CCCXXXV.—10-*Chloro*-5 : 10-*dihydrophenarsazine and its Derivatives. Part V. The General Method of Synthesis and Determination of Constitution.*

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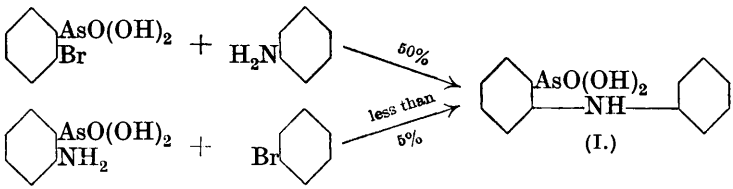
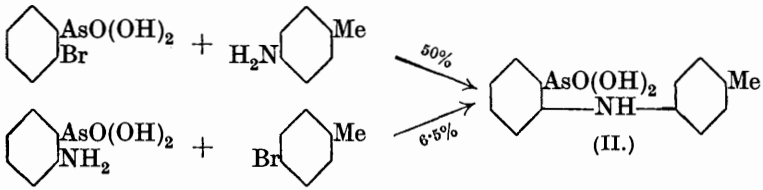
IT has been shown (J., 1927, 247) that carboxy-derivatives of 10-chloro-5 : 10-dihydrophenarsazine which are not accessible by the condensation of arsenious chloride with the corresponding substituted diphenylamines may be prepared by condensing *o*-bromophenylarsinic acid with aminobenzoic acids and subsequent ring closure. Further, it was shown (J., 1926, 2243) that certain substituted diphenylamines will not condense with arsenious chloride, although where at least two of the four ortho-positions in diphenylamine are unoccupied, there seemed reason to believe that the corresponding phenarsazine derivative should be capable of existence. By investigating in greater detail the conditions of the formation of various arsinic acids derived from diphenylamine and the conditions of ring closure to form the heterocyclic arsenic compound, it has been possible to study the properties of some of the compounds hitherto unprepared and to throw more light on the constitution of some already known compounds belonging to this series.

The preparation of *diphenylamine-o-arsinic acid* (I) has been effected by two methods as indicated :

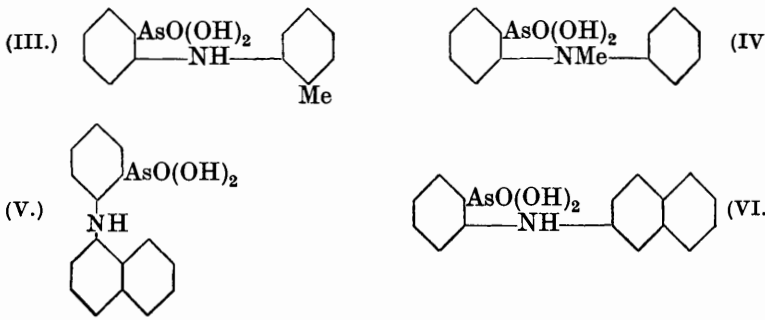


The condensations were carried out under identical conditions and it will be seen that the yield of the condensation product varied

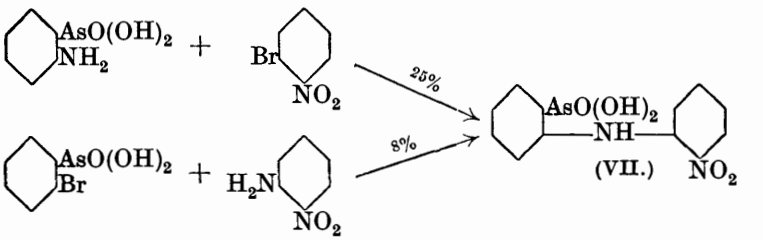
very considerably according as *o*-bromophenylarsinic acid or *o*-aminophenylarsinic acid was the initial material. A result of the same kind was obtained in the preparation by two methods of **4-*methyldiphenylamine*-6′-*arsinic acid*** (II) :



Since, in both cases, the use of *o*-bromophenylarsinic acid gave a higher yield of the desired arsinic acid, **2-*methyldiphenylamine*-6′-*arsinic acid*** (III) (23% yield), **N-*methyldiphenylamine*-o-*arsinic acid*** (IV) (28% yield), **2-α-*naphthylaminophenylarsinic acid*** (V) (81% yield), and **2-β-*naphthylaminophenylarsinic acid*** (VI) (90% yield) were readily obtained by condensing *o*-bromophenylarsinic acid with the corresponding amine.

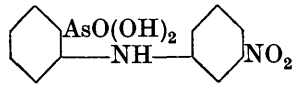
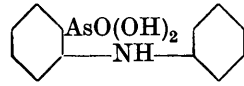


In the case of the production of **2-*nitrodiphenylamine*-6′-*arsinic acid*** (VII), the higher yield was obtained when *o*-aminophenyl-



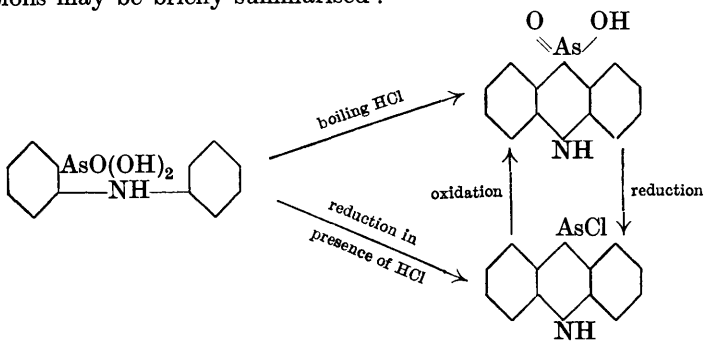
arsinic acid was used, and hence for the preparation of **3-*nitrodiphenylamine*-6′-*arsinic acid*** (VIII) and of **4-*nitrodiphenylamine*-**

6′-*arsinic acid* (IX), *o*-aminophenylarsinic acid was condensed with the corresponding bromonitrobenzene.

(VIII.)   (IX.)

These results would indicate that the ease with which the reaction proceeds depends on the reactivity of the bromine atom, being slight in bromobenzene, greatest in *o*-bromonitrobenzene, and intermediate in the case of *o*-bromophenylarsinic acid.

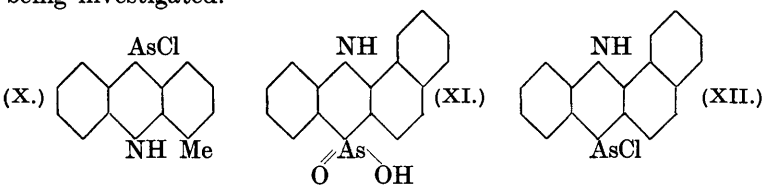
With the exception of *N*-methyldiphenylamine-*o*-arsinic acid (IV), all the above acids can be converted into the corresponding heterocyclic arsenic compounds. Diphenylamine-*o*-arsinic acid (I), when boiled with concentrated hydrochloric acid, is converted rapidly first into an oil and then into the previously described hydrochloride of phenarsazinic acid (J., 1924, **125**, 2277). The same acid, when reduced by the alcohol–iodine–hydrochloric acid–sulphur dioxide method, is rapidly converted into 10-chloro-5 : 10-dihydrophenarsazine, which again can be oxidised to phenarsazinic acid. Incidentally, 10-chloro-5 : 10-dihydrophenarsazine has thus again been synthesised by a simpler method and its constitution further verified (compare Burton and Gibson, J., 1926, 452). These reactions may be briefly summarised :



When 4-methyldiphenylamine-6′-arsinic acid (II) was boiled with concentrated hydrochloric acid, similar effects were observed and the already described hydrochloride of 2-methylphenarsazinic acid (J., 1926, 469) was readily obtained. Also, by reduction with sulphur dioxide under the usual conditions, 10-chloro-2-methyl-5 : 10-dihydrophenarsazine was produced, which again was easily oxidised to the heterocyclic arsinic acid. Ring closure also took place on boiling the acid (II) with acetic anhydride. The synthesis of 10-chloro-2-methyl-5 : 10-dihydrophenarsazine has thus been effected and, incidentally, the *hydrobromide* of 2-methylphenarsazinic

acid was prepared from the acid (II) by using hydrobromic acid instead of hydrochloric acid, and 10-*bromo*-2-*methyl*-5 : 10-*dihydrophenarsazine* was obtained from the acid (II) or from the corresponding phenarsazinic acid in the usual way.

Although the corresponding ring closure by means of hydrochloric acid took an appreciably longer time, 2-methyldiphenylamine-6′-arsinic acid (III) was converted into 4-*methylphenarsazinic acid hydrochloride* and 4-*methylphenarsazinic acid*. From both 2-methyldiphenylamine-6′-arsinic acid and 4-methylphenarsazinic acid, 10-*chloro*-4-*methyl*-5 : 10-*dihydrophenarsazine* (X) and also the corresponding *bromo*-compound have been prepared for the first time, since phenyl-*o*-tolylamine was not available when the condensation of arsenious chloride with various diphenylamines was being investigated.



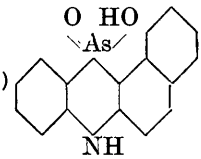
The formation of heterocyclic arsenic compounds from 2-α-naphthylaminophenylarsinic acid (V) can be accomplished very easily.

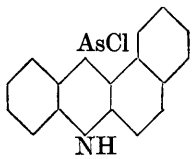
7 : 12-iso*Benzophenarsazinic acid* (XI) is easily produced by boiling the original acid for two minutes with concentrated hydrochloric acid containing a little alcohol, while the already described 7-chloro-7 : 12-dihydro*iso*benzophenarsazine * (XII) (Lewis and Hamilton, *J. Amer. Chem. Soc.*, 1921, **43**, 2218; Burton and Gibson, J., 1926, 467) is obtained very readily by the usual method of reduction. This synthesis effectively proves the correctness of the constitution assigned to the product of condensation of arsenious chloride and phenyl-α-naphthylamine.

* Previously called 7-chloro-7 : 12-dihydrobenzophenarsazine. It is considered advisable to regard (*a*) as the normal ring and (*b*) as the *iso*-ring, since

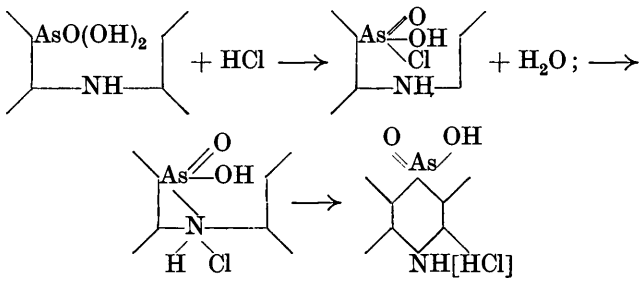
in (*b*) the hetero-atoms have to be numbered inversely to their accepted order on account of the geometry of the ring. This will avoid any confusion in the naming of the parent substances. The parent substance of compound (XII) will be 7 : 12-dihydro*iso*benzophenarsazine and of compound (XIV), 7 : 12-dihydrobenzophenarsazine.

The formation of the corresponding heterocyclic arsenic compounds from 2-β-naphthylaminophenylarsinic acid (VI) was just as readily accomplished. The *hydrochloride* of 7 : 12-*benzophenarsazinic acid* or the free acid (XIII) was readily produced by boiling 2-β-naphthylaminophenylarsinic acid with concentrated hydrochloric acid containing a little alcohol or by boiling it with acetic acid. Further, the previously described 12-chloro-7 : 12-dihydrobenzophenarsazine (XIV) (Burton and Gibson,* J., 1926, 2241) was easily obtained by the usual method of reduction from either 2-β-naphthylaminophenylarsinic acid or from the heterocyclic acid (XIII). On the assumption that the condensation goes in the α-position of the naphthalene nucleus, the constitution assigned previously to the condensation product of arsenious chloride and phenyl-β-naphthylamine is verified by the present work.

(XIII.) 

 (XIV.)

In several of the above cases when the ring closure was effected by boiling hydrochloric acid, an oily intermediate product possessing a characteristic acid chloride-like odour was formed prior to the formation of the crystalline hydrochloride of the heterocyclic arsinic acid. Although this intermediate product was never isolated, its repeated formation led us to believe that the condensation is preceded by the formation of an acid chloride and we suggest that the following scheme may represent the formation of the hydrochloride of the phenarsazinic acid :

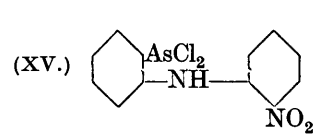


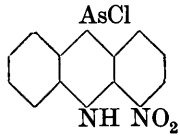
When ring closure was effected by the alcohol–hydrochloric acid–iodine–sulphur dioxide method, in none of the above cases were

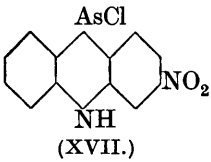
* There is a misprint on p. 2243 (line 4 from bottom) : " 12-chloro-7 : 12-dihydrophenarsazine " should be " 12-chloro-7 : 12-dihydrobenzophenarsazine."

we able to isolate the intermediate dichloroarsine; indeed, in only one case (described below) has this been possible.

When 2-nitrodiphenylamine-6′-arsinic acid (VII) was reduced for 5 minutes with sulphur dioxide in the presence of alcoholic hydrochloric acid and a trace of iodine, an oil was formed which, after solidification and recrystallisation, was obtained as deep red crystals of 2-*nitrodiphenylamine*-6′-*dichloroarsine* (XV), from which the original acid was regenerated by oxidation with hydrogen peroxide in acetic acid solution. When the dichloroarsine was boiled in acetic acid solution for 3 hours, 10-*chloro*-4-*nitro*-5 : 10-*dihydrophenarsazine* (XVI) crystallised in characteristic scarlet needles, m. p. 165°. The method of production of this compound leaves no doubt as to its constitution.







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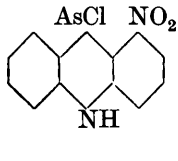
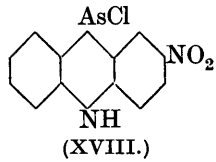




In the reduction of 3-nitrodiphenylamine-6′-arsinic acid (VIII) no intermediate dichloroarsine was obtained. From its method of formation, however, the homogeneous compound must be 10-*chloro*-3(or 1)-*nitro*-5 : 10-*dihydrophenarsazine* (XVII) and it was obtained in deep red, prismatic needles, m. p. 258—259° (decomp.). The corresponding 3(or 1)-*nitrophenarsazinic acid* and the 10-*bromo*-3(or 1)-*nitro*-5 : 10-*dihydrophenarsazine* were also isolated. [Previous work (J., 1926, 2241; compare Roberts and Turner, J., 1925, **127**, 2005) clearly suggests that the nitro-group in these compounds is probably in the 3 position.]

When 4-nitrodiphenylamine-6′-arsinic acid (IX) was reduced under similar conditions, no dichloroarsine was isolated, but there was no difficulty in isolating 10-*chloro*-2-*nitro*-5 : 10-*dihydrophenarsazine* (XVIII), m. p. 278° (decomp.), and the method of preparation leaves no doubt as to the constitution of this substance.

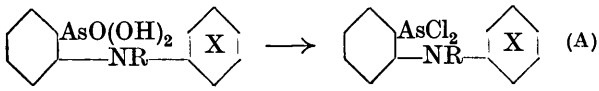
The synthesis and identification of these three nitro-derivatives have enabled us to clear up certain obscurities in the previous work on compounds of this series. 10-Chloro-4-nitro-5 : 10-dihydrophenarsazine (XVI) has been oxidised to the corresponding acid, and this reduced by ferrous hydroxide to the hydrochloride of 4-aminophenarsazinic acid, identical with the compound prepared

by Wieland and Rheinheimer (*Annalen*, 1921, **423**, 1). Although we expected a triazo-derivative might be formed, this compound is unaffected by nitrous acid at 5°.

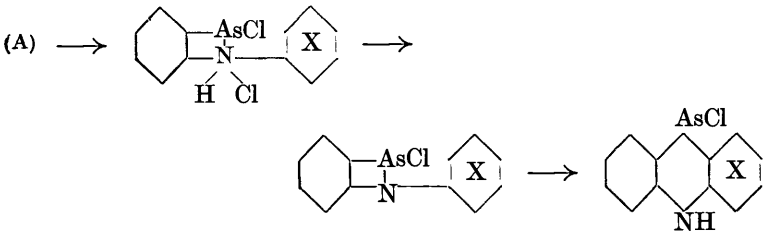
Wieland and Rheinheimer obtained two mononitro-derivatives by the nitration of 10-chloro-5 : 10-dihydrophenarsazine. They concluded that the one produced in less quantity (brilliant scarlet needles) had the nitro-group in the ortho-position to the :NH group and although the melting point recorded by them is somewhat low (156°), the description shows that the compound actually was 10-chloro-4-nitro-5 : 10-dihydrophenarsazine (XVI), now synthesised and obtained by us in a pure condition, m. p. 165°. The other mononitro-derivative, Wieland and Rheinheimer rightly concluded was the para-isomeride, *viz.*, 10-chloro-2-nitro-5 : 10-dihydrophenarsazine (XVIII). They described it as crystallising in greenish-yellow scales, but did not record any melting point. On carefully repeating their work, we found that this compound was identical with the synthesised substance (XVIII), m. p. 278° (decomp.). Wieland and Rheinheimer further stated that this compound on oxidation was converted into the nitrophenarsazinic acid (the 2-nitro-acid) which is the by-product of the nitration of phenarsazinic acid, the main product, according to them, being 4-nitrophenarsazinic acid. We have found, however, that the main (*i.e.*, the more easily isolated) product of the nitration of phenarsazinic acid under the conditions described by Wieland and Rheinheimer is the 2-nitro-acid, for on repeating their work we isolated an acid which, on reduction by the sulphur dioxide–alcohol–hydrochloric acid–iodine method, gave 10-chloro-2-nitro-5 : 10-dihydrophenarsazine (XVIII) in a slightly impure form. Moreover, Burton and Gibson's " 1-nitrophenarsazinic acid " (*loc. cit.*, p. 2243) is actually the 2-nitro-acid, for it gives the substance (XVIII) on reduction. As a result of the work now described, the conclusions drawn by Burton and Gibson as to the constitution of the corresponding amino-derivatives must be modified accordingly.

In view of the previous failure to prepare 10-chloro-5-methyl-5 : 10-dihydrophenarsazine (Burton and Gibson, J., 1926, 453; compare Wieland and Rheinheimer, *loc. cit.*), it is interesting to know that normal ring closure does not take place when *N*-methyldiphenylamine-*o*-arsinic acid (IV) is submitted to any of the treatments mentioned above for this purpose. Indeed, the only product which we have isolated by the alcohol–hydrochloric acid–iodine–sulphur dioxide reduction method was somewhat impure 10-chloro-5 : 10-dihydrophenarsazine in small quantity (compare Burton and Gibson, *loc. cit.*). Whilst we have again been unsuccessful in preparing 10-chloro-5-methyl-5 : 10-dihydrophenarsazine, the results

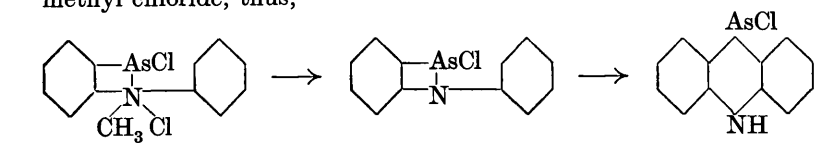
of the work indicate that ring closure effected by reduction by the sulphur dioxide method probably follows the course



Where R = H and X(*o*- or *p*-) = H or Me,



If X = NO_2 and R = H, the nitrogen atom will be less basic and arsenic–nitrogen ring closure will tend to take place with less ease, especially in the case of the 2-nitro-compound (VII). In this case we have actually isolated the dichloroarsine and it is possible that steric hindrance here plays some part (compare Roberts and Turner, *loc. cit.*). If R = Me and X = H, there will be less tendency for arsenic–nitrogen ring closure to take place. The small amount of the product of such ring closure will not be stable and should lose methyl chloride, thus,



with the formation of a small quantity of 10-chloro-5 : 10-dihydrophenarsazine, as found experimentally.

EXPERIMENTAL.

The method previously described for the preparation of *o*-bromophenylarsinic acid (J., 1926, 456) has been considerably modified, whereby a higher yield (56%) is obtained and economy in hydrobromic acid effected. *o*-Aminophenylarsinic acid (150 g.), dissolved in concentrated hydrochloric acid (210 c.c.) and water (210 c.c.), was diazotised below 5° with sodium nitrite (50 g.; water, 110 c.c.). Cuprous bromide (copper sulphate crystals, 150 g., in water, 500 c.c.; potassium bromide, 75 g., in water, 175 c.c.; the solution was reduced with sulphur dioxide, and the precipitate filtered off and washed with water) was dissolved in hydrobromic acid (of constant b. p.; 270 c.c.) and to this solution at the ordinary tem-

perature the diazo-solution was added with constant stirring. After stirring for 1 hour, the precipitated acid was dissolved in sodium hydroxide solution, and the solution was decolorised with charcoal and acidified with hydrochloric acid (Congo-red). The colourless crystals had m. p. 199—200° (decomp.).

o-Bromonitrobenzene may be obtained in 86% yield by the following modification of Ullmann's method (*Ber.*, 1896, **29**, 1880). *o*-Nitroaniline (138 g.), dissolved in concentrated hydrochloric acid (215 c.c.) and water (128 c.c.), was diazotised below 10° with sodium nitrite (75 g. in water, 150 c.c.). A solution of cuprous bromide in hydrobromic acid (of constant b. p.; 320 c.c.) was prepared from copper sulphate crystals (193 g. in water, 640 c.c.) and potassium bromide (96·5 g. in water, 210 c.c.) as described above, and the diazo-solution added to it at the ordinary temperature with constant stirring. The *o*-bromonitrobenzene, m. p. 43—44°, was isolated by steam distillation.

*Diphenylamine-*o*-arsinic Acid*, $C_6H_5{\cdot}NH{\cdot}C_6H_4{\cdot}AsO(OH)_2$ (I).—(*a*) A mixture of aniline (4·7 g.), *o*-bromophenylarsinic acid (14 g.), dry potassium carbonate (9·3 g.), amyl alcohol (38 c.c.), and a trace of copper powder was boiled for 5 hours. The volatile substances were removed by steam distillation and the residue was decolorised with charcoal. The filtrate on acidification with hydrochloric acid deposited a dark-coloured solid (7·1 g.), which was recrystallised from glacial acetic acid and then from dilute acetic acid.

(*b*) A mixture of bromobenzene (6·0 g.), *o*-aminophenylarsinic acid (6·75 g.), dry potassium carbonate (6·0 g.), amyl alcohol (35 c.c.), and a trace of copper powder was treated in a similar manner. Only 0·4 g. of product was obtained.

*Diphenylamine-*o*-arsinic acid* forms colourless, felted needles, m. p. 166° (slight decomp.). It cannot be titrated with 0·1*N*-sodium hydroxide and phenolphthalein, the end-point varying with the concentration; but its basicity is greater than unity (Found: As, 25·5. $C_{12}H_{12}O_3NAs$ requires As, 25·6%).

*Conversion of Diphenylamine-*o*-arsinic Acid into Phenarsazinic Acid and* 10-*Chloro*-5 : 10-*dihydrophenarsazine*.—(*a*) Diphenylamine-*o*-arsinic acid (1 g., either crude or pure) was boiled with concentrated hydrochloric acid (7 c.c.). An oil having a characteristic odour was first formed, but it rapidly disappeared and after 2 minutes' boiling the liquid became filled with crystals of phenarsazinic acid hydrochloride identical with an authentic specimen, m. p. 203—205° (decomp.). This hydrochloride dissolved in an excess of aqueous sodium hydroxide, from which solution phenarsazinic acid was precipitated on addition of acetic acid. The phenarsazinic acid was dissolved in hot alcohol–hydrochloric acid

and reduced with sulphur dioxide after addition of a trace of iodine. 10-Chloro-5 : 10-dihydrophenarsazine, m. p. 191°, identical with an authentic specimen, was obtained (Found : Cl, 12·9. Calc. : Cl, 12·8%).

(*b*) Diphenylamine-*o*-arsinic acid (1 g., either crude or pure), dissolved in a hot mixture of alcohol (5 c.c.) and concentrated hydrochloric acid (5 c.c.), deposited 10-chloro-5 : 10-dihydrophenarsazine, m. p. 191° (after recrystallisation from benzene), on reduction with sulphur dioxide after addition of a trace of iodine. The chloro-compound, on oxidation with chloramine-T in aqueous acetone (Burton and Gibson, J., 1924, **125**, 2276), was converted into phenarsazinic acid.

4-*Methyldiphenylamine*-6′-*arsinic Acid*,

$$C_6H_4Me{\cdot}NH{\cdot}C_6H_4{\cdot}AsO(OH)_2 \text{ (II)}.$$

—(*a*) The product obtained from *p*-toluidine (4·9 g.) and *o*-bromophenylarsinic acid (12·9 g.), worked up as described above, amounted to 10 g. (*b*) The amount obtained from *p*-bromotoluene (8·6 g.) and *o*-aminophenylarsinic acid (10·9 g.) was only 1·0 g. Pure 4-*methyldiphenylamine*-6′-*arsinic acid*, m. p. 160—165° (decomp.), was obtained as a cream-coloured solid by recrystallising the product from dilute acetic acid (Found : As, 24·1. $C_{13}H_{14}O_3NAs$ requires As, 24·4%). It is soluble in hot alcohol or hot glacial acetic acid and only slightly soluble in water.

4-Methyldiphenylamine-6′-arsinic acid (10 g. of crude acid) was boiled with concentrated hydrochloric acid (40 c.c.). An oil was formed and the mixture vigorously stirred during the heating. After about 2 minutes the solution became homogeneous and then suddenly filled with crystals (8·5 g.) of 2-methylphenarsazinic acid hydrochloride, m. p. 200—204° (decomp.), which was identical with an authentic specimen (J., 1926, 469). On treatment with sodium hydroxide, the sodium salt, which is sparingly soluble in cold water, was obtained, and from this 2-methylphenarsazinic acid, m. p. 306° (decomp.), was isolated by acidification with glacial acetic acid. This was identical with a specimen made by oxidising the condensation product of arsenious chloride and phenyl-*p*-tolylamine. The hydrochloride, m. p. 208° (decomp.), was readily re-formed on dissolving the acid in a hot mixture of equal volumes of alcohol and concentrated hydrochloric acid and allowing the solution to cool (Found : Cl, 11·2. Calc. : Cl, 10·9%).

A boiling solution of 4-methyldiphenylamine-6′-arsinic acid (1 g.) in alcohol (7 c.c.) and concentrated hydrochloric acid (7 c.c.) containing a trace of iodine was treated with sulphur dioxide; reduction was complete after 5 minutes. The product, recrystallised from benzene, gave 10-chloro-2-methyl-5 : 10-dihydrophenarsazine

in orange-yellow needles, m. p. 199—200°, which did not depress the melting point of an authentic specimen (Found: Cl, 12·2. Calc.: Cl, 12·2%). On oxidation with chloramine-T in aqueous acetone, it was converted into the colourless 2-methylphenarsazinic acid, m. p. 306—308° (decomp.), identical with an authentic specimen.

4-Methyldiphenylamine-6′-arsinic acid (3 g.) was boiled with acetic anhydride (15 c.c.) for 2 hours. The solution remaining after half of the anhydride had been distilled off was deep blue and deposited 0·6 g. of colourless, crystalline material. This was washed with alcohol and had m. p. 308° (decomp.). On reduction with sulphur dioxide under the usual conditions, it was converted into 10-chloro-2-methyl-5 : 10-dihydrophenarsazine. 2-Methylphenarsazinic acid under the same conditions was not acetylated.

2-*Methylphenarsazinic acid hydrobromide*,

$$NH\langle \begin{matrix} C_6H_3Me \\ C_6H_4 \end{matrix} \rangle AsO(OH),HBr,$$

was prepared by dissolving 2-methylphenarsazinic acid (1 g.) in a hot mixture of alcohol (5 c.c.) and hydrobromic acid (of constant b. p.; 6 c.c.) and allowing the solution to cool. It crystallised as an almost colourless, granular powder, which turned orange-coloured on heating above 100° and had m. p. 208—210° (decomp.) (Found: Br, 21·3. $C_{13}H_{13}O_2NBrAs$ requires Br, 21·6%). It was also formed by boiling 4-methyldiphenylamine-6′-arsinic acid (1 g.) with hydrobromic acid (of constant b. p.; 8 c.c.) for a few minutes, but the reaction did not take place so smoothly as in the formation of the hydrochloride: the tarry matter formed was removed by washing the precipitate with a mixture of hydrobromic acid and alcohol.

10-*Bromo*-2-*methyl*-5 : 10-*dihydrophenarsazine*,

$$NH\langle \begin{matrix} C_6H_3Me \\ C_6H_4 \end{matrix} \rangle AsBr,$$

was prepared by dissolving 2-methylphenarsazinic acid or 4-methyldiphenylamine-6′-arsinic acid (1 g.) in a hot mixture of alcohol (5 c.c.) and hydrobromic acid (of constant b. p.; 5 c.c.) and reducing the product in the usual way; it crystallised from benzene in rosettes of hard, orange-red needles, m. p. 180° (decomp.) (Found: Br, 23·9. $C_{13}H_{11}NBrAs$ requires Br, 23·8%).

2-*Methyldiphenylamine*-6′-*arsinic Acid*,

$$C_6H_4Me\cdot NH\cdot C_6H_4\cdot AsO(OH)_2 \quad (III).$$

—*o*-Toluidine (15 g.), *o*-bromophenylarsinic acid (39 g.), dry potassium carbonate (30 g.), amyl alcohol (120 c.c.), and a trace of copper powder were boiled for 7 hours and worked up as before. On acidifying the solution of the potassium salt, 2-methyldiphenyl-

amine-6′-arsinic acid (10 g.) was obtained as a light cream-coloured solid. It was difficult to purify, but from dilute acetic acid it was obtained as a slightly discoloured solid of indefinite melting point (130—140°) (Found : As, 24·2. $C_{13}H_{14}O_3NAs$ requires As, 24·4%).

4-*Methylphenarsazinic acid hydrochloride* was formed on boiling the preceding compound (crude) with concentrated hydrochloric acid as described for the isomeride, but the time elapsing before the separation of the hydrochloride was almost twice as long. The crude salt had m. p. 187—189° (decomp.). 4-*Methylphenarsazinic acid* was formed from the crude hydrochloride by treatment with an excess of sodium hydroxide solution and then acidification with acetic acid. The precipitated acid was recrystallised from dilute acetic acid and then had m. p. 309—310° (decomp.) (Found : As, 25·7. $C_{13}H_{12}O_2NAs$ requires As, 25·9%). This acid tends to form an unstable acetate, since, when it was recrystallised from glacial acetic acid and air-dried for 2 days, it still retained 5·61% of acetic acid (Calc. for 1 mol. of $C_2H_4O_2$, 17·2%). 4-Methylphenarsazinic acid resembles the 2-isomeride in most of its properties : the sodium salt is not very soluble in cold water and it is readily converted into the *hydrochloride*, colourless needles, m. p. 199° (decomp.), by the usual method (Found : Cl, 10·9. $C_{13}H_{13}O_2NClAs$ requires Cl, 10·9%).

10-*Chloro*-4-*methyl*-5 : 10-*dihydrophenarsazine* (X). — 4-Methylphenarsazinic acid or crude 2-methyldiphenylamine-6′-arsinic acid was reduced as described for the 2-isomeride. Recrystallised from benzene, the product formed yellow needles (occasionally greenish-yellow), m. p. 191° (decomp.). The yield was almost quantitative (Found : Cl, 12·3. $C_{13}H_{11}NClAs$ requires Cl, 12·2%).

10-*Bromo*-4-*methyl*-5 : 10-*dihydrophenarsazine* was prepared in an analogous manner from 4-methylphenarsazinic acid. It was recrystallised from benzene and obtained in light yellow needles, m. p. 190° (slight decomp.) (Found : Br, 24·0. $C_{13}H_{11}NBrAs$ requires Br, 23·8%). Both these compounds were converted into 4-methylphenarsazinic acid on oxidation with chloramine-T in aqueous acetone.

N-*Methyldiphenylamine*-o-*arsinic Acid* (IV).—Monomethylaniline * (15 g.), *o*-bromophenylarsinic acid (39 g.), dry potassium carbonate (30 g.), amyl alcohol (120 c.c.), and a trace of copper powder were boiled for 5 hours. The product was worked up in the usual manner, and the N-*methyldiphenylamine*-o-*arsinic acid* (12 g.) obtained as a colourless, crystalline solid, m. p. 182—184°

* Purified through its *p*-toluenesulphonyl derivative. It had b. p. 196°/764 mm., and gave quantitative yields of its acetyl and *p*-toluenesulphonyl derivatives (m. p.'s 101° and 94°, respectively).

(decomp.) after recrystallisation from dilute acetic acid. It was difficult to purify (Found: As, 24·2. $C_{13}H_{14}O_3NAs$ requires As, 24·4%). Boiling with concentrated hydrochloric acid for 5 minutes caused no separation of crystalline matter, but some decomposition took place and the characteristic odour, which we attribute to the intermediate formation of an acid chloride, was observed. On cooling, treatment with sodium hydroxide, and acidification with acetic acid, only an impure acid was precipitated. When hydrobromic acid was used instead of hydrochloric acid, marked decomposition took place.

N-Methyldiphenylamine-*o*-arsinic acid (8 g.) was reduced in hot alcoholic-concentrated hydrochloric acid solution in the manner already described, but the product of the reduction was a heavy, dark-coloured oil. A small amount of yellowish-brown solid separated from the oily matter on cooling. This was recrystallised from benzene and melted at 175—177°. The melting point was raised (187—188°) by admixture with pure 10-chloro-5 : 10-dihydrophenarsazine, but the quantity obtained was too small for further purification and attempts to work up the oil were unavailing. 10-Chloro-5-methyl-5 : 10-dihydrophenarsazine therefore cannot be prepared by this method and it was also found impossible to prepare the corresponding bromo-compound.

2-α-*Naphthylaminophenylarsinic Acid* (V).—On mixing α-naphthylamine (16·0 g.), *o*-bromophenylarsinic acid (28·2 g.), dry potassium carbonate (19·0 g.), amyl alcohol (80 c.c.), and a trace of copper powder an almost solid mass was produced. The mixture was boiled for 6½ hours and the product isolated (28 g., crude) in the usual way. The acid recrystallised from dilute acetic acid had m. p. 165° (Found: As, 21·6. $C_{16}H_{14}O_3NAs$ requires As, 21·9%).

2-α-Naphthylaminophenylarsinic acid (10 g.) was dissolved as rapidly as possible in a hot mixture of alcohol (50 c.c.) and concentrated hydrochloric acid (50 c.c.) and reduced with sulphur dioxide after addition of a trace of iodine. The precipitated 7-*chloro*-7 : 12-*dihydro*iso*benzophenarsazine* (XII) was filtered off from the cold liquid and recrystallised from toluene. The short, yellow needles, m. p. 219°, were identical with an authentic specimen (Found: Cl, 10·7. $C_{16}H_{11}NClAs$ requires Cl, 10·8%).

7 : 12-iso*Benzophenarsazinic Acid Hydrochloride*.—2-α-Naphthylaminophenylarsinic acid (3·5 g.) was dissolved in a mixture of alcohol (15 c.c.) and concentrated hydrochloric acid (15 c.c.), and the mixture rapidly heated on the water-bath. After 2 minutes and while the solution was still hot, small, colourless plates of the *hydrochloride* of 7 : 12-*iso*benzophenarsazinic acid began to separate. It has m. p. 232° (decomp.) (Found: Cl, 10·0. $C_{16}H_{13}O_2NClAs$

requires Cl, 9·8%). This, on treatment with warm dilute sodium hydroxide solution followed by acidification with acetic acid, was converted into colourless 7 : 12-*iso*benzophenarsazinic acid (XI), which was recrystallised from dilute acetic acid (Found : As, 22·9. Calc. : As, 23·1%). The sodium salt had the properties described by Lewis and Hamilton (*J. Amer. Chem. Soc.*, 1921, **43**, 2218).

2-β-*Naphthylaminophenylarsinic Acid* (VI).—β-Naphthylamine was condensed with *o*-bromophenylarsinic acid, the quantities taken and the conditions of the reaction being the same as in the preparation of the isomeric substance. The crude acid (31 g.) was deposited in colourless needles, m. p. 181°, after the solution in hot alcohol had been decolorised with charcoal (Found : As, 21·6. $C_{16}H_{14}O_3NAs$ requires As, 21·9%). 12-Chloro-7 : 12-dihydrobenzophenarsazine (XIV) was prepared from this compound (10 g.) by the method used for the preparation of the isomeride. It was recrystallised from *s*-tetrachloroethane and obtained in yellow leaflets, m. p. 254°, identical in every respect with the compound formed by the condensation of arsenious chloride with phenyl-β-naphthylamine. Yield, 7 g. (Found : Cl, 10·85. Calc. : Cl, 10·8%).

7 : 12-*Benzophenarsazinic Acid* (XIII).—When a solution of the preceding compound (25 g.) in hot glacial acetic acid (200 c.c.) was rapidly cooled and treated with hydrogen peroxide (20 vols.; 130 c.c.) and then heated almost to boiling to complete the oxidation, 7 : 12-benzophenarsazinic acid was precipitated as a brown, amorphous solid. It was recrystallised from dilute acetic acid after decoloration with charcoal and obtained in small, colourless needles, m. p. above 325°. Yield, 18 g. (Found : As, 22·8. $C_{16}H_{12}O_2NAs$ requires As, 23·1%). The same acid was produced when a solution of 12-chloro-7 : 12-dihydrobenzophenarsazine was oxidised with an aqueous solution of chloramine-T. It was also obtained when a solution of 2-β-naphthylaminophenylarsinic acid in the minimum quantity of boiling glacial acetic acid was heated on the water-bath for 30 minutes. The acid crystallised on cooling and the filtrate contained a small quantity of unchanged 2-β-naphthylaminophenylarsinic acid.

7 : 12-*Benzophenarsazinic acid hydrochloride* was obtained by dissolving 2-β-naphthylaminophenylarsinic acid (0·3 g.) in a hot mixture of alcohol (5 c.c.) and concentrated hydrochloric acid (5 c.c.). After a few minutes the compound, m. p. 234° (decomp.), separated in fine needles (Found : Cl, 10·0. $C_{16}H_{13}O_2NClAs$ requires Cl, 9·8%). It was converted into 7 : 12-benzophenarsazinic acid in the usual way. The sodium salt (colourless needles) of 7 : 12-benzophenarsazinic acid is not very soluble in cold water;

the ammonium salt crystallises in glistening plates from water; the barium, silver, and mercuric salts are produced as heavy, white precipitates; the ferric salt is brown and somewhat gelatinous; the copper salt is pale greenish-blue; the cobalt salt is pale blue, and the calcium salt forms fine, colourless needles.

12-*Bromo*-7 : 12-*dihydrobenzophenarsazine* was prepared by reducing 7 : 12-benzophenarsazinic acid in alcohol–hydrobromic acid solution in the usual way. It forms short, deep orange-coloured needles, m. p. 251—252° (decomp.), from toluene (Found: Br, 21·7. $C_{16}H_{11}NBrAs$ requires Br, 21·5%).

2-*Nitrodiphenylamine*-6′-*arsinic Acid* (VII). — A mixture of *o*-aminophenylarsinic acid (47·2 g.), *o*-bromonitrobenzene (49·0 g.), dry potassium carbonate (42 g.), amyl alcohol (245 c.c.), and a trace of copper powder was boiled for 6 hours. The product was worked up as usual, washed with dilute hydrochloric acid and water to remove unchanged *o*-aminophenylarsinic acid, and recrystallised from aqueous alcohol, forming golden-yellow needles, m. p. 238—240° (decomp.). Yield of pure acid, 25% (Found: N, 7·95. $C_{12}H_{11}O_5N_2As$ requires N, 8·3%). *o*-Bromophenylarsinic acid and *o*-nitroaniline, condensed in a similar manner, gave a 7·7% yield of the same product.

The acid is slightly soluble in water and is soluble in alcoholic hydrochloric acid, but a hydrochloride could not be isolated. Solutions of the sodium and potassium salts are deep red in contrast to that of the acid, which is deep yellow.

2-*Nitrodiphenylamine*-6′-*dichloroarsine* (XV).—The preceding compound (3·1 g.) was dissolved in a hot mixture of alcohol (20 c.c.) and concentrated hydrochloric acid (25 c.c.), and sulphur dioxide passed into the solution for 5 minutes only, after addition of a trace of iodine. The oil which separated quickly solidified on cooling. The solid crystallised from benzene–light petroleum (b. p. 60—80°) in deep red crystals, m. p. 110° (Found: Cl, 19·95. $C_{12}H_9O_2N_2Cl_2As$ requires Cl, 19·8%). On oxidation with hydrogen peroxide (20 vol.) in acetic acid solution, the above 2-nitrodiphenylamine-6′-arsinic acid was obtained.

10-*Chloro*-4-*nitro*-5 : 10-*dihydrophenarsazine* (XVI).—After a solution of 2-nitrodiphenylamine-6′-dichloroarsine (1·5 g.) in glacial acetic acid (25 c.c.) had been boiled for 3 hours, beautiful scarlet needles of 10-chloro-4-nitro-5 : 10-dihydrophenarsazine were deposited on cooling. It was recrystallised from glacial acetic acid and then had m. p. 165° (Wieland and Rheinheimer, *loc. cit.*, give m. p. 156°) (Found: Cl, 10·8. Calc.: Cl, 11·0%).

This compound was oxidised by hydrogen peroxide (20 vol.) in glacial acetic acid solution, whereby it was converted into 4-nitro-

phenarsazinic acid. This acid was reduced by ferrous hydroxide (Burton and Gibson, *loc. cit.*) and converted into the 4-aminophenarsazinic acid, which was conveniently isolated as the hydrochloride. The hydrochloride, suspended in excess of dilute hydrochloric acid, was unaffected by sodium nitrite at 5°.

3-*Nitrodiphenylamine*-6′-*arsinic acid* (VIII) was prepared from *o*-aminophenylarsinic acid (20·9 g.) and *m*-bromonitrobenzene (21·7 g.) in a similar manner to the isomeride, the boiling, however, being continued for 7 hours. The product (16 g.) crystallised from dilute acetic acid in light yellow needles, m. p. 202° (decomp.) (Found: As, 21·7. $C_{12}H_{11}O_5N_2As$ requires As, 22·2%). The solutions of the sodium and potassium salts are deep red.

10-*Chloro*-3(or 1)-*nitro*-5 : 10-*dihydrophenarsazine* (XVII).—The compound just described (20 g.) was reduced in the usual manner for 15 minutes by sulphur dioxide; a deep red, crystalline substance soon filled the liquid. The product was fractionally crystallised from glacial acetic acid and only one substance, which formed glistening, thin prisms, m. p. 258—259° (decomp.), was obtained (Found: As, 22·8; Cl, 11·2. $C_{12}H_8O_2N_2ClAs$ requires As, 23·2; Cl, 11·0%).

3(or 1)-*Nitrophenarsazinic Acid*.—The preceding compound (4 g.) was boiled with glacial acetic acid (60 c.c.) and rapidly cooled, and to the solution-suspension hydrogen peroxide (20 vol.; 40 c.c.) was added. The colour of the solution rapidly changed and a yellowish-brown acid was precipitated; the reaction was completed by gentle warming. The product was recrystallised from dilute acetic acid. The yellow substance did not melt below 320° (Found: N, 8·8; As, 23·0. $C_{12}H_9O_4N_2As$ requires N, 8·7; As, 23·4%). It was insoluble in water and most organic solvents, but dissolved in aqueous sodium hydroxide, and from a strong solution of the latter the sodium salt (brown) crystallised.

10-*Bromo*-3(or 1)-*nitro*-5 : 10-*dihydrophenarsazine* was prepared by reducing 3(or 1)-nitrophenarsazinic acid in the presence of hydrobromic acid in the usual way. When recrystallised from benzene, it was obtained in short, reddish-brown needles, m. p. 234° (decomp.) (Found: Br, 22·15. $C_{12}H_8O_2N_2BrAs$ requires Br, 21·8%).

4-*Nitrodiphenylamine*-6′-*arsinic acid* (IX) was prepared from *p*-bromonitrobenzene (52·2 g.) and *o*-aminophenylarsinic acid (50·3 g.) in a similar manner to the isomeric compounds, the boiling, however, being continued in this case for 7½ hours. The crude product (35 g.) was recrystallised from dilute acetic acid, and the pure acid obtained as a pale yellow, microcrystalline substance, m. p. 223° (decomp.) (Found: N, 8·3. $C_{12}H_{11}O_5N_2As$ requires N, 8·3%). The alkali salts are deep orange-red in aqueous solution.

10-*Chloro*-2-*nitro*-5 : 10-*dihydrophenarsazine* (XVIII) was prepared from the preceding compound (8 g.) by reduction in the presence of hydrochloric acid in the usual way. The product (6·1 g.) was recrystallised from glacial acetic acid, in which it was somewhat sparingly soluble. It seems to be dimorphous, for it separated first in soft, yellow needles which, on standing or when the solution was stirred, changed into compact, small, orange-yellow, prismatic needles. On heating, the substance turned dark red at about 194—197° and had m. p. 276—278° (decomp.) (Found : Cl, 10·8; As, 22·95. $C_{12}H_8O_2N_2ClAs$ requires Cl, 11·0; As, 23·2%).

Phenarsazinic acid (20 g.) was nitrated under the conditions described by Burton and Gibson (J., 1926, 2244), and the nitro-acid purified as described through the sodium and barium salts. This acid, on reduction in the usual way in the presence of hydrochloric acid, gave a chloro-compound which was identical in every way with the above compound. It was obtained in soft, yellow needles which were converted into the compact, orange-yellow prisms; on heating, the behaviour was the same as that already described (Found : As, 23·05. Calc. : As, 23·2%). It must have been formed from 2-nitrophenarsazinic acid.

Phenarsazinic acid (10 g.) was nitrated as far as possible under the conditions described by Wieland and Rheinheimer (*loc. cit.*). The mixture was kept for 1½ hours after the addition of the nitric acid (*d* 1·5) was completed. The nitro-acid obtained from the sodium salt was recrystallised twice from 50% acetic acid and was then dark yellow to orange. It was reduced in the presence of hydrochloric acid in the usual way, and the product had a very indefinite melting point, melting and decomposition not being complete at 250°. After this had been further recrystallised from glacial acetic acid, it melted at 265—267° (decomp.), and although even then it was not quite pure, its behaviour when admixed with pure 10-chloro-2-nitro-5 : 10-dihydrophenarsazine showed that it was chiefly composed of this substance.

We are therefore justified in concluding that the most easily isolated product of the nitration of phenarsazinic acid is 2-nitrophenarsazinic acid, and not 4-nitrophenarsazinic acid as stated by Wieland and Rheinheimer.

10-Chloro-5 : 10-dihydrophenarsazine was also nitrated under the conditions described by Wieland and Rheinheimer. The mononitro-derivative obtained in the larger amount (for which they quoted no melting point) was oxidised by means of hydrogen peroxide (20 vol.) in glacial acetic acid solution. The product was recrystallised from glacial acetic acid and then reduced in the presence of hydrochloric acid in the usual way, being thus con-

verted into 10-chloro-2-nitro-5 : 10-dihydrophenarsazine, m. p. 276° (decomp.), identical with the product described above.

The various nitro-derivatives of 10-chloro-5 : 10-dihydrophenarsazine can be readily distinguished from 2-nitrodiphenylamine-6′-arsinic acid, since the latter dissolves in concentrated sulphuric acid to form a characteristic deep red solution, whilst the former compounds yield deep violet solutions. All the solutions change to an olive-green colour on addition of a drop of concentrated nitric acid.

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