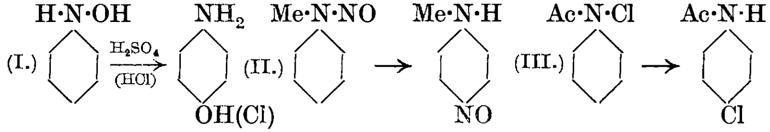
CLX.—*Investigations in the Diphenyl Series. Part I. Migration Reactions.*

By Frank Bell, Joseph Kenyon, and Percy Harry Robinson.

In view of the appearance of a paper by Vorländer (*Ber.*, 1925, **58**, 1913), in which 4-hydroxylaminodiphenyl is described, and of another by Scarborough and Waters on the chlorination and bromination of 4-aminodiphenyl (this vol., p. 557), it has been thought advisable to communicate some of the results already obtained by the authors in the same field.

The literature shows that numerous attempts have been made to elucidate the spatial relations of the two nuclei in diphenyl compounds, and there is considerable evidence in favour of the view of the closeness of the 4, 4′-positions in some derivatives. If the 4, 4′-positions in diphenyl are close together, there is a reasonable probability that those types of reactions which involve the para-migration of certain groups in simple benzene compounds might also be exhibited, under appropriate conditions, by certain derivatives of diphenyl, the migrating group passing from position 4 to position 4′. Migration reactions in the diphenyl series analogous to the following have been looked for, but have not been found :



In the corresponding diphenyl compounds decomposition occurs in case (II), whilst in cases (I) and (III) migration does take place, not, however, to the 4′-position but most probably to the adjacent 3-position.

There is an extensive literature on the preparation of diphenyl by the thermal decomposition of benzene, the most recent account being that of Lowe and James (*J. Amer. Chem. Soc.*, 1923, **45**, 2666), who, however, used an apparatus which is outside the resources of an ordinary laboratory. A simpler device is described in the experimental part; chlorobenzene, under similar treatment in the apparatus described, underwent extensive carbonisation, and no 4 : 4′-dichlorodiphenyl was obtained. The nitration of diphenyl was carried out by a modification of the methods due to Hübner (*Annalen*, 1881, **209**, 339) and Van Hove (*Bull. Soc. chim. Belg.*, 1923, **32**, 52).

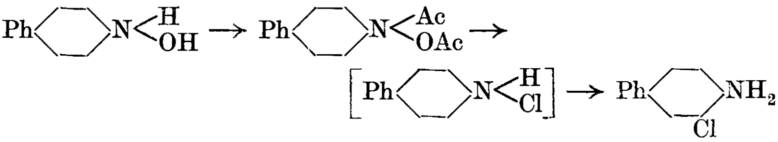
By the reduction of 4-nitrodiphenyl with aluminium amalgam and moist ether, there is obtained a complex mixture of 4-azodiphenyl, 4-azoxydiphenyl, 4-aminodiphenyl, and 4-hydroxylaminodiphenyl, together with unchanged nitrodiphenyl. By crystallisation of this mixture from benzene, a 30% yield of 4-hydroxylaminodiphenyl is obtained. Vorländer (*loc. cit.*), who gives no experimental details whatever, states that the compound was prepared " nach bekanntem Verfahren " and melted at 132—134°. The insolubility of 4-hydroxylaminodiphenyl militates seriously against migration experiments under favourable conditions. Sulphuric acid of various concentrations was employed at first, but as the minimum concentration of this acid necessary for solution of the hydroxylamino-compound at the ordinary temperature is above 50%, deep-seated decomposition occurs, and no crystalline material other than 4-azoxydiphenyl can be isolated from the products of the reaction. By the action of 10% sulphuric acid at 100°, a very small proportion of a new compound was formed. This substance has not yet been thoroughly investigated, but it is believed to be 4-diphenylyl(4-amino-3-diphenylyl)amine,

$$C_6H_4Ph{\cdot}NH{\cdot}C_6H_3Ph{\cdot}NH_2.$$

When hydrogen chloride is passed into a dry ethereal solution of 4-hydroxylaminodiphenyl, or when this compound is left for some time in contact with strong hydrochloric acid, 4-*hydroxylaminodiphenyl hydrochloride* is formed, which, on heating, decomposes to give principally 4-azoxydiphenyl.

An alcoholic solution of hydrogen chloride converts 4-hydroxylaminodiphenyl almost completely into 4-azoxydiphenyl, but at the same time there is produced a very small proportion of a compound which melts at 69° and contains chlorine.

Acetyl chloride reacts readily with 4-hydroxylaminodiphenyl to yield a diacetyl derivative believed to be *diacetyl*-4-*hydroxylaminodiphenyl.* This compound can be prepared in almost theoretical yield by dissolving 4-hydroxylaminodiphenyl in warm acetic anhydride, and when warmed with strong hydrochloric acid it undergoes hydrolysis and simultaneous conversion into a chloro-base (m. p. 69°), the hydrochloride of which hydrolyses very readily, and in consequence has not been prepared in a sufficiently pure state for analysis. The chloro-base yields a monoacetyl derivative of m. p. 146° which is identical with that obtained by the action of acetic acid on diphenylyl-4-acetylchloroamine (*vide* below), so that the course of this reaction is probably expressed by the following scheme :



4-*Methylaminodiphenyl* was prepared by treating 4-acetylaminodiphenyl with sodium and methyl iodide with subsequent elimination of the acetyl group, and was purified by conversion into its nitroso-derivative.

4-*Nitrosomethylaminodiphenyl*, both alone and when suspended in ether (in which it is only sparingly soluble), was mixed with an alcoholic solution of hydrogen chloride, when slow reaction ensued with evolution of gas. No nitroso-4-methylaminodiphenyl was found in the reaction mixture, which consisted mainly of 4-methylaminodiphenyl together with a little of the unchanged substance.

4-*Diazomethylaminodiphenyl* is a by-product in the preparation of 4-nitrosomethylaminodiphenyl from the crude secondary amine, which probably contains a little 4-aminodiphenyl.

Diphenylyl-4-*acetylchloroamine*. It is clear from the literature that the preparation of aryl acyl chloroamines is susceptible to slight variations in experimental conditions (compare Armstrong, J., 1900, **77**, 1047; Chattaway and Orton, J., 1901, **79**, 275).

A similar susceptibility has been found in the case of 4-acetylaminodiphenyl, which, however, reacts rapidly and quantitatively at 70—80°. One sample yielded 67% of diphenylyl-4-acetylchloroamine after only 10 minutes' heating. Further, the state of subdivision is very important, and may account for the difficulties met with by Armstrong and his students in the case of acetanilide (*loc. cit.*). When the 4-acetylaminodiphenyl was powdered mechanically, the yields were poor.

When diphenylyl-4-acetylchloroamine is warmed with glacial acetic acid it is transformed into a chloro-4-acetylaminodiphenyl believed to be 3-chloro-4-acetylaminodiphenyl (compare above).

No trace of 4′-chloro-4-acetylaminodiphenyl was detected, although its presence was specially sought.

3-Chloro-4-acetylaminodiphenyl results directly if the sodium hypochlorite solution used is above normal in strength.

A quantitative yield of 3-chloro-4-acetylaminodiphenyl results also from the direct chlorination of 4-acetylaminodiphenyl in acetic acid. Again no trace of 4′-chloro-4-acetylaminodiphenyl was detected. This is in marked contrast with the bromination of 4-acetylaminodiphenyl in acetic acid, which yields 30% of the theoretical quantity of 4′-bromo-4-acetylaminodiphenyl together with 65% of a bromo-base (m. p. 65°) not yet fully examined.

EXPERIMENTAL.

Diphenyl.—The heating coil, which consists of about 1 yard of 32 gauge nichrome wire, is loosely threaded through a strip of mica 5″ × 1¼″ and suspended in the neck and body of a 5-litre flask fitted with an upright condenser. Benzene (1½ litres) is placed in the flask and boiled. When benzene is dripping freely from the condenser, the current is switched on, and by means of a sliding resistance is gradually raised to the value (about 3 amps.) at which the flask begins to fill with fumes. Little attention is required, and at the end of about 30 hours the liquid is transferred to a flask and distilled. Benzene comes over first, and then the temperature rises rapidly. The fraction b. p. 245—260° is collected and crystallised from alcohol. The yield of pure diphenyl averages 9 g. per hour.

Nitration of Diphenyl.—To a solution of diphenyl in acetic acid (2 parts) at 70—90°, nitric acid (*d* 1·51; 2½—3 mols.) is added in small quantities. The solution darkens, and when about one-third of the acid has been added a visible and steady reaction sets in. The remaining acid is added more carefully, the experiment taking 1¼ to 1½ hours from the first addition of acid. After cooling, the crystalline crop of 4-nitrodiphenyl is filtered off, and the filtrate diluted with water. The oily layer thus precipitated is separated roughly from the aqueous layer and filtered from a further amount of 4-nitrodiphenyl. The oil is heated in a current of steam to free it from residual acid and unchanged diphenyl, and then distilled in a vacuum. Moisture and a trace of diphenyl come over first, and the main bulk distils at 188—193°/20 mm. The distillate is dissolved in alcohol at 40° and the crystals of 4-nitrodiphenyl which separate on cooling are filtered off. After evaporation of the alcohol, 2-nitrodiphenyl crystallises in characteristic large plates or prisms. 100 G. of diphenyl give 60—70 g. of 4-nitrodiphenyl, m. p. 114°, and 35—39 g. of 2-nitrodiphenyl, m. p. 35—37°.

4-Hydroxylaminodiphenyl.—A solution of 4-nitrodiphenyl (50 g.) in ether (1300 c.c., previously distilled from sodium hydroxide) is cooled in a freezing mixture and to it is added aluminium amalgam (10 g.), in very thin sheets, at such a rate that the reaction does not become too vigorous; the reaction vessel is shaken from time to time. Very little hydrogen is evolved if the mixture is kept cold, and the amalgam takes about 2 hours for complete reaction. The mixture is then filtered, the bulky aluminium hydroxide washed several times with dry ether, and the filtrate and washings are evaporated to dryness. The residue is dissolved in the minimum amount (about 250 c.c.) of boiling benzene, and the yellow solution allowed to cool. 4-Hydroxylaminodiphenyl separates in almost colourless, glistening leaflets which appear to fill the whole bulk of the liquid. These are filtered off and dried (yield, 10—14 g.). The compound melts at 152—154° to a red liquid which sets, and in turn melts at 188—190° (Found: C, 77·8; H, 6·0; N, 7·7. $C_{12}H_{11}ON$ requires C, 77·8; H, 5·9; N, 7·6%).

The formation of a deep damson colour with concentrated sulphuric acid is a sensitive reaction for this compound.

4-Hydroxylaminodiphenyl (2 g.) was maintained in the molten state for 30 minutes, and the cooled residue (1·86 g.) dissolved in boiling benzene. The solution on cooling deposited crystals of 4-azodiphenyl, and after evaporation of the benzene, the residue consisted of a mixture of 4-azoxydiphenyl (m. p. 211—212°) and 4-aminodiphenyl (m. p. 52°).

On treatment of an ethereal solution of 4-hydroxylaminodiphenyl with hydrogen chloride or by leaving a suspension in concentrated hydrochloric acid for some time, the *hydrochloride* is obtained as a white powder (Found: HCl, 16·6. $C_{12}H_{11}ON,HCl$ requires HCl, 16·5%). The principal product obtained on heating the hydrochloride is 4-azoxydiphenyl.

Action of 10% *sulphuric acid.* 4-Hydroxylaminodiphenyl (5 g.) is triturated with sulphuric acid (600 c.c. of 10%), and the mixture heated on a steam-bath until the whole assumes a deep chocolate colour. It is then filtered hot, and the insoluble residue extracted with 2 litres of boiling water. The filtrates deposit amine sulphates, which are filtered off and suspended in sodium carbonate solution. The mixture is boiled and, after addition of some alcohol, filtered from a trace of impurity. On cooling, the liquid fills with fine, silky crystals, which are filtered off and crystallised from aqueous alcohol; m. p. 156°. It is difficult to make certain that the product is quite free from 4-aminodiphenyl, since the sulphate of this compound must be present in the filtrate. As the compound is insoluble in sodium hydroxide, it is tentatively suggested that it may be produced by the *o*-semidine change of an intermediate reactive 4-hydrazodiphenyl (Found : C, 85·0; H, 6·1. $C_{24}H_{20}N_2$ requires C, 85·6; H, 6·0%).

By the action of an alcoholic solution of hydrogen chloride on the hydroxylamine there was obtained a small quantity of a chloro-base, m. p. 69° (see below).

Diacetyl-4-hydroxylaminodiphenyl was prepared by dissolving 4-hydroxylaminodiphenyl in acetic anhydride and pouring the solution, filtered from a little 4-azoxydiphenyl, into excess of water. The well-washed precipitate crystallised from alcohol in clusters of short, thick needles, m. p. 119° (Found : C, 71·2; H, 5·8; N, 5·2. $C_{16}H_{15}O_3N$ requires C, 71·4; H, 5·6; N, 5·2%).

This compound gives a deep damson colour with concentrated sulphuric acid. This diacetyl derivative (24 g.) was dissolved in 90 c.c. of concentrated hydrochloric acid by warming on a water-bath, 500 c.c. of water were added, and the whole was filtered while boiling. The hydrochloride which separated on cooling was difficult to purify by crystallisation, as it was so readily hydrolysed. It was decomposed by sodium carbonate, and the oil obtained was filtered off after solidification. By repeated crystallisation from aqueous alcohol, it was obtained as a constant-melting chloro-base, m. p. 69° (Found : N, 6·9. $C_{12}H_{10}NCl$ requires N, 6·9%).

It gives an acetyl derivative which crystallises from alcohol in glistening needles, m. p. 146° (Found : C, 68·4; H, 5·0; N, 6·0. $C_{14}H_{12}ONCl$ requires C, 68·4; H, 4·9; N, 5·7%).

4-*Aminodiphenyl*.—This compound is formed during the preparation of 4-hydroxylaminodiphenyl, but its separation from the accompanying azoxy-, azo-, and nitro-compounds is difficult. The benzene filtrate from 4-hydroxylaminodiphenyl was therefore evaporated to dryness, the residue finely powdered and suspended in ether, aluminium amalgam added until the ethereal solution became colourless, the filtered solution evaporated to dryness, and the residue dissolved in boiling alcohol; on cooling, 4-hydrazodiphenyl separated in colourless, glistening needles, m. p. 167—169°. This was filtered off, and by dilution of the mother-liquor 4-aminodiphenyl (m. p. 52—53°) was obtained.

4-Nitrodiphenyl is converted directly into 4-aminodiphenyl by the same process when excess of aluminium amalgam is added. This appears to be the cleanest method of preparation, and the yield is good.

4-*Hydrazodiphenyl* was heated with hydrochloric acid and sulphuric acid of various strengths, but only 4-azodiphenyl and 4-aminodiphenyl could be isolated from the products, thus confirming the observation of Rassow (*J. pr. Chem.*, 1901, **63**, 449).

4-*Azoxydiphenyl* was isolated from the product obtained by partial reduction of 4-nitrodiphenyl, by means of its ready solubility in benzene and insolubility in alcohol. It melts at 212° whether prepared by this method or by Zimmermann's (*Ber.*, 1880, **13**, 1960), who, however, gives the m. p. as 206° (Found: C, 81·8; H, 5·2; N, 8·1. Calc.: C, 82·3; H, 5·1; N, 8·0%).

4-*Azodiphenyl* (m. p. 249°) was obtained by distilling a mixture of 4-azoxydiphenyl and iron filings under reduced pressure.

4-*Methylaminodiphenyl.*—A mixture of 4-acetylaminodiphenyl (31·5 g.; m. p. 171°), dry xylene (200 c.c.), and sodium (5 g.) was heated at 130° for 2—3 hours and cooled, methyl iodide (25 g.) was added, and the reaction completed by warming for a short period. The xylene was distilled off and the residue heated under reflux with alcoholic potash for 15 hours. Alcohol and xylene were removed in a current of steam, and the residue was extracted with ether. The ethereal extract was dried with sodium sulphate and after evaporation of the ether the residue distilled almost wholly at 198—202°/20 mm., the distillate setting to a semi-solid mass. This was best purified by conversion into the nitroso-derivative, and subsequent decomposition of this by boiling with concentrated hydrochloric acid according to the following procedure. The semi-solid mass was dissolved in glacial acetic acid, and the calculated amount of sodium nitrite added. The precipitate was filtered off, dried on porous plate, and boiled with alcohol, which extracted the nitrosoamine from an insoluble yellow product (A). On cooling the filtrate, the *nitrosoamine* crystallised, and was obtained as an almost colourless, microcrystalline powder, m. p. 116°, by recrystallisation from alcohol (Found: C, 73·6; H, 5·7. $C_{13}H_{12}ON_2$ requires C, 73·6; H, 5·7%).

The nitrosoamine gave brilliant colours at the various stages of the Liebermann reaction. To obtain the secondary base, the nitroso-compound was boiled with concentrated hydrochloric acid. The *hydrochloride* thus obtained crystallised from dilute hydrochloric acid as a white powder (Found: HCl, 16·6. $C_{13}H_{13}N,HCl$ requires HCl, 16·6%). On decomposition with sodium carbonate, 4-methylaminodiphenyl was obtained as an oil which rapidly solidified and had m. p. 38°. It was readily soluble in almost all organic solvents, gave an *acetyl* derivative, m. p. 118—119°, which was very soluble in alcohol and separated from aqueous alcohol in a gelatinous condition.

This base is much better characterised as its p-*toluenesulphonyl* derivative, which was readily prepared by the action of *p*-toluenesulphonyl chloride in pyridine solution, and crystallised from alcohol in lustrous, white needles, m. p. 128° (Found: N, 4·2. $C_{20}H_{19}O_2NS$ requires N, 4·2%).

Its constitution is easily checked, since it may also be prepared by shaking the *p*-toluenesulphonate of 4-aminodiphenyl with methyl sulphate and sodium hydroxide. The p-*toluenesulphonate* of 4-*aminodiphenyl*, prepared by the usual method, crystallises from alcohol in colourless needles, m. p. 160° (Found : N, 4·5. $C_{19}H_{17}O_2NS$ requires N, 4·3%).

The yellow product (A) obtained in the preparation of 4-nitrosomethylaminodiphenyl crystallised readily from benzene in splendid, lustrous, yellow plates which decomposed violently at 187°. On boiling with dilute sulphuric acid, there was vigorous evolution of nitrogen. When this had ceased, water was added and the whole filtered boiling hot. 4-Methylaminodiphenyl sulphate crystallised from the filtrate; the residue, after solution in sodium hydroxide and precipitation, melted at 164° and was identical with 4-hydroxydiphenyl prepared directly from 4-aminodiphenyl. The compound (A) must therefore be 4-*diazomethylaminodiphenyl* (Found : C, 81·8; H, 5·7; N, 11·1. $C_{25}H_{21}N_3$ requires C, 82·6; H, 5·8; N, 11·6%).

4-Diazoaminodiphenyl is formed by treating an acetic acid solution of 4-aminodiphenyl with sodium nitrite and forms yellow plates, m. p. 147° (*Ber.*, 1925, **58**, 1913).

4-Nitrosomethylaminodiphenyl both alone and when suspended in ether was treated with an alcoholic solution of hydrogen chloride. After 24 hours, the white solid was filtered off and decomposed with sodium hydroxide. The solid thus obtained was dissolved in alcohol, and on cooling,, a small crop, m. p. 96°, was obtained. Although crystallisation does not alter this melting point, the product appears to be a mixture of unchanged 4-nitrosomethylaminodiphenyl and 4-methylaminodiphenyl, for, on treatment with acetic anhydride and subsequent crystallisation from alcohol, pure 4-nitrosomethylaminodiphenyl was obtained. After separation of the crop of m. p. 96°, the mother-liquor began to deposit an oil which, after purification, yielded 4-methylaminodiphenyl (m. p. 38°).

Diphenylyl-4-acetylchloroamine.—4-Acetylaminodiphenyl (31·5 g.) was dissolved in the minimum quantity of boiling alcohol, and the solution stirred rapidly into 3 litres of cold water, a paste of the consistency of whipped cream resulting. This paste was filtered off with the aid of the pump but not pressed out; it was washed with water to remove all alcohol, and then suspended in water (600 c.c.) containing potassium bicarbonate (60 g.). A considerable excess of sodium hypochlorite solution was added [equivalent to 11·6 g. of hypochlorous acid instead of 7·9 g. (calc.)], the strength of the whole mixture being 0·16*N* in respect of hypochlorous acid.

The mixture was maintained at about 70° with constant shaking for ½ hour, and then allowed to cool. The solid was filtered off and a sample extracted with chloroform. The solvent was removed by a current of air and finally by evacuation. A weighed quantity of this product was dissolved in chloroform and shaken with acetic acid and potassium iodide solution and the liberated iodine was estimated (Found : Cl, 13·9. $C_{14}H_{12}ONCl$ requires Cl, 14·4%).

This compound crystallises from chloroform–light petroleum in square plates melting at 127° if heated rapidly, and at 160° undergoes a vigorous change, presumably to 3-chloro-4-acetylaminodiphenyl.

*Transformation of Diphenylyl-*4*-acetylchloroamine.*—The main bulk of this substance was filtered off, well washed with water, dissolved in glacial acetic acid, and the solution kept at 80° for 10 minutes and cooled; the vessel then became filled with masses of colourless needles, m. p. 145°, and 147° after recrystallisation from aqueous alcohol. The final mother-liquors contained a little unchanged 4-acetylaminodiphenyl and a trace of a brown oil.

Fractional crystallisation of this substance and of the residues in the acetic acid mother-liquors failed to detect the presence of any trace of 4′-chloro-4-acetylaminodiphenyl. The compound, hydrolysed by boiling 50% sulphuric acid, gave a base which, after crystallisation from aqueous methyl alcohol, melted at 69°. 4′-Chloro-4-aminodiphenyl has m. p. 134°, so that it is highly probable that the above compound is 3-chloro-4-aminodiphenyl, and this view of its constitution is supported by its preparation by direct chlorination.

Chlorine (6·65 g.) (5% excess) was slowly bubbled through a solution of 4-acetylaminodiphenyl (21 g.) in glacial acetic acid (300 c.c.) in a tall vessel. A copious precipitate began to form at once, and after completion of the experiment 50 c.c. of water were added and the pale yellow product was filtered off. It melted at 144° and after recrystallisation from alcohol was obtained in fine, colourless needles, m. p. 146°. This substance on hydrolysis gave a base, m. p. 69°, identical with that obtained above. Exhaustive fractional crystallisation showed that the chlorination was practically quantitative, only 4% of unchanged 4-acetylaminodiphenyl being recovered and no trace of 4′-chloro-4-acetylaminodiphenyl was detected.

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