13. *The Cyanoethylation of Amines and Arsines.*

By Richard C. Cookson and Frederick G. Mann.

The cyanoethylation of arylarsines previously recorded has now been extended to alkylarsines, and various derivatives prepared. The cyanoethylation of diphenylamine yields *diphenyl-2-cyanoethylamine*, and the *carboxylic acid* obtained by hydrolysis can be readily cyclised to 4-*keto*-1-*phenyl*-1 : 2 : 3 : 4-*tetrahydroquinoline*. No similar cyclisation of the arsine analogue could be achieved, and attempts to prepare other heterocyclic arsenic systems also failed.

We have previously shown (*J.*, 1947, 618) that arylarsines, $RAsH_2$, combine with vinyl cyanide, particularly under the influence of alkaline catalysts, to give the corresponding bis-2-cyanoethylarsines, $R{\cdot}As(CH_2{\cdot}CH_2{\cdot}CN)_2$, which can be readily hydrolysed to the corresponding acids, $R{\cdot}As(CH_2{\cdot}CH_2{\cdot}CO_2H)_2$, and also converted into amidine salts, of the type

$$R{\cdot}As[CH_2{\cdot}CH_2{\cdot}C(:\overset{+}{N}H_2){\cdot}NH_2]_2(\overset{-}{N}O_3)_2.$$

Diarylarsines, R_2AsH, show the same series of reactions.

Further work on these lines has been performed with two objects in view: first, to determine whether alkylarsines show similar reactions, and secondly, to investigate the use of the above derivatives for the synthesis of new types of heterocyclic arsenic compounds.

We find that methylarsine, $MeAsH_2$, combines with vinyl cyanide under the influence of sodium methoxide to give the liquid *methylbis-2-cyanoethylarsine* (I). This arsine, unlike the lower trialkylarsines, underwent no apparent oxidation on exposure to air, although warming

with methyl iodide gave the crystalline *methiodide*. This resistance to atmospheric oxidation was shown by the above arylbis-2-cyanoethylarsines, by their amidine derivatives, and by the corresponding carboxylic acids: presumably in all these compounds the strong inductive effect towards these 2-substituents considerably reduces the normal activity of the tertiary arsenic atom (cf. Mann and Watson, *J. Org. Chem.*, 1948, **13**, 502). The methyl group in the

$$\underset{\text{(I.)}}{Me{\cdot}As(CH_2{\cdot}CH_2{\cdot}CN)_2} \longrightarrow \underset{\text{(II.)}}{Me{\cdot}AsCl_2(CH_2{\cdot}CH_2{\cdot}CN)_2} \longrightarrow$$

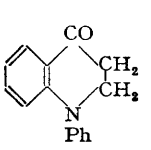
$$\underset{\text{(III.)}}{Cl{\cdot}As(CH_2{\cdot}CH_2{\cdot}CN)_2} \longrightarrow \underset{\text{(IV.)}}{HO{\cdot}As(:O)(CH_2{\cdot}CH_2{\cdot}CN)_2}$$

arsine (I) permits a reaction which is impossible in the aryl analogues, for the addition of chlorine gave the *dichloro*-derivative (II), which on thermal decomposition gave methyl chloride and *chlorobis-2-cyanoethylarsine* (III). The latter had normal properties: for example, on oxidation it furnished *bis-2-cyanoethylarsonous acid* (IV). It is clear that chloroarsines of type (III) may have considerable synthetic application.

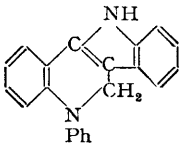
Before investigating the cyclisation of our aryl-arsenic derivatives, the conditions of formation and cyclisation of analogous nitrogen compounds were first briefly studied. Although patent specifications cite the reaction of several primary arylamines with vinyl cyanide, apparently only one such example has been described in chemical literature: Elderfield *et al.* (*J. Amer. Chem. Soc.*, 1946, **68**, 1262) obtained β-*p*-anisidinopropionitrile,

$$MeO{\cdot}C_6H_4{\cdot}NH{\cdot}CH_2{\cdot}CH_2{\cdot}CN,$$

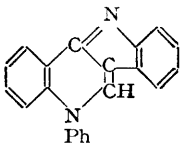
by boiling the reactants in glacial acetic acid. We find that aniline does not combine appreciably with boiling vinyl cyanide in the presence of sodium methoxide or acetic acid: when, however, the reactants were heated in acetic acid at 150°, a mixture of *phenyl-2-cyanoethylamine*, $Ph{\cdot}NH{\cdot}CH_2{\cdot}CH_2{\cdot}CN$, and *phenylbis-2-cyanoethylamine*, $Ph{\cdot}N(CH_2{\cdot}CH_2{\cdot}CN)_2$, was produced. Diphenylamine under the influence of a copper catalyst similarly gave *diphenyl-2-cyanoethylamine* which on hydrolysis furnished β-*diphenylaminopropionic acid*, $Ph_2N{\cdot}CH_2{\cdot}CH_2{\cdot}CO_2H$. This acid, when boiled in xylene with phosphoric anhydride, or alternatively when treated in



(V.)



(VI.)

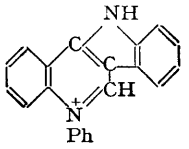


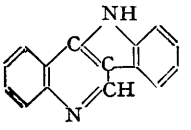
(VII.)

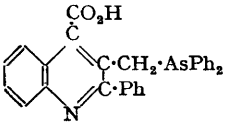
turn with phosphorus pentachloride and aluminium chloride, gave 4-*keto*-1-*phenyl*-1 : 2 : 3 : 4-*tetrahydroquinoline* (V). The *phenylhydrazone* of this quinoline when boiled in alcoholic hydrogen chloride solution, furnished a compound which initially appeared to be 1-phenyl-1 : 2-dihydroindolo(3′ : 2′ : 3 : 4)quinoline (VI), of formula $C_{21}H_{16}N_2$. We have accumulated considerable, although not decisive, evidence that this compound has the formula $C_{21}H_{14}N_2$ and is therefore 1-*phenyl*-ψ-*indolo*(3′ : 2′ : 3 : 4)*quinoline* (VII). First, our analytical data are consistently in support of the formula $C_{21}H_{14}N_2$, although the compositional difference between the two formulæ is, of course, small. Secondly, our base forms deep lemon-coloured crystals which dissolve in acids with immediate decolorisation; the crystalline *monohydrochloride*, for example, is colourless. Even weak acids such as acetic acid will cause this decolorisation, and addition of alkalis reprecipitates the yellow base. It is unlikely that the structure (VI) would cause this intense yellow colour, and far more unlikely that proton addition to this structure, even if followed by tautomeric change, would result in complete decolorisation. A compound of structure (VII), on the other hand, would very probably be coloured, and on salt formation might readily give the cation (VIII); this change in structure would almost certainly be accompanied by loss of colour. Thirdly, Clemo and Perkin (*J.*, 1924, **125**, 1608) have shown that the phenylhydrazone of 4-keto-1 : 2 : 3 : 4-tetrahydroquinoline when heated with aqueous sulphuric acid underwent indolisation and dehydrogenation in one operation to give the colourless indolo(3′ : 2′ : 3 : 4)quinoline (IX). It is therefore not unlikely that dehydrogenation has also accompanied our indolisation, with formation of the compound (VII). The structure of this yellow base is being further investigated.

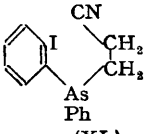
In view of the above results, we have attempted to cyclise diphenyl-2-carboxyethylarsine, and also its crystalline *chloride*, $Ph_2As{\cdot}CH_2{\cdot}CH_2{\cdot}COCl$, to the arsenic analogue of the quinolone (V), but all our attempts, using a wide variety of reagents and conditions, have failed. Similar

attempts to cyclise phenylbis-2-carboxyethylarsine, $Ph{\cdot}As(CH_2{\cdot}CH_2{\cdot}CO_2H)_2$, to a tricyclic diketone have also failed.


(VIII.)


(IX.)


(X.)


(XI.)

Phenylbis-2-cyanoethylarsine when treated with phenylmagnesium bromide gave *phenylbis-2-benzoylethylarsine*, $Ph{\cdot}As(CH_2{\cdot}CH_2{\cdot}COPh)_2$, and the diphenyl analogue similarly gave *diphenyl-2-benzoylethylarsine*, $Ph_2As{\cdot}CH_2{\cdot}CH_2{\cdot}COPh$. Attempts to cyclise the former ketone by an internal Claisen condensation failed. When the latter ketone was heated with isatin in alkaline solution, it furnished diphenyl-3-(4-carboxy-2-phenylquinolyl)methylarsine (X), which we have isolated as the *oxide* and other crystalline derivatives.

We have investigated the synthesis of phenyl-*o*-iodophenyl-2-cyanoethylarsine (XI) as a possible route to heterocyclic derivatives, since the Grignard reagent from this compound would probably react rapidly with the nitrile group to give the cyclic ketimine. The interaction of *o*-iodobenzenediazonium chloride and phenylarsine oxide, $PhAs{:}O$, in alkaline solution furnished *phenyl-o-iodophenylarsonous acid*, $Ph(C_6H_4I)As(:O)OH$, but the yield was too low for the method to have value. Alternatively, phenyl-*o*-nitrophenylarsonous acid,

$$Ph(C_6H_4{\cdot}NO_2)As(:O)OH,$$

was reduced in one operation to phenyl-*o*-aminophenylarsine, $Ph(C_6H_4{\cdot}NH_2)AsH$, which was then combined with vinyl cyanide to give *phenyl-o-aminophenyl-2-cyanoethylarsine*, $Ph(C_6H_4{\cdot}NH_2)As{\cdot}CH_2{\cdot}CH_2{\cdot}CN$. Attempts made to convert this compound into the *o*-iodo- or *o*-bromo-derivative gave only intractable gmus, and this synthetic approach was therefore abandoned.

It is noteworthy that phenylarsine reacted with acraldehyde also to give only an intractable gum, and with mesityl oxide to give arsenobenzene, the mesityl oxide having presumably undergone reduction. No interaction between phenylarsine and ethylene oxide could be detected.

Experimental.

Methylbis-2-cyanoethylarsine (I).—Dehn (*Amer. Chem. J.*, 1905, **33**, 117) prepared methylarsine, b. p. 2°/755 mm., but recorded no preparative details. In our experiments the arsine was passed, without isolation, directly into the vinyl cyanide. A mixture of sodium methylarsonate (30 g.) and zinc dust (120 g.) was placed in a flask fitted with a dropping funnel, an entrance tube for nitrogen, and a delivery tube. The air was replaced by nitrogen, and a solution of mercuric chloride (6 g.) in alcohol (100 c.c.) added with shaking. Concentrated hydrochloric acid (300 c.c.) was then added slowly with cooling and shaking. The issuing gases were passed through flaked sodium hydroxide and thence down a tube reaching to the bottom of a flask containing vinyl cyanide (25 c.c.) mixed with sodium methoxide (0·1 g.) and cooled in a mixture of solid CO_2 and acetone. White crystals separated. After 3 hours the gases in the flask were replaced by nitrogen and the flask was rapidly stoppered. As the latter attained room temperature, the crystals (possibly of methylarsine) dissolved. The flask was set aside for 2 weeks, and the liquid contents (which now contained a black solid in suspension) were then refluxed for 2 hours in an atmosphere of nitrogen. Unchanged vinyl cyanide (7 c.c.) was now distilled, and the residue, when fractionated at 0·1 mm., gave a main fraction (17 g.), b. p. 148—149°, of the pure *arsine* (I) as a colourless liquid of faint odour (Found : N, 14·1. $C_7H_{11}N_2As$ requires N, 14·1%); 53% calculated on arsonate used. This reaction is clearly much less vigorous than that with, for example, phenylarsine, which in the presence of alkaline catalysts may occur with almost explosive violence (Cookson and Mann, *loc. cit.*).

A solution of the arsine in methyl iodide on warming gave an oil, which on crystallisation from alcohol gave colourless needles of the *arsine methiodide*, m. p. 155—157° (Found : C, 28·5; H, 4·4; N, 8·0. $C_8H_{14}N_2IAs$ requires C, 28·25; H, 4·1; N, 8·2%). This compound in turn furnished the *arsine methopicrate*, orange-yellow needles from aqueous alcohol, m. p. 91—93° (Found : C, 38·6; H, 4·0; N, 15·8. $C_{14}H_{16}O_7N_5As$ requires C, 38·1; H, 3·6; N, 15·9%).

A solution of bromine in carbon tetrachloride was added to a similar suspension of the arsine until a permanent pale yellow colour was produced. The colourless very deliquescent crystals of the *dibromide* which separated were recrystallised from acetic acid containing acetic anhydride : plates, m. p. 76° (Found : N, 8·2. $C_7H_{11}N_2Br_2As$ requires N, 7·8%).

An aqueous solution of potassium palladochloride was added to an acetone solution of the arsine : the addition of water then precipitated *dichlorobis(methylbis-2-cyanoethylarsine)palladium*, yellowish-brown crystals from aqueous acetone, m. p. 129° (Found : N, 10·0. $C_{14}H_{22}N_4Cl_2As_2Pd$ requires N, 9·8%).

Formation and Thermal Decomposition of the Arsine Dichloride (II).—Dry chlorine was passed over the surface of a solution of the arsine (I) (11·4 g.) in carbon tetrachloride (15 c.c.) and chloroform (5 c.c.),

which was shaken and ice-cooled. The colourless oily *dichloride* separated and ultimately formed very deliquescent needle-shaped crystals (Found : N, 10·4. $C_7H_{11}N_2Cl_2As$ requires N, 10·4%). The solvents were then distilled off, and the residue heated for 30 minutes at 170—180°/17 mm. Distillation at 0·5 mm. then gave a low-boiling fraction (2·6 g.), followed by the *chlorobis-2-cyanoethylarsine* (III), b. p. 190—195°, a rather viscous liquid containing a trace of dark suspension which settled (Found : C, 32·7; H, 3·5; N, 12·6. $C_6H_8N_2ClAs$ requires C, 33·0; H, 3·7; N, 12·8%).

The chloroarsine was added dropwise to concentrated nitric acid which was cooled in ice and well stirred. Vigorous oxidation occurred, and fine needles of the *hydroxy-nitrate* of the arsonous acid (IV) separated, m. p. 113—116°, after recrystallisation from acetic acid (Found : C, 25·7; H, 3·4; N, 15·0. $C_6H_9O_2N_2As,HNO_3$ requires 25·8; H, 3·6; N, 15·0%) : yield, 80%. An aqueous solution of the nitrate was treated with sodium hydroxide (1 mol.) and evaporated to dryness : a hot alcoholic extract of the residue, when filtered and cooled, deposited the crystalline *arsonous acid* (IV), m. p. 142° (efferv.) (Found : N, 12·9. $C_6H_9O_2N_2As$ requires N, 13·0%).

When gaseous arsine, AsH_3, was passed into vinyl cyanide containing sodium methoxide, no interaction could be detected.

Cyanoethylation of Aniline.—A mixture of aniline (10 c.c.), vinyl cyanide (17 c.c.; 2·4 mols.) and acetic acid (15 c.c.) was heated in an autoclave first at 130° for 1·5 hours and then at 150° for 2 hours. The cold pale brown product, after filtration to remove a small quantity of gelatinous material, was distilled. After low-boiling constituents had been removed, three fractions were collected : (i) b. p. 178—186°/16 mm., (ii) 150—190°/0·3 mm., (iii) 190°/0·3 mm. Fraction (i) partly solidified, and when then recrystallised from aqueous alcohol furnished *2-cyanoethylaniline* in colourless crystals, m. p. 51·5° (Found : C, 74·0; H, 7·1; N, 18·7. $C_9H_{10}N_2$ requires C, 74·0; H, 6·8; N, 19·2%) : 2·8 g., 18%. Fraction (iii), a very viscous syrup, solidified when set aside; recrystallisation from alcohol gave *bis-2-cyanoethylaniline*, colourless crystals, m. p. 80—82° (Found : C, 72·6; H, 6·3; N, 21·7. $C_{12}H_{13}N_3$ requires C, 72·4; H, 6·5; N, 21·1%) : 5·0 g.; 23%.

Alkaline hydrolysis of this dinitrile in alcoholic solution afforded ultimately the anilinobis-2-propionic acid as a viscous syrup, which formed very deliquescent crystals when dried at 100° : it was therefore characterised as its *di-S-benzylthiouronium* salt; needles from alcoholic *cyclo*hexane, m. p. 146° (Found : N, 12·0; S, 11·2. $C_{12}H_{15}O_4N,2C_8H_{10}N_2S$ requires N, 12·3; S, 11·2%).

Cyanoethylation of Diphenylamine.—A mixture of diphenylamine (40 g.), vinyl cyanide (18 c.c.), copper acetate (2 g.) dissolved in acetic acid (18 c.c.), and fine copper powder (4 g.) was heated in an autoclave at 150° for 8 hours. Distillation of the crude product at atmospheric pressure removed unchanged nitrile and acetic acid, and further distillation in a vacuum gave a considerable fraction of unchanged diphenylamine, followed by the crude *diphenyl-2-cyanoethylamine*, b. p. 148—152°/0·1 mm. Refractionation gave the pure nitrile as a viscous liquid, b. p. 133°/0·05 mm., which ultimately solidified, and when recrystallised from *cyclo*hexane formed colourless crystals, m. p. 41° (Found : C, 80·8; H, 6·1. $C_{15}H_{14}N_2$ requires C, 81·1; H, 6·3%) : average yield, 12 g. Absence of the copper catalyst resulted in a very low yield of the cyano-amine : when the proportion of vinyl cyanide was increased, the proportion of unchanged diphenylamine did not correspondingly decrease.

β-Diphenylaminopropionic Acid.—A solution of the nitrile (15 g.) and potassium hydroxide (30 g.) in water (200 c.c.) containing alcohol (150 c.c.) was refluxed for 3—4 hours. The alcohol was then distilled and the cold residual solution acidified. The precipitated *acid* was collected and recrystallised from aqueous alcohol : colourless crystals, m. p. 111—112° (Found : C, 75·0; H, 6·6; N, 6·0. $C_{15}H_{15}O_2N$ requires C, 74·7; H, 6·2; N, 5·8%). If the crude nitrile is used in this preparation, unchanged diphenylamine crystallises in the cold residual solution and can be removed before acidification.

4-Keto-1-phenyl-1 : 2 : 3 : 4-tetrahydroquinoline (V).—(*a*) Phosphoric anhydride (5 g.) was added to a solution of the above acid (4 g.) in warm xylene (50 c.c.), which was then refluxed for 2 hours. The xylene was then removed by steam distillation, and the cold aqueous residue treated with an excess of sodium carbonate and extracted with benzene. The solvent was removed from the dried filtered extract, and the residue on distillation furnished the *quinolone* (V) as a pale yellow liquid (2·3 g.), b. p. 150—175°/0·2 mm., which readily solidified, and when recrystallised from ethyl alcohol gave cream-coloured crystals, m. p. 84° (Found : C, 80·5; H, 5·9; N, 6·1. $C_{15}H_{13}ON$ requires C, 80·7; H, 5·8; N, 6·3%). When this quinolone was once obtained crystalline, further preparations crystallised on evaporation of the solvent, and distillation was unnecessary.

(*b*) Phosphorus pentachloride (4·2 g.; 1 mol.) was added to a suspension of the above acid (4·8 g.) in carbon disulphide (25 c.c.), and the mixture refluxed for 1 hour. The dark purple solution, containing a heavy oil, was cooled in ice whilst aluminium chloride (2·7 g.; 1 mol.) was added, and the refluxing for 1 hour then repeated. The cold product was shaken with ice and water, and the disulphide decanted and evaporated. The residual syrup was thoroughly extracted with cold ether (leaving a brownish gum and a fine red powder), and the filtered extract distilled to remove the solvent and then to obtain the quinolone as described above. This method can be applied only on a small scale because otherwise the aluminium chloride causes the heavy oil to form a viscous intractable cake, and the yield of quinolone is low.

The *phenylhydrazone* was readily prepared, pale yellow crystals from alcohol, m. p. 140—142° (Found : N, 13·6. $C_{21}H_{19}N_3$ requires N, 13·4%). The 2 : 4-*dinitrophenylhydrazone* formed magnificent deep red crystals from ethyl acetate, m. p. 260° (Found : C, 62·0; H, 4·2; N, 17·4. $C_{21}H_{17}O_4N_5$ requires C, 62·5; H, 4·2; N, 17·4%).

The Yellow Base (VII).—A saturated solution (40 c.c.) of hydrogen chloride in alcohol was added to a suspension of the above phenylhydrazone (2 g.) in alcohol (20 c.c.), a deep red colour immediately developing. The mixture was refluxed for 3 hours, and on cooling colourless crystals of the *monohydrochloride monohydrate* (0·5 g.) slowly separated : addition of a trace of water to the cold solution increased the yield. Recrystallisation from alcohol gave crystals, m. p. 360° (decomp.) (Found : C, 72·0; H, 5·5; N, 8·0; Cl, 9·8. $C_{21}H_{14}N_2,HCl,H_2O$ requires C, 72·3; H, 4·9; N, 8·0; Cl, 10·2%).

When this salt was treated with aqueous sodium hydroxide, an immediate yellow colour developed : the free *base* (VII) was extracted with ether, the solvent evaporated, and the base recrystallised from

aqueous alcohol. It separated as bright lemon-yellow crystals, m. p. 215° (Found: C, 85·5, 85·8, 86·0; H, 5·05, 4·6, 4·7; N, 9·4. $C_{21}H_{14}N_2$ requires C, 85·7; H, 4·8; N, 9·5%. $C_{21}H_{16}N_2$ requires C, 85·1; H, 5·4; N, 9·5%). The base formed a very sparingly soluble *picrate*, which could, however, be recrystallised from acetic acid: yellow crystals, m. p. 312° (decomp.) (Found: C, 61·8; H, 3·2; N, 13·7. $C_{21}H_{14}N_2,C_6H_3O_7N_3$ requires C, 61·9; H, 3·3; N, 13·4%).

β-Diphenylarsinopropionyl Chloride.—A solution of thionyl chloride (2·6 c.c.; 1·1 mols.) in chloroform (6 c.c.) was slowly added to a cooled, agitated suspension of the propionic acid (10 g.) in chloroform (20 c.c.). The mixture was refluxed for 1 hour, and the cold solution then filtered, the solvent removed by distillation and the residue heated at 90°/0·05 mm. The viscous residue when repeatedly stirred with *cyclo*hexane solidified, and when then recrystallised from xylene gave the *chloride* as colourless crystals, m. p. 143—144° (Found: C, 55·9; H, 4·2; Cl, 10·9. $C_{15}H_{14}OClAs$ requires C, 56·2; H, 4·4; Cl, 11·1%): 7·5 g., 71%. Attempts to cyclise this compound to the arsenic analogue of (V) all failed.

Similar attempts to cyclise β-diphenylarsinopropionic acid by treatment with phosphorus pentachloride followed by aluminium chloride in nitrobenzene gave mainly diphenylarsine oxide, $(Ph_2As)_2O$, and in benzene gave the diphenyl-2-benzoylethylarsine described below. The use of phosphorus oxychloride or trichloride for the first stage and/or stannic chloride in the second stage, and the use of various other solvents, gave no evidence of cyclisation. The action of phosphoric anhydride in xylene, and also of anhydrous hydrogen fluoride, on the carboxylic acid gave indefinite products.

Many attempts were made to cyclise phenylbis-2-carboxyethylarsine by treatment successively with phosphorus pentachloride (or thionyl chloride) and aluminium chloride in various solvents and thus to obtain the tricyclic diketo-arsine, but these also failed. The acid could be distilled unchanged at 0·1 mm. pressure.

Phenylbis-2-benzoylethylarsine.—A solution of phenylbis-2-cyanoethylarsine (10 g.) in benzene (50 c.c.) was slowly added to a cooled, agitated Grignard reagent prepared from bromobenzene (32 c.c.; 8 mols.), ether (120 c.c.), and magnesium (7·9 g.; 8·5 atoms) in a nitrogen atmosphere. After 2 hours' refluxing, the product was cooled, hydrolysed by the addition of concentrated hydrochloric acid (100 c.c.) and water (150 c.c.), and the mixture again refluxed for 2 hours. The ether was distilled off, and the benzene solution separated, dried, and the solvent distilled. The viscous residue was twice extracted with cold ether, and the ethereal extract then filtered and evaporated. The residue thus obtained, when recrystallised from alcohol containing 10% of water, gave the *arsine* as pale yellow needles, m. p. 83—84° (Found: C, 69·3; H, 5·5. $C_{24}H_{23}O_2As$ requires C, 68·9; H, 5·5%): yield, 25%. It gave a *methiodide*, as colourless crystals from alcoholic ether, m. p. 145—146° (Found: C, 53·8; H, 5·0. $C_{25}H_{26}O_2IAs$ requires C, 53·55; H, 4·6%).

Diphenyl-2-benzoylethylarsine.—This was prepared essentially by the same method and similarly crystallised: colourless needles, m. p. 83—84° (Found: C, 69·7; H, 5·6. $C_{21}H_{19}OAs$ requires C, 69·6; H, 5·25%): yield, 41%. It gave a 2:4-*dinitrophenylhydrazone*, orange-red crystals, m. p. 124—126° (Found: N, 10·5. $C_{27}H_{23}O_4N_4As$ requires N, 10·3%), and its crude methiodide gave the *methopicrate*, yellow needles from aqueous alcohol, m. p. 114—115° (Found: C, 55·85; H, 4·35; N, 7·2. $C_{28}H_{24}O_8N_3As$ requires C, 55·5; H, 4·0; N, 6·9%).

A mixture of this monoketone (1·8 g.), isatin (0·8 g.), alcohol (12 c.c.), water (2 c.c.), and potassium hydroxide (1·2 g.) was refluxed for 18 hours, cooled, diluted with water, and extracted with ether. The aqueous solution on acidification deposited *diphenyl-3-(4-carboxy-2-phenylquinolyl)methylarsine oxide*, colourless plates from aqueous alcohol, m. p. 212—213° (efferv., with preliminary softening) (Found: C, 68·3; H, 4·3; N, 2·95. $C_{29}H_{22}O_3NAs$ requires C, 68·6; H, 4·3; N, 2·8%). It is clear that the arsine underwent atmospheric oxidation during the long refluxing. This acid gave a *monopicrate* (due probably to picric acid addition at the AsO bond), yellow crystals, m. p. 185—188° (decomp., bath preheated) (Found: C, 56·95; H, 3·5; N, 8·0. $C_{29}H_{22}O_3NAs,C_6H_3O_7N_3$ requires C, 57·05; H, 3·4; N, 7·6%): it also gave a *monohydrated benzylammonium* salt, colourless crystals from alcoholic ethyl acetate, m. p. 173—176° (efferv.) (Found: C, 68·55; H, 5·5; N, 4·5. $C_{29}H_{22}O_3NAs,C_7H_9N,H_2O$ requires C, 68·3; H, 5·2; N, 4·4%).

Cook and Read (*J.*, 1945, 401) have shown that methylbis-2-cyanoethylamine when treated with sodium undergoes the Thorpe cyclisation to the imino-nitrile. We have failed to effect a similar cyclisation of phenylbis-2-cyanoethylarsine using sodium, or sodium ethoxide (Thorpe *et al.*, *J.*, 1908, **93**, 176; 1909, **95**, 685, 1903) or lithium phenylmethylamide (Ziegler *et al.*, *Ber.*, 1933, **66**, 1867; *Annalen*, 1933, **504**, 94; 1934, **511**, 1). The destructive distillation of the barium salt of phenylbis-2-carboxyethylarsine failed to give the cyclic ketone.

Diphenyl-2-carboxyethylarsine Oxide.—When a solution of the carboxy-arsine (1 g.) in alcohol (10 c.c.) was refluxed with mercuric oxide (0·72 g.; 1 mol.), drops of mercury rapidly appeared. After 15 minutes' heating, charcoal was added, and the filtered solution evaporated. The residue when crystallised from water gave the *carboxyethylarsine oxide* as long colourless needles, m. p. 152° (efferv.) (Found: C, 56·8; H, 4·55. $C_{15}H_{15}O_3As$ requires C, 56·6; H, 4·7%): 1·0 g., 95%. When this oxide was heated, decomposition occurred just above its m. p., and propionic acid distilled over, and was identified as its *S*-benzylthiouronium salt, m. p. 148°, unchanged by admixture with an authentic sample. The residue from the decomposition solidified on cooling, and consisted of diphenylarsine oxide, $(Ph_2As)_2O$, in 98% yield: this was identified by its m. p. (alone and mixed), by conversion into the *N*-pentamethylenedithiocarbamate, and by oxidation to diphenylarsonous acid, which was also converted into its S-*benzylthiouronium* salt, colourless needles, m. p. 147° (efferv.) (Found: C, 56·0; H, 5·0; N, 6·8. $C_{12}H_{11}O_2As,C_8H_{10}N_2S$ requires C, 56·1; H, 4·9; N, 6·5%).

Diphenyl-2-carboxy-*n*-propylarsine was similarly oxidised by mercuric oxide to the *arsine oxide*, colourless crystals from aqueous alcohol, m. p. 157—160° (efferv.) (Found: C, 58·1; H, 5·1. $C_{16}H_{17}O_3As$ requires C, 57·8; H, 5·1%). This oxide on heating similarly gave *iso*butyric acid, identified as its *S*-benzylthiouronium salt, m. p. 144° (alone and mixed), and a residue of diphenylarsine oxide.

When diphenyl-2-carboxyethylarsine in chloroform solution was treated first with bromine (1 mol.) and then with hydrogen sulphide, and the residual product subjected to alkaline hydrolysis, *diphenyl-*

2-carboxyethylarsine sulphide was ultimately obtained, colourless crystals from aqueous alcohol, m. p. 131—134° (Found: C, 53·5; H, 4·2. $C_{15}H_{15}O_2SAs$ requires C, 53·9; H, 4·5%).

o-*Iododiphenylarsonous Acid*.—This compound was prepared by gradually mixing a solution of phenylarsine oxide in aqueous sodium hydroxide containing some sodium carbonate with a solution obtained by the diazotisation of *o*-iodoaniline (1 mol.) with hydrochloric acid and sodium nitrite. After the usual working up, and repeated purification, the *arsonous acid* was obtained as colourless crystals from alcohol, m. p. 211—214° (Found: C, 37·6; H, 3·1. $C_{12}H_{10}O_2IAs$ requires C, 37·1; H, 2·6%). It gave an S-*benzylthiouronium salt*, colourless crystals, m. p. 162° (Found: N, 5·0. $C_{12}H_{10}O_2IAs,C_8H_{10}N_2S$ requires N, 5·1%).

o-*Aminodiphenylarsine*.—A mixture of *o*-nitrodiphenylarsonous acid (50 g.) and zinc dust (160 g.) under an atmosphere of nitrogen in a flask fitted with a reflux condenser was treated with a solution of mercuric chloride (4 g.) in methyl alcohol (100 c.c.). Then, whilst the mixture was kept agitated but not cooled, concentrated hydrochloric acid (350 c.c.) was added over a period of 24 hours. The mixture, still protected by nitrogen, was set aside for 2 days, ether (350 c.c.) then added, and after 1 further day, the mixture was chilled and made strongly alkaline with 40% aqueous sodium hydroxide. The ethereal extract was separated, dried (potassium hydroxide), and distilled, giving the arsine as a colourless liquid, b. p. 140°/0·6 mm.: 17 g., 43%. It was so rapidly oxidised that neither analysis nor the preparation of crystalline derivatives was attempted.

Phenyl-o-aminophenyl-2-cyanoethylarsine.—The above arsine (16·3 g.) and vinyl cyanide (6·6 c.c., 1·5 mols.) were refluxed together for 4 hours, and the product on careful fractionation ultimately gave the *cyano-arsine* as a colourless liquid, b. p. 197—200°/0·35 mm. (Found: C, 60·1; H, 5·6; N, 9·2. $C_{15}H_{15}N_2As$ requires C, 60·4; H, 5·0; N, 9·4%): 9·2 g., 46%. It slowly developed a red colouration on exposure to air.

UNIVERSITY CHEMICAL LABORATORY, CAMBRIDGE. [*Received, March 23rd*, 1948.]