6H_4.AsO(OH)_2 \xrightarrow{2H_2O} (HO)_2As.C_6H_4.CO.NH.C_6H_4.AsO(OH)_2 + 3HCl$$

The above compounds are converted to arseno-compounds of the type $RNH.CO.C_6H_4.As=As.C_6H_4.CO.NHR$, by the following process:

The crude arsino-derivatives in the minimum quantity of hot alcohol are treated with an excess of phosphorous or hypophosphorous acid, and the mixture heated under reflux for thirty minutes. The yellow precipitate which forms is filtered hot and repeatedly washed with alcohol. All the arseno-compounds are yellow in colour, insoluble in the usual organic solvents, and do not melt below 250° C. On standing, they are slowly transformed to the corresponding oxides. The following have been isolated: *p-arsenobenzanilide*, $C_6H_5NH.CO.C_6H_4As:AsC_6H_4.CO.NH.C_6H_5$; *p-arsenobenzanthranilide*, $CO_2H.C_6H_4.NH.CO.C_6H_4As:AsC_6H_4.CO.NH.C_6H_4.CO_2H$; *p-arsenobenzo-p-anisidide*, $C_6H_4(OCH_3)NH.CO.C_6H_4As:AsC_6H_4.CO.NH(OCH_3)C_6H_4$; *p-arsinobenzo-p-phenetidide*, $C_6H_4(OC_2H_5)NH.CO.C_6H_4As:AsC_6H_4.CO.NH(OC_2H_5)C_6H_4$; *p-arsenobenzo-p-xylidide*, $C_6H_3(CH_3)_2NH.CO.C_6H_4As:AsC_6H_4.CO.NH(CH_3)_2C_6H_3$; *p-arsenobenzo-α-naphthylidide*, $C_{10}H_7.NH.CO.C_6H_4As:AsC_6H_4.CO.NH.C_{10}H_7$.

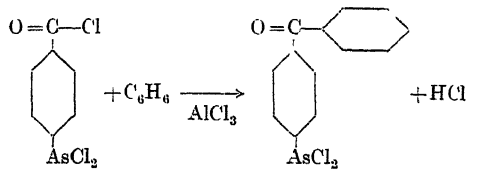
The halogen derivatives of the arsino-compounds are obtained by dissolving the latter in hot glacial acetic acid and adding an excess of the desired sodium halide in solid form. The mixture is heated under reflux for five minutes and the excess of sodium halide filtered off, the cool filtrate depositing a quantitative yield of the halogen compound.

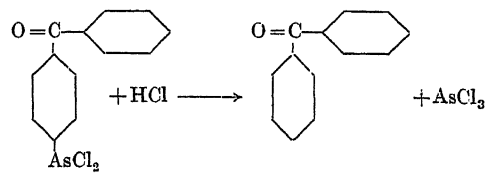
The following compounds have been obtained: *p-di-iodo-arsinebenzo-p-anisidide*, $C_6H_4(OCH_3).NH.CO.C_6H_4.AsI_2$, yellow needles, M.pt. 209° to 210° C.; *p-di-iodo-arsinebenzo-p-phenetidide*, $C_6H_4(OC_2H_5).NH.CO.C_6H_4.AsI$, yellow needles, M.pt. 227° to 228° C.; *p-di-iodo-arsinebenzo-ethylanilide*, $C_6H_5.N(C_2H_5).CO.C_6H_4.AsI_2$, canary-yellow needles, M.pt. 115° to 116° C.; *p-di-iodo-arsinebenzo-o-anisidide*, M.pt. 148° to 149° C.; *p-dibromoarsinebenzo-o-anisidide*, pale yellow crystals, M.pt. 167° to 168° C.; *p-dichloroarsinebenzo-o-anisidide*, pale yellow crystals, M.pt. 164° to 165° C.; *p-dichloroarsinebenzo-ethylanilide*, colourless cubes, M.pt. 147° to 148° C.

Arsenated Benzophenone and its Derivatives.

These compounds are prepared by the aid of the Friedel-Craft reaction. Dichloro-*p*-arsinobenzoyl chloride readily condenses with aromatic hydrocarbons and phenyl ethers in carbon disulphide solution

in the presence of aluminium chloride. Provided the action is not allowed to become too vigorous, its general course is shown by I, but if not controlled, de-arsenation takes place as in II:

I 

II 

Benzophenone-4′-arsenoxide, $C_6H_5.CO.C_6H_4.AsO$.[1]—20 grams of dichloro-*p*-arsinobenzoyl chloride in 100 c.c. of dry carbon disulphide are added to 25 c.c. of dry benzene, and 25 grams of anhydrous aluminium chloride are gradually added in 5-gram portions. The mixture is heated on the water-bath at 50° C., then poured whilst warm upon 300 grams of ice, 10 c.c. of concentrated hydrochloric acid are added, and the carbon disulphide and benzene removed in steam. The plastic substance thus obtained is dissolved by warming in 400 c.c. of dilute sodium carbonate solution and 50 c.c. of 6*N* sodium hydroxide. After filtering and cooling, the oxide is precipitated in an amorphous form by dilute hydrochloric acid in about 60 per cent. yield. It is slightly soluble in boiling water, alcohol, benzene, or ether, easily soluble in warm alkali.

Benzophenone-4′-arsenious acid, $C_6H_5.CO.C_6H_4.As(OH)_2$, results when the foregoing oxide is boiled for several hours with a large bulk of water. It forms fine crystals, which have a similar solubility to the oxide.

Benzophenone-4′-arsinic acid, $C_6H_5.CO.C_6H_4.AsO(OH)_2$, is formed when the arsenoxide is treated with hydrogen peroxide in dilute sodium hydroxide solution. The yield is quantitative, and the product crystallises in lustrous clusters of elongated plates, which soften at 195° C. but do not melt below 260° C. It is insoluble in cold water, benzene, or ether, but soluble in alkalis, alcohol, or warm acetic acid. When warmed in slightly alkaline solution with hydroxylamine sulphate, it gives an *oxime*, $C_6H_5.C(NOH).C_6H_4.AsO(OH)_2$, which crystallises from hot water in fine, colourless needles, which do not melt below 260° C. When warmed for one hour on the water-bath with fuming nitric acid the arsinic acid gives a *mononitrobenzophenone-p-arsinic acid*, $NO_2.C_6H_4.CO.C_6H_4.AsO(OH)_2$, which crystallises from water in fine, yellow needles.

The following compounds are prepared in a similar manner, substituting toluene, anisole, phenetole, and diphenyl ether, respectively, for benzene:

4-*Methylbenzophenone-4′-arsenoxide*, $C_6H_4(CH_3).CO.C_6H_4.AsO$.—This

[1] Lewis and Cheetham, *J. Amer. Chem. Soc.*, 1921, 43, 2117.

is an amorphous substance obtained in 50 per cent. yield. Its hydrate crystallises in fine needles. Oxidation yields *4-methylbenzophenone-4'-arsinic acid*, $C_6H_4(CH_3).CO.C_6H_4.AsO(OH)_2$, which crystallises from water in transparent plates.

4-Methoxy-, *4-ethoxy-* and *4-phenoxy-benzophenone-4'-arsinic acids.*—These have similar properties to the foregoing, but as the molecular weight of the acids increases, the solubility in water decreases, hence the last two compounds cannot be recrystallised from water.

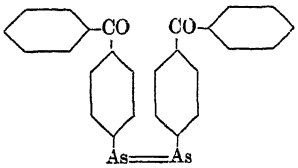
The following preparations are similar to the foregoing, save that dichloro-*o*-arsinobenzoyl chloride replaces the *p*-compound. In the absence of nitro- or amino-groups in the ring, the benzophenone arsinic acids are easily and quantitatively reduced in acetic acid solution by concentrated hydrobromic or hydriodic acid to derivatives of arsenious oxide. In some cases the reaction goes further, yielding dibromo- or di-iodoarsines. The latter are easily converted again into the oxide by hydrolysis with dilute sodium carbonate solution. If the arsinic acids, or better still the arsenoxides, are heated under reflux with phosphorous acid in ethyl alcohol solution, the arseno-derivatives are obtained.[1]

Benzophenone-2'-arsinic acid, $C_6H_5.CO.C_6H_4.AsO(OH)_2$.—The crude dichloro-*o*-arsinobenzoyl chloride obtained from 25 grams of *o*-carboxyphenylarsinic acid is treated successively with 75 c.c. of carbon disulphide, 25 c.c. of benzene, and 20 grams of aluminium chloride. When the evolution of hydrogen chloride slackens, the mixture is heated at 50° C. for two hours on the water-bath under reflux, then poured upon 300 c.c. of ice. Hydrochloric acid (10 c.c.) is added, and the benzene and carbon disulphide removed in steam. The gummy substance is dissolved in 400 c.c. of dilute sodium carbonate and 50 c.c. of 6*N* sodium hydroxide, a slight excess of 3 per cent. hydrogen peroxide added, the whole warmed for five minutes, cooled, and acidified with hydrochloric acid, when the arsinic acid immediately separates. Recrystallisation from 500 c.c. of 95 per cent. alcohol yields 8 grams of fine needles, insoluble in hot water, ether, or benzene, soluble in warm ethyl alcohol, glacial acetic acid, alkalis, or alkali carbonates. The crystals soften at 195° C. but do not melt below 250° C. In a more recent preparation [2] the melting-point is given as 215° to 219° C. In this case the acid was prepared from *benzophenone-2'-dichloroarsine*, $C_6H_5.CO.C_6H_4.AsCl_2$, a crystalline compound, M.pt. 107° to 108° C., which with sodium hydroxide yields the corresponding *oxide*, $C_6H_5.CO.C_6H_4.AsO$, softening at 105° C., but not completely melted at 200° C.

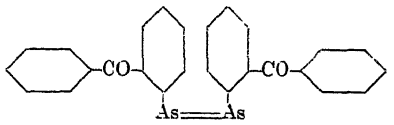
By substituting toluene,[3] anisole, phenetole or diphenyl ether for benzene in the above preparation, the following derivatives may be isolated: *4-Methyl-*, *4-methoxy-*, *4-ethoxy-* and *4-phenoxy-benzophenone-2'-arsinic acids.*

Arseno-compounds obtained by reducing the foregoing arsinic acids or their oxides are: *4 : 4'-Dibenzoylarsenobenzene*, (I), *2 : 2'-dibenzoylarsenobenzene*, (II), *2 : 2'-di-p-anisoylarsenobenzene*, (III), and *4 : 4'-diethoxydibenzoyl-2 : 2'-arsenobenzene*, (IV). These compounds are all yellow powders, insoluble in all the usual solvents.

[1] Lewis and Cheetham, *J. Amer. Chem. Soc.*, 1923, 45, 510.
[2] Aeschlimann and McCleland, *Trans. Chem. Soc.*, 1924, 125, 2031.
[3] Lewis and Cheetham, *loc. cit.*



I



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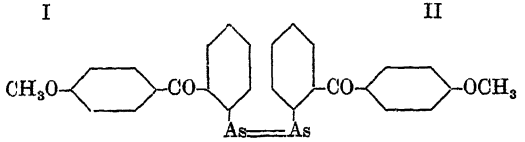
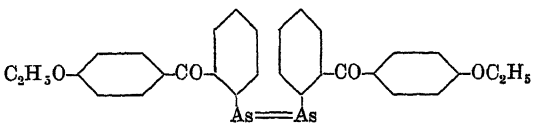
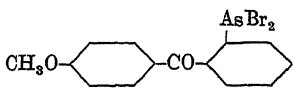


III



IV

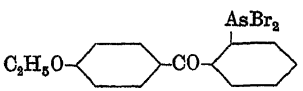
4-Methoxybenzophenone-2′-dibromoarsine,



is precipitated in fine, yellow needles, when 10 c.c. of 48 per cent. hydrobromic acid are added to 2 grams of 4-methoxybenzophenone-2′-arsinic acid in 25 c.c. of glacial acetic acid. Yield, 2 grams. The compound melts at 161° C., is readily soluble in alcohol and aromatic hydrocarbons, insoluble in water, slowly hydrolysed by aqueous sodium carbonate but more rapidly by the alcoholic reagent, giving the corresponding *arsenious acid*, $CH_3O.C_6H_4.CO.C_6H_4.As(OH)_2$, in shining plates.

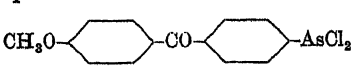
4-Methoxybenzophenone-2′-dichloroarsine yields colourless crystals, M.pt. 148° C., and the *di-iodoarsine* bright red crystals, M.pt. 137° C.

4-Ethoxybenzophenone-2′-dibromoarsine,



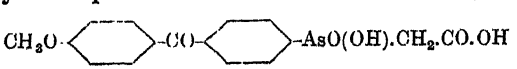
crystallises from glacial acetic acid in yellow needles, M.pt. 152° C.; the *di-iodoarsine* forms orange-coloured crystals, M.pt. 151° C.

4-Methoxybenzophenone-4′-dichloroarsine,



gives long, colourless crystals, M.pt. 152° C.; the *dibromoarsine* gives pale yellow crystals, M.pt. 136° C.; the *di-iodoarsine*, red crystals, M.pt. 105° C.

4-Methoxybenzophenone-4′-arsinoacetic acid,

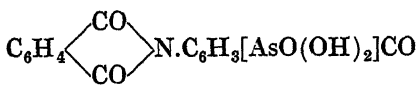


A solution of 2 grams of 4-methoxybenzophenone-4′-dibromoarsine and 0·7 gram of sodium hydroxide in 20 c.c. of water is cooled and

shaken with 1 gram of chloracetic acid in 6*N* alkali. After three hours' standing, the solution is acidified to phenolphthalein and filtered, acidification of the filtrate to Congo red precipitating the arsinic acid in colourless crystals.

Acetophenone-p-arsinic acid, $CH_3.CO.C_6H_4.AsO(OH)_2$ (see also below), is obtained from *p*-amino-acetophenone by diazotisation and treatment with sodium arsenite (Bart's reaction). The acid is insoluble in water, but soluble in alkalis or glacial acetic acid.

Further compounds of a similar type may be obtained by diazotising mono- or polyamino-derivatives of aromatic aldehydes or ketones, or of mixed aliphatic-aromatic ketones, and treating the solutions with aqueous sodium arsenite. This method has been used for the following preparations :[1] *Nitroxyacetophenonearsinic acid,* $CH_3.CO.C_6H_3(NO_2).AsO(OH)_2$, melting at about 200° C.; *benzophenone-4 : 4'-diarsinic acid,* $(HO)_2OAs.C_6H_4.CO.C_6H_4.AsO(OH)_2$, M.pt. 236° C.; *p-aldehydophenylarsinic acid,* $CHO.C_6H_4.AsO(OH)_2$; *3-hydroxybenzophenone-4'-arsinic acid,* $HO.C_6H_4.CO.C_6H_4.AsO(OH)_2$, M.pt. 180° C.; *4-acetamidobenzophenone-3'-arsinic acid,* $CH_3.CO.NH.C_6H_4.CO.C_6H_4.AsO(OH)_2$, M.pt. 253° C.; *ω-phthalimidoacetophenone-p-arsinic acid,*



M.pt. above 270° C.; *phenyl-p-arsinic acid benzyl ketone,* $C_6H_5.CH_2.CO.C_6H_4.AsO(OH)_2$, decomposing at 160° C.; *propiophenone-p-arsinic acid,* $C_3H_7.CO.C_6H_4.AsO(OH)_2$, M.pt. not below 275° C.; and *nitro-p-aldehydophenylarsinic acid,* $CHO.C_6H_3(NO_2).AsO(OH)_2$, decomposing at 130° C.

Arsenated Acetophenone Derivatives.[2]

When aromatic aldehydes or ketones containing halogens are heated in aqueous alcohol solution with sodium arsenite at 150° to 200° C., arsenated compounds result. In this way *p*-bromoacetophenone yields *acetophenone-p-arsinic acid,* $CH_3.CO.C_6H_4.AsO(OH)_2$, at a temperature of 160° to 170° C. (compare preparation above); 4-bromo-3-aminoacetophenone gives *3-aminoacetophenone-4-arsinic acid,* $CH_3.CO.C_6H_3(NH_2)AsO(OH)_2$, the reaction taking place at 180° C. in the presence of copper powder as a catalyst. The latter acid decomposes at 230° C. Acetophenone-*p*-arsinic acid and hydroxylamine hydrochloride form colourless plates, decomposing at 157° C.[3] This reaction is a general one in which arsenic compounds containing CO groups in non-cyclical linkage are caused to react with compounds containing the grouping NH_2–*a*–, where *a* is C or O, and in which the H atoms of the NH_2 group are reactive with CO groups. *Acetophenone-p-arsinic acid* and *1-acetophenone-3-hydroxy-4-arsenobenzene* have been *condensed with carbohydrazide, malonyl hydrazide, oxalyl hydrazide, thiocarbohydrazide, triaminoguanidine dinitrate,* and *diaminoguanidine dihydrobromide.*[4] These condensation products are part of a scheme for condensing

[1] British Patent, 220668 (1924).
[2] Austrian Patent, 100211 (1922).
[3] American Patent, 1647662.
[4] German Patent, 463313; compare 459649.

arsenicals containing a CO group not in a ring with derivatives containing several hydrazine groups.

Condensation products from mixed alkyl-aryl carbonyl arsenic compounds and amino-compounds (excluding hydrazine and its derivatives) have been reduced in aqueous solution or in aqueous suspension by hyposulphite.[1] The following examples show the mixture of compounds reduced, and the decomposition-points of the arseno-compounds produced: *Acetophenone-p-arsinic acid* and *p-aminoacetophenone*, arseno-compound is unchanged at 270° C.; *acetophenone-p-arsinic acid* and *anthranilic acid*, arseno-derivative unchanged at 270° C.; *aminoacetophenone-p-arsinic acid* and *urea*, arseno-compound unchanged at 280° C.; *benzaldehyde-p-arsinic acid* and *antipyrin*, arseno-compound decomposes at about 200° C.; 1-*hydroxy*-2-*acetophenone-p-arsinic acid* and *p-phenetidine*, arseno-compound sinters and darkens at 220° C.; *acetophenone-p-arsinic acid* and *o-aminobenzaldehyde*, arseno-compound decomposes at 225° C.; *acetophenone-p-arsinic acid* and *glycocoll*, arseno-compound darkens at 250° C.; *m-nitrobenzaldehydearsinic acid* and *benzylhydroxylamine hydrochloride*, arseno-compound decomposes at 120° C.; *benzaldehyde-p-arsenoxide* and *hydroxylamine hydrochloride*, arseno-compound is infusible at 280° C.

[1] German Patent, 463577.

CHAPTER IX.

ARSENO-COMPOUNDS.

THE arseno-compounds owe their importance principally to their therapeutic value, centred chiefly around 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene and its derivatives. They may be divided into two classes—(*a*) *symmetrical arseno-compounds*, R.As=As.R, in which the two radicals R are identical; (*b*) *unsymmetrical compounds* of the type R.As=As.R′. Three methods of preparation have been used for type (*a*), of which the first mentioned is the one in most general use :

(1) By reduction of the corresponding arsinic acids,

$$2RAsO(OH)_2+4H_2 \longrightarrow RAs=AsR+6H_2O$$

(2) By reducing arsenoxides,

$$2RAsO+2H_2 \longrightarrow RAs=AsR+2H_2O$$

(3) By the interaction of a mixture containing a primary arsine and an arsenoxide, both of which have the aryl radical,

$$RAsH_2+RAsO \longrightarrow RAs=AsR+H_2O$$

The unsymmetrical arseno-compounds are obtained by the following methods :—

(1) By the simultaneous reduction of two different arsinic acids (*a*), or arsenoxides (*b*), or a mixture containing an acid and an oxide (*c*), or an oxide and a chloride (*d*) :

(*a*) $RAsO(OH)_2+R'AsO(OH)_2+4H_2 \longrightarrow RAs=AsR'+6H_2O$
(*b*) $RAsO+R'AsO+2H_2 \longrightarrow RAs=AsR'+2H_2O$
(*c*) $RAsO(OH)_2+R'AsO+3H_2 \longrightarrow RAs=AsR'+4H_2O$
(*d*) $RAsO+R'AsCl_2+2H_2 \longrightarrow RAs=AsR'+H_2O+2HCl$

(2) By interaction of a primary arsine and a dichloroarsine (*a*) or arsenoxide (*b*) :

(*a*) $RAsH_2+R'AsCl_2 \longrightarrow RAs=AsR'+2HCl$
(*b*) $RAsH_2+R'AsO \longrightarrow RAs=AsR'+H_2O$

(3) By the re-arrangement of two symmetrical arseno-compounds :

$$RAs=AsR + R'As=AsR' \longrightarrow 2RAs=AsR'$$

Reducing agents used for the foregoing reactions are phosphorous acid, hypophosphorous acid, sodium hydrosulphite, stannous chloride in hydrochloric acid, and sodium amalgam in methyl alcohol ; in some cases electrolytic methods have been employed. Many arseno-compounds of low molecular weight have been isolated, using phosphorous acid for reduction. In the case of arsenoxides the reduction takes place in

alcoholic solution, but with arsinic acids heating in sealed tubes at temperatures above 100° C. is necessary. When hypophosphorous acid is used, a trace of potassium iodide appears to act as a catalyst, and this method has been used in the case of many of the unsymmetrical arseno-compounds recently reduced. Hydriodic acid also acts catalytically when stannous chloride and hydrochloric acid are used for reduction. Sodium hydrosulphite is used in sodium hydroxide solution, often in the presence of magnesium chloride, and a temperature of 40° to 55° C. is necessary. The objection to the last-named reducing agent is that by-products containing sulphur are formed during the reaction, and these accompany the arseno-compound and are often difficult to separate from the final product. A very good example of this reduction is the reduction of 3-nitro-4-hydroxyphenylarsinic acid to Salvarsan, and the by-products resulting from the reduction in this case are fully dealt with on pp. 381–383. Sodium amalgam has only been used on very few occasions, and electrolytic reduction is at present in its infancy.

Special care is needed in choosing the reducing agent when aldehydo- or ketoarsinic acids are being reduced, since it is necessary to reduce the quinquevalent arsenic without affecting the carbonyl groups, and in compounds containing reactive amino-groups reduction should not affect the carbon-nitrogen linkage. In such cases, sodium hyposulphite, phosphorus trichloride or sodium bisulphite are used for reduction.[1]

When arseno-compounds are obtained by condensation of an arsine (*a*) with an arsenoxide or a dihalogenated arsine, or (*b*) with the unisolated product of an arsinic acid, the presence of small quantities of a reducing agent such as phosphorous acid or its salts gives an increased yield.[2]

All the arseno-compounds dealt with are solids, many of them being crystalline and having definite melting-points. They are yellow in colour, this fact being supposed to be due to the grouping –As : As–. If the assumption is made that the range of from very pale yellow to bright yellow encountered in the compounds is due to some extent to the physical state of aggregation, or to the existence of certain groups substituted in the nucleus, we have still to account for the fact that all the following compounds are white: Arsenobenzene, arseno-*m*-toluene, arseno-*m*-xylene, 3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene, 4 : 4′-dioxalylaminoarsenobenzene, and the arseno-compounds of 3′-amino-benzenesulphonyl-4-aminophenylarsinic acid and 3′-amino-4′-toluene-sulphonyl-4-aminophenylarsinic acid. The arseno-compounds of the benzamide analogues of the two last-named derivatives are orange. The loss of colour may be due to the formation of a bimolecular complex:[3]

$$\begin{matrix} \mathrm{RAs{=}AsR} \\ \mathrm{RAs{=}AsR} \end{matrix} \longrightarrow \begin{matrix} \mathrm{RAs{-}AsR} \\ | \quad | \\ \mathrm{RAs{-}AsR} \end{matrix}$$

The bimolecular formula resembles one due to Fargher,[4] who explained the reaction between symmetrical arsenobenzenes to produce an unsymmetrical product by the following equation:

[1] British Patents, 199091, 199092, 199093 (1923); 220668, 249584, 249588 (1924).
[2] British Patents, 255839, 255861 (1926); see also 11901 (1911), 250577 (1926).
[3] Hewitt, King, and Murch, *J. Chem. Soc.*, 1926, p. 1357.
[4] Fargher, *Trans. Chem. Soc.*, 1920, 117, 867.

$$\begin{array}{l} R.As- \\ | \\ R.As- \end{array} \quad \begin{array}{l} -As.R' \\ | \\ -As.R' \end{array} \longrightarrow \begin{array}{l} RAs.AsR' \\ | \quad | \\ RAs.AsR' \end{array} \longrightarrow \begin{array}{l} RAs{=}AsR' \\ \\ RAs{=}AsR' \end{array}$$

The solubility of many of the compounds depends on the groups substituted in the nucleus ; *e.g.* arsenoarylamines, as might be expected, are soluble in acids, forming salts possessing the usual solubilities associated with arylamine salts ; compounds containing acidic radicals, arsenophenols and arsenocarboxylic acids dissolve in alkalis, giving water-soluble salts. A large number of the derivatives are rapidly oxidised in air, first yielding oxides, then acids, and the more highly substituted the arseno-compound the more readily it is oxidised. The speed of oxidation may be increased by dissolving the compounds in alkali. With salts such as silver nitrate and the chlorides of copper, gold, mercury, platinum and palladium, *co-ordination compounds* are formed. Alkyl iodides decompose arseno-compounds, the products depending upon experimental conditions, aryltrialkylarsonium iodides, periodides, aryldi-iodoarsines and free iodine being isolated in some cases. Chlorine ruptures the double bond, giving aryldichloroarsines, or excess of halogen yields the tetrahalide. Bromine, as far as investigated, forms aryldibromoarsines. Iodine adds on to the double bond in the case of *m*- and *p*-arsenoxylenes, yielding compounds of the type RAsI.AsIR:

$$RAs{=}AsR + 2Cl_2 = 2RAsCl_2 \xrightarrow{2Cl_2} 2RAsCl_4$$

$$RAs{=}AsR + 2Br_2 = 2RAsBr_2 \xrightarrow{2Br_2} 2RAsBr_4$$

$$RAs{=}AsR + I_2 = RAsI.AsIR$$

Heating with hydriodic acid or phosphorus tri-iodide in sealed tubes, decomposes arseno-compounds to hydrocarbons, arsenious iodide, and elemental arsenic. Sulphur gives arylarsenious sulphides, but an excess of the element at higher temperatures may cause decomposition :

$$RAs{=}AsR + S_2 = 2RAsS$$

$$RAs{=}AsR + 2S_2 = R_2S + As_2S_3$$

Arseno-compounds, heated in sealed tubes with ammonium sulphide, form sesquisulphides, $R_2As_2S_3$. Mercury dialkyls react, forming aryldialkylarsines :

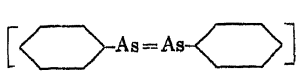
$$RAs{=}AsR + 2HgEt_2 = 2REt_2As + 2Hg$$

When heated above their melting-points arseno-compounds give triarylarsines and arsenic, but if heating is carried out in a carbon dioxide atmosphere, arylcacodyls and arsenic result :

$$3RAs{=}AsR \longrightarrow 2R_3As + As_4$$

$$2RAs{=}AsR \longrightarrow R_2As.AsR_2 + As_2$$

Arsenobenzene,[1]



[1] Michaelis and Schulte, *Ber.*, 1881, 14, 912 ; 1882, 15, 1952 ; Michaelis and Schäfer, *ibid.*, 1913, 46, 1742.

This derivative may be prepared by treating a concentrated alcoholic solution of phenylarsenoxide with phosphorous acid. It may be more readily obtained by reducing phenylarsinic acid in the following manner:[1] 100 grams of phenylarsinic acid in 700 c.c. of water are treated with 1000 c.c. of 50 per cent. hypophosphorous acid and the whole rapidly stirred in a flask fitted with a mercury-sealed stirrer and heated on a water-bath at 55° to 60° C. Should the material tend to cake, such pieces are removed, pulverised, and returned to the flask. After 4½ hours the reaction mixture is forced by carbon dioxide pressure into an anaerobic filter, and the precipitate washed with 500 c.c. of 10 per cent. sodium hydroxide, followed by 500 c.c. of warm 5 per cent. sodium hydroxide. All these operations are carried out in a carbon dioxide atmosphere. The crude arsenobenzene is then vigorously stirred with two successive 200 c.c. portions of 10 per cent. sodium hydroxide, the yellow powder being removed after each extraction. It is finally washed on the filter with 500 c.c. of warm 5 per cent. sodium hydroxide, followed by 1000 c.c. of distilled water, then dried for two days over phosphorus pentoxide in an evacuated carbon dioxide atmosphere. It may be purified by dissolving in the minimum quantity of boiling chlorobenzene and allowing the hot, filtered solution to cool. The crystals appear to consist of white, strongly birefringent needles, all of one type, which melt at 195° C.[2] Molecular weight determinations indicate some association of the solvents. The compound dissolves in benzene, chloroform, or carbon disulphide, is sparingly soluble in alcohol, and insoluble in ether or water. When heated at 255° C. in a carbon dioxide atmosphere, it decomposes, yielding arsenic and phenylcacodyl.[3] Solid arsenobenzene combines so vigorously with oxygen that explosion frequently occurs when the two are brought into contact.[4] Arsenobenzene combines with chlorine, giving phenyldichloroarsine, and with sulphur, yielding phenylarsenious sulphide. If heated with excess of sulphur at a higher temperature it reacts as follows:

$$C_6H_5.As:As.C_6H_5+2S_2=As_2S_3+(C_6H_5)_2S$$

Arsenobenzene (1 mol.), sulphur (1 mol.), and some fresh ammonium sulphide, when heated in a sealed tube, react to form arsenious sulphide and the sesquisulphide, $(C_6H_5)_2As_2S_3$. With mercury diethyl in a sealed tube at 250° C., phenyldiethylarsine and mercury result. Arsenobenzene is decomposed by boiling alcoholic ammonium sulphide, giving benzene, arsenious sulphide, and arsenic, but if aqueous ammonium sulphide is used at a high temperature, the products are triphenylarsine and arsenic. Decomposition also occurs on heating in sealed tubes with hydriodic acid or phosphorus tri-iodide, benzene, arsenious iodide and arsenic being isolated. When arsenobenzene is heated with methyl iodide at 100° C., it gives trimethylphenylarsonium iodide, the corresponding periodide, phenyldi-iodoarsine, and iodine, whilst ethyl iodide gives a similar result.[5] Arsenobenzene and trimethylphenylarsonium

[1] Palmer and Scott, *J. Amer. Chem. Soc.*, 1928, 50, 536; compare Binz, Bauer, and Hallstein, *Ber.*, 1920, 53, [B], 427.

[2] The following M.pts. have been given in the literature on this compound: 196° C. (Michaelis and Schulte, *loc. cit.*); 208° C. (Binz, Bauer, and Hallstein, *loc. cit.*); 212° C. (Michaelis and Schäfer, *loc. cit.*).

[3] Steinkopf, Dudek, and Schmidt, *Ber.*, 1928, 61, [B], 1906.

[4] Maschmann, *ibid.*, 1926, 59, [B], 1142, 1148.

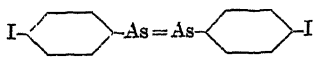
[5] Bertheim, *ibid.*, 1914, 47, 274; see Steinkopf and Schwen, *ibid.*, 1921, 54, [B], 1437.

tri-iodide yield trimethylphenylarsonium iodide and phenylarsenious iodide.

Co-ordination Compounds of Arsenobenzene.—(1) *With Silver Nitrate.*[1] 3 grams of arsenobenzene in pyridine are treated with an aqueous solution of silver nitrate (1·7 grams). A deep brown coloration appears, and on addition of a little alcohol and much ether, a black addition product is precipitated as a water-insoluble powder.

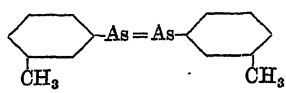
(2) *With Cupric Chloride.*[2] Four grams of phenylarsinic acid, 1·7 grams of cupric chloride ($2H_2O$) and 50 c.c. of 35 per cent. hypophosphorous acid are heated to boiling and stirred. The arsenobenzene addition product separates out as a yellowish-brown precipitate, readily soluble in pyridine.[3]

4 : 4′-Di-iodoarsenobenzene,[4]



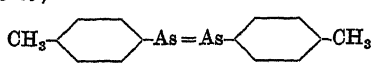
is isolated when *p*-iodophenylarsenoxide is reduced with phosphorous acid at 120° C. for twelve hours. It is an insoluble yellow powder, M.pt. 145° to 150° C. It combines with methyl iodide at 100° C. with formation of *p*-iodophenyltrimethylarsonium iodide (p. 92).[5]

Arseno-m-toluene,[6]



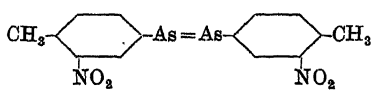
results when an alcoholic solution of *m*-tolylarsenoxide is treated with solid phosphorous acid. The compound is an amorphous white powder, M.pt. 106° C., somewhat soluble in carbon disulphide or warm cymene, but insoluble in the usual solvents. It combines readily with halogens and with sulphur.

Arseno-p-toluene,[7]



is formed by heating the corresponding oxide at 100° C. with an excess of phosphorous acid. It crystallises from chloroform in glistening needles or from benzene in plates, M.pt. 202° C., sparingly soluble in boiling alcohol, insoluble in water or ether. It is transformed successively to the dichloride and tetrachloride by the action of chlorine, and is oxidised by nitric acid to *p*-tolylarsinic acid. With methyl iodide it yields trimethyl-*p*-tolylarsonium iodide.[8]

3 : 3′-Dinitroarseno-p-toluene,[9]



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[1] German Patent, 270257. [2] German Patent, 270258.

[3] For estimation of arsenic in arsenobenzene, see Myttenaere, *Chemie et Industrie*, 1923, 10, 403; *Chem. Zentr.*, 1924, 221.

[4] Mameli and Patta, *Giorn. Farm. Chim.*, 1909, 58, 97; *Arch. Farmacol. sperim.*, 1909, 8, 395. [5] Bertheim, *Ber.*, 1914, 47, 274.

[6] Michaelis, *Annalen*, 1902, 320, 326; Eisenlohr, *Inaug. Dissert.*, Rostock, 1893.

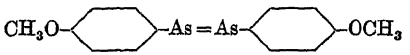
[7] Michaelis, *loc. cit.*, p. 301; see Michaelis and Schäfer, *Ber.*, 1913, 46, 1742.

[8] Bertheim, *Ber.*, 1914, 47, 274. [9] Michaelis, *loc. cit.*, p. 321.

3-Nitro-4-tolylarsinic acid (p. 177), 2 grams, is heated with 20 grams of phosphorous acid and 20 grams of water for twenty-four hours at 100° C. in a sealed tube. The compound is a yellow powder, decomposing at 165° C., insoluble in all solvents. When suspended in chloroform it reacts with bromine according to the equation:

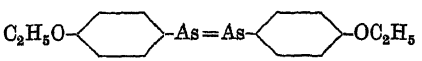
$$NO_2.C_7H_6.As : As.C_7H_6.NO_2 + 2Br_2 = 2C_7H_6.NO_2.AsBr_2$$

Arseno-p-anisole,



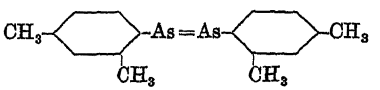
p-Anisylarsinic acid, when heated with seven times its weight of phosphorous acid and a little water in sealed tubes at 100° C., is transformed to the arseno-compound.[1] This is an amorphous yellow powder, decomposing at 200° C. Heating with methyl iodide at 100° C. gives *p-anisyltrimethylarsonium iodide*, consisting of prisms, M.pt. 213° C., and *p*-anisyldi-iodoarsine.[2]

Arseno-p-phenetole,



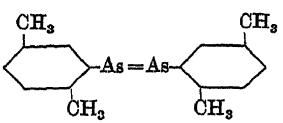
is a yellow product, difficult to obtain in a crystalline form.

Arseno-m-xylene,



is prepared in the usual manner. It is a white powder, crystallising from ether-chloroform in small, glistening needles, M.pt. 194° to 196° C. Treated with iodine (1 mol.) in alcoholic solution it yields *m-xylyldi-iodoarsine*, $C_8H_9AsI.AsIC_8H_9$, consisting of yellow crystals, M.pt. 89° C.[3]

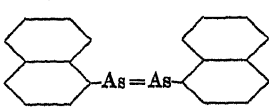
Arseno-p-xylene,



is a white powder, M.pt. 208° C., forming *p-xylyldi-iodoarsine*, M.pt. 97° C.

Nitroarseno-p-xylene, $NO_2.C_8H_8.As : As.C_8H_8.NO_2$, results when nitro-*p*-xylylarsinic acid is heated with phosphorous acid in a sealed tube. It is a yellow powder, sintering at 165° C., and exploding when strongly heated.

Arseno-α-naphthalene,[4]



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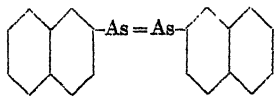
[1] Michaelis, *Annalen*, 1902, 320, 299. [2] Bertheim, *Ber.*, 1914, 47, 274.
[3] Michaelis, *loc. cit.*, p. 330; Seemann, *Inaug. Dissert.*, Rostock, 1891.
[4] Michaelis and Schulte, *Ber.*, 1882, 15, 1952; Michaelis, *loc. cit.*, p. 342; Büschler, *Inaug. Dissert.*, Rostock, 1893.

An alcoholic solution of α-naphthylarsenoxide is heated to boiling with solid phosphorous acid. After a time the liquid becomes bright yellow, and on cooling, yellow needles of the arseno-compound separate. It melts at 221° C., is sparingly soluble in the usual solvents and insoluble in water or ether. With chlorine it gives α-naphthyldichloroarsine; with sulphur, α-naphthylarsenious sulphide; it is oxidised by nitric acid to α-naphthylarsinic acid. When subjected to dry distillation the arseno-derivative yields naphthalene, arsenic, and carbon.

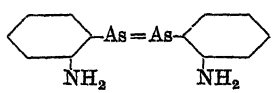
Arseno-β-naphthalene,



is prepared from the corresponding oxide or chloride in a similar manner to the preceding compound. It is a yellow powder, M.pt. 234° C., crystallising with difficulty in small needles from xylene. With chlorine, the chloride is regenerated.

Diamino- and Dihydroxy-arsenobenzenes.

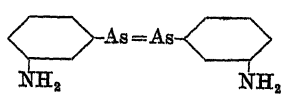
2 : 2′-Diaminoarsenobenzene,



2-Aminophenylarsinic acid (1·25 grams) in 70 c.c. of water is treated with 15 c.c. of 50 per cent. hypophosphorous acid and a crystal of potassium iodide added. The mixture is heated for two hours at 50° C. with vigorous stirring, a yellow precipitate separating out. After filtration, the liquor is made alkaline with 5*N* sodium hydroxide and centrifuged. The solid is washed with cold water and dried over sodium hydroxide. Yield, 0·8 gram.[1] This arsenobenzene also results when 2-nitrophenylarsinic acid is reduced by sodium hydrosulphite or electrolytically.[2]

2 : 2′-Diaminoarsenobenzene is a yellow, crystalline powder, decomposing at 115° to 125° C., and when thoroughly dry is almost insoluble in mineral acids. When condensed with formaldehyde and sodium bisulphite it yields *sodium 2 : 2′-diaminoarsenobenzene-N : N′-dimethylene-sulphonate*, $SO_3Na.CH_2.NH.C_6H_4As{=}AsC_6H_4.NH.CH_2.SO_3Na$, as a light red powder.[3]

3 : 3′-Diaminoarsenobenzene,

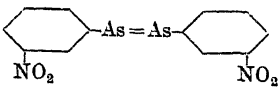


is obtained by the reduction of 3-aminophenylarsinic acid with hypophosphorous acid. It is a yellow powder, insoluble in water and organic solvents. The *dihydrochloride* is a grey substance. With formaldehyde and sodium bisulphite it yields *disodium 3 : 3′-diaminoarseno-*

[1] Kashima, *J. Amer. Chem. Soc.*, 1925, 47, 2207.
[2] Fichter and Elkind, *Ber.*, 1916, 49, 246.
[3] Kashima, *loc. cit.*

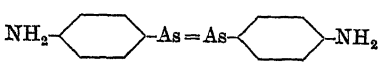
benzene-N : N'-dimethylenesulphonate, a brownish-yellow compound, readily soluble in water, and which reduces iodine solution.

3 : 3'-Dinitroarsenobenzene,[1]



results when the corresponding nitrophenylarsinic acid (10 grams) with a little water and 40 grams of phosphorous acid is heated in a sealed tube for twelve hours at 115° C. A yield of 6·5 grams is isolated as a yellow powder, insoluble in the usual organic solvents. It combines with sulphur and the halogens.

4 : 4'-Diaminoarsenobenzene,[2]



This derivative may be prepared in several ways:

(1) 250 grams of sodium *p*-aminophenylarsinate in 1400 c.c. of water are treated with 800 grams of crystallised stannous chloride in 800 c.c. of hydrochloric acid (density 1·19) and the whole digested for several days on the water-bath at a temperature not exceeding 40° C. The yellow double tin salt separates, is well washed, and dissolved in the requisite amount of hot dilute hydrochloric acid (not stronger than normal), then poured into a large excess of sodium hydroxide. The arsenobenzene separates in bright yellow flocks.

(2) 169 grams of *p*-aminophenylarsine (p. 64) in 1000 c.c. of *N* hydrochloric acid and 9000 c.c. of water is cooled and treated with 180 grams of *p*-aminophenylarsenoxide (p. 133) in 1000 c.c. of *N* hydrochloric acid and 4000 c.c. of water, a further 1000 c.c. of the hydrochloric acid then being added to the mixture. After standing for several hours in the cold, 450 grams of sodium acetate in 1500 c.c. of water are added, the diaminoarsenobenzene being precipitated in pale yellow flocks.

(3) 16 grams of sodium *p*-aminophenylarsinate in 100 c.c. of water are mixed with 105 c.c. of 50 per cent. hypophosphorous acid and an aqueous solution of 0·25 gram of potassium iodide. The mixture is stirred for two hours and maintained at 50° to 55° C., a yellow precipitate separating. After cooling, an excess of 5*N* sodium hydroxide is added and the solid separated by centrifuging. Yield, about 8·5 grams.[3]

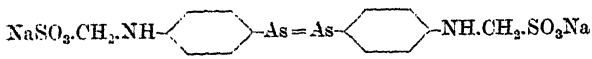
(4) A solution containing 9·2 grams of 4-aminophenylarsinic acid in a slight excess of 2*N* sodium carbonate solution, 5 grams of magnesium chloride hexahydrate, 40 grams of sodium hyposulphite, and 500 c.c. of ice-water, is heated for 1½ hours at 55° to 60° C. A yield of 4 grams, or 56 per cent., of product results. It is insoluble in the theoretical amount of hydrochloric acid, thereby differing from the base prepared by Method (3).[4]

The compound melts at 139° to 141° C.,[5] is readily soluble in dilute hydrochloric acid, but insoluble in water and the usual organic solvents. If the *p*-aminophenylarsinic acid in Method (1) above is replaced by

[1] Michaelis and Loesner, *Ber.*, 1894, 27, 263.
[2] German Patents, 206057, 254187.
[3] Kashima, *loc. cit.*
[4] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 116.
[5] German Patents, *loc. cit.*

p-oxalylaminophenylarsinic acid, and the reduction carried out by using sodium hydrosulphite, 4 : 4′-*dioxalyldiaminoarsenobenzene* results. This is a white, crystalline powder, unmelted at 360° C., soluble in hot water, alkalis, and alkali carbonates, insoluble in acids.

Sodium 4 : 4′-diaminoarsenobenzenedimethylenesulphite,

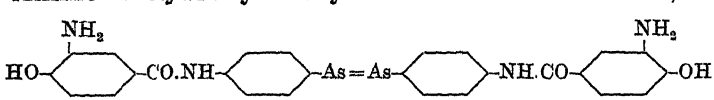


The composition of this derivative varies slightly according to the method of preparation. Two recent methods are as follows :[1]

(1) 4 grams of 4 : 4′-diaminoarsenobenzene, prepared by Method (3) (p. 343), are suspended in 30 c.c. of water and dissolved by the cautious addition of 2*N* hydrochloric acid. To this solution, 2·5 c.c. of formalin (40 per cent.) and, after the lapse of one minute, 3·25 grams of sodium bisulphite in 5 c.c. of water, are added. The mixture is shaken with charcoal, filtered, and precipitated in 500 c.c. of spirit. After filtering, washing with spirit, and drying *in vacuo* over sulphuric acid, 5 grams of dark yellow product are obtained. It is soluble in water, and a 10 per cent. solution is not precipitated by an equal volume of 2*N* hydrochloric acid, even after standing for some hours, nor does it decolorise a hot solution of indigo-carmine. Analysis gives the ratio As : N : S = 1 : 0·87 : 1·19.

(2) The moist base obtained by the hypophosphorous acid reduction of 8 grams of 4-aminophenylarsinic acid is ground with 5 grams of sodium formaldehyde-bisulphite and 25 c.c. of water. The mixture, after heating for 2½ hours at 60° C., is filtered through kieselguhr and precipitated by pouring into 500 c.c. of spirit. The product is filtered off, washed and dried, 3 grams of light yellow powder resulting. This dissolves readily in water, and a 10 per cent. solution does not decolorise hot indigo-carmine solution, but is precipitated by the addition of an equal volume of 2*N* hydrochloric acid. The acid obtained from the salt is gelatinous, readily oxidised in air, and rapidly dissolves in dilute alkali hydroxide or carbonate. Analysis of the base gives the ratio As : N : S = 1 : 1·0 : 0·94.

3′-Amino-4′-hydroxybenzoyl-4-aminoarsenobenzene,[2]

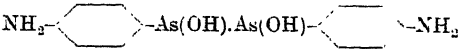


3′-Amino-4′-hydroxybenzoyl-4-aminophenylarsinic acid (3·3 grams) is suspended in 16·5 c.c. of hypophosphorous acid (density 1·137) with the addition of 33 c.c. of 50 per cent. acetic acid and a crystal of potassium iodide. After stirring for one hour at 50° to 55° C. the suspension becomes orange-yellow and amorphous; it is centrifuged off, washed with air-free water, and treated with sodium hydrogen carbonate solution until permanently alkaline. The base thus liberated is centrifuged, well washed and dried *in vacuo*, the yield being about 2·7 grams. The arseno-compound dissolves in sodium hydroxide but not in sodium carbonate or hydrochloric acid. Addition of nitrite to the latter solution causes the compound to dissolve, and the colour deepens. If β-naphthol in alkali is added, coupling takes place.[3]

[1] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 116; see Kashima, *J. Amer. Chem. Soc.*, 1925, 47, 2208. [2] King and Murch, *Trans. Chem. Soc.*, 1925, 127, 2632.

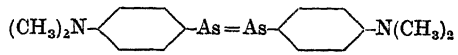
[3] Compare this compound with 3′-amino-4′-hydroxybenzoyl-4-amino-2-hydroxyarsenobenzene (p. 312).

asy.-Dihydroxydi-4-aminoarsenobenzene,[1]



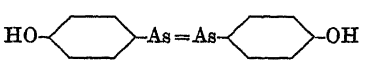
is formed when *p*-aminophenylarsenoxide (p. 133) in methyl alcohol solution is reduced by sodium amalgam. It is a pale yellow powder, M.pt. 227° C. The formula is deduced from analysis.

Tetramethyl-4-4′-diaminoarsenobenzene or **Arsenodimethylaniline,**[2]



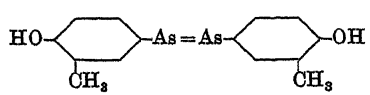
An alcoholic solution of dimethylaminophenyl-*p*-arsenoxide is reduced by gentle warming and shaking with a large excess of 3 to 4 per cent. sodium amalgam, and filtered after twelve hours. After washing with water, drying, and dissolving in chloroform, the arseno-compound is precipitated as a yellow, granular, crystalline powder, M.pt. 202° C., insoluble in water and alcohol, soluble in acid. It is readily oxidised in the solid state and in solution, regenerating the oxide. When heated with concentrated hydrochloric acid in a sealed tube for several hours at 150° C. it gives dimethylaniline, free arsenic, and arsenious chloride. The *hydrochloride* is a red, crystalline mass, readily soluble in water and rapidly oxidised by air, forming the hydrochloride of the corresponding oxide. *Tetraethyl-4-4′-diaminoarsenobenzene* is a crystalline, yellow powder, M.pt. 180° C., having similar properties to the foregoing derivative.

4 : 4′-Dihydroxyarsenobenzene,[3]



10 grams of sodium *p*-hydroxyphenylarsinate in water are reduced by a solution containing 50 grams of sodium hydrosulphite and 25 grams of magnesium chloride in 250 c.c. of water and 12 c.c. of 10*N* sodium hydroxide. The mixture is warmed on the water-bath for forty-five minutes, when the arseno-compound separates in yellow flakes. When dry it is a yellowish-brown powder, decomposing above 200° C., readily soluble in alcohol, acetone, ether, and sodium hydroxide, insoluble in benzene, chloroform, or dilute mineral acids. It forms a *co-ordination compound* with *auric chloride*, which is brownish-black.[4] The *sodium salt*, precipitated from concentrated solution by alcohol, is a yellow powder, readily soluble in water, sparingly soluble in methyl and ethyl alcohols.

By carrying out the above reaction at 50° C. and starting with 4-hydroxy-3-methylphenylarsinic acid, 3 : 3′-*dimethyl*-4 : 4′-*dihydroxyarsenobenzene,*



is obtained.

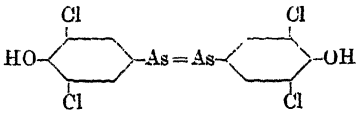
[1] German Patent, 206057.

[2] Michaelis and Rabinerson, *Annalen*, 1892, *270*, 139; Rabinerson, *Inaug. Dissert.*, Rostock, 1891.

[3] German Patent, 206456; British Patent, 9855 (1908); American Patents, 907978, 909380.

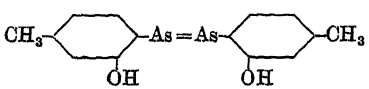
[4] German Patent, 270257.

3 : 5 : 3′: 5′-Tetrachloro-4 : 4′-dihydroxyarsenobenzene,[1]



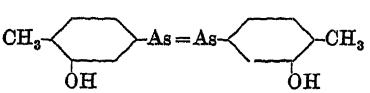
3 : 5-Dichloro-4-hydroxyphenylarsinic acid (57·4 grams) in 1150 c.c. of water and 150 grams of 2*N* sodium hydroxide is treated with 287 grams of sodium hydrosulphite and 58 grams of magnesium chloride in 1435 c.c. of water. The mixture is digested at 50° C. until a filtered test portion on boiling remains clear. The tetrachloro-compound separates as a pale yellow precipitate, which is removed, washed, and dried. In a similar manner the *tetrabromo-* and *tetraiodo-derivatives* may be obtained, both being pale yellow powders, insoluble in water but dissolving in alcohol, ether, and alkali. The *sodium salts* are readily soluble in water, with neutral reaction. The compounds decompose when heated above 200° C.

2 : 2′-Dihydroxy-4 : 4′-dimethylarsenobenzene,[2]



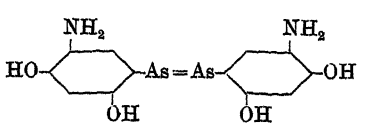
is obtained from 2-hydroxy-4-methylphenylarsinic acid by heating it on the water-bath with hypophosphorous acid (density 1·27). It is an amorphous, orange-yellow product, melting with decomposition at 108° to 110° C., and is soluble in aqueous alkalis. Replacement of the foregoing arsinic acid by its nitro-derivative yields 2 : 2′-*dihydroxy*-4 : 4′-*dimethyldinitroarsenobenzene*, an amorphous, canary-yellow compound, darkening towards 189° C., and melting with decomposition at 191° C. It dissolves in aqueous alkalis giving intensely orange-red solutions.

3 : 3′-Dihydroxy-4 : 4′-dimethylarsenobenzene,



is prepared from 3-hydroxy-4-methylphenylarsinic acid as described above. It melts at 192° to 197° C., and dissolves in aqueous alkalis.

5 : 5′-Diamino-2 : 4 : 2′ : 4′-tetrahydroxyarsenobenzene,[3]

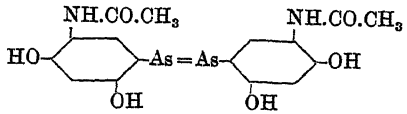


5-Nitro-2 : 4-dihydroxyphenylarsinic acid (p. 290), 6·5 grams, is gently warmed with 20 c.c. of alcohol, 25 c.c. of hydrochloric acid (density 1·19), and 25 grams of stannous chloride, whereby the nitro-group is reduced to the amino-group. After the addition of 20 c.c. of acetic acid the mixture is filtered, and the filtrate added dropwise to an ice-cold mixture

[1] German Patent, 235430.
[2] Finzi, *Atti II Cong. Naz. Chim. Pura Appl.*, 1926, p. 1302.
[3] Bauer, *Ber.*, 1915, 48, 509.

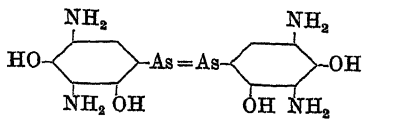
of 30 c.c. of hydrochloric acid (density 1·19), 20 c.c. of acetic acid, and 1 c.c. of hydriodic acid (density 1·7). The arseno-compound separates in the form of its yellow *dihydrochloride*, which, after adding 40 c.c. of acetic acid, is filtered off in a carbon dioxide atmosphere, washed with acetic acid and ether and dried *in vacuo*. It is readily soluble in water, from which sodium hydroxide precipitates the base, but the latter is soluble in excess of alkali, the solution becoming blue owing to oxidation by the air.

5 : 5′ - Diacetyldiamino - 2 : 4 : 2′ : 4′ - tetrahydroxyarsenobenzene,



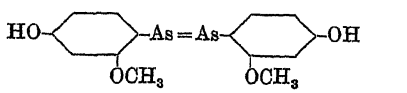
results when 5-acetylamino-2 : 4-dihydroxyphenylarsinic acid is reduced with hypophosphorous acid containing a little hydriodic acid as catalyst. The product is a yellow powder, insoluble in water, easily soluble in sodium hydroxide.

3 : 5 : 3′ : 5′-Tetramino - 2 : 4 : 2′ : 4′ - tetrahydroxyarsenobenzene,



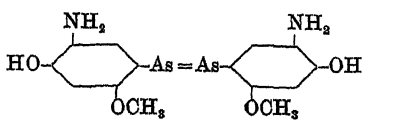
is formed by reducing 3 : 5-dinitro-2 : 4-dihydroxyphenylarsinic acid in a similar manner to that employed for the preceding compound. The *tetrahydrochloride* is a dull yellow powder, giving a dark yellow solution in water, and a pale yellow solution in dilute hydrochloric acid. Sodium hydroxide, carbonate or bicarbonate precipitate the base, which is soluble in excess, giving a brown solution, which changes to blue in the air, owing to the formation of an indophenol dye. Nitrous acid produces a dark brown precipitate, probably a dye of the Bismarck Brown type. A *tetracetyl-derivative* has been isolated. When the tetrahydrochloride is boiled with water for a few minutes, hydrolysis takes place, with the elimination of arsenic and formation of 2 : 4-diaminoresorcinol.

2 : 2′-Dimethoxy-4 : 4′-dihydroxyarsenobenzene,



may be obtained by the reduction of 2-methoxy-4-hydroxyphenylarsinic acid (p. 280) with hypophosphorous acid and potassium iodide. It is a yellow powder, readily soluble in sodium hydroxide but insoluble in sodium carbonate.

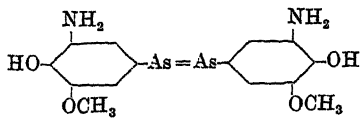
5 : 5′- Diamino-2 : 2′- dimethoxy - 4 : 4′- dihydroxyarsenobenzene,



5-Amino-2-methoxy-4-hydroxyphenylarsinic acid (p. 280), 3 grams, is added to a mixture of 15 c.c. of hypophosphorous acid (density 1·136),

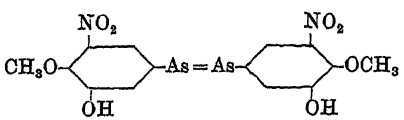
2 grams of potassium iodide and a little water, and the whole allowed to stand for one hour. The clear yellow solution is stirred in a carbon dioxide atmosphere and 400 c.c. of acetone added dropwise. A white precipitate of the *hypophosphite* of the arseno-compound is thus obtained, which is filtered and washed with acetone and ether. It is a yellow powder, readily dissolving in water; sodium hydroxide precipitates the base, which is soluble in excess of precipitant. The alkaline solution oxidises when in a thin film, becoming red. If the *dihydrochloride* is required, the acetone used above is replaced by concentrated hydrochloric acid. The dihydrochloride, when boiled with water for a few minutes, is hydrolysed, giving rise to 4-aminoresorcinol-1-methyl ether.

5 : 5′-Diamino-3 : 3′-dimethoxy-4 : 4′-dihydroxyarsenobenzene,



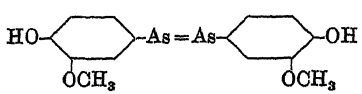
When 5-nitro-4-hydroxy-3-methoxyphenylarsinic acid is reduced by hypophosphorous acid, a bright yellow, granular precipitate of 5 : 5′-*dinitro*-3 : 3′-*dimethoxy*-4 : 4′-*dihydroxyarsenobenzene* is obtained.[1] Reduction of this compound by sodium hydrosulphite in sodium hydroxide solution at 60° C. in a carbon dioxide atmosphere yields the diamino-derivative. The product is soluble in water or methyl alcohol, less soluble in ethyl alcohol, insoluble in ether and acetone. It forms a *dihydrochloride* when treated with concentrated hydrochloric acid.

5 : 5′-Dinitro-4 : 4′-dimethoxy-3 : 3′-dihydroxyarsenobenzene,



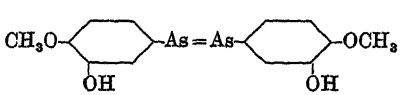
is a bright yellow precipitate, formed when 5-nitro-3-hydroxy-4-methoxyphenylarsinic acid is reduced with hypophosphorous acid. Its *hydrochloride* is reddish-brown.

3 : 3′-Dimethoxy-4 : 4′-dihydroxyarsenobenzene,



When 4-hydroxy-3-methoxyphenylarsinic acid is warmed with a dilute solution of hypophosphorous acid, the arseno-compound is obtained as a colourless precipitate. Its *acetyl derivative* crystallises in colourless, glistening plates from ethyl acetate containing a little alcohol; these sinter at 182° C. and melt at 186° C.

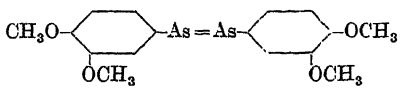
4 : 4′-Dimethoxy-3 : 3′-dihydroxyarsenobenzene,



[1] Fargher, *Trans. Chem. Soc.*, 1920, 117, 873.

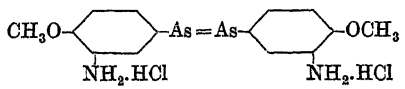
is the reduction product of 3-hydroxy-4-methoxyphenylarsinic acid. Its *acetyl derivative* forms woolly needles, which gradually decompose above 200° C., and are soluble in water, alcohol, or ethyl acetate, but sparingly soluble in benzene or light petroleum.

3 : 4 : 3′ : 4′-Tetramethoxyarsenobenzene,



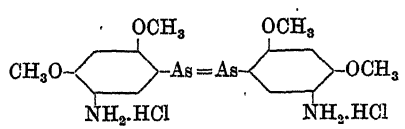
results on the reduction of 3 : 4-dimethoxyphenylarsinic acid as a white, amorphous precipitate. Heating with hydrobromic acid at 100° C., or with hydrochloric acid of varying concentrations at temperatures of 130° to 160° C., causes, principally, fission of the arsinic acid grouping, instead of partial demethylation.

3 : 3′ - Diamino - 4 : 4′ - dimethoxyarsenobenzene dihydrochloride,[2]



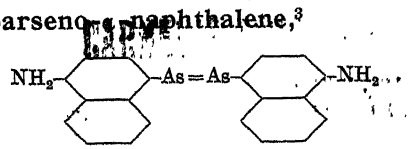
3-Acetylamino-4-methoxyphenylarsinic acid is hydrolysed by hydrochloric acid, and after making alkaline the solution is at once reduced with sodium hydrosulphite. The preparation thus obtained contains only 0·47 per cent. of sulphur, whereas the reduction of 3-nitro-4-methoxyphenylarsinic acid gives a product containing 3·47 per cent. of sulphur. The *dihydrochloride* contains 2 molecules of water, and its aqueous solution gives an insoluble yellow precipitate with excess of sodium hydroxide, which dissolves to a colourless solution when oxidised with iodine. Sodium sulphate precipitates the *sulphate* and sodium acetate the free base, when added to aqueous solutions of the hydrochloride. *p*-Dimethylaminobenzaldehyde gives an orange precipitate, and ferric chloride causes a gradual red coloration to appear.

3 : 3′ - Diamino - 4 : 4′ : 6 : 6′ - tetramethoxyarsenobenzene dihydrochloride,



3-Nitro-4 : 6-dimethoxyphenylarsinic acid is reduced by hydrosulphite, and the hydrochloride obtained by dissolving the base in methyl alcoholic-hydrochloric acid and precipitating with ether. It is a pale yellow compound.

4 : 4′-Diaminoarseno-α-naphthalene,[3]

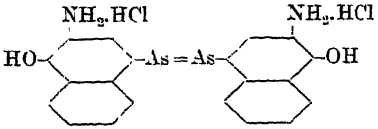


is formed by reducing 1-nitronaphthyl-4-arsinic acid in methyl alcohol solution by stannous chloride in hydrochloric acid. The *hydrochloride*

[1] Christiansen, *J. Amer. Chem. Soc.*, 1922, 44, 2340.
[2] Andreev, *J. Russ. Phys. Chem. Soc.*, 1913, 45, 1980.

is a fine, pale yellow powder, and it shares with the free base the property of being rapidly oxidised in moist air.

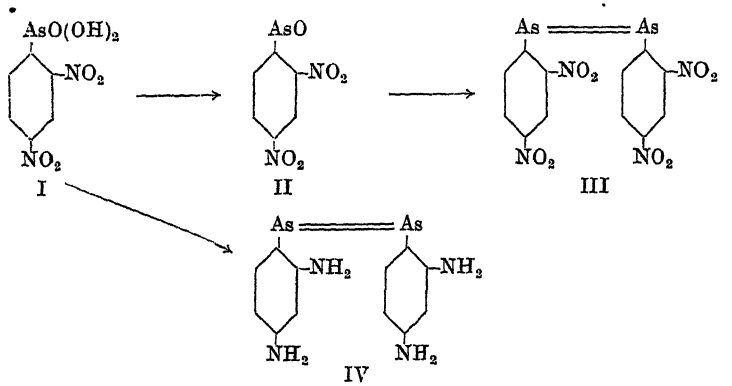
3 : 3′-Diamino-4 : 4′-dihydroxyarseno-α-naphthalene dihydrochloride,



is a fine, brownish-yellow powder, formed by nitrating 4-hydroxy-1-naphthylarsinic acid and reducing the nitro-compound by stannous chloride in hydrochloric acid.

Tetraminoarsenobenzenes.

2 : 4 : 2′ : 4′-Tetraminoarsenobenzene.[1]—This derivative (IV) may be synthesised as follows :



2 : 4-Dinitrophenylarsinic acid (I) has been described on p. 174. 6 grams of this acid in 100 c.c. of ether are treated with phosphorus trichloride in small portions until the reaction and gas evolution cease. The mixture is then shaken with 200 c.c. of water, separated, and then shaken with a further 300 c.c. of water. On allowing the ether to evaporate off, 2 : 4-*dinitrophenylarsenoxide* (II) is obtained in yellowish crusts. This dissolves in alcoholic hydrochloric acid with formation of the *chloride*. It is soluble in ether, insoluble in water or dilute acid. It dissolves in excess of sodium hydroxide, giving a yellow solution.

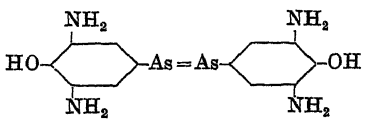
2 : 4 : 2′ : 4′-*Tetranitroarsenobenzene* (III) is formed by treating 5 grams of the preceding compound (II) in 150 c.c. of water containing a little sodium hydroxide with 50 c.c. of 25 per cent. hypophosphorous acid containing 5 to 6 drops of 10 per cent. potassium iodide solution, and heating the whole, with brisk stirring, for a long time at 50° to 60° C. The reddish-brown flocks which separate are filtered off, washed with water, and dried *in vacuo*. These operations are best carried out in an inert atmosphere, as the arseno-compound is readily oxidised. It is insoluble in all solvents.

[1] Karrer, *Ber.*, 1914, 47, 2275.

Reduction of 2 : 4-Dinitrophenylarsinic Acid to Tetraminoarsenobenzene (IV).—15 grams of the acid are added to 70 grams of stannous chloride in 150 c.c. of hydrochloric acid, the mixture being stirred and maintained at 70° to 80° C. A few drops of potassium iodide solution are added, and after cooling to 40° C. the whole is poured into 1500 c.c. of acetic acid, when the *tin double salt* is precipitated in yellowish-white flocks. This is treated with hydrochloric-acetic acid mixture, then with pure acetic acid, and finally washed with ether. The product is dissolved in 50 c.c. of 2 to 3*N* hydrochloric acid, 500 c.c. of glacial acetic acid are added, and then ether, until a thick, pale yellow precipitate is formed. The arseno-compound obtained contains only traces of tin.

2 : 4 : 2′ : 4′-Tetraminoarsenobenzene as a *m*-diamine couples with diazo-compounds giving arsenated azo-dyes, and with nitrous acid forms a reddish-brown precipitate, an azo-dye of the Bismarck Brown type. The base decomposes in forty-eight hours, becoming dark brown. It may be hydrolytically decomposed by shaking with water for thirty minutes at the ordinary temperature or warming for a short time at 50° C., arsenious and arsenic acids together with *m*-phenylenediamine being formed.

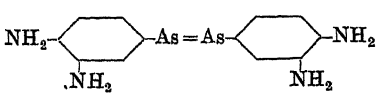
3 : 5 : 3′ : 5′-Tetramino-4 : 4′-dihydroxyarsenobenzene,[1]



This results as a pale yellow powder on reducing 3 : 5-dinitro-4-hydroxyphenylarsinic acid (p. 291) with a large excess of sodium hydrosulphite. It is insoluble in water and the usual organic solvents, but soluble in alkali or dilute acids. It decomposes at 155° to 157° C.

If 3 : 5-diacetylamino-4-hydroxyphenylarsinic acid is reduced, 3 : 5 : 3′ : 5′-*tetracetylamino*-4 : 4′-*dihydroxyarsenobenzene* results.[2] Reduction of 3-nitro-5-acetylamino-4-hydroxyphenylarsinic acid yields 3 : 3′-*diamino*-5 : 5′-*diacetylamino*-4 : 4′-*dihydroxyarsenobenzene.*[3]

3 : 4 : 3′ : 4′-Tetraminoarsenobenzene,[4]



10 grams of 3-nitro-4-aminophenylarsinic acid, 50 c.c. of hypophosphorous acid (25 per cent.) and 70 c.c. of acetic acid are boiled together, the mixture being stirred during the operation. 3 : 3′-*Dinitro*-4 : 4′-*diaminoarsenobenzene* separates out, and 20 grams of potassium iodide are added. A vigorous reaction ensues and the precipitate dissolves. After filtering, the tetraminoarseno-compound is precipitated by alkali, or as the hydrochloride by adding concentrated hydrochloric acid.[5]

[1] German Patent, 224953; American Patent, 986148; compare German Patent, 286432.

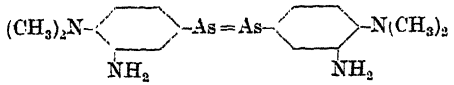
[2] Raiziss and Gavron, *J. Amer. Chem. Soc.*, 1921, 43, 582; see also British Patent, 269647 (1926).

[3] British Patent, 269647 (1926).

[4] German Patent, 286432.

[5] A co-ordination compound is formed between cupric chloride and 3 : 4 : 3′ : 4′-tetraminoarsenobenzene-N-methylenesulphinate—German Patent, 270259.

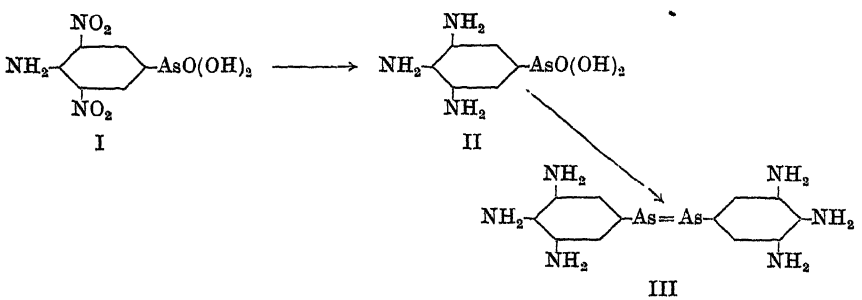
4 : 4′-Tetramethyl-3 : 4 : 3′ : 4′-tetraminoarsenobenzene,[1]



3-Nitro-4-dimethylaminophenylarsinic acid (5·8 grams) is dissolved in 250 c.c. of water and 20 c.c. of normal sodium hydroxide, 5 grams of magnesium chloride and 50 grams of sodium hydrosulphite added, and the whole heated on the water-bath and stirred at 50° to 60° C. for two hours. The arseno-compound separates in yellow flocks, which are dissolved in the calculated quantity of methyl alcoholic hydrochloric acid and filtered into ether, when the *tetrahydrochloride* is precipitated as a yellowish-white powder. Derivatives of the arseno-compound, which dissolve readily in water to give neutral solutions, are prepared by suspending the base in water and treating it with bicarbonates of the alkali metals in a carbon dioxide atmosphere.[2]

Hexaminoarsenobenzenes.

3 : 4 : 5 : 3′ : 4′ : 5′-Hexaminoarsenobenzene.[3] — This arsenobenzene may be obtained from 3 : 5-dinitro-4-aminophenylarsinic acid in two stages, according to the scheme :



The dinitro-compound (I) is dissolved in 300 c.c. of water and 100 c.c. of 2*N* sodium hydroxide, and, after cooling to 0°– 5° C., is well stirred whilst 130 grams of crystalline sodium hydrosulphite are added. The temperature rises to about 30° C., then falls, the stirring being maintained for an hour after room temperature is reached. Animal charcoal is then added, the whole boiled for a short time, filtered, and treated with 100 c.c. of 2*N* sodium hydroxide. The *triamino-compound* (II) separates in white needles on cooling and may be purified by crystallisation from acetic acid or by solution in sodium acetate and precipitation with hydrochloric acid. 3 : 4 : 5-Triaminophenylarsinic acid is insoluble in hot alcohol, water, or acetone, sparingly soluble in methyl alcohol. In alkalis and excess of acids it is readily soluble, and when heated it decomposes without melting.[4] The reduction of the amine is carried out as follows : 24·7 grams are added to a mixture of 125 c.c. of water and 125 c.c. of 35 per cent. hypophosphorous acid, and the whole heated for one hour at 30° to 40° C. The cooled solution is made feebly alkaline with

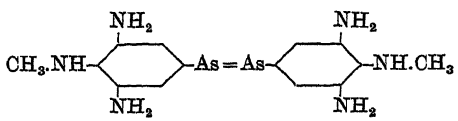
[1] Karrer, *Ber.*, 1913, 46, 515.
[2] German Patent, 269660.
[3] German Patent, 286854; British Patents, 7488, 8137 (1913); American Patent, 1156044.
[4] Compare p. 259.

dilute sodium hydroxide, when the yellow base separates and is filtered off, well washed with water, dissolved in 2.N hydrochloric acid, and an equal volume of concentrated hydrochloric acid added, the *hydrochloride* of the hexaminoarsenobenzene (III) separating as a greenish-yellow powder. This is filtered off and washed successively with the following solvents—normal hydrochloric acid, alcohol, and ether.

Another method consists of reducing the dinitroaminophenylarsinic acid with alcoholic hypophosphorous acid, *4 : 4′-diamino-3 : 5 : 3′ : 5′-tetranitroarsenobenzene* resulting, and this on treatment with stannous chloride in concentrated hydrochloric acid yields the hexamino-base. Reduction of the dinitro-compound has also been effected by treating it with sodium hydrosulphite,[1] and by the action of ferrous chloride in alkaline solution.[2]

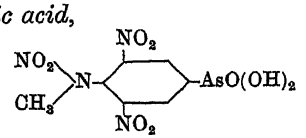
3 : 4 : 5 : 3′ : 4′ : 5′-Hexaminoarsenobenzene is a colourless, crystalline compound, decomposing at 170° to 175° C., sparingly soluble in cold water or alcohol, but soluble in alkalis, dilute mineral acids, and 50 per cent. acetic acid. It yields a yellow diazo-compound with nitrous acid; ammoniacal solutions of the base reduce silver nitrate, and when dissolved in sulphuric acid the base gives a brown coloration when a drop of nitric acid is added, this rapidly changing through olive green to blue. The *hydrochloride* of the base is a yellowish-green powder, readily soluble in water and dilute acids, but insoluble in alkali.[3]

4 : 4′-Dimethyl-3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene,



This arsenobenzene may be prepared from any arsinic acid having the following structure:

where R=hydrogen, methyl, or an acyl group, the acid being first nitrated, then reduced.[4] An interesting intermediate which may be used in the preparation of the arsenobenzene is *3 : 5-dinitro-4-methylnitroaminophenylarsinic acid,*



a complete synthesis using this derivative being as follows:[5] One part of *p*-dimethylanilinearsenoxide in 10 parts of concentrated sulphuric acid at 0° C. is treated with a mixture of 3 parts of concentrated

[1] German Patent, 286855.

[2] Benda, *Ber.*, 1914, 47, 1316.

[3] When the hydrochloride of this arseno-compound or a derivative is added to Salvarsan and heated to 80° C., or the mixture kept for some time, then poured into a large excess of glacial acetic acid, the hydrochloride of a new complex arseno-compound of unknown constitution is obtained—British Patent, 17482 (1915).

[4] German Patents, 285572, 286667, 293842, 286668, 294731; see American Patent, 1081079; British Patent, 9969 (1913).

[5] German Patent, 285572.

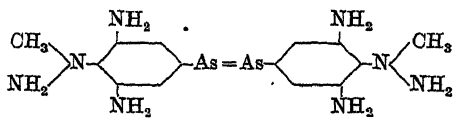
nitric acid (density 1·41) and 3 parts of concentrated sulphuric acid and the whole heated on the water-bath until red fumes are no longer evolved. After cooling, the solution is poured upon 20 parts of ice, 3 : 5-dinitro-4-methylnitroaminophenylarsinic acid separating out as a yellow precipitate, which is collected, washed, and dried. This acid is easily soluble in hot acetone, alcohol, or acetic acid, but whilst soluble in alkalis and sodium acetate solutions, it is insoluble in dilute mineral acids.

3 : 5-Dinitro-4-methylnitroaminophenylarsinic acid (7·4 parts) is suspended in 300 parts of concentrated hydrochloric acid and 26 parts of tin dust added. Heat is evolved and the arsinic acid slowly passes into solution. On cooling, the *tin double salt* of the hexamino base separates, which is dissolved in water and treated with a large excess of sodium hydroxide, whereby the hexamino base is precipitated in yellowish-green flocks. These are dissolved in dilute hydrochloric acid and concentrated hydrochloric acid added, the *hydrochloride* of the base being precipitated. This is filtered off, and well washed with alcohol and ether. The reduction may also be effected by a mixture of acetic acid, hypophosphorous acid, and potassium iodide.[1]

Another method of obtaining the hexamino base is by the reduction of 3 : 5-dinitro-4-methylaminophenylarsinic acid in a similar manner to that described above.

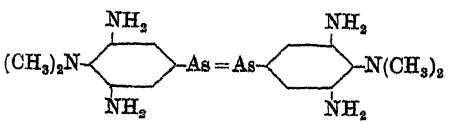
4 : 4′-Dimethyl - 3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene is a yellowish-green powder, decomposing at about 95° C.; it is insoluble in water, sparingly soluble in alcohol, readily soluble in acetone and acetic acid. In air it soon becomes dark, and its stable yellowish-green hydrochloride is very soluble in water.

4 : 4′-Dimethylhydrazino-3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene,[2]



Nine parts of 3 : 5-dinitro-4-methylnitroaminophenylarsinic acid are gradually stirred into a solution of 80 parts of stannous chloride in 250 parts of concentrated hydrochloric acid, the stirring being maintained until all the nitro-compound is in solution; the temperature during the operation is kept below 50° C. An equal volume of water is added, the base precipitated by sodium hydroxide, and converted to its hydrochloride as in the case of the preceding compound. The base melts at 102° to 105° C. with decomposition, and is insoluble in water and the usual solvents, whilst in the air it soon becomes dark. The *hydrochloride* is a greyish-green powder which is slowly darkened by exposure to air. It is insoluble in alkali but easily soluble in water and dilute acids.

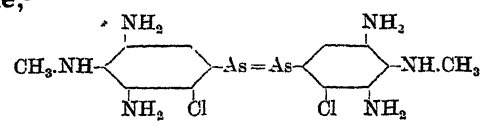
4 : 4′- Tetramethyl - 3 : 4 : 5 : 3′ : 4′ : 5′- hexaminoarsenobenzene,[3]



[1] German Patent, 286432. [2] German Patent, 285573. [3] German Patent, 294276.

results when the corresponding 3 : 5-dinitro-4-dialkylaminophenylarsinic acid is treated with reducing agents. In a similar manner the *tetraethyl derivative* and 4 : 4′-*dipiperidinotetraminoarsenobenzene* have been isolated.

2 : 2′-Dichloro-4 : 4′-dimethyl-3 : 4 : 5 : 3′ : 4′ : 5′-hexamino-arsenobenzene,[1]



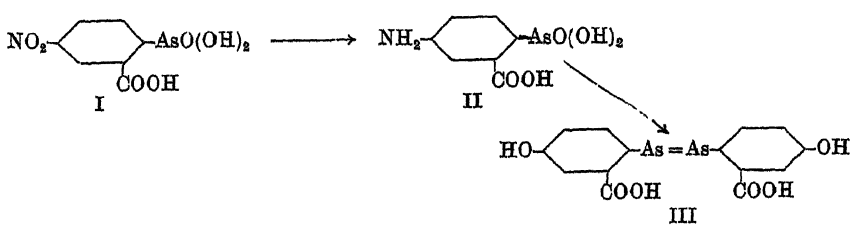
The starting-point for preparing this substance is 2-chloro-4-dimethylaminophenylarsenoxide. The oxide (24·5 grams) in 245 grams of concentrated sulphuric acid at −5° C. is treated very slowly with 80 grams of a strongly cooled mixture consisting of equal parts of concentrated sulphuric and fuming nitric acids, the temperature being kept below 35° C. After several hours the whole is poured upon ice, the nitro-compound collected, washed with water, dissolved in sodium acetate solution, filtered, and precipitated by hydrochloric acid. 2-*Chloro-4-methylnitroamino*-3 : 5-*dinitrophenylarsinic acid* is thus obtained as a yellow powder, which explodes on heating and gives a red solution in sodium hydroxide. In hot water, alcohols or acetone it is readily soluble, but is insoluble in ether, chloroform or benzene. In order to obtain the arsenobenzene, the dinitro-acid is reduced with tin or zinc and concentrated hydrochloric acid. Eight parts of the dinitroarsinic acid are suspended in 300 parts of concentrated hydrochloric acid and 28 parts of tin dust gradually added. After the reaction is complete, intense cooling causes separation of the *tin double salt*, which is transformed into the hydrochloride of the arsenobenzene in the usual manner. The free base is insoluble in water and soon becomes discoloured in air. The *hydrochloride* is a yellowish-green powder, readily soluble in water.

The corresponding 2 : 2′-*dibromo*-4 : 4′-*dimethyl*-3 : 4 : 5 : 3′ : 4′ : 5′-*hexaminoarsenobenzene* is obtained in a similar manner, starting with 2-bromo-4-dimethylaminophenylarsenoxide.

Water-soluble, neutral reacting derivatives of dihalogen-4 : 4′-dimethyl-3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene have been obtained.[2]

Carboxylated Arsenobenzenes.

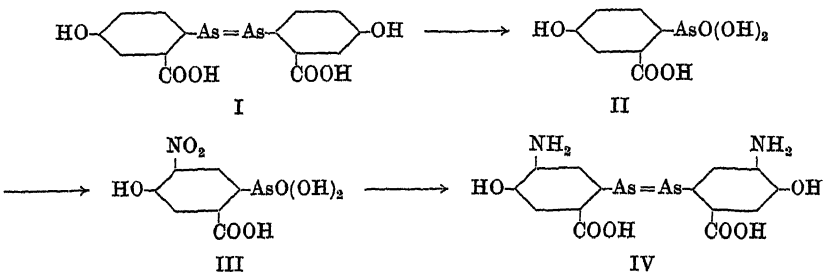
2 : 2′-Dicarboxy-4 : 4′-dihydroxyarsenobenzene[3] is prepared according to the scheme :



[1] German Patent, 286669; British Patent, 15657 (1914).
[2] German Patent, 291317.
[3] Karrer, *Ber.*, 1915, 48, 1058.

The isolation of 2-carboxy-4-nitrophenylarsinic acid (I) has already been dealt with on p. 324. This acid (14·5 grams) is dissolved in a mixture of 98 c.c. of 10*N* sodium hydroxide and 180 c.c. of water, and the solution added at once to a solution of 86 grams of crystallised ferrous sulphate in 200 c.c. of water at 70° C. The mixture is stirred, the ferric hydroxide removed and boiled with 200 c.c. of water, this liquor being added to the main filtrate. The filtrate is evaporated to crystallising-point, and hydrochloric acid (density 1·19) added (about 25 c.c.) until acid to Congo red, sodium chloride separating out on cooling. The clear solution contains 2-*carboxy*-4-*aminophenylarsinic acid* (II), which is then converted to the phenol without isolating the amino-acid. To the solution, 100 c.c. of water are added, the whole neutralised with 10*N* sodium hydroxide, 10 c.c. of concentrated sulphuric acid run in, and the product diazotised at 5° C. with sodium nitrite solution. The diazotised solution is boiled on the water-bath and, after completion of the reaction, is filtered. The 2-*carboxy*-4-*hydroxyphenylarsinic acid* in solution is then treated with 60 c.c. of 35 per cent. hypophosphorous acid containing a little potassium iodide, and warmed on the water-bath. After twenty to thirty minutes the reaction is complete and 2 : 2′-dicarboxy-4 : 4′-dihydroxyarsenobenzene (III) separates out as a yellow precipitate, which is filtered off and well washed with water.

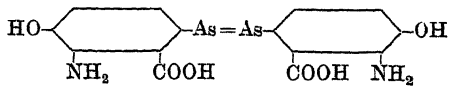
5 : 5′-Diamino-2 : 2′-dicarboxy-4 : 4′-dihydroxyarsenobenzene is obtained from the preceding compound by the series of reactions shown below. The 2 : 2′-dicarboxy-4 : 4′-dihydroxyarsenobenzene (I), whilst still moist, is treated with 3 c.c. of water, then with sufficient 30 per cent. hydrogen peroxide to give a colourless solution. The filtered solution, on cooling, yields white needles of 2-*carboxy*-4-*hydroxyphenylarsinic acid* (II). This is filtered off, washed with ice-water and dried. It is readily soluble in hot or cold water.



The hydroxy-acid (II) (3·9 grams) is dissolved in 20 c.c. of concentrated sulphuric acid, cooled below 0° C., and treated, dropwise, with 1·3 grams of nitric acid (density 1·42) in 5 c.c. of water. The temperature is allowed to rise to 10° C. and the whole poured upon 75 grams of ice. The resulting product, 5-*nitro*-2-*carboxy*-4-*hydroxyphenylarsinic acid* (III), crystallises from hot water in white needles, decomposing at 350° to 355° C. 2·2 grams of this compound are mixed with 20 c.c. of 25 per cent. hypophosphorous acid and 10 c.c. of acetic acid, and heated to boiling, with brisk stirring. The 5 : 5′-*dinitro*-2 : 2′-*dicarboxy*-4 : 4′-*dihydroxyarsenobenzene* separates, and 2 to 3 grams of potassium iodide are added, when, with violent reaction, the nitro-groups are reduced, yielding the yellow arseno-compound (IV). To this, 30 c.c. of water are added and the greater part of the acid neutralised by concentrated

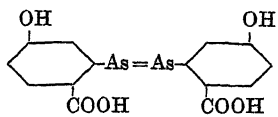
sodium hydroxide. The product is filtered, washed with hot water, alcohol, and ether. It is readily soluble in sodium hydroxide, sodium carbonate, bicarbonate or acetate, very sparingly soluble in dilute or concentrated hydrochloric acid. The amino-group is easily diazotised, and the arseno-compound yields a *condensation product* with *dimethylaminobenzaldehyde*. The arsenic atoms are removed from the compound by heating it for ten hours at 100° C. with sodium acetate solution, the resulting product being 4-amino-3-hydroxybenzoic acid.

3 : 3′-Diamino-2 : 2′-dicarboxy-4 : 4′-dihydroxyarsenobenzene,



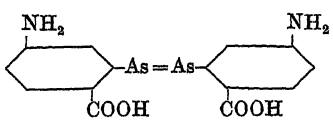
may be obtained by the reduction of 3-nitro-2-carboxy-4-hydroxyphenylarsinic acid.

2 : 2′-Dicarboxy-5 : 5′-dihydroxyarsenobenzene,[1]

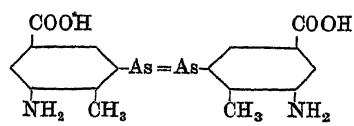


2-Carboxy-5-hydroxyphenylarsinic acid (5·2 grams) is suspended in 25 c.c. of hypophosphorous acid (density 1·15) and 25 c.c. of water. 2 grams of potassium iodide are added and the whole stirred at room temperature for forty-five minutes. The precipitate obtained is filtered off in an atmosphere of nitrogen and well washed with water. The arseno-compound is easily soluble in sodium carbonate and dilute alkalis.

5 : 5′-Diamino-2 : 2′-dicarboxyarsenobenzene and **3 : 3′-Diamino-2 : 2′-dimethyl-5 : 5′-dicarboxyarsenobenzene,**



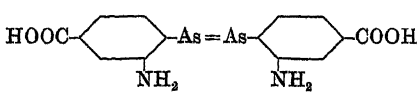
I



II

These compounds, (I) and (II) respectively, are prepared from 2-carboxy-5-nitrophenylarsinic acid and 2-methyl-3-nitro-5-carboxyphenylarsinic acid respectively by the hypophosphorous acid method described for the preceding compound. They are both obtained as yellow flocks, soluble in sodium carbonate or dilute caustic alkali.

4 : 4′-Dicarboxy-2 : 2′-diaminoarsenobenzene,



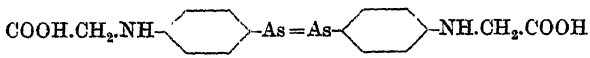
4-Carboxy-2-nitrophenylarsinic acid (p. 326), in 10 c.c. of water and 30 c.c. of hydrochloric acid (density 1·19), is treated at room temperature with 30 grams of stannous chloride, in small portions, stirring being maintained during the operation. 1 gram of potassium iodide is then added, and 250 c.c. of ice-cold hydrochloric acid (density 1·19) run in dropwise, the mixture being stirred for a short time. The *dihydro-*

[1] Maschmann, *Ber.*, 1924, 57, [B], 1766.

chloride separates in yellow flocks, is filtered off in a nitrogen atmosphere, and washed with hydrochloric acid, acetic acid, and ether. The product is soluble in water; with sodium carbonate or caustic alkali the base first separates, but dissolves in excess of reagent. The amino-groups are readily diazotised.

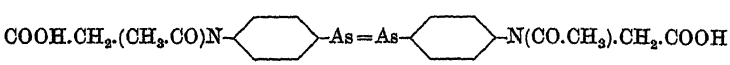
Arsenoarylglycines.

Arsenophenyl-4-glycine,[1]



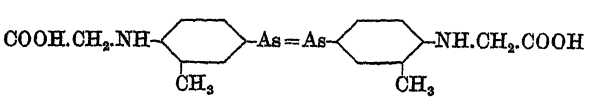
A solution of 200 grams of phenylglycine-*p*-arsinic acid in 4000 c.c. of boiling water is treated with a solution prepared as follows: To 2000 grams of sodium hydrosulphite in 10,000 c.c. of water, 600 c.c. of 10*N* sodium hydroxide are added, followed by 1000 grams of crystallised magnesium chloride, and the whole filtered from magnesium hydroxide. The mixture is warmed for forty-five minutes on the water-bath, the precipitate removed and dissolved in almost boiling dilute sodium carbonate solution. Treatment with acetic acid precipitates arsenophenyl-4-glycine, a reddish-brown powder dissolving in aqueous sodium carbonate to a yellow solution. In the solid state it adsorbs only a small proportion of oxygen, which is quantitatively evolved when the compound is heated *in vacuo*.[2] It dissolves in aniline and pyridine, but not in alcohol, ether, benzene, or mineral acids. The *disodium salt, Spirarsyl*,[3] is a yellow powder, yielding a neutral, yellow solution in water. Arsenophenyl-4-glycine forms a *derivative* with *formaldehyde*,[4] and a *co-ordination compound* with *gold chloride*.[5]

Diacetylarseno-4-phenylglycine,[6]



may be obtained (1) by reducing acetylphenylglycine-*p*-arsinic acid with sodium hydrosulphite, or (2) by the acetylation of arsenophenyl-4-glycine in sodium carbonate solution with acetic anhydride in an inert atmosphere. The acyl group is preferably introduced into one of the parent substances rather than into the arseno-compound itself. The compound is a yellow powder, stable in air.

5-Arsenotolyl-2-glycine,[7]

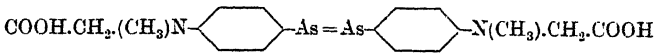


is the reduction product of *o*-tolylglycine-5-arsinic acid, the operation being carried out with alkaline hydrosulphite in the presence of magnesium chloride at 50° C. The product is a yellowish-brown powder,

[1] German Patent, 206057; British Patent, 17619 (1907); American Patents, 888321, 907016.
[2] Maschmann, *Ber.*, 1926, 59, [B], 1142, 1148.
[3] Ehrlich, *ibid.*, 1909, 42, 36.
[4] British Patent, 17 (1915); American Patent, 1299214.
[5] German Patent, 270257.
[6] British Patents, 17, 18 (1915); American Patent, 1299215.
[7] German Patent, 212205.

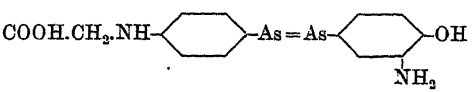
soluble in caustic alkali and alkali carbonate solutions, insoluble in water, sparingly soluble in the usual organic solvents except pyridine or aniline. It blackens above 200° C.

p-Arsenophenyl-N-methylglycine,[1]

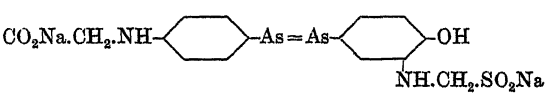


This derivative is prepared by reducing phenylmethylglycine-*p*-arsinic acid with alkali hydrosulphite. It is a pale yellow powder, soluble in alkalis or alkali carbonates, forming neutral salts, but insoluble in acids and the usual organic media. It is stable towards air and oxidising agents.

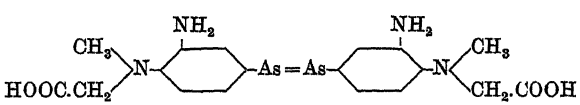
3-Amino-4-hydroxyarsenobenzene-4′-glycine,[2]



The hydrochlorides of phenylglycine-*p*-dichloroarsine and 3-amino-4-hydroxyphenylarsenoxide in methyl alcohol solution are reduced with alkaline sodium hydrosulphite. When the compound is treated in dilute alcohol with 33 per cent. formaldehyde (1 mol.), 30 per cent. sodium hydrosulphite solution (2 mols.), and sodium carbonate added, the resulting product is the *sodium salt* of *3-amino-4-hydroxyarsenobenzene-4′-glycine-N-methylene sulphonic acid.* When this is treated with formaldehyde sulphoxylate, the *sodium salt* of *3-amino-4-hydroxyarsenobenzene-4′-glycine-N-methylene sulphinic acid* results :

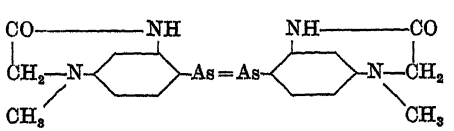


4 : 4′-Arsenobis[N-methyl-N-(2-aminophenyl)glycine],[3]



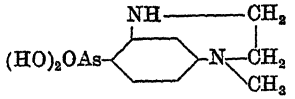
results when the corresponding nitroarsinic acid is reduced by sodium hydrosulphite. It yields a *disodium salt*, very soluble in water but insoluble in organic solvents. It is very readily oxidised, and can only be preserved *in vacuo*. *Ethyl* and *amyl derivatives* are also known, and resemble the methyl compound.

4 : 4′-Arsenobis[N-methyl-(3-aminophenyl)glycine].—When the corresponding nitroarsinic acid is reduced as in the foregoing case, the anhydride of this arseno-compound separates. It has the following structure :

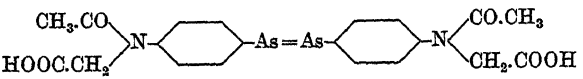


[1] French Patent, 462276 ; Öchslin, *Ann. Chim.*, 1914, [ix.], I, 239.
[2] Hart and Payne, *J. Amer. Pharm. Assoc.*, 1923, 12, 688, 759.
[3] French Patent, 473705.

The anhydride is insoluble in acids, alkalis, or organic solvents, and when oxidised with hydrogen peroxide yields a *water-soluble acid* having the composition

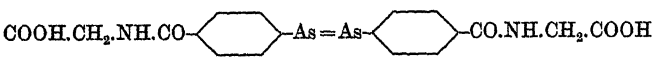


4 : 4′-Arsenobis(N-acetyl-N-phenylglycine),



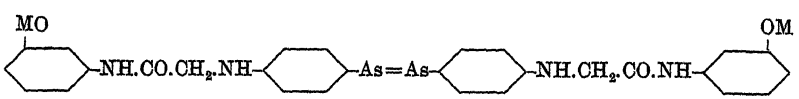
is obtained by reducing the corresponding arsinic acid with hydrosulphite, or by acetylating 4-arsenophenylglycine in sodium carbonate solution at 5° C. in an inert atmosphere. It is a yellow powder, far more stable than 4-arsenophenylglycine.[1]

Arsenohippuric acid,[2]



p-Dichloroarsinobenzoyl chloride (p. 318) is condensed with glycine in the presence of normal sodium hydroxide and the solution treated with hydrochloric acid. A precipitate separates, which is dissolved in sodium hydroxide and oxidised with hydrogen peroxide, a mixture of *hippuroarsinic acid* and *p*-carboxyphenylarsinic acid resulting. The latter is completely precipitated by adding hydrochloric acid, and the filtrate, on rendering alkaline and concentrating under reduced pressure, yields *trisodium hippuroarsinate*, $AsO(ONa)_2.C_6H_4.CO.NH.CH_2.CO_2Na.4H_2O$, colourless needles, on the addition of alcohol. This salt, when treated with alcohol and hydrochloric acid, gives the free hippuroarsinic acid, which is very soluble in water, but decomposes when its aqueous solution is boiled with calcium or barium chloride or magnesia mixture. Reduction with hydrosulphite by Ehrlich and Bertheim's method gives arsenohippuric acid, a yellow powder, giving unstable solutions in alkali carbonate or phosphate solutions, but stable solutions in alkali hydroxides in the absence of air.

Compounds of the type



When equivalent quantities of sodium hydroxide and N-(arsenophenyl)-*bis*glycyl-*m*-aminophenol are dissolved in water and the resulting salt obtained by evaporation or precipitation, a yellow powder is isolated. The process is a general one, sodium or potassium salts of the N-(arsenoaryl)-*bis*-α-aminoacylarylamides of the above formula being obtained, where M is the alkali metal.[3]

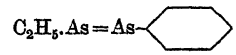
[1] British Patent, 18 (1915); American Patent, 1299215.

[2] Hugounenq and Morel, *J. Pharm. Chim.*, 1913, [vii.], 7, 383.

[3] British Patent, 128181 (1919). The following patents deal with derivatives of N-phenylglycine-*p*-arsinic acid: American Patents, 1280119 to 1280223, and 1280225 to 1280227.

Unsymmetrical Arsenobenzenes.

Ethylarsenobenzene,[1]

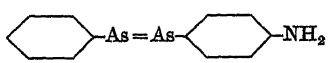


This compound may be prepared by two methods :

(1) 8 grams of ethylarsenoxide are dissolved in 100 c.c. of alcohol containing 9 grams of phenylarsenoxide, and after adding 12 grams of phosphorous acid, the mixture is gently warmed on a water-bath. At about 75° C. a pale yellow, thick, crystalline mass separates, and is filtered off and washed with alcohol. The filtrate is warmed with a further 10 grams of phosphorous acid, when a second crop of product results, the combined yields being 8 grams, or 58 per cent. The crude product is purified by boiling with alcohol, filtering, and washing with hot alcohol, the resulting substance melting at 177° C.

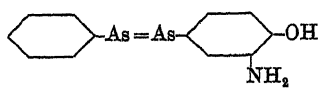
(2) This method is not so satisfactory as the preceding one; it consists of mixing solutions of 9 grams of phenylarsine and 7 grams of ethylarsenoxide in cold methyl alcohol, the operation being conducted in carbon dioxide. The yield is about 3 grams of a yellowish, sticky substance, which is recrystallised from benzene or toluene, and melts at 177° C. Its solution in benzene, and more so its solution in nitrobenzene, shows a tendency to oxidise, forming ethyl- and phenyl- arsenoxides. Two atoms of iodine convert an alcoholic suspension of the arseno-compound to *ethylphenyldi-iododiarsine*, (C_2H_5)IAs.AsI(C_6H_5). This melts with decomposition at 110° to 112° C., and is unstable in air, soon becoming dark and a viscous oil separating. Alcohol oxidises it to ethyl- and phenyl- arsinic acids.

4-Aminoarsenobenzene,[2]



To an ice-cold solution of 10 grams of magnesium chloride hexahydrate and 40 grams of sodium hyposulphite in 600 c.c. of water, is added a solution of 4-aminophenylarsinic acid, 4·4 grams, and 4 grams of phenylarsinic acid in 20 c.c. of saturated sodium carbonate solution. The mixture is treated with charcoal, filtered, and heated for two hours at 30° to 40° C., a yield of 4 grams, or 62 per cent., of arseno-compound resulting. It is a pale yellow powder, insoluble in dilute acids, alkalis, methyl alcohol, and the usual organic solvents. Trituration with methyl alcoholic hydrochloric acid yields the *hydrochloride*, which is insoluble in water and contains two molecules of water of crystallisation.

3-Amino-4-hydroxyarsenobenzene,[3]

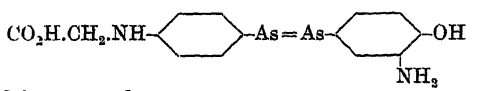


results when a mixture of phenylarsenoxide and 3-amino-4-hydroxyphenylarsenious oxide is reduced, or by the following process :[4] 3-Amino-

[1] Steinkopf, Schmidt, and Smie, *Ber.*, 1926, 59, [B], 1463.
[2] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 116.
[3] German Patents, 251104, 254187.
[4] Newbery and Phillips, *loc. cit.*, p. 120.

4-hydroxyphenylarsinic acid, 5·8 grams, and 5 grams of phenylarsinic acid, are reduced by 50 grams of sodium hyposulphite and 10 grams of magnesium chloride hexahydrate in 500 c.c. of water, by heating for two hours at 60° C. The yield is 5 grams, or 60 per cent. The product is a pale yellow powder, soluble in alcohol, acetone, dilute hydrochloric acid, and sodium hydroxide, insoluble in benzene, chloroform, water, or aqueous sodium carbonate. The *hydrochloride* was first prepared as follows: [1] 55·5 grams of 3-amino-4-hydroxyphenylarsine in 1000 c.c. of alcohol containing 100 c.c. of cold saturated alcoholic hydrochloric acid were mixed with 50 grams of phenylarsenoxide in 1000 c.c. of cooled benzene. The hydrochloride is obtained as a yellow powder, soluble in water and alcohols, the aqueous solution yielding the free base when treated with sodium hydroxide, excess being avoided or the base redissolves. If the base is suspended in methyl alcohol, addition of alcoholic hydrochloric acid, and finally of ether, yields a soluble *hydrochloride dihydrate.*

3-Amino-4-hydroxy-4′-glycinearsenobenzene,[2]



may be prepared in several ways:

(1) 320 grams of phenylglycine-*p*-dichloroarsine hydrochloride in 5000 c.c. of water are treated with a solution of 250 grams of 3-amino-4-hydroxyphenylarsine in 2500 c.c. of methyl alcohol, 2000 c.c. of water, and 2000 c.c. of normal hydrochloric acid. After standing for twelve hours, the mixture is treated with an excess of sodium acetate to precipitate the arseno-compound. The *phenylglycine-p-dichloroarsine hydrochloride* required for this preparation is obtained by passing sulphur dioxide into a saturated solution of phenylglycine-*p*-arsinic acid in concentrated hydrochloric acid containing a little hydriodic acid, at a temperature of −10° C. The arsine decomposes at 120° C., and is a white, crystalline product, readily soluble in methyl alcohol, water, and alkalis.

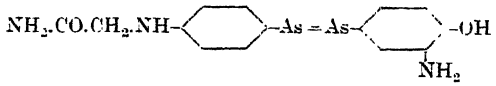
(2) A mixture of 41·6 grams of phenylglycine-*p*-dichloroarsine hydrochloride and 24·9 grams of 3-amino-4-hydroxyphenylarsenoxide in 200 c.c. of methyl alcohol is poured into 500 c.c. of normal sodium hydroxide. After dilution with 2000 c.c. of water, 200 grams of sodium hydrosulphite are added, with vigorous stirring, the arseno-compound being precipitated as a yellowish-brown mass. The reaction is complete in about fifteen minutes.

(3) 275 grams of phenylglycine-*p*-arsinic acid are dissolved in 2500 c.c. of methyl alcohol and 1000 c.c. of 2*N* sulphuric acid, 50 grams of potassium iodide in 50 c.c. of water added, and the whole saturated with sulphur dioxide. To this solution is added 185 grams of 3-amino-4-hydroxyphenylarsine in 2000 c.c. of alcohol and 1000 c.c. of normal hydrochloric acid, the mixing being conducted in the cold. The arseno-compound separates in brownish-yellow flocks.

3-Amino-4-hydroxy-4′-glycinearsenobenzene is a brownish powder, soluble in sodium hydroxide, carbonate or bicarbonate, but insoluble in water, alcohol, and the usual organic solvents.

[1] German Patent, 254187.
[2] German Patents, 251104, 254187.

3-Amino-4-hydroxy-4′-glycineamidearsenobenzene,[1]



This derivative may be obtained in three ways :

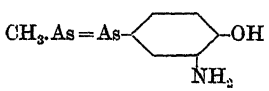
(1) A mixture of 3-amino-4-hydroxyphenylarsinic acid and phenylglycineamide-4-arsinic acid is reduced with sodium hydrosulphite in the presence of magnesium chloride.

(2) Sodium phenylglycineamide-4-arsinate, $NH_2.CO.CH_2.NH.C_6H_4.AsO(ONa)_2$, is reduced to the corresponding oxide and this condensed in aqueous solution with 3-amino-4-hydroxyphenylarsine hydrochloride.

(3) In the form of the *dihydrochloride* the compound results when a mixture of 3-amino-4-hydroxyphenylarsinic acid and phenylglycineamide-4-arsinic acid in hydrochloric acid is reduced by 50 per cent. hypophosphorous acid,[2] the yield being about 73 per cent. The compound is soluble in water, and the free base and *N-methylenesulphoxylic acid derivative* are prepared in the usual way.

By similar means [3] the following have also been prepared : *3-Acetamido-4-hydroxy-4′-glycineamidearsenobenzene*, *3-amino-5-acetamido-4-hydroxy-4′-glycineamidearsenobenzene*, and *3-amino-5-acetamido-2-hydroxy-4′-glycineamidearsenobenzene*.

3-Amino-4-hydroxybenzenearsenomethane, *Methane-4-arseno-2-aminophenol*,[4]



Three methods are available for the preparation of this compound :

(1) 20 grams of 3-amino-4-hydroxyphenylarsenoxide in 100 c.c. of methyl alcohol are mixed with 10·6 grams of methylarsenoxide in 50 c.c. of the same solvent and the whole poured into 2500 c.c. of water. To this, 200 grams of sodium hydrosulphite are added, with brisk stirring, the arseno-compound being precipitated, and the reaction going to completion in five minutes.

(2) 36·5 grams of sodium methylarsinate, $CH_3.AsO(ONa)_2.6H_2O$, and 29·2 grams of 3-amino-4-hydroxyphenylarsinic acid in 1200 c.c. of water and 40 c.c. of 2*N* sodium hydroxide, are treated with 600 grams of sodium hydrosulphite and 120 grams of magnesium chloride in 3000 c.c. of water. The product is stirred at 50° C. until no further precipitation occurs.

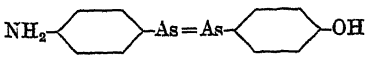
(3) 23·3 grams of 3-amino-4-hydroxyphenylarsinic acid and 10·6 grams of methylarsenoxide are dissolved in 100 c.c. of methyl alcohol and 50 c.c. of alcohol saturated with hydrogen chloride at 15° C. The solution is treated with 75 grams of stannous chloride in 300 c.c. of hydrochloric acid (density 1·19) and 300 c.c. of acetone containing 5 c.c. of hydriodic acid (density 1·7) at a temperature of −20° to −10° C., when the *hydrochloride* of the arseno-derivative separates out.

3-Amino-4-hydroxybenzenearsenomethane is a yellow powder, soluble in dilute hydrochloric acid or aqueous sodium hydroxide, a

[1] British Patent, 270091 (1926); see also British Patents, 11709, 11901 (1911).
[2] Palmer and Kester, *J. Amer. Chem. Soc.*, 1928, 50, 3109.
[3] British Patents, *loc. cit.*
[4] German Patent, 253226.

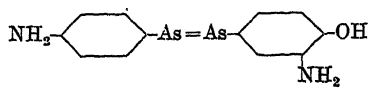
solution in the former soon becoming turbid on warming, whilst the alkali solution remains unchanged.

4-Amino-4′-hydroxyarsenobenzene,[1]



results when 4-hydroxyphenylarsenoxide in methyl alcohol is mixed with 4-aminophenylarsine in dilute hydrochloric acid. After standing for several hours, the product is precipitated by sodium acetate. It is a yellow powder, decomposing at about 200° C., insoluble in water and the usual organic solvents, but dissolves in hydrochloric acid or sodium hydroxide. The *hydrochloride* is obtained [2] when a mixture of arsanilic acid and *p*-hydroxyphenylarsinic acid in hydrochloric acid is reduced by stannous chloride in the presence of a little potassium iodide. The yield is about 67 per cent. and the product is completely soluble in sodium hydroxide solution.

3 : 4′-Diamino-4-hydroxyarsenobenzene,[3]



may be prepared in three ways :

(1) 23·3 grams of 3-amino-4-hydroxyphenylarsinic acid and 21·9 grams of 4-aminophenylarsenoxide in 90 c.c. of alcohol and 60 c.c. of alcoholic hydrochloric acid are treated at −10° C. with a solution of 75 grams of stannous chloride in 200 c.c. of alcohol, 400 c.c. of alcohol saturated with hydrogen chloride at 15° C., and 5 c.c. of hydriodic acid (density 1·7). The arseno-compound is immediately precipitated.

(2) 21·7 grams of 4-aminophenylarsinic acid and 23·3 grams of 3-amino-4-hydroxyphenylarsinic acid in 100 c.c. of methyl alcohol and 39 c.c. of hydrochloric acid (density 1·12) are treated with 100 grams of stannous chloride in 100 c.c. of alcohol and 500 c.c. of alcoholic hydrochloric acid. At −10° to −5° C. 10 c.c. of hydriodic acid (density 1·7) are stirred in, the dihydrochloride of the base separating as a yellow, microcrystalline precipitate. This is washed with alcohol containing hydrogen chloride and with ether. The dihydrochloride is only slightly soluble in organic solvents, but gives a clear solution in water, from which no precipitate is obtained on addition of alkali. This shows the absence of diaminoarsenobenzene in the product. A solution of the dihydrochloride yields a yellow insoluble sulphate with sulphuric acid.

(3) The compound may also be isolated as the *dihydrochloride* in the following manner :[4] A mixture made up from fiftieth molecules of arsanilic and 3-amino-4-hydroxyphenylarsinic acids, 30 c.c. of water, 40 c.c. of pyridine, 10 c.c. of hydrochloric acid (density 1·19), and 53 c.c. of hypophosphorous acid, is heated on a water-bath at 100° C. for one hour. The precipitate which forms is then redissolved in 100 c.c. of water, the solution acidified with a few c.c. of concentrated hydrochloric acid,

[1] German Patent, 254187.

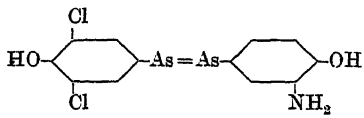
[2] Kahn, *Chem. Zeit.*, 1912, 36, 1099 ; Hart and Payne, *J. Amer. Pharm. Assoc.*, 1923, 12, 688 ; German Patents, 254187, 251571, 352226 ; American Patent, 1033904 ; Palmer and Kester, *J. Amer. Chem. Soc.*, 1928, 50, 3109.

[3] German Patent, 251104.

[4] Palmer and Kester, *loc. cit.*

and the compound reprecipitated by stirring into 100 c.c. of 6N hydrochloric acid. The product is then filtered off, washed with dilute hydrochloric acid, acetone, and ether, the yield by this method being 5·5 grams, or 65 per cent.

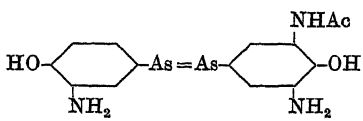
3′ : 5′-Dichloro-3-amino-4 : 4′-dihydroxyarsenobenzene,



3 : 5-Dichloro-4-hydroxyphenylarsenoxide (33·9 grams) and 24·9 grams of 3-amino-4-hydroxyphenylarsenoxide are dissolved in 200 c.c. of methyl alcohol, 125 c.c. of normal sodium hydroxide added, and 2300 c.c. of water. Sodium hydrosulphite (200 grams) is stirred in, and the arseno-compound separates out. It is a bright yellow powder, very soluble in ether, soluble in alcohols and acetone, insoluble in water. It gives clear solutions in hydrochloric acid, and sodium hydroxide or carbonate, but is only slightly soluble in sodium bicarbonate.

The 3 : 5-*dichloro-4-hydroxyphenylarsenoxide* required for the above preparation is obtained by the gentle reduction of 3 : 5-dichloro-4-hydroxyphenylarsinic acid (p. 272). It crystallises in small prisms which are slightly soluble in water, readily soluble in alcohol or sodium carbonate.

3 : 3′-Diamino-5-acetamido-4 : 4′-dihydroxyarsenobenzene,[1]

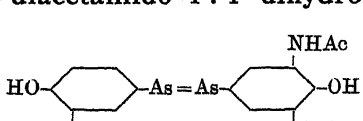


This derivative is isolated in the form of its *dihydrochloride* when a mixture of 3 : 3′-diamino-5 : 5′-diacetamido-4 : 4′-dihydroxyarsenobenzene and 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene in a common solvent is treated with an excess of methyl alcoholic hydrochloric acid or with ether. The reaction is an example of the general reaction indicated by the following equation :

$$Ar.As_2.Ar + Ar'.As_2.Ar' = 2Ar.As_2.Ar'$$

The group Ar′ is a diaminoaryl group, and Ar a diacyldiaminoaryl grouping.

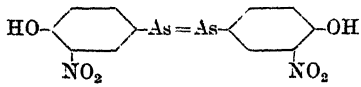
3-Amino-3′ : 5′-diacetamido-4 : 4′-dihydroxyarsenobenzene,



This is prepared in a similar manner to the foregoing arseno-compound by the condensation of 3 : 3′ : 5 : 5′-tetra-acetamido-4 : 4′-dihydroxyarsenobenzene and 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene.

[1] British Patent, 269647 (1926).

3 : 3′-Dinitro-4 : 4′-dihydroxyarsenobenzene,[1]



may be isolated in three ways :

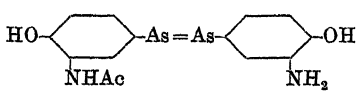
(1) 10 grams of 3-nitro-4-hydroxyphenylarsinic acid, or the corresponding oxide, in the form of a powder, are added to 50 grams of hypophosphorous acid (density 1·15) in 50 c.c. of water. The whole is warmed on the water-bath, and well stirred, air being excluded. After one hour the product is poured into 2000 c.c. of water, when the arseno-derivative is precipitated.

(2) A solution of 10 grams of stannous chloride in 40 c.c. of hydrochloric acid (density 1·19) is treated with 1 c.c. of hydriodic acid (density 1·7) and the whole cooled in ice. The solution is well stirred, and 5·3 grams of 3-nitro-4-hydroxyphenylarsinic acid in 20 c.c. of methyl alcohol added dropwise. The precipitated arseno-compound is filtered off and washed with methyl alcohol.

(3) 4·6 grams of 3-nitro-4-hydroxyphenylarsenoxide in 15 c.c. of methyl alcohol are cooled to between −15° and −10° C. and 5 grams of stannous chloride in 20 c.c. of hydrochloric acid (density 1·19) and 20 c.c. of methyl alcohol stirred in. Yield, 3·3 grams, or 77·5 per cent.

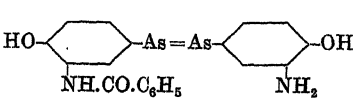
Dinitrodihydroxyarsenobenzene is a bright yellow powder, which becomes electrified by friction. It is insoluble in water and only slightly soluble in the usual solvents. In alkalis it dissolves readily, forming sodium salts which are sparingly soluble in excess of reagent. Acid precipitates yellow flocks from the orange-coloured alkali solutions, and this product, when dry, tends to decompose spontaneously, with inflammation.[2]

3-Acetamido-3′-amino-4 : 4′-dihydroxyarsenobenzene,[3]



This product is a light yellow powder obtained by the condensation of 3-acetamido-4-hydroxyphenylarsenoxide with 3-amino-4-hydroxyphenylarsine hydrochloride in 10 per cent. sodium hydroxide solution. It may also be obtained by adding acetic acid to a solution of 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene and its diacetyl derivative in dilute sodium hydroxide.

3-Benzamido-3′-amino-4 : 4′-dihydroxyarsenobenzene,[4]



3-Amino-4-hydroxyphenylarsinic acid and an equimolecular proportion of 3-benzamido-4-hydroxyphenylarsinic acid are dissolved in dilute

[1] German Patents, 269886, 269887.

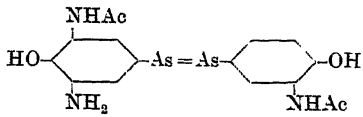
[2] For 3-amino-4 : 4′-dihydroxyarsenobenzene, 3-amino-4-hydroxyarsenophenyl-4′-glycine, and their N-methylenesulphinates and N-methylenesulphonates, see Hart and Payne, *J. Amer. Pharm. Assoc.*, 1923, 12, 688, 759.

[3] British Patents, 248523 (1925); 269647 (1926).

[4] British Patent, 248523 (1925).

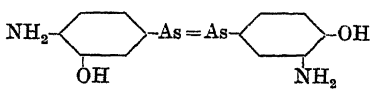
sodium carbonate, and the mixture reduced by sodium hydrosulphite in the presence of magnesium chloride. The resulting arseno-compound is a yellow powder.

3-Amino-3′ : 5-diacetamido-4 : 4′-dihydroxyarsenobenzene,[1]



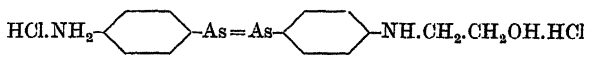
The preparation of this compound is carried out in a similar manner to that of the preceding acetyl derivative by the condensation of 3 : 3′-diamino-5 : 5′-diacetamido-4 : 4′-dihydroxyarsenobenzene with 3 : 3′-diacetamido-4 : 4′-dihydroxyarsenobenzene.

3 : 4′-Diamino-4 : 3′-dihydroxyarsenobenzene,[2]



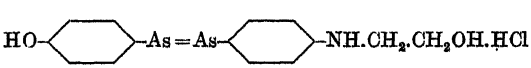
is a yellow, amorphous powder, soluble in sodium hydroxide, and yielding a *diacetyl derivative.*

4-Amino-4′-β-hydroxyethylaminoarsenobenzene dihydrochloride,[3]



A solution of a fiftieth of a gram-molecule each of *β-p*-arsinoanilinoethyl alcohol (p. 400) and arsanilic acid in 30 c.c. of water and 10 c.c. of 12*N* hydrochloric acid is prepared, half a gram-molecule of 50 per cent. hypophosphorous acid added, and the solution kept for three days, the temperature being maintained below 15° C. The solution is then stirred into 100 c.c. of cold 6*N* hydrochloric acid, when the arseno-compound is precipitated. The precipitate is filtered off, repeatedly washed with dilute hydrochloric acid, triturated with 30 c.c. of methyl alcohol containing 5 c.c. of hydrochloric acid (density 1·19), again filtered, and washed with ether. The yield is about 7 grams, or 78 per cent. The compound turns red and sticky in contact with water, but addition of a little hydrochloric acid causes rapid solution. When 5 grams of the compound are dissolved in 50 c.c. of water containing 3 c.c. of hydrochloric acid (density 1·19), and 2·5 grams of sodium formaldehydesulphoxylate in 25 c.c. of water are added, a yellow precipitate separates in a few minutes. This is *4-amino-4′-β-hydroxyethylaminoarsenobenzene-N-methylenesulphoxylic acid.* After standing for one hour at room temperature, the product is filtered off in a carbon dioxide atmosphere, carefully washed with water, methyl alcohol, and ether. The yield is quantitative.

4-Hydroxy-4′-β-hydroxyethylaminoarsenobenzene hydrochloride,



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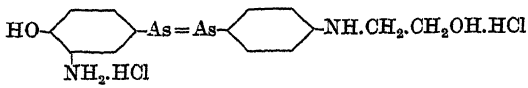
[1] British Patent, 269647 (1926).
[2] Balaban, *J. Chem. Soc.*, 1928, p. 811.
[3] Palmer and Kester, *J. Amer. Chem. Soc.*, 1928, 50, 3109.

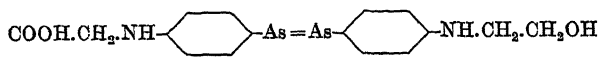
is obtained when the arsanilic acid of the preceding preparation is replaced by *p*-hydroxyphenylarsinic acid and the arseno-compound is precipitated as formed. A yield of about 60 per cent. is obtained, the substance being readily soluble in dilute sodium hydroxide, less soluble in methyl alcohol or acetone, and sparingly soluble in dilute hydrochloric acid. Water turns it red and sticky. The *free base* may be obtained by dissolving the hydrochloride in dilute sodium hydroxide and passing in carbon dioxide. The precipitate can be readily filtered off and should be washed rapidly with warm water.

3-Amino-4-hydroxy-4′-β-hydroxyethylaminoarsenobenzene dihydrochloride,



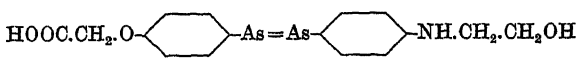
This derivative is obtained in about 53 per cent. yield when 3-amino-4-hydroxyphenylarsinic acid is used in the foregoing reductions. The compound is readily soluble in water or dilute alkali. By the action of sodium formaldehydesulphoxylate, as detailed before, it may be converted into *3-amino-4-hydroxy-4′-β-hydroxyethylaminoarsenobenzene-N-methylenesulphoxylic acid*, in quantitative yield.

4-β-Hydroxyethylaminoarsenobenzene-4′-glycine,



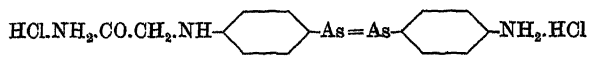
This is prepared by reducing a mixture of β-*p*-arsinoanilinoethyl alcohol and phenylglycine-*p*-arsinic acid in hydrochloric acid solution by 50 per cent. hypophosphorous acid in the usual way, or by the use of stannous chloride. The product is deep yellow, does not darken on exposure to the air, and is wholly soluble in sodium bicarbonate. The *free base* is obtained by converting the above product to its *sodium salt* and adding acetic acid to the solution.

4-β-Hydroxyethylaminoarsenobenzene-4′-oxyacetic acid,



This derivative is the reduction product of a mixture of β-*p*-arsinoanilinoethyl alcohol and *p*-arsinophenoxyacetic acid, the yield of arseno-compound being about 92 per cent. It is a yellow powder, completely soluble in sodium bicarbonate solution. The preparation of this compound differs slightly from the preparations previously given. The alcohol is reduced independently, before reducing the *p*-arsinophenoxyacetic acid, and this shows that as the latter is reduced, there is a rearrangement of the two arseno-compounds to give a product composed entirely of the unsymmetrical derivative.

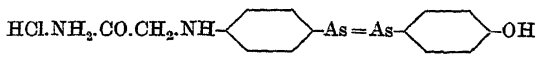
4-Amino-4′-glycineamidearsenobenzene dihydrochloride,



A solution is prepared containing 0·01 gram-molecule each of phenylglycineamide-4-arsinic acid and arsanilic acid in 30 c.c. of hydrochloric acid (density 1·19) and 10 c.c. of water. To this, 20 grams of crystallised stannous chloride are gradually added, followed by 1 gram of potassium iodide in 5 c.c. of water. A heavy, pale yellow precipitate separates

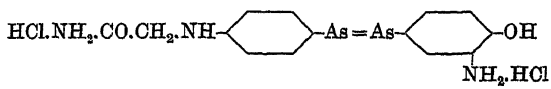
immediately, which is filtered off, washed with dilute hydrochloric acid, triturated with dilute hydrochloric acid and again filtered. The solid is then washed with dilute hydrochloric acid and methyl alcohol, and dried over sulphuric acid, the yield being 4 grams, or 86 per cent. It is not appreciably soluble in water, and only sparingly soluble in warm dilute hydrochloric acid, which acid seems to favour decomposition. If the two arsinic acids are reduced with sodium formaldehydesulphoxylate instead of stannous chloride, the resulting product is *4-aminoarsenobenzene-4′-glycineamide-N-dimethylenesulphoxylic acid*, which is a yellow powder, obtained in only about 18 per cent. yield.

4-Hydroxy-4′-glycineamidearsenobenzene hydrochloride,



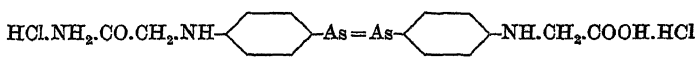
is obtained when the arsanilic acid of the preceding preparation is replaced by *p*-hydroxyphenylarsinic acid. The yield is about 67 per cent. and the free base is isolated in the usual manner.

3-Amino-4-hydroxyarsenobenzene-4′-glycineamide dihydrochloride,



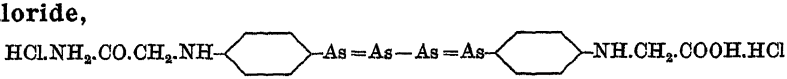
is obtained from phenylglycineamide-4-arsinic acid and 3-amino-4-hydroxyphenylarsinic acid. The product is worked up as usual.

Arsenobenzene-4-glycine-4′-glycineamide dihydrochloride,[1]



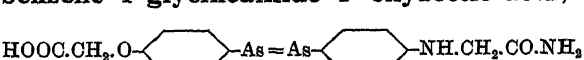
results when phenylglycine-4-arsinic acid and phenylglycineamide-4-arsinic acid in hydrochloric acid are simultaneously reduced in the presence of a little potassium iodide. The bright yellow powder thus isolated is entirely soluble in sodium bicarbonate solution, and is somewhat soluble in methyl alcohol.

Tetra-arsenobenzene-4-glycine-4′-glycineamide dihydrochloride,



A solution of fiftieth gram-molecules of phenylglycine-4-arsinic acid and phenylglycineamide-4-arsinic acid is prepared in 25 c.c. of hydrochloric acid (density 1·19) and 30 c.c. of water. To this is added 53 c.c. of 50 per cent. hypophosphorous acid, and the whole allowed to stand at room temperature for several days. The solution gradually acquires a deep red colour, and at this stage precipitation commences, 4 grams (30 per cent.) of product separating. This is filtered off, washed with dilute hydrochloric acid, methyl alcohol, and ether, then dried in a vacuum over phosphorus pentoxide.

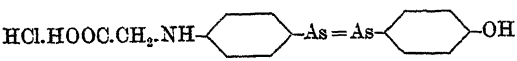
Arsenobenzene-4-glycineamide-4′-oxyacetic acid,



[1] Palmer and Kester, *J. Amer. Chem. Soc.*, 1928, 50, 3109.

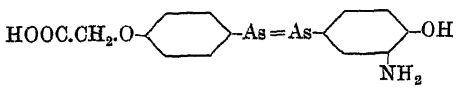
is the reduction product of phenylglycineamide-4-arsinic acid and *p*-arsinophenoxyacetic acid in hydrochloric acid, using hypophosphorous acid. The mixture is kept for four or five days below 15° C., then warmed to 40° C., the arseno-compound immediately filtered off, washed, and dried. The yield is about 67 per cent., the product being entirely soluble in alkaline solutions.

4-Hydroxyarsenobenzene-4′-glycine hydrochloride,



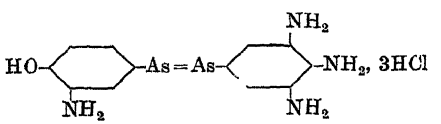
results when phenylglycine-4-arsinic acid and *p*-hydroxyphenylarsinic acid in hydrochloric acid are reduced by hypophosphorous acid. The reaction mixture is kept in ice for five or six days to complete the reduction, and a yield of about 56 per cent. is obtained.

3-Amino-4-hydroxyarsenobenzene-4′-oxyacetic acid,



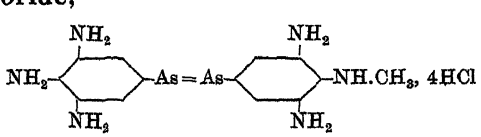
is obtained when *p*-arsinophenoxyacetic acid and 3-amino-4-hydroxyphenylarsinic acid are reduced by hypophosphorous acid below 15° C., the process taking about eighteen hours. It is a yellow compound obtained in about 73 per cent. yield.

3 : 4 : 5 : 3′-Tetramino-4′-hydroxyarsenobenzene trihydrochloride,[1]



20 grams of 3 : 4 : 5 : 3′ : 4′ : 5′-hexaminoarsenobenzene tetrahydrochloride (p. 352) and 16 grams of 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene dihydrochloride in 400 c.c. of water are quickly heated to 80° C. The solution is then poured in a thin stream into 4000 c.c. of hydrochloric acid (density 1·12), the mixture being well stirred. The trihydrochloride separates in pale yellow flocks, which are washed with hydrochloric acid, acetone, and ether, and dried in a vacuum. The product contains 3 molecules of water of crystallisation, is soluble in sodium hydroxide, like Salvarsan, and in sodium bicarbonate, like hexaminoarsenobenzene.

3 : 4 : 5 : 3′ : 5′ - Pentamino - 4′ - methylaminoarsenobenzene tetrahydrochloride,

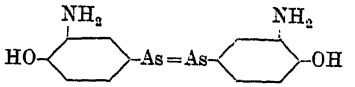


results when hexaminoarsenobenzene hydrochloride reacts with 3 : 5 : 3′ : 5′-tetramino-4 : 4′-dimethyldiaminoarsenobenzene hydrochloride at 70° C., and the product is precipitated by acetic acid. The compound forms a stable *carbamate*.

[1] Karrer, *Ber.*, 1916, 49, 1648.

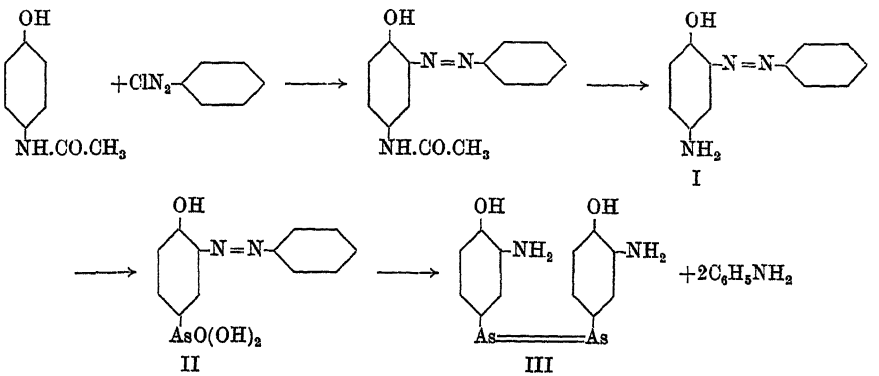
Salvarsan and Related Compounds.

3 : 3′ - Diamino - 4 : 4′ - dihydroxyarsenobenzene, (*Salvarsan, Arsphenamine, Ehrlich* 606, *Arsenobenzol, Arsenobillon, Kharsivan*),



The extreme importance of this compound as a drug has led to much research dealing with its preparation and properties. It is, therefore, only possible to deal with a few of the methods of preparation in detail in these pages, but everything of importance has been included. Two recent syntheses are as follows : [1]

1. The general scheme for this synthesis is shown below.

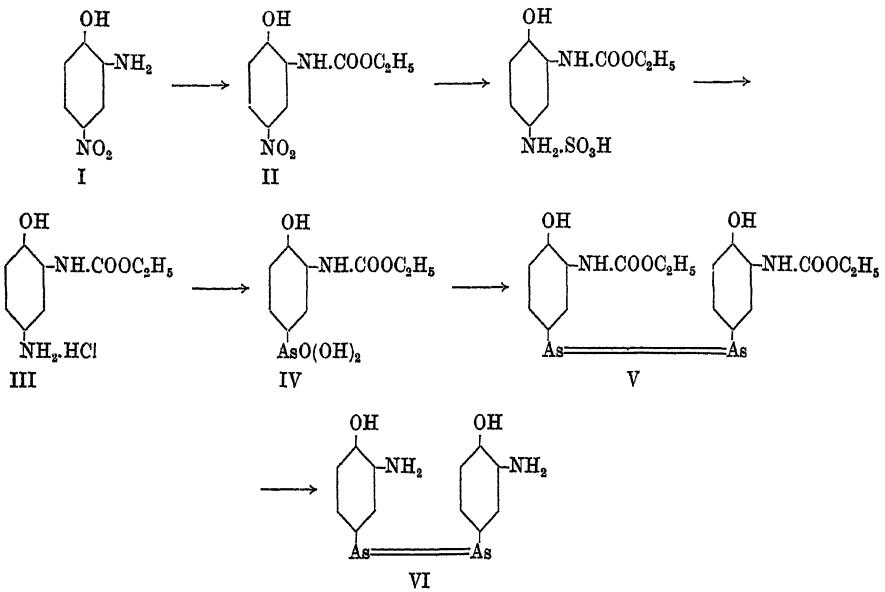


3-Amino-6-hydroxyazobenzene (I) is obtained from diazotised aniline and 4-monoacetylaminophenol. A suspension of 21·32 grams of the azo-compound in 1500 c.c. of water at about 80° C. is brought into solution by the addition of 35 c.c. of hydrochloric acid (density 1·126) and diazotised with 100 c.c. of sodium nitrite solution. The liquid is then poured into a solution of 500 c.c. of 10 per cent. sodium arsenite, 750 c.c. of normal sodium hydroxide, and 1200 c.c. of water. The mixture is rapidly stirred, nitrogen being slowly evolved ; three hours are required to complete the reaction. After twenty-four hours, hydrochloric acid is added until the product is just alkaline, then the mass is acidified with acetic acid, heated to boiling, and the by-product filtered off whilst hot. Hydrochloric acid is added to the filtrate until acid to Congo red, when, on cooling, *4-hydroxy-3-benzeneazophenylarsinic acid* (II) separates out. This may be purified by filtering and drying, then dissolving 16 grams in a solution of 45 grams of sodium bicarbonate in 800 c.c. of water, heating to about 65° C., filtering, and passing carbon dioxide, which precipitates the *monosodium salt* in glistening bronze plates from the filtrate. This salt is converted into the free acid by methyl alcoholic hydrogen chloride, and the product recrystallised from dilute methyl alcohol. To reduce the acid, 6·4 grams are suspended in 100 c.c. of water and dissolved by the addition of 22 c.c. of normal sodium carbonate solution. Sodium hydrosulphite (25 grams) and 7 grams of magnesium chloride in 150 c.c. of water are added and the

[1] Bart, *Annalen*, 1922, 429, 113.

whole heated to about 60° C., stirred, and carbon dioxide passed in. The azo-compound decomposes and the mixture at first decolorises, then 3 : 3′-*diamino*-4 : 4′-*dihydroxyarsenobenzene* (III) separates as a voluminous, yellow precipitate. When reduction is complete, the crude base is filtered off in a carbon dioxide atmosphere and suspended whilst still moist in methyl alcohol, aniline and sulphurous acid salts passing into solution. The base is now dissolved in 10 per cent. methyl alcoholic hydrogen chloride in a carbon dioxide atmosphere until faintly acid to Congo red, then the solution is poured in a thin stream into dry ether, when the *dihydrochloride* is precipitated. This is filtered off, washed with ether, and dried in a desiccator in a carbon dioxide atmosphere.

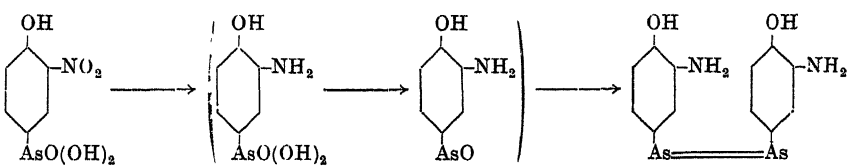
2. The second synthesis is carried out using the following series of reactions :



p-Nitro-*o*-aminophenol (I), in chloroform solution containing pyridine, is condensed with ethyl chloroformate, giving the *urethane* (II), M.pt. 208° C. Reduction of this by alkaline hydrosulphite results in *p-amino-o-carbethoxyaminophenol* (III), diazotisation and addition of sodium arsenite then yielding 3-*carbethoxyamino*-4-*hydroxyphenylarsinic acid* (IV). This compound crystallises from water in colourless needles, decomposing above 200° C., soluble in alcohols, sparingly soluble in cold water, and insoluble in ether, benzene, and chloroform. Hypophosphorous acid reduces IV to the urethane of the required base (V). The urethane is a pale yellow product, readily soluble in dilute alkali, sparingly soluble in acids, insoluble in ether, benzene, and chloroform. With concentrated alkali it gives sparingly soluble salts. Alkaline hydrolysis in a hydrogen atmosphere converts the urethane to Salvarsan base (VI).

Another method of obtaining Salvarsan, and the one in general

use, depends upon the reduction of 3-nitro-4-hydroxyphenylarsinic acid. This may be carried out directly, or in stages, 3-amino-4-hydroxyphenylarsinic acid and 3-amino-4-hydroxyphenylarsenoxide being obtained in the case of progressive reduction.[1] The following is a method of direct reduction, specially designed to avoid the use of methyl alcohol and ether, which are physiologically dangerous and inflammable:[2] 3-Nitro-4-hydroxyphenylarsinic acid (85 grams), in 290 c.c. of 2*N* sodium hydroxide and 1700 c.c. of water, is added to 220 grams of magnesium chloride and 1100 grams of sodium hyposulphite in 5500 c.c. of water, the whole being vigorously stirred during the addition. The mixture is kept below 40° C. and, when the suspended matter seems about to settle, the liquor is rapidly filtered and the solution maintained at 50° to 60° C. for about two hours. The yellow diaminodihydroxyarsenobenzene separates out and is washed with ice-water, suspended in 400 c.c. of water, and dissolved by the addition of about 150 c.c. of 2*N* sodium hydroxide, the materials being maintained at 0° C. during the process. The solution, after filtration through an anærobic filter, is mixed with 150 c.c. of hydrochloric acid (1 : 1), then diluted to 1700 c.c. with ice-cold distilled water. From this solution the hydrochloride is precipitated by stirring into 3250 c.c. of hydrochloric acid (1 : 1), the product obtained being dried *in vacuo* over calcium chloride and sodium hydroxide. After twelve hours hydrogen is introduced into the vacuum desiccator to equalise the pressure. The Salvarsan is ground and again dried until constant in weight, a yield of about 75 per cent. being obtained.



The latest method of reducing 3-nitro-4-hydroxyphenylarsinic acid to Salvarsan is to subject the acid to electrolysis in the presence of hydrochloric acid, using a mercury cathode, and carrying out the operation in carbon dioxide. According as the hydrochloric acid is above or below 4·7*N*, Salvarsan or 3-amino-4-hydroxyphenylarsine hydrochloride is produced.[3]

3-Nitro-4-hydroxyphenylarsinic acid may also be reduced by zinc and acetic acid at 25° to 35° C., and then in hydrochloric acid solution at 50° to 60° C., in the presence of a small quantity of sulphurous acid.[4] The latter appears to prevent the reduction going beyond the arseno-compound.

Using 3-amino-4-hydroxyphenylarsinic acid the reduction may also be readily accomplished as follows:[5] Five grams of the amino-acid are dissolved in a solution containing 25 c.c. of hypophosphorous acid

[1] See German Patent, 271894.

[2] Kober, *J. Amer. Chem. Soc.*, 1919, 41, 442; *Proc. Soc. exp. Biol. Med.*, New York, 1918, 16, 23; see Ehrlich and Bertheim, *Ber.*, 1912, 45, 756.

[3] Matsumiya and Nakata, *Mem. Coll. Sci. Kyoto*, 1927, 10, 199.

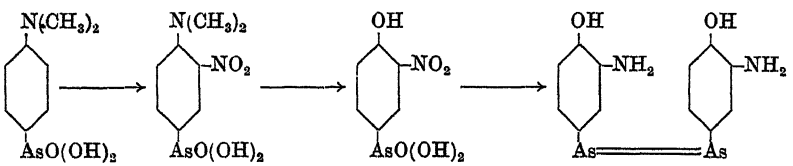
[4] British Patent, 21421 (1914).

[5] Fargher and Pyman, *Trans. Chem. Soc.*, 1920, 117, 376; see Christiansen, *J. Amer. Chem. Soc.*, 1920, 42, 2402.

(density 1·15), 25 c.c. of water, and 0·1 gram of potassium iodide. The solution, after heating at 60° C. in a carbon dioxide atmosphere for two hours, is cooled, made slightly alkaline with 10 per cent. aqueous sodium carbonate, and the precipitate removed and well washed with water. The base so obtained is converted to the hydrochloride by means of methyl alcoholic hydrogen chloride, precipitated by dry ether, filtered off, and dried *in vacuo*. Yield, 3·7 grams.

An earlier process consisted in reducing 3-amino-4-hydroxyphenylarsinic acid to 3-amino-4-hydroxyphenylarsenoxide, saturating this with sulphur dioxide and mixing it with 3-amino-4-hydroxyphenylarsine in alcohol and hydrochloric acid, the arsenobenzene being precipitated.[1] More recently the 3-amino-4-hydroxyphenylarsenoxide hydrochloride, obtained from the corresponding arsinic acid by reduction in hydrochloric acid solution with hydriodic acid and sulphur dioxide, is aerated to remove the sulphur dioxide. The liquor is then reduced by hypophosphorous acid and Salvarsan hydrochloride precipitated by pouring in hydrochloric acid (1 : 1).[2]

Another starting-point in the preparation of Salvarsan is *p*-dimethylaminophenylarsinic acid.[3]



The acid (23·5 grams) is finely powdered and suspended in 300 c.c. of glacial acetic acid and 9·8 grams of 62 per cent. nitric acid added at room temperature, complete solution resulting. About 20 c.c. of acetic anhydride are added and in a few seconds the whole solidifies to a crystalline mass, with evolution of heat. After standing for an hour in the ice-chest, the crystals are filtered off and washed with ether. Yield, 20 grams. Recrystallisation from water yields glistening yellow plates of 3-nitro-4-dimethylaminophenylarsinic acid. This compound is transformed to 3-nitro-4-hydroxyphenylarsinic acid by warming 12 grams with 30 c.c. of 40 per cent. sodium hydroxide at 85° C. for three to four hours. The mixture is then diluted with 70 grams of ice and acidified with 25 c.c. of hydrochloric acid (density 1·2), the required acid rapidly separating out. The reduction may then be carried out by one of the foregoing processes.

3 : 3′-Diamino-4 : 4′-dihydroxyarsenobenzene is a pale yellow powder, dissolving in aqueous sodium hydroxide or carbonate and dilute hydrochloric acid. In therapeutics it is used in the form of its dihydrochloride, which has a formula approximating to $C_{12}H_{12}O_2N_2As_2$, 2HCl, $2H_2O$. Prepared according to the method given on p. 373,[4] in which no methyl alcohol or ether is used, very pure specimens are practically colourless and do not melt when slowly heated, but gradually

[1] German Patent, 254187.

[2] Christiansen, *J. Amer. Chem. Soc.*, 1921, 43, 370; see Ehrlich and Bertheim, *Ber.*, 1912, 45, 756.

[3] Karrer, *Ber.*, 1913, 46, 515; compare British Patent, 22521 (1914).

[4] Kober, *J. Amer. Chem. Soc.*, 1919, 41, 442; compare American Patents, 1564859, 1564860.

darken from 160° C. onwards and at 180° C. begin to char. When moistened with water the compound becomes brownish-yellow and dissolves in 5 parts of water to form a gel or gelatinous solution, according to the temperature. It readily dissolves in hot or warm water, is slightly soluble in methyl alcohol, sparingly soluble in ethyl alcohol, and insoluble in ether or benzene. When methyl alcohol and ether are used in the preparation of Salvarsan the latter may contain methyl alcohol in amount varying from nil to 1·4 per cent., and when precipitated from methyl alcohol solution by acetone, the product contains one molecular proportion of acetone.[1] The methyl alcohol preparations have definitely been shown to contain two molecules of water of crystallisation.[2] The *diacetyl derivative* results when 3-acetylamino-4-hydroxyphenylarsinic acid is reduced.[3]

Sulphur Content of Salvarsan.—Commercial Salvarsan always contains a certain proportion of sulphur, which is not indicated in the formula given, different specimens showing from 0·4 to 3 per cent., according to the method of preparation.[4] It has been shown that Salvarsan prepared from an amino-acid has the lowest sulphur content, from a nitro-acid under the most favourable conditions a slightly higher sulphur content, whilst from a nitro-acid under the least favourable conditions the sulphur content is the highest. From these observations it is obvious that the sulphur must be introduced during the reduction of the nitrohydroxy-compound through the reducing agent employed. The reduction of the nitro-group by means of sodium hydrosulphite is extremely rapid and not easy to control, but it has been shown that the formation of products with a high sulphur content is not due to inpurities in the commercial sodium hydrosulphite.[5] It was therefore suggested that the sulphur in Salvarsan might be present as a sulpho-acid,[6] and this is actually found to be the case. The principal sulpho-acid present is 3 : 3′-diamino-4 : 4′-dihydroxy-5-sulphoarsenobenzene,[7] which, along with other sulphur derivatives of Salvarsan,[8] is dealt with on pp. 381–384.

Oxidation of Salvarsan.—Although solid arsenobenzene combines with oxygen so vigorously that it frequently explodes, this property diminishes in the substituted derivatives of arsenobenzene, and Salvarsan, Sodium Salvarsan, Salvarsan Glycide and Silver Salvarsan adsorb only a small proportion of oxygen. This gas is quantitatively evolved when the products are gently warmed *in vacuo*.[9] Salvarsan dihydrochloride is extremely stable towards atmospheric oxygen, but the addition of alkali leads to a rapid increase in the rate of oxidation.[10] The dihydrochloride in 6 to 10 per cent. aqueous solution absorbs molecular oxygen very slowly without any colour change taking place, but an increase in the viscosity of the solution is noticed. In the case of alkaline solutions the rate of absorption of oxygen increases greatly as the alkalinity increases,

[1] Fargher and Pyman, *Trans. Chem. Soc.*, 1920, 117, 370.
[2] Fargher and Pyman, *ibid.*; see Gaebel, *Apoth. Zeit.*, 1911, 26, 215; Kober, *loc. cit.*
[3] Raiziss and Gavron, *J. Amer. Chem. Soc.*, 1921, 43, 582.
[4] Christiansen, *J. Amer. Chem. Soc.*, 1922, 44, 847, 854; see Fargher and Pyman, *loc. cit.*
[5] Christiansen, *loc. cit.*, p. 2334.
[6] Strzyzowski, *Zentr. Biochem. Biophys.*, 1918, 19, 794.
[7] King, *Trans. Chem. Soc.*, 1921, 119, 1118.
[8] Christiansen, Norton, and Shohan, *J. Amer. Chem. Soc.*, 1925, 47, 2712.
[9] Maschmann, *Ber.*, 1926, 59, [B], 1142.
[10] Voegtlin and Smith, *J. Pharm. Exp. Ther.*, 1920, 16, 199.

the solution becoming dark and solid matter separating out. Although this oxidation is mainly due to the vicinal amino- and hydroxyl-groups, the arseno-group enters in to some extent, as a 7 per cent. yield of 3-amino-4-hydroxyphenylarsinic acid may be isolated.[1]

Physico-Chemical Properties of Salvarsan Solutions.—These solutions show the characteristic properties of colloids,[2] dialysis through a parchment membrane showing but slight diffusion, whilst in methyl alcohol solution diffusion takes place more readily. The disodium salt diffuses about four times as quickly as the free hydrochloride.[3] The viscosity of aqueous solutions of Salvarsan increases from the moment of preparation until an approximately constant value is reached. This value is much higher than the initial value. As the concentration of the solution increases, the initial velocity of increase of viscosity and the final value are affected, and the presence of acid or alkali also has a marked effect. With rise of temperature the viscosity more quickly attains its maximum value, but this value is diminished. The viscosity of dilute solutions diminishes on keeping.[4] The p_H value of Salvarsan is 7·60; of the dihydrochloride, 2·41; of the monohydrochloride, 3·00; of the monosodium salt, 10·88; and of the disodium salt, 11·43. The presence of an isoelectric point at p_H value about 3·4 is indicated.[5]

Salvarsan dipicrate is obtained by the interaction of an aqueous solution of Salvarsan and a one per cent. aqueous picric acid solution at 0° C. It is a deep yellow powder, sparingly soluble in water, moderately soluble in ethyl alcohol, and readily soluble in methyl alcohol or moist acetone.[6]

Salvarsan dinitrate.—To obtain this salt, Salvarsan is dissolved in dry methyl alcohol and the solution treated with the theoretical quantity of nitric acid, afterwards pouring the whole into dry ether. The product is a pale yellow, granular solid, readily soluble in water and alcohols, and decomposing without melting on heating.

Reactions of Salvarsan. — The yellow aqueous solution of the dihydrochloride is acid to litmus and turns Congo red slightly violet. When two gram-molecules of caustic alkali are added to the solution, the free base separates, but redissolves in excess of the reagent to give the monosodium salt, which can be precipitated by carbon dioxide. With *p*-dimethylaminobenzaldehyde in dilute hydrochloric acid, an orange coloration is produced, followed by a precipitate of orange needles. With phosphotungstic acid the usual coloration due to phenols is produced, and with silver nitrate a red complex is precipitated. A number of investigations have been conducted with a view to finding the best method for estimating arsenic in Salvarsan.[7]

The preparation of derivatives of Salvarsan which are readily soluble in water, such solutions having a neutral reaction, has been the subject

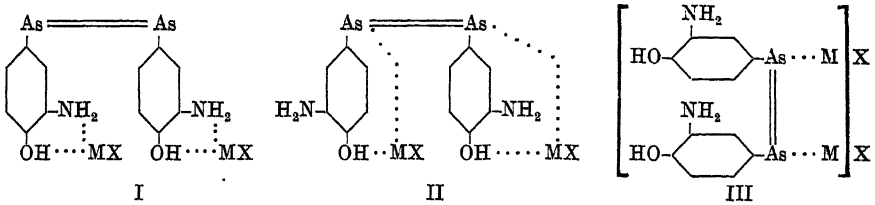
[1] Maschmann, *Ber.*, 1926, 59, [B], 1148.
[2] Danysz, *Ann. Inst. Pasteur*, 1917, 31, 114.
[3] Raiziss and Gavron, *J. Pharm. Exp. Ther.*, 1922, 20, 163.
[4] Klemensiewicz, *Bull. Soc. chim.*, 1920, [iv.], 27, 820; see Voegtlin, Johnson, and Dyer, *U.S. Public Health Rep.*, 1924, 179.
[5] Hunter and Patrick, *J. Lab. Clin. Med.*, 1925, 10, 343.
[6] Gray, *Trans. Chem. Soc.*, 1923, 123, 640.
[7] Kircher and Ruppert, *Ber. Deut. pharm. Ges.*, 1920, 30, 419; *Arch. Pharm.*, 1924, 262, 613; Myttenaere, *Chim. et Ind.*, 1923, 10, 403; Sensi, *Annali Chim. Appl.*, 1926, 16, 491; see also Fargher, *Trans. Chem. Soc.*, 1919, 115, 992; Lehmann, *Apoth. Zeit.*, 1912, 27, 545; Ewins, *Trans. Chem. Soc.*, 1916, 109, 1356.

of much investigation,[1] as has also been the preparation of non-toxic solutions of Salvarsan,[2] and the manufacture of solutions of Salvarsan derivatives, from the point of view of stabilisation of arsenical drug solutions.[3]

The formation of stable alkali salts of Salvarsan in solid form has been investigated,[4] and Salvarsan Glucoside and Diglucoside are known.[5]

Compounds of Salvarsan and Metallic Salts.

Compounds with Silver Salts.[6]—These compounds have for many years given rise to considerable discussion, chemists being unable to agree as to their constitution. The first investigators considered them to be co-ordination compounds of the types I, II, III, where M is the metal and X is the acid radical:



Considering these formulæ,[7] I may be dismissed, since *o*-aminohydroxyphenylarsinic acids do not give metallic additive products, which they ought to do if the co-ordinative properties are due to the amino- and hydroxyl-groups. Formula II is inadmissible, since unsubstituted arsenobenzene also gives additive compounds. This leaves only III, in which the co-ordination takes place between the arsenic atoms and the metallic salts. The next suggestion was that the dark-coloured Sodium-silver Salvarsan might contain colloidal silver.[8] Evidence here is again conflicting, some investigators claiming that when Sodium-silver Salvarsan is dialysed, arsenic diffuses to the extent of about 26 per cent. in thirty-six hours, whilst the silver completely remains behind,[9] another worker claiming that the solution passes entirely through the dialyser.[10] From these results it is at present impossible to say whether the silver is chemically combined or in a colloidal form.

Another formula has been put forward in which the silver complex

[1] German Patents, 249726, 245756, 260235, 263460, 264014, 271893, 250745, 272035, 261542; American Patent, 1048002; French Patent, 441392; British Patent, 5797 (1912).

[2] American Patents, 1621121, 1559899.

[3] British Patents, 155577 (1921), 221565 (1924), 272567 (1925); American Patent, 1588252; Christiansen, *J. Amer. Chem. Soc.*, 1921, 43, 2202; German Patent, 375718.

[4] German Patent, 264266; French Patent, 445325; British Patent, 15931 (1912); American Patents, 1059983, 1078135, 1611461, 133028.

[5] Aubry and Dormoy, *Compt. rend.*, 1922, 175, 819; Contardi and Cazzani, *Atti I. Congr. naz. Chim. pur. appl.*, 1923, p. 329; from *Chem. Zentr.*, 1924, i. 2512. The oxidation of Salvarsan to aminophenolarsinic acid by hydrogen peroxide in alkaline solution is dealt with in German Patent, 224953.

[6] For the estimation of arsenic and silver in silver arsenobenzenes, see Cazzani, *Boll. Chim. farm.*, 1925, 64, 513.

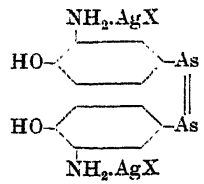
[7] Ehrlich and Karrer, *Ber.*, 1915, 48, 1634; Karrer, *ibid.*, 1919, 52, [B], 2319.

[8] Kolle, *Deut. med. Woch.*, 1918, 1177.

[9] Raiziss and Gavron, *J. Pharm. Exp. Ther.*, 1922, 20, 163.

[10] Bauer, *Arb. Inst. exper. Ther. Georg Speyer-Hause*, 1919, 8, 45; *Ber.*, 1920, 53, [B], 416.

is considered to be united by the residual affinity of the nitrogen atom: [1]



This constitution was suggested on the following grounds: (1) That Salvarsan does not contain colloidal silver. (2) That one gram-molecule of Salvarsan or its derivatives reacts with two gram-molecules of silver nitrate as follows: $[HCl.NH_2(OH).C_6H_2Cl.As=]_2+2AgNO_3=[AgCl.NH_2(OH).C_6H_2Cl.As=]_2+2HNO_3$. (3) That Silver Salvarsan contains silver oxide in complex form. (4) That if the complex is formed by the residual affinities of the arsenic atoms, the latter would tend to pass into the quinquevalent state, which would destroy the therapeutic power of the compound. (5) The capacity for forming complex salts is well established in the case of the amino-group.

Later, two isomeric Silver Salvarsans were isolated: [2] (I), $NH_2.C_6H_3(OH).As=As.C_6H_3(OH).NH_2$ . . . AgOH, and (II), $NH_2.C_6H_3(OH).As=As(. . . AgOH).C_6H_3(OH).NH_2$. This result apparently justifies both co-ordination formulæ given above. The formation of these isomeric Silver Salvarsans seems to be due to the incomplete expulsion of the acid radical when sodium carbonate replaces the sodium hydroxide in the preparation. The result is the formation of a compound $As(Ag)Cl(OH.C_6H_3.NH_2)=As.C_6H_3(OH).NH_2$. Silver Salvarsan is considered to be the sodium salt of this derivative, having the formula $As(Ag)(ONa)(ONa.C_6H_3.NH_2)=As.C_6H_3(ONa).NH_2$, and the brown compound obtained by the passage of carbon dioxide into Silver Salvarsan solution is $As(Ag)(OH)(OH.C_6H_3.NH_2)=As.C_6H_3(OH).NH_2$.[3]

Colloidal silver chloride and oxide have recently been isolated from methyl alcohol or aqueous solutions of Silver Salvarsan and Sodium-silver Salvarsan respectively.[4]

The following is an account of the experimental details necessary for the preparation of these silver derivatives:

(1) (*a*), *Using Two Gram-molecules of Silver Nitrate*, $C_{12}H_{12}O_2N_2As_2$, 2HCl, $2AgNO_3$.—One gram of Salvarsan in 30 c.c. of methyl alcohol is mixed with 0·716 gram of silver nitrate. The reddish-brown liquid is then poured into ether, when a brown, flocculent precipitate settles, which is removed and washed with ether. It is soluble in water, methyl alcohol, sodium hydroxide, and glycerine.[5] The nitrate derivative is dissolved in water and sodium chloride added, a brownish-yellow chloride being precipitated. This is moderately soluble in water, but sparingly soluble in salt solution:

$$\begin{matrix} R.As \; . \; . \; . \; AgNO_3 \\ \| \\ R.As \; . \; . \; . \; AgNO_3 \end{matrix} \xrightarrow{2NaCl} \left[\begin{matrix} R.As \; . \; . \; . \; Ag \\ \| \\ R.As \; . \; . \; . \; Ag \end{matrix}\right] Cl \; Cl + 2NaNO_3$$

[1] Binz, *Arb. Inst. exper. Ther. Georg Speyer-Hause*, 1919, 8, 25; Binz, Bauer, and Hallstein, *Ber.*, 1920, 53, [B], 416. [2] Binz and Ludwig, *Ber.*, 1922, 55, [B], 3826.
[3] Binz, Bauch, and Urbschat, *Zeitsch. angew. Chem.*, 1925, 38, 740.
[4] Gray, *Trans. Chem. Soc.*, 1923, 123, 635.
[5] Karrer, *loc. cit.*; see Gray, *loc. cit.*; German Patent, 270253.

(*b*), *Using One Gram-molecule of Silver Nitrate.*—1·08 grams of silver nitrate in 52 c.c. of methyl alcohol when added to 3 grams of Salvarsan in 52 c.c. of methyl alcohol give a clear red solution. This is added to 79 c.c. of dry ether at 0° C., when 1·3 grams of solid are obtained.[1]

(2) *Isomeric Silver Salvarsans.*[2]

(I), $NH_2.C_6H_3(OH).As=As.C_6H_3(OH).NH_2$ . . . AgOH.

1·5 grams of Salvarsan in 125 c.c. of water are treated with 25 c.c. of 0·1*N* silver nitrate solution, then 5 c.c. of concentrated sodium carbonate are added. A brown, amorphous powder is precipitated, which is washed with water, alcohol, and ether. It is insoluble in sodium carbonate solution or ammonium hydroxide, soluble in dilute hydrochloric acid, readily soluble in sodium hydroxide, the solution immediately becoming dark brown. It is unaffected by hypophosphorous acid.

(II), $NH_2.C_6H_3(OH).As=As(. . . AgOH).C_6H_3(OH).NH_2$.

1·5 grams of Salvarsan in 125 c.c. of water are mixed with 26 c.c. of 0·1*N* silver nitrate solution, 3·2 c.c. of 15 per cent. sodium hydroxide are added and carbon dioxide passed in. The product obtained is dark brown, soluble in sodium carbonate, sodium hydroxide, ammonium hydroxide, and dilute hydrochloric acid. It is reduced by hypophosphorous acid.

(3) When the preceding isomerides are treated with hydrochloric acid they are converted into corresponding monosilver chlorides, the change taking place much more rapidly with (I) than with (II). A *monosilver chloride dihydrochloride, dinitrate* and *sulphate* have been isolated.[3]

$C_{12}H_{12}O_2N_2As_2$, 2AgI, $6H_2O$.—This *di-silver iodide* is obtained by dissolving 6·6 grams of Salvarsan in 100 c.c. of water and 10 c.c. of pure 2·9*N* hydriodic acid. A solution of 3 grams of silver nitrate in 75 c.c. of water is then stirred in. An orange-red colloidal precipitate separates out. Yield, 6·3 grams. Attempts to convert this into the base, $As_2[C_6H_3(NH_2).OH]_2$, Ag_2O, have not been altogether successful owing to oxidation.

(4) Another preparation is made by dissolving one gram-molecule of Salvarsan, one gram-molecule of freshly prepared silver halide and one gram-molecule of antimony trichloride in water, by the aid of heat, then adding a concentrated solution of citric acid, followed by a dilute solution of sulphuric acid to precipitate the base. The silver salt may be replaced by salts of gold, platinum, or copper.[4]

Copper Derivatives.—(1), $C_{12}H_{12}O_2N_2As_2$, HCl, $CuCl_2$.[5]—3 grams of Salvarsan in 60 c.c. of water are treated with 2 grams of cupric chloride in 50 c.c. of water, and after a few minutes a gelatinous yellow precipitate separates. Yield, 2·3 grams.

(2), $C_{12}H_{12}O_2N_2As_2$, 2HCl, $CuCl_2$.[6]—To a solution of 100 grams of Salvarsan in 1600 c.c. of methyl alcohol, 16 c.c. of saturated alcoholic hydrochloric acid are added and a solution of 35·8 grams of crystallised cupric chloride ($2H_2O$) in 400 c.c. of methyl alcohol run in, with stirring.

[1] Gray, *loc. cit.*
[2] Binz and Ludwig, *loc. cit.*
[3] Binz, Bausch, and Urbschat, *loc. cit.*
[4] British Patent, 104497 (1916).
[5] Binz, Bauer, and Hallstein, *loc. cit.*
[6] Ehrlich and Karrer, *loc. cit.*; see German Patent, 270253.

The copper salt separates and the whole is poured into 8000 c.c. of ether, the brisk red precipitate collected, washed with ether, and dried *in vacuo*. The operations are best conducted in an atmosphere of carbon dioxide or nitrogen. The product is a red to orange-yellow powder, moderately soluble in water, readily soluble in glycerine and glycol, also in 2*N* sodium hydroxide. In the latter case no copper hydroxide separates unless the solution is heated.

(3), $C_{12}H_{12}O_2N_2As_2$, 2HCl, $2CuCl_2$.—This may be prepared in two ways, either as in the preceding case, but doubling the amount of cupric chloride, or from 3-amino-4-hydroxyphenylarsinic acid, as follows :[1] 10 grams of the arsinic acid are dissolved in 100 c.c. of water and 43 c.c. of 2*N* sodium hydroxide, and a solution of 3·64 grams of cupric chloride stirred in at 50° C. An aqueous solution containing 100 grams of sodium hydrosulphite is added, then 43 c.c. of 2*N* sodium hydroxide, and the whole stirred at 50° C. for two hours. The copper derivative separates in yellowish-brown flocks, which are removed, washed with water and dried *in vacuo*. It is very soluble in dilute hydrochloric acid and in sodium hydroxide.

Gold Derivatives.[2]—Methyl alcohol solutions of Salvarsan and gold chloride are mixed and treated with ether. The gold derivative separates, and is isolated as a brownish-yellow powder, very soluble in sodium hydroxide and in alcohol. Another mode of preparation is as follows: 3 grams of 3-amino-4-hydroxyphenylarsenoxide in the requisite amount of dilute hydrochloric acid are treated with a solution of 2·25 grams of gold chloride in water, then with 30 grams of sodium hydrosulphite. The gold compound separates as a golden-yellow precipitate.

A mixed *silver-gold compound*[3] is formed by adding one gram-molecule of silver nitrate and one gram-molecule of gold chloride dissolved in methyl alcohol to a solution of Salvarsan in the same solvent. The product is a brownish-red powder, readily soluble in water or glycerine.

Platinum Derivatives.—These are prepared in a similar way to the gold compounds, using platinic chloride. The compounds are brown powders, soluble in water, alcohols, and sodium hydroxide.

Palladium Derivative.—A palladium derivative has been isolated which is almost black, and is prepared in the usual manner.

Mercury Derivatives.—The mode of preparation of these compounds is similar to that adopted for the preceding compounds. When mercuric chloride is used and the operations are carried out in methyl alcohol, a yellow powder results, which is soluble in methyl alcohol, glycerine, ethylene glycol, and acidified potassium iodide solution.[4] It is decomposed by water or sodium hydroxide and is only slightly soluble in dilute acids, but if treated with antimony compounds, *antimonyl derivatives* are obtained, which are more soluble and are stable in alkaline solutions.[5] The decomposition by water is said to give rise to colloidal mercury and 3-amino-4-hydroxyphenylarsenoxide, $OH.C_6H_3.(NH_2).AsO$. If an excess of mercuric chloride is used, the oxidation proceeds to *o*-aminophenol, mercurous chloride, and arsenious

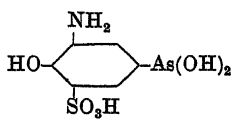
[1] Ehrlich and Karrer, *loc. cit.*; see German Patent, 270258.
[2] Ehrlich and Karrer, *loc. cit.*; German Patents, 270253, 268220, 270258.
[3] German Patent, 270253.
[4] Ehrlich and Karrer, *loc. cit.*; German Patent, 270253.
[5] British Patent, 104496 (1916).

acid.[1] If mercuric iodide replaces the chloride, a more stable compound is obtained, which readily dissolves in water. A more recent method of preparing mercurated Salvarsan (prophylactic)[2] consists in treating an acidified solution of Salvarsan dihydrochloride in methyl alcohol with a solution of mercuric chloride in the same solvent. The precipitate obtained is mixed with glycerine, gelatine, and mercuric chloride, to give a product of firm consistency at ordinary temperatures, but which may be less viscous at body temperature.[3]

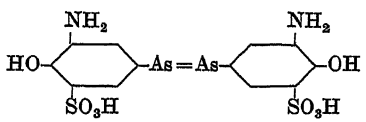
Sulphur Derivatives Present in Salvarsan.

The reduction of 3-nitro-4-hydroxyphenylarsinic acid by sodium hydrosulphite is very rapid and difficult to control, and consequently when this arsinic acid is used in the preparation of Salvarsan, secondary reactions occur, with the formation of sulphur-containing arsenicals, which give a sulphur content to Salvarsan itself. Since this sulphur content is variable with different samples, it is of importance that the experimental conditions underlying the reduction of the nitro-acid to the corresponding amino-acid should be thoroughly understood. In the following pages the reduction is described as carried out by two processes—(*a*) using sodium hydrosulphite, (*b*) using sodium bisulphite. Very definite products have been obtained in case (*a*), whilst in case (*b*) the reducing agent may act in three distinct ways, according to the experimental conditions. The work so far carried out seems to show that the main sulphur-containing impurity in commercial Salvarsan is 3 : 3′-diamino-4 : 4′-dihydroxy-5-sulpharsenobenzene monohydrochloride, which may be present in varying portions in different samples.

3-Amino-4-hydroxy-5-sulphophenylarsenious acid and **3 : 3′-Diamino-4 : 4′-dihydroxy-5 : 5′-disulphoarsenobenzene,**[4]



I



II

These two compounds, I and II respectively, result during the reduction of 3-nitro-4-hydroxyphenylarsinic acid to the amino-acid using sodium hydrosulphite, the isolation of the derivatives being effected as follows : 106 grams of 3-nitro-4-hydroxyphenylarsinic acid in 800 c.c. of normal sodium hydroxide are treated with 216 grams of sodium hydrosulphite, added in four equal portions, the temperature being maintained at −2° C. during each addition and the whole well stirred. The stirring is maintained for one hour after the addition of the hydrosulphite, and the product cooled in ice overnight, 48 grams of 3-amino-4-hydroxyphenylarsinic acid resulting. To the filtrate, 120 c.c. of concentrated hydrochloric acid are added and the liquor kept for a week at 0° C. ; the solid is then removed and stirred with 100 c.c. of water at 40° C., the operation

[1] Binz and Bauer, *Zeit. angew. Chem.*, 1921, 34, 261.

[2] American Patent, 1559899.

[3] For the manufacture of complex metallic arsenobenzene compounds, see American Patent, 1616204 ; British Patent, 214237 (1924).

[4] King, *Trans. Chem. Soc.*, 1921, 119, 1107.

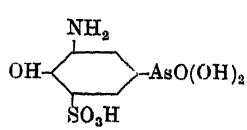
removing sodium sulphate. The undissolved solid (13·6 grams) is suspended in 80 c.c. of water and dissolved by adding 25 c.c. of 2*N* ammonia, the *calcium salt* of the arseno-acid being precipitated by the addition of 10 c.c. of four per cent. calcium chloride. The solution is then centrifuged, the supernatant liquor siphoned off and acidified to Congo red paper with hydrochloric acid, when pure 3-amino-4-hydroxy-5-sulphophenylarsenious acid (I) separates. This process is repeated until all the arsenious acid has been extracted, about 9·3 grams being isolated. The gelatinous calcium salt of the arsenobenzene in air-free water is acidified with hydrochloric acid, and the gelatinous acid obtained by centrifuging and re-suspending in fresh water, until all chloride is removed from the supernatant liquor. The gelatinous solid (II) is dried *in vacuo* over sulphuric acid, a yield of 2·75 grams being obtained.

The arsenious acid (I) may also be obtained by suspending 1 gram of 3-amino-4-hydroxy-5-sulphophenylarsinic acid in 8 c.c. of water and 4·5 c.c. of concentrated hydrochloric acid containing 0·25 gram of potassium iodide, then passing in sulphur dioxide for one hour. A yield of 0·95 gram is isolated.[1]

The 3-amino-4-hydroxy-5-sulphophenylarsenious acid, obtained as described, crystallises in minute, elongated plates with pointed ends, very sparingly soluble in water, insoluble in acids, but dissolving on addition of sodium nitrite; it can then be coupled with β-naphthol to give a reddish-brown soluble dye. The sulphur is not removed by heating with alkaline lead acetate solution, and the acid is very stable towards a boiling solution of dilute sodium hydroxide. In dilute ammonia, the acid gives no precipitate with lithium or calcium chloride and magnesia mixture, but an abundance of sphæro-crystals are produced on the addition of barium chloride. Metallic silver is precipitated from ammoniacal silver nitrate solution on addition of the acid, and iodine solution is decolorised.

The 3 : 3′-diamino-4 : 4′-dihydroxy-5 : 5′-disulphoarsenobenzene may also be formed by reducing 3-amino-4-hydroxy-5-sulphophenyl-arsenious acid with sodium hydrosulphite or hypophosphorous acid, or by using the corresponding arsinic acid and reducing it with hypophosphorous acid in glacial acetic acid solution in the presence of a little hydriodic acid at 55° C. The compound is insoluble in water and does not yield salts with acids, but it can be diazotised and coupled with β-naphthol. It is soluble in sodium hydroxide, sodium carbonate, and dilute ammonia, but is precipitated by excess of the reagents. Its solution in sodium bicarbonate is not precipitable in this way. Calcium and barium chlorides, magnesia mixture, lanthanum and thorium nitrates, give gelatinous precipitates with ammoniacal solutions of the arseno-compound. Hydrolysis of the compound yields 6-aminophenol-*o*-sulphonic acid.

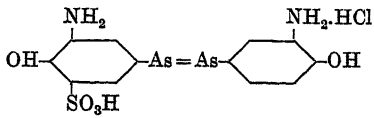
3-Amino-4-hydroxy-5-sulphophenylarsinic acid,



[1] King, *Trans. Chem. Soc.*, 1921, 119, 1420.

results when the corresponding arsenious acid is oxidised at 40° C. with 3 per cent. hydrogen peroxide solution. The acid decomposes at 258° C., is soluble in four times its weight of boiling water and yields a reddish-brown, soluble azo-dye. It instantly reduces ammoniacal silver nitrate solution, and its hot ammoniacal solution gives crystalline *barium* and *calcium salts* on addition of the respective chlorides.

3:3′-Diamino-4:4′-dihydroxy-5-sulphoarsenobenzene hydrochloride,



3-Amino-4-hydroxy-5-sulphophenylarsinic acid (1·15 grams) and 0·85 gram of 3-amino-4-hydroxyphenylarsinic acid are reduced at 60° C. by a mixture of 10 c.c. of hypophosphorous acid (density 1·14), 5 c.c. of water, 5 c.c. of glacial acetic acid, and a crystal of potassium iodide. A quantitative yield of the arseno-derivative is obtained in an hour.

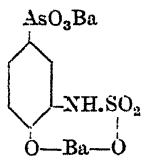
The hydrochloride dissolves slowly in water, is soluble in 2*N* sodium hydroxide, but is precipitated by excess of reagent. Its rate of solution in sodium carbonate solution is slow and it is not precipitated by excess, whilst it is insoluble in sodium bicarbonate solutions. It dissolves in ammonium hydroxide, the solution forming gelatinous precipitates with calcium, barium or magnesium chloride, but with lithium chloride only on adding excess.[1]

Reduction of 3-Nitro-4-hydroxyphenylarsinic Acid with Sodium Bisulphite.[2]

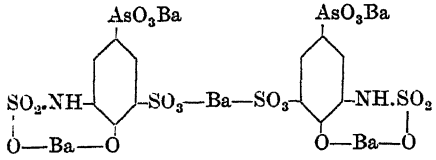
A solution of 20 grams of the acid in 300 c.c. of water containing 9·12 grams of sodium hydroxide (sufficient to form the trisodium salt) is added to 42 grams of sodium bisulphite in 300 c.c. of water. After forty-six hours' standing at room temperature, 2·8 grams of sodium hydroxide are added, as the solution smells of sulphur dioxide, and after another twenty-four hours, 8 grams of sodium bisulphite in 30 c.c. of water poured in. In six days the reaction is complete, and 150 grams of barium hydroxide ($8H_2O$) in 320 c.c. of water are added to the clear, brown solution. The barium sulphite and sulphate thereby precipitated are filtered off, and the filtrate treated with saturated sodium carbonate to remove the barium as carbonate. The filtrate from the latter contains the sodium salts of the organic acids on p. 384, sodium carbonate and sodium hydroxide. After concentration to 100 c.c., the pasty mass is washed many times with 80 c.c. portions of alcohol, when an oil remains undissolved. This oil, in aqueous solution, is treated with an excess of barium bromide, and after filtering off the barium salts of the organic acids, is fractionally precipitated by the addition of successive portions of alcohol containing barium bromide.

[1] For the sulphur content of Salvarsan, see Christiansen, *J. Amer. Chem. Soc.*, 1923, 45, 1316. A *Salvarsan polyarsenide* has been described by Christiansen, *ibid.*, p. 2182; compare also, Christiansen, *ibid.*, p. 1807.

[2] Christiansen, Norton, and Shohan, *J. Amer. Chem. Soc.*, 1925, 47, 2716.



I

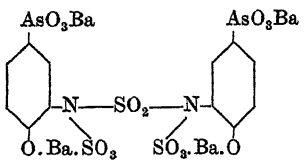


II

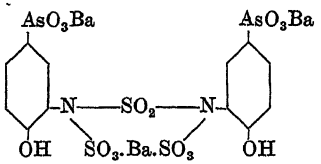
The first fraction is *dibarium 2-hydroxy-5-arsinobenzenesulphamate* (I), which separates as a flocculent, yellow precipitate, the dry yellow powder (3 grams) being readily soluble in water.

The second fraction is *tribarium 2-hydroxy-3-sulpho-5-arsinobenzenesulphamate* (II), of which 0·8 gram is isolated in the form of white needles after recrystallisation from boiling water. It dissolves readily in cold dilute hydrochloric acid, the solution on heating depositing barium sulphate. Hydrolysis of the sulphamate by about 20 per cent. hot sulphuric acid gives 3-amino-4-hydroxy-5-sulphophenylarsinic acid (p. 382).

The third fraction consists of *tetrabarium 2 : 2′-dihydroxy-5 : 5′-diarsinosulphoanilide-N : N′-disulphonate* (III).



III



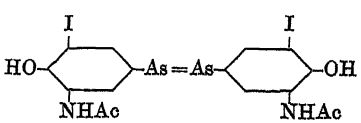
IV

This product is obtained as a dense yellow powder, the yield being 12·6 grams. When hydrolysed, it yields 3-amino-4-hydroxyphenylarsinic acid, the same as substance I. When carbon dioxide is passed through an aqueous solution of III, barium carbonate is precipitated, and alcohol then precipitates the yellow *tribarium salt* (IV) from the filtrate.

If the monosodium salt of 3-nitro-4-hydroxyphenylarsinic acid is used instead of the trisodium salt, reduction with sodium bisulphite at room temperature gives mainly 3-nitro-4-hydroxyphenylarsenoxide, whilst in boiling aqueous solution the arsenic is eliminated and *o*-nitrophenol obtained.[1]

Halogen Derivatives of Salvarsan.

5 : 5′-Di-iodo-3 : 3′-diacetylamino-4 : 4′-dihydroxyarsenobenzene,[2]

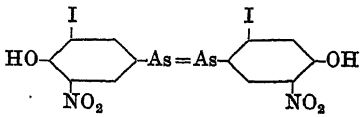


5-Iodo-3-acetylamino-4-hydroxyphenylarsinic acid (2·7 grams) in 100 c.c. of water containing 3 grams of sodium bicarbonate is treated with 15 grams of sodium hyposulphite and the mixture maintained at 55° to

[1] See King, *loc. cit.* [2] Macallum, *J. Chem. Soc.*, 1926, p. 1645.

60° C., in an atmosphere of nitrogen, for four to five hours. The product, 1·66 grams or 70 per cent. yield, is well washed and dried *in vacuo*. It is a lemon-yellow powder, sintering at about 180° C. and melting at 194° C., soluble in acetone, phenol, benzaldehyde, or pyridine.

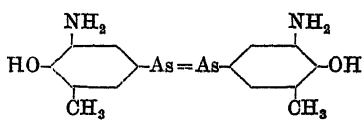
5 : 5′-Di-iodo-3 : 3′-dinitro-4 : 4′-dihydroxyarsenobenzene,



results when a solution of 5-iodo-3-nitro-4-hydroxyphenylarsinic acid in methyl alcohol is treated with hypophosphorous acid at 55° to 60° C. It is a stable, orange-yellow powder, darkening at about 200° C., has a similar solubility to the foregoing compound, and is rendered water-soluble by adding alkali hydroxide or carbonate.

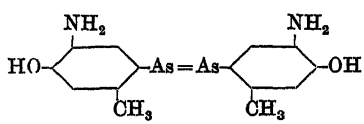
C-Methyl Derivatives of Salvarsan.

5 : 5′-Diamino-3 : 3′-dimethyl-4 : 4′-dihydroxyarsenobenzene,



results in 70 per cent. yield when 5-nitro-4-hydroxy-3-methylphenylarsinic acid is reduced by sodium hydrosulphite.[1] The *dihydrochloride* is a pale yellow, microcrystalline powder, readily soluble in water or methyl alcohol, less soluble in ethyl alcohol, and insoluble in ether or acetone.

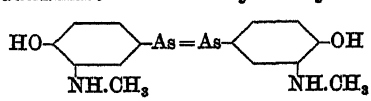
5 : 5′-Diamino-2 : 2′-dimethyl-4 : 4′-dihydroxyarsenobenzene,[2]



This derivative is obtained by reducing 5-nitro-4-hydroxy-2-methylphenylarsinic acid by means of sodium hydrosulphite. It has similar properties to the preceding compound.

N-Methyl Derivatives of Salvarsan.

3 : 3′-Dimethyldiamino-4 : 4′-dihydroxyarsenobenzene,[3]



This is obtained by reducing 3-methylamino-4-hydroxyphenylarsinic acid with hydrosulphite. The *dihydrochloride* is a greyish-white, microcrystalline powder. It gives a brownish-orange liquid with *p*-dimethylaminobenzaldehyde, but no subsequent precipitate separates as noted

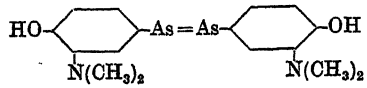
[1] Fargher, *Trans. Chem. Soc.*, 1919, 115, 990; compare German Patent, 224953; American Patent, 986148.

[2] German Patent, 245536.

[3] Bertheim, *Ber.*, 1912, 45, 2130.

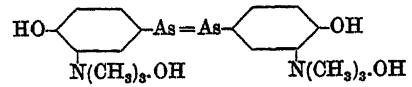
in the case of Salvarsan. The arseno-compound forms a sparingly soluble sulphate.

3 : 3′-Tetramethyldiamino-4 : 4′-dihydroxyarsenobenzene,



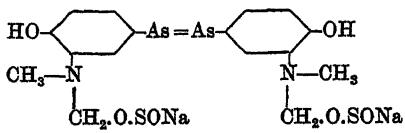
is the reduction product of 3-dimethylamino-4-hydroxyphenylarsinic acid. It gives a yellowish-grey *dihydrochloride*, readily soluble in water or methyl alcohol.

3 : 3′ - Hexamethyldiammonium - 4 : 4′ - dihydroxyarsenobenzene,



results when 3-trimethylammonium-4-hydroxyphenylarsinic acid is reduced with hydrosulphite. It is a light yellow powder, insoluble in water, soluble in dilute hydrochloric acid or sodium hydroxide.

3 : 3′-Dimethylamino-4 : 4′-dihydroxyarsenobenzene-N-N′-dimethylene sulphinate,[1]

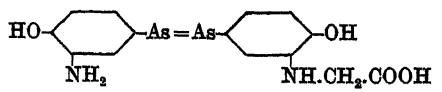


This is obtained when 3 : 3′-dimethylamino-4 : 4′-dihydroxyarsenobenzene dihydrochloride in aqueous alkali is heated for thirty minutes at 55° C. with sodium formaldehydesulphoxylate. The filtered solution is treated with carbon dioxide until neutral to phenolphthalein, poured into alcohol, and the arseno-compound precipitated by the addition of ether. If the sulphoxylate is replaced by formaldehyde and sulphurous acid, a *monoformaldehyde hydrogen sulphite derivative* results, which on further treatment yields a *diformaldehyde hydrogen sulphite compound*. The dihydrochloride of 3 : 3′-dimethylamino-4 : 4′-dihydroxyarsenobenzene gives a complex compound with silver nitrate, which with formaldehyde sodium hydrogen sulphite yields a *N-methyl sulphurous acid derivative*. Condensation of chloracetic acid and the parent arseno-compound gives a *N-acetic acid compound*.

3-Ethylamino-4-hydroxyphenylarsinic acid, M.pt. 270° C. with decomposition, on reduction yields *3 : 3′-diethylamino-4 : 4′-dihydroxyarsenobenzene*, which gives similar compounds to the methyl homologue.

Glycine Derivatives of Salvarsan.[2]

3-Amino-4 : 4′-dihydroxyarsenobenzene-3′-aminoacetic acid,



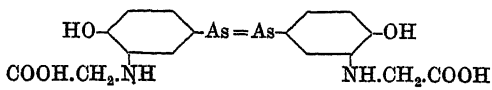
[1] German Patent, 423036.

[2] German Patent, 250745; British Patent, 5797 (1912); French Patent, 441392; American Patent, 1048002.

Salvarsan dihydrochloride (100 grams) in 300 c.c. of methyl alcohol and 300 c.c. of water containing 4 gram-molecules of sodium hydroxide is treated with a solution of 50 grams of sodium chloroacetate and 36 grams of potassium iodide in 5 to 10 parts by weight of water. The mixture is heated at 60° to 65° C. in an inert atmosphere for two to three hours, then faintly acidified, when the glycine derivative is precipitated. The product is a yellow powder, readily soluble in alkali and excess of acid, but insoluble in all the usual solvents. The *sodium salt* is yellowish-brown and dissolves readily in water with neutral reaction. The *potassium* and *ammonium salts* are also known.

If the sodium chloroacetate in the above preparation is replaced by α-bromopropionic acid, the corresponding *aminopropionic acid derivative* is obtained. It has similar properties to the aminoacetic acid compound.

4 : 4′-Dihydroxyarsenobenzene-3 : 3′-diaminoacetic acid,



results when the foregoing monoaminoacetic acid derivative is treated with bromoacetic acid at 60° to 65° C. The solution is neutralised with sodium hydroxide and the *disodium salt* precipitated by alcohol or acetone. It is yellowish-brown and dissolves in water, forming a neutral solution.

Condensation Products of Salvarsan with Aldehydes.[1]

The interaction of Salvarsan and aldehydes leads to the production of compounds of the type $As_2[C_6H_3(OH).NH.CH(OH).R]_2$, the general method of preparing these derivatives being as follows :

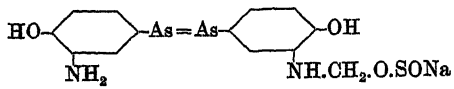
3 : 3′-Diamino-4 : 4′-dihydroxyarsenobenzene dihydrochloride in methyl alcohol is treated with four molecular proportions of aqueous sodium hydroxide, and two molecular proportions of the requisite aldehyde are added. The mixture is then boiled under reflux for two hours, or in some cases it is only necessary to stir for two hours in an inert atmosphere. The solution is then neutralised with hydrochloric acid to precipitate the condensation product. The compounds are solids, reddish-brown or yellow in colour, and cannot readily be crystallised from the usual organic solvents. The following are known: 3 : 3′-*Bis-o-α-dihydroxybenzylamino*-4 : 4′-*dihydroxyarsenobenzene*, $As_2[C_6H_3(OH).NH.CH(OH).C_6H_4.OH]_2$, M.pt. 182° C., which yields an orange-yellow *dihydrochloride*; 3 : 3′-*bis*-α-*hydroxy*-*p*-*methoxybenzylamino*-4 : 4′-*dihydroxyarsenobenzene*, a yellow powder, which softens at 80° C., then gradually decomposes; 3 : 3′-*bis*-*p*-α-*dihydroxy*-*m*-*methoxybenzylamino*-4 : 4′-*dihydroxyarsenobenzene*, M.pt. 175° to 176° C.; 3 : 3′-*bishydroxymethylamino*-4 : 4′-*dihydroxyarsenobenzene dihydrochloride*, decomposing at 185° to 190° C.; 3 : 3′-*bis*-α-*hydroxy*-*m*-*nitrobenzylamino*-4 : 4′-*dihydroxyarsenobenzene*, decomposing at 247° to 250° C.; and 3 : 3′-*bis*-α-*hydroxy*-γ-*phenylallylamino*-4 : 4′-*dihydroxyarsenobenzene*, $As_2[C_6H_3(OH).NH.CH(OH).CH=CH.C_6H_5]_2$, decomposing at 195° to 200° C., obtained by using cinnamaldehyde.

[1] Raiziss and Blatt, *J. Amer. Chem. Soc.*, 1922, 44, 2023.

The antimonyl derivative of 2 : 3 : 4-trihydroxybenzaldehyde when treated with Salvarsan in aqueous hydrochloric acid solution, gives the *diantimonyl derivative* of *di*-2 : 3 : 4-*trihydroxybenzylidene*-3 : 3′-*diamino*-4 : 4′-*dihydroxyarsenobenzene*, which is deep orange.[1]

Miscellaneous Derivatives of Salvarsan.

Sodium 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene-N-monomethylene sulphinate, *Neosalvarsan, Neoarsphenamine, Ehrlich* 914, *Neokharsivan, Novarsenbillon, Novarsenbenzol,*



This compound may be prepared in a variety of ways :

(1) *From* 3-*nitro*-4-*hydroxyphenylarsinic acid.*[2]—One part of the nitro-acid is dissolved in 5 parts of water containing 3·8 parts of 4 per cent. sodium hydroxide and the solution treated with 2 parts of sodium formaldehydesulphoxylate in 10 parts of water. The mixture is warmed on the water-bath, and when no more precipitate separates, the yellow solid is filtered and washed with water. This product is the free acid, and may be converted to the sodium salt by sodium hydroxide or sodium carbonate solution. The nitro-acid in this preparation may be replaced by 3-amino-4-hydroxyphenylarsinic acid, and the free sulphinic acid precipitated by normal hydrochloric acid.

(2) *From* 3-*nitro*-4-*hydroxyphenylarsenoxide.*[3]—100 grams of the oxide in 1000 c.c. of water containing 15 grams of sodium hydroxide are treated with a solution of 200 grams of sodium formaldehydesulphoxylate in 1000 c.c. of water, and the mixture warmed for one to two hours. After cooling, the free sulphinic acid is precipitated by acidification with dilute sulphuric acid. 3-Amino-4-hydroxyphenylarsenoxide may replace the nitro-oxide in this preparation.

(3) *From* 3 : 3′-*dinitro*-4 : 4′-*dihydroxyarsenobenzene.*[4]—100 grams of this compound are dissolved in 60 grams of sodium hydroxide solution (40° Bé.) and 1000 c.c. of water. Sodium formaldehydesulphoxylate (200 grams) in 1000 c.c. of water is added and the whole warmed for about two hours on the water-bath. The solution is then cooled and filtered and the free sulphinic acid precipitated by acidification with dilute sulphuric acid.

(4) *From Salvarsan.*[5]—(*a*) Salvarsan dihydrochloride (25 grams) in 250 c.c. of water is treated with 12·5 grams of sodium formaldehydesulphoxylate in 125 c.c. of water, the mixture being stirred during the addition. After an hour, 80 c.c. of 10 per cent. sodium carbonate are added and the clear yellow solution acidified with 12 per cent. hydrochloric acid to precipitate the free sulphinic acid. The use of 250 grams of sodium formaldehydesulphoxylate in 250 c.c. of water in this preparation gives the same product. The free sulphinic acid is converted into its sodium salt as follows : 20 grams of acid are dissolved in 70 to 80 grams of water by the aid of 20 c.c. of 2*N* sodium hydroxide, and this solution poured in a thin stream into 1000 c.c. of alcohol.

[1] Christiansen, *J. Amer. Chem. Soc.*, 1926, 48, 1365.
[2] German Patent, 263460.
[3] German Patent, 264014.
[4] German Patent, 271893.
[5] German Patent, 245756.

The precipitate is filtered off, washed with alcohol, and dried in a vacuum. The salt thus obtained contains one atom of sodium.

(*b*) 21 grams of Salvarsan base are introduced into 25 grams of sodium formaldehydesulphoxylate in 60 c.c. of water and the mixture gently warmed on the water-bath until complete solution is obtained. The sulphinic acid is then precipitated by the addition of 25 c.c. of concentrated hydrochloric acid. The product thus formed contains two sulphinic acid groups and the sodium salt two atoms of sodium.

(*c*) 50 parts of Salvarsan dihydrochloride in 200 parts of ethylene glycol are treated with 31 parts of sodium formaldehydesulphoxylate in 50 parts of water, and the whole stirred. After five minutes the solution is neutralised with sodium carbonate, then poured into a large volume of alcohol, or a mixture of alcohol and ether or acetone, when the sulphinate separates as a light yellow precipitate. This method of preparation may be varied by adding the sodium carbonate prior to the addition of the sodium formaldehydesulphoxylate.[1]

Neosalvarsan, as obtained by the foregoing processes, is a pale yellow powder. The free acid explodes when heated, is soluble in alcohols and acetic acid, but sparingly soluble in cold water. Its solutions in alkali are orange-yellow, and it is precipitated by the addition of mineral acids, the freshly precipitated product being readily soluble in ether. It shows rapid oxidation on exposure to air.[2] In neutral aqueous solution it absorbs oxygen readily, the solution becoming discoloured and a brownish-black precipitate separating. The probability that oxygen primarily affects the iminomethylenesulphoxylate group of Neosalvarsan is supported by the behaviour of *o*-aminophenolsulphoxylate.[3] When Neosalvarsan and mercuric chloride react in alcoholic solution, at least six products are formed unless the mercuric chloride is in large excess.[4] The pròportions in which these products occur depend upon the conditions of the preparation. Colloidal mercury and *Neosalvarsanic acid*, $OH.C_6H_3NH_2.As{=}As.C_6H_3(OH).NH.CH_2.SO_2H$, usually predominate, the latter remaining in colloidal or semi-colloidal solution. The following products may also be present: Formaldehydesulphurous acid, $OH.CH_2.O.SO_2H$, from the oxidation of the formaldehydesulphoxylate residue; 3-*amino*-4 : 4′-*dihydroxyarsenobenzene*-3′-*iminomethylene sulphurous acid*, a bright yellow, insoluble product, formed by the oxidation of the Neosalvarsan; 3-*amino*-4-*hydroxyphenylarsenoxide* and 4-*hydroxyphenylarsenoxide*-3-*iminomethylene sulphurous acid*, the two latter remaining in solution. Neosalvarsan also forms co-ordination compounds with certain metallic salts.[5] Three parts of Neosalvarsan in a little water, when treated with 0·7 part of *cupric chloride* ($CuCl_2.2H_2O$), also in water, and the mixture poured into ether-alcohol, give a voluminous, yellow powder, which forms a yellowish-red solution in water. In the cold it does not give the usual reactions for copper, but the complex is decomposed when the solution is boiled. When the cupric chloride is replaced by *silver nitrate*, a black product results, which gives a clear, strongly fluorescent solution in water.

[1] German Patent, 260235; compare American Patents, 1564859, 1564860. For the constitution of Neosalvarsan, see Bertheim, Raiziss, and Falkov, *J. Biol. Chem.*, 1921, 46, 210; Voegtlin and Johnson, *J. Amer. Chem. Soc.*, 1922, 44, 2573.

[2] Voegtlin and Smith, *J. Pharm. exp. Ther.*, 1920, 16, 199.

[3] Maschmann, *Ber.*, 1926, 59, [B], 1142, 1148.

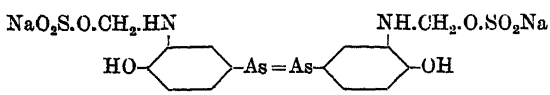
[4] Binz and Bauer, *Zeitsch. angew. Chem.*, 1921, 34, 261.

[5] German Patent, 268221.

The product with *gold chloride* is brownish-red and that with *platinic chloride* brown, both being readily soluble in water and precipitated therefrom by ether-alcohol.

From a study of the colloidal properties of *Salvarsan*, *Neosalvarsan*, *Luargol* and *Galyl* it appears that with the exception of Neosalvarsan, which possesses more the properties of a salt, the compounds have the characteristic properties of colloids. *Luargol* is the most colloidal and *Galyl* the least colloidal derivative.[1]

Sodium 3:3′-diamino-4:4′-dihydroxyarsenobenzene-N-N′-dimethylenesulphite, *Sulpharsphenamine*,[2]



To 50 grams (1 mol.) of *Arsphenamine* (Salvarsan), 75 c.c. of 95 per cent. alcohol are added and the mixture stirred. The solid is dissolved by adding 675 c.c. of water, the mixture being mechanically stirred, and after solution, 18·15 c.c. of 33·8 per cent. formaldehyde (2 mols.) are rapidly added, and after sixty-nine seconds, 65 c.c. of a 32·64 per cent. solution of sodium bisulphite (2 mols.) are poured in at once. The light yellow precipitate which forms immediately, with simultaneous liberation of sulphur dioxide, gradually redissolves as the stirring is continued. After seven minutes a second 65 c.c. of sodium bisulphite are added and the stirring maintained for seventeen minutes. The liquid is then filtered and the dark orange filtrate poured in a fine stream, with vigorous stirring, into 4040 c.c. of 95 per cent. alcohol. The light yellow precipitate is filtered off, washed with 95 per cent. alcohol, followed by absolute alcohol, and the product dried over sodium hydroxide in a vacuum. The yield is about 64 grams. The product is purified by dissolving in a small amount of water and reprecipitating by means of a large excess of glacial acetic acid. It is centrifuged, and washed with glacial acetic acid and water, being drained each time in the centrifuge. The free acid is then dried in a vacuum over soda-lime until free from acetic acid. The product so obtained is not a pure chemical substance, but if the directions given are adhered to, the arsenic and sulphur content are fairly uniform, and analysis points to the constitutional formula shown. It will be noted that the product differs from Neosalvarsan, especially in that the substituting radical in the amino-group contains three oxygen atoms instead of two, being an ester of sulphurous acid. It is believed [3] that there are two types of combination between Arsphenamine and sodium formaldehydesulphoxylate, one being of the N—CH_2 type, and the other resembling a double salt formation.

More recent investigations [4] have shown that the conditions of pre-

[1] Danysz, *Ann. Inst. Pasteur*, 1917, 31, 114. The following reference deals with the detection of arsenic in Salvarsan and Neosalvarsan: Utz, *Pharm. Zentr.-h.*, 1920, 61, 39; and the estimation of arsenic in Neosalvarsan: Kircher and Ruppert, *Ber. Deut. pharm. Ges.*, 1920, 30, 419. In his work on the constitution of French drugs, Neosalvarsan is dealt with by Macallum, *J. Amer. Chem. Soc.*, 1921, 43, 643; 1922, 44, 2578.

[2] Voegtlin and Johnson, *J. Amer. Chem. Soc.*, 1922, 44, 2573.

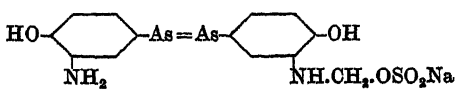
[3] Jurist and Christiansen, *J. Amer. Chem. Soc.*, 1928, 50, 191.

[4] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 116; see Christiansen, *J. Amer. Chem. Soc.*, 1922, 44, 853.

paration, and the form in which the formaldehyde is introduced, cause a decided variation in the properties of the resultant Sulpharsphenamine: (1) A specimen prepared by the method of Christiansen,[1] and examined by Newbery and Phillips,[2] gave the following analysis, using the Elvove[3] oxidation method for sulphur, As : N : unoxidised S = 1 : 0·98 : 1·12. The sodium salt was hydrolysed as follows: Five grams of the salt in 15 c.c. of water and 10 c.c. of 2*N* hydrochloric acid caused no precipitation [compare (2) below]. After warming at 60° to 70° C. for five to seven minutes, the whole was cooled, allowed to stand for ten minutes and the solid filtered off, washed with water and dried over sulphuric acid. The yield was 2·5 grams, and the product was fairly soluble in alkali hydroxide or carbonate, the solution so obtained being readily precipitated by 2*N* acetic or hydrochloric acid. In this case As : N : total S = 2 : 1·92 : 1·16.

(2) The 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene obtained from 50 grams of 3-amino-4-hydroxyphenylarsinic acid by the usual hyposulphite reduction method is taken whilst moist and ground to a paste with 30 grams of sodium formaldehydebisulphite in 250 c.c. of water. After heating for about three hours at 60° C. until solution is complete, the whole is filtered and poured into 3000 c.c. of spirit. The product is washed, and dried *in vacuo*, analysis giving As : N : S = 1 : 1·0 : 0·91. A solution in water is not precipitated by an equal volume of 2*N* acetic acid and does not decolorise a hot indigo-carmine solution. A similar solution gives a light yellow precipitate after a few seconds with 2*N* hydrochloric acid. This precipitate remains soluble for some minutes at the ordinary temperature and for thirty to sixty minutes at 0° C. The insoluble acid formed on standing appears to be identical with that described below, under "hydrolysis of the sodium salt." It has so far been impossible to isolate the soluble acid for analysis, and figures obtained for the insoluble acid indicate a mono-substitution product. For hydrolysis of the sodium salt, 7 grams in 20 c.c. of water are treated with 2*N* hydrochloric acid and the mixture heated on the water-bath. The acid which separates quickly redissolves, and sulphur dioxide is evolved. On cooling, a dark yellow product separates, which, after washing and drying to constant weight, is readily soluble in dilute caustic alkali or alkali carbonate solution. From such solutions, 2*N* acetic and hydrochloric acids precipitate the free acid, which does not decolorise hot indigo-carmine solution.[4]

Sodium 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene-N-monomethylenesulphite,



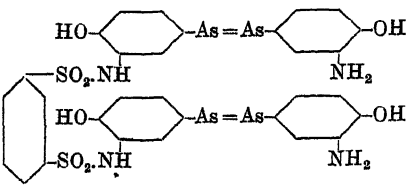
To a solution of 2·5 grams of sodium formaldehydebisulphite in 30 c.c. of water, 6·8 grams of Salvarsan (free base) are added, and the whole heated at 60° C. and mechanically stirred until solution is complete, a period of one to two hours being necessary. The solution is then filtered

[1] Christiansen, *loc. cit.*
[2] Newbery and Phillips, *loc. cit.*
[3] Elvove, *U.S. Public Health Reports*, 12th June 1925.
[4] For combination of Sulpharsphenamine and Salvarsan, see British Patent, 249515 (1926).

through Kieselguhr, and poured into an excess of alcohol. The resulting product is filtered, washed, and dried *in vacuo*. It dissolves readily in water, and the free acid is precipitated by dilute acetic acid, even in the presence of an excess of sodium formaldehydebisulphite, and by mineral acids. The solution does not decolorise hot indigo-carmine solution, and analysis gives As : N : S=2 : 1·84 : 1·06.[1]

3 : 3′-Diamino-4 : 4′-dihydroxyarsenobenzene-silver bromide-antimonyl sulphate, *Luargol*, $(C_{12}H_{12}O_2N_2As_2)_2.AgBr.SbO(H_2SO_4)_2$.[2] —Combinations of this type are effected in the following manner: A solution of silver bromide in potassium cyanide is added drop by drop to a solution of Salvarsan, each drop forming a precipitate which rapidly redissolves, the liquid produced evolving hydrogen cyanide. If the precipitate does not dissolve, hydrochloric acid is added to assist the solution, and the addition of silver bromide is continued until one gram-molecule of this salt has been added for each gram-molecule of Salvarsan. On acidification with sulphuric acid the insoluble sulphate is precipitated. The product varies in colour from yellowish-orange to brown.

Benzene - m - 3′ : 3′ - disulphamino - bis - 3 - amino - 4 : 4′ - dihydroxyarsenobenzene, *Ludyl* (1151 *of Mouneyrat's Series*);



This arsenical is obtained by the Schotten-Baumann reaction from benzene-*m*-disulphonic chloride and Salvarsan. It is a yellow or yellowish-grey powder, yielding a yellowish-brown solution in sodium carbonate, but is insoluble in water. Addition of sodium chloride or alcohol to its aqueous solution precipitates the *sodium salt*, which has a neutral reaction in water and may be kept unchanged for several days if air is excluded.[3]

Galyl (1116 *of Mouneyrat's Series*).—This product appears to be a mixture of the two compounds shown opposite and is prepared as follows:[4] 3-Amino-4-hydroxyphenylarsinic acid (23·3 grams) in 300 c.c. of water and 190 c.c. of sodium hydroxide (36° Bé.) is added to 350 c.c. of 90 per cent. alcohol, the whole cooled, and 27 c.c. of phosphoryl chloride stirred in. The mixture is then neutralised by adding 18 c.c. of sodium hydroxide (36° Bé.) and the whole poured into a solution consisting of 1800 c.c. of water, 100 grams of magnesium chloride, and 500 grams of sodium hydrosulphite. The reaction is completed by heating at 50° C. for four hours. The resulting product is a yellow powder, composed of two complex arsenicals of the following structures :

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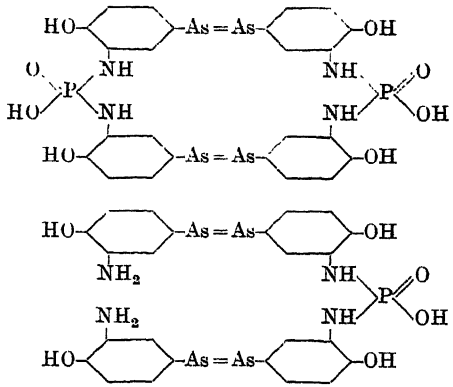
[1] Salvarsanpolyarsenide and Sulpharsphenamine are dealt with by Christiansen, *J. Amer. Chem. Soc.*, 1923, 45, 2182.

[2] Danysz, *Compt. rend.*, 1913, 157, 644; 1914, 158, 199; 1914, 159, 452.

[3] Morgan, *Organic Compounds of Arsenic and Antimony*, p. 256 (Longmans, Green & Co., 1918).

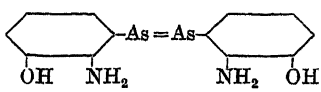
[4] British Patent, 9234 (1915); American Patent, 1232373.



The composition of the mixture varies with the proportions of the original reagents, and the product is soluble in dilute hydrochloric acid or sodium carbonate solution, the alkaline solution reducing Fehling's, Nessler's and Tollen's reagents. Addition of alcohol or sodium chloride to the sodium carbonate solution precipitates the sodium salt of Galyl.

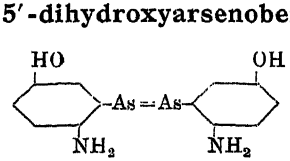
Isomerides of Salvarsan.

2 : 2′-Diamino-3 : 3′-dihydroxyarsenobenzene,[1]



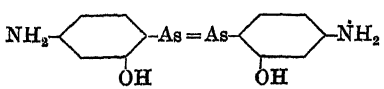
This compound is derived from 2-nitro-3-aminophenylarsinic acid (p. 261), which, on boiling with concentrated potassium hydroxide, has its amino-group replaced by hydroxyl, giving 2-nitro-3-hydroxyphenylarsinic acid. The latter, when reduced with sodium hydrosulphite, yields the arseno-compound.

2 : 2′-Diamino-5 : 5′-dihydroxyarsenobenzene,[2]



results when 2-nitro-5-aminophenylarsinic acid is treated in a similar manner to the 2-nitro-3-amino-compound of the preceding preparation.

4 : 4′-Diamino-2 : 2′-dihydroxyarsenobenzene,[3]



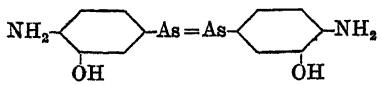
4-Amino-2-hydroxyphenylarsinic acid (p. 301) in 20 c.c. of hydrochloric acid (density 1·19) is added dropwise to a reduction solution consisting of 10 grams of stannous chloride, 10 c.c. of hydrochloric acid (density 1·19),

[1] German Patent, 256343.
[2] German Patent, 261643.
[3] Bauer, *Ber.*, 1915, 48, 1581.

20 c.c. of acetic acid, and 1 c.c. of hydriodic acid (density 1·7), the whole being at −5° C. The hydrochloride is precipitated and filtered off in a stream of carbon dioxide, then washed with acetic acid and ether. Yield, 3·9 grams. The substance gives a pale yellow solution in water, from which sodium hydroxide precipitates the base, which is soluble in excess of alkali. The *sulphate* is sparingly soluble.

Reduction of 4-carbethoxyamino-2-hydroxyphenylarsinic acid (p. 302) with hypophosphorous and hydriodic acids in methyl alcohol solution gives rise to *4 : 4′-dicarbethoxyamino-2 : 2′-dihydroxyarsenobenzene.* This is a pale yellow substance, soluble in sodium hydroxide, yielding a yellow solution.

4 : 4′-Diamino-3 : 3′-dihydroxyarsenobenzene,[1]



3-Nitro-4-aminophenylarsinic acid (130 grams) in 400 c.c. of 2*N* sodium carbonate is treated with 500 c.c. of normal sodium nitrite solution, and the whole poured into 2550 c.c. of 2*N* sulphuric acid at the ordinary temperature. After diazotisation, 1400 grams of crystallised sodium acetate are stirred in and the temperature maintained at 18° C. until a test portion no longer couples with *R*-salt. The brown solution is then run into a mixture of 80 grams of β-naphthol, 556 c.c. of 10*N* sodium hydroxide, 500 grams of sodium carbonate, and 2900 c.c. of water, the mixture being stirred for two hours at 20° to 25° C. The *dye* separates in glistening, coppery crystals, and the portion remaining dissolved is obtained by neutralising the filtrate and salting out. It may be purified by dissolving the paste in 3000 c.c. of boiling water, filtering, and acidifying with hydrochloric acid. The free dye separates in red flocks, which are filtered off and washed, the process of purification then being repeated.

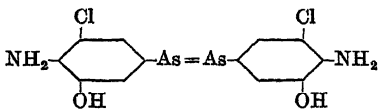
Reduction of the Dyestuff.—100 grams of the dye in 1500 c.c. of water, 100 c.c. of 10*N* sodium hydroxide and 500 c.c. of 2*N* sodium acetate at a temperature of 25° C. are treated with 500 grams of sodium hydrosulphite. The mixture is warmed at 35° to 38° C. until colourless, then cooled to −10° C. and the 1 : 2-aminonaphthol removed by filtration. The filtrate is saturated with carbon dioxide to remove the remainder of the aminonaphthol, and, after filtering, the temperature of the clear solution is slowly raised to from 65° to 70° C. Yellow flocks separate, and after two hours these are collected and washed with water. The arseno-compound is purified by treating with alcoholic hydrochloric acid, when the hydrochloride is formed, the solution being filtered and the salt precipitated by ether. To further purify, the operation is repeated, excluding air. The hydrochloride is a pale yellow powder, readily soluble in water, and the free base is precipitated in yellow flocks by the addition of sodium carbonate or acetate. The base is sparingly soluble in water, readily soluble in dilute hydrochloric acid. As an *o*-aminophenol derivative it yields an intensely yellow *diazo-compound*, and only reacts with easily coupling components. With 1-amino-8-hydroxynaphthalene-4-sulphonic acid it gives a blue *azo-compound.* The base forms a very sparingly soluble *sulphate.* Feeble reduction with

[1] Benda, *Ber.*, 1911, 44, 3578; Balaban, *J. Chem. Soc.*, 1928, p. 811.

sulphurous acid containing a little iodine gives 4-amino-3-hydroxyphenylarsenoxide, a white powder, readily soluble in acids and alkalis, but not obtained in a crystalline form. An *acetyl* and *diacetyl* derivative of the arseno-compound are also known.

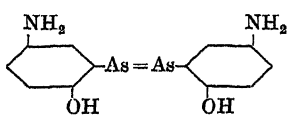
The foregoing reduction of the dyestuff may be carried out in two stages. The first consists in reducing the dyestuff to 4-amino-3-hydroxyphenylarsinic acid (p. 304) by alkaline hydrosulphite or aluminium powder and sodium hydroxide, the second in further reducing this arsinic acid at 60° to 65° C. with alkaline hydrosulphite.[1] Another modification of the process is as follows: The alkaline solution of the purified β-naphthol dye is treated at 0° to 5° C. with sufficient hydrosulphite to discharge the colour of the solution, which is then saturated with carbon dioxide. After removing the 1-amino-2-naphthol, the filtrate is reduced with a 50 per cent. excess of sodium hydrosulphite for two hours at 60° C.[2]

5 : 5′-Dichloro-4 : 4′-diamino-3 : 3′-dihydroxyarsenobenzene,[3]



3 : 5-Dichloro-4-aminophenylarsinic acid (p. 223) is diazotised, treated with sodium acetate and stirred until the solution no longer couples with R-salt. The addition of alkaline β-naphthol then precipitates the azo-dye, which is reduced at 40° to 45° C. with alkaline hydrosulphite in the presence of sodium acetate. The 1 : 2-aminonaphthol is removed from the cool solution and the filtrate again treated with hydrosulphite at 60° C. The arseno-compound separates in yellow flocks, soluble in acids and alkalis. Concentrated hydrochloric acid precipitates the *hydrochloride*.

5 : 5′-Diamino-2 : 2′-dihydroxyarsenobenzene,[4]



is obtained by reducing 5-nitro-2-hydroxyphenylarsinic acid (p. 286) with sodium hydrosulphite. It is a yellow powder, soluble in hydrochloric acid and alkalis. The alkaline solution and *p*-xylenol when oxidised together by sodium hypochlorite give a cornflower blue solution of the corresponding *indophenolarsinic acid*.

[1] Benda, *loc. cit.*; German Patents, 243648, 244166, 244789, 244790.
[2] Newbery and Phillips, *J. Chem. Soc.*, 1928, p. 123.
[3] Karrer, *Ber.*, 1914, 47, 1779.
[4] Benda, *ibid.*, 1911, 44, 3293.

CHAPTER X.

MISCELLANEOUS ARSENICAL COMPOUNDS.

Aliphatic-Aromatic Arsenious Acids.[1]

The general procedure for the preparation of these derivatives is as follows: The dichloroarsine (1 mol.) in alkali (4 mols.) is treated with halogen compound (1 mol.) at room temperature. The reaction takes place readily, and, to isolate the product, the solution is first made neutral to phenolphthalein by adding hydrochloric acid. This precipitates unchanged arylarsenoxide, which is removed. The filtrate is then made acid with hydrochloric acid until Congo red just commences to turn blue, when the required acid is precipitated. If the product contains an amino-group, the final acidification must be carried out carefully, or the precipitate redissolves. Most of the following compounds have decomposition and not melting-points, these being considerably affected by the rate of heating.

Phenylarsinoacetic acid, $C_6H_5.AsO(OH).CH_2.CO.OH$, from phenyldichloroarsine and sodium chloroacetate, melts with decomposition at 141° to 142° C. The dichloroarsine may be replaced by phenylarsenoxide, and the melting-point by this method is given as 145° C.[2]

Phenylchloroarsineacetic acid,[3] $C_6H_5.AsCl.CH_2.CO_2H$, results when the preceding acid in concentrated hydrochloric acid is treated with a crystal of potassium iodide and sulphur dioxide passed in. It is recrystallised from chloroform and melts at 102° to 103° C. Phosphorus pentachloride in chloroform converts it into phenyldichloroarsine. *Phenylbromoarsineacetic acid* melts at 113° to 114° C.

Phenylarsinoacetanilide, $C_6H_5.AsO(OH).CH_2.CO.NH.C_6H_5$, obtained from phenyldichloroarsine and chloroacetanilide in sodium hydroxide, forms small needles, melting with decomposition at 182° to 183° C. Treatment with boiling hydrobromic acid in glacial acetic acid in the presence of potassium iodide, and finally with sulphur dioxide, yields *phenylbromoarsineacetanilide,* $C_6H_5.AsBr.CH_2.CO.NH.C_6H_5$, M.pt. 108° to 110° C.

Phenylarsinoacetophenetidine, $C_6H_5.AsO(OH).CH_2.CO.NH.C_6H_4.OC_2H_5$, crystallises in needles, melting and decomposing at 175° C.

Phenylarsinoaceto-p-arsanilic acid, $C_6H_5.AsO(OH).CH_2.CO.NH.C_6H_4.AsO(OH)_2$, obtained from sodium chloracetoarsanilate, does not melt below 250° C., and is insoluble in the usual solvents. The following have also been obtained: *Phenylarsino-o-acetylaminobenzoic acid,* $C_6H_5.AsO(OH).CH_2.CO.NH.C_6H_4.CO_2H$, M.pt. 198° to 200° C.; *β-phenoxyethylphenylarsinous acid,* $C_6H_5O.CH_2.CH_2.C_6H_5.AsO(OH)$, M.pt. 122° to 123° C.; *ethylenediphenyldiarsinous acid,* $C_2H_4[C_6H_5.AsO(OH)]_2$, M.pt. 209° to 211° C.

[1] Quick and Adams, *J. Amer. Chem. Soc.*, 1922, 44, 805.
[2] Austrian Patent, 93325; Swiss Patent, 97997; from *Chem. Zentr.*, 1923, iv. 721.
[3] Quick and Adams, *loc. cit.*

p-Aminophenylarsinoacetanilide, $NH_2.C_6H_4.AsO(OH).CH_2.CO.NH.C_6H_5$, is the condensation product of *p*-aminophenyldichloroarsine hydrochloride (prepared from *p*-arsanilic acid by passing sulphur dioxide into its hydrochloric acid solution in the presence of potassium iodide) and chloracetanilide. It melts at 181° to 182° C., and forms a *p-acetyl derivative* when treated with acetic anhydride, this crystallising from water in plates, decomposing at 205° to 206° C. The *p-glycyl derivative* melts with decomposition at 199° C.

p-Aminophenylarsinoacetophenetidine, $NH_2.C_6H_4.AsO(OH).CH_2.CO.NH.C_6H_4.OC_2H_5$, melts at 211·5° to 212·5° C., and forms an *acetyl derivative*, decomposing at 214° to 215° C.

p-Aminophenylarsinoacetoarsanilic acid, $NH_2.C_6H_4.AsO(OH).CH_2.CO.NH.C_6H_4.AsO(OH)_2$, obtained from chloracetoarsanilic acid and sodium *p*-aminophenylarsenite, is unmelted below 350° C., and its *acetyl derivative* does not melt below 250° C.

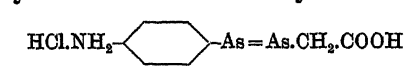
p-Aminophenylarsino-p-acetylaminobenzoic acid, $NH_2.C_6H_4.AsO(OH).CH_2.CO.NH.C_6H_4.CO_2H$. — *p*-Chloracetylaminobenzoic acid, $ClCH_2.CO.NH.C_6H_4.COOH$, is first prepared by condensing a suspension of *p*-aminobenzoic acid in glacial acetic acid and saturated sodium acetate (1 : 1) with chloracetylchloride; the product is a white, amorphous solid, M.pt. 239° C., which, when treated with *p*-aminophenyldichloroarsine hydrochloride, yields the required acid, which crystallises in needles, melting with decomposition at 217° C.

Phenylacetic-p-arsinic acid, $CO_2H.CH_2.C_6H_4.AsO(OH)_2$.[1]—This is obtained by applying the Bart reaction to *p*-aminophenylacetic acid, the resulting arsinic acid melting at 195° C. Neutralisation by alkali and heating with sodium hydrosulphite yields an *arseno-derivative*, which dissolves in sodium carbonate.

Aliphatic-Aromatic Arseno-compounds.

Aryl Arsenoacetic Acids.

4-Aminophenylarsenoacetic acid hydrochloride,[2]



Sodium arsinoacetate (4·56 grams) and 4·34 grams of *p*-aminophenylarsinic acid in 10 c.c. of hydrochloric acid (density 1·19) and 10 c.c. of water, are mixed, cooled, filtered, and treated with 30 c.c. of pyridine and 53 c.c. of 50 per cent. hypophosphorous acid, and the mixture then placed in an ice-chest for twelve days. The product which separates is bright yellow, and after washing with cold dilute hydrochloric acid is dried *in vacuo*. The yield is about 6·6 grams, or 89 per cent., and the compound is readily soluble in cold aqueous alkalis.

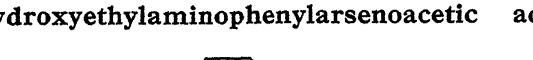
When *p*-aminophenylarsinic acid and an equimolecular quantity of arsinoacetic acid are reduced by sodium hypophosphite in sulphuric acid, most of the amino-acid is reduced to the sulphate of 4 : 4′-diaminoarsenobenzene, the filtrate on long standing yielding arsenoacetic acid. When the sulphuric acid is replaced by hydrochloric acid, the dihydrochloride of 4 : 4′-diaminoarsenobenzene, a small quantity of 4-amino-

[1] Robertson and Stieglitz, *J. Amer. Chem. Soc.*, 1921, 43, 179.
[2] Palmer and Edee, *ibid.*, 1927, 49, 998.

phenylarsenoacetic acid, arsenoacetic acid and tetra-arsenoacetic acid result. The addition of a little pyridine to the hydrochloric acid gives rise to the unsymmetrical compound as the exclusive product.

4-Acetylaminophenylarsenoacetic acid hydrochloride results when 4-acetylaminophenylarsinic acid replaces the non-acetylated acid in the previous preparation. It is a bright yellow product, slightly soluble in warm dilute hydrochloric acid and readily soluble in cold alkalis.

4 - β - Hydroxyethylaminophenylarsenoacetic acid hydrochloride,



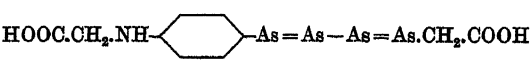
is obtained when a mixture of 4-β-hydroxyethylaminophenylarsinic acid and arsinoacetic acid is reduced below 0° C. by stannous chloride in the presence of hydrochloric acid. The compound is light orange in colour, fairly soluble in water and very soluble in dilute aqueous alkalis.

Using the appropriate phenylarsinic acids the following compounds may be obtained in a similar way, all the products being orange in colour: *4-γ-Hydroxypropylaminophenylarsenoacetic acid hydrochloride*, *4-glycylphenylarsenoacetic acid hydrochloride*, and *4-aminoglycylphenylarsenoacetic acid hydrochloride*.

The following are obtained by the hypophosphorous acid method of reduction given before: *4-Hydroxyphenyl-*, *4-acetoxyphenyl-*, *hydrochloride of 3-amino-4-hydroxyphenyl-*, *phenyl-*, *p-tolyl-* and *o-chlorophenylarsenoacetic acids*. All these products are yellow to red in colour.

Aryl Tetrarsenoacetic Acids.

4-Glycylphenyltetrarsenoacetic acid,

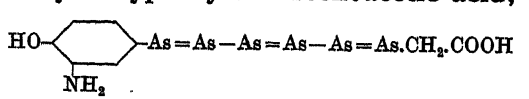


A solution of 5·5 grams of *p*-arsinophenylglycine, 4·56 grams of sodium arsinoacetate and 53 c.c. of 50 per cent. hypophosphorous acid in 10 c.c. of hydrochloric acid (density 1·19) and 30 c.c. of water is filtered and the filtrate allowed to stand in ice for seven days. A brick-red precipitate separates which is washed with water and dried *in vacuo* over phosphorus pentoxide. It is readily soluble in alkaline solution; the yield is 3·8 grams, or 37·7 per cent. The reduction may also be carried out using stannous chloride.

In a similar manner the following are prepared: *4-Aminoglycylphenyl-*, *4-β-hydroxyethylaminophenyl-*, *4-γ-hydroxypropylaminophenyl-* and *3-amino-4-hydroxyphenyl-tetrarsenoacetic acids*.

Aryl Hexarsenoacetic Acid.

3-Amino-4-hydroxyphenylhexarsenoacetic acid,

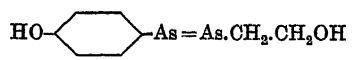


To a solution of 4·38 grams of 3-amino-4-hydroxyphenylarsinic acid and 4·56 grams of sodium arsinoacetate in 15 c.c. of hydrochloric acid

(density 1·19), 30 c.c. of water are added and the mixture filtered from the sodium chloride which separates. Arsenic trichloride (7 grams) is added dropwise and with vigorous shaking, then 53 c.c. of 50 per cent. hypophosphorous acid, when a brick-red precipitate separates and is filtered off, washed with water, alcohol, and ether, and dried *in vacuo*. The yield is 4·7 grams, or 45 per cent. The compound is readily soluble in alkaline solutions.

Arylarsenoethyl Alcohols of the Type $C_6H_4R.[As]_n.CH_2.CH_2OH$.[1]

4-Hydroxyphenylarsenoethyl alcohol,

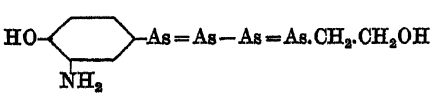


To 6·44 grams of a 53 per cent. solution of β-hydroxyethylarsinic acid and 4·36 grams of 4-hydroxyphenylarsinic acid in 30 c.c. of water and 10 c.c. of hydrochloric acid (density 1·19), 53 c.c. of 50 per cent. hypophosphorous acid are added. After filtration, the mixture is placed in ice for two days, when the orange precipitate which separates is filtered off, washed with dilute hydrochloric acid and water, and dried in a vacuum over phosphorus pentoxide. The product may be further purified, if necessary, by trituration with warm dilute hydrochloric acid (1 : 5). The yield is 3·86 grams, or 67 per cent., and the compound is completely soluble in dilute aqueous alkalis.

4-Aminophenylarsenoethyl alcohol hydrochloride is obtained when arsanilic acid and β-hydroxyethylarsinic acid are treated as above in the presence of pyridine. If the latter is omitted the *free base* results instead of the hydrochloride. The salt is orange-yellow, and may be converted to the base by trituration with warm water containing the slightest trace of hydrochloric acid, the resulting product being orange.

4-Acetoxyphenylarsenoethyl alcohol results when a mixture of *p*-acetoxyphenylarsinic acid and β-hydroxyethylarsinic acid is reduced at the ordinary temperature, the reaction taking about ten days. The resulting product is yellow and alkali-soluble. If in this reaction the reactants after three days' standing are heated to 60° C. for ten minutes, a yellow, alkali-soluble product is obtained, which is probably *4-acetoxyphenyltriarsenoethyl alcohol*, $C_{10}H_{12}O_4As_3$.

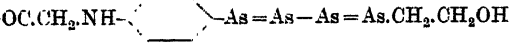
3-Amino-4-hydroxyphenyltetrarsenoethyl alcohol,



To a solution of 4·66 grams of 3-amino-4-hydroxyphenylarsinic acid and 3·76 grams of β-hydroxyethylarsinic acid monohydrate in 15 c.c. of water and 15 c.c. of hydrochloric acid (density 1·19), 53 c.c. of 50 per cent. hypophosphorous acid are added, and the mixture allowed to stand for six days at 15° C. The orange precipitate is removed, well washed with dilute hydrochloric acid and water, then dried over phosphorus pentoxide. The yield is 1·02 grams, or 11·2 per cent., and the product is soluble in dilute aqueous alkalis or concentrated hydrochloric acid.

[1] Edee, *J. Amer. Chem. Soc.*, 1928, 50, 1394.

4-Carboxymethylaminophenyltetrarsenoethyl alcohol,



This compound is the reduction product of a mixture of phenylglycine-*p*-arsinic acid and β-hydroxyethylarsinic acid. It is an orange-coloured product, completely soluble in dilute aqueous alkalis.

Arsinated N-Arylamino-alcohols.[1]

The isolation of these compounds is based on the fact that ethylene chlorohydrin under suitable conditions can be condensed with aromatic amines to give arylamino-alcohols. Although condensation has been accomplished using *p*-arsanilic acid as the amine, negative results are obtained when the amino-group is in the *meta* position with respect to the arsenic, as in the case of *m*-arsanilic acid, 3-amino-4-methylphenylarsinic acid, and 3-amino-4-hydroxyphenylarsinic acid.

The general method for preparing these compounds is to add 1 molecular equivalent of the amino-arylarsinic acid to sufficient normal sodium hydroxide solution to give the monosodium salt, then adding 1·5 molecular equivalents of the chlorohydrin and boiling the whole under reflux for four to five hours. Concentrated hydrochloric acid is added to the cold mixture to hold any unchanged *p*-arsanilic acid in solution, the crystals of the arsino-acid being removed and recrystallised from hot water.

β - p - Arsinoanilinoethyl alcohol, $OH.CH_2.CH_2.NH.C_6H_4.AsO(OH)_2$, forms colourless needles, M.pt. 167° to 168° C., soluble in hot water and dilute alkalis, insoluble in ether and benzene. Yield, 35 to 40 per cent. The *monosodium salt* gives colourless crystals, the *monoammonium salt*, colourless needles, and the *barium salt*, a white precipitate.

γ-p-Arsinoanilinopropyl alcohol, $OH.CH_2.CH_2.CH_2.NH.C_6H_4.AsO(OH)_2$, crystallises from hot water in colourless crystals, M.pt. 160° to 161° C. Its *sodium*, *ammonium* and *barium salts* are known.

These arsino-compounds may be reduced to the corresponding arseno-derivatives as follows: 1 molecular equivalent of arsino-compound in hot water is added, with shaking, to 10 equivalents of sodium hydrosulphite in 550 equivalents of water, after the latter has been previously treated with 6 equivalents of 10*N* sodium hydroxide and 10 equivalents of crystalline magnesium chloride and filtered from magnesium hydroxide. The mixture is heated on the water-bath for thirty minutes and frequently shaken, the yellow precipitate filtered off, washed with water, alcohol, and ether, and dried *in vacuo*.

β-p-Arsenoanilinoethyl alcohol,

$$\begin{matrix} As.C_6H_4.NH.CH_2.CH_2OH \\ \| \\ As.C_6H_4.NH.CH_2.CH_2OH \end{matrix}$$

is a yellow compound, insoluble in the usual organic solvents, and remaining unmelted below 250° C.

[1] Hamilton, *J. Amer. Chem. Soc.*, 1923, 45, 2751.

γ-p-Arsenoanilinopropyl alcohol has similar properties to the foregoing.

sym.-Di-p-arsinoanilinoethane, $C_2H_4[NH.C_6H_4.AsO(OH)_2]_2$, is obtained by boiling *p*-arsanilic acid, sodium hydroxide solution and ethylene dibromide under reflux. It is readily soluble in dilute alkalis and does not melt below 250° C. The *monosodium salt* forms colourless crystals.

ARSINO-ARYLAMINO-ALCOHOLS.[1]

Amino-arylarsinic acids in aqueous alkaline solution condense with β-chloroethyl- and γ-chloropropyl-chloroformates to yield *ω-chloroalkyl (arsino-aryl) carbamates.* These latter compounds when refluxed with 2 molecular equivalents of aqueous or alcoholic alkali yield *arsino-aryl-oxazolidones* and *3-arsino-aryl-tetrahydro-1 : 3 : 2-oxazones,* according to whether β-chloroethyl or γ-chloropropyl compounds are used. Excess of alkali hydrolyses the oxazolidones to *β-arsino-aryl-aminoethanols* and the oxazones to *γ-arsino-aryl-aminopropanols.*

β-Chloroalkyl (p-arsinoaryl) carbamates. — One molecular equivalent of β-chloroalkyl-chloroformate is added, with shaking, to a solution containing 1 molecular equivalent of arylaminoarsinic acid in eight times its weight of water and one equivalent of 5*N* sodium hydroxide. During the operation the temperature is kept below 35° C., and the shaking is continued for ten minutes after the addition of the chloroformate. Concentrated hydrochloric acid is then added in sufficient quantity to dissolve any unchanged aminoarylarsinic acid, and the carbamate filtered off. The latter is recrystallised from 30 per cent. acetic acid, when white needles are isolated in all cases. The carbamates are soluble in aqueous sodium carbonate or bicarbonate.

The following derivatives have been prepared: *β-Chloroethyl (p-arsinophenyl) carbamate,* $C_6H_4[AsO(OH)_2]NH.CO.O.CH_2.CH_2Cl$, M.pt. above 250° C; *β-chloroethyl (o-arsinophenyl) carbamate,* M.pt. 156° to 157° C.; *β-chloroethyl (2-methyl-5-arsinophenyl) carbamate,* M.pt. 193° to 195° C.; *γ-chloropropyl (p-arsinophenyl) carbamate,* $C_6H_4[AsO(OH)_2]NH.CO.O.(CH_2)_3.Cl$, M.pt. 245° to 246° C.; *γ-chloropropyl (o-arsinophenyl) carbamate,* M.pt. 130° to 132° C.; *γ-chloropropyl (2-methyl-5-arsinophenyl) carbamate,* M.pt. 160° to 162° C.

3-p-Arsinophenyl-2-oxazolidone,

$$C_6H_4[AsO(OH)_2].N.CO.O.CH_2.CH_2$$

A mixture of 24 grams of β-chloroethyl (*p*-arsinophenyl) carbamate, 150 c.c. of water and 5·9 grams of sodium hydroxide is refluxed for five hours. After cooling, the liquor is strongly acidified to Congo red by concentrated hydrochloric acid, the oxazolidone being precipitated. It is filtered off, washed with water, and crystallised from 30 per cent. acetic acid. Yield, 20 grams, or 95 per cent. It forms colourless plates, melting above 280° C. By a similar method, *3-o-arsinophenyl-2-oxazolidone* is isolated in colourless plates, melting at 212° to 213° C. with decomposition.

[1] Rodewald and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 3102; see British Patent, 255971 (1925).

3-p-Arsinophenyl-1 : 3 : 2-oxazone,

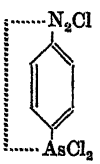
$$C_6H_4[AsO(OH)_2].N.CO.O.CH_2.CH_2.CH_2$$

results when γ-chloropropyl (*p*-arsinophenyl) carbamate is heated with alcoholic potassium hydroxide. It crystallises in thin plates, melting with decomposition at 245° to 247° C.

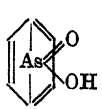
Arsino-arylamino-ethanols and **propanols** are obtained by dissolving the β-chloroethyl or the γ-chloropropyl (arsinoaryl) carbamate, respectively, in 10 per cent. aqueous sodium hydroxide containing 5 molecular equivalents of alkali. The solution is then heated under reflux for four hours, cooled, and made neutral to Congo red by concentrated hydrochloric acid. The amino-alcohols usually separate as white solids, but sometimes as oils which solidify on standing. The products are filtered off, washed with cold water, and recrystallised from water. They are soluble in dilute hydrochloric acid. They may also be obtained by hydrolysing the corresponding oxazolidone or oxazone. The following compounds have been isolated: *β-(p-Arsinophenyl)-aminoethanol*, $C_6H_4[AsO(OH)_2]NH.CH_2.CH_2OH$, M.pt. 173° to 174° C.; *β-(o-arsinophenyl)-aminoethanol*, M.pt. 144° to 146° C; *β-(2-methyl-5-arsinophenyl)-aminoethanol*, M.pt. 144° to 146° C.; *γ-(p-arsinophenyl)-aminopropanol*, $C_6H_4[AsO(OH)_2]NH.(CH_2)_3OH$, M.pt. 167° to 168° C.; *γ-(o-arsinophenyl)-aminopropanol*, M.pt. 84° to 85° C.; *γ-(2-methyl-5-arsinophenyl)-aminopropanol*, M.pt. 142° to 143° C.

p-Arsinophenyl-β-hydroxyethyl nitrosamine, $C_6H_4[AsO(OH)_2]N(NO).CH_2.CH_2OH$, is isolated from the corresponding aminoethanol and nitrous acid. It crystallises in bright yellow needles, which commence to darken at 170° to 175° C., and melt with decomposition at 236° C. *p-Arsinophenyl-γ-hydroxypropyl nitrosamine* forms yellow crystals from water, which melt at 142° to 143° C.

Complex Salts of Benzenediazonium Chloride with Arsenic Chloride.[1]

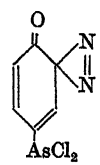


I



II

III



IV

Complex I is prepared as follows: 11 grams of *p*-aminophenylarsinic acid in 60 c.c. of 5*N* hydrochloric acid are cooled with 30 grams of ice, diazotised with 10*N* sodium nitrite solution, the solution filtered, and the filtrate mixed with 60 c.c. of ice-cooled hydrochloric acid (density 1·17). Sulphur dioxide is then passed in, and, after a few minutes, one drop of normal hydriodic acid in 3 c.c. of hydrochloric acid is added as catalyst. A fine, yellow, crystalline precipitate separates out, which after ten minutes is removed, washed with ice-cold hydrochloric acid, followed by acetic acid and ether. The yield is about 12 grams.

The same compound may be obtained by direct diazotisation of

[1] Schmidt and Hoffman, *Ber.*, 1926, 59, [B], 560.

p-aminophenyldichloroarsine in aqueous hydrochloric acid solution, or better still, using amyl nitrite in alcoholic hydrochloric acid.

The *complex* is a yellow powder, decomposing at about 100° C. It is insoluble in cold methyl alcohol, but on standing or warming, solution takes place with evolution of nitrogen. Boiling benzene and acetic acid also cause decomposition. It dissolves in dilute alkali with evolution of nitrogen and formation of the arsinic acid. With sodium bicarbonate solution it yields *p*-phenylenearsinic acid (II).

p-Phenylenearsinic acid.—12 grams of the preceding compound are stirred into a suspension of 40 grams of sodium bicarbonate and ice in 300 grams of water, a clear yellow solution being obtained and carbon dioxide evolved. After a time, nitrogen is vigorously evolved and the solution becomes red, and in two hours the diazo-compound has disappeared. The arsinic acid is precipitated by acidifying to Congo red with hydrochloric acid. The precipitate is filtered off, washed with water, and dried, then stirred several times with water in a mortar, filtered and dried. The yield is 7 grams, or 70 per cent. It is a light brown powder, readily soluble in alkalis and ammonium hydroxide, giving a reddish solution. It is sparingly soluble in methyl alcohol, more soluble in alcoholic hydrochloric acid, and insoluble in water.

p-Phenylenechloroarsine.—*p*-Phenylenearsinic acid in concentrated alcoholic hydrochloric acid is cooled in ice and treated with sulphur dioxide. After five minutes one drop of normal hydriodic acid is added, and the chloroarsine (III) soon separates as a reddish-grey powder. This is filtered off, washed with dilute alcoholic hydrochloric acid, and dried. The product is a voluminous, reddish-brown powder. It is sparingly soluble in methyl alcohol, acetone, and benzene, more soluble in chloroform and carbon disulphide. When heated above 100° C. it intumesces, and above 200° C. softens.

1-Arsinic chloride-3-diazo-4-phenol or 1-Arsinic chloride-3:4-quinone-3-diazide.—This has the constitution (IV), and is obtained as follows: 3-Amino-4-hydroxyphenylarsinic acid, when diazotised in 5*N* hydrochloric acid and subsequently treated with sulphur dioxide and hydriodic acid as described above, yields a compound $C_6H_4ON_2Cl_3As$, which on solution in methyl alcohol and precipitation by ether loses 1 molecule of hydrogen chloride, giving the diazide. In this preparation 1-*arsinic acid*-3-*diazo*-4-*phenol* is also obtained.

Hydrazones and Semicarbazones of Substituted Phenylarsinic Acids.[1]

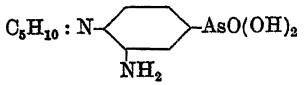
p-Acetylphenylarsinic acid phenylhydrazone forms yellow plates, decomposing above 225° C. When dissolved in dilute sodium carbonate solution, treated with hydrazine hydrate and subsequently with hydrochloric acid, *p-acetylphenylarsinic acid*, unmelted at 340° C., is obtained. 4-*Hydroxy*-3-*propionylphenylarsinic acid p-nitrophenylhydrazone* forms yellow needles, decomposing above 235° C. 3-*Nitro*-1-*hydroxyacetylphenylarsinic acid semicarbazone* (?) becomes brown above 240° C. *p*-(*Acetylvinyl*)-*phenylarsinic acid semicarbazone* forms thick needles, decomposing above 300° C. *p-Aminoguanidinoacetylphenylarsinic acid* decomposes above 300° C. The *diethyl-* and *phenylmethyl- hydrazones* of *p-formylphenylarsinic acid* are known, the former decomposing above

[1] American Patents, 1425929, 1425930, 1425931.

140° C., the latter crystallising in feathery needles, melting with decomposition at 295° C.

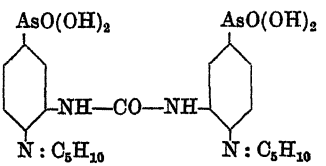
Amphoteric sym.-Carbamidoarylarsinic Acids.

3-Amino-4-piperidinophenylarsinic acid,[1]



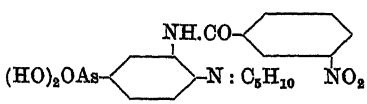
This acid is obtained by reducing the corresponding nitro-acid (p. 171) with ferrous chloride and alkali. It is instantly soluble in an excess of normal hydrochloric acid, and with sodium nitrite gives an orange-brown solution which couples with β-naphthol. The *monohydrochloride* of the arsinic acid crystallises in clear prisms; *calcium*, *magnesium* and *barium salts* may be obtained. The *acetyl derivative* separates in small prisms, sparingly soluble in boiling water, readily soluble in acids.

sym.-Carbamide of 3-amino-4-piperidinophenylarsinic acid,



3 grams of the preceding amino-compound in 200 c.c. of water containing 21·2 grams of anhydrous sodium carbonate (20 mols.) are treated with carbonyl chloride until an acid reaction is obtained. The carbamide is precipitated by making the solution faintly acid to Congo paper, and recrystallised by solution in 30 c.c. of normal ammonium hydroxide and addition of concentrated hydrochloric acid. A microscopic, white powder (2·9 grams) separates, which is almost insoluble in boiling acetic acid, but dissolves readily on addition of a little water, crystallising in microscopic rods on cooling. The *magnesium salt* forms elongated leaflets.

3-m-Nitrobenzamido-4-piperidinophenylarsinic acid,

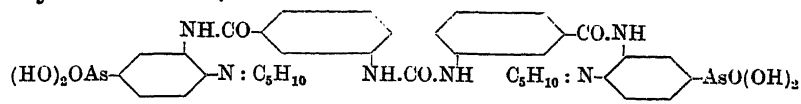


This is the condensation product of 3-amino-4-piperidinophenylarsinic acid and *m*-nitrobenzoyl chloride, the operation being conducted in sodium hydroxide solution. It separates in flattened prisms when its solution in concentrated hydrochloric acid is diluted with water. It crystallises from boiling acetic acid in spiked rods. The *calcium* and *barium salts* are precipitated by adding the corresponding chloride to an ammoniacal solution of the acid.

3-m-Aminobenzamido-4-piperidinophenylarsinic acid results when the foregoing acid is reduced by ferrous chloride and alkali. Its *magnesium salt* (narrow plates) and *barium salt* (leaflets) are known.

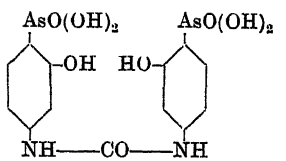
[1] King, *J. Chem. Soc.*, 1927, p. 1049.

sym.-Carbamide of 3-m-aminobenzamido-4-piperidino-phenylarsinic acid,



This is obtained in a similar manner to the preceding carbamide. It crystallises from formic acid solution in microscopic, woolly needles. The *sodium*, *magnesium*, *calcium* and *barium salts* are known.

sym.-Carbamide of 4-amino-2-hydroxyphenylarsinic acid,



This crystallises from boiling water in rods, and its solution in water or alcohol gives a port-wine coloration with ferric chloride. Dilute ammoniacal solutions give immediate amorphous precipitates of the *calcium*, *magnesium* and *barium salts* with the respective chlorides.

sym.-Carbamide of 5-nitro-4-amino-2-hydroxyphenylarsinic acid.—This is formed when the preceding compound is nitrated, using mixed acid. It crystallises from boiling water either in yellow plates as the anhydrous product, or in fine yellow needles as the dihydrate. The *magnesium*, *calcium* and *barium salts* are known, also a *tetra-ammonium salt* which crystallises in fine orange-yellow needles. When this carbamide is reduced by alkaline hydrosulphite it yields the *sym.-4-carbamide of 4 : 5-diamino-2-hydroxyphenylarsinic acid*, a white, microcrystalline powder. This is readily soluble in dilute mineral acids, but its salts are hydrolysed on dilution.

Symmetrical Bisarsinoarylbenzamidocarbamides.[1]

The first stage in the synthesis of this type of compound is the production of nitrobenzoylaminoarylarsinic acids, which are obtained by refluxing and stirring for two hours molecular equivalents of nitrobenzoyl chloride dissolved in dry toluene or benzene and the sodium salts of the aminoarylarsinic acids. In this way the following compounds have been obtained: 4-*o*-, *m*- and *p-nitrobenzamidophenylarsinic acids*, M.pt. above 250° C.; 2(*o*-, *m*- and *p-nitrobenzamido*)-*tolyl-5-arsinic acids*, M.pt. above 250° C.; 3-*m-nitrobenzamido*- and 3-*o-nitrobenzamido-phenylarsinic acids*, M.pt. above 250° C. and 249° to 250° C. (with decomposition) respectively. The second stage consists in the reduction of these nitro-compounds to the corresponding amino-derivatives by means of ferrous hydroxide in alkaline solution, and owing to the ease with which the amino-compounds are oxidised, they are precipitated *in vacuo* and filtered in an inert gas. The reduction products are: 4-*o*-, *m*- and *p-aminobenzamidophenylarsinic acids*, M.pt. above 250° C.; 2(*m*- or *p-aminobenzamido*)-*tolyl-5-arsinic acid*, M.pt. above 250° C.; and *m-amino-3-benzamidophenylarsinic acid*, melting at 160° C., with

[1] Hamilton and Major, *J. Amer. Chem. Soc.*, 1925, 47, 1128; compare the work of King and Murch, *Trans. Chem. Soc.*, 1924, 125, 2601.

decomposition. The third stage of the synthesis is conducted as follows: 6 millimoles of the aminobenzoylaminoarylarsinic acid in a 250 c.c. distilling flask are dissolved in 12 millimoles of sodium hydroxide in 100 c.c. of water, cooled in an ice-bath. The flask is then evacuated by suction, and whilst it is still in the ice-bath, phosgene is slowly bubbled through the solution until the mixture turns acid to Congo red paper. The precipitate is then removed and washed with water, alcohol, and ether. It is first dried over sodium hydroxide, then in the oven. The compounds are cream coloured and do not darken on exposure to air. They are soluble in sodium hydroxide, sodium carbonate and sodium bicarbonate solutions, concentrated sulphuric acid, and ammonium hydroxide, but insoluble in ether, alcohols, glacial acetic acid, acetone, toluene, and water. The following may be obtained from the foregoing compounds: 4 : 4′-*di-p-arsino-o-methylanilinoformyl-sym.-diphenylcarbamide*, $(AsO(OH)_2C_6H_3.CH_3.NH.CO.C_6H_4.NH)_2CO$, M.pt. above 250° C.; 4 : 4′-*di-p-arsinoanilinoformyl-sym.-diphenylcarbamide*, M.pt. above 250° C.; 3 : 3′-*di-m-arsinoanilinoformyl-sym.-diphenylcarbamide*, melting with decomposition at 249° to 250° C.; 3 : 3′-*di-p-arsinoanilinoformyl-sym.-diphenylcarbamide*, M.pt. above 250° C.; and 2 : 2′-*di-p-arsinoanilinoformyl-sym.-diphenylcarbamide*, M.pt. above 250° C.

Compounds formed by the Condensation of Alkyl Chloroformates with Aminoarylarsinic Acids.[1]

The condensation of these compounds is effected by dissolving the arsinic acid in a slight excess of normal sodium carbonate solution and slowly adding a slight excess of the chlorocarbonate. The products are usually colourless and crystalline, their melting-points becoming lower with increase in length of the carbon chain of the alkyl chlorocarbonate; compounds obtained from *iso*alkyl chlorocarbonates have slightly higher melting-points than those from straight chain alkyl chlorocarbonates. Most of the products are soluble in cold alcohol, insoluble in chloroform, benzene, and ether, with decreasing solubility in cold water as the carbon content of the alkyl chlorocarbonate increases, but all are soluble in hot water. The following products have been isolated by condensing methyl, ethyl, propyl, *iso*propyl, butyl and *iso*butyl chlorocarbonates with *p*-arsanilic acid, *m*-arsanilic acid, 3-amino-4-methyl-phenylarsinic acid, 3 : 4-diaminophenylarsinic acid, and 3-amino-4-hydroxyphenylarsinic acid: 4-*Carboxyaminophenylarsinic acid*, M.pt. above 350° C.; 3-*carbomethoxyaminophenylarsinic acid*, melting with decomposition at 231° C.; 3-*carbomethoxyamino-4-methylphenylarsinic acid*, M.pt. 191° to 193° C.; 3-*carbomethoxyamino-4-carbomethoxyhydroxyphenylarsinic acid*, M.pt. 172° to 174° C.; 3 : 4-*dicarboxyaminodiaminophenylarsinic acid*, M.pt. above 250° C.; 4-*carbethoxyaminophenylarsinic acid*, M.pt. above 250° C.; 3-*carbethoxyaminophenylarsinic acid*, M.pt. 180° C.; 3-*carbethoxyamino-4-methylphenylarsinic acid*, M.pt. 181° C.; 3-*carbethoxyamino-4-carbethoxyhydroxyphenylarsinic acid*, M.pt. 165° C.; 3 : 4-*dicarbethoxydiaminophenylarsinic acid*, M.pt. 187° C.; 4-*carbo-n-propoxyaminophenylarsinic acid*, M.pt. above 250° C.; 3-*carbo-n-propoxyaminophenylarsinic acid*, M.pt. 117° C.; 3-*carbo-n-propoxyamino-4-methylphenylarsinic acid*, M.pt. 150° to 151° C.; 3-*carbo-n-propoxyamino-4-carbo-*

[1] Hamilton and Sly, *J. Amer. Chem. Soc.*, 1925, 47, 435; see German Patent, 232879.

n-propoxyhydroxyphenylarsinic acid, M.pt. 133° to 134° C.; 3 : 4-*dicarbo-n-propoxydiaminophenylarsinic acid*, M.pt. 165° to 166° C.; 4-*carboisopropoxyaminophenylarsinic acid*, M.pt. above 250° C.; 3-*carboisopropoxyaminophenylarsinic acid*, M.pt. 144° to 145° C.; 3-*carboisopropoxyamino-4-methylphenylarsinic acid*, M.pt. 179° C.; 3-*carboisopropoxyamino-4-carboisopropoxyhydroxyphenylarsinic acid*, M.pt. 154° to 155° C.; 3 : 4-*dicarboisopropoxydiaminophenylarsinic acid*, M.pt. 177° C.; 4-*carbo-n-butoxyaminophenylarsinic acid*, M.pt. above 250° C.; 3-*carbo-n-butoxyaminophenylarsinic acid*, M.pt. 83° to 84° C.; 3-*carbo-n-butoxyamino-4-methylphenylarsinic acid*, M.pt. 143° to 144° C.; 3-*carbo-n-butoxyamino-4-carbo-n-butoxyhydroxyphenylarsinic acid*, M.pt. 143° C.; 3 : 4-*dicarbo-n-butoxydiaminophenylarsinic acid*, M.pt. 197° to 198° C.; 4-*carboisobutoxyaminophenylarsinic acid*, M.pt. above 250° C.; 3-*carboisobutoxyaminophenylarsinic acid*, M.pt. 142° to 143° C.; 4-*methyl*-3-*carboisobutoxyaminophenylarsinic acid*, M.pt. 162° C.; 3-*carboisobutoxyamino-4-carboisobutoxyhydroxyphenylarsinic acid*, M.pt. 142° to 143° C.; 3 : 4-*dicarboisobutoxydiaminophenylarsinic acid*, M.pt. 172° C.

Compounds formed by the Condensation of Alkyl Chloroformates with Hydroxyarylarsinic Acids.[1]

The alkyl chlorocarbonates are added dropwise to slightly alkaline solutions of the hydroxyarylarsinic acids and the condensation products precipitated by the addition of dilute hydrochloric acid until the mixture is acid to Congo red. The products form colourless or slightly cream-coloured crystals, soluble in hot water, alcohol, and chloroform, but insoluble in ether and benzene. They usually melt with effervescence, the decomposition point becoming lower with increase in length of the carbon chain of the chlorocarbonate. The *iso*-compounds have a higher decomposition point than the corresponding straight chain compounds. The following derivatives are obtained by the condensation of methyl, ethyl, propyl, *iso*propyl, butyl and *iso*butyl chlorocarbonates with *para-* and *meta*-hydroxyphenylarsinic acids and with 3-nitro-4-hydroxyphenylarsinic acid: *p-Arsinophenylmethyl*, *p-arsinophenylethyl*, *p-arsinophenylpropyl*, *p-arsinophenylisopropyl*, *p-arsinophenylbutyl*, *p-arsinophenylisobutyl* and 2-*nitro*-4-*arsinophenylmethyl carbonates*, all melting above 250° C.; 2-*nitro*-4-*arsinophenylethyl carbonate*, M.pt. 154° C.; 2-*nitro*-4-*arsinophenylpropyl carbonate*, M.pt. 133° C.; 2-*nitro*-3-*arsinophenylisopropyl carbonate*, M.pt. 168° C.; 2-*nitro*-4-*arsinophenylbutyl carbonate*, M.pt. 137° C.; 2-*nitro*-4-*arsinophenylisobutyl carbonate*, M.pt. 141° C.; *m-arsinophenylmethyl carbonate*, M.pt. 143° C.; *m-arsinophenylethyl carbonate*, M.pt. 128° C.; *m-arsinophenylpropyl carbonate*, M.pt. 115·5° C.; *m-arsinophenylisopropyl carbonate*, M.pt. 154° C.; *m-arsinophenylbutyl carbonate*, M.pt. 87° C.; and *m-arsinophenylisobutyl carbonate*, M.pt. 100° C.

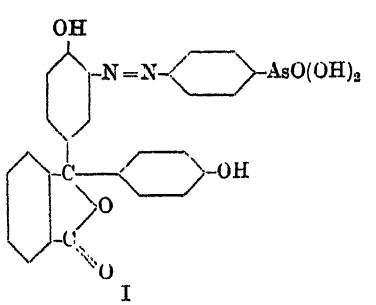
p-Arsinobenzeneazophthaleins.[2]

These derivatives are readily obtained by adding diazotised arsanilic acid to alkaline solutions of phthaleins, the general method of preparation

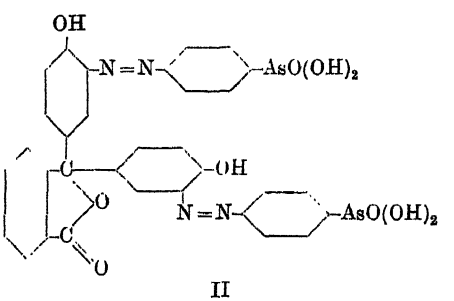
[1] Hamilton and Johnson, *J. Amer. Chem. Soc.*, 1926, 48, 1405.
[2] Christiansen, *ibid.*, 1925, 47, 2244.

being according to the following example: Arsanilic acid (4·3 grams), in 43 c.c. of water and 4·1 c.c. of hydrochloric acid (density 1·19), is diazotised between 0° and 6° C. with 1·38 grams of sodium nitrite in 8·6 c.c. of water. After fifteen minutes the diazo-solution is syphoned into 6·5 grams of fluorescein in 55 c.c. of water containing 4·5 grams of sodium hydroxide, the mixture cooled in ice and mechanically stirred. After thirty minutes 10 c.c. of concentrated hydrochloric acid are added, and, after standing in an ice-chest for a further thirty minutes, the product is centrifuged. The gelatinous precipitate is washed with water by centrifuging and dried at 80° C., an amorphous red powder being obtained, which is a mixture of unchanged product and mono- and diarsinobenzeneazo-derivatives, which may be separated by fractional precipitation from an aqueous alkaline solution with alcohol. The following have been obtained, all being coloured, amorphous powders:

o-4-Arsinobenzeneazophenolphthalein (I); **o-o'-di-4-arsinobenzeneazophenolphthalein** (II),



I



II

also *o-4-arsinobenzeneazo-* and *o-o'-di-4-arsinobenzeneazo-phenoltetrachlorophthalein*; *o-4-arsinobenzeneazo-* and *o-o'-di-4-arsinobenzeneazofluorescein*; *o-4-arsinobenzeneazo-* and *o-o'-di-4-arsinobenzeneazo-dibromofluorescein*.

1-Phenylbenzthiazolearsinic Acids.

1-Phenylbenzthiazole-5-arsinic acid[1] results when 5-amino-1-phenylbenzthiazole is diazotised and treated with sodium arsenite in the presence of copper-bronze. The yield is only 5·4 per cent., and the compound is unmelted at 310° C.

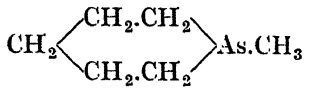
1-Phenylbenzthiazole-4'-arsinic acid is prepared in a similar manner from 1-*p*-aminophenylbenzthiazole, the yield being about 26 per cent.; the product does not melt at 302° C. Mixed acid at 40° to 45° C. converts this compound into 5(?)-*nitro*-1-*phenylbenzthiazole*-4'-*arsinic acid*, which gives the corresponding *amino-compound* when reduced with ferrous sulphate and alkali. When diazotised and coupled with β-naphthol it gives a cherry-red dye.

1-p-Hydroxyphenylbenzthiazolearsinic acid is obtained by nitrating and reducing 1-*p*-hydroxyphenylbenzthiazole and converting the amine into the arsinic acid by means of Bart's reaction.

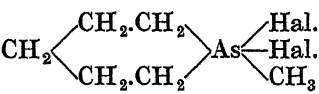
[1] Bogert and Corbitt, *Proc. Nat. Acad. Sci.*, 1925, 11, 768.

Heterocyclic Rings containing Arsenic.

1-Methylarsepidine or Methylcyclopentamethylenearsine,[1]



The requisite quantity of methyldichloroarsine is added to the Grignard reagent prepared from 40·46 grams of 1 : 5-dichloropentane, 13·95 grams of magnesium, and 3 drops of methyl iodide in 300 c.c. of ether. After the reaction has subsided, the mixture is heated for eight hours on the water-bath, the operations being carried out as far as possible in the absence of air. The mass is decomposed with 200 c.c. of hydrochloric acid (1 : 2), cooled for twenty-four hours, and made alkaline by the addition of 300 c.c. of 50 per cent. sodium hydroxide, the vessel being cooled during the addition. The liquor is then distilled in a current of hydrogen from an oil-bath, and when 500 c.c. of ether-water mixture have passed over, the operation is stopped. Petroleum ether is added to the residue, which is agitated in a carbon dioxide atmosphere, the arsepidine dissolving in the petroleum ether. The latter is separated, dried by calcium chloride, and filtered off in a carbon dioxide atmosphere. Fractionation of the liquor in an inert gas gives 16·5 grams of product. It is a colourless liquid, having an odour of mustard oil, B.pt. 156° C. at 760 mm., 76° C. at 36 mm., 65° C. at 20 to 22 mm.; density 1·218 at 18° C. It is soluble in alcohol, ether, petroleum ether, benzene, and carbon tetrachloride, insoluble in hydrochloric acid and water, imparting an acid reaction to the latter. It is volatile in steam, but when heated alone it decomposes, giving an arsenic mirror and gaseous hydrocarbons. The arsepidine is not combustible, but when poured upon filter-paper it causes the latter to inflame, and clouds of arsenious oxide vapour are given off. In contact with air it is oxidised with formation of the oxide. The arsine reduces ammoniacal silver nitrate and alkaline permanganate solutions. It combines additively with halogens, giving compounds of the type



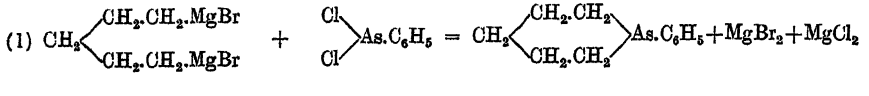
The *dichloride* is very hygroscopic and decomposes on heating, with formation of chloroform and dichloropentane. The chlorine may be removed by the action of silver nitrate. The *dibromide* has similar properties to the dichloride, but the *di-iodide* is an ochre powder, M.pt. 120° C.

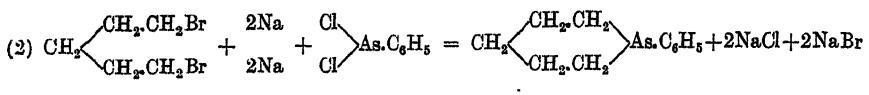
The *oxide* is a white powder, having an aromatic odour, and decomposing at 150° C. It is insoluble in water, but soluble in alkalis, especially in ammonium hydroxide. The *methiodide* occurs in colourless, rhombic crystals, melting with decomposition at about 290° C. It dissolves in water and alcohol, but is insoluble in ether; with moist silver oxide it is converted into the *hydroxide*, which forms a strongly alkaline solution readily absorbing carbon dioxide. The *platinichloride* is a pale yellow powder, M.pt. 163° C., and the *picrate* a yellow compound, M.pt. 258° C., both sparingly soluble in water.

[1] Zappi, *Bull. Soc. chim.*, 1916, [iv.], 19, 151, 247, 290.

Ethylcyclopentamethylenearsine [1] is obtained in poor yield by a method similar to that used in the foregoing. It boils at 62° to 64° C. at 12·5 mm. and is volatile in ether vapour. Methyl iodide converts it into *methylethylcyclopentamethylenearsonium iodide*, M.pt. 276° C., and ethyl iodide gives *diethylcyclopentamethylenearsonium iodide*. Both compounds are somewhat unstable and are readily soluble in water, chloroform, hot alcohol, and acetone, insoluble in ether and benzene. The arsine yields a *cyanobromide*, which is very susceptible to moisture, and readily changes to the *hydroxybromide*, M.pt. 71° C. Decomposition of the cyanobromide by heat appears to be complicated, the following having been identified amongst other products: Ethylcyclopentamethylenearsine, cyanogen bromide, ethyl bromide.

1-Phenylarsepidine or Phenylcyclopentamethylenearsine.[2]—This arsine may be prepared by two methods, as shown by the following equations, but that indicated by equation (1) gives the larger yield:



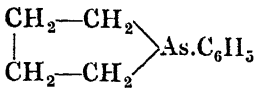


75 grams of phenyldichlorarsine in 3 volumes of ether are slowly added, with good shaking and cooling, to the magnesium compound from 75 grams of 1 : 5-dibromopentane in 500 grams of ether. When the reaction slows down, the mixture is heated for thirty minutes on the water-bath, then decomposed with very dilute hydrochloric acid, the ether layer washed with dilute potassium hydroxide, dried over calcium chloride, and the ether distilled off. The residual oil is fractionated in a carbon dioxide atmosphere at 18 to 20 mm. pressure, a yield of 24 grams of arsine being obtained. It is a colourless, viscous oil, boiling at 153° to 154° C. at 18 to 20 mm.; density 1·2480 at 20° C.; n_D 1·5944 at 21·4° C.; $n_F - n_C$ 0·02167 at 22·4° C. It has a faint, unpleasant odour, and is not appreciably oxidised in air at ordinary temperatures. It is sparingly soluble in water, easily soluble in hot alcohol, and miscible with carbon tetrachloride, ether, and benzene. The *dichloride* forms colourless, hygroscopic prisms or plates, melting at 138° to 139° C.; the *dibromide* is an oil; the *di-iodide* crystallises in pale yellow crystals, and the *tetra-iodide* is a brown oil. The *mercurichloride* occurs as hair-like needles, M.pt. 201·5° to 202° C. The following arsonium derivatives of this arsine have also been described: *Methiodide*, white leaflets, M.pt. 179·5° C.; *ethiodide*, white prisms, M.pt. 185° C.; *n-propiodide*, white crystals, M.pt. 137° to 138° C.; *sec.-propiodide*, white crystals; *n-butiodide*, white, star-like crystals, M.pt. 140° C.

1-p-Tolylarsepidine is prepared in a similar manner to the preceding compound, and it possesses the same characteristics. It boils at 162° to 163° C. at 20 mm. and 177° to 178° C. at 50 mm.; density 1·2174, n_D 1·5948, $n_F - n_C$ 0·02068, all at 20° C. The *dichloride* crystallises in snow-white needles from carbon tetrachloride, and melts at 134° C.; the *mercurichloride* forms short rods, M.pt. 175° C.

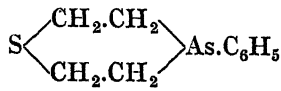
[1] Steinkopf, Donat, and Jaeger, *Ber.*, 1922, 55, [B], 2597.
[2] Grüttner and Wiernik, *ibid.*, 1915, 48, 1479.

Phenylcyclotetramethylenearşine,[1]



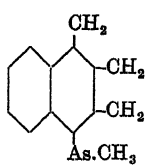
This is prepared in a similar manner to phenylcyclopentamethylenearsine, the 1 : 5-dibromopentane being replaced by 1 : 4-dibromobutane. It is a colourless oil of faint, unpleasant smell, B.pt. 128·5° C. at 15 to 16 mm., density 1·2997 at 0° C., 1·2896 at 10° C., 1·2794 at 20° C., 1·2694 at 30° C., 1·2824 at 17° C., n_D 1·6768 at 17° C., $n_F - n_C$ 0·02434 at 17° C. The *dichloride* is very hygroscopic and melts at 120·5° C.; the *mercurichloride* forms six-sided plates, M.pt. 160° to 162° C. The following arsonium derivatives have also been described: *Methiodide*, a pale yellow powder, M.pt. 135° to 136° C.; *ethiodide*, M.pt. 85° to 86° C.; *n-propiodide*, white needles, M.pt. 123° to 124° C.; *sec.-propiodide*, a yellowish, crystalline powder, M.pt. 113° to 114° C., with decomposition.

Phenylthiarsane,[2]



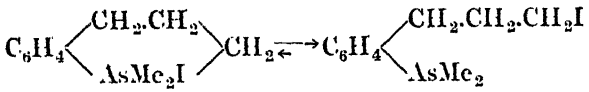
is the product of the interaction of the compound $As.C_6H_5(MgBr)_2$ (p. 63), and β-β-dichloroethylsulphide. It melts at 38° C., B.pt. 134° C. at 4 mm. or 177° C. at 16 mm. It forms a *mercurichloride*, decomposing at 181° C., and a yellow *mercuri-iodide*, decomposing at 153° C. The *methiodide* melts at 226° C. and forms a *mercuri-iodide*, M.pt 147° C., and a *nitrate*.

Asym.-Methyltetrahydroarsinoline,[3]



5 grams of γ-phenylpropylmethylchloroarsine and 2·7 grams of aluminium chloride in carbon disulphide are heated until no further evolution of hydrogen chloride takes place, an operation occupying about three hours. The mass is then decomposed by ice, acidified, and extracted with carbon tetrachloride, from which solution 2 grams of compound are isolated on vacuum distillation. When 21 grams of γ-phenylpropylmethylbromoarsine are used a 10-gram yield is obtained. Using benzene as a solvent, 10 grams of chloroarsine give 6 grams of the arsinoline. The arsinoline is a colourless liquid, B.pt. 140° C. at 14 mm., highly refractive and having an odour faintly resembling that of quinoline. It slowly oxidises in air, and gives a colourless solution in concentrated sulphuric acid, from which water precipitates the unchanged arsine. The *methiodide* crystallises from water or alcohol in colourless prisms, M.pt. 239° to 240° C. The hot alcoholic solution possesses a yellow colour which disappears as the solution cools, the colour change probably being due to intramolecular change:

[1] Grüttner and Krause, *Ber.*, 1916, 49, 437.
[2] Job, Reich, and Vergnaud, *Bull. Soc. chim.*, 1924, [iv.], 35, 1404.
[3] Burrows and Turner, *Trans. Chem. Soc.*, 1921, 119, 430.

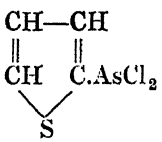


The *ethiodide* and *benzobromide* form colourless prisms, melting at 185° to 186° C. and 210° to 211° C. respectively. The *platinichloride* is a yellow, microcrystalline powder, M.pt. 170° C.; the *picrate* and *picrolonate* are yellow, crystalline solids.

Asym.-Chlorotetrahydroarsinoline.[1]—The foregoing methyl compound (20 grams) is dissolved in carbon tetrachloride and a current of chlorine allowed to impinge upon the surface of the solution. The white solid *dichloride* separates, and excess of chlorine is removed by adding a little arsinoline. Distillation of the product yields methyl chloride and 16 grams of liquid, B.pt. 155° C. at 16 mm. On cooling, this solidifies to large, irregular, hexagonal rhomboids, M.pt. 22° C.

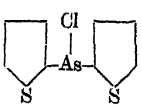
Arsenic Compounds of the Thiophene Series.

Thienyldichloroarsine,[2]



To 130 grams of arsenious chloride 110 grams of powdered mercury dithienyl, $(C_4H_3S)_2Hg$, are added in small portions, the whole being stirred and water-cooled during the addition. The mixture is then stirred for five hours without cooling and afterwards allowed to stand for twenty-four hours. The mercuric chloride is then quickly filtered off and washed with arsenious chloride, and the dark brownish-red filtrate distilled *in vacuo*. A yield of 22·5 grams of a fraction of B.pt. 116° to 130° C. at 11 mm. gives, on further fractionation, 9 grams of crude thienyldichloroarsine, B.pt. 115° to 125° C. at 11 mm. This is cooled to −80° C. in ether-carbon dioxide mixture, any crystals which are formed removed, and the liquid remaining, after allowing to rise to room temperature, is again fractionated. A pale brown oil is thus obtained, B.pt. 118° to 122° C. at 11 mm.

Dithienylchloroarsine,

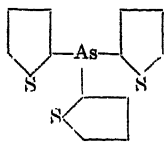


This product is present in a fraction from the preceding preparation boiling between 150° and 194° C. at 11 mm. The crude distillate weighs about 10 grams and yields 2·35 grams of pure chloride as a brownish, pungent liquid, B.pt. 219° to 232° C. at 13 mm. Another method of preparation is as follows: To 50 grams of chloromercuri-

[1] Roberts, Turner, and Bury, *J. Chem. Soc.*, 1926, p. 1444.
[2] Steinkopf, *Annalen*, 1917, 413, 310.

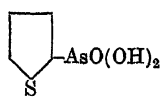
thiophene, $C_4H_3S.HgCl$, in 750 c.c. of boiling toluene, 35 grams of arsenious chloride are gradually added and the boiling maintained for six to seven hours. The mercuric chloride is filtered off from the cooled mixture, the excess of arsenious chloride and toluene removed in a hydrogen atmosphere, and the residue fractionated, using a Gaede pump. The fraction of B.pt. 106° to 110° C. at 0·5 mm. (3·1 grams) is principally dithienylchloroarsine.

Trithienylarsine,

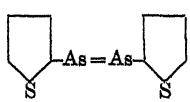


The fractions obtained above 190° C. in the two preceding preparations are again fractionated, using a Gaede pump, and 11·6 grams of product are thus obtained, B.pt. 199° to 200·5° C. at 0·5 mm. This arsine is a pale greenish-yellow, viscous, odourless liquid. It has also been obtained by the action of metallic sodium on an ethereal solution of 2-bromothiophene and arsenious chloride.[1]

Thienyl-2-arsinic acid,[2]



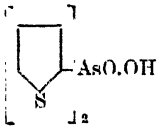
Chloromercurithiophene or mercury 2 : 2′-dithienyl is treated with arsenious chloride and the product warmed on the water-bath. The filtrate from this mixture is treated with aqueous sodium hydroxide, then with hydrogen peroxide. Addition of barium chloride then helps to remove any inorganic arsenic which has not crystallised out as sodium arsenate. The whole is filtered, the filtrate freed from barium and sulphuric acid and evaporated down after the addition of concentrated hydrochloric acid. The residue is dissolved in alcohol, boiled with charcoal, and treated with sodium hydroxide. The *sodium salt* of the arsinic acid crystallises out in transparent, colourless, non-deliquescent, rhombic plates, which are very soluble in water. The free acid forms tufts of needles, M.pt. 135·5° C., fairly soluble in water or alcohol. At 105° to 108° C. it is converted into the corresponding *anhydride*. Sulphurous acid in the presence of a trace of hydriodic acid reduces it to *thienyl-2-arsenoxide*, whilst with sodium hydrosulphite it yields 2 : 2′-*arsenothiophene*,



The acid and its derivatives do not give the usual colour reactions for thiophene with a sulphuric acid solution of isatin. *Magnesium*, *barium* and *silver salts* have been described.

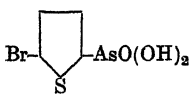
[1] Finzi, *Gazzetta*, 1925, 55, 824.
[2] Finzi, *ibid.*, 1915, 45, ii. 280.

2 : 2′-Dithienylarsinic acid,



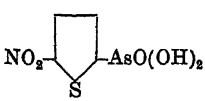
This acid results as a by-product in the preparation of the preceding acid, the mother-liquors from the sodium salt of which are evaporated to dryness, the residue dissolved in water, and dilute hydrochloric acid added. This precipitates the dithienylarsinic acid, which is sparingly soluble in cold water. It may be obtained in better yield by heating thienyldichloroarsine with chloromercurithiophene in sealed tubes. The acid crystallises from hot water in groups of minute needles, M.pt. 172° C., soluble in alcohol, but insoluble in ether or benzene.

5-Bromothienyl-2-arsinic acid,



is obtained by the oxidation of 2-bromo-5-thienyldichloroarsine by means of hydrogen peroxide in the presence of sodium hydroxide. It is a crystalline substance, remaining unfused at 300° C. It is unattacked by concentrated nitric acid, but mixed acid partly decomposes it without nitration. *5-Iodothienyl-2-arsinic acid* has similar properties, but mixed acid converts it into 3-(or 4-)*nitro-5-iodothienyl-2-arsinic acid.*

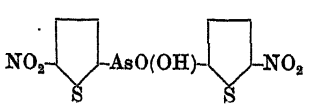
5-Nitrothienyl-2-arsinic acid,[1]



Thienyl-2-arsinic acid is added to a cooled mixture of fuming nitric and sulphuric acids, the nitrous fumes being withdrawn by a current of air. Addition of water precipitates the nitro-acid, which crystallises from boiling water in small prisms. These, if rapidly heated, melt with spluttering and conversion to the *anhydride* at 194° C., but when slowly heated the anhydride is formed without melting and remains solid above 250° C.

5-Aminothienyl-2-arsinic acid results when the preceding acid is reduced by sodium amalgam in methyl alcohol solution. It crystallises in pale yellow, microscopic laminæ, decomposing at 194° C. It is readily diazotised and coupled with amines and phenols, yielding highly coloured compounds. The *acetyl derivative* forms white prisms, M.pt. 134° C., with decomposition.

Di-5-nitrodi-2-thienylarsinic acid,

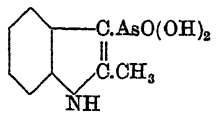


[1] Finzi and Furlotti, *Gazzetta*, 1915, 45, ii. 290.

forms brownish-red, microscopic crystals, M.pt. 287° C., with decomposition.

Arsinic Acids of the Indole Series.

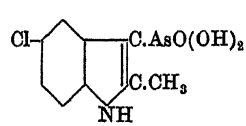
Methylindolearsinic acid (Methylketolearsinic acid),



This acid may be isolated as follows: [1] Anhydrous arsenic acid, 28·4 parts, is dissolved in 6 parts of water by the aid of heat, and 13·1 parts of methylketole added. The mixture is warmed on the water-bath until a crystalline product separates. This is triturated with water, filtered, and well washed with water to remove excess of arsenic acid. The product is dissolved in dilute sodium hydroxide solution, filtered, and the filtrate acidified with hydrochloric acid. The arsinic acid separates in fine needles, M.pt. 180° to 182° C., 93 per cent. yield. It dissolves readily in absolute alcohol or acetic acid, but is insoluble in other organic solvents. The *sodium salt* is readily soluble in water; its crystals contain 2·5 molecules of water of crystallisation, and it melts with decomposition at 225° to 235° C. A *quinine salt* is known, $C_{20}H_{24}N_2O_2.C_6H_{10}NAsO_3.2\frac{1}{2}H_2O$, which is readily soluble in methyl and ethyl alcohols, addition of water causing it to separate in fine needles. It sinters at 155° C. and melts at 170° to 172° C.

The conditions underlying the preparation of the foregoing acid have been investigated recently.[2] It is stated that arsenic compounds of the type in question are easily obtained from indole derivatives in toluene, nitrobenzene or concentrated aqueous solution on the addition of arsenic acid. The more concentrated the aqueous solution of arsenic acid the greater the yield of arsinic acid, and it has been shown that there is an optimum temperature at which the reaction takes place instantly. Applying these conditions to indole and some of its derivatives, such as N-methyl- and N-α-dimethylindole, *indole-β-arsinic acid*, *N-methyl-* and *N-α-dimethyl-indole-β-arsinic acids*, respectively, are readily obtained. The optimum temperatures for the foregoing reactions are 65° C., 69° C., and 60° to 70° C., respectively. For *methylindolearsinic acid* the optimum temperature is 59° C., and the decomposition point is given as 181° to 181·5° C. The product is said to be very unstable towards acids and alkalis; its *sodium salt* shows no change up to 290° C., and contains 5 to 14 molecules of water of crystallisation. It has been ascertained that only the hydrogen atom in the 3-position shows any tendency to be replaced by the arsinic acid grouping.

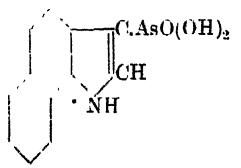
Chloromethylindolearsinic acid,[1]



[1] German Patent, 240793.
[2] Funakubo, *J. Chem. Soc. Japan*, 1927, 48, 526.

Chloromethylindole (16·7 parts) is dissolved in 100 parts of toluene, treated with 284 parts of arsenic acid in 20 parts of alcohol, and the mixture boiled for two hours under reflux. The toluene is then distilled off and the residue extracted with alcohol. The solvent is removed on the water-bath, the solid dissolved in dilute sodium hydroxide solution, the solution filtered, and the filtrate acidified with hydrochloric acid. The arsinic acid separates in crystalline form, melting with decomposition at 185° to 186° C., and is soluble in alcohol, from which solution the acid is reprecipitated on dilution with water.

α-Naphthindolearsinic acid,



Four parts of α-naphthindole in 40 parts of toluene are treated with 6·4 parts of anhydrous arsenic acid in 5 parts of absolute alcohol and the mixture treated as described for the preceding compound. A 56 per cent. yield of the arsinic acid results. It is a crystalline product, sparingly soluble in alcohol, and insoluble in other organic solvents.

Arsenic Compounds of the Pyrazolone Series.[1]

These derivatives are formed by introducing the arsinic acid residue into amino-pyrazolones by means of the diazo-reaction.

5-Chloro-3-methylpyrazole-1-benzene-4′-arsinic acid is prepared by treating diazotised 5-chloro-3-methylpyrazole-1-*p*-aminobenzene with sodium arsenite and subsequently acidifying the mixture. It is a crystalline compound, melting at 192° to 195° C. on rapid heating, and forming an *anhydride*. This solidifies when the water is eliminated, and completely decomposes above 290° C.

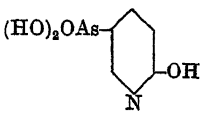
3-Methyl-5-pyrazolone-1-benzene-4′-arsinic acid crystallises from hot water and gives a yellow *nitroso-compound*. When methylated the acid forms 2 : 3-*dimethyl*-5-*pyrazolone*-1-*benzene*-4′-*arsinic acid*, which by the action of sodium nitrite and dilute sulphuric acid is converted into 4-*nitroso*-2 : 3-*dimethyl*-5-*pyrazolone*-1-*benzene*-4′-*arsinic acid*, reduction of which leads to 1-*p*-*arsenodiphenyl*-*di*(4-*amino*-2 : 3-*dimethyl*-5-*pyrazolone*). This compound yields a yellow, crystalline *hydrochloride*, a *monoacetate*, and a *diglycine*. When the hydrochloride or the above nitroso-derivative is treated with formaldehydesulphoxylate, 1-*p*-*arsenodiphenyl*-*di*(4-*amino*-2 : 3-*dimethyl*-5-*pyrazolone*)-*monomethylenesulphoxylate* is produced as a yellow powder, excess of formaldehyde giving a *dimethylenesulphoxylate*. The 1-*p*-*arsenodiphenyl*-*di*(4-*amino*-2 : 3-*dimethyl*-5-*pyrazolone*) with sodium bisulphite and formaldehyde gives a yellow powder, which is the 4-*N*-*methylsulphinic acid*. 1-*p*-*Arsenodiphenyl*-*di*(4-*amino*-5-*pyrazolone*) gives a *carbamate* as a clear, stable solution.

[1] German Patent, 313320; *Chem. Zentr.*, 1921, iv. 262; German Patent, 360424; *Chem. Zentr.*, 1923, ii. 407.

Arsenic Compounds of the Pyridine Series.

These compounds are prepared by diazotising aminopyridines and treating the solutions with sodium arsenite in the usual way. The arsinic acids are not obtained directly from the reaction mixture but are reduced to the arseno-compounds, which are filtered off and oxidised with hydrogen peroxide to yield the acids. The latter are reducible in the normal way to arsenoxides, yellow amorphous arseno-compounds, and arsines.

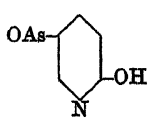
2-Hydroxypyridine-5-arsinic acid,[1]



2-Hydroxy-5-aminopyridine hydrochloride is dissolved in 60 c.c. of water, after the addition of 8 c.c. of 30 per cent. hydrochloric acid, and diazotised with 4·2 grams of sodium nitrite in 42 c.c. of water. The diazo-solution is then added to 6·6 grams of arsenious oxide in 120 c.c. of 5 per cent. sodium hydroxide. After two hours' stirring the liquor is filtered and faintly acidified with hydrochloric acid, again filtered, charcoal added, and the solution evaporated to half-bulk. It is then reduced to the arseno-compound by heating with sodium hypophosphite in the presence of a little potassium iodide, the reaction being carried out on the water-bath. The arseno-compound is filtered off, washed, and oxidised to the arsinic acid by 3 per cent. hydrogen peroxide in the cold. The acid is obtained by evaporating the solution to crystallising-point, and recrystallisation from water gives white needles, unmelted at 360° C. The yield is about 25 per cent. *Silver*, *copper*, *barium* and *mercury salts* are known.

When 2-hydroxypyridine-5-arsinic acid is mixed with 2-nitrophenol-4-arsinic acid and the whole reduced, 2-*amino*-4-(2-*hydroxy*-5-*pyridine*-*arseno*-)*phenol* results, $HO.C_5H_3.N.As{=}As.C_6H_3(OH)NH_2$.[2] The same compound is obtained when 2-hydroxypyridyl-5-dichloroarsine is converted to the oxide by water and condensed with 3-amino-4-hydroxyphenylarsine. Various compounds containing the arseno grouping are obtained by reducing 2-hydroxypyridine-5-arsinic acid or similar compounds by sodium hypophosphite or suitable reducing agent in the presence of 4-hydroxy-3-aminophenylarsine or similar compound containing the grouping $-AsH_2$.[3]

2-Hydroxypyridyl-5-arsenoxide,[4]

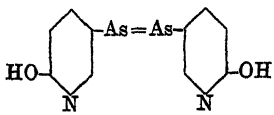


22 grams of the previous arsinic acid in 700 c.c. of water are treated with 6 grams of potassium iodide and the solution faintly acidified with

[1] Binz and Räth, *Annalen*, 1927, 455, 127; see British Patent, 250287 (1924).
[2] British Patent, 250577 (1926).
[3] American Patent, 1678760.
[4] Binz and Räth, *loc. cit.*

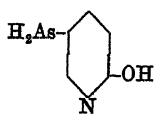
sulphuric acid. A strong stream of sulphur dioxide is passed for two hours at 15° C. and the whole allowed to stand for a further two hours at 0° C. Ammonium hydroxide is then added until the liquid is alkaline and the mixture evaporated to dryness in a vacuum. The residue is treated with much water and the insoluble residue washed with water, alcohol and ether, and dried. The yield is about 12 grams, and the compound is soluble in acids and alkalis.

2 : 2′-Dihydroxy-5 : 5′-arsenopyridine,



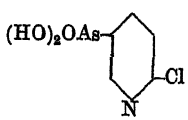
2-Hydroxypyridine-5-arsinic acid (4 grams) with 15 grams of sodium hypophosphite and 2 c.c. of 10 per cent. potassium iodide solution in 60 c.c. of water are gently warmed until a solution is obtained. Concentrated hydrochloric acid (20 c.c.) is slowly added, the arseno-compound separating. It is washed with hot water and dried in a vacuum at 70° to 80° C., a yellow product, insoluble in alkali, being obtained.

2-Hydroxypyridyl-5-arsine,



2-Hydroxypyridine-5-arsinic acid is dissolved in 200 c.c. of water and 75 c.c. of hydrochloric acid by gentle heating and 45 grams of zinc dust slowly added to the hot solution with vigorous stirring. The reaction mixture is warmed on the water-bath until a clear solution is obtained, and the zinc dust then filtered off. The filtrate contains the arsine, which rapidly oxidises in air to the yellow *arseno-compound*. It has not been isolated in the solid state and therefore not analysed.

2-Chloropyridine-5-arsinic acid,



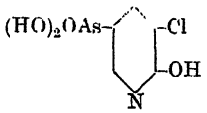
is prepared in a similar manner to the preceding arsinic acid, 2-chloro-5-aminopyridine (13 grams) yielding 4·8 grams of the arsinic acid, which crystallises from water in white needles, M.pt. 178° to 179° C. Reduction leads to the *oxide*, decomposing at 138° C., and 2 : 2′-*dichloro*-5 : 5′-*arsenopyridine*, an insoluble yellow product, decomposing at 140° C. 2-*Chloropyridyl*-5-*arsine* is a white, amorphous substance, soon becoming yellow in air and decomposing at 135° C. It is soluble in water and ether.

2 - Bromopyridine - 5 - arsinic acid.—2-Bromo-5-aminopyridine (17·5 grams) yields only 5 grams of the arsinic acid, M.pt. 175° C. The *oxide* decomposes at 159° C.; the *arseno-derivative* and *arsine* are known.

2-Iodopyridine-5-arsinic acid.—The yield of this acid from 22 grams of 2-iodo-5-aminopyridine is 6·5 grams. It forms compact

crystals, M.pt. 173° C.; it gives an *oxide* decomposing at 145° C., an *arsine* decomposing at 140° C., and an *arseno-compound*.

3-Chloro-2-hydroxypyridine-5-arsinic acid,

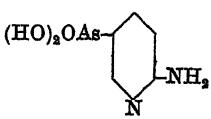


This acid is prepared from 3-chloro-5-amino-2-hydroxypyridine hydrochloride, 18·1 grams giving 4·3 grams of the acid. It melts at 237° C. and forms an *oxide*, decomposing at 195° C., and a dark yellow *arseno-compound*.

3-Bromo-2-hydroxypyridine-5-arsinic acid is obtained in quantitative yield from 2-hydroxypyridine-5-arsinic acid by direct bromination in acetic acid solution, the temperature being maintained below 30° C. It does not melt at 300° C. The *oxide* decomposes at 232° C., and the *arseno-compound* can be obtained in quantitative yield.

3-Iodo-2-hydroxypyridine-5-arsinic acid.—This is isolated from 3-iodo-5-amino-2-hydroxypyridine, 27·2 grams of which give 6·4 grams of the arsinic acid. It crystallises from water in compact needles, decomposing at 289° C., and losing iodine when boiled with water. The *oxide* decomposes at 200° C., and the *arseno-compound* has the usual properties.

2-Aminopyridine-5-arsinic acid,

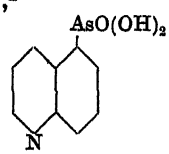


is obtained when 2 : 5-diaminopyridine hydrochloride is diazotised and the solution mixed with sodium arsenite in the usual manner, 18 grams of the diamine giving 6 grams of the acid. It is readily soluble in water and acetic acid, sparingly soluble in alcohol. Prolonged boiling with water splits off arsenic acid. The *oxide* decomposes at 90° C. and is a white substance, soluble in dilute acid and alkali. The *arseno-compound* can readily be isolated in the form of its *tetrahydrochloride*, the free base being liberated by alkali. The base is insoluble in ether and benzene, sparingly soluble in alcohol.[1]

Arsenic Compounds of the Quinoline Series.

The remarks regarding the preparation of pyridine derivatives in the introduction to the preceding section apply also to the formation of quinoline derivatives.

Quinoline-5-arsinic acid,[2]

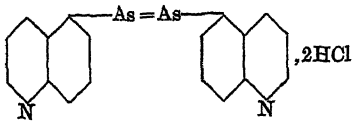


[1] For nitropyridinearsinic acids, see American Patent, 1675402; British Patent, 275590 (1926).

[2] Binz and Räth, *Annalen*, 1927, 453, 238.

5-Amino-quinoline (30 grams) in 400 c.c. of water and 100 c.c. of concentrated hydrochloric acid are diazotised with 15 grams of sodium nitrite in 150 c.c. of water. The mixture is cooled and treated with 440 c.c. of 10 per cent. potassium hydroxide until the solution is no longer acid to Congo red. It is then mixed with 130 c.c. of 2*N* potassium arsenite solution in 500 c.c. of water. The wine-red colour disappears, nitrogen is evolved, and a brown by-product separates. After stirring for an hour, 500 c.c. of hot water are added and the solution filtered. The isolation of the acid is carried out by reducing the product to the arseno-compound and then oxidising the latter to the acid. The filtrate is, therefore, acidified with hydrochloric acid, and after adding 30 to 40 grams of sodium hypophosphite and 10 c.c. of one per cent. potassium iodide solution, the mixture is gently warmed on the water-bath for several hours and stirred. The *arseno-compound* separates as a pale red precipitate, which is filtered off, washed with dilute hydrochloric acid, suspended in ice-water, and treated with three per cent. hydrogen peroxide until starch-iodide paper is turned blue. Charcoal is then added and the solution boiled, filtered, and the filtrate evaporated on the water-bath to crystallising-point. The arsinic acid separates in colourless crystals containing 1 molecule of water and decomposing at 232° C. The yield is only about 15 per cent. and the product is soluble in water, alkalis, alkali carbonates, and concentrated acids.

5 : 5′-Arsenoquinoline dihydrochloride,



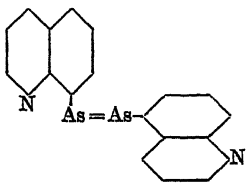
The preceding arsinic acid (5 grams), in 50 c.c. of water and 10 c.c. of concentrated hydrochloric acid, is reduced with 7 to 10 grams of sodium hypophosphite and 3 c.c. of a one per cent. solution of potassium iodide by warming the mixture on the water-bath and passing in a stream of carbon dioxide. The reduction product separates, is filtered off, washed with dilute hydrochloric acid, and dried at 50° C. in a vacuum. The yield is 80 per cent. The arseno-compound is a yellowish-red, amorphous powder, soluble in water and in small quantities in methyl alcohol, from which it may be precipitated by absolute alcohol. In acids and alkalis it is insoluble.

Quinoline-6-arsinic acid is prepared in a similar way to the preceding arsinic acid, 30 grams of 6-amino-quinoline yielding 10 grams of the arsinic acid. It crystallises with 1 molecule of water, melts at 260° to 262° C., and is readily soluble in alkalis, alkali carbonates, concentrated hydrochloric acid, and acetic acid, sparingly soluble in water and methyl alcohol. Reduction, as in the previous case, yields 6 : 6′-*arsenoquinoline dihydrochloride* in 80 per cent. yield, which is a yellowish-red amorphous product, insoluble in water and dilute acids, soluble in concentrated hydrochloric acid.

Quinoline-8-arsinic acid, obtained from 8-amino-quinoline in 33 per cent. yield, crystallises in white needles, M.pt. 230° C., readily soluble in dilute alkali, sodium carbonate, and concentrated mineral acids, insoluble in dilute acids, alcohol, and cold water. When reduced

it yields 8 : 8′-*arsenoquinoline dihydrochloride* in 80 per cent. yield. The arseno-compound is a yellowish-red powder, soluble only in concentrated hydrochloric acid.

When a mixture of quinoline-5- and quinoline-8-arsinic acids is reduced with hypophosphorous acid at 70° C., 5 : 8-*arsenoquinoline* (I) is obtained, and in a similar manner 8-(2-*hydroxypyridine*-5-*arseno*-)*quinoline* (II) and 2-(2-*hydroxypyridine*-5-*arseno*-)*benzoic acid* are prepared.[1]



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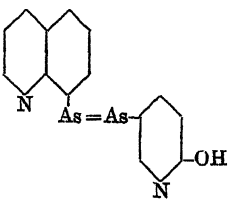
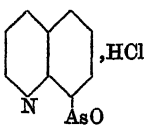


II

The following three derivatives[2] of quinoline-8-arsinic acid have also been obtained :



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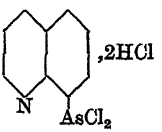
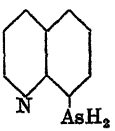


II



III

Quinoline-8-arsenoxide hydrochloride.—10 grams of the arsinic acid in 150 c.c. of water containing 3·2 grams of sodium hydroxide are treated with 3 grams of potassium iodide and 200 c.c. of 10 per cent. sulphuric acid, and sulphur dioxide is passed into the whole for seven hours, the temperature being kept below 15° C. The solution is then stirred and made alkaline by adding concentrated ammonium hydroxide dropwise, the liquor being cooled. After several hours' standing, the oxide separates. It is purified by solution in 50 c.c. of water and 45 c.c. of 2*N* sodium hydroxide, the solution being shaken several times with ether to remove basic by-products. After filtration, the liquid is treated with 25 c.c. of ammonium chloride solution, when the oxide (I) is precipitated in white flocks, the yield being 6 grams. It is soluble in alkali, dilute and concentrated mineral acids, sparingly soluble in water and alcohols, and insoluble in ammonium hydroxide and alkali carbonates.

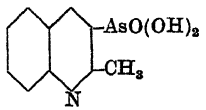
Quinoline-8-dichloroarsine hydrochloride.—The preceding oxide is dissolved in 8 per cent. hydrochloric acid and cold concentrated hydrochloric acid stirred into the solution, when the *dichloro-compound* (II) separates. It melts with decomposition at 250° C. and is readily soluble in alcohol, sparingly soluble in water, and insoluble in ether and acetic acid.

Quinolyl-8-arsine.—Quinoline-8-arsinic acid (8 grams) is dissolved in a mixture of 20 c.c. of concentrated hydrochloric acid and 15 c.c. of water and reduced by adding 10 grams of zinc dust in small portions. After twenty minutes the mixture is filtered and the zinc residues extracted with ether, evaporation of the ethereal solution in a vacuum

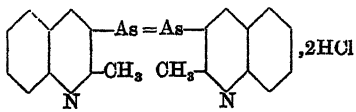
[1] British Patent, 250577 (1926). [2] Binz and Räth, *loc. cit.*

yielding the arsine (III) as a white, amorphous product. It is soluble in ether, alcohol, and sodium hydroxide, and readily oxidised in air to the corresponding *arseno-compound.*

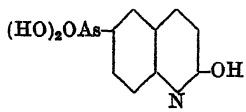
2-Methylquinoline-3-arsinic acid,



This acid is obtained in the usual way from 2-methyl-3-amino-quinoline. It crystallises in white needles, melting with decomposition at 220° C., soluble in alkali, alkali carbonates, hot water, and concentrated acids. The yield is very small. Reduction with hypophosphite and potassium iodide yields the red arseno-compound, 2 : 2′-*dimethyl*-3 : 3′-*arseno-quinoline dihydrochloride,*

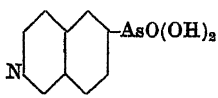


2-Hydroxyquinoline-6-arsinic acid,



crystallises in small scales and is only obtained in poor yield. The arseno-compound, 2 : 2′-*dihydroxy*-6 : 6′-*arsenoquinoline* is yellowish-white.

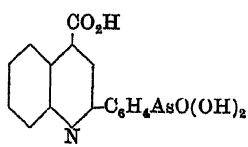
isoQuinoline-5(?)-arsinic acid,



is isolated from amino*iso*quinoline as a crystalline product, which produces 5 : 5′-*arsenoisoquinoline,* an insoluble yellow powder, on reduction.

Arsinophenylcinchoninic Acid and its Derivatives.[1]

p-4-Carboxyquinoline-2-phenylarsinic acid,



A solution of 17 grams of acetophenone-p-arsinic acid (obtained by diazotisation of aminoacetophenone and replacement of the diazo

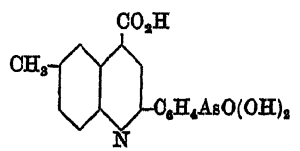
[1] Ogden and Adams, *J. Amer. Chem. Soc.*, 1925, 47, 827 ; see Fränkel and Lowy, *Ber.*, 1913, 46, 2546.

grouping by the arsinic acid group) in 50 c.c. of water containing 7·5 grams of sodium hydroxide is added to 10 grams of isatin in a similar solvent and 300 c.c. of alcohol added to the mixture. After refluxing for twenty-four hours on the steam-bath, the alcohol is distilled off and the cooled solution acidified with dilute hydrochloric acid, when a yellow solid is precipitated. The crude product is purified by crystallisation from hot ethylene glycol, washing with methyl alcohol, then redissolving in hot sodium hydroxide and precipitating by the addition of acid. The arsinic acid is a white powder, unmelted at 270° C.:

$$C_8H_5NO_2+CH_3.CO.C_6H_4.AsO(OH)_2=CO_2H.C_9H_5N.C_6H_4.AsO(OH)_2+H_2O$$

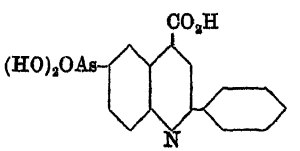
When treated with three molecular equivalents of alkali and the solution poured into an excess of methyl alcohol and cooled, the *disodium salt* results. Esterification with ethyl alcohol gives the *carbethoxy-derivative* in 70 per cent. yield. This melts with decomposition at 117° to 119° C. The corresponding *carbomethoxy-acid* melts at 153° C. and is only obtained in 45 per cent. yield. Reduction of the original acid with sodium hydrosulphite yields *p* : *p'-di-4-carboxyquinoline-2* : *2'-arsenobenzene*, which does not melt below 250° C.

p-4-Carboxy-6-methylquinoline-2-phenylarsinic acid,



This is prepared in a similar way to the preceding compound, the isatin being replaced by methyl-isatin. Crystallised from ethylene glycol, it is a fine, white powder, unmelted below 250° C. Its *carbethoxy-* and *carbomethoxy-derivatives* do not melt below 275° C. Its arseno-compound, *p* : *p'-di-4-carboxy-6-methylquinoline-2* : *2'-arsenobenzene*, is a reddish-brown product, unmelted below 250° C.

6-Arsino-2-phenylquinoline-4-carboxylic acid (Arsinocinchophen),[1]

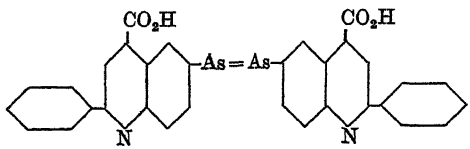


A suspension of 5·36 grams of 6-amino-2-phenylquinoline-4-carboxylic acid in 30 c.c. of 2*N* hydrochloric acid and 20 c.c. of water is cooled to 0° to 5° C., diazotised with 10 c.c. of 2*N* sodium nitrite solution and stirred for three hours at about 5° C. A solution consisting of 2·9 grams of arsenious oxide, 5·6 grams of potassium hydroxide in 24 c.c. of water, 15 c.c. of 4*N* sodium carbonate solution and 200 c.c. of water is cooled to −5° C., 0·5 gram of copper sulphate in a little water added, then the diazo-solution added immediately and all at once. When nitrous acid can no longer be detected, the mixture is stirred for one hour, then slowly warmed to 60° C. and filtered. The filtrate is acidified with dilute hydrochloric acid, any precipitate being dissolved by a little alkali and

[1] Calvery, Noller, and Adams, *J. Amer. Chem. Soc.*, 1925, 47, 3058.

the alkaline solution acidified until a precipitate just begins to form. The dark brown solution is then boiled with Norite until it is colourless, and acidified with hydrochloric acid. A white, flocculent precipitate separates (1·8 grams), which may be further purified by crystallisation from *n*-butyl alcohol. It does not melt below 360° C., and is insoluble in water and the usual organic solvents.

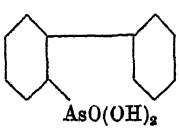
2 : 2′-Diphenyl-6 : 6′-arsenoquinoline-4 : 4′-dicarboxylic acid,



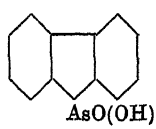
results when the foregoing compound is reduced with sodium hydrosulphite. It is a red compound, unmelted below 300° C., insoluble in the usual organic solvents and water, but soluble in sodium hydroxide.

Derivatives of *o-o′*-Diphenylylenearsine (Dibenzarsenole).

These compounds are the arsenic analogues of carbazole and may be obtained by subjecting *o*-aminodiphenyl to the Bart reaction, when diphenylyl-*o*-arsinic acid (I) is produced, then converting this by warm concentrated sulphuric acid into *o-o′*-diphenylylenearsinic acid (II):[1]



I



II

Diphenylyl-o-arsinic acid.—This is isolated by coupling sodium arsenite with diazotised *o*-aminodiphenyl in alkaline solution at 50° to 60° C. in the presence of a cupric salt. Yield, about 60 per cent. It crystallises from boiling water in bristle-like needles, M.pt. 205° C. When reduced in warm concentrated hydrochloric acid by sulphur dioxide in the presence of an iodide, it yields *diphenylyl-o-dichloroarsine*, a heavy oil, soluble in chloroform, insoluble in water. The chloride, with alcoholic potash, yields the *oxide*, an amorphous substance with no definite melting-point.

o-o′-Diphenylylenearsinic acid.—The preceding *o*-arsinic acid in concentrated sulphuric acid is warmed for a few minutes, then poured into water. The product recrystallised from a large bulk of water melts at 290° C. Reduction of this acid gives a solution of the free arsine, but the latter has not been isolated in the solid state.

o-o′-Diphenylylenechloroarsine may either be obtained by distilling diphenylyl-*o*-dichloroarsine *in vacuo* or by the following process:

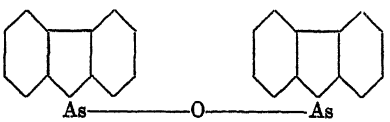
Diphenylylenearsinic acid, suspended in concentrated hydrochloric acid, is treated with an equal volume of chloroform, and sulphur dioxide and hydrogen chloride passed in below the surface of the chloroform.

[1] Aeschlimann, Lees, McCleland, and Nicklin, *J. Chem. Soc.*, 1925, 127, 66.

After a few minutes a little potassium iodide is added and the reduction carried on under reflux on a water-bath, the *diphenylylenechloroarsine* passing into the chloroform layer. The product crystallises from benzene in colourless plates, M.pt. 161° C., B.pt. about 230° C. at 25 mm., more soluble in chloroform or carbon tetrachloride than in benzene or alcohol.

The corresponding *iodide* is obtained by reduction of the acid in 10 per cent. sulphuric acid with sulphur dioxide in the presence of potassium iodide. It crystallises in golden plates, M.pt. 166° C., soluble in chloroform and benzene, very sparingly soluble in alcohol. With magnesium methyl iodide the iodide gives *diphenylylenemethylarsine*, forming large, transparent prisms from alcohol, M.pt. 46° C. This arsine combines with methyl iodide forming *diphenylylenedimethylarsonium iodide*, needles, M.pt. 190° C.

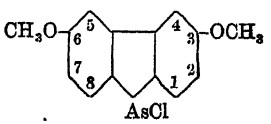
o-o'-Diphenylylenearsenoxide,



The chloride is treated with warm alcoholic potash or the iodide with ammonium hydroxide, when the oxide separates in white crystals, M.pt. 178° C., readily soluble in organic solvents. In chloroform or absolute alcohol the oxide yields the *cyanide* on treatment with anhydrous hydrocyanic acid. The cyanide forms long, silky needles, M.pt. 178° C., soluble in the usual organic solvents.

The formation of this dibenzarsenole ring system may be essayed from a different standpoint from that described in the foregoing, and to prepare 3 : 6-dimethoxy-*o*-*o'*-diphenylylenechloroarsine, 3 : 3'-dimethoxydiphenyl is used as the starting-point.[1]

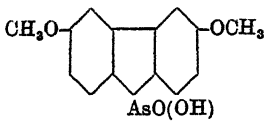
3 : 6-Dimethoxy-o-o'-diphenylylenechloroarsine,



43 grams of 3 : 3'-dimethoxydiphenyl and 39 grams of arsenic trichloride are heated under reflux for six hours, then poured into 80 c.c. of hot xylene. The xylene solution is boiled with charcoal, filtered and cooled, the filtrate yielding the arsine on cooling. Recrystallisation from xylene gives 16 grams of the arsine as a yellowish, crystalline product, M.pt. 198° to 199° C. It dissolves in nitrobenzene and pyridine, but is insoluble in other organic solvents and concentrated sulphuric acid. The chlorine atom is very firmly bound, shaking with molecular silver in xylene at 100° C. for twelve hours not affecting it. When heated for six hours in a sealed tube with 10 per cent. sodium hydroxide at 150° to 160° C. the arsine yields an amorphous substance, softening at about 85° C., the carbon and hydrogen contents of which correspond to those of the *oxide*, but the properties are not those to be expected from such a compound.

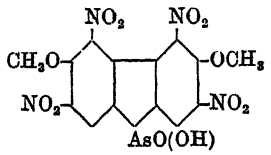
[1] Gottlieb-Billroth, *J. Amer. Chem. Soc.*, 1927, 49, 482.

3 : 6-Dimethoxy-o-o′-diphenylylenearsinic acid,



results when the foregoing arsine in pyridine solution is oxidised by hydrogen peroxide (39 per cent.) at a temperature of 45° to 65° C. It is a white powder, decomposing at 220° C.

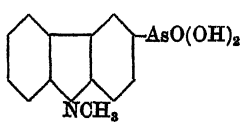
2 : 4 : 5 : 7-Tetranitro-3 : 6-dimethoxy-o-o′-diphenylylene-arsinic acid,



The preceding acid (4·2 grams), in 40 c.c. of concentrated sulphuric acid, is treated during twenty minutes with 7 c.c. of fuming nitric acid (density 1·6) at 25° to 30° C. and the whole allowed to stand for eighteen hours. The mixture is then poured into water and the precipitate recrystallised from glacial acetic acid, 1·2 grams of yellow powder, decomposing at 265° C., being isolated. It is very sensitive to light, turning reddish, and is insoluble in hot ether, hot benzene, and hot chloroform.

Methylcarbazole-3-arsinic Acid and its Reduction Products.[1]

9-Methylcarbazole-3-arsinic acid,

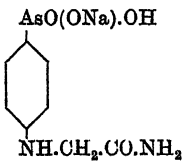


A suspension of 3-amino-methylcarbazole (19·6 grams) in 250 c.c. of water and 25 c.c. of concentrated hydrochloric acid is diazotised with sodium nitrite, the temperature being maintained below 10° C. The solution is then cooled to 0° C., neutralised with cold sodium hydroxide and added with stirring to a solution of 15 grams of arsenious oxide and 24 grams of sodium carbonate in 105 c.c. of water, to which 10 c.c. of 10 per cent. copper sulphate solution previously treated with ammonium hydroxide have been added. The mixture is stirred for one hour, boiled and filtered, acidification of the filtrate then depositing 10·5 grams of crude acid. This crystallises from glacial acetic acid in clusters of small, colourless needles, which are unmelted below 300° C. Reduction of the acid in alcoholic hydrochloric acid by sulphur dioxide in the presence of a trace of iodine yields 9-*methylcarbazole*-3-*dichloroarsine*, which crystallises from a mixture of benzene and light petroleum in small, colourless prisms, M.pt. 121° to 122° C. The chloride in acetone, when shaken with ammonium hydroxide, gives the *oxide*, an insoluble product, melting with decomposition at 182° to 185° C.

[1] Burton and Gibson, *J. Chem. Soc.*, 1927, p. 2386.

Derivatives of 1 : 4-Benzisoxazine.

The preparation of this type of compound was the outcome of work [1] undertaken to obtain a pharmacological comparison between 1 : 4-benzisoxazine derivatives and two other well-known compounds of therapeutic importance, namely, sodium hydrogen phenylarsinate-4-glycineamide (*Tryparsamide*), I, (pp. 233 and 234), and 3-acetamido-4-hydroxyphenylarsinic acid (*Stovarsol*), II, (p. 297).



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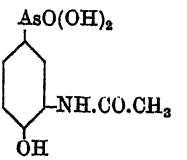
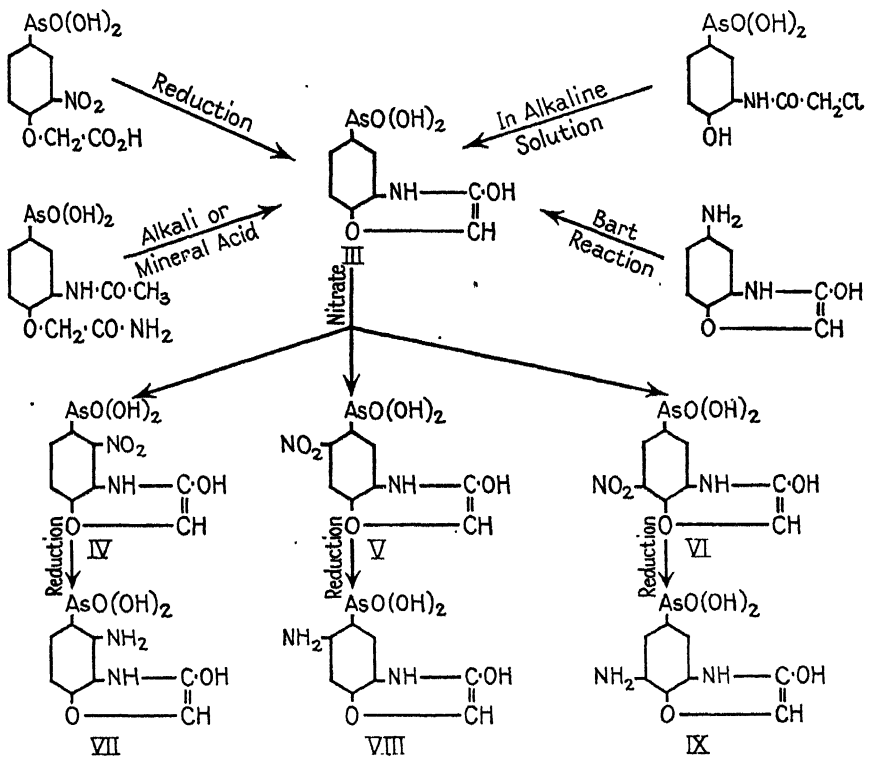


II

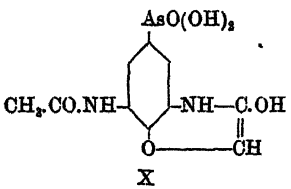
The following scheme shows the preparation and derivatives of a typical compound of this class, 3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid (III) :



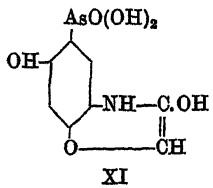
In the preparation of 3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid, the 2-acetamidophenoxyacetamide-4-arsinic acid shown in the foregoing may be replaced by the corresponding acetic acid. The nitro derivative VI is only obtained in 1 to 3 per cent. yield by direct nitration, and is

[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3051.

better prepared from 5-nitro-3-amino-4-hydroxyphenylarsinic acid by the chloracetyl chloride method. The proportions of compounds IV and V vary with the temperature of nitration, product IV predominating at low temperatures. The structure of the amino derivatives VII and VIII is confirmed by de-arsenation—VII, on boiling with 5*N* hydrochloric acid, giving a quantitative yield of 5-amino-3-hydroxy-1 : 4-benzisoxazine, and VIII, on boiling with sodium bisulphite, forming 7-amino-3-hydroxy-1 : 4-benzisoxazine. If the 3-chloracetamido-4-hydroxyphenylarsinic acid shown in the foregoing is replaced by 3-chloracetamido-5-acetamido-4-hydroxyphenylarsinic acid, 8-acetamido-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid (X) results, and 5-acetamido-2 : 4-dihydroxyphenylarsinic acid yields 3 : 7-dihydroxy-1 : 4-benzisoxazine-6-arsinic acid (XI):



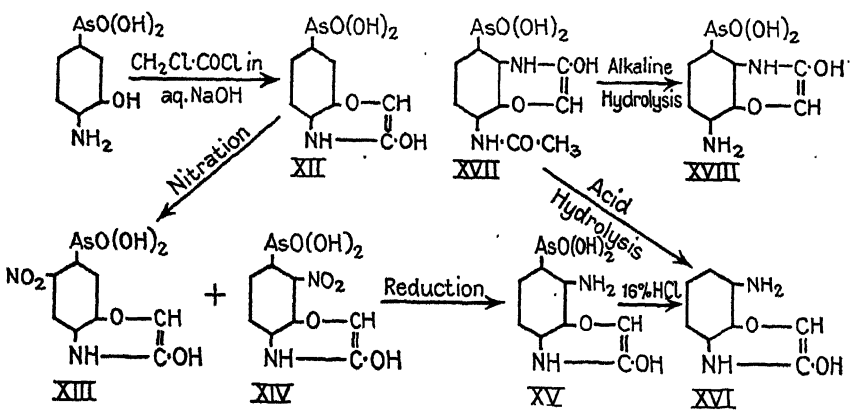
X



XI

The parent substance in the foregoing preparations is 3-amino-4-hydroxyphenylarsinic acid, and using as a starting-point 3-amino-2-hydroxyphenylarsinic acid, a series of 3-hydroxy-1 : 4-benzisoxazine-8-arsinic acids is obtainable. Another starting-point for the latter series is 8-amino-3-hydroxy-1 : 4-benzisoxazine.

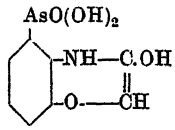
A similar series of reactions has also been applied to 4-amino-3-hydroxyphenylarsinic acid,[1] and in this case the reactions take the following course :



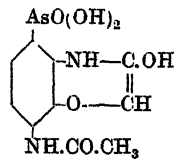
3-Hydroxy-1 : 4-benzisoxazine-7-arsinic acid (XII), obtained by treating 4-amino-3-hydroxyphenylarsinic acid in aqueous sodium hydroxide with chloracetyl chloride, yields two nitro-acids (XIII and XIV), the latter giving the amine (XV) on reduction. De-arsenation of the amine yields 8-amino-3-hydroxy-1 : 4-benzisoxazine (XVI), which is also the acid hydrolysis product of 8-acetamido-3-hydroxy-1 : 4-benzisoxazine-5-arsinic acid (XVII), alkaline hydrolysis of the latter giving the 8-amino-derivative (XVIII).

[1] Balaban, *J. Chem. Soc.*, 1928, p. 3066.

3-Hydroxy-1 : 4-benzisoxazine-5-arsinic Acid and its Derivatives.



I



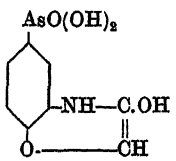
II

3-Hydroxy-1 : 4-benzisoxazine-5-arsinic acid.[1]—20 grams of 2-amino-3-hydroxyphenylarsinic acid in 50 c.c. of 2*N* sodium hydroxide are treated alternately with chloracetyl chloride (15 c.c. in all) and 25 per cent. sodium hydroxide at 50° C. The mixture is then made strongly alkaline and heated for ten minutes at 90° C., more alkali being added as the acidity develops. A 60 per cent. yield of the arsinic acid (I) is obtained by acidifying the liquor, and subsequent crystallisation from water yields colourless rhombs, M.pt. 245° to 248° C. with decomposition. The *calcium*, *barium* and *magnesium salts* are amorphous, white solids.

8-Acetamido-3-hydroxy-1 : 4-benzisoxazine-5-arsinic acid.[2]—This results when the 2-amino-3-hydroxyphenylarsinic acid used above is replaced by 2-amino-4-acetamido-3-hydroxyphenylarsinic acid. The yield is 24·6 per cent., and the acid (II) separates from 2*N* acetic acid in fine, colourless, anhydrous needles, readily soluble in 80 per cent. formic acid, moderately soluble in glacial acetic acid, very sparingly soluble in boiling water, and insoluble in alcohol. The *calcium salt* forms acicular crystals and the *magnesium salt* is amorphous. Hydrolysis of the acetamido derivative by 2*N* sodium hydroxide gives 8-*amino*-3-*hydroxy*-1 : 4-*benzisoxazine-5-arsinic acid.* This acid crystallises from water in long, rectangular prisms, containing 0·5 molecule of water, which is not eliminated at 100° C. It has a similar solubility to the acetyl derivative, and forms amorphous *calcium* and *barium salts*, also a *magnesium salt* crystallising in irregular plates.

3-Hydroxy-1 : 4-benzisoxazine-6-arsinic Acid and its Derivatives.

3-Hydroxy-1 : 4-benzisoxazine-6-arsinic acid,[3]



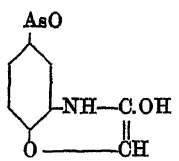
There are five methods available for obtaining this acid : (1), 2-Nitrophenoxyacetic acid-4-arsinic acid (3-nitro-4-carbomethoxyphenylarsinic acid, p. 284), when reduced by ferrous hydroxide, gives a 57 per cent. yield of the required acid. (2), 2-Acetamidophenoxyacetic acid-4-arsinic

[1] Newbery, Phillips, and Sticklings, *J. Chem. Soc.*, 1928, p. 3051.
[2] Balaban, *loc. cit.*
[3] Newbery, Phillips, and Sticklings, *loc. cit.*; British Patent, 278444 (1926).

acid (10 grams) is heated with 20 c.c. of 5*N* sodium hydroxide for one hour at 90° C., or 2 grams are refluxed with 10 c.c. of 4*N* hydrochloric acid. Acidification in the first case and cooling in the second gives yields of 5·5 grams and 1 gram, respectively, of the required acid. The corresponding amide may be hydrolysed in a similar manner. (3), 20 grams of 6-amino-3-hydroxy-1 : 4-benzisoxazine hydrochloride in 200 c.c. of water and 20 c.c. of hydrochloric acid (density 1·12) are diazotised at 0° to 5° C. by 7 grams of sodium nitrite in water and the solution slowly added to a suspension of copper arsenite (prepared from 15 grams of arsenious oxide, 40 c.c. of water, 6 grams of sodium hydroxide, and 1·5 grams of copper sulphate). The reaction mixture is kept slightly alkaline during this operation. The whole is then heated with charcoal at 80° C., filtered, acidified to litmus, filtered after standing for some time, then acidified to Congo red. The arsinic acid is thus precipitated, a yield of 12·5 grams, or 46 per cent., being obtained. (4), 1 gram of 3-chloracetamido-4-hydroxyphenylarsinic acid, heated at 90° C. with slightly more than 1 molecular equivalent of sodium hydroxide in 100 c.c. of water for fifteen minutes, gives, on acidification, 0·6 gram of the required acid. (5), The acid may also be isolated by treating 3-amino-4-hydroxyphenylarsinic acid as described under 3-hydroxy-1 : 4-benzisoxazine-5-arsinic acid.

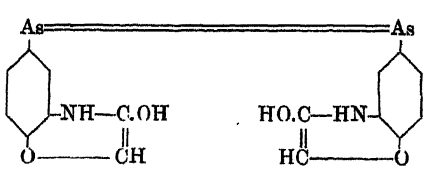
The acid prepared by the foregoing methods crystallises from boiling water in rhombs, unmelted at 300° C., insoluble in cold water, dilute hydrochloric acid, and the usual organic solvents, but soluble in alkalis and alkali carbonates. The *calcium salt* forms rosettes of needles, but the *magnesium salt* is amorphous.

3-Hydroxy-1 : 4-benzisoxazine-6-arsenoxide,



The previous arsinic acid in hydrochloric acid solution containing a little potassium iodide is saturated at 10° C. with sulphur dioxide and the gas passed for one hour. The addition of an equal volume of hydrochloric acid then precipitates 3-hydroxy-1 : 4-benzisoxazine-6-dichloroarsine in 60 per cent. yield, but the product is difficult to purify. Solution in 2*N* sodium hydroxide and addition of hydrochloric acid until only a faint acidity is shown to Congo red, causes the arsenoxide to separate in sphæro crystals, insoluble in water, dilute mineral acids, alkali carbonates, or dilute ammonia, but readily soluble in an excess of dilute caustic alkali solution. Treatment with excess of hydrochloric acid gives the *dichloroarsine.*

3 : 3′-Dihydroxy-6 : 6′-arseno-1 : 4-benzisoxazine,



A solution containing 2·7 grams of 3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid, 20 c.c. of water and 5 c.c. of saturated sodium carbonate solution is added to a cold solution consisting of 2 grams of magnesium chloride hexahydrate and 10 grams of sodium hyposulphite in 200 c.c. of water. After filtration the mixture is heated at 50° to 60° C. for one and a half hours, the resulting arseno-compound washed with water and dried in a vacuum over sulphuric acid. A light yellow, amorphous solid results, which is insoluble in water, dilute mineral acids, alkalis, and the usual organic solvents.

Nitration of 3-Hydroxy-1 : 4-benzisoxazine-6-arsinic Acid.—20 grams of the acid, intimately mixed with 7·5 grams of potassium nitrate, are added to 70 c.c. of sulphuric acid (see table below for temperature). The mixture is poured on ice, the nitro-derivative collected and recrystallised from 500 c.c. of hot water, using a little sodium hydroxide initially to effect solution, followed by acidification. For treatment of the liquors, see under the 8-nitro derivative. The recrystallised solid is suspended in 40 c.c. of water and treated with 15 per cent. ammonium hydroxide until a faint smell of ammonia and a faintly alkaline reaction are produced. This converts the nitro-acids to their ammonium salts, and the precipitate obtained is collected and washed with ice-water, dissolved in 100 c.c. of boiling water, and the solution acidified, when 7-nitro-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid is precipitated. The mother-liquid from which the ammonium salt has separated contains a di-ammonium salt, which on acidification gives 5-nitro-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid. The following table indicates the relative yields of the 7- and 5-nitro isomerides :

Temperature of Nitration.	Total Yield.	7-Isomeride.	5-Isomeride.
°C.	Per cent.	Per cent.	Per cent.
0	72	29	39
10	75	35	35
30	73	41	28

5-Nitro-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid crystallises from water in yellow prisms. Its *calcium*, *barium* and *magnesium salts* are crystalline and soluble, but the *mono-ammonium salt* is only sparingly soluble. Reduction with ferrous hydroxide gives *5-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid*, which crystallises from water in colourless prisms, changing to hexagonal plates. These do not melt below 300° C.; they dissolve in excess of mineral acids, but are reprecipitated on addition of water. The *triazole* forms white, hexagonal tufts or prisms, M.pt. 247° C. The *calcium*, *barium* and *magnesium salts* are white, amorphous solids, sparingly soluble in water. If the amino-acid is refluxed with 5*N* hydrochloric acid the arsinic acid grouping is removed.

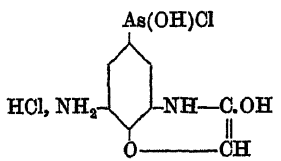
7-Nitro-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid crystallises from boiling water in long, yellow prisms. Its *calcium*, *barium* and *magnesium salts* are soluble yellow solids. Reduction with ferrous hydroxide or glucose and alkali gives a 70 per cent. yield of *7-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid*, consisting of white prisms,

melting with decomposition at 258° to 260° C. The *barium* and *calcium salts* crystallise in needles, but the *magnesium salt* is amorphous. The *acetyl derivative* forms white prisms, decomposing at 275° C., and the *urethane derivative*, long needles. Both give amorphous *calcium* and *magnesium salts*. When the amino-acid is boiled with aqueous sodium bisulphite the arsenic is removed.

8-Nitro-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid may be obtained in two ways: (1) The mother-liquors from the crystallisation of the crude nitration product of 3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid are neutralised with ammonium hydroxide, excess of magnesium chloride added, and the whole heated. The magnesium salt of the 8-nitro-acid separates and is converted to the free acid by hydrochloric acid. The yield by this process is very poor. (2) The chloracetylation of 3-nitro-5-amino-4-hydroxyphenylarsinic acid yields 3-nitro-5-chloracetamido-4-hydroxyphenylarsinic acid (p. 800), which, treated with slightly more than 1 molecular equivalent of sodium hydroxide, gives a 60 per cent. yield of the 8-nitro-acid. The latter forms colourless prisms, decomposing at 320° C., and gives *calcium* and *magnesium salts* in the form of yellow needles. The magnesium salt is insoluble in water, this distinguishing it from the magnesium salts of the 5- and 7-nitro-compounds.

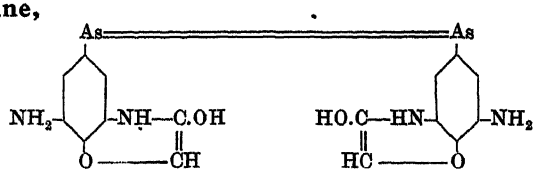
8-Amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid results when 2 : 6-diacetamidophenoxyacetic acid-4-arsinic acid is treated with boiling 5*N* sodium hydroxide or 5*N* hydrochloric acid. It may also be prepared in the usual way, by ferrous hydroxide reduction of the 8-nitro derivative. It forms staggered plates, unmelted at 300° C., insoluble in water, but dissolving in dilute mineral acids and alkalis. The *sulphate* crystallises in rhombs, sparingly soluble in water, the *barium salt* forms colourless prisms, the *calcium salt* white needles, and the *magnesium salt* is amorphous.

8-Amino-3-hydroxy-1 : 4-benzisoxazine-6-hydroxychloroarsine hydrochloride,



results in 90 per cent. yield when the previous amino-acid in 5*N* hydrochloric acid is reduced by sulphur dioxide in the presence of potassium iodide, followed by precipitation with excess of hydrochloric acid (density 1·16). It crystallises in tiny rhombs or needles, which yield *8-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsenoxide hydrochloride* when treated with water. This crystallises from a little water in colourless, hexagonal plates.

8 : 8′-Diamino-3 : 3′-dihydroxy-6 : 6′-arseno-1 : 4-benzisoxazine,

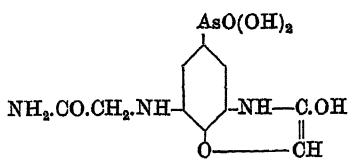


is a pale yellow, amorphous solid, insoluble in water, dilute caustic alkali, or organic solvents, soluble in dilute hydrochloric acid.

8 - Acetamido - 3 - hydroxy - 1 : 4 - benzisoxazine - 6 - arsinic acid may be prepared by acetylation of the corresponding amino-acid, or by chloracetylation in alkaline solution of 3-amino-5-acetamido-4-hydroxyphenylarsinic acid. It crystallises in colourless prisms, M.pt. 275° to 280° C. with decomposition, and forms amorphous *barium* and *magnesium salts*. Reduction with sulphur dioxide and potassium iodide yields 8-*acetamido*-3-*hydroxy*-1 : 4-*benzisoxazine*-6-*dichloroarsine* in tufts of white needles, which are converted to the *arsenoxide* by water. The oxide forms clusters of white needles, insoluble in water, sodium carbonate, or dilute mineral acids, soluble in dilute sodium hydroxide and in an excess of 10*N* ammonium hydroxide.

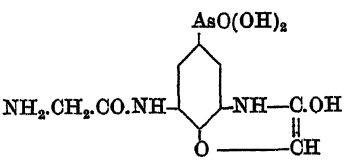
8 : 8′-Diacetamido-3 : 3′-dihydroxy - 6 : 6′-arseno-1 : 4-benzisoxazine is a yellow, amorphous solid, stable in air and insoluble in water, dilute mineral acids, alkalis, and organic solvents.

3 - Hydroxy - 1 : 4 - benzisoxazine - 6 - arsinic acid - 8 - glycineamide,



results when the 8-amino-acid in sodium carbonate is treated alternately with chloracetamide and sodium bicarbonate, the solution being kept faintly alkaline to litmus during the operation. Acidification to Congo red precipitates a 60 per cent. yield of the arsinic acid, which crystallises from boiling water in hexagonal plates.

8-Glycylamino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid,



The 8-amino-acid is subjected to chloracetylation and the 8-chloracetamido-acid treated with sodium acetate. The glycyl compound forms minute needles, soluble in mineral acids and alkalis.

8-Chloro-3-hydroxy-1 : 4 - benzisoxazine - 6-arsinic acid is obtained from the 8-amino-acid in 50 per cent. yield by aid of the diazo-reaction. It forms yellow prisms, unmelted at 280° C., sparingly soluble in boiling water, and yielding an amorphous *magnesium salt*.

3-Hydroxy-8-methyl-1 : 4-benzisoxazine-6-arsinic acid, prepared by the chloracetylation in alkaline solution of 8-amino-4-hydroxy-5-methylphenylarsinic acid, crystallises from water in white prisms, soluble in alkalis.

3 : 3′-Dihydroxy-8 : 8′-dimethyl-6 : 6′-arseno-1 : 4-benzisoxazine is a yellow, amorphous solid, insoluble in all solvents except 50 per cent. acetic acid.

8-β-Hydroxyethylamino - 3 - hydroxy-1 : 4 - benzisoxazine-6-

arsinic acid.—15 grams of 8-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid are treated with 10 c.c. of β-chloroethyl-chlorocarbonate and 10N sodium hydroxide at 40° to 50° C. On acidification, *8-ω-chlorocarbethoxyamino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid* separates. 12 grams of this product are refluxed for forty minutes with 60 c.c. of 5N sodium hydroxide solution; on acidification, carbon dioxide is liberated and the 8-β-hydroxyethylamino-acid separates. It crystallises from boiling water in white prisms.

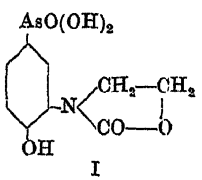
3-Hydroxy-8-carboxy-1 : 4-benzisoxazine-6-arsinic acid is prepared by chloracetylation in alkaline solution of 3-amino-4-hydroxy-5-carboxyphenylarsinic acid, and crystallises from water in white rhombs, M.pt. 300° to 305° C., with decomposition.

3-Hydroxy-2-methyl-1 : 4-benzisoxazine-6-arsinic acid, obtained from 3-amino-4-hydroxyphenylarsinic acid and α-bromopropionyl bromide (as described under 3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid), crystallises from water in colourless, pointed needles, unmelted at 300° C. The *calcium salt* forms tufts of needles, but the *magnesium salt* is amorphous.

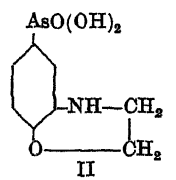
3-Hydroxy-2-ethyl-1 : 4-benzisoxazine-6-arsinic acid is obtained from α-bromobutyryl chloride and 3-amino-4-hydroxyphenylarsinic acid. It forms colourless needles from water, unmelted at 280° C.; the *calcium salt* forms tiny polyhedral crystals, whilst the *magnesium salt* is amorphous.

8-Acetamido-3-hydroxy-2-methyl-1 : 4-benzisoxazine-6-arsinic acid is isolated from 3-amino-5-acetamido-4-hydroxyphenylarsinic acid and α-bromopropionyl bromide; it crystallises from boiling water in white prisms, decomposing at 265° C. It forms an amorphous *magnesium salt.* The *8-acetamido-3-hydroxy-2-ethyl-derivative* crystallises from boiling water in colourless needles.

2 : 3-Dihydro-1 : 4-benzisoxazine-6-arsinic acid,



I

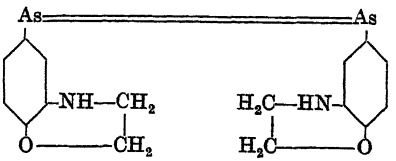


II

8-ω-Chlorocarbethoxyamino-4-hydroxyphenylarsinic acid (9 grams) is refluxed with 30 c.c. of 4N sodium hydroxide for fifteen minutes, and the solution filtered and acidified to Congo red, when carbon dioxide is evolved and the required arsinic acid (II) precipitated. Crystallised by acidification of its hot alkaline solution, it forms white or buff-coloured hexagonal prisms, unmelted at 300° C., insoluble in water and most organic solvents, but soluble in alkalis. It yields a white, amorphous *magnesium salt.* It is assumed that **2′-hydroxy-2-keto-3-phenyl-4 : 5-dihydro-1 : 3-isoxazole-5′-arsinic acid** (I) is formed as an intermediate product in the formation of this arsinic acid. Reduction of the latter by sulphur dioxide and potassium iodide in hydrochloric acid solution yields the corresponding *dichloroarsine,* which gives the *arsenoxide* when treated with water. The oxide is a white, amorphous solid, insoluble in water, sodium carbonate, ammonium hydroxide, and

organic solvents. An excess of hydrochloric acid converts it into white prisms of the dichloroarsine.

6 : 6′-Arseno (2 : 3-dihydro-1 : 4-benzisoxazine),

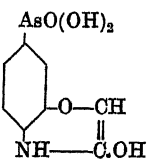


obtained by reducing the corresponding arsinic acid with hyposulphite, is a yellow, amorphous solid, insoluble in all the usual solvents.

3 : 7-Dihydroxy-1 : 4-benzisoxazine-6-arsinic acid, formed by the chloracetylation in alkaline solution of 5-amino-2 : 4-dihydroxyphenylarsinic acid, crystallises from boiling water in plates, unmelted at 300° C. Its *barium salt* forms colourless prisms from boiling water, but the *calcium* and *magnesium salts* are amorphous.

3-Hydroxy-1 : 4-benzisoxazine-7-arsinic Acid and its Derivatives.[1]

3-Hydroxy-1-4-benzisoxazine-7-arsinic acid,



This is isolated in 47 per cent. yield by the chloracetylation, in 2*N* sodium hydroxide solution, of 4-amino-3-hydroxyphenylarsinic acid. It may also be prepared from 7-amino-3-hydroxy-1 : 4-benzisoxazine by the Bart-Schmidt reaction. It crystallises from boiling water in rhombs containing 1 molecule of water. It dissolves in hot alcohol more readily than in glacial acetic acid, from which it crystallises in rhomboids. The *calcium salt* crystallises in bunches of spikes ; the *barium* and *magnesium salts* are amorphous.

Nitration of 3-hydroxy-1 : 4-benzisoxazine-7-arsinic acid.—10 grams of the acid are nitrated at 0° C. and the mixture poured on ice. After standing, 6·6 grams of nitro-compounds, decomposing at 275° C., are obtained, and the mother-liquor gives a further 1·8 grams, bringing the total yield to 72·4 per cent. Recrystallisation from water gives the two crops as very pale yellow needles, and colourless, rectangular plates, respectively, representing the 8-nitro- and 6(?)-nitro-3-hydroxy-1 : 4-benzisoxazine-7-arsinic acids.

8-Nitro-3-hydroxy-1 : 4-benzisoxazine-7-arsinic acid decomposes at 280° C., is sparingly soluble in glacial acetic acid, from which it crystallises in rods, insoluble in alcohol. The *magnesium, calcium* and *barium salts* are amorphous. Reduction of the acid using the ferrous sulphate method gives a 66·6 per cent. yield of *8-amino-3-hydroxy-1 : 4-benzisoxazine-7-arsinic acid.* This crystallises from 2*N* acetic acid in clusters of almost colourless, fine, silky needles, containing 0·75 molecule

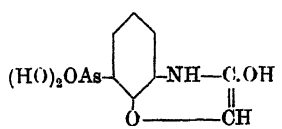
[1] Balaban, *loc. cit.*

of water. It dissolves readily in 2*N* hydrochloric acid or 80 per cent. formic acid, but is only sparingly soluble in glacial acetic acid and insoluble in alcohol. When diazotised it gives a bright red solution with sodium β-naphthoxide. The *barium salt* forms fine needles, the *calcium salt* is microcrystalline, and the *magnesium salt* amorphous. The *acetyl derivative* crystallises from water in colourless, silky, anhydrous needles, and gives a *calcium salt*, crystallising in needles, and a gelatinous *magnesium salt*. When the amino-acid is boiled with 16 per cent. hydrochloric acid, the arsenic residue is removed, and 8-amino-3-hydroxy-1 : 4-benzisoxazine produced.

6(?)-Nitro-3-hydroxy-1 : 4-benzisoxazine-7-arsinic acid decomposes with violence at 280° C. It is sparingly soluble in glacial acetic acid, from which it crystallises in rectangular plates, insoluble in alcohol. Its *calcium salt* forms bunches of needles, the *barium salt* forms diamond-shaped crystals, and the *magnesium salt* is amorphous.

3-*Hydroxy*-1 : 4-*benzisoxazine*-8-*arsinic Acid and its Derivatives.*[1]

3-Hydroxy-1 : 4-benzisoxazine-8-arsinic acid,



This derivative may be obtained from 8-amino-3-hydroxy-1 : 4-benzisoxazine by the Bart reaction, or by the chloracetylation in alkaline solution of 3-amino-2-hydroxyphenylarsinic acid. It forms white needles from boiling water, melting with decomposition at 298° C. The *calcium salt* crystallises in many-sided nodules, the *barium salt* in white prisms, and the *magnesium salt* in clusters of needles. The *sodium salt* forms water-soluble, white needles, the solution being neutral to litmus.

6-Amino-3-hydroxy-1 : 4-benzisoxazine-8-arsinic acid, formed by the chloracetylation of 3 : 5-diamino-2-hydroxyphenylarsinic acid or by the hydrolysis of the 6-acetamido compound, separates from water in white prisms, unmelted at 300° C. These are insoluble in cold water and organic solvents, but readily soluble in alkalis and mineral acids; the *hydrochloride* separates in prisms and the *sulphate* in rhombs when the solutions stand. The *barium salt* forms white prisms and the *calcium salt* rhombs, whilst the *magnesium salt* is amorphous or microcrystalline. This acid is more basic than 7- and 5-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acids, but less basic than 8-amino-3-hydroxy-1 : 4-benzisoxazine-6-arsinic acid. The *acetyl derivative* of the 6-amino-8-arsinic acid may be prepared by direct acetylation of the 6-amino acid or by chloracetylation of 3-amino-5-acetamido-2-hydroxyphenylarsinic acid. It separates from boiling water in white needles, unmelted at 300° C., insoluble in cold water. Its *magnesium salt* is a white, amorphous solid.

6 : 6′-Diacetamido-3 : 3′-dihydroxy-8 : 8′-arseno-1 : 4-benzisoxazine,

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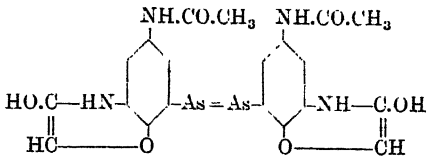
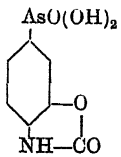
[1] Newbery, Phillips, and Sticklings, *loc. cit.*



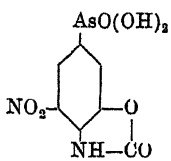
prepared by hyposulphite reduction of the acetyl derivative of the preceding acid, is a pale yellow, amorphous solid, fairly stable in air. It is insoluble in the usual solvents.

Benzoxazolone-5-arsinic acid,[1]



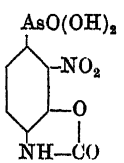
20 grams of 4-amino-3-hydroxyphenylarsinic acid in 2*N* sodium hydroxide are treated with carbonyl chloride, when about 20·6 grams (93 per cent.) of solid result.[2] The acid is insoluble in hydrochloric acid, and after treatment with nitrous acid does not couple with sodium β-naphthoxide. It crystallises from 25 parts of boiling water in long, colourless, anhydrous, boat-shaped plates, very sparingly soluble in glacial acetic acid and alcohol, fairly soluble in 80 per cent. formic acid. The *magnesium salt* is microcrystalline.

3-Nitrobenzoxazolone-5-arsinic acid,[3]



is the only nitration product isolated in a pure state when the preceding acid is nitrated at 0° C., although there is evidence of more than one nitro-acid being produced. This acid crystallises from 20 parts of boiling water in almost colourless, stout, anhydrous, quadrilateral prisms, easily soluble in acetic acid, sparingly soluble in 80 per cent. formic acid, and almost insoluble in alcohol.

6-Nitrobenzoxazolone-5-arsinic acid,



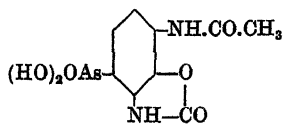
[1] Balaban, *loc. cit.*; American Patent, 1543544; compare British Patent, 214628 (1924).

[2] Compare British Patent, 214628 (1924).

[3] Compare American Patent, 1539798.

results in about 60 per cent. yield when 2-nitro-4-amino-3-hydroxyphenylarsinic acid is treated with carbonyl chloride in the usual manner. It crystallises from water in long, pale brown, anhydrous, hexagonal plates, almost insoluble in alcohol and glacial acetic acid. The *magnesium* and *barium salts* are microcrystalline. Reduction of the acid gives an 82·4 per cent. yield of *6-aminobenzoxazolone-5-arsinic acid*, which crystallises from 30 parts of boiling water in colourless, hexagonal laminæ, containing 1 molecule of water, is soluble in concentrated hydrochloric acid, diazotises normally, is readily soluble in 80 per cent. formic acid, sparingly soluble in glacial acetic acid, and insoluble in alcohol. The *calcium*, *barium* and *magnesium salts* are microcrystalline. The *acetyl derivative* crystallises from 2*N* acetic acid in colourless, anhydrous leaflets, and from glacial acetic acid in rods. The *calcium salt* is microcrystalline and the *magnesium salt* amorphous.

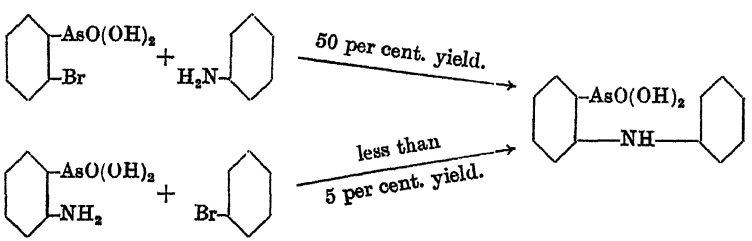
6-Acetamidobenzoxazolone-3-arsinic acid,



obtained in about 82 per cent. yield by the interaction of carbonyl chloride and 2-amino-4-acetamido-3-hydroxyphenylarsinic acid in alkaline solution, crystallises from 2*N* acetic acid in colourless leaflets, which are readily soluble in water but almost insoluble in glacial acetic acid. The *calcium*, *barium* and *magnesium salts* are amorphous.[1]

Diphenylamine- and Triphenylamine-arsinic Acids and their Derivatives.

Diphenylamine-*o*-arsinic acid may be prepared either by the condensation of *o*-bromophenylarsinic acid and aniline or *o*-aminophenylarsinic acid and bromobenzene, but the better yield is given by the first method:[2]

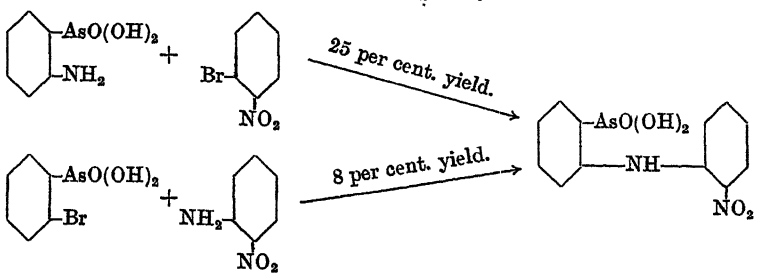


[1] For 1 : 2-dihydrobenzoxazolone-4-arsinic acid, 6-methyl-1 : 2- and 6-chloro-1 : 2-dihydrobenzoxazolone-4-arsinic acids, see British Patent, 261133 (1925); for benzoxazolone arsinic acids, American Patent, 1635168; compare British Patent, 261133 (1926); for benzoxazolone arsenoxides, American Patent, 1635167; compare British Patent, 257361 (1925). The following arsenoxides are described in British Patent, 257361 (1925): 1 : 2-dihydrobenzoxazolone-5-arsenoxide, 4-methyl-1 : 2-dihydrobenzoxazolone-5-arsenoxide, 1 : 2-dihydrobenzoxazolone-4-arsenoxide and 6-chloro-1 : 2-dihydrobenzoxazolone-4-arsenoxide. Treatment of *o*-aminohydroxy-compounds of arsenobenzene with carbonyl chloride in alkaline solution yields substances which probably contain the benzoxazolone grouping (British Patent, 239951 (1925)). Compounds of this type have been isolated from 3 : 3′-diamino-4 : 4′-dihydroxy- and 4 : 4′-diamino-3 : 3′-dihydroxyarsenobenzene.

[2] Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2499.

A similar result is noticed in the preparation of 4-methyldiphenylamine-6′-arsinic acid by analogous methods.

In the case of 2-nitrodiphenylamine-6′-arsinic acid, however, the greater yield is obtained when *o*-aminophenylarsinic acid is used :



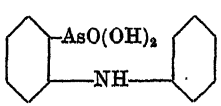
Bromine substitution products are obtained by using dibromobenzene in the condensation, and carboxylated compounds by the aid of bromobenzoic acids or anthranilic acid.

Diphenylamine-*p*-arsinic acid may be produced by the hydrolysis of *p*-phenylacetylaminophenylarsinic acid or by the direct arsenation of diphenylamine. The nitrodiphenylamine-*p*-arsinic acids may also be formed by the direct arsenation of nitrodiphenylamines. Direct arsenation of diphenylamine leads to the formation of two by-products, diphenylamine-*p*-*p*′-diarsinic acid and *bis*diphenylaminearsinic acid, the former yielding an arseno-compound on reduction.

Triphenylamine-*o*-arsinic acid is obtained when *o*-arsanilic acid, bromobenzene and potassium carbonate are heated together in amyl alcohol in the presence of copper powder and cuprous iodide at 160° to 170° C. If this reaction is carried out at 130° to 140° C. only diphenylamine-*o*-arsinic acid results. If *p*-dibromobenzene is used in the condensation, the corresponding bromo-substituted triphenylamine-*o*-arsinic acid results.

Since some of the foregoing diphenylaminearsinic acids are used in the preparation of phenarsazines, dealt with in the following section, the following appear only in that section: 4-methyldiphenylamine-6′-arsinic acid (p. 463); 2-methyldiphenylamine-6′-arsinic acid (p. 464); and N-methyldiphenylamine-*o*-arsinic acid (p. 465). Where compounds appear in both sections, suitable references have been added.

Diphenylamine-o-arsinic acid,[1]

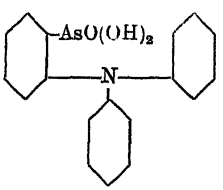


This compound may be obtained in three ways : (1) A mixture of 4·7 grams of aniline, 14 grams of *o*-bromophenylarsinic acid, 9·8 grams of dry potassium carbonate, 38 c.c. of amyl alcohol, and a trace of copper powder, is boiled for five hours. After steam distillation and decolorisation the acidified filtrate yields 7·1 grams of crude product. (2) When the condensation is carried out using bromobenzene, *o*-aminophenylarsinic acid, dry potassium carbonate, amyl alcohol, and a trace of copper powder, only 0·4 gram of product is obtained. (3) 2 grams of *o*-arsanilic acid, 60 c.c. of bromobenzene, 3 grams of anhydrous

[1] Gibson and Johnson, *loc. cit.*

potassium carbonate, a trace of copper powder and cuprous iodide in 8 c.c. of amyl alcohol, are heated for eleven hours in an oil-bath at 130° to 140° C., the vessel being stirred during the operation. From the reaction mixture a 50 to 60 per cent. yield of diphenylamine-*o*-arsinic acid is isolated.[1] The acid crystallises from acetic acid in colourless, felted needles, melting at 166° C. with slight decomposition. It is readily soluble in alcohols, acetone, and ethyl acetate, soluble in warm nitrobenzene, sparingly soluble in water, and practically insoluble in ether, chloroform, and benzene. The yellowish-green solution of the acid in a little concentrated nitric acid is instantly coloured deep red by the addition of concentrated sulphuric acid. The yellowish solution in concentrated sulphuric acid becomes Burgundy red on addition of nitric acid. The acid forms a *disodium salt*, crystallising with 6 molecules of water. When boiled for a few minutes with concentrated hydrochloric acid the acid yields *phenarsazinic acid hydrochloride*, from which the free acid is isolated by solution in sodium hydroxide and precipitation with acetic acid. The phenarsazinic acid in hot alcoholic hydrochloric acid, when reduced with sulphur dioxide after adding a trace of iodine, gives 10-*chloro*-5 : 10-*dihydrophenarsazine*. Diphenylamine-*o*-arsinic acid, dissolved in a mixture of hot alcohol and concentrated hydrochloric acid, deposits crystals of 10-*chloro*-5 : 10-*dihydrophenarsazine* when reduced with sulphur dioxide, using iodine as a catalyst.

o-Diphenylaminophenylarsinic acid or **Triphenylamine-o-arsinic acid,**[2]

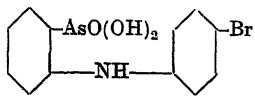


When the mixture used in the preparation of the preceding acid (Method 3) is heated at 160° to 170° C., only a small quantity of diphenylamine-*o*-arsinic acid results, the main product being triphenylamine-*o*-arsinic acid. This acid crystallises from ethyl alcohol in colourless, prismatic crystals, decomposing at 150° C. It is easily soluble in warm alcohols, very sparingly soluble in water, and insoluble in ether and acetone. Its acetic acid solution is coloured intense green on the addition of a little nitric acid.

o-Acetanilidophenylarsinic acid or **Diphenylacetamide-o-arsinic acid,** $C_6H_5.N(CO.CH_3).C_6H_4.AsO(OH)_2$, results when the *o*-arsanilic acid in the preceding preparations is replaced by its acetyl derivative and the mixture heated for ten hours at 140° C. The acid forms prismatic crystals, decomposing at 158° C., and having a similar solubility to diphenylamine-*o*-arsinic acid. With concentrated nitric acid it forms a yellow solution which changes through brown and olive-green to dark green, and becomes deep blue on addition of concentrated sulphuric acid. The solution in concentrated sulphuric acid is colourless, addition of concentrated nitric acid causing it to become brown.

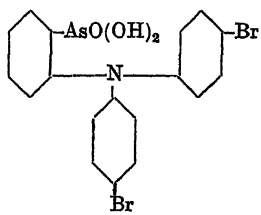
[1] Wintersteiner and Lieb, *Ber.*, 1928, 61, [B], 1126.
[2] Wintersteiner and Lieb, *ibid.*

o-p'-Bromophenylaminophenylarsinic acid or **p'-Bromodiphenylamine-o-arsinic acid,**



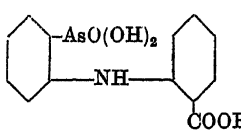
One gram of *o*-arsanilic acid, 1·1 grams of *p*-dibromobenzene, 10 c.c. of amyl alcohol, 1·5 grams of potassium carbonate, with traces of copper powder and cuprous iodide, are heated for five hours at 130° to 140° C., whilst the mass is stirred. The crude product is dissolved in methyl alcohol, treated with charcoal, filtered, and water added to the filtrate until turbidity persists. After standing for a day, brown crystals separate, and the mother-liquor, when again treated with water, yields a further crop of white crystals of the acid. The solubility of the acid is similar to that of the unbrominated product. The bromo-acid melts at 80° C., and dissolves in concentrated nitric acid to give a blue solution, which soon changes to red. The greenish solution in concentrated sulphuric acid becomes red on addition of nitric acid.

o-Di-p'-bromophenylaminophenylarsinic acid,



This compound is the main product formed when *o*-arsanilic acid and an excess of *p*-dibromobenzene (1 : 4) in amyl alcohol are heated at 150° to 160° C. The acid crystallises from acetone, melts at 215° C., is insoluble in ether, very sparingly soluble in water, soluble with difficulty in cold methyl and ethyl alcohols, easily soluble on warming. Nitric acid changes the green solution of the arsinic acid in concentrated sulphuric acid to brown; the yellow solution in concentrated nitric acid on treatment with concentrated sulphuric acid becomes greenish-brown and finally brown. The acetic acid solution with a drop of concentrated nitric acid becomes green to yellowish-green.

2-Carboxydiphenylamine-6'-arsinic acid,



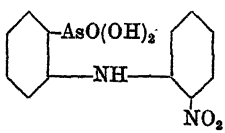
The preparation of this acid from anthranilic acid is dealt with on p. 468. It may also be obtained by heating together *o*-arsanilic acid, *o*-bromobenzoic acid, potassium carbonate, traces of copper powder and potassium iodide in amyl alcohol suspension, for ten hours at 145° to 155° C., the mixture being stirred. Prepared by this method it separates from acetic acid in colourless needles, M.pt. 237° C., with decomposition, and from alcohol in prismatic crystals. It is insoluble in ether, acetone, and benzene, sparingly soluble in water, readily

soluble in methyl and ethyl alcohols. The yellowish-brown solution in concentrated nitric acid becomes reddish-violet on the addition of concentrated sulphuric acid, whilst the greenish-yellow solution in concentrated sulphuric acid becomes brown to brownish-red when treated with nitric acid. The *monosodium salt* forms colourless crystals.

3-Carboxydiphenylamine-6′-arsinic acid.—This may be prepared from *m*-aminobenzoic acid as detailed on p. 463, or by replacing the *o*-bromobenzoic acid in the preceding preparation by the corresponding *m*-acid. This acid crystallises from dilute acetic acid in small, yellowish needles, decomposing at 235° to 238° C. Its solubility and colour reactions are similar to those given above.

4-Carboxydiphenylamine-6′-arsinic acid is obtained when *p*-bromobenzoic acid is used in the foregoing. It crystallises from dilute acetic acid in needles, decomposing at 210° C., and is less soluble in cold alcohol or acetic acid than the preceding acids.

2-Nitrodiphenylamine-6′-arsinic acid,

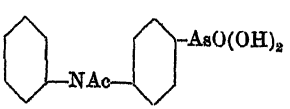


o-Arsanilic acid, *o*-bromonitrobenzene, potassium carbonate, a little copper powder and cuprous iodide, are heated in amyl alcohol suspension for six hours at 110° C. If a higher temperature is used, an amorphous dark brown condensation product of an acid nature is formed, which dissolves in an excess of hydrochloric acid. The crude product from this reaction is dissolved in a large bulk of hot water by the aid of sodium hydroxide. The addition of acid, followed by cooling, precipitates the arsinic acid as reddish needles, which decompose at 245° C., are insoluble in ether, acetone, and benzene, but soluble in alcohols, acetic acid, and ethyl acetate, especially on warming. With concentrated sulphuric acid the arsinic acid gives an intense red coloration, changing to yellow on the addition of nitric acid. Concentrated nitric acid causes the acid to become yellow; see also p. 454.

3-Nitrodiphenylamine-6′-arsinic acid is formed when *m*-bromonitrobenzene is used in the foregoing condensation, the time being increased to eight hours and the temperature to 145°–150° C. The acid crystallises in glistening yellow needles, decomposing between 205° and 210° C., in other properties resembling the previous acid; see also p. 455.

4-Nitrodiphenylamine-6′-arsinic acid, obtained when *p*-bromonitrobenzene is used in the foregoing, crystallises from acetic acid or ethyl alcohol in yellow prisms, possessing similar properties to the preceding acids.

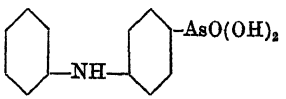
p-Phenylacetylaminophenylarsinic acid or **N-Acetyldiphenylamine-p-arsinic acid,**[1]



[1] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 460; Gibson and Johnson, *ibid.*, 1928, p. 1286.

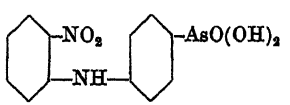
A diazotised solution of N-acetyl-*p*-aminodiphenylamine is gradually added with vigorous stirring to a solution of sodium arsenite containing a little copper sulphate, the arsenite solution being maintained at 30° to 35° C., and kept alkaline by the addition of sodium hydroxide solution. When the reaction is complete, the solution is filtered and made slightly acid to litmus, any further precipitate being removed. Evaporation to small bulk gives the crude acid, which crystallises from water in colourless prisms, containing 1 molecule of solvent and melting with decomposition at 126° C. Reduction of a solution of the acetyl acid in hot alcohol and hydrochloric acid by sulphur dioxide in the presence of a trace of iodine yields *p-phenylacetylaminophenylchloroarsine*, which crystallises from benzene-ligroin in colourless needles, M.pt. 141° C.

Diphenylamine-p-arsinic acid,



This acid is prepared by hydrolysing the foregoing compound (10·5 grams) by boiling for one hour with 21 c.c. of alcohol and a similar volume of hydrochloric acid and pouring the whole into water. The precipitate is dissolved in boiling dilute ammonium hydroxide and the solution decolorised by charcoal, filtered, heated to boiling, acidified with dilute hydrochloric acid, treated again with charcoal, and filtered. On cooling, the solution deposits long, fine, colourless needles of the arsinic acid, which are dried over potassium hydroxide in a vacuum. The acid, thus prepared, melts with decomposition at 295° to 297° C., after darkening at 287° C. Another method of preparation [1] consists in the direct arsenation of diphenylamine, using arsenic acid. 12 grams of arsenic acid, 10 grams of diphenylamine and 1·5 c.c. of water are heated first at 100° C. and finally at 140° to 145° C. From this reaction mixture 3 grams (18 per cent.) of diphenylamine-*p*-arsinic acid (decomposition point 286° C.) are obtained, together with diphenylamine-*p*-*p*'-diarsinic acid and *bis*-diphenylaminearsinic acid. Diphenylamine-*p*-arsinic acid yields an *ammonium salt*, a *disodium salt* containing 8 molecules of water of crystallisation, a *magnesium salt*, and a *hydrochloride* crystallising in small, colourless needles, sintering at 148° C. and melting with decomposition at 153° to 155° C. The free acid is reduced by 50 per cent. hypophosphorous acid to *di-p-phenylamino-arsenobenzene*.

2-Nitrodiphenylamine-4'-arsinic acid,[2]



This is produced by the direct arsenation of *o*-nitrodiphenylamine, 2 grams of the latter with 2 grams of arsenic acid and two drops of water being heated for fifteen minutes at 145° to 150° C. The crude melt is treated with hot sodium carbonate solution, filtered, and the filtrate

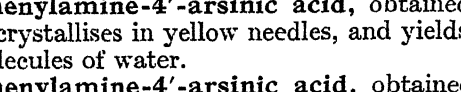
[1] Lieb and Wintersteiner, *Ber.*, 1928, 61, [B], 107.
[2] Wintersteiner and Lieb, *ibid.*, p. 1126.

acidified with hydrochloric acid, when the arsinic acid separates. The yield is 0·24 gram. The acid decomposes at 343° C., and forms a *disodium salt* containing 6 molecules of water.

3-Nitrodiphenylamine-4′-arsinic acid, obtained from *m*-nitrodiphenylamine, crystallises in yellow needles, and yields a *disodium salt* containing 3 molecules of water.

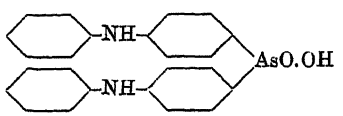
4-Nitrodiphenylamine-4′-arsinic acid, obtained from *p*-nitrodiphenylamine, separates in fine, yellow needles, decomposing above 320° C.

Diphenylamine-p-p′-diarsinic acid,[1]



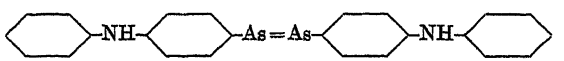
This is obtained during the direct arsenation of diphenylamine (p. 443). It decomposes without melting at 330° to 340° C., and forms an *ammonium salt,* sparingly soluble in alcohol.

Bisdiphenylaminearsinic acid,



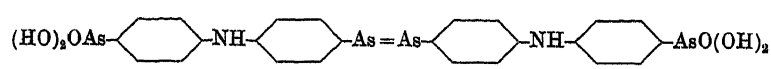
This is also occasionally obtained during the direct arsenation of diphenylamine. It is a white, amorphous product, which smells like diphenylamine when burned. Its *alkali* and *ammonium salts* are precipitated from aqueous solution on addition of alcohol, but are not obtained in crystalline form.

N-N′-Diphenyl-p-p′-diaminoarsenobenzene or **Di-p-phenylaminoarsenobenzene,**[1]



Diphenylamine-*p*-arsinic acid (0·5 gram) is suspended in 12 to 15 c.c. of 50 per cent. hypophosphorous acid and heated for a few seconds on a boiling water-bath, the mixture being rapidly stirred. Most of the solid dissolves; the solution is cooled and filtered, and after a few seconds' heating it is allowed to stand for five hours, the yellow precipitate washed with water, ammonium hydroxide and alcohol, and then dried over sulphuric acid in an atmosphere of hydrogen. The arseno-compound is readily soluble in benzene, sparingly soluble in ethyl alcohol. The foregoing reaction readily proceeds further, with the formation of polyarsenides.

N-N′-Diphenyl-p-p′-diaminoarsenobenzene-p″-p‴-diarsinic acid or **p-p′-Diphenylaminoarsenobenzene-p″-p‴-diarsinic acid,**



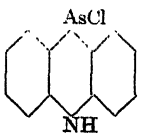
This compound is prepared from diphenylamine-*p*-*p*′-diarsinic acid by the method of reduction previously used, the solution being allowed to stand for fifteen to twenty hours after reduction. The acid is very

[1] Lieb and Wintersteiner, *loc. cit.*

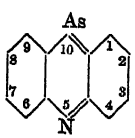
hygroscopic in air, is insoluble in alcohol, ether, and benzene, but dissolves readily in alkalis, ammonium hydroxide, and sodium carbonate solutions, from which it is precipitated by acids in yellowish-red flocks. A *magnesium salt* is known.

Phenarsazines.

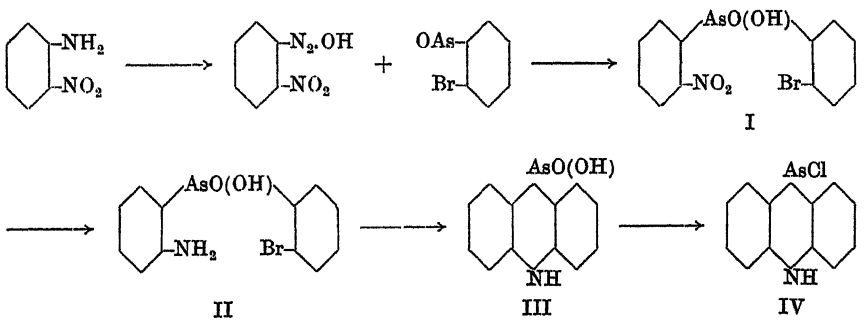
This interesting group of compounds is the outcome of the observation that arsenious chloride, when heated with diphenylamine, forms a condensation product. The reaction is the subject of a patent taken out by F. Bayer & Co. in 1913.[1] It has been shown that the compound formed has the following constitution :



The name phenarsazine chloride was given to this substance,[2] although it has also appeared under the names of diphenylamine arsenious chloride[3] and 6-chlorophenarsazine.[4] The compound was also prepared, and some of its properties examined, by Ball, and also by Morgan, during the War, but their work, unfortunately, has never been published. The bulk of the investigations on this compound and its derivatives of recent years have been carried out by Gibson and his co-workers,[5] and the nomenclature used for the compounds is due to them, and is shown below :



The following scheme shows how the formula given to phenarsazine chloride has been proved to be correct :

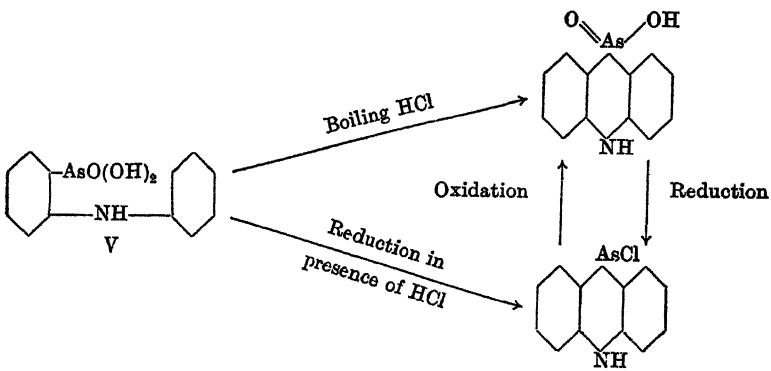


[1] German Patent, 281049. [2] Wieland and Rheinheimer, *Annalen*, 1921, 423, 1.
[3] Contardi, *Giorn. Chim. Ind. Appl.*, 1920, i. 11 ; ii. 100.
[4] Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1921, 43, 2218 ; Lewis, Lowry, and Bergeim, *ibid.*, p. 891.
[5] *J. Chem. Soc.*, 1926, pp. 450, 464, 2241 ; 1927, pp. 247, 2499 ; 1928, p. 2204.

Diazotised *o*-nitroaniline coupled with *o*-bromophenylarsenoxide yields 2-bromo-6′-nitrodiphenylarsinic acid (I), reduction of which by ferrous hydroxide gives the amino-derivative (II). This loses hydrobromic acid when heated in amyl alcohol with potassium carbonate and a little copper powder, forming *phenarsazinic acid* (III). This acid, when reduced in alcoholic hydrochloric acid by sulphur dioxide, is converted into 10-chloro-5 : 10-dihydrophenarsazine (IV). This product is identical with the substance prepared according to the equation :

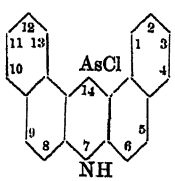
$$(C_6H_5)_2NH + AsCl_3 = NH\begin{matrix}C_6H_4\\C_6H_4\end{matrix}AsCl + 2HCl$$

The presence of the : NH group is shown by the fact that the hydrogen may be replaced by acetyl or similar groups. A further verification of the structure is afforded by the following series of reactions :

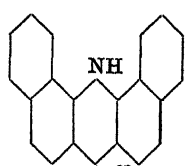


Diphenylamine-*o*-arsinic acid (V), prepared by the condensation of *o*-bromophenylarsinic acid and aniline, when reduced in alcoholic hydrochloric acid by sulphur dioxide in the presence of iodine, gives 10-chloro-5 : 10-dihydrophenarsazine, or if boiled with concentrated hydrochloric acid yields the chloride of phenarsazinic acid, which may be reduced to the 10-chloro-compound under suitable conditions. 2-Methyl- and 4-methyldiphenylamine-6′-arsinic acids are also capable of undergoing similar reactions to those just indicated.

Condensation also takes place between arsenious chloride and β-naphthylamine, di-β-naphthylamine, or di-α-naphthylamine (not with α-naphthylamine), to yield 14-*chloro*-14 : 7-*dihydrodibenzophenarsazine* (VI) in the case of the β-compounds, and 7-*chloro*-7 : 14-*dihydrodibenzophenarsazine* (VII) with the α-compound :

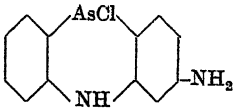


VI

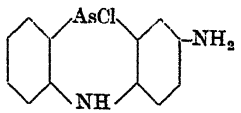


VII

When *m*-aminodiphenylamine is condensed with arsenious chloride, 10-*chloro*-3-*amino*-5 : 10-*dihydrophenarsazine* (VIII) is produced, and 10-chloro-2-amino-5 : 10-dihydrophenarsazine (IX) is the reduction product of mononitrophenarsazinic acid:

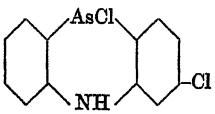


VIII

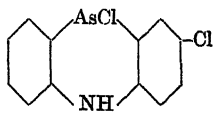


IX

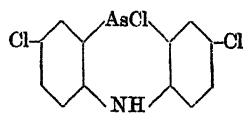
Formula IX has been shown to be correct by obtaining the compound by the condensation of arsenious chloride and *p*-aminodiphenylamine. If the latter is replaced by *m*- or *p*-chlorodiphenylamine, or by *p*-*p*'-dichlorodiphenylamine, the following products result (X), (XI), (XII):



X

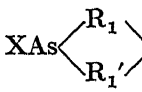


XI



XII

Attempts to extend the foregoing type of reaction, using phenyldichloroarsine instead of arsenious chloride, did not yield 10-phenyl-5 : 10-dihydrophenarsazine, but only 10-chloro-5 : 10-dihydrophenarsazine, and this seems to be a general rule, no compounds of the type



(X=hydrocarbon radical)

being obtained by this reaction.

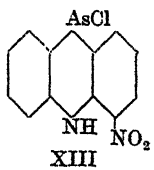
10-Chloro-5 : 10-dihydrophenarsazine reacts with 2 molecules of the appropriate Grignard reagent to give 10-*methyl*-5 : 10-, 10-*ethyl*-5 : 10- and 10-*phenyl*-5 : 10-*dihydrophenarsazine*. By regulating the conditions of the preparation, it is possible to obtain 10 : 10-*dimethyl*-5 : 10-*dihydrophenoxarsonium iodide*, also produced by methylating 10-methyl-5 : 10-dihydrophenarsazine.

Condensation between diphenylamine and arsenious oxide in the presence of phosphorus pentoxide yields 10 : 10'-*oxy*-5 : 10-*dihydrophenarsazine*:

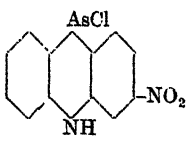
$$2(C_6H_5)_2NH+As_2O_3=[NH(C_6H_4)_2As]_2O+2H_2O$$

and when this oxy-compound in glacial acetic acid solution is treated with concentrated halogen acids, *chloro*-, *bromo*- and *iodo*-*phenarsazines* are produced. The oxy-derivative also reacts with certain alcohols, yielding *alkoxy-compounds*.

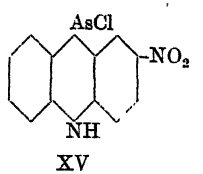
Continuing examples of ring closure of diphenylamine arsinic acids and their derivatives, 2-nitrodiphenylamine-6'-dichloroarsine when boiled in acetic acid solution for three hours is transformed into 10-*chloro*-4-*nitro*-5 : 10-*dihydrophenarsazine* (XIII), and reduction of 3-nitrodiphenylamine-6'-arsinic acid does not give a dichloroarsine, but gives rise to 10-*chloro*-3(or 1)-*nitro*-5 : 10-*dihydrophenarsazine* (XIV). 4-Nitrodiphenylamine-6'-arsinic acid behaves like the 3-nitro-compound, and produces 10-*chloro*-2-*nitro*-5 : 10-*dihydrophenarsazine* (XV):



XIII

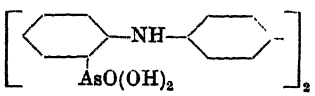


XIV

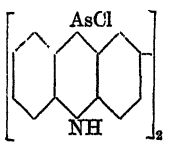


XV

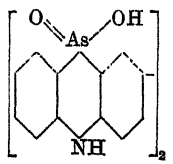
Condensation of benzidine (1 mol.) and *o*-bromophenylarsinic acid (2 mols.) yields 4 : 4′-*bis*(*diphenylamine*-2′-*arsinic acid*) (XVI), which can be reduced in alcoholic hydrochloric acid by sulphur dioxide in the presence of iodine to 2 : 2′-*bis*(10-*chloro*-5 : 10-*dihydrophenarsazine*) (XVII):



XVI

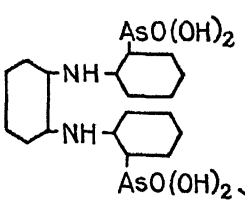


XVII

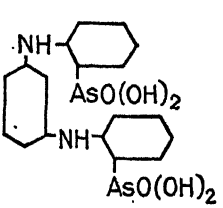


XVIII

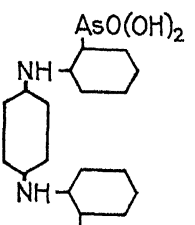
Compound XVII appears to be identical with that formed by the condensation of N-N′-diphenylbenzidine (1 mol.) with arsenious chloride (2 mols.), and oxidation gives 2 : 2′-*bis*(*phenarsazinic acid*) (XVIII). If N-N′-di-*p*-tolylbenzidine is used in the condensation, 2 : 2′-*bis*(10-*chloro*-8-*methyl*-5 : 10-*dihydrophenarsazine*) is formed, from which 2 : 2′-*bis*(8-*methylphenarsazinic acid*) is obtained by oxidation. The *bromo*- and *iodo-compounds* are obtained from the acid by reduction, using the requisite halogen acid. *o*-Bromophenylarsinic acid has also been condensed with *o*-, *m*- and *p*-phenylenediamines, giving 1 : 2-, 1 : 3- and 1 : 4-*phenylenediaminodi-o-phenylarsinic acids* (XIX), (XX), (XXI), but only with the *meta* compound was the condensation considered satisfactory. Compound XIX resists purification; it may be reduced in the presence of hydrochloric acid to XXII:



XIX

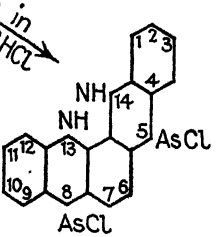


XX



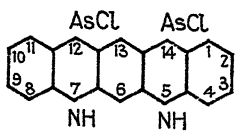
XXI

Reduction in presence of HCl

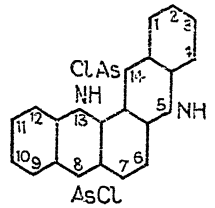


XXII

The reduction of 1 : 3-phenylenediaminodi-*o*-phenylarsinic acid (XX) in the presence of hydrochloric acid gives a compound which may have a structure denoted by (XXIII) or (XXIV):

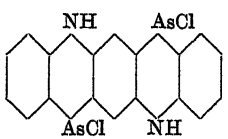


XXIII

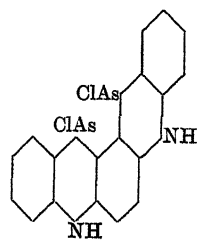


XXIV

Compound XXIII is 12 : 14-*dichloro*-5 : 7 : 12 : 14-*tetrahydrobenzarsazinephenarsazine*, and XXIV is 8 : 14-*dichloro*-5 : 13 : 8 : 14-*tetrahydrobenzarsazinephenarsazine*. The derivative is bright yellow in colour and well crystallised. Condensation of N-N′-diphenyl-*p*-phenylenediamine (1 mol.) and arsenious chloride (2 mols.) leads to the formation of a product which may be 7 : 14-*dichloro*-5 : 12 : 7 : 14-*tetrahydrobenzarsazinephenarsazine* (XXV) or 13 : 14-*dichloro*-5 : 8 : 13 : 14-*tetrahydrobenzarsazinephenarsazine* (XXVI):

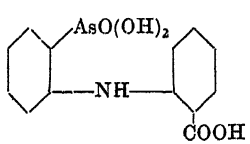


XXV

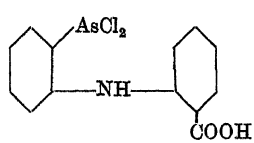


XXVI

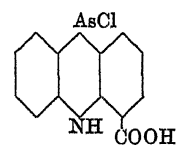
Phenarsazines containing carboxyl groups are obtainable by the method indicated below. Anthranilic acid condenses with *o*-bromophenylarsinic acid in boiling nitrobenzene solution in the presence of anhydrous potassium carbonate and a little copper powder, to give 2-*carboxydiphenylamine*-6′-*arsinic acid* (XXVII):



XXVII



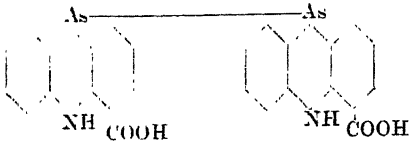
XXVIII



XXIX

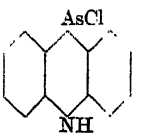
This acid, when reduced by sulphur dioxide in the usual manner, gives 2-*carboxydiphenylamine*-6′-*arsenic dichloride* (XXVIII), not isolated in the pure state owing to the ease with which it loses hydrochloric acid. It may be converted to 10-*chloro*-5 : 10-*dihydrophenarsazine*-4-*carboxylic acid* (XXIX), either by boiling the acetic acid solution of the reduction product or by dissolving the latter in hot sodium hydroxide, boiling the solution for a few minutes, then adding an excess of concentrated hydrochloric acid. Reduction of compound XXIX by hypophosphorous acid

yields 10 : 10'-*bis*-4-*carboxy*-5 : 10-*dihydrophenarsazine* (XXX). In a similar manner, 10-*chloro*-5 : 10-*dihydrophenarsazine*-3-*carboxylic acid* is obtained from *m*-aminobenzoic acid, but *p*-aminobenzoic acid and N-methylanthranilic acid have not given condensation products.



XXX

Phenarsazine chloride or **10-Chloro-5 : 10-dihydrophenarsazine,**



This compound may be prepared in a variety of ways : (1) Diphenylamine (17 grams), 20 grams of arsenious chloride and 40 c.c. of *o*-dichlorobenzene are boiled under reflux for five hours. A dark green solution is formed, which deposits crystals on cooling. These are filtered off, washed with petrol, dried, and recrystallised from carbon tetrachloride.[1] (2) Diphenylamine and arsenious chloride are heated together for four hours at 210° C.[2] (3) The diphenylamine in the foregoing may be replaced by diphenylhydrazine [3] or methyldiphenylamine. (4) 2-Bromo-6'-methylaminodiphenylarsinic acid, dry potassium carbonate, amyl alcohol and a trace of copper powder are boiled under reflux for twelve hours. (5) By condensation of phenyldichloroarsine with diphenylamine in *o*-dichlorobenzene solution. The presence of the solvent in this case is not essential. (6) By condensing β-chlorovinyldichloroarsine and diphenylamine with or without a solvent.[4]

The crude product is usually greenish-yellow, due to the formation of a dyestuff during the reaction. When pure it is bright yellow and melts at 191° to 192° C. It may be recrystallised from xylene, glacial acetic acid, or carbon tetrachloride. It sublimes *in vacuo* without change. Its solution in concentrated sulphuric acid is dark red, addition of water precipitating the orange-yellow sulphate. From the following solvents the arsazine crystallises with solvent of crystallisation, which may be removed by heating at 110° C. : acetic acid, *sym.*-tetrachloroethane, chlorobenzene, *o*-dichlorobenzene, acetone, carbon tetrachloride. It readily dissolves in arsenious chloride, yielding a dark green solution, from which magnificent scarlet scales are deposited on cooling. These contain 1 molecule of arsenious chloride of crystallisation, which is readily removed by solvents or by exposure to air.

10-Bromo-5 : 10-dihydrophenarsazine.[5]—This may be prepared in two ways : (1) 8·5 grams of diphenylamine, 17·3 grams of arsenious

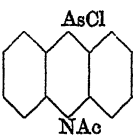
[1] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 451.
[2] Wieland and Rheinheimer, *loc. cit.*
[3] Lewis and Hamilton, *loc. cit.*
[4] Burton and Gibson, *J. Chem. Soc.*, 1926, pp. 467, 469; compare this Vol., p. 57.
[5] Burton and Gibson, *ibid.*, p. 463.

bromide and 20 c.c. of *o*-dichlorobenzene are boiled under reflux for eighteeen hours. On cooling, 9·6 grams of crude product are obtained. (2) 10-Acetyl-5 : 10-dihydrophenarsazine in boiling glacial acetic acid is treated with hydrobromic acid in the same solvent. The bromide separates in greenish-yellow prisms, M.pt. 217° to 218° C., on crystallisation from toluene.

10 - Iodo - 5 : 10 - dihydrophenarsazine. — When 4·5 grams of 10-acetyl-5 : 10 - dihydrophenarsazine in 70 c.c. of glacial acetic acid are heated and treated with 2·5 c.c. of hydriodic acid (50 per cent.) in 10 c.c. of glacial acetic acid, 5·6 grams of the iodo-compound are obtained. It crystallises in brownish-orange needles, M.pt. 217° to 221° C., with decomposition.

10 - Cyano - 5 : 10 - dihydrophenarsazine is obtained from the corresponding 10-chloro compound and silver cyanide in benzene solution ; it melts with decomposition at 227° to 228° C.[1]

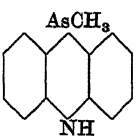
10-Chloro-5-acetyl-5 : 10-dihydrophenarsazine,[2]



is prepared by boiling 10-chloro-5 : 10-dihydrophenarsazine with an excess of acetyl chloride in benzene solution for four hours. It crystallises in colourless needles, M.pt. 229° to 230° C.

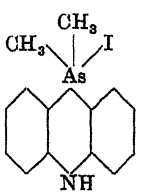
10-Chloro-5-propionyl-5 : 10-dihydrophenarsazine crystallises from benzene-petrol in colourless plates, M.pt. 135° to 136° C.

10-Methyl-5 : 10-dihydrophenarsazine,[3]



and the following compounds, are formed by treating 10-chloro-5 : 10-dihydrophenarsazine with the appropriate Grignard reagent. The methyl compound melts at 105° C., and is soluble in the usual solvents. The 10-*ethyl*- and 10-*phenyl*-derivatives melt at 75° and 142° C. respectively.

10 : 10-Dimethyl-5 : 10-dihydrophenarsazonium iodide,



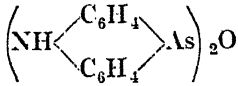
[1] Grischkievitch-Trochimovski, Mateyak, and Zablotski, *Bull. Soc. chim.*, 1927, [iv.], 41, 1323.

[2] Burton and Gibson, *Trans. Chem. Soc.*, 1924, 125, 2277.

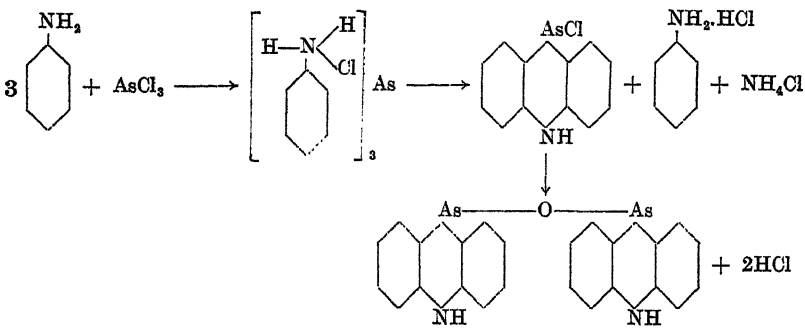
[3] Aeschlimann, *J. Chem. Soc.*, 1927, p. 416.

melts respectively at 259° or 268° C. on slow or rapid heating. 10-*Methyl*-10-*ethyl*-5 : 10-*dihydrophenarsazonium iodide* melts at 229° or 236° C., 10-*phenyl*-10-*methyl*-5 : 10-*dihydrophenarsazonium iodide* with decomposition at 158° C., and 5-*acetyl*-10-*methyl*-5 : 10-*dihydrophenarsazine* at 154° C.

Phenarsazine oxide or 10 : 10′-Oxy-5 : 10-dihydrophenarsazine,

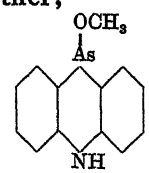


This is produced by the action of alkali upon an acetone solution of phenarsazine chloride, or by hydrolysis of the cyanide. It may also be obtained from diphenylamine by heating with arsenious oxide and phosphorus pentoxide at 160° to 170° C. for one hour, the mixture being mechanically stirred.[1] When aniline and arsenious chloride are condensed in *n*-heptane solution, trianilinoarsine hydrochloride is formed, and this, when heated alone or in the presence of aniline, yields phenarsazine chloride, treatment of which with sodium hydroxide gives the oxide.[2] The reaction may be represented as follows :



Phenarsazine oxide crystallises from nitrobenzene or pyridine in colourless plates, which soon become yellow, M.pt. 350° C. It is sparingly soluble in most solvents, and when boiled with alcohols yields ethers, and with phenols, phenyl ethers. Boiling with acetic acid transforms it into 10-*acetyl*-5 : 10-*dihydrophenarsazine*, which occurs in greenish, shimmering plates, M.pt. 223° to 224° C. The corresponding 10-*n-butoxy-compound* forms pale yellow needles, M.pt. 158° to 160° C., and the 10-*benzyloxy-derivative*, colourless needles, M.pt. 173° to 175° C.

Phenarsazine methyl ether,



The chloride is suspended in methyl alcohol and treated with methyl alcohol-sodium cyanide solution. The ether crystallises in long,

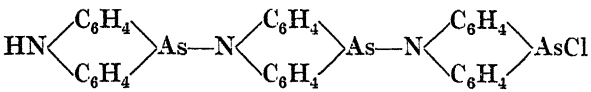
[1] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 462.

[2] Schmidt, *J. Amer. Chem. Soc.*, 1921, 43, 2449 ; see Schiff, *Compt. rend.*, 1863, 56, 268.

colourless needles, melting at 194° C. to a yellow liquid. The oxide is generated if the compound is boiled with water or alkali. A suspension of the ether in methyl alcohol is decomposed by hydrogen sulphide with formation of *phenarsazine sulphide*, which crystallises from benzene-acetone in fine, matted needles or plates, M.pt. 262° C. Boiling with high-boiling solvents causes the splitting off of hydrogen sulphide and the formation of phenarsazine.

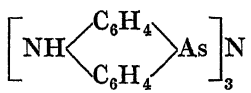
The Interaction of Phenarsazine Chloride and Amines.

When phenarsazine chloride in dry pyridine is boiled for two hours, an orange-yellow crystalline product is formed, melting at 260° to 263° C. Its properties and analysis point to the structure,



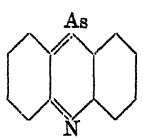
The same product is isolated when the pyridine is replaced by quinoline or dimethylaniline. On prolonged boiling with a fresh quantity of base the compound yields phenarsazine oxide.

When ammonia is passed into a solution of phenarsazine chloride in dry, boiling xylene, a colourless, chlorine-free body is obtained, which appears to be *triphenarsazinamine*,



It is sparingly soluble and melts with decomposition at 295° to 300° C. When treated with acetic acid, ammonia is evolved and phenarsazine acetate formed, whilst in high-boiling, indifferent solvents, ammonia is split off and phenarsazine formed; a sublimate of the latter is also formed if the compound is heated from 200° to 300° C. in high vacuum.

Phenarsazine,



When the foregoing methyl ether in methyldiphenylamine is boiled in a carbon dioxide atmosphere, orange-red prisms are obtained, melting above 310° C. The compound is soluble in nitrobenzene and gives an orange-red solution in methyldiphenylamine. In ether it is bright yellow, and when the solution is shaken in air the oxide separates out. Like all its derivatives it gives a carmine-red solution in concentrated sulphuric acid.

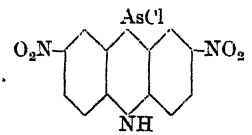
Nitrophenarsazine Chlorides and their Derivatives.[1]

The nitration of phenarsazine chloride leads to the production of two mononitro-compounds and a dinitro-derivative. The chloride (18 grams) is dissolved in 120 c.c. of boiling acetic acid, the solution

[1] Wieland and Rheinheimer, *loc. cit.*

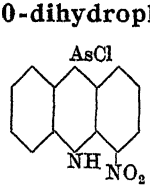
rapidly cooled to 18° C., and 4·5 c.c. of nitric acid (density 1·52) added dropwise, the temperature being maintained below 20° C. Each drop of acid produces a blue coloration, and when all has been added the temperature is raised to 25° C., when complete solution takes place, and on subsequent cooling a deep-coloured nitro-compound separates. This product is filtered off and washed with a little acetic acid and much ether, then ground with acetone, the two mononitro-derivatives going into solution, leaving the dinitro-compound as the residue.

2 : 8-Dinitrophenarsazine chloride,



The positions of the nitro-groups in this substance have not been definitely determined. It crystallises from nitrobenzene in shining yellow needles, melting above 300° C. When its alcoholic suspension is treated dropwise with sodium hydroxide, the reddish-violet colour of a quinonoid *aci*-nitro salt appears, which is destroyed by the addition of water.

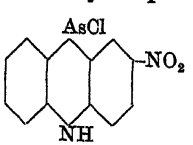
10-Chloro-4-nitro-5 : 10-dihydrophenarsazine,



results together with the 2-isomer in the acetone extract mentioned previously. It is isolated by evaporating the solution to dryness and fractionally crystallising the residue from ether, in which it is more soluble than the *p*-compound. A more recent method of preparation [1] consists in boiling 2-nitrodiphenylamine-6′-dichloroarsine in glacial acetic acid for three hours, when ring closure takes place. The compound crystallises in scarlet needles, M.pt. 165° C.

In the latter preparation, the dichloroarsine is obtained from *2-nitrodiphenylamine-6′-arsinic acid.* This is prepared by the condensation of *o*-aminophenylarsinic acid and *o*-bromonitrobenzene in amyl alcohol in the presence of copper powder and potassium carbonate. It crystallises in golden-yellow needles, melting with decomposition at 238° to 240° C. When reduced in alcoholic concentrated hydrochloric acid solution by sulphur dioxide in the presence of iodine, it yields *2-nitrodiphenylamine-6′-dichloroarsine*, which crystallises from benzene-light petroleum in deep red crystals, M.pt. 110° C.

10-Chloro-2-nitro-5 : 10-dihydrophenarsazine,

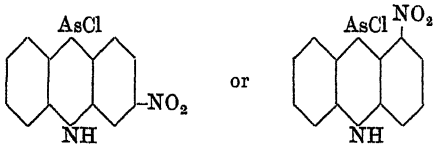


[1] Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2513.

may be separated from the nitration products of phenarsazine chloride, as already detailed, or formed by the ring closure of *4-nitrodiphenylamine-6′-arsinic acid* on reduction in the presence of hydrochloric acid in the usual manner. The 6′-arsinic acid is a pale yellow, microcrystalline substance, melting with decomposition at 223° C. 10-Chloro-2-nitro-5 : 10-dihydrophenarsazine occurs as small, orange-yellow, prismatic needles, which turn dark red at 194° to 197° C. and melt with decomposition at 276° to 278° C. Reduction leads to *10-chloro-2-amino-5 : 10-dihydrophenarsazine*,[1] which may also be obtained by condensing arsenious chloride with *p*-aminodiphenylamine.[2] The *hydrochloride* of the amino-compound forms glistening, yellowish-green plates, which give a colourless solution in water. The compound has a very irritant action on the mucous membrane of the eyes, nose, and throat.

3-Nitrodiphenylamine-6′-arsinic acid, obtained in a similar manner to its isomers, crystallises in yellow needles, M.pt. 202° C., with decomposition.[3]

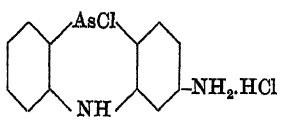
10-Chloro-3(or 1)-nitro-5 : 10-dihydrophenarsazine,



The preceding compound yields this derivative on reduction. It crystallises in thin, glistening prisms, melting with decomposition at 258° to 259° C. The corresponding *10-bromo-derivative* crystallises in short, reddish-brown needles, M.pt. 234° C., with decomposition.

10-Chloro-2-amino-5 : 10-dihydrophenarsazine.[4]—The corresponding 2-nitro-acid in dilute sodium hydroxide is reduced by ferrous hydroxide. The *hydrochloride* separates from alcoholic hydrochloric acid in yellow plates, which decompose at a high temperature.

10 - Chloro - 3 - amino - 5 : 10 - dihydrophenarsazine hydrochloride, or m-Aminophenarsazine chloride hydrochloride,

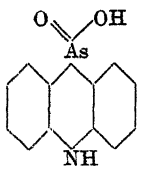


5 grams of *m*-aminodiphenylamine and 8 grams of arsenious chloride are heated for five hours under reflux, the temperature being slowly raised from 140° to 170° C. The reaction mixture yields the hydrochloride in yellowish-green plates. Treatment with sodium hydroxide produces the *oxide*, and perhydrol in alkaline solution forms the *phenarsazinic acid.*

[1] Wieland and Rheinheimer, *loc. cit.*
[2] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 2244.
[3] *Ibid.*, 1927, p. 2514.
[4] *Ibid.*, 1926, p. 2245.

Phenarsazinic Acid and its Derivatives.

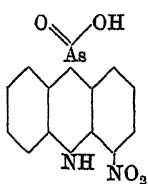
Phenarsazinic acid,[1]



This acid has been prepared in several ways: (1) By the action of perhydrol on the chloride. (2) By oxidation of the oxide. (3) By the action of a 10 per cent. aqueous solution of Chloramine-T (2 mols.) on a cold acetone solution of the chloride (1 mol.), 20 c.c. of acetone being used per gram of chloride. The last method gives a yield of 92 per cent. The acid does not melt at 300° C., crystallises from acetone in needles, and from acetic acid contains 1 molecule of acetic acid of crystallisation. The following salts have been described: *Sodium salt*, fine needles; *hydrochloride*, colourless needles, M.pt. 200° to 205° C.; *nitrate*, pale yellow needles, having no melting-point; *sulphate*, colourless prisms, M.pt. 138° to 140° C. with decomposition.

N-Acetylphenarsazinic acid is obtained in theoretical yield by oxidising 10-chloro-5-acetyl-5 : 10-dihydrophenarsazine. It is insoluble in water, but crystallises from aqueous alcohol in colourless, flat prisms, M.pt. 244° to 245° C. with decomposition, containing two molecules of water of crystallisation. *N-Propionyl-* and *N-benzoyl-phenarsazinic acids* melt at 232° and 250° C., respectively, both decomposing at the melting-point.

4-Nitrophenarsazinic acid,



results together with its 2-isomer, when phenarsazinic acid in acetic acid solution is nitrated with fuming nitric acid at 16° C. It is also obtained when 4-nitrophenarsazine chloride is oxidised by perhydrol. It crystallises from dilute acetic acid with 1 molecule of water, and from glacial acetic acid with 1 molecule of acetic acid of crystallisation. The crystals separate as bright yellow needles of high melting-point. 2-*Nitrophenarsazinic acid* has also been obtained by direct nitration. It yields a *barium salt* crystallising in silky, yellow needles, containing 7 molecules of water of crystallisation, the anhydrous salt being bronze in colour. The *sodium salt* crystallises in brownish-yellow needles.[2] 3(or 1)-*Nitrophenarsazinic acid* yields a brown *sodium salt*.

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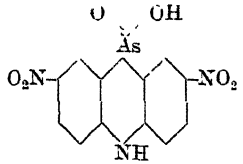
[1] Wieland and Rheinheimer, *loc. cit.*; Schmidt, *loc. cit.*; Burton and Gibson, *Trans. Chem. Soc.*, 1924, 125, 2276.

[2] See Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2514.

2 : 8-Dinitrophenarsazinic acid,

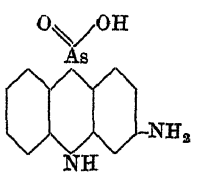


Phenarsazinic acid, or the chloride, is warmed with concentrated nitric acid (density 1·4) and the temperature gradually raised to boiling-point. The dinitro-acid has also been obtained by the nitration of the oxide. It separates in bright yellow needles. The *sodium salt* forms glistening bronze plates from sodium hydroxide solution. This salt is dibasic, but replacement of the hydroxide by sodium carbonate gives a monobasic salt, crystallising in yellow needles.

4-Aminophenarsazinic acid is obtained by reduction of the corresponding nitro-acid with ferrous chloride in 5*N* sodium hydroxide. It crystallises in pale pink plates containing 1 molecule of alcohol of crystallisation, has not a sharp melting-point, but blackens when heated. It is soluble in alkalis and mineral acids, but in contrast to the *para* acid is not auto-oxidisable, and forms no dyestuff with oxidising agents. The corresponding 2-*isomeride* yields a *sodium salt* crystallising in glistening, bronze laminæ. The free acid quickly polymerises in solution with the separation of a red, amorphous, flocculent precipitate.

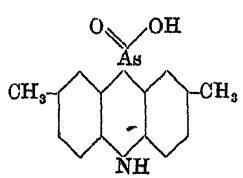
2 : 8-Diaminophenarsazinic acid, isolated by reduction of the dinitro-acid, has not been analysed. The *hydrochloride* is obtained, in 80 per cent. yield, as colourless plates, which give a deep bluish-violet colour with ferric chloride solution, dark red oxidation products soon separating out. The acid is characterised by the intense colour which aqueous solutions of its alkali salts give when shaken with silver oxide.

3-Aminophenarsazinic acid,



has already been mentioned under *m*-aminophenarsazine chloride hydrochloride. The latter is suspended in 0·1*N* sodium hydroxide solution, treated with hydrogen peroxide, and after completion of the reaction by gentle warming, the requisite amount of 0·1*N* hydrochloric acid added to liberate the acid. It crystallises in prisms, having a rhombic cross-section, and dissolving in concentrated hydrochloric acid to form the *hydrochloride*, which crystallises in colourless prisms.

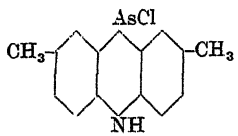
2 : 8-Dimethylphenarsazinic acid,



prepared by boiling a suspension of the chloroarsine in acetone with an aqueous solution of Chloramine-T, crystallises in colourless, glistening plates, which decompose at a high temperature without melting. Its *sodium salt* forms colourless needles, and the *hydrochloride* also colourless needles, M.pt. 216° C., with decomposition. *N-Acetyl-2 : 8-dimethylphenarsazinic acid* separates from dilute acetic acid in colourless prisms, M.pt. 240° C., with decomposition.

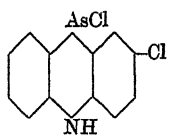
Miscellaneous Phenarsazine Derivatives.

10-Chloro-2 : 8-dimethyl-5 : 10-dihydrophenarsazine,



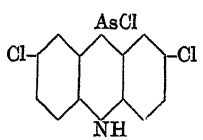
is obtained when di-*p*-tolylamine is condensed with arsenious chloride in the usual way. It separates from nitrobenzene in orange prisms, M.pt. 261° to 262° C. Its *acetyl derivative* crystallises from benzene-light petroleum in colourless needles, M.pt. 164° to 165° C.

2 : 10-Dichloro-5 : 10-dihydrophenarsazine,[1]



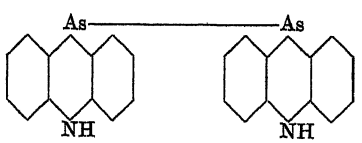
This is obtained from *p*-chlorodiphenylamine, condensation being carried out in the usual manner. It crystallises in yellow needles from glacial acetic acid, M.pt. 230° to 231° C., with decomposition. Using *m*-chlorodiphenylamine, 3 : 10-*dichloro*-5 : 10-*dihydrophenarsazine* is obtained in yellow needles, M.pt. 220° to 221° C., with decomposition.

2 : 8 : 10-Trichloro-5 : 10-dihydrophenarsazine,



For this compound, *p-p'*-dichlorodiphenylamine is used in the condensation. The product crystallises from acetic acid in yellow needles, M.pt. 273° to 274° C., with decomposition.

10 : 10'-Bis-5 : 10-dihydrophenarsazine,



may be obtained by two methods : (1) A hot solution of phenarsazine chloride, 5·5 grams, in 75 c.c. of alcohol and 100 c.c. of acetone is treated

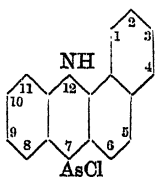
[1] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 2244.

with 8 c.c. of hypophosphorous acid (density 1·136) in 15 c.c. of alcohol. The product (2·7 grams) separates in orange-yellow needles as the solution cools. (2) To a boiling acetic acid solution (120 c.c.) containing a trace of iodine and 5 grams of phenarsazinic acid the same amount of hypophosphorous acid is added as in (1). On cooling, 2·5 grams of product are obtained. The compound melts with decomposition at 304° to 305° C., and is sparingly soluble in the usual solvents, but when boiled with xylene or acetone is rapidly oxidised to phenarsazinic acid. When suspended in carbon tetrachloride and treated with a 10 per cent. solution of bromine in the same solvent, crystals of 10-bromo-5 : 10-dihydrophenarsazine separate.

10 : 10′ - Bis - 5 - acetyl - 5 : 10 - dihydrophenarsazine. — When N-acetylphenarsazinic acid is reduced by method (2) above, this compound separates in clusters of almost colourless needles, M.pt. 293° to 294° C., after decomposition.

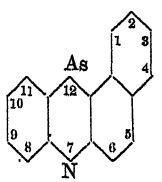
Benzophenarsazines.

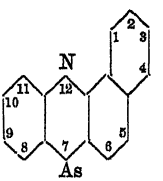
7-Chloro-7 : 12-dihydroisobenzophenarsazine,[1]



This compound may be prepared in four ways : (1) Phenyl-α-naphthylamine (88 grams) and 80 grams of redistilled arsenious chloride (10 per cent. excess) are heated under reflux, the mixture commencing to boil at 165° to 170° C., with evolution of hydrogen chloride. After about two hours, the temperature gradually rises to 200° C. and the gas evolution practically ceases. On cooling, 115 grams of greenish-yellow solid are obtained, which is recrystallised from xylene and washed with alcohol. Yield, 87 per cent. (2) By the condensation of phenyldichloroarsine with phenyl-α-naphthylamine. (3) By the condensation of β-chlorovinyldichloroarsine with phenyl-α-naphthylamine, with or without the use of a solvent. (4) By the reduction of 2-α-naphthylaminophenylarsinic acid. It forms canary yellow needles, M.pt. 219° C., insoluble in water and unattacked by 6*N* sodium hydroxide solution. It is soluble in xylene, glacial acetic acid, alcohol, benzene, and carbon tetrachloride.

[1] Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1921, 43, 2218; Burton and Gibson, *J. Chem. Soc.*, 1926, pp. 467, 470; Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2511.

(*a*) 

(*b*) 

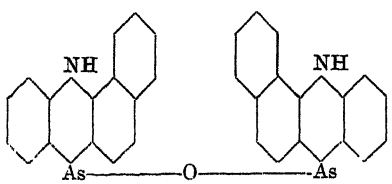
(*a*) = normal ring.
(*b*) = *iso*-ring.

7-Methoxy-7 : 12-dihydroisobenzophenarsazine results when the preceding compound is treated with sodium methylate in dry xylene. It melts at 209° C., is soluble in benzene, acetone, and carbon tetrachloride, insoluble in water. 10 per cent. sodium hydroxide decomposes it.

In a similar manner the following have been prepared, the yields being shown in brackets: *7-ethoxy-* (70 per cent.), M.pt. 165° C., crystals becoming yellow on standing in air; *7-n-propoxy-* (74 per cent.), pale yellow crystals, M.pt. 152° C.; *7-n-butoxy-* (67 per cent.), colourless product, softening at 120° but not completely melted at 260° C.; *7-phenoxy-* (61 per cent.), fine yellow needles, M.pt. 179° C.; *7-benzyloxy-* (67 per cent.), almost colourless compound, M.pt. 154° C.

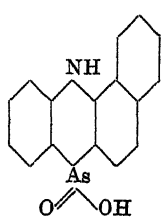
7-Bromo-7 : 12-dihydroisobenzophenarsazine is obtained from the 7-phenoxy-derivative by heating for four hours under reflux with an excess of concentrated hydrobromic acid. It crystallises from xylene in dark yellow needles, M.pt. 227° C., insoluble in water, but soluble in the usual organic solvents. It is unacted upon by dilute alkalis. Replacing the hydrobromic acid by hydriodic acid, the *7-iodo-7 : 12-dihydroisobenzophenarsazine* is formed in 62 per cent. yield. It may also be obtained from the corresponding oxide by the action of hydriodic acid. From xylene it separates in beautiful red needles, M.pt. 205° C.

7 : 7′-Oxy-7 : 12-dihydroisobenzophenarsazine,



A xylene solution of the 7-chloro derivative is treated with silver oxide and ammonia, a 90 per cent. yield of the oxide resulting. It is pale yellow, does not darken or melt below 250° C., is soluble in glacial acetic acid, but insoluble in benzene, xylene, and carbon tetrachloride. The corresponding *sulphide* is obtained from the 7-chloro compound by passing hydrogen sulphide through a solution in absolute alcohol. The sulphide is a yellow solid, M.pt. 204° to 205° C., insoluble in the usual solvents.

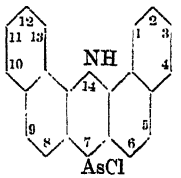
7 : 12-iso-Benzophenarsazinic acid,



The chloro-compound in acetic acid solution is oxidised by 3 per cent. hydrogen peroxide, an 81 per cent. yield of the acid being obtained. It does not melt below 260° C., and is insoluble in the usual solvents, except glacial acetic acid. It dissolves in alkalis, the *sodium salt* being unchanged up to 260° C., and is hygroscopic. The *hydrochloride* may be

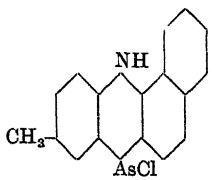
obtained by heating an alcoholic hydrochloric acid solution of 2-*α-naphthylaminophenylarsinic acid* (M.pt. 165° C.). It melts at 232° C. with decomposition.[1]

7-Chloro-7 : 14-dihydrodi-isobenzophenarsazine,[2]



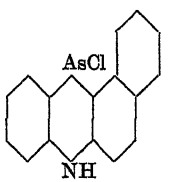
Di-α-naphthylamine, 13·5 grams (1 mol.), and 10 grams of arsenious chloride (1·1 mols.) in 20 c.c. of *sym.*-tetrachloroethane, are boiled for seven hours. Hydrogen chloride is slowly evolved, and on cooling, the product separates as a brown powder, 11·4 grams or a 60·3 per cent. yield being obtained.

7-Chloro-9-methyl-7 : 12-dihydroisobenzophenarsazine,



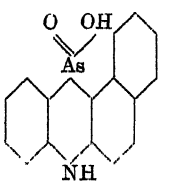
is prepared in the usual manner, using *p*-tolyl-α-naphthylamine. It separates from toluene in deep yellow needles, M.pt. 252° to 255° C., with decomposition.

12-Chloro-7 : 12-dihydrobenzophenarsazine,



This product results when phenyl-β-naphthylamine is used in the general method, or by reduction of 2-β-naphthylaminophenylarsinic acid.[3] It crystallises from *sym.*-tetrachloroethane in yellow needles, M.pt. 249° to 250° C. The corresponding 12-*bromo-derivative* is obtained by reducing 7 : 12-benzophenarsazinic acid in alcoholic hydrobromic acid. It forms short, deep, orange-coloured needles, M.pt. 251° to 252° C., with decomposition.

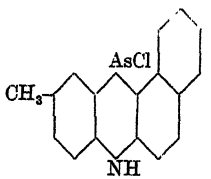
7 : 12-Benzophenarsazinic acid,



[1] Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2511.
[2] Lewis and Hamilton, *loc. cit.*
[3] Gibson and Johnson, *loc. cit.*

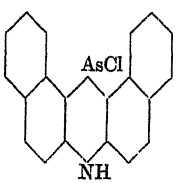
may be obtained in three ways: (1) A solution of 12-chloro-7 : 12-dihydrobenzophenarsazine is oxidised by an aqueous solution of Chloramine-T. (2) A solution of 2-β-naphthylaminophenylarsinic acid, M.pt. 181° C., in the minimum quantity of boiling glacial acid, is heated on the water-bath for thirty minutes. (3) An acetic acid solution of the latter compound is treated with hydrogen peroxide, then heated almost to boiling, when 7 : 12-benzophenarsazinic acid separates as a brown, amorphous solid. It crystallises from dilute acetic acid in colourless needles, melting above 325° C. The *hydrochloride* may be obtained by dissolving 2-β-naphthylaminophenylarsinic acid in a hot mixture of alcohol and concentrated hydrochloric acid, when it separates in fine needles, M.pt. 234° C., with decomposition. The following salts of the acid have been isolated: *sodium salt*, colourless needles; *ammonium salt*, glistening plates; *barium*, *silver* and *mercuric salts*, heavy white precipitates; *ferric salt*, brown; *copper salt*, pale greenish-blue; *cobalt salt*, pale blue; *calcium salt*, fine, colourless needles.

12-Chloro-10-methyl-7 : 12-dihydrobenzophenarsazine,



results when *p*-tolyl-β-naphthylamine is employed in the general method. It crystallises in yellow needles, M.pt. 266° to 267° C., with decomposition.

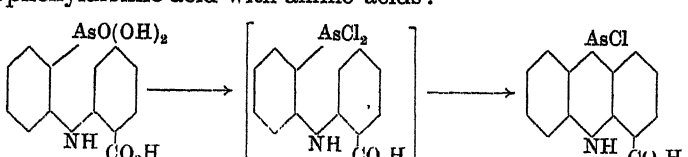
14-Chloro-14 : 7-dihydrodibenzophenarsazine,



Di-β-naphthylamine and arsenious chloride in *sym.*-tetrachloroethane condense after ninety minutes' boiling, the product being filtered and recrystallised from nitrobenzene. It separates in yellow needles, M.pt. 355° C., with decomposition. Yield, 55 per cent.

Carboxy-derivatives of 10-*Chloro*-5 : 10-*dihydrophenarsazine.*[1]

Since diphenylaminomonocarboxylic acids are difficult to obtain, the following carboxylated compounds are formed by the condensation of *o*-bromophenylarsinic acid with amino-acids:

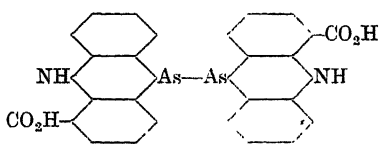


[1] Burton and Gibson, *J. Chem. Soc.*, 1927, p. 247.

2 - Carboxydiphenylamine - 6′ - arsinic acid.—A mixture of 13·6 grams of anthranilic acid, 14 grams of *o*-bromophenylarsinic acid, 14 grams of anhydrous potassium carbonate, 100 c.c. of nitrobenzene and a trace of copper powder is boiled under reflux for seven hours. Any volatile constituents are then removed by steam distillation and the resulting solution boiled with charcoal, filtered, and acidified. The acid (I) (11 grams) is crystallised from acetic acid, colourless, silky needles being deposited, M.pt. 243° C., with decomposition.

10-Chloro-5 : 10-dihydrophenarsazine-4-carboxylic acid.—Five grams of the preceding acid in 20 c.c. of alcohol and 20 c.c. of concentrated hydrochloric acid, containing a trace of iodine, are heated to boiling and sulphur dioxide passed in for a few minutes. A yellow precipitate is formed, the mixture cooled, and the solid collected. The latter appears to be an impure form of *2-carboxydiphenylamine-6′-dichloroarsine* (II), which may be converted into the required acid (III), either by boiling its solution in the minimum quantity of acetic acid for three hours or boiling with 3*N* sodium hydroxide and acidifying the solution to precipitate the acid. The carboxylic acid crystallises from acetic acid in yellow needles, melting with decomposition at 243° C.

10 : 10′-Bis-4-carboxy-5 : 10-dihydrophenarsazine,

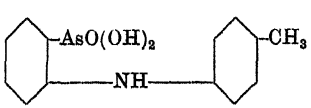


results when the preceding carboxylic acid in acetic acid solution is reduced by hypophosphorous acid, using iodine as a catalyst. It is an orange-coloured compound, melting with decomposition at 253° C., soluble in sodium hydroxide, but practically insoluble in the usual organic solvents.

3-Carboxydiphenylamine-6′-arsinic acid is prepared from *m*-aminobenzoic acid in a similar manner to the 2-carboxy-acid, amyl alcohol replacing nitrobenzene in the condensation mixture. It forms colourless needles, M.pt. 238° to 239° C. *10-Chloro-5 : 10-dihydrophenarsazine-3-carboxylic acid* is obtained from it in a similar way to the above, and is a yellow compound, unmelted below 300° C., and very sparingly soluble in organic solvents.

Derivatives of Methyldiphenylamine.

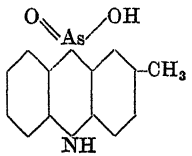
4-Methyldiphenylamine-6′-arsinic acid,[1]



is obtained by similar methods to diphenylamine-*o*-arsinic acid. It is a cream-coloured solid, melting with decomposition at 160° to 165° C., sparingly soluble in water, soluble in hot alcohol or hot glacial acetic acid.

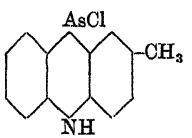
[1] Gibson and Johnson, *J. Chem. Soc.*, 1927, p. 2508.

2-Methylphenarsazinic acid,



may be prepared either by oxidation of 10-chloro-2-methyl-5 : 10-dihydrophenarsazine with Chloramine-T,[1] or by boiling the preceding 6′-arsinic acid with concentrated hydrochloric acid. It crystallises from aqueous acetic acid in fine, colourless needles, which decompose above 300° C. Its *sodium salt* forms colourless, hair-like needles, and the *hydrochloride*, small colourless prisms, M.pt. 209° to 211° C., with decomposition. The *hydrobromide* is prepared by dissolving 2-methylphenarsazinic acid in a mixture of hot alcohol and hydrobromic acid, or by boiling 4-methyldiphenylamine-6′-arsinic acid with hydrobromic acid. It is a granular powder, which turns orange at about 100° C., and melts with decomposition at 208° to 210° C.

10-Chloro-2-methyl-5 : 10-dihydrophenarsazine,



Phenyl-*p*-tolylamine (36·6 grams) and 40 grams of arsenious chloride in 80 c.c. of *o*-dichlorobenzene are boiled under reflux for four hours. The crude product (51 grams) separates as green crystals, and after crystallisation from benzene is obtained in yellow needles, M.pt. 199° to 200° C., with decomposition. It also occurs when 4-methyldiphenylamine-6′-arsinic acid in alcohol and concentrated hydrochloric acid is reduced by sulphur dioxide in the presence of iodine, or when the product of reaction between the 6′-arsinic acid and acetic anhydride is reduced by sulphur dioxide. When the chlorophenarsazine is boiled for three and a half hours with acetic anhydride it yields 10-*chloro* 5-*acetyl*-2-*methyl*-5 : 10-*dihydrophenarsazine*, which crystallises from benzene-light petroleum in clusters of almost colourless needles, M.pt. 154° to 155° C.

10-Bromo-2-methyl-5 : 10-dihydrophenarsazine is obtained when 2-methylphenarsazinic acid or 4-methyldiphenylamine-6′-arsinic acid is dissolved in a hot mixture of alcohol and hydrobromic acid and the mixture reduced. It crystallises from benzene in rosettes of hard, orange-red needles, melting with decomposition at 180° C.

2-Methyldiphenylamine-6′-arsinic acid is prepared in a similar manner to the 4-methyl derivative. It is a light cream-coloured solid and has an indefinite melting-point.

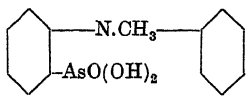
4-Methylphenarsazinic acid hydrochloride separates on boiling the preceding compound with concentrated hydrochloric acid. The free acid melts with decomposition at 309° to 310° C., and its hydrochloride forms colourless needles, M.pt. 199° C., with decomposition.

10-Chloro-4-methyl-5 : 10-dihydrophenarsazine forms yellow

[1] Burton and Gibson, *J. Chem. Soc.*, 1926, p. 469.

needles, M.pt. 191° C., with decomposition, and the corresponding *bromo-derivative* melts with decomposition at 190° C., both compounds being converted into 4-methylphenarsazinic acid on oxidation with Chloramine-T in aqueous acetone.

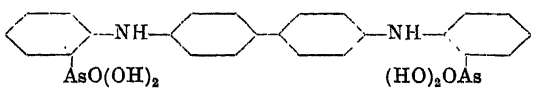
N-Methyldiphenylamine-o-arsinic acid,



The preparation of this compound resembles that of diphenylamine-*o*-arsinic acid, the aniline used in the latter case being now replaced by monomethylaniline. It is a colourless, crystalline solid, M.pt. 182° to 184° C., with decomposition.

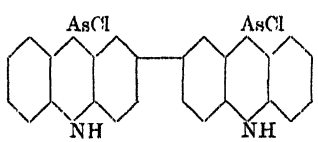
Phenarsazines containing Two Nitrogen and Two Arsenic Atoms in the System.

4 : 4-Bis(diphenylamine-2'-arsinic acid),[1]



This compound is a condensation product of benzidine (1 mol.) and *o*-bromophenylarsinic acid (2 mols.). 3·45 grams of benzidine, 11·3 grams of *o*-bromophenylarsinic acid, 8·8 grams of anhydrous potassium carbonate, 40 c.c. of amyl alcohol and a trace of copper powder are boiled under reflux for five hours. The amyl alcohol is then removed by steam distillation, the mixture filtered hot and hydrochloric acid added to the filtrate, a precipitate separating. Recrystallisation from dilute acetic acid yields a white powder, unmelted at 320° C.

2 : 2'-Bis(10-chloro-5 : 10-dihydrophenarsazine),



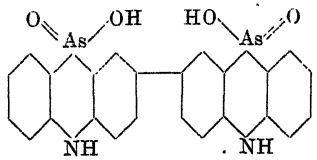
Three methods are available for the preparation of this derivative: (1), The preceding compound, dissolved in 25 c.c. of alcohol and 20 c.c. of hydrochloric acid containing a trace of iodine, is reduced by passing in sulphur dioxide for a few minutes. The precipitated compound is washed with alcohol and dried at 120° C. (2), N-N'-Diphenylbenzidine (23·1 grams) and 27·8 grams of arsenious chloride are boiled for five hours in 100 c.c. of *o*-dichlorobenzene, the mixture filtered whilst hot, washed with hot *o*-dichlorobenzene, then heated for a short time at 160° C. to remove the last traces of solvent. Pure materials should be used in this condensation or coloured by-products are formed. The yield is about 58 per cent. (3), 2 : 2'-Bis(phenarsazinic acid) in a hot mixture of alcohol and hydrochloric acid containing a trace of iodine

[1] Gibson and Johnson, *J. Chem. Soc.*, 1928, p. 2204.

is reduced with sulphur dioxide and the resulting product washed with alcohol and dried at 140° C. The product obtained by these methods is a pale orange-yellow, microcrystalline powder, insoluble in all the usual solvents. It dissolves slightly in boiling naphthalene, from which it crystallises in minute prisms, unmelted at 325° C.

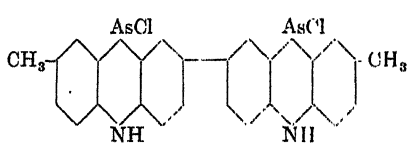
2 : 2′-Bis(10-bromo-5 : 10-dihydrophenarsazine) is prepared by Method (3) given for the preceding compound, the hydrochloric acid being replaced by hydrobromic acid.

2 : 2′-Bis(phenarsazinic acid),



2 : 2′-Bis(10-chloro-5 : 10-dihydrophenarsazine), 5 grams, is boiled with 100 c.c. of acetic acid, 16 c.c. of hydrogen peroxide (20 vol.) added to the cooled suspension and the whole carefully heated to boiling. The oxidation is completed in about five minutes, the solution cooled, diluted with 250 c.c. of water and filtered. The solid, after washing with water, is boiled with dilute sodium hydroxide solution and filtered. Addition of 20 per cent. sodium hydroxide causes deposition of the disodium salt of the acid. The free acid is isolated by dissolving the salt in warm water and adding dilute hydrochloric acid, the white precipitate being washed with water and dried at 140° to 145° C. 2 : 2′-Bis(phenarsazinic acid) is a white, amorphous powder, unmelted at 325° C., and insoluble in the usual organic solvents. The *disodium* and *potassium salts* crystallise in short, colourless needles ; the *magnesium*, *calcium*, *barium*, *mercury* and *silver salts* are all white precipitates, whilst the *cupric salt* is pale greenish-blue.

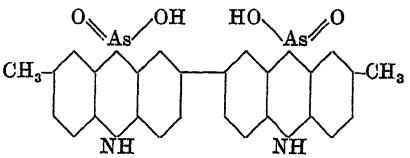
2 : 2′-Bis(10-chloro-8-methyl-5 : 10-dihydrophenarsazine),



The condensation of 10·5 grams of arsenious chloride with 9·5 grams of N-N′-di-*p*-tolylbenzidine in 38 c.c. of *o*-dichlorobenzene gives a 64 per cent. yield of the required compound. It may also be obtained by the reduction of 2 : 2′-bis(8-methylphenarsazinic acid) in hot alcoholic hydrochloric acid containing a trace of iodine by means of sulphur dioxide. The resulting product forms small, orange-red crystals, which may be dried at 140° C.

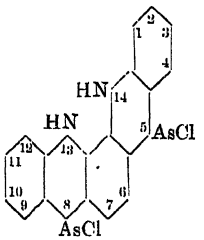
2 : 2′-Bis(10-bromo-8-methyl-5 : 10-dihydrophenarsazine) may be obtained from 2 : 2′-bis(8-methylphenarsazinic acid), as described for the preceding chloro-compound, the hydrochloric acid being replaced by hydrobromic acid. It is a red, microcrystalline substance. In a similar manner, by using approximately 30 per cent. hydriodic acid, 2 : 2′-*bis*(10-*iodo*-8-*methyl*-5 : 10-*dihydrophenarsazine*) is isolated as a purplish-red solid, unmelted at 320° C.

2 : 2′-Bis(8-methylphenarsazinic acid),



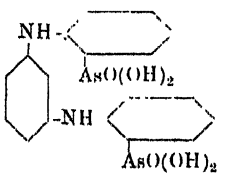
2 : 2′-Bis(10-chloro-8-methyl-5 : 10-dihydrophenarsazine) 9·5 grams, when suspended in 150 c.c. of acetic acid and oxidised by 32 c.c. of 20 vol. hydrogen peroxide, gives a 64 per cent. yield of the required acid. It is a white, amorphous powder; the *disodium salt* forms short, colourless needles.

5 : 8-Dichloro-13 : 14 : 5 : 8-tetrahydroisobenzarsazinephenarsazine,



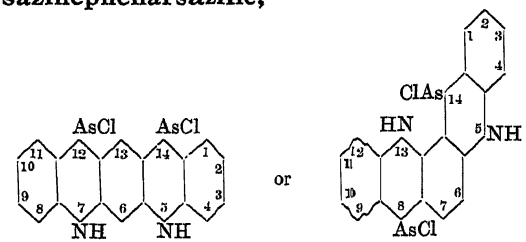
To obtain this substance, *o*-phenylenediamine (5·3 grams), 27·4 grams of *o*-bromophenylarsinic acid and 21·4 grams of potassium carbonate are boiled in 100 c.c. of amyl alcohol containing a trace of copper powder, until condensation is complete (about five hours). Reduction of the crude product by sulphur dioxide in alcoholic hydrochloric acid containing a trace of iodine yields a non-crystalline product. This is suspended in acetic acid and oxidised by hydrogen peroxide, when a compound having the above structure is said to result. It is dark brown, insoluble in ordinary solvents, and unmelted at 320° C.

1 : 3-Phenylenediaminodi-o-phenylarsinic acid,



This compound results from the condensation of *m*-phenylenediamine and *o*-bromophenylarsinic acid, the quantities of materials used being the same as described for the preceding compound. The resulting product is worked up as described under 4 : 4-bis(diphenylamine-2′-arsinic acid), a 22 per cent. yield being obtained. Crystallisation from dilute acetic acid and drying at 160° C. gives a colourless solid, insoluble in water, sparingly soluble in glacial acetic acid and dilute mineral acids, readily soluble in alcoholic hydrochloric acid. The latter solubility distinguishes it from the corresponding ring acid.

12 : 14(or 8 : 14)-Dichloro-5 : 7 : 12 : 14(or 5 : 13 : 8 : 14)-tetrahydrobenzarsazinephenarsazine,



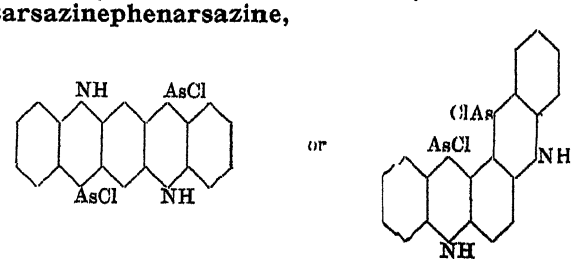
Reduction of the preceding acid by the general method gives a 69 per cent. yield of chloro-compound in the form of slender, yellow prisms. Interaction of arsenious chloride and N-N'-diphenyl-*m*-phenylenediamine in *o*-dichlorobenzene solution yields stout, red prisms. These two products do not appear to be identical; that formed by reduction has a more penetrating effect on the mucous membrane; both are unmelted at 320° C. The diarsinic acid obtained from each on oxidation gives a chloro-compound on reduction, the two derivatives again showing some difference in physical properties.

12 : 14(or 8 : 14)-Dibromo-5 : 7 : 12 : 14(or 5 : 13 : 8 : 14)-tetrahydrobenzarsazinephenarsazine is prepared by reducing 5 : 7 : 12 : 14 (or 5 : 13 : 8 : 14)-benzarsazinicphenarsazinic acid by the general method. It forms deep yellow prisms, which are unmelted at 325° C.

12 : 14(or 8 : 14)-Di-iodo-5 : 7 : 12 : 14(or 5 : 13 : 8 : 14)-tetrahydrobenzarsazinephenarsazine.—Two methods are available for isolating this derivative: (1) Reduction of the corresponding acid by sulphur dioxide in alcoholic hydriodic acid in the presence of a trace of iodine. (2) The acid (0·8 gram) is boiled with 20 c.c. of acetic acid, 10 c.c. of hypophosphorous acid (density 1·136) added to the hot suspension, after which 3·3 grams of iodine are added in small portions to the boiling mixture. The whole is then treated with 30 c.c. of acetic acid, cooled and filtered. The di-iodide is obtained as a deep red, microcrystalline powder, which is washed in turn with acetic acid, alcohol, and ether, and dried at 140° C.

5 : 7 : 12 : 14(or 5 : 13 : 8 : 14)-Benzarsazinicphenarsazinic acid results when 12 : 14(or 8 : 14)-dichloro-5 : 7 : 12 : 14(or 5 : 13 : 8 : 14)-tetrahydrobenzarsazinephenarsazine in glacial acetic acid suspension is oxidised by hydrogen peroxide in a similar manner as described for 2 : 2'-bis(phenarsazinic acid). The free acid is a white, amorphous powder, purified by means of its *disodium salt*, which crystallises in colourless, soft needles. *Calcium*, *barium*, *silver*, *mercury*, *lead*, and *iron salts* are also known.

7 : 14(or 13 : 14)-Dichloro-5 : 12 : 7 : 14(or 5 : 8 : 13 : 14)-tetrahydrobenzarsazinephenarsazine,



The condensation product obtained from arsenious chloride and N-N'-diphenyl-*p*-phenylenediamine in boiling *o*-dichlorobenzene solution is oxidised to the arsinic acid, and this is reduced by the usual means, when the chloro-compound is isolated in orange-red, doubly refracting, prismatic needles, unmelted at 320° C.

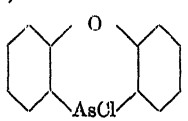
7 : 14(or 13 : 14)-Dibromo-5 : 12 : 7 : 14(or 5 : 8 : 13 : 14)-tetrahydrobenzarsazinephenarsazine is obtained from 5 : 12 : 7 : 14(or 5 : 8 : 13 : 14)-benzarsazinicphenarsazinic acid in the usual manner. It forms deep red, doubly refracting, prismatic needles, unmelted at 320° C., insoluble in the usual solvents.

5 : 12 : 7 : 14(or 5 : 8 : 13 : 14)-Benzarsazinicphenarsazinic acid is obtained when the preceding dichloro-compound is oxidised in acetic acid suspension by hydrogen peroxide. It is isolated by means of its *disodium salt*, which crystallises in colourless, flat plates and needles. The free acid crystallises from dilute acetic acid in colourless, rhomb-shaped plates, unmelted at 320° C., sparingly soluble in hot glacial acetic acid and insoluble in water.

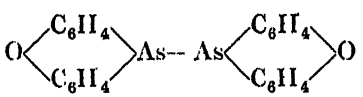
The Phenoxarsines.

The first synthesis of a chlorophenoxarsine was effected by the condensation of arsenic trichloride with diphenyl ether, but more recent investigation has shown that the type of compound under consideration is more readily produced from *o*-phenoxyphenyldichloroarsine and its substitution products.

5-Chlorophenoxarsine,

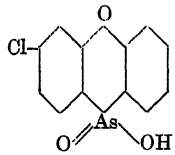


may be prepared by the condensation of arsenic trichloride and diphenyl ether in the presence of aluminium chloride,[1] or by heating *o*-phenoxyphenyldichloroarsine at 10 mm. pressure.[2] It crystallises in colourless prisms, M.pt. 122° C. Its methyl alcohol solution on pouring into potassium bromide, iodide or thiocyanate solution yields, respectively, *5-bromophenoxarsine*, M.pt. 128° C., *5-iodophenoxarsine*, M.pt. 144° C., and *5-thiocyanophenoxarsine*, M.pt. 129° C.[3] Alkalis or sodium methoxide precipitate *5-phenoxarsine oxide*, M.pt. 182° C., from alcohol solutions of the 5-chloro-compound, whilst hydrogen sulphide converts the latter into *5-phenoxarsine sulphide*. Oxidation of 5-chlorophenoxarsine in aqueous suspension by bromine or hydrogen peroxide in glacial acetic acid gives *phenoxarsinic acid*, M.pt. 219° C., whilst reduction by phosphorous acid in boiling alcohol yields *phenoxycacodyl*(*5 : 5-bisphenoxarsine*), M.pt. 159° C.:



[1] Lewis, Lowry, and Bergeim, *J. Amer. Chem. Soc.*, 1921, 43, 890.
[2] Turner and Sheppard, *Trans. Chem. Soc.*, 1925, 127, 544.
[3] Lewis, Lowry, and Bergeim, *loc. cit.*

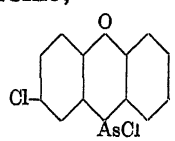
8-Chlorophenoxarsinic acid,[1]



Two grams of 2-*m*-chlorophenoxyphenylarsinic acid and 100 c.c. of concentrated sulphuric acid are heated at 100° C. for fifteen minutes, the solution poured into water, and the precipitate filtered off. The product is purified by conversion into the *sodium salt*, which forms colourless leaflets, and treating a solution of the salt with acid. The acid crystallises in prisms from alcohol, M.pt. 250° to 252° C.

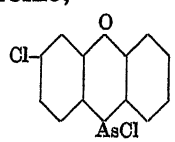
7-Chlorophenoxarsinic acid crystallises from alcohol in colourless plates or prisms, M.pt. 240° to 242° C.

5 : 7-Dichlorophenoxarsine,



results when the preceding acid is reduced in the presence of hydrochloric acid. It crystallises in almost colourless rhombs, M.pt. 144° to 145° C. It may also be obtained by boiling the corresponding chlorophenoxyphenyldichloroarsine under diminished pressure for six hours.

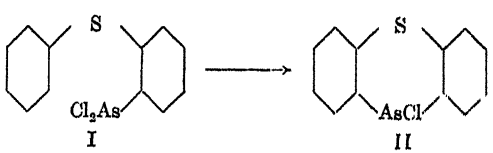
5 : 8-Dichlorophenoxarsine,



may be prepared by either of the methods just described or by the following synthesis: 2 : 4-Dichloronitrobenzene is condensed with phenol in sodium hydroxide solution, giving 5-chloro-2-nitrodiphenyl ether, which is reduced to the corresponding amino-compound. The latter is then converted into 4-chloro-2-phenoxyphenylarsinic acid, which yields the dichloroarsine, the latter giving the *phenoxarsine* when heated at 200° C. in a current of pure carbon dioxide. It melts at 125° C., and may be crystallised from light petroleum.

5 : 9-Dichlorophenoxarsine, from 2-*o*-chlorophenoxyphenyldichloroarsine, crystallises in pale yellow needles, M.pt. 99° C.

10-Chlorophenthiarsine,[2]

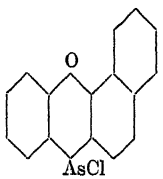


I II

[1] Roberts and Turner, *Trans. Chem. Soc.*, 1925, 127, 2010.
[2] Roberts and Turner, *J. Chem. Soc.*, 1926, p. 1207.

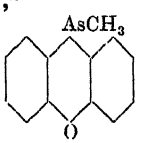
This derivative (II) is obtained from *o*-phenylthiolphenyldichloroarsine (I) by heating at 200° C. in pure carbon dioxide for twenty-four hours. It crystallises from light petroleum in sulphur-yellow, rhombohedral masses, which appear to consist of rectangular plates, M.pt. 129° to 130° C.

7-Chloro-α-β-naphthaphenoxarsine,[1]



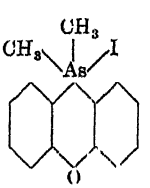
results when arsenious chloride, phenyl α-naphthyl ether and aluminium chloride are heated together from 180° to 250° C. The product is distilled *in vacuo* and the portion distilling at 240° C. at 20 mm. recrystallised from benzene.

10-Methylphenoxarsine,[2]



This compound and compounds of a similar type are obtained by treating the corresponding chlorophenoxarsine with the appropriate Grignard reagent. It is a colourless oil, B.pt. 185° C. at 20 mm., or 198° to 200° C. at 40 mm. When dissolved in an excess of hydrogen peroxide solution, the water evaporated off and the residue recrystallised from benzene, 10-*methylphenoxarsine dihydroxide*, M.pt. 94° C., is obtained.

10 : 10-Dimethylphenoxarsonium iodide,



crystallises in white needles, M.pt. 225° C. on slow heating, or 220° C. on rapid heating.

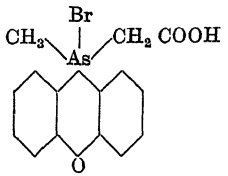
10-Methyl-10-ethylphenoxarsonium iodide is less readily formed from the 10-methyl- than from the 10-ethylphenoxarsine and the requisite alkyl iodide. It crystallises from hot alcohol in compact white crystals, M.pt. 186° or 193° C. according to the rate of heating. When the 10-ethyl compound is used as the starting material, an orange-red compound, probably an isomeride, is also obtained.

10-*Methyl*-10-*ethylphenoxarsonium d-bromocamphorsulphonate* is obtained from the iodide and silver *d*-bromocamphorsulphonate in alcohol.

[1] Aeschlimann, *Trans. Chem. Soc.*, 1925, 127, 814.
[2] Aeschlimann, *J. Chem. Soc.*, 1927, p. 414.

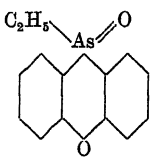
The salt has the following constants: $[M]_{5461}+339°$ in 1·5 per cent. aqueous solution, and $+398°$ in 5 per cent. alcoholic solution.

10-Methyl-10-carboxymethylphenoxarsonium bromide,



derived from the interaction of 10-methylphenoxarsine and bromoacetic acid, is a crystalline compound, moderately soluble in alcohol.

10-Ethylphenoxarsine [1] is a colourless liquid, B.pt. 194° C. at 20 mm. The corresponding *oxide,*



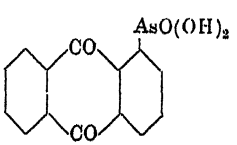
may be isolated by evaporation of a hydrogen peroxide solution of the arsine; it contains a molecule of water and melts at 99° C. The action of hydrogen sulphide on the oxide or excess of sulphur on the phenoxarsine in carbon disulphide gives 10-*ethylphenoxarsine sulphide.* This crystallises from alcohol in long needles, M.pt. 109° C. Sulphonation of the oxide yields *sulpho*-10-*ethylphenoxarsenoxide,* which changes its appearance at 250° C. but does not melt below 300° C.

10 : 10-Diethylphenoxarsonium iodide crystallises in pale straw-coloured needles, M.pt. 193° C., and 10-*carboxymethyl*-10-*ethylphenoxarsonium bromide* is prepared similarly to the corresponding methyl compound.

10-Phenylphenoxarsine crystallises from alcohol in colourless needles, M.pt. 107° C.; the corresponding *oxide* melts at 93° C., contains 1·5 molecules of water, and is deliquescent. The corresponding *arsonium iodide* melts at 175° C.

Arsenic Derivatives of Anthraquinone.

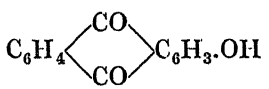
Anthraquinone-1-arsinic acid, [2]



22·3 grams of α-aminoanthraquinone are dissolved in 80 c.c. of sulphuric acid (66° Bé.) and diazotised at the ordinary temperature with a mixture

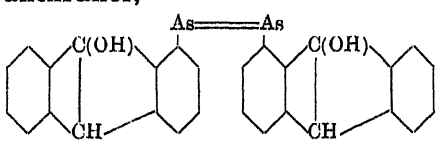
[1] Aeschlimann, *Trans. Chem. Soc.*, 1925, 127, 813.
[2] Benda, *J. prakt. Chem.*, 1917, [ii.] 95, 74.

of 70 grams of nitrose (containing 47 per cent. of nitrosyl sulphuric acid) and 60 c.c. of sulphuric acid of the foregoing strength. The whole is stirred with 600 grams of ice and filtered after half an hour. The reddish precipitate is mixed with 250 c.c. of water and treated with a solution of 25 grams of sodium arsenite in 250 c.c. of water and 250 c.c. of 2*N* sodium carbonate solution, the mixture being stirred for three to four hours, much gas evolution taking place. The *sodium salt* of the arsinic acid separates in glistening, silver-grey scales, which, after standing overnight, are boiled with 500 c.c. of water containing charcoal, filtered, and the filtrate treated with hydrochloric acid. The arsinic acid separates in pale yellow crystals, which are filtered off, washed, and dried. Yield, 8 grams. From the mother-liquors from the sodium salt a further 7 grams of acid may be obtained on acidifying. The crude product is purified by crystallisation from 80 parts of 75 per cent. acetic acid. The arsinic acid crystallises in colourless needles, sparingly soluble in hot water and insoluble in alcohols. It readily dissolves in 2*N* sodium acetate or normal sodium hydroxide solution, the sodium salt being precipitated by the addition of alcohol. The solution in concentrated sulphuric acid is yellow. Solutions of the acid give precipitates with barium hydroxide, magnesia mixture, ammonium hydroxide, and calcium chloride. When the sodium hydroxide solution of the acid is treated with 4 per cent. sodium amalgam, pure anthraquinone is obtained, the arsenic residue being eliminated; the arsinic group is also removed when the acid is heated to its decomposition point, erythrohydroxyanthraquinone being formed,



Thionyl chloride converts anthraquinone-1-arsinic acid into 1-chloroanthraquinone. *Anthraquinone-1-dichloroarsine*, M.pt. 237° C., is obtained only by reduction of the acid in the usual manner.[1]

1 : 1′-Arsenoanthranol,[2]

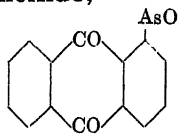


Two grams of the foregoing acid in 10 c.c. of normal sodium hydroxide and 80 c.c. of water are treated at the ordinary temperature with 40 grams of sodium hydrosulphite in 150 c.c. of water. The mixture is slowly warmed to 50° C. and maintained at that temperature for one hour, a dark brown precipitate separating out. The whole is then heated for two and a half hours at 60° C., filtered, washed with water, and dried.

The arseno-compound is very soluble in alcohol and ether, giving yellow solutions, and in normal sodium hydroxide, giving a bluish-red solution. It may readily be oxidised back to the acid by atmospheric oxygen.

[1] Steinkopf and Schmidt, *Ber.*, 1928, 61, [B], 675.
[2] Benda, *loc. cit.*

Anthraquinone-1-arsenoxide,

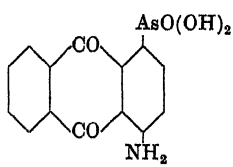


The same quantity of materials are mixed together as in the preceding preparation. The temperature is slowly raised to 60° C., and after thirty minutes to 65° C., being maintained at this point for four hours. The mixture is then filtered, the solid washed with water and ground in a mortar with 100 c.c. of 2*N* sodium carbonate solution, then heated, with stirring, until the chocolate colour changes to greenish-yellow. The solid is filtered off, washed with water until the washings give a neutral reaction, then dried. Yield, 1·1 grams, or 62 per cent.

The oxide is a dirty yellow powder, very sparingly soluble in the usual solvents. Concentrated sulphuric acid gives a yellow solution, from which ice-water precipitates yellow flocks. When the oxide is suspended in normal sodium hydroxide solution and heated with hydrogen peroxide, a colourless solution results, from which hydrochloric acid precipitates the arsinic acid.

Anthraquinone-2-arsinic acid is prepared in a similar manner to the 1-arsinic acid, a yield of 23 per cent. resulting. From boiling acetic acid it crystallises in needles, which remain unchanged at 270° C. It has similar solubility and reactions to the 1-compound, but yields very little anthraquinone when treated with sodium amalgam, showing that the arsenic residue is more firmly bound in this case.

4-Aminoanthraquinone-1-arsinic acid,



This compound, which is the arsanilic acid of the anthraquinone series, is obtained by the diazotisation of 1 : 4-diaminoanthraquinone. Its *sodium salt* crystallises in brick-red needles containing 4 molecules of water of crystallisation. The free acid is isolated by dissolving the sodium salt in a large bulk of hot water and adding hydrochloric acid, the red precipitate being recrystallised from a large quantity of acetic acid.

The arsinic acid is a vermilion, crystalline powder, decomposing at 278° C., sparingly soluble in boiling water and insoluble in alcohols. When boiled with 5*N* hydrochloric acid, reddish-grey crystals of the *hydrochloride* are deposited. On diazotisation a red dye is given with R-salt and a yellowish-orange dye with resorcinol. Magnesia mixture and barium hydroxide give red precipitates when added to solutions of the acid. Alkali hydroxide and carbonate solutions of the acid are orange in colour.

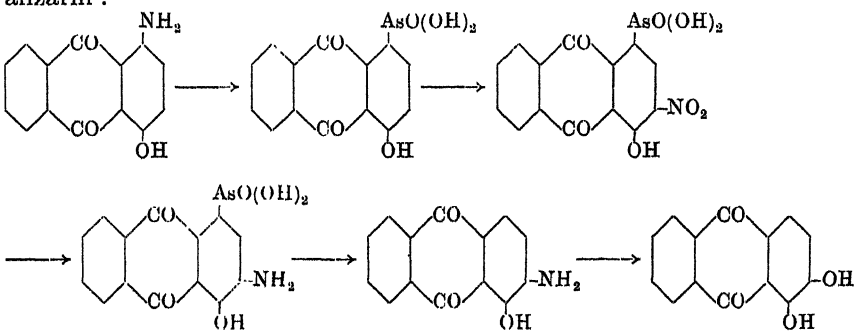
4-Hydroxyanthraquinone-1-arsinic acid.—The starting-point for the preparation of this compound is 1 : 4-diaminoanthraquinone, but whereas the diazotisation in the preceding case is carried out in dilute

sulphuric acid, it is now performed in concentrated sulphuric acid, using an excess of nitrosylsulphuric acid. The *sodium salt* is first isolated as yellow needles and the free acid liberated by hydrochloric acid. The yield is about 70 per cent.

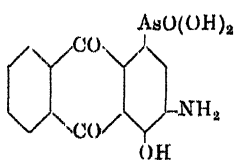
The arsinic acid crystallises from acetic acid in pure yellow, matted needles, decomposing at about 200° C., somewhat soluble in water and boiling alcohols. In sodium hydroxide it gives a bluish-red solution; in hot sodium acetate, an orange-yellow solution; in concentrated sulphuric acid, an intensely yellow solution.

3-Nitro-4-hydroxyanthraquinone-1-arsinic acid.—14 grams of the preceding acid in 80 c.c. of sulphuric acid (monohydrate) are cooled to 0° C., and, maintaining the temperature between 0° and 5° C., 7 c.c. of mixed acid (100 c.c.=77·3 grams HNO_3) are added dropwise. After twenty minutes the temperature is raised to 10° C., and after a further fifteen minutes to 20° C., and the mixture is stirred for one hour at this temperature. The whole is then poured upon 400 grams of ice, the yellow precipitate filtered off, washed, and dried. Yield, 14 grams, or 89 per cent.

The acid crystallises from boiling acetic acid in yellow needles, which decompose indefinitely about 230° C. It is insoluble in water, but in alkali or sodium acetate it gives red solutions, and a yellow solution in concentrated sulphuric acid. Its constitution has been proved by the following series of reactions, the final product being alizarin:



3-Amino-4-hydroxyanthraquinone-1-arsinic acid,

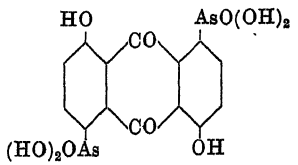


12 grams of the nitro-compound are dissolved in 90 c.c. of sodium hydroxide solution and 250 c.c. of water. The temperature is raised to 65° C. and 150 grams of 4 per cent. sodium amalgam stirred in, the temperature rising to 78° C. After forty-five minutes' stirring the liquor is poured off from the mercury and hydrochloric acid added, a violet-brown precipitate being deposited. This is filtered off, washed, and dried. Yield, 9·9 grams, or 90 per cent. The crude product is purified by solution in 2*N* sodium carbonate solution, precipitation by

hydrochloric acid, followed by crystallisation from sodium acetate solution. This yields the *sodium salt*, from which the free acid is isolated in the usual way.

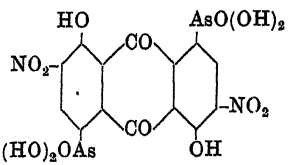
The acid forms glistening violet crystals, melting indefinitely about 265° C., giving violet solutions in ammonium hydroxide or 2*N* sodium carbonate, a reddish-violet solution in normal sodium hydroxide, a red solution in 2*N* sodium acetate, and a brownish-yellow solution in concentrated sulphuric acid. Magnesia mixture and ammonium hydroxide yield reddish-violet precipitates with the acid. When the acid is diazotised and coupled with R-salt, it gives a violet dye. Reduction with sodium hydrosulphite forms an orange-coloured vat, which imparts a violet stain to filter-paper.

4 : 8-Dihydroxyanthraquinone-1 : 5-diarsinic acid or **Anthrarufindiarsinic acid,**



Anthrarufindiarsinic acid is obtained from 1 : 5-diaminoanthrarufin. It is a yellow to brownish-yellow, microcrystalline powder, commencing to decompose and becoming violet at about 270° C. It is only very slightly soluble in hot water, insoluble in alcohol, acetic acid, or normal hydrochloric acid. It is soluble in 10*N* hydrochloric acid, giving a yellow solution, and is brownish-yellow in concentrated sulphuric acid. Its alkali solutions are orange-yellow.

4 : 8 - Dihydroxy - 3 : 7 - dinitroanthraquinone-1 : 5 - diarsinic acid,



The preceding acid, when nitrated by mixed acid at about 80° C., using 4 molecular equivalents of nitric acid to 1 molecular equivalent of arsinic acid, gives an 85 per cent. yield of the dinitro-compound. It is a dirty, greenish-yellow, microcrystalline powder, sparingly soluble in water, giving a red solution, which becomes bluish on boiling. This blue colour changes to red on addition of ammonium chloride, then slowly becoming yellow, with the separation of crystals. Concentrated sulphuric acid gives an intense citron-yellow solution, and 2*N* sodium acetate a bluish-red solution, the *disodium salt* separating out on cooling as violet flocks.

4 : 8 - Dihydroxy - 3 : 7 - diaminoanthraquinone - 1 : 5 - diarsinic acid results when the dinitro-compound is reduced by 4 per cent. sodium amalgam. It is a dark brown to violet-black powder, having a metallic reflex, insoluble in the usual solvents. In sulphuric acid it gives an intensely yellow solution, dilution with water first giving a green coloration, which changes to blue, and finally reddish-violet flocks separate. When diazotised and coupled with resorcinol it forms

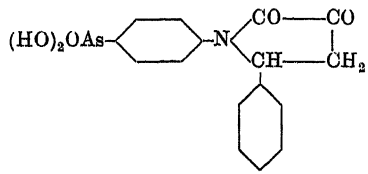
a green dye. Alkaline hydrosulphite gives an orange-coloured vat, which becomes reddish-violet in the air.

Derivatives of Diketophenylpyrollidine.[1]

This type of compound is produced by boiling pyruvic acid, $CH_3.CO.CO.OH$, with an alcoholic solution of aminoarylarsinic acid and an aromatic aldehyde. Aminoarylarsinic acids having a substituent in the *ortho*-position to the amino-group, however, form benzylidene derivatives which do not react with pyruvic acid, and the reaction is not applicable to the simple aliphatic aldehydes.

The general method of preparation for compounds of this type is as follows: One molecular equivalent of aminoarylarsinic acid in ten to twelve times its weight of absolute alcohol, together with one molecular equivalent of aldehyde, is boiled under reflux until complete solution takes place. A molecular equivalent of pyruvic acid is then added, the mixture boiled for three to four hours, filtered hot and cooled. The product does not always separate immediately, in which case the solution is evaporated to half-bulk *in vacuo*. The crystals are purified by crystallisation from alcohol, the yields varying from 50 to 70 per cent.

4 : 5-Diketo-2-phenylpyrollidine-1-p-phenylarsinic acid,

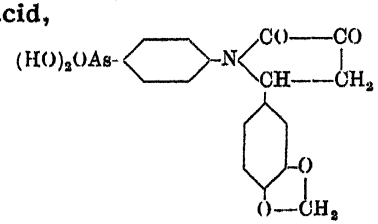


This is formed from benzaldehyde, *p*-arsanilic acid and pyruvic acid. It melts at 186° to 187° C., with decomposition. The same product is isolated when ethyl pyruvate is substituted for pyruvic acid.

4 : 5-Diketo-2-o-anisylpyrollidine-1-p-phenylarsinic acid is isolated when the benzaldehyde in the foregoing is replaced by *o*-methoxybenzaldehyde. It is a pale yellow powder, melting at 173° to 176° C., with decomposition.

4 : 5-Diketo-2-p-anisylpyrollidine-1-p-phenylarsinic acid occurs in almost white crystals, M.pt. 164° to 165° C.

4 : 5-Diketo-2-m-p-methylenedioxyphenylpyrollidine-1-phenylarsinic acid,



obtained from arsanilic acid, piperonal and pyruvic acid, is a pale yellow powder, M.pt. 176° to 178° C., with decomposition.

[1] Johnson and Adams, *J. Amer. Chem. Soc.*, 1923, 45, 1307; *ibid.*, 1921, 43, 2255; American Patent, 1501894.

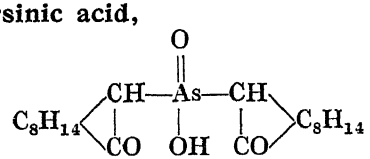
4 : 5 - Diketo - 2 - p - chlorophenylpyrollidine - 1 - p - phenyl - arsinic acid, formed when *p*-chlorobenzaldehyde is used in the general method, is a white powder, M.pt. 163° to 165° C., with decomposition.

4 : 5-Diketo-2-phenylpyrollidine-1-m-tolyl-6-arsinic acid is prepared by substituting 6-amino-*o*-tolylarsinic acid for *p*-arsanilic acid in the preparation of the first compound of this type described. It is a cream-coloured powder, M.pt. 180° to 186° C., with decomposition.

4 : 5 - Diketo - 2 - phenylpyrollidine - 1 - m - anisyl - 4 - arsinic acid is a yellow powder, M.pt. 175° to 176° C., the acid used in its preparation being *p*-amino-*o*-anisylarsinic acid.

Arsenical Camphor Derivatives.[1]

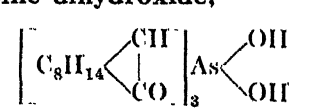
Dicamphorylarsinic acid,



Camphor (75 grams), in 200 c.c. of warm toluene, is treated with 7·5 grams of sodium. The precipitated sodium-camphor, suspended in 200 c.c. of fresh toluene, is treated with 38 grams of arsenious chloride, added in small portions at a time. Heat is developed, the mass sets to a jelly, and becomes deep crimson in colour. The colour gradually disappears, the mass regains its fluidity, and a yellow, mobile solution is obtained, a precipitate of sodium chloride separating out. After an hour the mass is heated on the water-bath, poured into water, and extracted with hot aqueous sodium hydroxide. The extract, on acidification, yields a brownish-white precipitate of dicamphorylarsinic acid. Crystallisation from benzene gives colourless crystals, and further purification gives highly refractive, obliquely truncated prisms, melting with decomposition at 266° C., $[\alpha]_D$+186·6° at 20° C. The yield is about 10 per cent. on the weight of camphor used. The acid readily dissolves in chloroform or alcohol, less readily in benzene, and is practically insoluble in water or petroleum. It gives salts with ammonium hydroxide and alkali hydroxides, which are extremely soluble in water or alcohol. The *barium*, *calcium*, *strontium*, *nickel* and *cobalt salts* do not separate from aqueous solution, whilst the *cupric*, *mercuric* and *ferric salts* are almost insoluble in water. The *silver* and *cadmium salts* are white, crystalline compounds. The free acid is liberated from aqueous solutions of its salts by acidification with acetic acid.

Dicamphorylarsinic oxychloride, $(C_{10}H_{15}O)_2AsO.Cl$, results when potassium dicamphorylarsinate reacts with phosphorus pentachloride. It crystallises from chloroform and benzene in colourless crystals, M.pt. 158° C. It rapidly decomposes in air, and its specific rotation in dry chloroform has the value $[\alpha]_D$+106°.

Tricamphorylarsine dihydroxide,

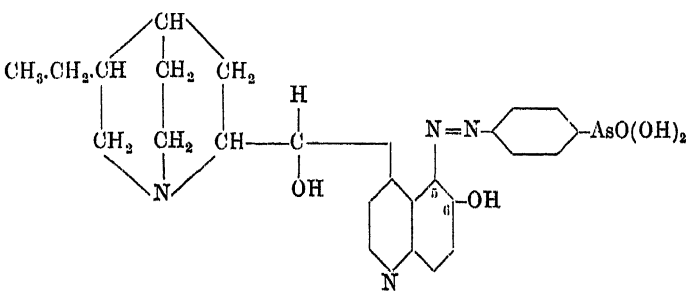


[1] Morgan and Micklethwait, *Trans. Chem. Soc.*, 1908, 93, 2146; 1909, 95, 1476.

The condensation between sodium-camphor and arsenious chloride is conducted as described before and the product repeatedly extracted with aqueous sodium hydroxide. The extract is acidified, and the precipitate extracted with small quantities of benzene until a residue results consisting of dicamphorylarsinic acid. The final brown mother-liquors are taken to dryness, the residue taken up in dilute aqueous sodium hydroxide, the solution boiled with charcoal and concentrated until crystals appear. These consist of sodium dicamphorylarsinate. After filtration and acidification, the sticky precipitate is again treated with alkali and benzene. After again acidifying, the precipitate is a brown solid, which cannot be crystallised. It softens at 110° C. and melts indefinitely at 130° C. This acid is soluble in dilute alcohol, very soluble in benzene, alcohol, or acetic acid. The *silver salt* is a greyish-white precipitate.

Arsenic Derivative of Cupreine.[1]

Dihydrocupreine-5-azobenzene-p-arsinic acid,

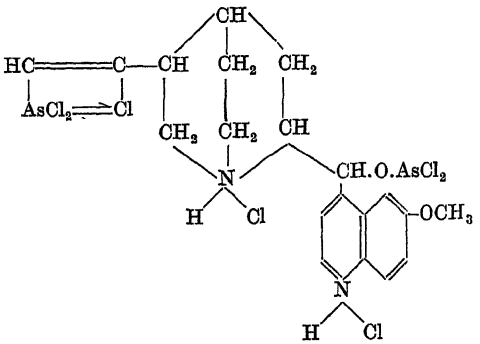


Arsanilic acid (2·08 grams), in 24 c.c. of normal hydrochloric acid, is diazotised and cooled to −10° C., then 3·0 grams of dihydrocupreine and 5 grams of sodium acetate in 24 c.c. of normal sodium hydroxide are added dropwise, the mixture being mechanically stirred. The product is allowed to stand for two hours at −5° C., then filtered off and washed with ice-water. About 3·0 grams of a vermilion, crystalline compound are obtained. It is soluble in acid and alkali, and after crystallisation from hot alcohol it decomposes at 218° C. after previously darkening. The free acid is isolated from the sodium salt by adding very dilute hydrochloric acid until a precipitate commences to separate, when alcohol is added and the crystalline acid comes down. It darkens at 170° C., and melts indefinitely at 215° C. Like the sodium salt it absorbs oxygen on desiccation. The *hydrochloride* crystallises in orange-red needles containing two molecules of water. It does not absorb atmospheric oxygen, and when anhydrous is very deliquescent.

[1] Erben and Schniderschitsch, *Ber.*, 1925, 58, [B], 693.

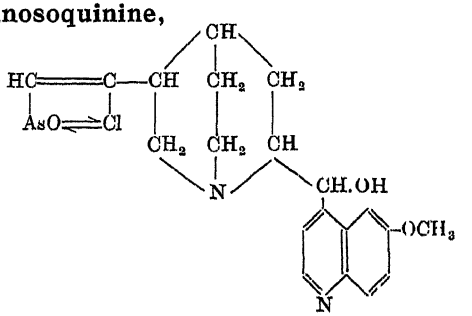
Arsenated Quinines.[1]

Action of Arsenic Trichloride on Dehydroquinine:



The product to which the above formula has been ascribed is formed when 3 grams of dehydroquinine in 20 c.c. of chloroform are heated with 5 c.c. of arsenic trichloride in a little chloroform in a sealed tube at 150° C. for five hours. The crude product is washed with chloroform, warmed at 70° to 80° C. *in vacuo* to remove any adhering arsenic trichloride, then powdered and digested with chloroform, filtered, and dried. Yield, 6 to 6·5 grams, or 80 to 95 per cent. It is a glistening, brownish-green powder, very susceptible to moisture, decomposing in moist air with evolution of hydrogen chloride. Six of the seven chlorine atoms are removed by silver nitrate in the cold, the seventh remaining attached to the molecule.

Chloroarsinosoquinine,



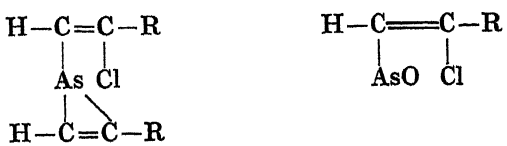
This product is best obtained by heating dehydroquinine with about five times its weight of arsenic trichloride in an oil-bath at 130° to 135° C. for three hours, in the absence of a solvent. It may also be prepared by digesting the previous compound with aqueous ammonium carbonate. It darkens at 199° to 200° C., sinters at about 204° C., and melts at 207° to 209° C.; it is easily soluble in alcohols and pyridine, very sparingly soluble in chloroform and acetone, and insoluble in ether, ethyl acetate, aromatic hydrocarbons, and carbon disulphide. Its salts are not crystalline. The fact that it forms a benzoyl derivative shows the presence of a free hydroxyl group, and consequently the attachment of the arsenic to the vinyl group.

[1] Erben, Philippi, and Schniderschitz, *Ber.*, 1925, 58, [B], 2854; Erben and Philippi, *ibid.*, 1927, 60, [B], 122.

When quinine is heated with arsenic trichloride in chloroform solution, as described before, it yields a dark green product, $C_{20}H_{25}O_2N_2Cl_4As$. Three grams of quinine give 3·4 grams of this substance, an 80 per cent. yield. It is not so hygroscopic as the dehydroquinine derivative. Ammonium carbonate solution converts it into the *arsenious ester*, $C_{20}H_{23}O_3N_2As$, a pale grey powder.

In a similar manner, *dihydroquinine* yields a *derivative*, $C_{20}H_{27}O_2N_2Cl_4As$, and an *arsenious ester*, $C_{20}H_{25}O_3N_2As$. These arsenious esters contain the arsenic atom united to the secondary hydroxyl group, $-CH.O.As=O$.

Chloroarsinosodiquinine, $(C_{20}H_{22}O_2N_2)_2AsCl$.[1]—Dehydroquinine (3·5 grams) is dissolved in 20 grams of arsenic trichloride by gentle warming, and preserved in a well-stoppered bottle in the dark at room temperature for six months. A thin, brownish syrup results, most of which dissolves in a large volume of warm water. The addition of ammonium hydroxide precipitates a white solid. This is washed with much water, dissolved in very dilute hydrochloric or sulphuric acid and reprecipitated, the operation being carried out several times. The product is dried and extracted with chloroform to remove unchanged dehydroquinine. The compound is soluble in methyl and ethyl alcohols, pyridine and aniline, sparingly soluble in acetone and chloroform, insoluble in ethyl acetate, ether, and benzene hydrocarbons. It may be separated from chloroarsinosoquinine by means of its solubility in warm nitrobenzene or carbon disulphide. The constitution of the two compounds may be represented as follows :



Chloroarsinosodiquinine sulphite is obtained by treating chloroarsinosoquinine sulphate with sodium sulphite.

Arsenic Compounds containing other Metals.

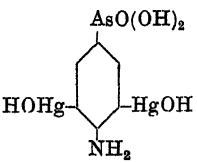
The mercury-arsenic compounds belonging to this section are the result of direct mercuration of arsenical derivatives. Compounds derived from arsenic derivatives and antimony and bismuth, which contain the arseno-grouping, are prepared by the general methods given on p. 386 for producing arseno-compounds. The colours of the chromophoric groupings involved, compared with similar groupings, are as follows: R.N=N.R′, red azo chromophore; R.P=P.R′, light yellow phospho chromophore; R.As=As.R′, yellow arseno chromophore; R.As=Sb.R′, orange to yellowish-brown arseno-stibino chromophore; R.Sb = Sb.R′, yellow stibino chromophore; R.As = Bi.R′, black arseno-bismuth chromophore. The azo group is a powerful chromophore; arseno and phospho groups are weak chromophores, the phospho group being the weakest of the series. Arseno-stibino compounds are not very stable; hot water does not change them, but they are readily oxidised in alkaline solution by oxidising agents. Arseno-

[1] Erben, *Ber.*, 1928, 61, [B], 2016.

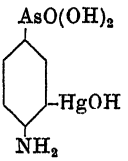
compounds containing an amino group are sparingly soluble, but mixed compounds readily dissolve in alkali, especially if they contain an hydroxyl group. Arseno-bismuth compounds are still less stable, the double bond being readily ruptured. They are decomposed by hot water, and in air they become completely white.

Mercury-Arsenic Derivatives.

3 : 5 - Dihydroxymercuri - 4 - aminophenylarsinic acid and **3-Hydroxymercuri-4-aminophenylarsinic acid,**[1]



I



II

These compounds, I and II respectively, are obtained by the action of mercuric acetate upon *p*-arsanilic acid, as follows : 329 grams of the acid in 1700 c.c. of water are treated with 636 grams of mercuric acetate in 1800 c.c. of water and the whole heated at 100° C. for five hours. The solid is then filtered off, dissolved in 1200 c.c. of 10 per cent. sodium hydroxide solution, and after filtering, 120 grams of glacial acetic acid added. The mixture of acids is separated by dissolving in a slight excess of aqueous sodium hydroxide and concentrating the liquor, when the *sodium salt* of I first crystallises out with four molecules of water, followed by the *sodium salt* of II, containing fourteen molecules of water of crystallisation. The free acids are liberated from these salts by the aid of acetic acid.[2]

The following derivatives have been obtained by direct mercuration of arsinic acids :[3] *5-Acetoxymercuri-3-nitro-4-aminophenylarsinic acid*, $OAc.Hg.C_6H_2(NO_2)(NH_2).AsO(OH)_2$, *5 - Acetoxymercuri - 3 - nitro - 4 - hydroxyphenylarsinic acid,*[4] *5 : 5′-mercuribis - 3 - nitro - 4 - hydroxyphenylarsinic acid*, *2-acetoxymercuri-3 : 5-dinitro-4-hydroxyphenylarsinic acid*, *3-acetoxymercuri-5-amino-4-hydroxyphenylarsinic acid*, *2-acetoxymercuri-3 : 5-diamino-4-hydroxyphenylarsinic acid*, *2-acetoxymercuri-4-carboxyphenylarsinic acid*, *acetoxymercuri - diacetyl - 3 : 5-diamino - 4 - hydroxyphenylarsinic acid*, *3-acetoxymercuri-5-bromo-4-aminophenylarsinic acid*, *3 - acetoxymercuri-5-bromo-4-oxalylaminophenylarsinic acid.* All the foregoing compounds are soluble in dilute alkali. *3-Acetoxymercuri-4-benzylaminophenylarsinic acid* and *3-acetoxymercuri-4-benzylamino-5-nitrophenylarsinic acid* are yellow, amorphous compounds ;[5] *3-acetoxymercuri-4-hydroxy-5-acetaminophenylarsinic acid* is a brown, amorphous product. *3-Hydroxymercuri-4-hydroxy-5-carboxyphenylarsinic acid* is obtained in the usual manner, and *6 : 6′-mercuribis-1-hydroxy-2-methylphenyl-4-arsinic acid* is prepared by reducing the product from *o*-cresol-arsinic acid and mercuric oxide in neutral or alkaline solution.

[1] British Patent, 12472 (1908).

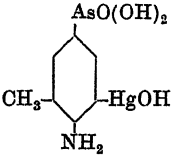
[2] For the estimation of carbon and hydrogen in substances containing arsenic and mercury see Falkov and Raiziss, *J. Amer. Chem. Soc.*, 1923, 45, 998.

[3] Raiziss, Kolmer, and Gavron, *J. Biol. Chem.*, 1919, 40, 533.

[4] Compare Stieglitz, Kharasch, and Hanke, *J. Amer. Chem. Soc.*, 1921, 43, 1185.

[5] Whitmore, *Organic Compounds of Mercury*, p. 357 (Chem. Catalog. Co.).

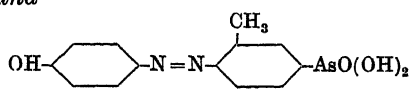
If *methylatoxyl* is treated in a similar manner to *p*-arsanilic acid the following derivative is obtained : [1]



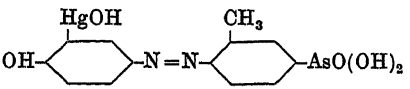
Its *sodium salt* crystallises with 9 molecules of water and is soluble in one part of water.

4-Hydroxyphenylarsinic acid yields 3 : 5-*dihydroxymercuri*-4-*hydroxyphenylarsinic acid*, the *sodium salt* of which contains 5 molecules of water. Similar derivatives are formed from 2-hydroxytolyl-5-arsinic acid.

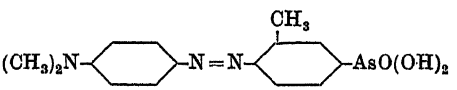
The *azo compound*



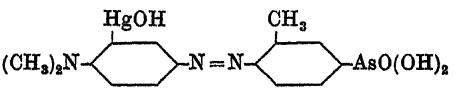
yields



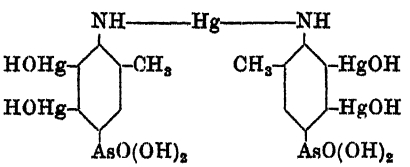
and



yields

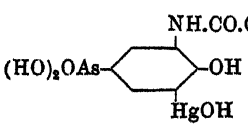


Orsudan and mercuric oxide yield a complex known as *Hydryl*, supposed to have the following constitution : [2]



When the sodium salts of many of the foregoing compounds are treated with iodine in aqueous potassium iodide the mercury is replaced by iodine, and this provides a method of ascertaining the position of the mercury in the nucleus.

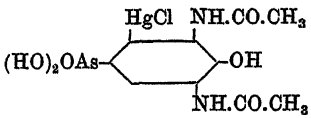
3-Acetylamino-4-hydroxy-5-hydroxymercuriphenylarsinic acid,[3]



[1] British Patent, 12472 (1908).
[2] Compare Morgan, *Organic Compounds of Arsenic and Antimony*, p. 184.
[3] Maschmann, *Ber.*, 1926, 59, [B], 216.

A suspension of 2·75 grams of 3-acetylamino-4-hydroxyphenylarsinic acid in 30 c.c. of ice-cold water is quickly dissolved by the addition of 11 c.c. of 2*N* sodium hydroxide, then treated with an ice-cooled solution of 3·2 grams of mercuric acetate in 2 c.c. of acetic acid and 20 c.c. of water. After keeping in the dark for six to seven days, the yellowish-brown precipitate is washed with water and dried. Any unchanged arsinic acid is removed from the product by shaking with methyl alcohol; the yield is quantitative. The compound is not decomposed below 300° C.; it is soluble in sodium carbonate, caustic alkali, and ammonia solutions. Saponification of the acid cannot be accomplished without decomposition. The position of the mercury has been proved by shaking the compound with iodine in potassium iodide, when *5-iodo-3-acetylamino-4-hydroxyphenylarsinic acid* results.

3 : 5-Diacetylamino-4-hydroxy-2-chloromercuriphenylarsinic acid,



This derivative is obtained in a similar manner to the preceding one, from 3 : 5-diacetylamino-4-hydroxyphenylarsinic acid, the product being purified by solution in alkali and precipitation with dilute hydrochloric acid. In this case, however, the reaction requires thirty days for completion. The mercurated arsinic acid melts at 234° C., and gives clear solutions in aqueous sodium carbonate, caustic alkalis, and ammonia, the latter solution when boiled with ammonium sulphide yielding mercury sulphide. The position of the mercury is ascertained by converting the compound into *2-iodo-3 : 5-diacetylamino-4-hydroxyphenylarsinic acid.*

Phosphorus-Arsenic Derivatives.

Arseno-phosphorus compounds have been obtained by treating *m*-amino-*p*-hydroxyphenylarsinic acid with phosphoryl chloride in the presence of aqueous sodium hydroxide and subsequently reducing the mixture with sodium hydrosulphite. The compounds are soluble in dilute sodium carbonate and in hydrochloric acid, their alkaline solutions reducing Fehling's solution and Nessler's and Tollen's reagents.[1]

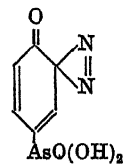
Arsenic-Antimony Derivatives.

p - Phenylenearsinicstibinic acid, $[(C_6H_4.AsO_2.SbO_2.H_2O).4H_2O]_x$.[2]—*p*-Aminophenylarsinic acid (21·7 grams), in 100 c.c. of water and 60 c.c. of 5*N* hydrochloric acid, is diazotised and treated with 34 grams of tartar emetic in 200 c.c. of water, then with 120 c.c. of 5*N* sodium hydroxide, the mixture being well cooled and stirred during the addition. Nitrogen is evolved, and when the reaction is complete, the arsinicstibinic acid is precipitated by the addition of dilute hydrochloric acid. The crude product is removed and, whilst moist, stirred with 200 c.c. of 5*N* hydrochloric acid to remove antimony oxide, then filtered and washed with acid until a test of the filtrate on dilution with

[1] British Patent, 9234 (1915); German Patent, 269700.
[2] Schmidt, *Ber.*, 1924, 57, [B], 1142.

water and treatment with hydrogen sulphide gives only a pale yellow, not an orange-red, precipitate. The product is then dissolved in 200 c.c. of hydrochloric acid (density 1·19), the solution treated with charcoal, filtered, and stirred into an ice-cold mixture of 20 c.c. of pyridine and 75 c.c. of hydrochloric acid (density 1·19). The double salt with pyridine hydrochloride is precipitated; this is filtered off and decomposed by water. The product obtained is dissolved in sodium hydroxide and reprecipitated by dilute hydrochloric acid. It is then filtered off, washed and dried, about 25 grams being obtained as a colourless powder. The compound may also be produced by treating diazotised *p*-aminophenylstibinic acid with arsenite solution. When heated on platinum foil the acid burns feebly, emitting white fumes and giving a cacodyl-like odour. It is insoluble in the usual solvents, but dissolves in alkalis and concentrated hydrochloric acid. With alkali hydroxides it exhibits the phenomenon of gradual neutralisation, the rate of neutralisation depending on the concentration of hydroxyl ions, the temperature, and the particular kation. Treated with ammonium chloride in concentrated hydrochloric acid it forms the compound $[AsO(OH)_2.C_6H_4.Sb(OH)Cl_3]_3[NH_3]_2.6H_2O$, unmelted at 250° C.; pyridine hydrochloride gives the substance $(AsO(OH)_2.C_6H_4.SbCl_4)_2.(C_5H_5N.HCl)_3.1\frac{1}{3}H_2O$, M.pt. 155° C.

4-Hydroxyphenylene-3-stibinicarsinic acid is prepared by diazotising 3-amino-4-hydroxyphenylarsinic acid and treating the solution with tartar emetic as before. During the diazotisation of the amine in 5*N* hydrochloric acid, 1-*arsinic acid*-3 : 4-*quinone*-3-*diazide* separates out:



This can be recrystallised from water, is pale yellow, and decomposes violently at about 150° C. Exposed to light it becomes deep red and evolves nitrogen. The stibinicarsinic acid is a pale yellow powder having similar properties to the preceding acid.

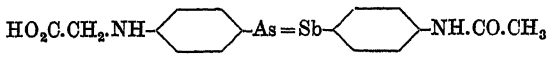
Another method of producing arsenic-antimony compounds is to condense tervalent inorganic antimony compounds with primary aromatic arsines in alkaline solution. In this way, 3-amino-4-hydroxyphenylarsine reacts with potassium antimonyltartrate in aqueous alkaline solution to give a dark brown compound, soluble in acids and alkalis. With salicylaldehyde this forms a *N-hydroxybenzylidene derivative*. *p*-Hydroxyphenylarsine in sodium hydroxide, on treatment with an alkaline antimony solution from antimony trichloride and glycerol, gives a dark brown compound, soluble in dilute alkalis, insoluble in dilute acids.[1]

Phenylarsinic acid stibinic acid, $AsO(OH)_2.C_6H_4.SbO(OH)_2$, and its substitution products may be reduced in one or two stages.[2] 4-*Hydroxyphenyl*-1-*arsinic acid*-3-*stibinic acid*, formed from diazotised 4-hydroxy-3-aminophenyl-1-arsinic acid and alkaline potassium antimonyltartrate,

[1] German Patent, 397275, from *Chem. Zentr.*, 1924, ii. 760.
[2] German Patent, 397151, from *Chem. Zentr.*, 1924, ii. 761.

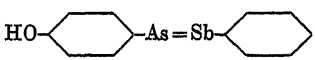
gives an orange-yellow reduction product when treated with stannous chloride and concentrated hydrochloric acid in the presence of iodine. *Phenyl*-1-*arsinic acid*-4-*stibinic acid*, on reduction with sulphur dioxide in the presence of iodine in methyl alcoholic hydrogen chloride solution, yields *phenyl*-1-*arsenoxide*-4-*stibinoxide*, a colourless powder. If iodine is absent, an intermediate product is formed, and if the oxide is reduced with phosphorous acid in acetic acid-hydrochloric acid solution in the presence of iodine, a pale yellow reduction product results. Phenylarsinic acid-stibinic acid, reduced with sodium hyposulphite, gives a dark brown product.

4-Acetylaminophenylstibinoarseno-4-phenylglycine,[1]



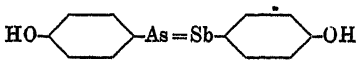
This derivative results when 14 grams of phenylglycine-*p*-arsinic acid in 200 c.c. of water and 100 c.c. of normal sodium hydroxide are mixed with 15·2 grams of 4-acetylaminophenylstibinic acid in 300 c.c. of water and 50 c.c. of sodium hydroxide and the whole reduced with sodium hydrosulphite. The product is brownish-black, soluble in aqueous alkalis or aqueous pyridine, but insoluble in water, alcohol, or acetone.

4-Hydroxyphenylarsenostibinobenzene,[2]



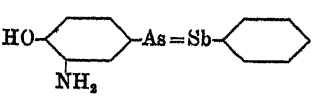
Phenylstibinoxide (2·13 grams) is dissolved in 100 c.c. of hot acetic acid and a methyl alcohol solution of 1·7 grams of 4-hydroxyphenylarsine added. After boiling for a short time the solution is poured into ether, the required compound being precipitated as a brown powder, soluble in alkalis.

4 : 4′-Dihydroxystibinoarsenobenzene,[3]



Solutions containing, respectively, 12 grams of sodium 4-hydroxyphenylarsinate in 240 c.c. of water, and 13·2 grams of 4-hydroxyphenylstibinic acid in 30 c.c. of water and 50 c.c. of normal sodium hydroxide, are mixed together and diluted with 1250 c.c. of water. To this solution, 250 grams of sodium hydrosulphite are added and the whole stirred until no further precipitate separates (for about two hours). The product is then filtered off, washed with water, and dried *in vacuo*. It is a brownish-black powder, insoluble in water, soluble in alcohols, acetone, pyridine, and aqueous sodium hydroxide.

3-Amino-4-hydroxyarsenostibinobenzene,[4]



This derivative may be prepared by either of the following methods: (1), 3-Amino-4-hydroxyphenylarsine (1·9 grams) is dissolved in 30 c.c.

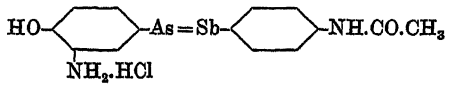
[1] German Patent, 270255.
[2] German Patent, 269744.
[3] German Patent, 270255.
[4] German Patents, 269743, 270255, 270259; Ehrlich and Karrer, *Ber.*, 1913, 46, 3564.

of methyl alcohol and about 1 c.c. of 10*N* alcoholic hydrochloric acid added, oxygen being excluded. To the solution, 2·7 grams of phenylstibine dichloride in methyl alcohol are added and 500 c.c. of ether stirred into the mixture. The *hydrochloride* of the required base separates out as a brown, amorphous powder, which is washed with ether and dried *in vacuo*.

(2), 10 grams of 3-amino-4-hydroxyphenylarsenoxide in 60 c.c. of methyl alcohol, 200 c.c. of water and 50 c.c. of normal sodium hydroxide are mixed with 12·3 grams of phenylstibinic acid in 300 c.c. of water and 50 c.c. of normal sodium hydroxide. The mixture is then treated with 200 grams of sodium hydrosulphite and 40 grams of magnesium chloride in 1000 c.c. of water and the whole stirred at room temperature until a test portion remains clear on warming. The precipitate is filtered off, washed with water and dried *in vacuo*, the yield being quantitative.

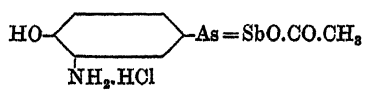
The product is a brownish-yellow powder, readily soluble in pyridine, aqueous alkalis, and methyl alcohol. The *hydrochloride* yields a yellowish-brown *addition product with gold chloride* and a brownish-green compound with *osmium chloride*, these being soluble in water but insoluble in ether.

3-Amino-4-hydroxyarseno-4′-acetylamino-stibinobenzene hydrochloride,[1]



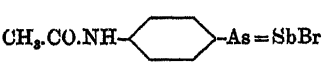
This compound is obtained in brown flocks when 1·64 grams of 4-acetylaminophenylstibine di-iodide[2] in 40 c.c. of acetic acid are treated with 0·8 gram of 3-amino-4-hydroxyphenylarsine in alcoholic hydrochloric acid and the whole diluted with ether. It is readily soluble in water and methyl alcohol and gives a clear solution in alkalis.

3-Amino-4-hydroxyphenylarsenoantimonious acetate hydrochloride,[3]



This is the condensation product of 3-amino-4-hydroxyphenylarsine (2 grams) in a little methyl alcohol with a hot solution of 3·58 grams of tartar emetic in acetic acid. After boiling for a minute, brownish-yellow flocks separate, which are easily soluble in water, alkali, or dilute hydrochloric acid. From the latter solution, sulphuric acid precipitates a sparingly soluble *sulphate*, and dimethylaminobenzaldehyde a slightly soluble *Schiff's base*.

4-Acetylaminophenylarsenoantimonious bromide,[4]

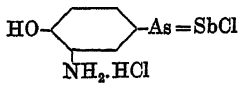


4-Acetylaminophenylarsine (0·6 part), obtained by the reduction of 4-acetylaminophenylarsinic acid with zinc dust and hydrochloric acid, is dissolved in 50 c.c. of methyl alcoholic hydrochloric acid, and 1·08 parts of antimony tribromide in 25 c.c. of methyl alcohol added. On

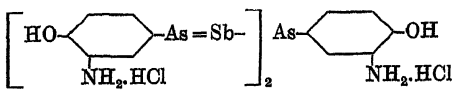
[1] Ehrlich and Karrer, *loc. cit.*
[2] German Patent, 214428.
[3] German Patent, 269744.
[4] German Patent, 269743.

pouring into ether, a reddish-brown powder of the constitution indicated is precipitated. It is soluble in water and dilute hydrochloric acid.

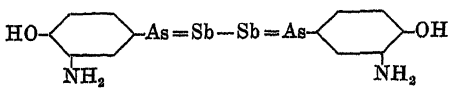
3 - Amino - 4 - hydroxyphenylarsenoantimonious chloride hydrochloride,[1]



A solution of 1 gram of 3-amino-4-hydroxyphenylarsine in methyl alcohol is mixed with a similar solution of 1·23 grams of antimony trichloride. After adding 0·88 gram of crystalline cupric chloride in methyl alcohol, the required compound is precipitated in the form of its *cupric chloride addition compound* by the addition of ether. For the product obtained when the preparation is carried out in methyl alcohol solutions containing hydrochloric acid the following formula has been suggested, but it is not supported by analysis : [2]

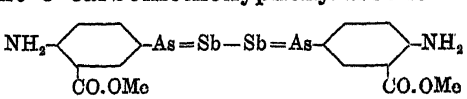


Bis-3-Amino-4-hydroxyphenylarsenoantimonide,[3]



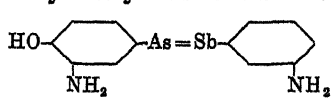
A solution of 23·3 grams of 3-amino-4-hydroxyphenylarsinic acid in 400 c.c. of water and 60 c.c. of 2*N* sodium hydroxide is mixed with 33·2 grams of tartar emetic in 650 c.c. of water. The mixture is then added to a solution of 500 grams of sodium hydrosulphite and 100 grams of magnesium chloride in 2500 c.c. of water and the whole well stirred at 50° to 55° C. until a test portion remains clear on warming. The precipitate is then filtered off, washed and dried *in vacuo*. It is a reddish-brown powder giving clear solutions in dilute hydrochloric acid or aqueous sodium hydroxide.

Bis-4-Amino-3-carbomethoxyphenylarsenoantimonide,[4]



results when antimonyl chloride is condensed with methyl anthranilylarsine in acetic acid solution. It is a brown powder, sparingly soluble in water and methyl alcohol.

3 : 3′-Diamino-4-hydroxyarsenostibinobenzene,[5]

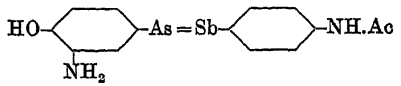


m-Amino-*p*-hydroxyphenylarsine in aqueous acid or aqueous alcohol solution is condensed with *m*-aminophenylstibinoxide, the resulting compound being a brown, water-insoluble powder, dissolving in sodium

[1] German Patent, 270259.
[2] Ehrlich and Karrer, *loc. cit.*
[3] German Patent, 270255.
[4] German Patent, 269744.
[5] German Patent, 396697, from *Chem. Zentr.*, 1924, ii. 760.

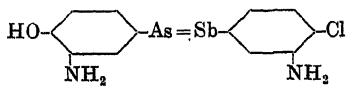
hydroxide solution to give a brownish-red solution. Oxidising agents cause scission of the molecule in this solution. The arsenostibinobenzene forms a *hydrochloride* on treatment with hydrogen chloride.

3-Amino-4′-acetamido-4-hydroxyarsenostibinobenzene,



This is produced by the condensation of *m*-amino-*p*-hydroxyphenylarsine and *p*-acetamidophenylstibinoxide. It is a brown powder, soluble in dilute acids or alkalis.

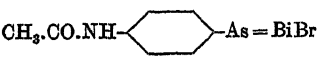
4′-Chloro-3 : 3′-diamino-4-hydroxyarsenostibinobenzene,



The stibinoxide in the preceding preparation is here replaced by *p*-chloro-*m*-aminophenylstibinoxide; the product is a reddish-brown mass, which yields an orange-yellow *hydrochloride*, fairly stable in air.

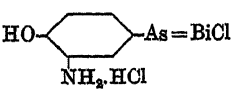
Arsenic-Bismuth Derivatives.

4-Acetylaminophenylarsenobismuth bromide,[1]



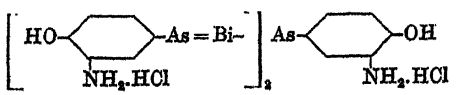
4-Acetylaminophenylarsine (2·1 parts) is dissolved in 30 parts of methyl alcohol containing hydrogen bromide, and 4·5 parts of bismuth tribromide in methyl alcohol added. Addition of ether precipitates a heavy, black powder, decomposed by acids and alkalis.

3-Amino-4-hydroxyphenylarsenobismuth chloride hydrochloride,



This derivative is obtained by condensing 3-amino-4-hydroxyphenylarsine with bismuth trichloride in methyl alcohol solution in the presence of hydrogen chloride. It is a black powder, decomposing in a similar manner to the preceding compound, and boiling its aqueous solution even leads to decomposition.

Tris-3-amino-4-hydroxyphenylarsenodibismuth dihydrochloride,[2]



This compound is prepared in a similar manner to the corresponding antimony derivative (p. 488), bismuth trichloride taking the place of the antimony trichloride. The substance has a similar solubility to the antimony compound, but is black in colour. Its aqueous solutions are decomposed on boiling, and hydrogen peroxide in alkaline solution

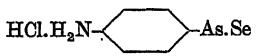
[1] German Patent, 269745.

[2] Ehrlich and Karrer, *Ber.*, 1913, 46, 3564.

instantly causes decomposition, with formation of 3-amino-4-hydroxyphenylarsinic acid and bismuth oxide.[1]

Arsenic-Selenium and Arsenic-Tellurium Derivatives.

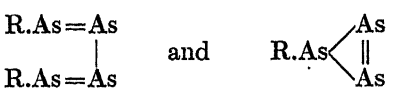
4-Aminophenylarsenoselenide hydrochloride,[2]



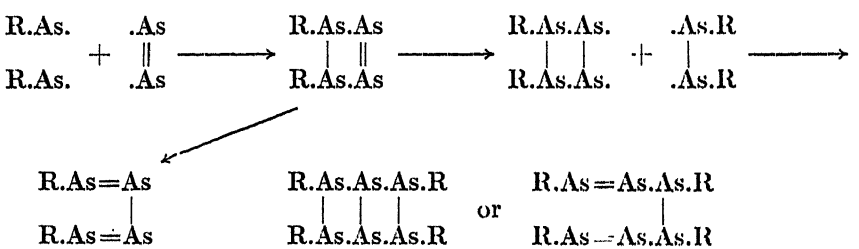
5 grams of 4-aminophenyldichloroarsine hydrochloride in 20 c.c. of alcohol are treated with a rapid stream of hydrogen selenide. The required compound separates out as an orange-yellow powder, sparingly soluble in dilute hydrochloric acid. If the hydrogen selenide is replaced by the corresponding telluride, *4-aminophenylarsenotelluride* is isolated as a reddish-brown powder, having a similar solubility to the selenide.

POLYARSENICAL COMPOUNDS CONTAINING AROMATIC GROUPS.

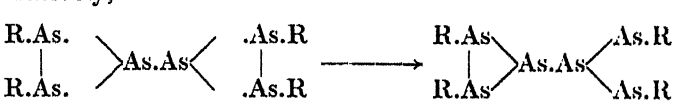
These compounds are prepared by the condensation of one molecular equivalent of an arylarsinic acid or oxide with one or more molecular equivalents of inorganic arsenic compounds. Morgan[3] has suggested that these compounds are tervalent arsenicals of the general types



Fargher[4] suggests the following method of formulation for the types R_2As_4 and R_4As_6:



or, alternatively,



The following is an account of some preparations of the foregoing types:

(1) A solution of 20 grams of phenylarsinic acid in 400 c.c. of water and 50 c.c. of 2*N* sodium hydroxide is mixed with 13 grams of

[1] When an alkali bismuth tartrate and the disodium salt of Salvarsan are mixed in aqueous solution and the whole poured into ether-methyl alcohol solution, a complex is precipitated which is said to have the general formula, R.As.Bi.As(R).Bi.As.R_1, where R is an aminoaryl radical (American Patent, 1605691).

[2] German Patent, 269699.

[3] Morgan, *Organic Compounds of Arsenic and Antimony* (Longmans), 1918.

[4] Fargher, *Trans. Chem. Soc.*, 1920, 117, 865.

sodium arsenite in 500 c.c. of water and the whole neutralised by the addition of 50 c.c. of 2*N* acetic acid. A solution of 200 grams of sodium hydrosulphite and 40 grams of magnesium chloride in 1000 c.c. of water is mixed with the preceding solution and the whole stirred for twenty-four hours at room temperature. A pale yellow precipitate separates and is removed, washed with water and dried in a vacuum. The substance is insoluble in water, aqueous mineral acids, and alkalis, sparingly soluble in most organic solvents, but moderately soluble in chloroform. The arsenic content of the product is 54·2 per cent.[1]

(2) 3-Amino-4-hydroxyphenylarsinic acid (23·3 grams) in 400 c.c. of water and 60 c.c. of 2*N* sodium hydroxide is mixed with 13 grams of sodium arsenite in 500 c.c. of water, the solution neutralised with 50 c.c. of 2*N* acetic acid and reduced by 500 grams of sodium hydrosulphite and 100 grams of magnesium chloride in 2500 c.c. of water at 50° to 55° C. The reaction is considered complete when a test portion on warming yields no further precipitate. The preparation is orange-yellow, contains 48·9 per cent. of arsenic, and easily dissolves in aqueous sodium hydroxide and dilute hydrochloric acid; it forms a sparingly soluble *sulphate*. The polyarsenide forms a series of *co-ordination compounds* as follows:[2] (*a*) *With cuprous chloride:* One gram of this salt in 2·5 c.c. of hydrochloric acid (density 1·12) and 20 c.c. of methyl alcohol is added to 3 grams of the polyarsenide in 60 c.c. of methyl alcohol and 1·5 to 2 c.c. of hydrochloric acid (density 1·12). The dark red solution obtained is poured into several volumes of ether, a pale brown powder resulting, which is soluble in methyl alcohol and water. Sodium hydroxide does not precipitate the copper from aqueous solutions of the complex; sulphuric acid causes the separation of a sparingly soluble *sulphate*. (*b*) *With mercuric chloride:* Replacing the cuprous chloride in the foregoing by 2·7 grams of mercuric chloride in 20 c.c. of methyl alcohol gives an orange product. This is insoluble in water and methyl alcohol, and is decomposed by sodium hydroxide, becoming black. (*c*) *With silver nitrate:* In this case 0·85 gram of silver nitrate in 5 c.c. of water and 20 c.c. of methyl alcohol is used and a brown powder is formed, which readily dissolves in water and methyl alcohol, but the product is not affected by sodium hydroxide.

(3) The preparation is conducted as in (2), except that two molecular equivalents of sodium arsenite are used. The polyarsenide is a brownish-red powder, soluble in sodium hydroxide, the solution remaining clear on acidification with hydrochloric acid, the acid solution yielding a precipitate with sulphuric acid. The preparation contains 57 per cent. of arsenic.

(4) A solution containing 22 grams of *p*-aminophenylarsenoxide and 18·15 grams of arsenic trichloride in 100 c.c. of methyl alcohol is slowly added to a well-cooled solution of 50 grams of stannous chloride in 200 c.c. of hydrochloric acid (density 1·19) and 200 c.c. of methyl alcohol. The product is brownish-yellow and contains 45 per cent. of arsenic. It is soluble in hot dilute hydrochloric acid and in moist pyridine, the acid solution yielding precipitates with dilute sulphuric acid and excess of sodium hydroxide.

[1] German Patent, 270254. [2] German Patent, 270256.

APPENDIX I.

TABLE I.—DISSOCIATION CONSTANTS FOR SOME PHENYLARSINIC ACIDS.*

Values for K.

Acid.	v				
	64	128	256	512	1024
Phenylarsinic acid	0·027	0·027	0·027	0·025	0·025
Arsanilic acid	0·0054	0·0057	0·0059	0·0059	..
p-Hydroxyphenylarsinic acid	0·015	0·015	0·015	0·015	0·014
4-Amino-3-hydroxyphenylarsinic acid	..	..	..	0·0067 ?	0·0080 ?
Resorcinolarsinic acid	0·0063	0·0061	0·0063	0·0063	0·0063
Dichlorophenolarsinic acid	0·059	0·056	0·055	0·055	0·053
o-Toluidinoarsinic acid	..	0·0051	0·0053	0·0056	0·0056
m-Toluidinoarsinic acid	..	0·013	0·014	0·014	0·014
Methoxy-N-acetylarsanilic acid	0·032	0·031	0·029	0·029	0·032
m-Nitrophenylarsinic acid	0·137	0·135	0·132	0·127	0·118
m-Nitro-*p*-hydroxyphenylarsinic acid	0·083	0·084	0·083	0·083	0·078
p-Nitrophenylarsinic acid	0·144	0·144	0·137	0·130	0·118
o-Nitrophenylarsinic acid	0·038	0·037	0·037	0·036	0·035
o-Nitro-*p*-aminophenylarsinic acid	..	..	0·0086	0·0085	..

* See p. 179.

TABLE II.—DENSITIES OF SOME ARSINIC ACIDS.[1]

Acid.	Density at 20° C.	Acid.	Density at 20° C.
p-Aminophenylarsinic acid	1·9571	Dichlorohydroxyphenylarsinic acid	2·1029
o-Aminotolylarsinic acid	1·7475	Dibromohydroxyphenylarsinic acid	2·4150
o-Diaminophenylarsinic acid	1·8313	3-Nitro-4-hydroxyphenylarsinic acid	2·0314
Dimethylaminophenylarsinic acid	1·6746	Dinitrohydroxyarsinic acid	2·0565
m-Dihydroxyphenylarsinic acid	2·0040	*p*-Phenylenediarsinic acid	2·2025
3-Nitro-4-aminophenylarsinic acid	2·0359		

[1] Lorenz and Schmidt, *Zeitsch. anorg. Chem.*, 1920, 112, 269. See this Vol. p. 179.

Kopp's Law, applied to calculate the atomic volumes of arsenic in the above compounds, gives results ranging from 11·2 to 33·3 with different compounds.

TABLE III.—AZO-DYES DERIVED FROM P-AMINOPHENYLARSINIC ACID.[1]

Azo-dye.	M.pt. ° C.
1-Amino-2-methoxynaphthalene-4-azobenzene-4′-arsinic acid	..
1-Amino-4-methoxynaphthalene-2-azobenzene-4′-arsinic acid	195
4-Methylamino-5-carboxybenzeneazobenzene-4′-arsinic acid	..
4-Ethylamino- „ „ „ „	..
4-*Iso*amylamino- „ „ „ „	..
4-Amino-2 : 3-dimethoxy-5-carboxybenzeneazobenzene-4′-arsinic acid	..
2-Amino-4 : 5-dimethoxy-5-carboxybenzeneazobenzene-4′-arsinic acid	..
4-Benzene(4′-arsinic acid)azo-phenylglycine	170–175
„ „ „ azo-2-methylphenylglycine	157
„ „ „ azo-2-methoxyphenylglycine	167
„ „ „ azo-2-ethoxyphenylglycine	245–250
α′-Benzene(4-arsinic acid)azo-α-naphthylglycine	275
4-Benzene(4′-arsinic acid)azo-phenylaminomethane sulphonic acid	187–189
„ „ „ azo-2-methoxyphenylaminomethane sulphonic acid	158–160
6-Benzene(4′-arsinic acid)azo-3-aminophenoxyacetic acid	..
„ „ „ azo-3-amino-4-methylphenoxyacetic acid	242–243
4-Benzene(4′-arsinic acid)azo-5-amino-2-methylphenoxyacetic acid	187–188
„ „ „ azo-3-amino-6-methylphenoxyacetic acid	..
4-Amino-6-methoxy-3-[phenyl-(4′-arsinic acid)azo]-phenoxyacetic acid	..
5-Benzene(4′-arsinic acid)azo-4-amino-1 : 2-bisphenoxyacetic acid	..
β-Benzene(4-arsinic acid)azo-α-amino-α′-naphthoxyacetic acid	285
α-Benzene(4-arsinic acid)azo-α-amino-β-naphthoxyacetic acid	..
5-Benzene(4′-arsinic acid)azo-2-hydroxyphenoxyacetic acid	..

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1921, 43, 1646. The melting-points given above are also the decomposition points of the compounds. See p. 231.

TABLE IV.—DIAZOAMINO-COMPOUNDS FROM P-AMINOPHENYLARSINIC ACID AND ITS DERIVATIVES.[1]

Diazoamino-compound.	M.pt. ° C.
Diazobenzene(4-arsinic acid)dimethylamine	182
,, ,, ,, diethylamine	195–200
,, ,, ,, piperidine	162–163
Bisdiazo ,, ,, pentamethylenetetramine	210–212
Diazo ,, ,, aniline	112–113
,, ,, ,, methylaniline	160–162
,, ,, ,, *p*-toluidine	130–132
,, ,, ,, 4′-chloroaniline	177
,, ,, ,, *o*-anisidine	95–99
,, ,, ,, *p*- ,,	116–119
,, ,, ,, 4′-aminoacetanilide	165–170
,, ,, ,, 4′-aminophenol	..
,, ,, ,, 4′-aminoacetophenone	177–178
,, ,, ,, *o*-aminobenzoic acid	160
,, ,, ,, *m*- ,, ,,	141
,, ,, ,, *p*- ,, ,,	..
Methyldiazobenzene-4-arsinic acid-3′-amino-6′-methoxybenzoate	90–95
Diazobenzene(4-arsinic acid)-3′-aminoanisic acid	150–155
Methyldiazobenzene(4-arsinic acid)-6-aminopiperonylate	..
Diazobenzene(4-arsinic acid)-4′-aminocinnamic acid	155–160
,, ,, ,, 4′-aminophenylarsinic acid	154
,, ,, ,, phenylglycine	..
,, ,, ,, *p*-tolylglycine	148–149
Diazobenzene(4-arsinic acid)benzylglycine	155–160
,, ,, ,, 4′-ethoxyphenylglycine	..
,, ,, ,, 4′-aminophenoxyacetic acid	132
,, ,, ,, 4′-methylaminophenoxyacetic acid	155–160
,, ,, ,, 3′-methyl-4′-aminophenoxyacetic acid	..
,, ,, ,, 4′-amino-2′-methylphenoxyacetic acid	..
Methyldiazobenzene(4-arsinic acid)-4′-amino-2′ : 5′-dimethylphenoxyacetate	120
,, ,, ,, -4′-amino-2-methyl-5′-*iso*-propylphenoxyacetate	145
,, ,, ,, -4′-amino-3′-methyl-6′-*iso*-propylphenoxyacetate	..
Diazobenzene(4-arsinic acid)-2′-bromo-4′-aminophenoxyacetic acid	120
,, ,, ,, -6-bromo-4-amino-2-methylphenoxyacetic acid	155
,, ,, ,, -4′-amino-6′-acetophenoxyacetic acid	..
6-Diazo-*o*-toluene(3-arsinic acid)-*p*-aminophenoxyacetic acid	..
Diazo-2-bromobenzene(4-arsinic acid)-*p*-aminophenoxyacetic acid	130

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1921, 43, 1632. The melting-points given above are also the decomposition points. See p. 231.

TABLE V.—PRODUCTS DERIVED FROM DIAZOTISED ARSANILIC ACID AND HYDROXY- AND AMINO-QUINOLINES.[1]

Compound.	Decomposition Point.
2-Methyl-3-azo-4-hydroxyquinoline-*p*-phenylarsinic acid . . .	Unmelted at 300° C.
5-Azo-8-hydroxyquinoline-*p*-phenylarsinic acid	..
2-Phenyl-4-azo-3-hydroxyquinoline-*p*-phenylarsinic acid . . .	..
2-Methyl-4-azo-3-hydroxyquinoline-*p*-phenylarsinic acid . . .	..
3-Amino-2-methylquinoline-4-azo-*p*-phenylarsinic acid	150 to 152° C.
3-Amino-2-phenylquinoline-4-azo-*p*-phenylarsinic acid	About 100° C.
3-Amino-*p*-methoxyphenylquinoline-4-azo-*p*-phenylarsinic acid . .	About 145° C.
8-Aminoquinoline-5-azo-*p*-phenylarsinic acid	Not appreciably altered below 250° C.
5-Aminoquinoline-8-azo-*p*-phenylarsinic acid	,, ,, ,,

[1] The above hydroxyazo-compounds are red or brown in colour, and give red colorations with concentrated sulphuric acid. See p. 231.

TABLE VI.—THE CARBAMIDES AND β-SUBSTITUTED CARBAMIDES OF N-ARYLGLYCINEARSINIC ACIDS.[1]

Compound.	Crystalline Form.	M.pt. ° C.	Compound.	Crystalline Form.	M.pt. ° C.
N(Phenyl-*p*-arsinic acid)-glycinecarbamide . .	..	..	N(Phenyl-*p*-arsinic acid)-glycyl-*m*′-carbamidobenzamide . . .	Needles	213–214
,, ,, ,, -glycinemethylcarbamide	Needles	224–225	,, ,, ,, -glycyl-*p*′-carbamidobenzamide . . .	..	245
,, ,, ,, -glycine-ethylcarbamide	,,	223–224	,, ,, ,, -glycyl-*m*′-carbamidophenylacetamide .	Needles	214–216
,, ,, ,, -glycinebenzylcarbamide	,,	225	,, ,, ,, -glycyl-*p*′-carbamidophenylacetamide .	,,	218–221
,, ,, ,, -glycinephenylcarbamide	,,	280	N(Phenyl-*o*-arsinic acid)-glycinecarbamide . .	,,	231–232
,, ,, ,, -glycine-*p*′-acetylaminophenylcarbamide .	,,	265–266	,, ,, ,, -glycinemethylcarbamide	,,	218
,, ,, ,, -glycine-*m*′-oxamylaminophenylcarbamide .	Powder	223–224	N(Phenyl-*m*-arsinic acid)-glycinecarbamide .	,,	208–209
,, ,, ,, -glycine-*p*′-hydroxyphenylcarbamide . . .	Needles	..	,, ,, ,, -glycinemethylcarbamide	..	213–213·5
,, ,, ,, -glycyl-*p*′-carbamidophenoxyacetamide . .	Plates	243–244	N(*m*-Tolyl-6-arsinic acid)-glycinecarbamide .	,,	235
α-N(Phenyl-*p*-arsinic acid)-aminopropionylcarbamide	Needles	225–226	,, ,, ,, -glycinemethylcarbamide	,,	218–219
			N(2-Hydroxyphenyl-5-arsinic acid)-glycinecarbamide	,,	203–205

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, *41*, 1600. See this Vol. p. 237.

TABLE VII.—AROMATIC AMIDES OF N-ARYLGLYCINEARSINIC ACIDS.[1]

Compound.	Crystalline Form.	M.pt. °C.
N(Phenyl-*p*-arsinic acid)-glycineanilide	Needles	..
,, ,, ,, -glycine-*o'*-toluidide	,,	..
,, ,, ,, ,, -*m'*- ,,	Plates	285
,, ,, ,, ,, -*p'*- ,,	Needles	..
,, ,, ,, ,, -*α*-naphthylamide	,,	..
,, ,, ,, ,, -*β*- ,,	,,	285–286
,, ,, ,, -glycinediphenylamide	Leaflets	271–272
,, ,, ,, -glycine-*p'*-chloroanilide	,,	..
,, ,, ,, ,, -*p'*-iodoanilide	Needles	..
,, ,, ,, ,, -*p'*-nitroanilide	,,	..
,, ,, ,, ,, -*p'*-acetylaminoanilide	,,	..
,, ,, ,, ,, -*p'*-aminoanilide	Needles or plates	253–254
,, ,, ,, ,, -*p'*-carbamidoanilide	..	230
,, ,, ,, ,, -4'-methyl-5-carbamidoanilide	Plates	257–258
,, ,, ,, ,, -*m'*-oxamylaminoanilide	..	280
,, ,, ,, -glycyl-*o'*-aminophenol	..	190
,, ,, ,, -glycine-*m'*-hydroxyanilide	..	..
,, ,, ,, ,, -4-hydroxy-*o*-toluidide	Prisms	220–225
,, ,, ,, ,, -2-hydroxy-*p*-toluidide	..	258
,, ,, ,, ,, -*p'*-hydroxyanilide	Plates	255–256
,, ,, ,, ,, -*p'*-anisidide	Leaflets	soften 230
N(Phenyl-*p*-arsinic acid)-glycine-1-hydroxy-*β*-naphthalide	Prisms	189–191
,, ,, ,, ,, -4-hydroxy-*α*-naphthalide	..	240–242
,, ,, ,, -glycyl-4 : 6-dichloro-3-hydroxyanilide	Needles	280
,, ,, ,, ,, -6-bromo-3-hydroxyanilide	Leaflets	255
,, ,, ,, -glycine-3' : 4'-dihydroxyanilide	,,	260–265
,, ,, ,, -glycylanthranilic acid	Octahedra	230–235
,, ,, ,, -glycyl-N-methylanthranilic acid	Needles or plates	230
,, ,, ,, ,, -2'-aminobenzamide	Needles	170
,, ,, ,, ,, -*m'*- ,,	Plates	..
,, ,, ,, ,, -*p'*- ,,	Needles	..
,, ,, ,, ,, -5-aminosalicylamide	Scales	255
,, ,, ,, ,, -*m'*-aminophenylacetamide	Needles	275–280
,, ,, ,, ,, -*p'*-aminophenylacetic acid	Globules	280
,, ,, ,, ,, -*p'*-aminophenylacetamide	Hairs	..
,, ,, ,, ,, -*p'*-aminophenylacetylcarbamide	,,	..

[1] See p. 237.

TABLE VII.—AROMATIC AMIDES OF N-ARYLGLYCINEARSINIC ACIDS[1]—*Contd.*

Compound.	Crystalline Form.	M.pt. °C.
N(Phenyl-*p*-arsinic acid)-glycyl-*o'*-aminophenoxyacetamide	Needles	280
,, ,, ,, ,, -*m'*-aminophenoxyacetic acid	..	250–260
,, ,, ,, ,, -*p'*-aminophenoxyacetic acid	Needles or plates	..
,, ,, ,, ,, -*p'*-aminophenoxyacetamide	Needles	..
,, ,, ,, ,, -*p'*-aminophenoxyacetylcarbamide	,,	290
,, ,, ,, ,, -3-methyl-4-aminophenoxyacetic acid	,,	270
,, ,, ,, ,, -*m'*-aminobenzenesulphonamide	,,	265
,, ,, ,, ,, -*p'*-aminobenzenesulphonic acid	,,	245–246
,, ,, ,, ,, -*p'*-aminobenzenesulphonamide	Plates and needles	..
N(Phenyl-*p*-arsinic acid)-glycyl-4-amino-6-hydroxybenzenesulphonic acid	Leaflets	..
,, ,, ,, ,, -4-aminoacetophenone	Hairs	..
N(Phenyl-*o*-arsinic acid)-glycineanilide	Prisms	160–163
,, ,, ,, -glycine-*o'*-hydroxyanilide	Needles	151–153
,, ,, ,, ,, -*m'*- ,,	Plates	103–105
,, ,, ,, ,, -*p'*- ,,	,,	208–209
N(Phenyl-*m*-arsinic acid)-glycineanilide	Prisms	217–218
,, ,, ,, -glycine-*o'*-hydroxyanilide	Needles	190–192
,, ,, ,, ,, -*m'*- ,,	Plates and needles	180–190
,, ,, ,, ,, -*p'*- ,,	Plates	180
N(*o*-Tolyl-5-arsinicacid)-glycine-*m'*-hydroxyanilide	Needles	285
,, ,, ,, ,, -*p'*- ,,	,,	232–233
N(*m*-Tolyl-6-arsinic acid)-glycine-*m'*-hydroxyanilide	..	232–235
N(2-Carboxyphenyl-4-arsinic acid)-glycine-*m'*-hydroxyanilide	Plates	204–207

[1] See p. 237.

TABLE VIII.—N-SUBSTITUTED GLYCYL-ARSANILIC ACIDS.[1]

Compound.	Crystalline Form.	M.pt. °C.	Compound.	Crystalline Form.	M.pt. °C.
Glycyl-*p*-arsanilic acid	Plates	..	*p*-Carboxylamidophenylglycyl-*p*-arsanilic acid	Prisms	..
Iminobisacetyl-*p*-arsanilic acid	..	..	N-Phenylglycineanilide-*p*-acetamide-*p'*-arsinic acid	Plates	256–258
N-Methylglycyl-*p*-arsanilic acid	Needles	..	,, ,, ,, -*p*-acetylcarbamide-*p'*-arsinic acid	Hairs	270–273
N-Phenylglycyl-*p*-arsanilic acid	,,	..	,, ,, ,, -*p*-oxyacetic-*p'*-arsinic acid	Plates	275
m-Oxaminophenylglycyl-*p*-arsanilic acid	..	179	,, ,, ,, -*p*-oxyacetamide-*p'*-arsinic acid	Needles	..
p-Aminophenylglycyl-*p*-arsanilic acid	..	..	,, ,, ,, -*p*-oxyacetocarbamide-*p'*-arsinic acid	Plates	257–258
p-Acetylaminophenylglycyl-*p*-arsanilic acid	Plates	..	,, ,, ,, -*p*-glycineamide-*p'*-arsinic acid	..	..
p-Oxaminophenylglycyl-*p*-arsanilic acid	..	..	,, ,, ,, -4 : 4'-diarsinic acid	Needles	..
p-Oxamylaminophenylglycyl-*p*-arsanilic acid	Needles	..	*p*-Acetylphenylglycyl-*p*-arsanilic acid	,,	..
p-Carbamidophenylglycyl-*p*-arsanilic acid	Leaflets	..			
m-Hydroxyphenylglycyl-*p*-arsanilic acid	Prisms	..			
p- ,, ,, ,, ,,	Hairs	..			
m-Carboxylamidophenylglycyl-*p*-arsanilic acid	Needles	248			
N-Phenylglycineanilide-*m*-carboxycarbamide-*p'*-arsinic acid	,,	280			

[1] See p. 238.

TABLE IX.—AMIDES OF N-(PHENYL-P-ARSINIC ACID)-α-PHENYLGLYCINE.[1]

Compound.	Crystalline Form.	M.pt. °C.	Compound.	Crystalline Form.	M.pt. °C.
N(Phenyl-*p*-arsinic acid)-α-phenylglycineamide .	Needles	..	N(Phenyl-*p*-arsinic acid)-α-phenylglycine-4′-carbamidoanilide . .	..	255
„ „ „ -α-phenylglycinecarbamide . . .	„	195–197	„ „ „ -α-phenylglycine-3′-carbamidoanilide . .	..	261–262
„ „ „ -α-phenylglycine-3′-hydroxyanilide . .	Plates	155–160	„ „ „ -α-phenylglycyl-4-aminophenylacetamide .	Plates	222–223

[1] See p. 238.

TABLE X.—SUBSTITUTED BENZYL-, PHENOXYETHYL- AND PHENACYL-ARSANILIC ACIDS.[1]

Compound.	Crystalline Form.	M.pt. °C.	Compound.	Crystalline Form.	M.pt. °C.
Benzyl-*p*-arsanilic acid	Prisms	255	Phenoxyethylarsanilic acid	Scales	..
p-Nitrobenzyl-*p*-arsanilic acid	Needles	..	*p*-Acetylaminophenoxyethylarsanilic acid . .	Plates	..
p-Aminobenzyl-*p*-arsanilic acid. . . .	Leaflets	202	*o*-Carboxylamidophenoxyethylarsanilic acid .	Needles	..
3-Nitro-4-hydroxybenzylarsanilic acid . .	..	245–250	Phenacylarsanilic acid	„	185–187
3-Amino-4- „ „ „ . .	Plates	..	2-Hydroxy-5-acetylaminophenacylarsanilic acid .	Plates	228
p-Carboxybenzylarsanilic acid	Needles	..			

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1826. See this Vol. p. 238.

TABLE XI.—AMIDES OF (P-ARSINIC ACID)-PHENOXYACETIC ACID AND THE ISOMERIC PHENOXYACETYLARSANILIC ACIDS.[1]

Compound.	Crystalline Form.	M.pt. ° C.	Compound.	Crystalline Form.	M.pt. ° C.
Methyl(*p*-arsinic acid)-phenoxyacetate . .	Plates	192–195	Phenoxyacetylarsanilic acid	..	..
(*p*-Arsinic acid)-phenoxyacetamide . . .	Prisms	..	*p*-Oxaminophenoxyacetylarsanilic acid . .	..	..
,, ,, ,, -phenoxyacetanilide	Plates	..	*p*-Carbamidophenoxyacetylarsanilic acid . .	..	280–283
,, ,, ,, -phenoxyaceto-*m*-hydroxyanilide .	..	238–240	*o*-Carboxylamidophenoxyacetylarsanilic acid .	Needles	..
,, ,, ,, - ,, -*p*- ,, .	..	238–240	*p*- ,, ,, ,, ,, .	,,	..
,, ,, ,, - phenoxyacetyl - 4 - aminophenyl - carbamide	Needles	..			

[1] Jacobs and Heidelberger, *J. Amer. Chem. Soc.*, 1919, 41, 1834. See this Vol. p. 239.

APPENDIX II.

APPENDIX II.

Action of Ammonia on Halogen-substituted Arsines.[1]

It has already been pointed out on p. 181 that phenyldichloroarsine in benzene solution reacts with ammonia to form phenylarsenimide, and phenarsazine chloride and ammonia yield triphenarsazinamine (p. 453). The reaction has now been applied to methyldichloroarsine and diphenylchloroarsine, both compounds giving derivatives according to the equations

$$R.AsCl_2 + 3NH_3 = R.As : NH + 2NH_4Cl$$
$$R_2.AsCl + 2NH_3 = R_2As.NH_2 + NH_4Cl$$

Methylarsenimide, $(CH_3.As : NH)_6$, is a colourless, crystalline product, having a faint odour, and yielding tetrahedral crystals from benzene, M.pt. 205° C. It dissolves in chloroform, is sparingly soluble in alcohol, carbon tetrachloride, acetone, and petroleum ether. Water decomposes it, ammonia being evolved and methylarsenoxide produced, whilst hydrogen peroxide oxidises it to methylarsinic acid :

$$CH_3.As : NH + H_2O = CH_3.AsO + NH_3$$
$$CH_3.As : NH + 2H_2O + O = CH_3.AsO(OH)_2 + NH_3$$

Concentrated nitric acid causes energetic oxidation and hydrogen chloride gives the dichloro-compound :

$$CH_3.As : NH + 3HCl = CH_3.AsCl_2 + NH_4Cl$$

Phenylarsenimide, $(C_6H_5.As : NH)_4$, is a colourless, crystalline product, M.pt. about 265° C., which undergoes reactions similar to those described above (compare p. 181), except that hydrogen chloride does not give the dichloro-compound.

Diphenylarsenamide, $(C_6H_5)_2As.NH_2$, crystallises from benzene in small prisms, M.pt. 53° C., readily soluble in benzene, ether, acetone, and carbon tetrachloride, sparingly soluble in alcohol and insoluble in petroleum ether. Spontaneous evaporation of its benzene solution gives diphenylarsenoxide, and hydrogen peroxide converts it to diphenylarsinic acid.

Alkylarsinic Acids and their Derivatives.

β-Substituted Acids.[2]

β-Hydroxyethylenearsine dichloride, $HO.CH_2.CH_2.AsCl_2$, is prepared according to the equation

$$HO.CH_2.CH_2.As : O + 2HCl = HO.CH_2.CH_2.AsCl_2 + H_2O$$

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[1] Ipatiev, Razubaiev, and Stromski, *Ber.*, 1929, 62, [B], 598.
[2] Sherlin and Epstein, *J. Russ. Phys. Chem. Soc., Chem.* Part 60, No. 9, 1928, p. 1487.

The compound is precipitated as a colourless, odourless, transparent oil, which cannot be distilled even under reduced pressure owing to decomposition. It dissolves in water and chloroform, but is less soluble in alcohol. Boiling water or alkalis cause decomposition, with evolution of ethylene. When mixed with a 20 per cent. excess of 95 to 96 per cent. acetic acid and treated with a rapid stream of hydrogen chloride, it forms β-hydroxyethyldichloroarsine acetate,

$$HO.CH_2.CH_2.AsCl_2+CH_3.COOH=CH_3.CO.CH_2.CH_2.AsCl_2+H_2O.$$

β-Hydroxyethyldichloroarsine acetate, $CH_3.CO.CH_2.CH_2.AsCl_2$, obtained as just described, is fairly stable and can be distilled *in vacuo*. The yield is 80 to 85 per cent., and the compound is a strongly refractive, colourless, odourless, viscous oil, B.pt. 120° to 121° C. at 9 to 10 mm., soluble in alcohol or chloroform, sparingly soluble in water. Boiling water or alkali quantitatively eliminates ethylene, the reaction possibly being due to the migration of the hydroxyl group :

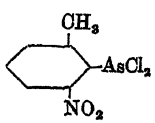
$$HO.CH_2.CH_2.As(ONa)_2+CH_2:CH_2+HO.As(ONa)_2.$$

This migration seems to be a characteristic common to all β-hydroxy fatty acids containing tervalent arsenic, and it explains the decomposition of β-hydroxyethyldichloroarsine and its oxide by heat.

Chloroethyldichloroarsine, $Cl.CH_2.CH_2.AsCl_2$, results in 70 per cent. yield when β-hydroxyethyldichloroarsine is treated with phosphorus oxychloride or pentachloride and the resulting product heated and fractionated in a vacuum. It is a colourless oil, B.pt. 90·8° C. at 12·5 mm., 87° C. at 10 mm., and 80·6° C. at 8 mm., density 1·8401 at 20° C., soluble in benzene or chloroform, sparingly soluble in water. It is saponified by water or alkali, giving a quantitative yield of ethylene. Careful oxidation with hydrogen peroxide yields *chloroethylarsinic acid*, $Cl.CH_2.CH_2.AsO(OH)_2$, consisting of small scales, M.pt. 134° C., readily soluble in water or alcohols, sparingly soluble in acetone, insoluble in carbon tetrachloride.

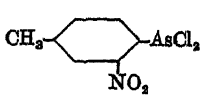
Arylarsinic Acids and their Derivatives.

2-Nitro-6-methylphenyldichloroarsine,[1]



is obtained in the usual manner from 2-nitro-6-methylphenylarsinic acid (p. 176). It crystallises from ligroin in pale yellow needles, M.pt. 93° C., readily soluble in acetone or benzene, and hydrolysed by water. *2-Nitro-6-methylphenyldibromoarsine* forms pale yellow, flat plates, M.pt. 116·5° to 117·5° C.

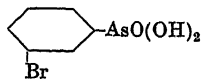
2-Nitro-4-methylphenyldichloroarsine,



[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 767.

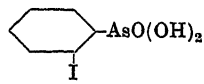
obtained from 2-nitro-4-methylphenylarsinic acid, forms pale yellow, flat prisms, M.pt. 113° C.

3-Bromophenylarsinic acid,[1]



results in 35 per cent. yield when 3-bromoaniline is subjected to the Bart reaction. It crystallises from 2*N* acetic acid in long, slender prisms, and gives a *thiolacetamide*, M.pt. 131° to 132° C.

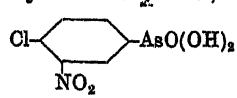
2-Iodophenylarsinic acid,



If 2-iodoaniline is subjected to the Bart reaction under the usual conditions, a 20 per cent. yield of *o*-phenylenediarsinic acid results, but if the reaction be conducted at room temperature, 2-iodophenylarsinic acid is obtained. The two products are separated by means of glacial acetic acid, the iodo-acid being readily soluble and the diarsinic acid insoluble in this acid. The Sandmeyer reaction applied to 2-aminophenylarsinic acid gives a 50 per cent. yield of the iodo-acid. The latter forms hexagonal plates from 50 per cent. acetic acid and long prisms from water, both forms being monohydrated. In normal sodium hydroxide solution the acid reacts with arsenious oxide on boiling for one hour in the presence of a trace of copper sulphate to give *o*-phenylenediarsinic acid in 40 per cent. yield. The iodine may be removed from the iodo-acid by dissolving in 2*N* sodium hydroxide and boiling with "Naturkupfer C" for four hours. A mixture of phenylarsinic acid and 2-hydroxyphenylarsinic acid results.

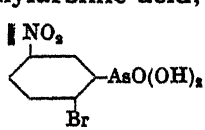
3-Iodophenylarsinic acid is obtained in 24 per cent. yield from 3-iodoaniline. It forms slender prisms, and the *thiolacetamide derivative* melts at 138° to 139° C.

4-Chloro-3-nitrophenylarsinic acid,[2]



This acid is mentioned on p. 171, but the following is a more recent method of preparation: To 24 grams of 4-chlorophenylarsinic acid dissolved in 70 c.c. of concentrated sulphuric acid, 7·5 c.c. of nitric acid (density 1·52) are added, without cooling. After heating for one hour on the water-bath the solution is poured on ice, 24 grams of the arsinic acid separating (85 per cent. yield). Nitration does not occur at 0° C.[3] The acid crystallises from hot water in diamond-shaped plates, and yields a *calcium salt* forming needles and a *barium salt* separating in plates.

2-Bromo-5-nitrophenylarsinic acid,[4]

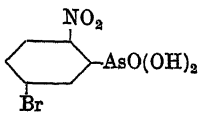


[1] Barber, *J. Chem. Soc.*, 1929, p. 2333.
[2] Barber, *ibid.*, p. 473.
[3] Compare German Patent, 285604.
[4] Barber, *loc. cit.*, p. 2333.

This acid is obtained: (1) By subjecting 2-bromo-5-nitroaniline to the Bart reaction. The yield is 25 per cent. (2) Twenty-eight grams of 2-bromophenylarsinic acid are dissolved in 60 c.c. of concentrated sulphuric acid, 7·5 c.c. of nitric acid (density 1·52) added, and the mixture heated on a boiling water-bath for one to two hours, then after cooling poured into 500 c.c. of cold water, 31 grams (95 per cent. yield) of crude product resulting. The acid crystallises from 50 per cent. acetic acid in prisms, which are either anhydrous or monohydrated. The *thiolacetamide derivative* melts at 137° to 139° C. When the acid is boiled for one hour with 25 per cent. sodium hydroxide solution it gives *5-nitro-2-hydroxyphenylarsinic acid*, the *thiolacetamide derivative* of which melts at 194° to 195° C.

2-Iodo-5-nitrophenylarsinic acid is prepared by nitrating 2-iodophenylarsinic acid. It forms rhombic plates which give a *thiolacetamide*, M.pt. 158° to 160° C. With alkali the arsinic acid yields 5-nitro-2-hydroxyphenylarsinic acid. Treatment with copper powder causes complete elimination of iodine.

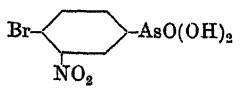
3-Bromo-6-nitrophenylarsinic acid,



This is prepared by nitration in the usual manner, and crystallises from 50 per cent. acetic acid in plates, transformed by alkali into 3-bromo-6-nitrophenol.

3-Iodo-6-nitrophenylarsinic acid forms slender prisms, converted by alkali into 3-iodo-6-nitrophenol.

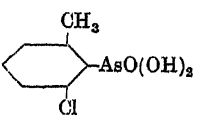
4-Bromo-3-nitrophenylarsinic acid,



obtained by the nitration of 4-bromophenylarsinic acid, forms rectangular plates from hot water. **4-Iodo-3-nitrophenylarsinic acid** separates from hot water in leaflets. Both these compounds give 3-nitro-4-hydroxyphenylarsinic acid on treatment with alkali.

The bromination of sodium *p*-aminophenylarsinate with 48 per cent. hydrobromic acid and hydrogen peroxide yields *mono-* or *di-bromo-derivatives* or *tribromoaniline*.[1] The yield of monobromo-compound is nearly theoretical and that of dibromo-compound 85 per cent. In the case of 3-nitro-4-hydroxyphenylarsinic acid [2] an 84 per cent. yield of *monobromo-compound*, decomposing at 280° C., is obtained. A 70 per cent. yield of *monohalogeno-derivative* is obtained in the case of 3-nitro-4-aminophenylarsinic acid.

2-Chloro-6-methylphenylarsinic acid,[3]

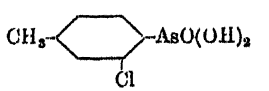


[1] Leulier and Dreyfuss, *Compt. rend.*, 1929, 188, 1416.
[2] Leulier and Dreyfuss, *J. Pharm. Chim.*, 1929, [viii.], 10, 258.
[3] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 767.

12 grams of 2-amino-6-methylphenylarsinic acid (p. 206) are dissolved in a mixture of 22·4 c.c. of hydrochloric acid and 20 c.c. of water and diazotised below 5° C. by a solution of 4 grams of sodium nitrite in 8 c.c. of water. The suspension of diazo-compound which separates is added at the ordinary temperature and with constant stirring to 4·55 grams of cuprous chloride in 15·3 c.c. of hydrochloric acid, ether being added to prevent excessive frothing. The mixture is heated to complete the reaction, water added, and the precipitate filtered off, washed with water and crystallised from alcohol. The yield is 9·85 grams or 76 per cent. The acid forms colourless prisms or prismatic needles, sintering at 232° C. and melting with decomposition at 236° to 239° C. It readily dissolves in ethyl alcohol and acetic acid, but is practically insoluble in water. The *silver salt* forms clusters of colourless needles and the *mercurous salt* has a similar crystalline form. Reduction of the acid with sulphur dioxide in boiling hydrochloric acid solution containing a little hydriodic acid yields 2-*chloro*-6-*methylphenyldichloroarsine*. This distils in 78 per cent. yield as a colourless oil, B.pt. 156° C. at 11 mm., M.pt. 37·5° C., the solid forming colourless, stout prisms. It has a phenolic odour and is readily soluble in the usual solvents. Hydrolysis by water, or more readily by ammonium hydroxide, converts the dichloroarsine into 2-*chloro*-6-*methylphenylarsenoxide*, M.pt. 234° to 237° C. The oxide is insoluble in the usual solvents and in alkali carbonate and hydroxide solutions.

2-Bromo-6-methylphenylarsinic acid is obtained in 75 per cent. yield by a process similar to that given for the corresponding chloro-compound. It crystallises from alcohol in colourless, thin needles, which on heating appear to form an anhydride remaining unmelted at 306° C. The *alkali* and *mercuric salts* are readily soluble in water; the *silver*, *lead* and *mercurous salts* are white, curdy precipitates; the *magnesium salt* is a white, amorphous precipitate; the *calcium salt* forms colourless needles and the *barium salt* colourless plates. By the usual process the acid yields 2-*bromo*-6-*methylphenyldichloroarsine*, a colourless oil, B.pt. 170° to 171° C. at 13 mm., solidifying in a freezing mixture to stout prisms, M.pt. 25° to 27° C. The arsine has a faint, not unpleasant odour; it is soluble in the usual solvents and is slowly hydrolysed by water. It yields 2-*bromo*-6-*methylphenylarsenoxide* in the usual way, an amorphous product melting indefinitely at 214° to 219° C.

2-Chloro-4-methylphenylarsinic acid,



This acid is obtained in 65 per cent. yield by the diazotisation of 2-amino-4-methylphenylarsinic acid.[1] It forms colourless, flat, truncated prisms, sintering at 184° C. and melting at 189° to 191° C.; it is practically insoluble in cold water but moderately soluble on boiling; it dissolves readily in concentrated hydrochloric acid, alcohols, alkali hydroxides and alkali carbonates. It may be converted into 2-*chloro*-4-*methylphenyldichloroarsine*, a colourless, highly refracting liquid, B.pt. 166° to 167° C. at 17 mm., solidifying to a mass of short needles, M.pt. 27° to

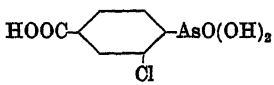
[1] The M.pt. of 2-amino-4-methylphenylarsinic acid is given as 184° to 185° C.; compare p. 203.

29° C. These are soluble in ligroin, ethyl alcohol, and benzene, insoluble in but slowly hydrolysed by water. *2-Chloro-4-methylphenylarsenoxide* is a white, amorphous mass, M.pt. 277° C., insoluble in the usual solvents and in sodium carbonate solution.

2-Bromo-4-methylphenylarsinic acid crystallises in colourless, flat, truncated prisms, M.pt. 208° to 210° C. with decomposition. It is readily soluble in acetic acid, hydrochloric acid, hot water, and ethyl alcohol, almost insoluble in cold water or benzene. The *mercurous salt* is a white precipitate, the *silver salt* is also white, and the *mercuric salt* is a brown precipitate. Treated in the usual manner the bromo-acid gives a 60 per cent. yield of *2-bromo-4-methylphenyldichloroarsine*, a colourless, highly refracting liquid, B.pt. 176° to 177° C. at 14 mm., solidifying to a mass of radiating needles, M.pt. 47° to 49° C., soluble in ligroin or benzene, and only slowly attacked by water, in which the arsine is insoluble.

2-Bromo-4-methylphenylarsenoxide, obtained from the preceding compound in the usual way, is a white, amorphous mass, M.pt. 266° to 268° C., soluble in caustic alkalis, from which it is precipitated by carbon dioxide, and insoluble in the usual organic solvents.

2-Chloro-4-carboxyphenylarsinic acid,



A warm solution containing 5 grams of 2-chloro-4-methylphenylarsinic acid and 5·7 grams of sodium carbonate (decahydrate) in 20 c.c. of water is added to 12·6 grams of potassium permanganate in 312 c.c. of water and the mixture boiled for eight hours. A current of carbon dioxide is passed through the solution during the reaction. The liquid is filtered whilst hot and the manganese dioxide extracted with boiling water. The aqueous solutions are mixed and concentrated to about 250 c.c., cooled, and acidified with concentrated hydrochloric acid. The chloro-acid slowly separates as colourless needles or long, flat plates, unmelted at 310° C. Its *alkali salts* are readily soluble in water; the *barium salt* forms rhomb-shaped plates; the *calcium salt* crystallises in tufts of colourless needles; the *silver*, *mercurous* and *mercuric salts* are white precipitates; the *magnesium salt* is soluble in water.

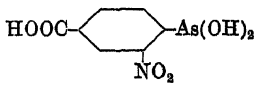
2-Bromo-4-carboxyphenylarsinic acid is obtained in 65 per cent. yield from 2-bromo-4-methylphenylarsinic acid by oxidation as described for the preceding acid. It forms colourless needles, unmelted at 317° C., slightly soluble in boiling water, almost insoluble in cold water.

2-Nitro-4-carboxyphenylarsinic acid.[1]—The preparation of this acid has already been described (p. 326). M'Cluskey has described, however, a modified method convenient for preparing large quantities of the acid. The *sodium salt* of the acid is very soluble in water. The *menthyl ester* is prepared by oxidising the menthyl ester of 2-nitro-4-carboxyphenylarsenious acid in acetone solution with 3 per cent. hydrogen peroxide; it is a white, crystalline substance, decomposing at 210° to 211° C., soluble in alcohol and chloroform, less soluble in ether, insoluble in petroleum ether. It gives a *sodium salt* crystallising with four molecules of water.

[1] M'Cluskey, *J. Amer. Chem. Soc.*, 1929, 51, 1462.

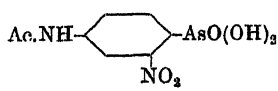
Reduction of 2-nitro-4-carboxyphenylarsinic acid in concentrated hydrochloric acid with either hypophosphorous acid, sulphur dioxide, hydroquinone or Camelite, yields *2-nitro-4-carboxyphenyldichloroarsine*, a light yellow, fluffy product, melting at 173° to 174° C.

2-Nitro-4-carboxyphenyldihydroxyarsine or **2-Nitro-4-carboxyphenylarsenious acid,**



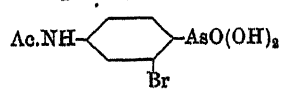
This is obtained either by hydrolysing the corresponding dichloroarsine or by reduction of the corresponding arsinic acid in water by means of sulphur dioxide in the presence of potassium iodide as catalyst. It is a light yellow substance, unmelted below 290° C. Its *menthyl ester* is prepared by refluxing the dichloroarsine with thionyl chloride, removing excess of the latter, adding menthol and continuing the heating. The product is a light yellow, crystalline substance, which gradually evolves a gas above 100° C., but has no sharp melting-point.[1]

2-Nitro-4-acetamidophenylarsinic acid,[2]



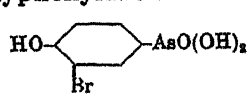
is prepared from diazotised 3-nitro-4-aminoacetanilide and copper arsenite. When boiled with 50 per cent. sulphuric acid it yields *m*-nitroaniline, and reduction with ferrous sulphate at 30° C. gives *2-amino-4-acetamidophenylarsinic acid.*

2-Bromo-4-acetamidophenylarsinic acid,



The preceding amino-compound is converted to the bromo-derivative by means of the diazo-reaction. The bromo-acid crystallises in hexagonal plates from hot water and is soluble in hot alcohol. The *barium* and *calcium salts* crystallise in rosettes of needles; the *magnesium salt* is amorphous. Hydrolysis of the acid yields *2-bromo-4-aminophenylarsinic acid*, forming colourless plates from hot water. This is soluble in hot alcohol, and gives amorphous *calcium* and *magnesium salts.*

3-Bromo-4-hydroxyphenylarsinic acid,



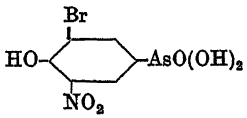
obtained from 3-amino-4-hydroxyphenylarsinic acid, crystallises in irregular plates, soluble in hot water and hot alcohol. The *calcium salt* is insoluble in hot water but very soluble in cold water. The *magnesium salt* is amorphous.

[1] 2-Nitro-4-methylphenylarsinic acid, which forms the starting-point for preparing the 2-nitro-4-carboxy-acids, is described on p. 177. The method given here differs in technique from that already described.

[2] Haythornthwaite, *J. Chem. Soc.*, 1929, p. 1011; compare German Patent, 267307; Fourneau, Navarro-Martin, and Tréfouël, *Ann. Inst. Pasteur*, 1923, p. 590.

3-Acetylamino-4-hydroxyphenylarsinic acid.[1]—The following salts of this acid have been obtained: *lithium salt*, $Li_2O_3As.C_6H_3(OH)(NH.CO.CH_3),2H_2O$, a colourless, amorphous powder; *calcium salt*, $CaO_3As.C_6H_3(OH)(NH.CO.CH_3),2H_2O$, forming colourless, highly refractive crystals; *barium salt*, $BaO_3As.C_6H_3(OH)(NH.CO.CH_3)$, colourless needles; *strontium salt*, $SrO_3As.C_6H_3(OH)(NH.CO.CH_3)$, colourless rhombohedra.

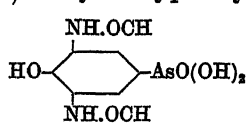
5-Bromo-3-nitro-4-hydroxyphenylarsinic acid,



263 grams of 3-nitro-4-hydroxyphenylarsinic acid are suspended in 800 c.c. of 95 per cent. methyl alcohol, 20 grams of iron added, the flask connected to a reflux condenser and a solution of 160 grams of bromine in 200 c.c. of methyl alcohol added dropwise, with frequent shaking. The mixture is cooled, filtered, and the filtrate treated with 10 volumes of water. The yellow bromo-acid separates, is washed with water and crystallised from the same solvent. The yield is 154 grams. The acid crystallises in yellow, microscopic plates, which start to decompose at about 280° C., but remain unmelted at 300° C. It is soluble in hot water, almost insoluble in cold water, sparingly soluble in dilute hydrochloric acid, readily soluble in dilute alkalis, acetone, methyl or ethyl alcohol, insoluble in ether and most other organic solvents.

5-Bromo-3-amino-4-hydroxyphenylarsinic acid is obtained by reducing the preceding compound with sodium hydrosulphite in alkaline solution in the presence of magnesium chloride. It forms colourless prisms, soluble in hot water, sparingly soluble in cold water, insoluble in dilute alkali, dilute hydrochloric acid, methyl and ethyl alcohols, acetone or ether. Acetylation of the amino-compound gives *5-bromo-3-acetamido-4-hydroxyphenylarsinic acid.* This derivative forms colourless prisms, darkening at 267° to 270° C., but remaining unmelted at 300° C. It is soluble in water, 10 per cent. hydrochloric acid, dilute alkalis, methyl and ethyl alcohols, but insoluble in ether.

3 : 5-Di-(formamido)-4-hydroxyphenylarsinic acid,

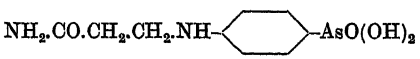


3 : 5-Diamino-4-hydroxyphenylarsinic acid, required for this preparation, is obtained by reducing the 3 : 5-dinitro-acid with sodium hydrosulphite at a low temperature. Formic acid is allowed to react with the diamino-acid at room temperature for twenty-four hours, the formamido-acid being produced. This forms short, colourless, spear-shaped needles, which commence to decompose rapidly at about 200° C., but are unmelted at 275° C. The acid is sparingly soluble in cold water, soluble in dilute aqueous sodium hydroxide, methyl or ethyl alcohol, insoluble in most other organic solvents, and decomposed by hydrochloric acid. The *sodium salt* has been prepared.

[1] Fisher and Raiziss, *J. Amer. Chem. Soc.*, 1929, 51, 527.

The following derivatives of similar type to the foregoing are known : 3 : 5-*Di*-(*acetamido*)-4-*hydroxyphenylarsinic acid*, forming clusters of colourless needles, darkening at 235° to 240° C., unmelted at 275° C. ; 3 : 5-*di*-(*propionylamino*)-4-*hydroxyphenylarsinic acid*, consisting of long, silky, colourless needles, melting at 197° to 198° C. to a dark red liquid ; 3 : 5-*di*-(*butyrylamino*)-4-*hydroxyphenylarsinic acid*, colourless needles, M.pt. 177° C. ; and 3 : 5-*di*-(*chloracetamido*)-4-*hydroxyphenylarsinic acid*, colourless needles, darkening at 200° C. and melting with decomposition at 210° to 211° C.

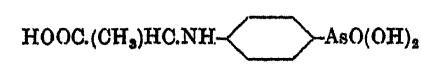
N-Phenyl-β-aminopropionamide-4-arsinic acid,[1]



The general method for the preparation of compounds of this type is as follows: One molecular equivalent of the amino-arylarsinic acid is dissolved in the calculated amount of normal sodium hydroxide solution to form the monosodium salt ; one and a half molecular equivalents of the halogenated propionamide are then added and the mixture boiled for five hours under reflux. Sufficient concentrated hydrochloric acid is added to the hot solution to hold any unchanged arsanilic acid in solution. Almost colourless crystals separate as the solution cools, the product being filtered off, washed with a little cold water and purified by solution in 2*N* sodium hydroxide, filtering and reprecipitating by the addition of concentrated hydrochloric acid. This process of purification is repeated until the product gives a negative result with R-salt. The yield of N-phenyl-β-aminopropionamide-4-arsinic acid is 35 to 40 per cent. This acid gives a *sodium salt* crystallising in fine, white needles, containing two molecules of water of crystallisation. Boiling with 2*N* sodium hydroxide until evolution of ammonia ceases converts the acid into *N-phenyl-β-aminopropionic acid-4-arsinic acid*, consisting of flake-like crystals, unmelted below 250° C. *N-Phenyl-β-aminopropionamide-2-methyl-5-arsinic acid* and *-2-methyl-4-arsinic acid* are prepared by the general method.

N-4-Methylcarbamidophenylarsinic acid, $CH_3.NH.CO.NH.C_6H_4.AsO(OH)_2$, is obtained from sodium *p*-arsanilate and methylcarbamyl chloride in 25 per cent. yield.

dl-N-Phenylalanine-4-arsinic acid,[2]



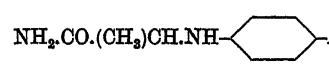
A solution containing 35 grams of α-bromopropionic acid in 38 c.c. of water is added to a hot solution of 50 grams of sodium *p*-aminophenylarsinate ($5H_2O$) in 165 c.c. of water, and the mixture boiled for eight hours. The product separates after standing for sixteen to forty hours in an ice-chest. Crystallisation from a large volume of boiling water, using decolorising charcoal, gives 16·75 grams of colourless needles, M.pt. 207° to 210° C. with decomposition. The acid is readily soluble in dilute mineral acids, acetic acid and hot alcohols, slightly soluble in acetone, insoluble in benzene and ether. In water it dissolves to the extent of about 0·5 per cent. in cold water and about 6 per cent. in boiling water, the solution reducing ammoniacal silver nitrate with

[1] Hamilton and Simpson, *J. Amer. Chem. Soc.*, 1929, 51, 3158.
[2] Gibson, Johnson, and Levin, *J. Chem. Soc.*, 1929, p. 479.

formation of a silver mirror. The *methyl ester* forms colourless acicular prisms, M.pt. 181° C. with slight decomposition, and is distinctly more soluble than the *ethyl ester*. The latter crystallises in doubly refracting prisms, M.pt. 175° to 177° C. with decomposition; it readily dissolves in ethyl alcohol or hot water.

Resolution of dl-N-Phenylalanine-4-arsinic acid.—The acid is converted into its *brucine salt*, which crystallises from water in large, colourless plates, containing seven molecules of water of crystallisation, and giving the value $[\alpha]-10{\cdot}61°$. This salt yields a *d-N-phenylalanine-4-arsinic acid* crystallising in colourless needles, melting with decomposition at 220° to 221° C. The *sodium salt* of this acid gives the value $[\alpha]+56{\cdot}40°$. The *disodium salt* of the corresponding *l-acid* gives $[\alpha]-55{\cdot}94°$. The *ethyl d-acid* melts at 275° to 276° C. with decomposition, and gives $[\alpha]+127{\cdot}9°$ in ethyl alcohol; its *sodium salt* gives $[\alpha]+103{\cdot}0°$. The *ethyl l-N-phenylalanine-4-arsinic acid* has M.pt. 275° to 276° C. with decomposition, $[\alpha]-125{\cdot}8°$ in ethyl alcohol, and its *sodium salt* $[\alpha]-102{\cdot}8°$. The corresponding *methyl esters* have values as follows: *methyl d-acid*, melts with decomposition at 277° to 278° C., *sodium salt* gives $[\alpha]+117{\cdot}6°$; *methyl l-acid*, M.pt. 277° to 278° C. with decomposition, *sodium salt* gives $[\alpha]-116{\cdot}3°$. These are separately converted into optically active amide-acids by means of ammonium hydroxide (density 0·88), the *amide-acid* from the *d-ester* melting with decomposition at 242° to 243° C., and its *sodium salt* showing the rotation $[\alpha]-13{\cdot}3°$, whilst the *amide-acid* from the *l-ester* has the same decomposition point and its *sodium salt* $[\alpha]+13{\cdot}9°$. (The rotations of the *sodium salts* of the acids derived from these esters are $+26{\cdot}6°$ and $-29{\cdot}5°$ respectively.)

dl-N-Phenylalanineamide-4-arsinic acid,



is obtained either from the methyl ester of *dl*-N-phenylalanine-4-arsinic acid by the action of ammonium hydroxide, or by boiling an aqueous solution of atoxyl with α-bromopropionamide. By the first method the product melts with decomposition at 233° to 240° C., by the second method the melting and decomposition point is 244° C. The *quinine salt* of the *dl-acid* gives the rotation $[\alpha]-123{\cdot}8°$. Resolution of this salt yields the *l-amide-acid*, consisting of colourless needles, decomposing and melting at 247° C., the *sodium salt* showing the rotation $[\alpha]-17{\cdot}88°$. The *d-amide-acid* shows a decomposition point of 247° C., and its *sodium salt* gives the value $[\alpha]+16{\cdot}5°$. (All the foregoing rotations are $[\alpha]^{20}_{5461}$ in water, except where alcohol is stated.)

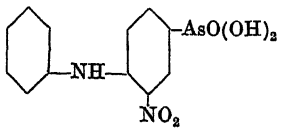
Resolution of dl-N-phenyl-β-methylglycineamide-p-arsinic acid.[1]—From the *sodium salt* of this acid by means of quinine the *l-acid*, $[\alpha]_D^{20}-15{\cdot}83°$, the *quinine salt* of which crystallises first, and the *d-acid*, $[\alpha]_D^{20}+16{\cdot}1°$, can be obtained. N-Phenyl-β-methylglycineamide-*p*-arsinic acid is the condensation product of α-bromopropionamide with *p*-aminophenylarsinic acid, and if the amide be replaced by α-bromopropionyl bromide, a 70 per cent. yield of *p-α-bromopropionamidophenylarsinic acid* results. Condensation of phenyl-α-bromoacetamide

[1] Fourneau and Nicolitch, *Bull. Soc. chim.*, 1928, [iv.], 43, 1232; see also this Vol., p. 235.

with *p*-aminophenylarsinic acid gives a 56 per cent. yield of *phenylphenylglycineamide-p-arsinic acid.*[1]

Diphenylamine Arsinic Acids.

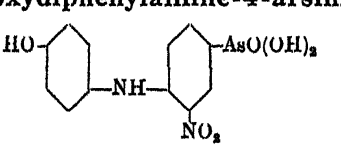
2-Nitrodiphenylamine-4-arsinic acid,[2]



28 grams of 4-chloro-3-nitrophenylarsinic acid in a mixture of 150 c.c. of water and 50 c.c. of 2*N* caustic soda are heated for sixteen to twenty hours on a steam-bath with 10 grams of aniline (5 per cent. in excess of two molecular equivalents). Some of the required acid separates and the remainder is precipitated by adding hydrochloric acid until the solution is acid to Congo red; the yield is almost quantitative. The crude product is converted to the *sodium salt* in concentrated aqueous solution and salted out with sodium chloride. After filtering off, the solid is dissolved in a large volume of water, the solution heated to boiling in the presence of charcoal, filtered, and the filtrate treated whilst hot with hydrochloric acid. The required acid separates as fine, yellow needles, sparingly soluble in boiling water, almost insoluble in cold water. It is more soluble in dilute acetic acid and readily soluble in the hot glacial acid.

2-Aminodiphenylamine-4-arsinic acid results in 80 per cent. yield when the foregoing acid is reduced with ferrous hydroxide at 80° to 90° C. It crystallises from hot water in white, rectangular plates, M.pt. 170° to 175° C., rapidly turning blue on exposure to air. The *monohydrochloride* forms long, slender needles from 2*N* hydrochloric acid, readily hydrolysed by water and slowly losing hydrogen chloride in air. Attempts to recrystallise the base from hot acetone yield a condensation product, which may be *2-isopropylideneaminodiphenylamine-4-arsinic acid* or *N-phenyl-2 : 2-dimethyl-2 : 3-dihydrobenziminazole.* Treatment of the base with nitrous acid gives, quantitatively, *N-phenylbenztriazole-5-arsinic acid.* Acetylation of the amino-acid yields *2-acetamidodiphenylamine-4-arsinic acid,* consisting of small, diamond-shaped plates. Boiling with 2*N* hydrochloric acid converts this into *N-phenyl-2-methylbenziminazole-5(6)-arsinic acid.* Nitration of the acetamido-acid yields *2' : 4'(?)-dinitro-2-acetamidodiphenylamine-4-arsinic acid,* crystallising from 50 per cent. acetic acid in clusters of fine, yellow needles.

2-Nitro-4'-hydroxydiphenylamine-4-arsinic acid,

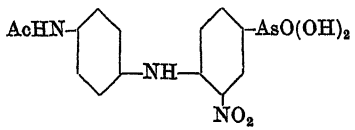


is the condensation product of 4-chloro-3-nitrophenylarsinic acid with *p*-aminophenol, the reaction being carried out as in the case of aniline. The acid crystallises from alcohol in reddish-brown needles.

[1] N-(Carbamylmethyl)-2-chloroarsanilic acid is dealt with in French Patent, 636658.
[2] Barber, *J. Chem. Soc.*, 1929, p. 471.

2-Amino-4'-hydroxydiphenylamine-4-arsinic acid, formed by the ferrous hydroxide reduction of the nitro-acid, crystallises from very dilute acetic acid in flat grey needles, very susceptible to atmospheric oxidation. Nitrous acid transforms the acid into *4'-hydroxy-1-phenyl-1 : 2 : 3-benztriazole-5-arsinic acid.*

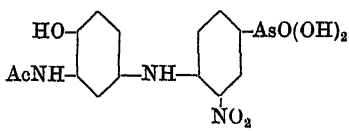
2-Nitro-4'-acetamidodiphenylamine-4-arsinic acid,



prepared from 4-chloro-3-nitrophenylarsinic acid and *p*-aminoacetanilide, crystallises in faintly red needles.

2-Amino-4'-acetamidodiphenylamine-4-arsinic acid forms irregular, flat needles, acetylation yielding *2 : 4'-diacetamidodiphenylamine-4-arsinic acid,* which crystallises in fine, colourless needles from dilute acetic acid. Hydrolysis of the latter compound yields *2 : 4'-diaminodiphenylamine-4-arsinic acid,* crystallising in long, slender prisms.

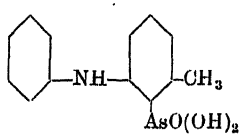
2-Nitro-3'-acetamido-4'-hydroxydiphenylamine-4-arsinic acid,



crystallises in fine, yellow needles from hot water; the *amino-acid* separates in fine, colourless needles from 50 per cent. acetic acid.

2'-Carboxy-2-nitrodiphenylamine-4-arsinic acid forms yellow needles from hot 50 per cent. acetic acid.

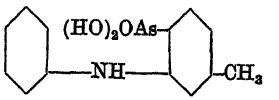
3-Methyldiphenylamine-2-arsinic acid,[1]



A mixture of 2-bromo-6-methylphenylarsinic acid, 11·8 grams, 3·75 grams of aniline, 8·8 grams of anhydrous potassium carbonate, 35 c.c. of amyl alcohol and a trace of copper powder, is boiled for five hours. It is then steam distilled to remove volatile products and the aqueous solution decolorised by charcoal, cooled, and carefully acidified with dilute hydrochloric acid. The yield is 8·2 grams (67 per cent.), recrystallisation from 50 per cent. acetic acid giving colourless needles melting with decomposition at 170° to 171° C. The acid is soluble in alcohol and acetic acid, almost insoluble in water. The *sodium salt* is precipitated on cooling its solution in 20 per cent. sodium hydroxide; the *silver, lead, mercurous* and *mercuric salts* are white, amorphous precipitates; the *ammonium, calcium* and *magnesium salts* are readily soluble in water; the *barium salt* crystallises from hot water in colourless plates.

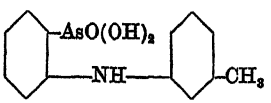
[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 767.

3-Methyldiphenylamine-6-arsinic acid,



This results in 63 per cent. yield when the same quantities of materials are used as in the preceding preparation, the 2-bromo-6-methylphenylarsinic acid being replaced by 2-bromo-4-methylphenylarsinic acid. The compound crystallises in colourless needles, melting with decomposition at 158° to 159° C., readily soluble in acetic acid, methyl and ethyl alcohols, and acetone, very sparingly soluble in water. The *sodium*, *potassium* and *ammonium salts* are readily soluble in water; the *silver*, *mercuric* and *lead salts* form white, flocculent precipitates, insoluble in cold or hot water; the *silver salt* is soluble in ammonia; the *mercurous*, *calcium* and *barium salts* are white precipitates, insoluble in cold but soluble in hot water. The *magnesium salt* is obtained when a solution of the ammonium salt is boiled with magnesia mixture.

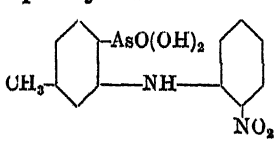
3-Methyldiphenylamine-6′-arsinic acid,



is obtained by condensing *o*-bromophenylarsinic acid with *m*-toluidine in the usual manner. It crystallises from dilute acetic acid in clusters of prismatic needles or elongated hexagonal prisms, M.pt. 141° to 142° C., readily soluble in acetic acid and ethyl alcohol, insoluble in water. The reduction products are given on p. 531.

Nitromethyldiphenylamine-arsinic Acids and their Derivatives.[1]

2-Nitro-3′-methyldiphenylamine-6′-arsinic acid,

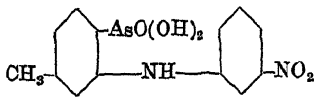


A mixture of 23·1 grams of 2-amino-4-methylphenylarsinic acid, 20·2 grams of *o*-bromonitrobenzene, 17·3 grams of anhydrous potassium carbonate, 100 c.c. of amyl alcohol and a trace of copper powder, is boiled for five hours. The amyl alcohol is removed in steam and the hot aqueous solution filtered, cooled and carefully acidified with concentrated hydrochloric acid. The acid is precipitated, a yield of 23·1 grams (66 per cent.) resulting. It is recrystallised from dilute acetic acid containing charcoal, and forms clusters of well-defined, golden-yellow, prismatic needles, melting with decomposition at 215° to 217° C. It is somewhat volatile, and its amphoteric nature is shown by its solubility in a mixture of alcohol and hydrochloric acid and in aqueous alkali. It is sparingly soluble in cold or hot alcohol, moderately soluble in acetone. The *alkali salts* form deep red solutions; the *magnesium salt* is formed only on boiling with magnesia mixture. When reduced in the usual manner the acid gives *2-nitro-3′-methyldiphenylamine*-6′-

[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 1229.

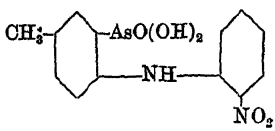
dichloroarsine, which is deposited in bright yellow, rhomb-shaped plates, M.pt. 129·5° to 130° C., readily soluble in hot benzene, moderately soluble in acetic acid, almost insoluble in ligroin.

3-Nitro-3′-methyldiphenylamine-6′-arsinic acid,



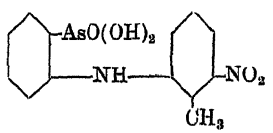
This is prepared using similar quantities to those in the preceding preparation but replacing the *o*-bromonitrobenzene by *m*-bromonitrobenzene. The yield is 73 per cent. and the acid separates from glacial acetic acid in long, yellow needles, M.pt. 191° to 192° C., very soluble in hot glacial acetic acid but only slightly soluble in the cold acid, soluble in a mixture of alcohol and concentrated hydrochloric acid. The use of *p*-bromonitrobenzene in this preparation gives rise to **4-nitro-3′-methyldiphenylamine-6′-arsinic acid** in 89 per cent. yield. This acid crystallises from glacial acetic acid in minute yellow prisms, M.pt. 276° C. with vigorous decomposition.

2-Nitro-4′-methyldiphenylamine-6′-arsinic acid,



is obtained in 65 per cent. yield when 2-amino-5-methylphenylarsinic acid and *o*-bromonitrobenzene are condensed in the usual manner. It crystallises from 50 per cent. acetic acid in deep bronze-yellow prismatic needles, M.pt. 226° to 227° C., decomposing at 234° C. It is slightly soluble in acetone and the *alkali salts* give deep red solutions.

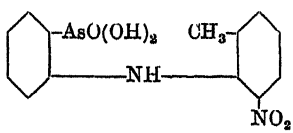
3-Nitro-2-methyldiphenylamine-6′-arsinic acid,



is the condensation product of 2-bromo-6-nitrotoluene with *o*-aminophenylarsinic acid. The yield is 68 per cent. and the acid crystallises from dilute acetic acid in very pale yellow, glistening plates, melting with decomposition at 223° to 224° C. It is readily soluble in hot alcohol. The *sodium salt* forms pale yellow, glistening needles, the *ammonium salt* yellow needles, the *barium salt* pale, truncated, flat prisms, and the *calcium salt* clusters of pale yellow needles. If the 2-bromo-6-nitrotoluene is replaced by 2-bromo-5-nitrotoluene in the preparation, **4-nitro-2-methyldiphenylamine-6′-arsinic acid** is obtained in 73 per cent. yield. This crystallises in thin, pale yellow needles, decomposing vigorously at 277° C., insoluble in water, alcohol and acetic acid, soluble in concentrated sulphuric acid, yielding an orange-coloured solution which rapidly changes to bluish-green, addition of nitric acid then causing the solution to become olive-green and finally orange. The *sodium salt* forms flat, golden-yellow needles, the *ammonium salt* orange-yellow needles, the *barium salt* thick, yellow

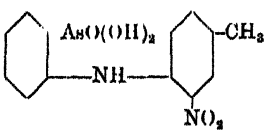
plates, the *calcium salt* orange-yellow plates, the *magnesium salt* is an amorphous, orange precipitate, the *mercurous* and *mercuric salts* yield tufts of yellow needles, and the *silver* and *lead salts* are flocculent, yellow precipitates. Replacement of the 2-bromo-6-nitrotoluene in the preparation of the 3-nitro-compound by 2-bromo-4-nitrotoluene gives a 56 per cent. yield of **5-nitro-2-methyldiphenylamine-6′-arsinic acid.** This crystallises in clusters of light yellow needles, melting with slight decomposition at 224° to 226° C. It is insoluble in water, slightly soluble in cold alcohol, somewhat readily soluble in hot alcohol. It dissolves in a mixture of alcohol and concentrated hydrochloric acid. The *alkali salts* dissolve readily in water, forming deep red solutions, the *barium salt* forms yellow plates, the *calcium salt* yields bright yellow needles, the *lead, silver* and *mercurous salts* are yellow precipitates, the *mercuric salt* crystallises in thin yellow needles, and the *magnesium salt* forms tufts of colourless needles. The acid may be transformed in the usual manner to *5-nitro-2-methyldiphenylamine-6′-dichloroarsine*, consisting of bright yellow, rhomb-shaped plates, M.pt. 173° C. The corresponding *6′-dibromoarsine* forms flat, yellow plates, M.pt. 164° C.

2-Nitro-6-methyldiphenylamine-6′-arsinic acid,



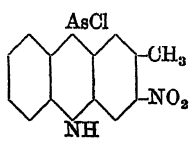
is formed by the condensation of 2-bromo-3-nitrotoluene with *o*-aminophenylarsinic acid. The yield is 35 per cent. and the acid crystallises in golden-yellow plates, M.pt. 195° to 197° C., readily soluble in boiling glacial acetic acid, but not very soluble in the cold solvent. It is sparingly soluble in alcohol or water, but dissolves rapidly in a mixture of alcohol and concentrated hydrochloric acid. It is very volatile, especially under reduced pressure. The *ammonium salt* is a microcrystalline yellow powder, the *sodium salt* forms yellow needles, and the *barium salt* separates in yellow plates. Reduction of the acid in the usual manner yields *2-nitro-6-methyldiphenylamine-6′-dichloroarsine*, consisting of small, orange-yellow prisms, M.pt. 104° to 105° C., readily soluble in benzene, acetone, chloroform and hot acetic acid, sparingly soluble in ligroin. *2-Nitro-6-methyldiphenylamine-6′-dibromoarsine* crystallises in slender, bronze-orange prisms, M.pt. 97° to 98° C. It has a similar solubility to the dichloroarsine.

2-Nitro-4-methyldiphenylamine-6′-arsinic acid,

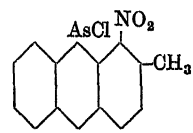


is obtained by condensing 4-bromo-3-nitrotoluene with *o*-aminophenylarsinic acid. It crystallises from dilute acetic acid in golden-yellow needles, melting with decomposition at 227° to 229° C. It is insoluble in water; solutions of its *alkali salts* are deep red. A *magnesium salt* is known. *2-Nitro-4-methyldiphenylamine-6′-dichloroarsine* forms short, orange-yellow prisms, M.pt. 91° to 93° C. It is readily soluble in benzene

and acetone and somewhat readily soluble in hot ligroin. If the 4-bromo-3-nitrotoluene in the foregoing preparation be replaced by 4-bromo-2-nitrotoluene, **3-nitro-4-methyldiphenylamine-6′-arsinic acid** results. This cannot be crystallised directly, but it is purified by means of its barium salt, when it yields bright yellow needles, M.pt. 165° to 166° C. The *barium salt* is chocolate-brown when anhydrous, but crystallises from boiling dilute ammonium hydroxide in golden-yellow, rhomb-shaped plates, containing six molecules of water of crystallisation. When reduced in the usual manner the acid gives *two isomeric compounds*, (I), consisting of orange-yellow prisms, M.pt. 257° to 258° C. with decomposition, and (II), consisting of bright red needles, M.pt. 225° to 226° C. with decomposition. These compounds probably have the following structures:

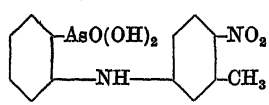


I



II

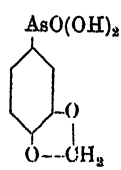
4-Nitro-3-methyldiphenylamine-6′-arsinic acid,



This is obtained in 86 per cent. yield by condensing 3-bromo-6-nitrotoluene with *o*-aminophenylarsinic acid in the usual manner. It is purified by means of its sodium salt and forms pale yellow needles with no definite melting-point, ultimately decomposing vigorously at 200° C. The *sodium salt* crystallises in golden-yellow needles, all salts except this and the *ammonium salt* appearing to be amorphous. Using 3-bromo-5-nitrotoluene in the condensation gives **5-nitro-3-methyldiphenylamine-6′-arsinic acid**, consisting of long, pale yellow needles, M.pt. 228° to 230° C. with decomposition. The yield is 88 per cent. The *ammonium salt* gives deep red solutions in water, the *calcium salt* crystallises in clusters of yellow needles, the *barium salt* forms yellow plates, the *silver*, *mercurous*, *mercuric* and *lead salts* are amorphous, yellow precipitates, the *sodium salt* is deep reddish-brown, and the *magnesium salt* forms clusters of yellow needles.

3 : 4-*Methylenedioxyphenylarsinic Acid and its Derivatives.*[1]

3 : 4-Methylenedioxyphenylarsinic acid,

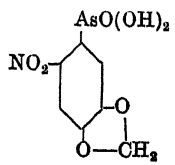


25 grams of 4-aminopyrocatechol methylene ether hydrochloride in 100 c.c. of hydrochloric acid (16 per cent.) at 0° C. are diazotised with

[1] Balaban, *J. Chem. Soc.*, 1929, p. 1088.

22 c.c. of 10 per cent. sodium nitrite solution. The diazo-solution is added to a sodium arsenite solution containing 18 grams of arsenious oxide, 20 grams of sodium hydroxide and 200 c.c. of water. After filtration the liquid is acidified to Congo red by concentrated hydrochloric acid, when 14·7 grams (41·7 per cent.) of the required acid slowly separate. Recrystallisation from boiling water yields colourless, silky rhomboids, containing $\frac{3}{4}H_2O$, and decomposing at 270° C. after previous darkening. The acid is soluble in cold 80 per cent. formic acid, moderately soluble in glacial acetic acid or hot alcohol. The *calcium salt* forms bunches of fine needles, the *barium salt* is microcrystalline, and the *magnesium salt* is amorphous. The acid is very stable towards boiling concentrated hydrochloric acid and 25 per cent. sodium hydroxide solution. Reduction with sodium hydrosulphite at 60° C. gives a 65 per cent. yield of *arsenopyrocatechol methylene ether* as a pale yellow, amorphous, insoluble powder.

6-Nitro-3 : 4-methylenedioxyphenylarsinic acid,



The foregoing acid, 30·75 grams, when nitrated at 0° C. and the solution poured on ice and made just acid to Congo red with anhydrous sodium carbonate, gives 21·6 grams (59·5 per cent. yield) of the nitro-acid. The latter crystallises from 2*N* acetic acid in pale brown, anhydrous spikes, and from water in short, stout prisms, melting at 231° C. with decomposition, and insoluble in alcohol. The *magnesium salt* is amorphous, the *calcium salt* forms irregular transparent plates, and the *barium salt* is microcrystalline.

6-Amino-3 : 4-methylenedioxyphenylarsinic acid is obtained by reducing the nitro-acid at 70° C. with ferrous sulphate, the yield being 60·5 per cent. It crystallises from boiling water in long, colourless, fine, silky, anhydrous needles, readily soluble in 2*N* hydrochloric acid, soluble in 80 per cent. formic acid, moderately soluble in acetic acid, almost insoluble in alcohol. The *magnesium salt* is amorphous and the *calcium salt* forms irregular prisms. When reduced, the acid yields **6 : 6′-diaminoarsenopyrocatechol methylene ether,** a bright yellow, amorphous powder, soluble in hydrochloric acid. Acetylation of the amino-acid yields *6-acetamido-3 : 4-methylenedioxyphenylarsinic acid*, which crystallises from 2*N* acetic acid in colourless, rectangular, anhydrous prisms, moderately soluble in water, sparingly soluble in glacial acetic acid, and yielding an amorphous *magnesium salt.*

Electrolytic Reduction of Arylarsinic Acids.[1]

The reduction of 3-nitro-4-hydroxyphenylarsinic acid to 3 : 3′-diamino-4 : 4′-dihydroxyarsenobenzene by electrolytic methods has already been dealt with on p. 373. If the operation is carried out using a platinum, nickel or copper cathode, the arsinic acid group is not reduced. In this way the foregoing arsinic acid gives *3 : 3′-azoxy-4 : 4′-dihydroxy-*

[1] Matsumiya and Nakata, *Mem. Coll. Sci. Kyōtō*, 1929, A, 12, 63.

phenyl-1 : 1′-*diarsinic acid*, darkening at 210° C. and decomposing without melting, also 3-amino-4-hydroxyphenylarsinic acid, and traces of arsine. 3-Nitro-4-aminophenylarsinic acid, reduced using a copper cathode, gives 3 : 4-diaminophenylarsinic acid, darkening at 140° C. and melting with decomposition at 158° C. *p*-Aminophenylarsinic acid, reduced in the presence of hydrochloric acid, and using a mercury cathode, yields *p*-aminophenylarsine hydrochloride or 4 : 4′-diaminoarsenobenzene dihydrochloride, the result depending upon whether the concentration of acid is below or above 8*N* (compare p. 343). Reduction of *p*-hydroxyphenylarsinic acid gives *p*-hydroxyphenylarsine or 4 : 4′-dihydroxyarsenobenzene at acidities below or above 4*N*, respectively.

Arsenical Compounds containing Sulphur.

Derivatives of Arylthioarsinous Acids.[1]

Di(carboxymethyl) - 4 - aminophenylthioarsinite, $NH_2.C_6H_4.As(S.CH_2.CO_2H)_2$. — To obtain this compound 4-aminophenylarsinic acid, 2·2 grams, is added to a neutral solution of 3·8 grams of thiolacetic acid in 40 c.c. of normal sodium hydroxide solution. The arsinic acid dissolves and the solution remains neutral. Acidification with acetic acid causes the thioarsinite to crystallise in needles, M.pt. 142° to 143° C. It is sparingly soluble in cold water, more readily soluble in hot water, readily soluble in glacial acetic acid.

Di(carbethoxymethyl)-4-aminophenylthioarsinite.—A solution of 2·2 grams of 4-aminophenylarsinic acid in 20 c.c. of 2*N* hydrochloric acid is stirred with 5 grams of ethyl thiolacetate and after sixty minutes the hydrochloride of the required ester is collected. This is washed free from ethyl dithiodiacetate with ether, and recrystallised as *hydrochloride* from hydrochloric acid. It forms needles, M.pt. 100° to 105° C., soluble in but hydrolysed by water; it is soluble in alcohol and acetic acid but insoluble in ether. The *free base* has only been obtained as an oil, which is hydrolysed by cold alkali, the preceding di(carboxymethyl)thioarsinite being formed.

Di(carbamylmethyl) - 4 - aminophenylthioarsinite may be obtained by the action of ammonium hydroxide on the preceding ester or by the interaction of 4-aminophenylarsinic acid and thiolacetamide in hot water. It crystallises as colourless needles, M.pt. 145° C., sparingly soluble in cold water, readily soluble in hot water and glacial acetic acid.

Di(carboxymethyl)-3-amino-4-hydroxyphenylthioarsinite.—This is prepared from 3-amino-4-hydroxyphenylarsinic acid by the method used for the 4-amino-compound. The acid crystallises as colourless, prismatic needles, M.pt. 157° to 158° C., sparingly soluble in cold water or alcohol, more readily soluble in these solvents when hot, and readily soluble in glacial acetic acid.

Di(carbamylmethyl)-3-amino-4-hydroxyphenylthioarsinite forms needles, M.pt. 132° to 133° C.

Di(β-carboxy-β-aminoethyl)-3-amino-4-hydroxyphenylthioarsinite is obtained by the interaction of 3-amino-4-hydroxyphenylarsinic acid and cysteine hydrochloride; it crystallises in fine, matted needles.

Di(carboxymethyl) - 5 - acetamido - 2 - hydroxyphenylthioarsinite melts at 172° to 174° C.

[1] Barber, *J. Chem. Soc.*, 1929, p. 1020; compare American Patent, 1677392.

Di(carboxymethyl) - 4 - carbamylmethylaminophenylthioarsinite crystallises in long, slender prisms, M.pt. 90° C. The *sodium salt* forms square plates.

Di(carboxymethyl) - 8 - acetamido - 3 - hydroxy - 1 : 4 - benzisoxazine-6-thioarsinite crystallises in needles melting at 212° C. with decomposition.

Di(carbamylmethyl) - 8 - acetamido - 3 - hydroxy - 1 : 4 - benzisoxazine-6-thioarsinite forms needles, M.pt. 233° to 235° C.

Di(β - carboxy - β - aminoethyl) - 8 - acetamido - 3 - hydroxy - 1 : 4-benzisoxazine-6-thioarsinite crystallises in fine, matted needles, which set to a gel-like substance.

Di(β - hydroxyethyl) - 8 - acetamido - 3 - hydroxy - 1 : 4 - benzisoxazine-6-thioarsinite crystallises in needles.

Di(carbamylmethyl) - o - bromophenylthioarsinite melts at 137° to 138° C.[1]

It has been suggested [2] that the production of thioarsinites may be used as a method for identifying arsinic acids. In normal cases the arsinic acid is added to a hot aqueous solution of thiolacetamide (4 mols.); it dissolves, and the thioarsinite crystallises on cooling. The reaction is represented by the equation

$$Ar.AsO(OH)_2 + 4SH.CH_2.CO.NH_2 = Ar.As(S.CH_2.CO.NH_2)_2 + (.S.CH_2.CO.NH_2)_2 + 3H_2O$$

If the arsinic acid is sparingly soluble its sodium salt may be used, and with nitro-compounds the reaction is conducted in the cold to minimise reduction of the nitro-group by the thiol-compound. The thioarsinites are recrystallised from hot water or dilute acetic acid, and may be estimated rapidly by direct titration with standard iodine solution:

$$Ar.As(S.CH_2.CO.NH_2)_2 + 2I_2 + 3H_2O = Ar.AsO(OH)_2 + (.S.CH_2.CO.NH_2)_2 + 4HI$$

The following table gives the melting-points and molecular weights of some thioarsinites:

Arsinic acid.	Thioarsinite.		Molecular weight.	
	M.pt., °C.	Formula.	Calc.	Observed.
Phenyl-	129–130	$C_{10}H_{13}O_3N_2S_2As$	332	331
2-Aminophenyl-	140	$C_{10}H_{14}O_3N_3S_2As$	347	351
4-Aminophenyl-	145	$C_{10}H_{14}O_3N_3S_2As$	347	347
2-Hydroxyphenyl-	161–163	$C_{10}H_{13}O_4N_2S_2As$	348	348
4-Hydroxyphenyl-	160–162	$C_{10}H_{13}O_4N_2S_2As$	348	351
3-Amino-4-hydroxyphenyl-	132–133	$C_{10}H_{14}O_4N_3S_2As$	363	363
3-Acetamido-4-hydroxyphenyl-	176	$C_{12}H_{16}O_4N_3S_2As$	405	405
5-Acetamido-2-hydroxyphenyl-	188	$C_{12}H_{16}O_4N_3S_2As$	405	408
3-Amino-4-methylaminophenyl-	141–143	$C_{11}H_{17}O_2N_4S_2As$	382	376
4-Chlorophenyl-	134–136	$C_{10}H_{12}O_3N_2ClS_2As$	366·5	371
4-Chloro-3-nitrophenyl-	142–143	$C_{10}H_{11}O_4N_3ClS_2As$	411·5	418
3 : 5-Diamino-4-hydroxyphenyl-	159–161	$C_{10}H_{15}O_3N_4S_2As$	378	381
2 : 6-Diacetamidophenoxyacetic-4-	157	$C_{16}H_{21}O_7N_4S_2As$	520	532
8-Acetamido-3-hydroxy-1 : 4-benzisoxazine-6-	233–235	$C_{14}H_{17}O_5N_4S_2As$	460	464

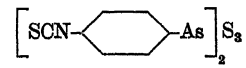
[1] Barber, *J. Chem. Soc.*, 1929, p. 2335.

[2] Barber, *ibid.*, p. 1024.

Sulphur Derivatives derived from Aminoarylarsinic Acids.[1]

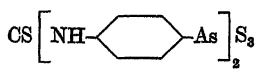
The following arsenicals containing sulphur are prepared by the condensation of aminophenylarsinic acid with carbon disulphide in the presence of alcohol and sodium hydroxide, the thiocarbonyl group entering the amino-group, and the sulphides formed attacking the arsinic acid group, giving thioarsenates, which yield amorphous sulphides on acidification.

p-p′-Dithiocarbiminophenylarsenic sesquisulphide,



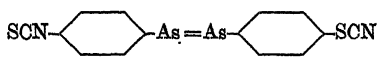
22 grams of *p*-arsanilic acid, 60 grams of carbon disulphide and 200 c.c. of ethyl alcohol are boiled for two hours. After cooling, 50 c.c. of 25 per cent. sodium hydroxide are added and boiling continued for four hours. The alcohol and carbon disulphide are then removed by distillation, the residue dissolved in warm water and the solution acidified to Congo red by hydrochloric acid. The precipitated sesquisulphide is dissolved in 20 per cent. boiling sodium carbonate solution, the solution treated with charcoal, the sulphide again precipitated and treated with carbon disulphide to remove free sulphur. The sesquisulphide is a pale yellow, amorphous solid, insoluble in water, acids and organic solvents, but soluble in excess of cold sodium hydroxide solution or in excess of boiling sodium carbonate solution.

Diphenylthiourea-p-p′-arsenic sesquisulphide,



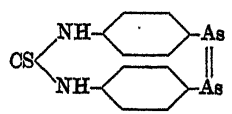
results when 10 grams of the foregoing compound are boiled for six hours with 50 c.c. of 25 per cent. sodium hydroxide solution and the cooled solution acidified to Congo red by hydrochloric acid. The product is a pale yellow, amorphous solid, resembling the preceding compound in solubility.

p-p′-Dithiocarbiminoarsenobenzene,



30 grams of *p-p′*- dithiocarbiminophenylarsenic sesquisulphide are mixed with 300 c.c. of water and just sufficient sodium hydroxide added to effect solution. Sodium hyposulphite (375 grams) and 7·5 grams of sodium hydroxide are dissolved in 3000 c.c. of water and this solution mixed with the preceding one and maintained at 55° C. for sixty minutes. The precipitated arseno-compound is washed with water and dried in a vacuum over concentrated sulphuric acid. The yield is 18 grams, or 74 per cent. The compound is a light yellow, amorphous solid, soluble in 5 per cent. sodium hydroxide solution.

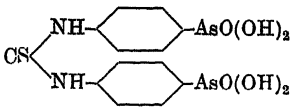
p-p′-Arseno(diphenylthiourea),



[1] Everett, *J. Chem. Soc.*, 1929, p. 670.

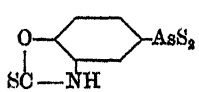
The reduction of *p*-*p*′-dithiocarbiminophenylarsenic sesquisulphide is carried out as before, except that 100 c.c. of 25 per cent. sodium hydroxide solution are added and the temperature kept at 90° C. The yield of arseno-compound by this method is 40 per cent. The compound may also be produced by reducing diphenylthiourea-*p*-*p*′-arsenic sesquisulphide or diphenylthiourea-*p*-*p*′-diarsinic acid with sodium hyposulphite, the yields being 62 per cent. and 71 per cent., respectively. *p*-*p*′-Dithiocarbiminoarsenobenzene, when boiled with 20 per cent. sodium hydroxide, is transformed to the required arseno-compound. The latter is an amorphous, orange solid, soluble in sodium hydroxide.

Diphenylthiourea-p-p′-diarsinic acid,



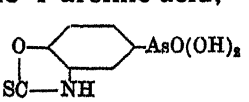
This acid may be prepared in three ways: (1) Six grams of thiocarbonyl chloride are gradually added with vigorous shaking to 22 grams of *p*-arsanilic acid dissolved in 180 c.c. of normal sodium hydroxide, alkalinity being maintained by the addition of 20 per cent. sodium hydroxide solution as required. The filtered solution, after treatment with charcoal, is acidified to Congo red by hydrochloric acid, which precipitates the diarsinic acid. The latter is dissolved in sodium bicarbonate solution, reprecipitated, and finally recrystallised from 50 per cent. alcohol. The yield is 17 grams, or 69 per cent. (2) *p*-*p*′-Arseno(diphenylthiourea), 3·8 grams, is stirred with 20 c.c. of water and *N*/10 iodine added gradually until no more is absorbed (500 c.c.). A solution of the precipitate in 60 c.c. of 6 per cent. aqueous sodium bicarbonate is treated with charcoal, filtered, and acidified to Congo red with hydrochloric acid. The yield is 2 grams, or 42 per cent. (3) Diphenylthiourea-*p*-*p*′-arsenic sesquisulphide, 4·7 grams, is stirred with 20 c.c. of water and 300 c.c. of *N*/10 iodine added. The precipitate obtained is then treated as in method (2). The diarsinic acid obtained by the foregoing methods forms rosettes of fine, pale yellow needles, insoluble in cold water or dilute mineral acids, sparingly soluble in hot water, moderately soluble in warm alcohol. The *calcium* and *magnesium salts* are amorphous, and the *barium salt* is microcrystalline.

1-Thiobenzoxazolone-4-arsenic disulphide,



This is obtained from 3-amino-4-hydroxyphenylarsinic acid and carbon disulphide in the usual manner, the yield being 64 per cent. It is soluble in solutions of sodium cyanide, this being a characteristic property of 1-thiobenzoxazolone.

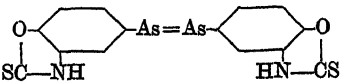
1-Thiobenzoxazolone-4-arsinic acid,



may be obtained: (1) From 3-amino-4-hydroxyphenylarsinic acid as described under 2-thiolbenziminazole-5-arsinic acid, the yield being

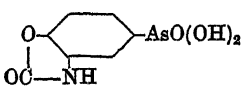
78 per cent. (2) From 4 : 4′-arseno-(1-thiobenzoxazolone) as described under 2-thiolbenziminazole-5-arsinic acid, the yield being 45 per cent. (3) From 1-thiobenzoxazolone-4-arsenic disulphide as described under 2-thiolbenziminazole-5-arsinic acid, the yield in this case being 30 per cent. The compound forms small, pale yellow needles, insoluble in cold water or dilute mineral acids, sparingly soluble in hot water, moderately soluble in warm alcohol. The *magnesium salt* is amorphous.

4 : 4′-Arseno-(1-thiobenzoxazolone),



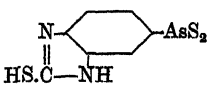
is obtained in 70 per cent. yield when the preceding acid is reduced with sodium hyposulphite, or in 73 per cent. yield from 1-thiobenzoxazolone-4-arsenic disulphide. It is a light yellow, amorphous powder, soluble in sodium hydroxide solution and very soluble in dilute solutions of sodium cyanide.

Benzoxazolone-4-arsinic acid,



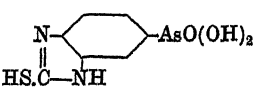
isolated as already described (p. 296), has now been formed by the interaction of 1-thiobenzoxazolone-4-arsinic acid and *N*/2 iodine, as described under diphenylurea-*p*-*p*′-diarsinic acid. The yield by the latter method is 77 per cent., and the product forms prismatic needles, insoluble in cold water or dilute mineral acids and readily soluble in hot water or alcohol.

2-Thiolbenziminazole-5-arsenic disulphide,



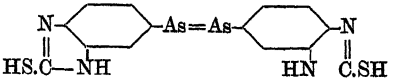
is prepared in 64 per cent. yield from 3 : 4-diaminophenylarsinic acid, the method being similar to that used for *p*-*p*′-dithiocarbiminophenylarsenic sesquisulphide.

2-Thiolbenziminazole-5-arsinic acid,



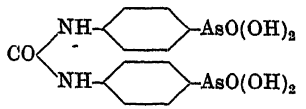
may be obtained by the interaction of 3 : 4-diaminophenylarsinic acid and thiocarbonyl chloride, or by treating 5 : 5′-arseno-(2-thiolbenziminazole) with *N*/10 iodine. The latter arseno-compound may be replaced by 2-thiolbenziminazole-5-arsenic disulphide. The arsinic acid, isolated by these methods, crystallises in small, buff-coloured needles, insoluble in cold water or dilute mineral acids, moderately soluble in hot water, readily soluble in warm alcohol. The *calcium salt* forms rosettes of needles and the *barium salt* fine needles ; the *magnesium salt* is amorphous.

5 : 5′-Arseno-(2-thiolbenziminazole),



is the reduction product of 2-thiolbenziminazole-5-arsenic disulphide or thiolbenziminazole-5-arsinic acid, and is a light yellow, amorphous powder, readily soluble in dilute solutions of sodium hydroxide.

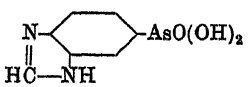
Diphenylurea-p-p′-diarsinic acid,



obtained from *p*-arsanilic acid and carbonyl chloride (see *sym.*-diphenylcarbamide-4 : 4′-diarsinic acid, p. 210), has now been isolated by the action of *N*/2 iodine on diphenylthiourea-*p*-*p*′-diarsinic acid in sodium bicarbonate solution. It forms small, white needles ; the *calcium* and *magnesium salts* are amorphous ; the *barium salt* forms rosettes of small prisms. Reduction with sodium hyposulphite yields *p*-*p*′-*arseno*(*diphenylurea*), an amorphous, orange powder, insoluble in sodium hydroxide solution.

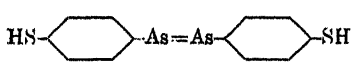
5 : 5′-Arseno-(2 : 3-dihydrobenziminazolone) is obtained by reducing 2 : 3-dihydrobenziminazolone-5-arsinic acid with sodium hyposulphite. It is an amorphous, yellow powder, insoluble in sodium hydroxide solution.

Benziminazole-5-arsinic acid,



is prepared from 2-thiolbenziminazole-5-arsinic acid by the action of *N*/2 iodine. It forms rosettes of needles, insoluble in cold water, sparingly soluble in hot water or alcohol, readily soluble in dilute mineral acids. The *magnesium salt* is amorphous and the *barium* and *calcium salts* are microcrystalline.

4 : 4′-Dithiolarsenobenzene,[1]



is obtained by adding diazotised *p*-aminophenylarsinic acid to an alkaline solution of potassium ethyl xanthate and hydrolysing the intermediate *p*-xanthyldiazobenzenearsinic acid (potassium salt) with hydrochloric acid. It decomposes above 280° C., and yields *disodium* and *dipotassium salts*, a *dihydrochloride* and a *disulphate*. It forms *additive compounds with* 1 molecule of *ethyl chloroformate*, 2 molecules of *picric acid*, 2 molecules of *perchloric acid*, and 2 molecules of *methyl iodide*. Acetylation of the arseno-compound produces a *diacetyl derivative*, whilst thionyl chloride forms a product which is hydrolysed by water to the substance $SO_2H.S.C_6H_4.As(\cdots SO_2H) : As(\cdots Cl).C_6H_4.S.SO_2H$, isolated as the *trisodium salt*. Methyl sulphate and 4 : 4′-dithiolarsenobenzene give 4 : 4′-*dimethyldithiolarsenobenzene*, and oxidation

[1] Krishna and Krishna, *J. Indian Chem. Soc.*, 1929, 6, 665.

of the original arseno-compound with chlorine in alcoholic suspension gives, probably, *p*-sulphophenylarsinic acid (p. 162). If 30 per cent. nitric acid is used for the oxidation, *p*-sulphophenylarsinic acid and *diphenyl disulphide*-4 : 4'-*diarsinic acid* are obtained. Oxidation with alkaline hydrogen peroxide gives *p*-thiolphenylarsinic acid, decomposing above 250° C.

Arsenicals containing the Benzthiazole Grouping.

The following benzthiazole arsenicals have recently been isolated.[1]—2-*o*-Hydroxyphenylbenzthiazole reacts with arsenic acid at 150° to 160° C., forming 2-*o-hydroxyphenylbenzthiazole*-5'-*arsinic acid*, melting with decomposition at about 315·5° C. This compound may also be prepared by application of the Bart reaction to 2 : 5'-amino-2'-hydroxyphenylbenzthiazole. Nitration of the arsinic acid with mixed acid gives the 3'(?)-*nitro-derivative*, M.pt. 297·7° to 298·7° C.; reduction with stannous chloride and hydrochloric acid in acetic acid solution yields 5(?) : 5'(?) - *diamino* - 4 : 4'-*dihydroxy* - 3 : 3' - *di* - (2 - *benzthiazolyl*) - *arsenobenzene dihydrochloride*. Reduction of 2-*o*-hydroxyphenylbenzthiazole-5'-arsinic acid by alkaline sodium hyposulphite gives 4 : 4'-*dihydroxy*-3 : 3'-*di*-(2-*benzthiazolyl*)-*arsenobenzene*, M.pt. 240·8° to 241·3° C.

2 - *o* - *p* - *Dihydroxyphenylbenzthiazole* - 5'(?) - *arsinic acid*.—This may be prepared from 2-*o*-*p*-dihydroxyphenylbenzthiazole and arsenic acid at 160° to 170° C., the product melting with decomposition at about 279·9° C. It is reduced by stannous chloride and hydrochloric and acetic acids to impure 4 : 6 : 4' : 6'-*tetrahydroxy*-3 : 3'-*di*-(2-*benzthiazolyl*)-*arsenobenzene*.

Arsenobenzenes.

The following arsenobenzenes are all yellow, amorphous powders, obtained by reducing the corresponding phenylarsinic acids with sodium hydrosulphite:[2] 4 : 4' - *Dibromoarsenobenzene*, 3 : 3' - *dibromo* - 4 : 4' - *diaminoarsenobenzene*, 2 : 2' - *dibromo* - 4 : 4' - *diaminoarsenobenzene*, 4 : 4' - *diacetamidoarsenobenzene*, 2 : 2' - *dibromo* - 4 : 4' - *diacetamidoarsenobenzene*. All the foregoing are insoluble in sodium hydroxide solution; the following are soluble: 3 : 3'-*Dibromo*-4 : 4'-*dihydroxyarsenobenzene*, 5 : 5' - *dibromo* - 3 : 3' - *diamino* - 4 : 4' - *dihydroxyarsenobenzene*, 5 : 5' - *dibromo*-3 : 3' - *diacetamido*-4 : 4' - *dihydroxyarsenobenzene*, 3 : 3' - *diamino* - 4 : 4' - *dianilinoarsenobenzene*,[3] 3 : 3' - *diamino* - 4 : 4' - *di* - *p* - *acetamidoanilinoarsenobenzene*. 3 - *Amino* - 4 - *hydroxy* - 4' - *propionamidaminoarsenobenzene dihydrochloride*[4] results when a mixture of 3-amino-4-hydroxyphenylarsinic acid and N-phenyl-β-aminopropionamide-4-arsinic acid in hydrochloric acid is reduced by hypophosphorous acid. Both it and the *free base* are yellow, the latter decomposing at 120° to 125° C.

Symmetrical arsenobenzenes are formed by reduction of the following compounds with sodium hypophosphite in the presence of hydriodic acid:[5] 3-Chloro-4-hydroxy-5-acetamidophenylarsinic acid, 2-*chloro*-4-

[1] Bogert and Hess, *Rec. trav. chim.*, 1929, 48, 904.
[2] Haythornthwaite, *J. Chem. Soc.*, 1929, p. 1011. [3] Barber, *ibid.*, p. 475.
[4] Hamilton and Simpson, *J. Amer. Chem. Soc.*, 1929, 51, 3158.
[5] British Patent, 296327 (1927).

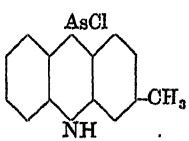
hydroxy-5-acetamidophenylarsinic acid (obtained by nitrating 2-4-dichlorophenylarsinic acid, heating the product with potassium hydroxide, reducing and acetylating), *2-methyl-4-hydroxy-5-acetamidophenylarsinic acid* (prepared by nitrating 2-methyl-4-acetamidophenylarsinic acid, heating the nitro-acid with potassium hydroxide to form the hydroxy-compound, which is then reduced and acetylated), and 3-methyl-4-hydroxy-5-acetamidophenylarsinic acid.[1]

Tetra-aryldiarsines.[2]

Quantitative yields of tetra-aryldiarsines may be obtained by treating diaryliodoarsines in ether or benzene solution with mercury, finely divided silver or zinc. The reaction takes place more readily in the case of mercury. Tetra-aryldiarsines in solution are colourless and stable towards light; they react instantaneously with iodine and potassium permanganate and rapidly absorb the amount of oxygen required for a peroxide of constitution $(R_2As.O.)_2$. Crystalline tetraphenyldiarsine, M.pt. 120° to 125° C., exhibits similar behaviour in solution, and is probably partly dissociated into free radicals. Diphenyliodoarsine and triphenylmethyl bromide in bromobenzene give diphenylbromoarsine and triphenylmethyl iodide.

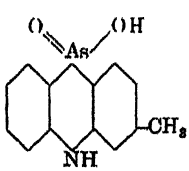
Phenarsazines.

10-Chloro-3-methyl-5 : 10-dihydrophenarsazine,[3]



3·45 grams of 3-methyldiphenylamine-6-arsinic acid, dissolved in a hot mixture of 15 c.c. of hydrochloric acid and 15 c.c. of alcohol containing a trace of iodine, are reduced by passing sulphur dioxide for a few minutes. The precipitated solid is filtered off, washed with a little alcohol and dried at 100° C. Recrystallisation from benzene produces slender yellow needles, M.pt. 216° to 216·5° C. The yield is 2·2 grams.

3-Methylphenarsazinic acid,



This derivative may be isolated from the preceding compound in two ways: (1) Two grams of 10-chloro-3-methyl-5 : 10-dihydrophenarsazine in 70 c.c. of cold acetone are treated with a cold solution of Chloramine-T (4·5 grams in 63 c.c. of water). The yellow colour of the solution

[1] General directions for the preparation of unsymmetrical arseno-compounds are given in American Patent, 1688351.

[2] Blicke and Smith, *J. Amer. Chem. Soc.*, 1929, 51, 2272.

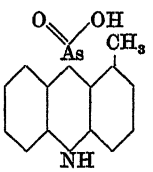
[3] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 767.

immediately disappears and 1·6 grams (81 per cent.) of crystals separate. After thirty minutes these are filtered off, washed with water, and crystallised from glacial acetic acid. The acid separates in fine, colourless needles, which retain a molecule of acetic acid of crystallisation even after drying over potassium hydroxide. It decomposes slightly at 316° C. (2) If the foregoing oxidation be carried out using 20 c.c. of boiling acetic acid and 4 c.c. of hydrogen peroxide (20 vols.), a 79 per cent. yield of product is obtained.

The *hydrochloride* of 3-methylphenarsazinic acid is prepared either by treating a hot alcohol solution of the acid with hydrochloric acid or by boiling 3-methyldiphenylamine-6-arsinic acid with an excess of concentrated hydrochloric acid. It crystallises in colourless needles or elongated plates, melting with decomposition and turning emerald-green at 232° to 233° C.

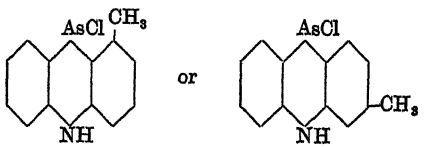
10-Bromo-3-methyl-5 : 10-dihydrophenarsazine is produced when 3-methylphenarsazinic acid is dissolved in a boiling mixture of alcohol and hydrobromic acid containing a trace of iodine and reduced by passing sulphur dioxide for a few minutes. It crystallises from benzene in rectangular orange plates or slender needles, M.pt. 206° to 208° C.

1-Methylphenarsazinic acid,



This acid is obtained by oxidising 10-chloro-1-methyl-5 : 10-dihydrophenarsazine in a similar manner to that described for the 3-methyl isomeride. It crystallises from acetic acid in colourless needles, melting with decomposition at 316° C. The *sodium salt* crystallises from 20 per cent. sodium hydroxide in fine, colourless needles. The *hydrochloride* crystallises in fine needles, melting with decomposition and turning emerald-green at 231° to 232° C.

1- and/or 3-Methyl-10-chloro-5 : 10-dihydrophenarsazine,[1]



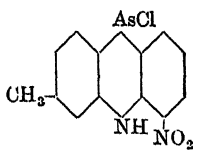
The reduction of 3-methyldiphenylamine-6′-arsinic acid by sulphur dioxide in hot alcoholic hydrochloric acid solution yields this product, M.pt. 216° to 217° C., obtained as a homogeneous body identical with the reduction product of 3-methyldiphenylamine-6-arsinic acid. The substance also results when arsenious chloride is condensed with phenyl-*m*-tolylamine.[2] Oxidation with hydrogen peroxide or Chloramine-T gives a product indistinguishable from synthesised 1-methyl- or 3-methyl-phenarsazinic acid. The action of concentrated hydrochloric acid on

[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 767; compare Razubaiev, *Ber.*, 1929, 62, [B], 1208.

[2] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 1473.

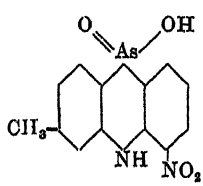
3-methyldiphenylamine-6′-arsinic acid gives a *hydrochloride*, melting with decomposition and turning emerald-green at 232° to 233° C. This is indistinguishable from the hydrochlorides of 1-methyl- and 3-methylphenarsazinic acids. Reduction of 1- and/or 3-methylphenarsazinic acid with sulphur dioxide in boiling alcoholic hydrobromic acid solution yields **1- and/or 3-methyl-10-bromo-5 : 10-dihydrophenarsazine**, apparently identical with the genuine 3-methyl compound. Hot 50 per cent. sulphuric acid appears to convert 3-methyldiphenylamine-6′-arsinic acid into 3-methylphenarsazinic acid. The solubilities of 10-chloro-1-methyl- and 10-chloro-3-methyl-5 : 10-dihydrophenarsazines in benzene are approximately the same, viz. about 0·3 per cent. at the ordinary temperature and about 3 per cent. at the boiling-point.

10-Chloro-4-nitro-7-methyl-5 : 10-dihydrophenarsazine,[1]



10·75 grams of 2-nitro-3′-methyldiphenylamine-6′-arsinic acid are reduced in the usual manner to the dichloroarsine and the latter boiled for ninety minutes with 140 c.c. of acetic acid. After cooling, the precipitate is filtered off and recrystallised from acetic acid (1 gram in 25 c.c. of boiling acid). The yield is 7·4 grams (72 per cent.), and the compound crystallises in sheaves of deep red, doubly refracting needles, M.pt. 201° to 202° C. It is readily soluble in hot acetone or benzene, sparingly soluble in these solvents when cold, and insoluble in ligroin.

4-Nitro-7-methylphenarsazinic acid,

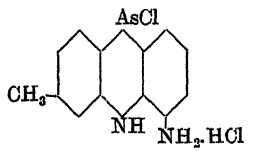


A fine suspension of 5·5 grams of the foregoing compound in 55 c.c. of acetic acid is mixed with 36 c.c. of hydrogen peroxide (20 vols.) and gently heated to boiling. The oxidation is complete after fifteen minutes' heating on the water-bath. The solution is then cooled and 110 c.c. of water added, the solid filtered off, washed with water, and dissolved in a hot dilute solution of sodium hydroxide. The hot liquor is filtered, and on cooling, rhomb-shaped plates of the orange-coloured *sodium salt* separate. The latter is dissolved in hot water and the solution acidified with hydrochloric acid, the precipitated nitro-acid (4 grams) filtered off, washed with water, dried at 140° C., and recrystallised from dilute acetic acid. It separates in yellow needles, melting with decomposition at 300° to 303° C. The acid is not very soluble in cold aqueous alkaline solutions, but dissolves in hot dilute aqueous sodium hydroxide to give a deep red solution. It dissolves in a mixture of alcohol and hydrochloric acid, is soluble in hot glacial acetic acid, sparingly soluble in acetone and alcohol, insoluble in water.

[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 1229.

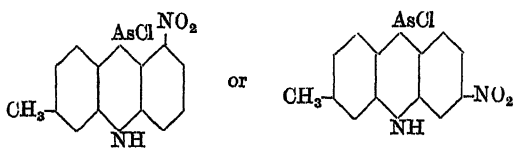
4-Amino-7-methylphenarsazinic acid results when the preceding nitro-acid in dilute aqueous sodium hydroxide is reduced by ferrous hydroxide. It separates from dilute acetic acid in short, colourless needles, unmelted at 310° C. It is readily soluble in acetic acid, somewhat soluble in concentrated hydrochloric acid, insoluble in ethyl alcohol or water. The *sodium salt* is precipitated as colourless needles when a strong aqueous solution of sodium hydroxide is added to it in warm aqueous solution and the mixture allowed to cool.

10-Chloro-4-amino-7-methyl-5 : 10-dihydrophenarsazine hydrochloride,



is isolated when the preceding compound, dissolved in a hot mixture of alcohol and hydrochloric acid containing a trace of iodine, is reduced with sulphur dioxide. It crystallises in clusters of greyish-yellow needles, melting with decomposition at 216° to 220° C., is sparingly soluble in cold alcohol, readily soluble in the hot solvent.

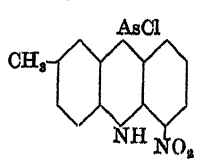
10-Chloro-1(or 3)-nitro-7-methyl-5 : 10-dihydrophenarsazine,



15 grams of 3-nitro-3′-methyldiphenylamine-6′-arsinic acid are dissolved in a boiling mixture of 90 c.c. of alcohol and 120 c.c. of hydrochloric acid containing a trace of iodine, and reduced with sulphur dioxide in the usual manner. The precipitate is filtered off, dried, and recrystallised from nitrobenzene, the product being thoroughly washed with benzene. It separates as small deep red plates, melting with decomposition at 253° to 255° C., almost insoluble in benzene, acetic acid, formic acid and acetone, slightly soluble in chloroform and somewhat readily soluble in *o*-dichlorobenzene and nitrobenzene.

10-Bromo-1(or 3)-nitro-7-methyl-5 : 10-dihydrophenarsazine is obtained in a similar manner to the preceding compound, the hydrochloric acid being replaced by hydrobromic acid (35 per cent.). It crystallises from *o*-dichlorobenzene in small deep red plates, melting with decomposition at 248° to 250° C.

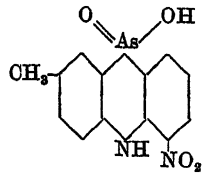
10-Chloro-4-nitro-8-methyl-5 : 10-dihydrophenarsazine,



This compound is the reduction product of 2-nitro-4′-methyldiphenylamine. It crystallises from acetic acid in minute prismatic needles, M.pt. 206° C., soluble in benzene or acetone, insoluble in ligroin, and

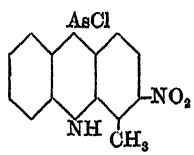
somewhat readily volatile under reduced pressure at the ordinary temperature.

4-Nitro-8-methylphenarsazinic acid,



This acid is the oxidation product of the preceding compound. It crystallises from slightly diluted acetic acid in small orange-yellow needles, decomposing at 297° to 300° C., soluble in a mixture of alcohol and hydrochloric acid, insoluble in alcohol or acetone. The *sodium salt* forms bronze-yellow hair-like needles when concentrated aqueous sodium hydroxide is added to its solution. The *ammonium salt* separates from solution in hot concentrated aqueous ammonia, on cooling, in thin, deep red needles. The *barium salt* forms clusters of reddish-yellow needles; the *calcium salt* forms clusters of orange-yellow needles; the *magnesium salt* is obtained as glistening, orange-coloured, rhomb-shaped plates. The *salts* of the *heavy metals* are amorphous.

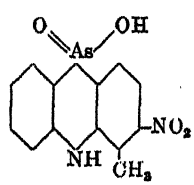
10-Chloro-3-nitro-4-methyl-5 : 10-dihydrophenarsazine,



This is obtained in the usual manner from 3-nitro-2-methyldiphenylamine-6′-arsinic acid. It crystallises from benzene in thick yellow prisms, M.pt. 216·5° C.

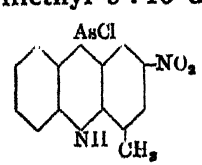
10-Bromo-3-nitro-4-methyl-5 : 10-dihydrophenarsazine separates from benzene as orange-yellow prisms, M.pt. 216·5° C.

3-Nitro-4-methylphenarsazinic acid,



Oxidation of the preceding chloro-compound with hydrogen peroxide in acetic acid solution yields this acid. It crystallises from a mixture of acetic acid and dilute hydrochloric acid in clusters of pale yellow needles, unmelted at 306° C. The *sodium salt* forms orange-yellow needles.

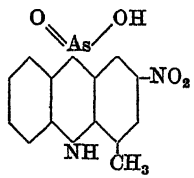
10-Chloro-2-nitro-4-methyl-5 : 10-dihydrophenarsazine,



This compound is obtained by reducing 4-nitro-2-methyldiphenylamine-6′-arsinic acid, or by reducing 2-nitro-4-methylphenarsazinic acid with sulphur dioxide. From *o*-dichlorobenzene it separates in deep yellow needles, melting with decomposition at 303° to 305° C., insoluble in benzene, acetic acid, alcohol and ether, but slightly soluble in acetone.

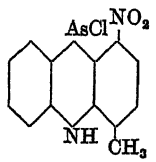
10-Bromo-2-nitro-4-methyl-5 : 10-dihydrophenarsazine crystallises from *o*-dichlorobenzene as orange-yellow plates, M.pt. 301° to 302° C. with decomposition. It is insoluble in benzene or ether, slightly soluble in alcohol, acetic acid, and acetone.

2-Nitro-4-methylphenarsazinic acid,



Either of the two preceding compounds yields this acid when oxidised. It crystallises from glacial acetic acid in clusters of pale yellow needles, unmelted at 306° C. The *ammonium salt* forms fine, yellow needles; the *barium salt* forms clusters of pale yellow needles; the *calcium salt* forms short, orange-yellow prisms; the *silver salt* is an amorphous, yellow precipitate; the *magnesium salt* forms thin, yellow prisms; the *mercurous* and *mercuric salts* are pale yellow, amorphous precipitates; the *lead salt* is amorphous and deep yellow; the *potassium salt* forms thin, golden-yellow prisms; and the *sodium salt* crystallises in tufts of orange-yellow needles.

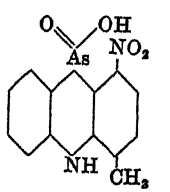
10-Chloro-1-nitro-4-methyl-5 : 10-dihydrophenarsazine,



Reduction of 5-nitro-2-methyldiphenylamine-6′-arsinic acid gives a dichloroarsine, which, on boiling in acetic acid solution for two hours, is transformed to this phenarsazine. The compound crystallises from glacial acetic acid as thick, deep red prisms, M.pt. 258° to 260° C., slightly soluble in hot acetic acid, sparingly soluble in acetone, alcohol and benzene, insoluble in ligroin, but readily soluble in boiling *o*-dichlorobenzene.

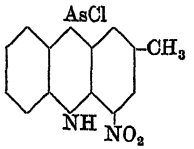
10-Bromo-1-nitro-4-methyl-5 : 10-dihydrophenarsazine separates from *o*-dichlorobenzene as stout, deep red prisms, decomposing vigorously at 272° C., only slightly soluble in the usual solvents.

1-Nitro-4-methylphenarsazinic acid,



obtained from 10-chloro-1-nitro-4-methyl-5 : 10-dihydrophenarsazine in the usual manner, is orange-yellow. It cannot be recrystallised directly, darkens at about 295° C., but remains unmelted at 305° C.

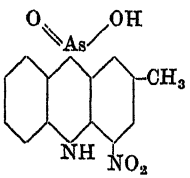
10-Chloro-4-nitro-2-methyl-5 : 10-dihydrophenarsazine,



resulting from the reduction of 2-nitro-4-methyldiphenylamine-6'-arsinic acid, crystallises from glacial acetic acid as deep red needles, M.pt. 187° to 188° C., readily soluble in acetone or benzene and only sparingly soluble in ligroin.

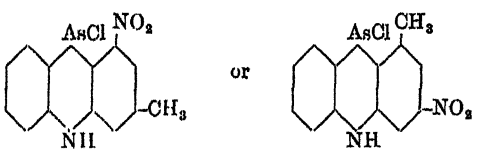
10-Bromo-4-nitro-2-methyl-5 : 10-dihydrophenarsazine separates from glacial acetic acid as deep crimson needles, M.pt. 186° to 188° C.

4-Nitro-2-methylphenarsazinic acid,



crystallises from 80 per cent. acetic acid in clusters of fine needles, which decompose violently at 305° C., and are insoluble in cold alcohol, sparingly soluble in hot alcohol, and apparently insoluble in cold or hot water. It exhibits amphoteric properties. The *ammonium salt* loses ammonia when its aqueous solution is boiled, the acid being precipitated; the *sodium salt* forms short, yellow plates; the *silver salt* is an orange-yellow, amorphous substance; the *barium salt* gives small, deep yellow, flat needles; the *calcium salt* yields long plates, arranged in clusters.

10-Chloro-1(or 3)-nitro-3(or 1)-methyl-5 : 10-dihydrophenarsazine,

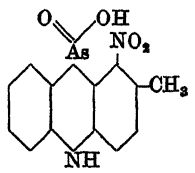
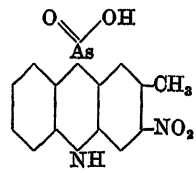


5-Nitro-3-methyldiphenylamine-6'-arsinic acid on reduction in the usual manner gives this compound. It crystallises from butyric acid in clusters of orange needles, melting with decomposition at 245° to 247° C., insoluble in the usual organic solvents, sparingly soluble in nitrobenzene.

10-Bromo-1(or 3)-nitro-3(or 1)-methyl-5 : 10-dihydrophenarsazine separates from a large volume of acetic acid as thick, red prisms, having an indefinite melting-point (237° to 242° C.).

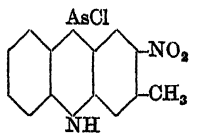
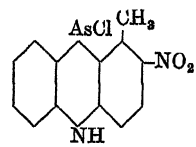
1(or 3)-Nitro-3(or 1)-methylphenarsazinic acid is the oxidation product of the foregoing chloro-compound, and crystallises from dilute acetic acid in clusters of short, yellow needles, unmelted at 300° C. The *sodium salt* is isolated as soft needles, sparingly soluble in dilute sodium hydroxide solution.

1- and 3-Nitro-2-methylphenarsazinic acids,

These two acids have not been distinguished from each other up to the present; they are the oxidation products of the two chlorodihydrophenarsazines (M.pts. 257° to 258° C. and 225° to 226° C.) obtained by the reduction of 3-nitro-4-methyldiphenylamine-6′-arsinic acid. The acids crystallise in minute, yellow needles, unmelted at 297° C. The *sodium salts* form thin, pale yellow needles, and the *barium salts* form orange needles.

10 - Chloro - 2 - nitro - 1(or 3) - methyl - 5 : 10 - dihydrophenarsazine,

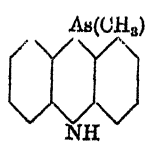

or


derived from 4-nitro-3-methyldiphenylamine-6′-arsinic acid, separates from acetic acid in orange-yellow prisms, melting with decomposition at 236° to 238° C. It is moderately soluble in acetone, sparingly soluble in alcohol and *sym.*-tetrachloroethane, insoluble in carbon tetrachloride.

2-Nitro-1(or 3)-methylphenarsazinic acid, formed by oxidising the preceding compound, crystallises from a mixture of acetic acid and dilute hydrochloric acid in yellow needles, unmelted at 308° C. It is insoluble in water and only sparingly soluble in acetic acid. The *calcium* and *barium salts* form pale yellow needles, and the *salts* of the *heavy metals* are amorphous. The *sodium salt* forms crimson needles.

Bromination of compounds of the phenarsazine type (which may be considered to be derivatives of *o*-aminophenylarsinic acid) leads to replacement of the arsenic group by bromine.[1]

10-Methyl-5 : 10-dihydrophenarsazine,[2]



When 10-chloro-5 : 10-dihydrophenarsazine is treated with magnesium methyl iodide the chlorine is replaced by the methyl group. The compound crystallises in colourless plates, M.pt. 107° to 108° C., soluble in the usual organic solvents, insoluble in water. Its solution in concen-

[1] Ellson, Gibson, and Johnson, *J. Chem. Soc.*, 1929, p. 1080.
[2] Seide and Gorski, *Ber.*, 1929, **62**, [B], 2186.

trated sulphuric acid is orange in colour. Chlorine in carbon tetrachloride converts the compound into a *perchloride*, a viscous, dark red oil. The latter on heating decomposes with formation of 10-chloro-5 : 10-dihydrophenarsazine. If the 10-methyl-compound is heated in a current of hydrogen chloride at 100° to 150° C., it yields methyldichloroarsine and diphenylamine; heating with an equimolecular quantity of hydrogen chloride in chloroform at 100° C. gives a similar result.

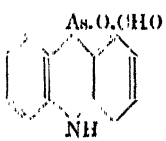
10-Ethyl-5 : 10-dihydrophenarsazine forms colourless needles, M.pt. 71° to 72° C., insoluble in water, soluble in organic solvents. It gives a dark orange solution in concentrated sulphuric acid.

10-Phenyl-5 : 10-dihydrophenarsazine is isolated as colourless prisms, M.pt. 148° to 149° C., readily soluble in acetone and ethyl acetate, less soluble in alcohol and carbon tetrachloride, insoluble in water. Its solution in concentrated sulphuric acid is dark red. Chlorine in carbon tetrachloride gives a *perchloride*, which decomposes on heating in a similar manner to the corresponding 10-methyl-compound. Hydrogen chloride at 150° to 180° C. converts the 10-phenyl-compound to phenyldichloroarsine and diphenylamine. 10-Chloro-5 : 10-dihydrophenarsazine, when treated with hydrogen chloride at 160° to 180° C., yields arsenic chloride and diphenylamine.

10-α-Naphthyl-5 : 10-dihydrophenarsazine forms colourless prisms, M.pt. 154° to 155° C., soluble in acetone and ethyl acetate, sparingly soluble in alcohol, insoluble in water. Its solution in concentrated sulphuric acid is carmine-red.

Meriquinoid Derivatives of 5 : 10-*Dihydrophenarsazines.*

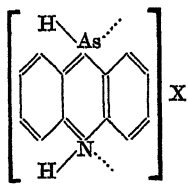
5 : 10-Dihydrophenarsazine formate,[1]



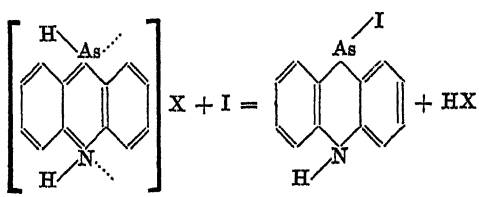
This results when 10-methoxy-5 : 10-dihydrophenarsazine or its oxide is dissolved in cold formic acid. It is unstable in air. Colourless needles are obtained when its acetone solution is evaporated in a vacuum over potassium hydroxide. It darkens towards 100° C. and becomes yellow but does not melt at about 150° C. When heated with alcohol or acetone it does not give a red coloration, but if formic acid is added to these solutions the colour develops, carbon dioxide is evolved and the liberated hydrogen reduces the compound to a coloured derivative. The use of spongy platinum, especially in the presence of hydrogen, stannous chloride, or zinc and acetic acid, also gives a coloured derivative. The latter reagents also produce intensely coloured solutions on exposure to the air for a sufficient time or when treated with a solution of unreduced 10-chloro-5 : 10-dihydrophenarsazine. These facts point to a quinhydrone structure for the coloured compound, but it has also been shown that 10-chloro-5 : 10-dihydrophenarsazine adds on oxygen, chlorine, bromine, iodine, nitric oxide and nitrogen dioxide, which points to an unsaturated structure. The high electrical con-

[1] Razubaiev, *Ber.*, 1929, 62, [B], 605.

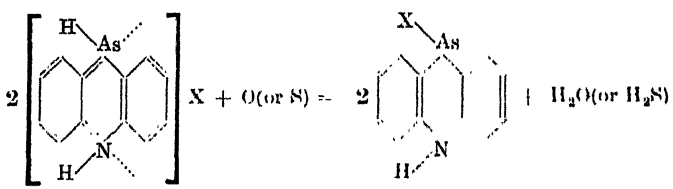
ductivity of the solutions also indicates the presence of a free radical. The meriquinoid structure of a half-free radical,



is preferred to a simpler constitution, since the absorption spectrum of the substance exhibits a broad band commencing in the green instead of lines which would be expected from a radical, and the compound behaves as a salt. Coloured solutions are obtained in formic and acetic acids, alcohol, acetone and phenol, from which the colour is not removed by shaking with benzene or other hydrocarbons. Furthermore, the electrical conductivity of 10-chloro-5 : 10-dihydrophenarsazine in formic acid undergoes a marked increase if the solution is warmed. Decolorisation of solutions of the semi-radical by halogen is effected by exactly one atom per molecule. The product of direct addition cannot be isolated, theoretical yields of 10-halogeno-5 : 10-dihydrophenarsazine being obtained regardless of the particular acid residue originally united with the nucleus (Cl, Br, O.CHO, HSO_3). The reaction takes place according to the equation:



From the action of halogen on the semi-radical of dihydrophenarsazine it appears that the hydrogen atom is very loosely bound to the arsenic, so that it is readily removed by oxygen or sulphur, half an atom of which is required for each molecule of the original compound:



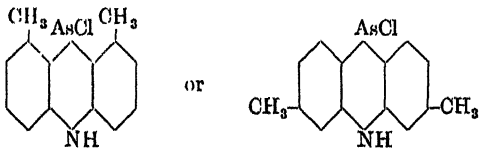
The regenerated arsazine can be again reduced by warm formic acid and the operation repeated. Oxygen reacts so rapidly that a part of the formic acid is converted to water and carbon dioxide, a portion of the compound being destroyed, so that the colour does not again appear when the solution is warmed.

10-Chloro-3(or 1)-methyl-, 10-chloro-3 : 7-dimethyl- and 10-chloro-3 : 4-benzo-5 : 10-dihydrophenarsazines also react with formic acid giving addition products containing one atom of hydrogen per molecule of

substance.[1] These products form intensely coloured solutions in formic acid, decolorised by atmospheric oxygen; warming the solutions causes reappearance of the colour, which may again be discharged by air. The added hydrogen is estimated by the amount of carbon dioxide evolved, calculated according to the equation $H.COOH=CO_2+H_2$. Addition of halogen to the reduced solutions causes disappearance of the colour after reaction of one atom of the halogen per molecule of substance. The following substances are not reduced by formic acid: 10-chloro-1 : 2 : 8 : 9-dibenzo- and 10-chloro-2 : 8-dinitro-5 : 10-dihydrophenarsazine, also 10-chlorophenoxarsine.

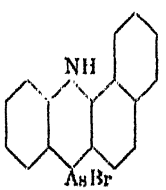
10-Bromo-3(or 1)-methyl-5 : 10-dihydrophenarsazine is obtained by the action of bromine on the reduced product formed by treating the 10-chloro-compound with formic acid. It forms yellow needles melting with decomposition at about 220° C. In a similar manner 10-*iodo*-3(or 1)-*methyl*-5 : 10-*dihydrophenarsazine* is isolated as orange-red needles, M.pt. 188° C.

10-Chloro-3 : 7(or 1 : 9)-dimethyl-5 : 10-dihydrophenarsazine,



is formed by condensing arsenic trichloride with di-*m*-tolylamine in *o*-dichlorobenzene. It crystallises from nitrobenzene in yellow crystals, M.pt. 250° to 252° C. When reduced by formic acid and the solution treated with iodine, 10-*iodo*-3 : 7(or 1 : 9)-*dimethyl*-5 : 10-*dihydrophenarsazine* is isolated, M.pt. 241° to 244° C.

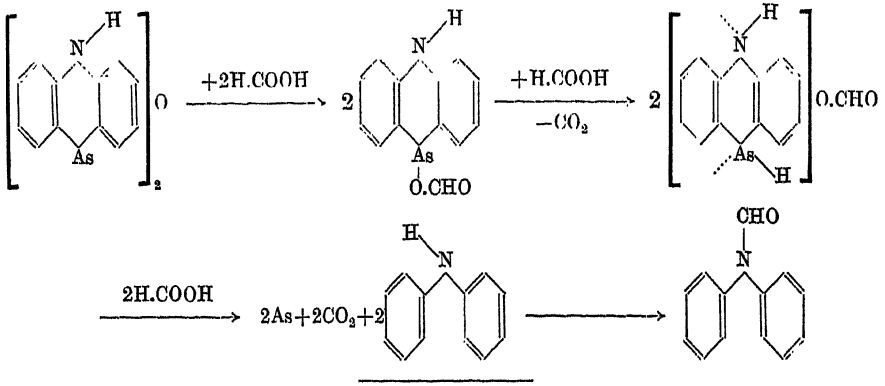
7-Bromo-7 : 12-dihydroisobenzophenarsazine,



The corresponding chloro-compound (p. 459) is reduced by formic acid and treated with bromine. The bromo-derivative melts at 209° C. In a similar way the 7-*iodo-compound* is formed. This crystallises in large, orange-red needles, M.pt. 202° to 203° C.

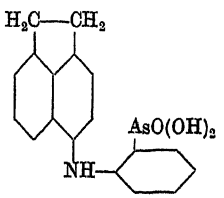
Two reductions of derivatives of 5 : 10-dihydrophenarsazine have recently been studied,[2] namely, that of 5 : 10-*dihydrophenarsazine oxide* and that of 2 : 8-*dimethyl*-5 : 10-*dihydrophenarsazine oxide*. In both cases arsenic is eliminated from the molecule, the reaction in the first case being supposed to take place as follows:

[1] Razubaiev, *Ber.*, 1929, 62, [B], 1208.
[2] Razubaiev, *ibid.*, 2075.



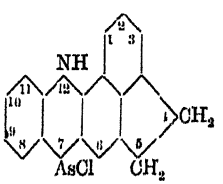
Compounds of the Phenarsazine Type containing the Acenaphthene Nucleus.

o-(3-Acenaphthylamino)phenylarsinic acid,[1]



30 grams of 3-aminoacenaphthene, 50·4 grams of *o*-bromophenylarsinic acid, 34·2 grams of anhydrous potassium carbonate, 150 c.c. of amyl alcohol and a trace of copper powder, when boiled together for five hours give a 17·5 per cent. yield of the crude acid. This is dissolved in dilute ammonium hydroxide and the solution treated with an equal volume of aqueous ammonia (density 0·880), when the *ammonium salt* separates in small, shining plates. From an aqueous solution of this salt the acid is recovered by means of acetic acid; recrystallisation from dilute acetic acid gives fine, colourless needles, melting with decomposition at 180° to 181° C.

7-Chloro-12 : 7-dihydroisoacenaphthabenzarsazine,



The foregoing compound, 7·2 grams, dissolved in a hot mixture of 40 c.c. of alcohol and 40 c.c. of concentrated hydrochloric acid containing a trace of iodine, is reduced by the passage of sulphur dioxide. A red precipitate separates and crystallisation from toluene yields deep orange-red rhombic plates, melting with decomposition at 241° C.

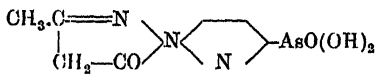
7 - Bromo - 12 : 7 - dihydroisoacenaphthabenzarsazine results when the hydrochloric acid used in the preceding preparation is replaced

[1] Gibson and Johnson, *J. Chem. Soc.*, 1929, p. 1621.

by hydrobromic acid (38 per cent.). The compound forms deep orange-red rhombic prisms, melting with decomposition at 244° to 246° C.

Pyridine Derivatives.[1]

2-Chloropyridine-5-arsinic acid (p. 418) is converted by heating with hydrazine hydrate in aqueous solution for three and a half hours into *2-hydrazinopyridine-5-arsinic acid*, which remains unmelted below 240° C., and forms a *p-nitrobenzylidene derivative*, the latter being reducible to the *p-aminobenzylidene derivative*. The hydrazino-compound condenses with ethyl acetoacetate, and the product heated in toluene gives *1-(2'-pyridyl)-3-methyl-5-pyrazolone-5'-arsinic acid*,



Oxidation of the hydrazino-compound with hydrogen peroxide and 5 per cent. hydrochloric acid gives **pyridine-3-arsinic acid**, M.pt. 112° to 113° C. The yield is 10 to 12 per cent. The copper salt of this acid can be obtained, and also the following derivatives, which are prepared as indicated on pp. 417–419: *3-pyridyldichloroarsine*, decomposing at 137° C., *3-pyridylarsenoxide*, decomposing at 187° C., and *3-pyridylarsine*, decomposing at 102° C. Reduction of the acid by hypophosphorous acid gives *3 : 3'-arsenopyridine*.

Arsenic compounds of therapeutic value are formed[2] when sodium arsenite reacts with a pyridine diazo-compound such as obtained from α-hydroxy-β'-aminopyridine. The compound formed from the latter separates in colourless needles, decomposing at about 215° C. The derivatives are purified in the usual way by reduction to the arseno-compound, followed by re-oxidation with hydrogen peroxide.

Another method of preparation of pyridine arsenicals has recently been devised.[3] For the isolation of compounds such as *α-hydroxy-β-pyridinearsinic acid*, a diazo-compound such as that from α-hydroxy-β-pyridine in acetic acid is treated with arsenic trichloride, the reaction product being decomposed and subsequently purified by heating, or by the use of sodium hydrosulphite, hydrogen peroxide and reprecipitation. Copper compounds are used as catalysts in the reaction.

Miscellaneous Arsines, Arsenoxides, Halogenoarsines and Arsinic Acids.

Tribenzylarsine, $(C_6H_5.CH_2)_3As$.[4]—This compound has been described on p. 77. It has more recently been prepared by the interaction of arsenic trichloride or tribromide with magnesium benzyl chloride in ether solution, employing a nitrogen atmosphere. The arsine, M.pt. 104° C., is thus isolated, and from the mother-liquors a mixture of dibenzylarsinic acid, M.pt. 211° C., and tribenzylarsine oxide, M.pt. 220° C., is obtained. The separation of the two latter compounds is effected by treatment with 20 per cent. aqueous sodium hydroxide, in which the acid dissolves. When arsenic tribromide is used in the

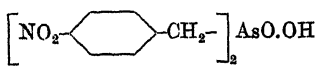
[1] Binz, Räth, and Gante, *Annalen*, 1928, 467, 11.
[2] American Patent, 1702334. [3] American Patent, 1704106.
[4] Challenger and Peters, *J. Chem. Soc.*, 1929, p. 2610.

preparation, *tetrabenzylarsonium bromide*, M.pt. 175° to 177° C., remains after removal of the dibenzylarsinic acid. This compound is converted to a *picrate* by the action of aqueous sodium picrate, the salt forming yellow needles, M.pt. 173° C.

Tribenzylarsine dibromide, $(C_6H_5.CH_2)_3AsBr_2$, results when the components are mixed in dry chloroform. It forms a crystalline precipitate, M.pt. 110° to 115° C., very sensitive to moisture.

Tri-p-nitrotribenzylarsine oxide and **Tri-p-nitrotribenzylarsine hydroxynitrate.**—These compounds result when tribenzylarsine oxide is nitrated. The oxide, $(NO_2.C_6H_4.CH_2)_3AsO$, crystallises in white needles, M.pt. 230° C. The hydroxynitrate, $(NO_2.C_6H_4.CH_2)_3As(OH)(NO_3)$, forms needles, M.pt. 189° C. with gas evolution.

Di-p-nitrodibenzylarsinic acid,[1]



results when dibenzylarsinic acid is nitrated and separates from dilute acetic acid in almost colourless needles, M.pt. 210° to 211° C.

The arsines and arsenoxides described in the following have been obtained by the action of aromatic Grignard reagents on arsenious oxide.[2] Magnesium phenyl bromide and arsenious oxide in a mixture of ether and benzene at 0° C. give diphenylarsenoxide, M.pt. 95·5° to 96·5° C., and triphenylarsine, the latter being the only product when excess of Grignard reagent is used in boiling solution. Similar results are obtained with magnesium *p*-tolyl bromide and magnesium *p*-anisyl iodide, but in the case of magnesium α-naphthyl bromide only di-α-naphthylarsenoxide, melting with decomposition at 250° to 253° C., is isolated. Magnesium 4-diphenylyl bromide under similar conditions yields bis-4-phenylarsenoxide, M.pt. 150° to 152° C. Phenylarsenoxide and diphenylarsenoxide give good yields of triphenylarsine when boiled with magnesium phenyl bromide in a mixture of ether and benzene. The following have also been described: Diphenylchloroarsine, M.pt. 40° to 42° C., diphenylbromoarsine, M.pt. 52° to 54° C., diphenyliodoarsine, M.pt. 42° to 43° C., di-*p*-tolylchloroarsine, M.pt. 44° to 45° C., di-*p*-tolylbromoarsine, M.pt. 65° to 66° C., di-*p*-tolyliodoarsine, M.pt. 64° to 65° C., di-*p*-anisylchloroarsine, M.pt. 83° to 84° C., di-*p*-anisylbromoarsine, M.pt. 60° to 62° C., di-*p*-anisyliodoarsine, M.pt. 40° to 42° C., di-α-naphthylchloroarsine, M.pt. 167° to 168° C., di-α-naphthylbromoarsine, M.pt. 172° to 173° C., di-α-naphthyliodoarsine, M.pt. 140° to 141° C., bis-4-diphenylchloroarsine, M.pt. 145° to 147° C., bis-4-diphenylbromoarsine, M.pt. 147° to 149° C., and bis-4-diphenyliodoarsine, M.pt. 140° to 141° C.

General procedures for the preparation of arsenoxides are as follows:[3]

Method I.—Mercury diaryls are heated with one and a half times the theoretical amount of freshly distilled arsenic trichloride for three hours at 130° to 140° C. The reaction mixture is then extracted with benzene and filtered. After removing the benzene on a steam-bath,

[1] Challenger and Peters, *loc. cit.*
[2] Blicke and Smith, *J. Amer. Chem. Soc.*, 1929, 51, 1558.
[3] Blicke and Smith, *ibid.*, p. 3479.

the product is distilled under diminished pressure in an atmosphere of hydrogen until the excess of arsenic trichloride has been removed. The crude aryldichloroarsine thus obtained is added to a warm 10 per cent. solution of sodium hydroxide with rapid stirring, sufficient alkali being used to dissolve all the arsenoxide formed. After filtration, the filtrate is neutralised and the precipitate washed by decantation and then filtered off.

Method II.—The oxides may also be obtained from the corresponding acids: One part of arylarsinic acid in five parts of methyl alcohol and two parts of concentrated hydrochloric acid containing 0·1 gram of potassium iodide is treated with sulphur dioxide. Most of the dichloroarsine precipitates as an oil, and water is added to complete the precipitation. The oil is washed with water and treated with warm 10 per cent. sodium hydroxide until a clear solution results. The latter is neutralised, when the arsenoxide is precipitated.

The oxides prepared by the foregoing methods, with the exception of the naphthyl compound, are dissolved in hot benzene and an equal volume of absolute ether added to the cold benzene solution; they slowly precipitate. The α-naphthylarsenoxide is purified by suspending the crude product in benzene, treating the suspension with dry hydrogen chloride, whereby α-naphthyldichloroarsine is produced, and heating the mixture until all the solvent has been removed. The addition of a small quantity of petroleum ether causes the residual oil to solidify, and the product is recrystallised from petroleum ether. Thus prepared and purified the dichloride melts at 70° to 72° C. (compare p. 109). When hydrolysed it gives pure α-naphthylarsenoxide. The following table indicates the arsenoxides which have been prepared by the foregoing methods:

	Phenyl-.	*p*-Tolyl-.	*p*-Anisyl-.	α-Naphthyl-.
M.pt.	144–146° C.	188–190° C.	114–116° C.	245° C.
Yield per cent. (Method I) .	60	..	..	60
„ „ (Method II)	80	87	90	..

These melting-points should be compared with those given previously in this volume.

The Interaction of Arylmagnesium Halides and Arylarsenoxides.—The general procedure to effect this interaction is as follows: 0·03 of a gram-molecule of arylarsenoxide is dissolved in 100 c.c. of dry benzene, the solution cooled in ice and rapidly stirred. 0·45 of a gram-molecule of the Grignard reagent is then added, and after thirty minutes the ice-bath is removed and the mixture stirred for four hours. After twelve hours the mass is decomposed with ice and a small amount of acetic acid, the ether-benzene layer separated, washed with 10 per cent. sodium hydroxide, then dried over fused sodium sulphate. The solvents are removed, and the oily residue, which cannot be obtained in crystalline form in the case of mixed diarylarsenoxides, is dissolved in dry ether and the solution saturated with chlorine. The solvent is removed and the residue treated with 5 per cent. sodium hydroxide to convert the tetrachloride to arsinic acid. The alkaline solution of the latter is

extracted with ether to remove by-products, heated on a steam-bath to remove dissolved ether, and then neutralised, the arsinic acid separating as a gum, which soon solidifies. The crude arsinic acid is boiled with acetone, the solution cooled and then filtered. This process is repeated several times. The acid is only slightly soluble in acetone, but the by-products are much more soluble. The diarylarsinic acids are converted to the corresponding chlorides, and the latter changed to the oxides by alcoholic sodium hydroxide. The following diarylarsinic acids and diarylchloroarsines have thus been isolated: *Phenyl-p-tolylarsinic acid*, M.pt. 148° to 150° C.; *phenyl-p-anisylarsinic acid*, M.pt. 167° to 169° C.; phenyl-α-naphthylarsinic acid, M.pt. 175° to 176° C.; *phenylbiphenylarsinic acid*, M.pt. 218° to 220° C.; *p-anisylbiphenylarsinic acid*, M.pt. 228° to 231° C. *Phenyl-p-tolyl-*, *phenyl-p-anisyl-*, *phenyl-α-naphthyl-* and *p-anisyl-biphenylchloroarsines* are all oils; phenylbiphenylchloroarsine melts at 83° to 85° C. A number of oxides of the type RR'As-O-AsR'R have been isolated and are shown in the following table:

OXIDES OF THE TYPE RR'As-O-AsR'R.

Arsenoxide	Reagents for the Preparation.		M.pt.
	Oxide.	Magnesium Compound.	
Diphenyl-di-*p*-tolyl- .	Phenylarsen-	Phenyl-magnesium-bromide	75–77° C.
,, ,, *p*-anisyl- .	,,	Anisyl-magnesium-iodide	Oil.
,, ,, *α*-naphthyl-	,,	Naphthyl-magnesium-bromide	,,
Diphenyldibiphenyl- .	,,	Biphenyl-magnesium-bromide	124–126° C.
Di-*p*-anisyldibiphenyl-	Anisylarsen-	,, ,, ,,	Oil.
Tetra-*p*-tolyl- . .	Tolylarsen-	Tolyl-magnesium-bromide	108° C.
,, -*p*-anisyl- . .	Anisylarsen-	Anisyl-magnesium-iodide	128–129° C.
,, -*α*-naphthyl- .	Naphthylarsen-	Naphthyl-magnesium-bromide	250–251° C.

Miscellaneous Patents.

Aminophenylarsinic Acids.[1]—These acids and their derivatives may be isolated by reducing the corresponding nitro-acids with iron and hydrochloric acid. The preparation of 3-amino-4-hydroxy-, 4-amino-2-hydroxy- and 4-amino-phenylarsinic acids is dealt with in the patent. In a later patent[2] examples are given of the preparation of 3-amino-4-hydroxy-, 4-amino-, 3 : 4-diamino- and 4-amino-2-hydroxy-phenylarsinic acids.

Mixed Aliphatic-aromatic Ketone Arsinic Acids.[3]—These compounds are formed by the interaction of bromine-substituted mixed aliphatic-aromatic ketones, such as 4-bromoacetophenone or 3-amino-4-bromoacetophenone, with arsenites in hot solution.

10-*Chloro*-5 : 10-*dihydrophenarsazine.*[4]—It is stated in the patent that agitating the crude molten product with water until it solidifies effects purification.

[1] French Patent, 636660.
[2] German Patent, 468757.
[3] German Patent, 468403.
[4] American Patent, 1696539.

Arsenoxides.[1]—The patent describes the treatment of organic arsenoxides with sulphur compounds containing sulphur directly attached to carbon. Examples given are as follows: Aminophenylarsenoxide in sodium hydroxide solution is added to a solution of thioglycolamide in ammonium hydroxide, neutralisation of the mixture yielding a compound of composition $NH_2.C_6H_4.As(S.CH_2.CO.NH_2)_2$. Thioethanol and potassium xanthogenate give compounds having the compositions $NH_2.C_6H_4.As(S.CH_2.CH_2.OH)_2$ and $NH_2.C_6H_4.As(S.S.CO.C_2H_5)_2$, respectively, the latter melting at 85° C. Hydroxyaminophenylarsenoxide and thioglycolamide give m-NH_2.p-$OH.C_6H_3.As(S.CH_2.CO.NH_2)_2$; 4-hydroxy-3-acetamidophenylarsenoxide and glycerol-monothiol give $CH_3.CO.NH(OH)C_6H_3.As[S.CH_2.CH(OH)CH_2OH]_2$; 4-hydroxy-3-acetamidophenylarsenoxide and potassium xanthogenate yield m-$CH_3.CO.NH(p\text{-}OH)C_6H_3.As(S.CS.OC_2H_5)_2$, M.pt. 115° C. If hydroxypropyldiarsinic acid is reduced with sulphur dioxide in the cold and monothioglycerol added, the resulting product has the composition $[CH_2.OH.CH(OH)CH_2.S]_2As.CH_2.CH(OH)CH_2.As[S.CH_2.CH(OH)CH_2OH]_2$.

Methyldichloroarsine, CH_3AsCl_2, may be obtained in 83 per cent. yield from sodium dimethylarsinate ($3H_2O$) and concentrated hydrochloric acid.[2]

Salvarsan and *Neosalvarsan* give colour reactions with aldehydes, the most suitable aldehydes for distinguishing them being *o*- and *p*-nitrobenzaldehydes and furfuraldehyde.[3]

[1] French Patent, 643911.
[2] Zappi and Deulofeu, *Bull. Soc. chim.*, 1928, 43, 1230.
[3] van Urk, *Pharm. Weekblad*, 1929, 66, 297.

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