21. *The Mechanism of Indole Formation from Phenacylarylamines. Part I.*

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The conversion of the phenacyl derivatives of primary arylamines into the corresponding 2-arylindoles is dependent on the presence of catalytic impurities (*e.g.*, amine hydrobromides and hydriodides); non-recognition of this factor has invalidated much previous work, and earlier theories of the mechanism of this conversion based on such work are now shown to be incorrect. The behaviour of such phenacyl derivatives when heated alone and in the presence of possible catalysts, and also when heated with primary and secondary arylamines, has been investigated in detail, and an ionic mechanism for the above conversion is suggested.

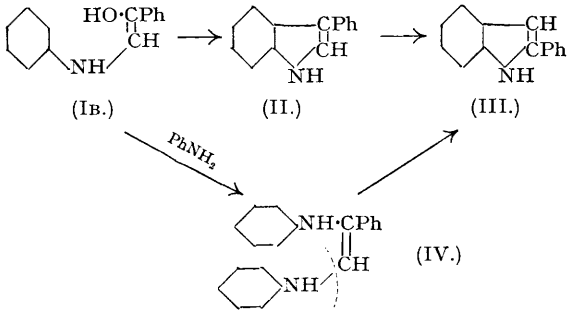
The phenacyl derivatives of secondary arylalkylamines behave entirely differently, giving 3-aryl-1-alkylindoles, which (with one exception) could not be isomerised to 2-aryl-1-alkylindoles. The reaction of these phenacyl derivatives with primary and secondary amines has also been investigated, and these reactions correlated with those of the phenacyl primary amines.

The mechanism whereby the phenacyl derivatives of aromatic amines undergo cyclisation to give 2-arylindoles has, in spite of much investigation and controversy,* remained obscure. Möhlau (*Ber.*, 1881, **14**, 173; 1882, **15**, 2480) showed that phenacyl bromide when heated with aniline gave 2-phenylindole, the identity of which

* Further references, in addition to those given, are: Wolff, *Ber.*, 1888, **21**, 124; 1889, **22**, 428; Möhlau, *Ber.*, 1892, **25**, 2485; Lachowicz, *Monatsh.*, 1894, **15**, 402; Collet, *Bull. Soc. chim.*, 1897, **17**, 66; Hell and Cohen, *Ber.*, 1904, **37**, 866; Strain, *J. Amer. Chem. Soc.*, 1929, **51**, 269.

was confirmed by Fischer and Schmidt (*Ber.*, 1888, **21**, 1071, 1811), who prepared it also by the action of zinc chloride on acetophenonephenylhydrazone. Möhlau (*loc. cit.*; *Ber.*, 1885, **18**, 165) stated that phenacylaniline, $NHPh{\cdot}CH_2{\cdot}COPh$ (I), the initial product in his reaction, gave 2-phenylindole slowly at room temperature when exposed to the air, more rapidly when confined over sulphuric acid, and readily when dry-distilled or heated with either phosphorus pentachloride or aniline : the reaction with aniline was confirmed by Bischler (*Ber.*, 1892, **25**, 2868). Two theories have been advanced to explain this formation of 2-phenylindole.

(A) The enolic form of (I), *i.e.*, (IB), undergoes normal cyclisation to give 3-phenylindole (II), which in the above circumstances isomerises to 2-phenylindole (III). Fischer and Schmidt (*loc. cit.*) pointed out that this explanation was supported by the fact that 3- was isomerised to 2-phenylindole by heating with zinc chloride, but was weakened by the fact that 3-phenylindole was unaffected by boiling with aniline. (B) Bischler (*loc. cit.*)



stated alternatively that (I), again in the enolic form (IB), condensed with free aniline to give the diamine (IV), which underwent cyclisation with loss of the *original* aniline residue to give 2-phenylindole. Bischler showed that, *e.g.*, both phenacylaniline and phenacyl-*o*-toluidine when heated with aniline gave 2-phenylindole, and that both when heated with *o*-toluidine gave 2-phenyl-7-methylindole, the free amine thus always forming the final indole. This theory was put forward when indoles were obtained by interaction of phenacyl bromide and excess of amine : it is extremely unlikely to apply to the conversion of phenacylaniline alone into the indole when no excess of free aniline is present.

These two theories, which may be termed the isomerisation and the diamine theory respectively, will be considered in turn. Our experiments show that neither can be correct. It should be noted that all this early work concerned phenacyl primary amines with the exception of a brief study of phenacyl-*N*-methylaniline (Staedel, *Ber.*, 1888, **21**, 2197; Culmann, *ibid.* p., 2595), discussed below. We find that the cyclisation of phenacyl secondary amines is, with the exception of this methyl derivative, entirely different from that of the corresponding phenacyl primary amines.

(A) *The Isomerisation Theory.*—It is now clear that early work on the cyclisation of phenacylaniline was invalidated by the use of impure material, which contained traces of the hydrobromide of aniline or of phenacylaniline, which we find to be active catalysts in promoting the formation of 2-phenylindole. Similarly, Japp and Murray (J., 1894, **65**, 889) showed that Bischler and Fireman's claim (*Ber.*, 1893, **26**, 1336) that desylanilide reacted with boiling aniline to give 2 : 3-diphenylindole was true only if a trace of aniline hydrochloride was present : the pure compounds did not interact. Campbell and Cooper (J., 1935, 1208) likewise found traces of hydrogen bromide essential for the formation of, *e.g.*, 2-phenyl-7-methylindole. We find that *pure* phenacylaniline, contrary to Möhlau's statement, is remarkably stable and can be exposed to the air at room temperature for 18 months or distilled under reduced pressure without change. Furthermore, when subjected to dry distillation it gives aniline, diphenacyl, $COPh{\cdot}CH_2{\cdot}CH_2{\cdot}COPh$ and 1 : 2 : 5-triphenylpyrrole : both the origin and identity of the pyrrole are clearly indicated by its ready formation when aniline and diphenacyl undergo condensation in boiling acetic acid solution. When, however, phenacylaniline is heated with traces of many amine hydrobromides and hydriodides and quaternary bromides and iodides at 180° for short periods, it undergoes smooth conversion into 2-phenylindole. Similar treatment with amine hydrochlorides and other salts produces a mixture of aniline and diphenacylaniline, $NPh(CH_2{\cdot}COPh)_2$, or leaves the phenacylaniline unchanged, or gives a viscous indeterminate syrup. The compounds thus tested as catalysts are here listed : in all cases the phenacylaniline was mixed with 0·01 g.-mol. of the compound, and was heated at 180°, usually for 6 minutes (p. 63).

(a) *Causing conversion into 2-phenylindole.* I_2; NH_2Ph,HBr; NH_2Ph,HI; p-$C_6H_4Me{\cdot}NH_2,HBr$; p-$C_6H_4Me{\cdot}NHEt,HBr$; $NHPh_2,HBr$; NMe_2Ph,HI; NMe_3PhI; $NHPh{\cdot}CH_2{\cdot}COPh,HBr$; $NHPh{\cdot}CH_2{\cdot}COPh,HI$; pyridine methiodide, quinoline methiodide and ethiodide; quinaidine methiodide and ethiodide; $AsPh_3,MeI$.

(b) *Causing partial conversion into diphenacylaniline.* $(CO_2H)_2$; NH_2Ph,HCl; $2NH_2Ph,(CO_2H)_2$; $2NH_2Ph,H_2SO_4$; p-$C_6H_4Me{\cdot}NH_2,HCl$; pyridine ethiodide.

(c) *Causing no apparent change.* NH_4Br; NH_4I; $NH_2Ph,CCl_3{\cdot}CO_2H$; NMe_4I; $AsPh_4Br$; $AsPh_4I$; benzoyl peroxide.

(d) *Causing decomposition to viscous uncrystallisable syrups.* $NHPh{\cdot}CH_2{\cdot}COPh,HCl$; $NHPh_2,HCl$; $ZnCl_2$; $AlCl_3$.

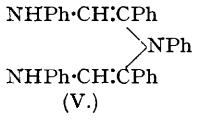
Since 3-phenylindole can be distilled unchanged (b. p. 226°/14 mm.) and is moreover unaffected by heating

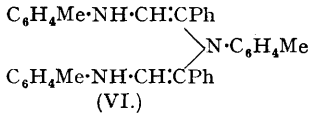
with aniline hydrobromide under the above conditions, it clearly cannot be an intermediate in the above formation of 2-phenylindole.

It should be noted that all the compounds in Group (a) give rise under these conditions not only to bromide or iodide ions but also to hydrogen ions. Free iodine will do this by direct iodination of the amine, the amine salts by slight dissociation, the quaternary salts by decomposition (the quinoline and quinaldine salts, in particular, slowly decompose even at room temperature). Pyridine ethiodide in Group (b) and tetramethylammonium iodide and the tetraphenylarsonium salts in Group (c) are, however, very stable and could not give hydrogen ions under these conditions. The lack of catalytic action shown by amine hydrochlorides is, however, in marked contrast to Japp and Murray's results. The negative result with benzoyl peroxide shows that the reaction is not promoted by the " peroxide effect."

It is noteworthy that pure phenacylaniline when fused with a much greater quantity of zinc chloride (*e.g.*, 10 mols.) at 180° for 15 minutes gave only an amorphous powder from which no crystalline product could be isolated : pure *p*-chlorophenacylaniline gave a similar result. On the other hand, the acetyl derivatives of these two phenacyl compounds were unaffected by this fusion with zinc chloride.

(B) *Bischler's Diamine Theory.*—Bischler (*loc. cit.*) stated that phenacylaniline, when boiled with aniline (9 mols.) for 1 hour, gave 2-phenylindole, but when boiled with *p*-toluidine (10 mols.) gave 2-phenyl-5-methylindole. Many similar results were cited. We find however that pure phenacylaniline reacts with pure aniline to give a triamine, NN-*di*-(β-*phenylamino*-α-*phenylvinyl*)*aniline* (V), and with excess of pure *p*-toluidine to give the homologous *tri*-p-*tolyl* derivative (VI). Phenacylaniline, however, when heated with aniline (2 mols.)


(V.)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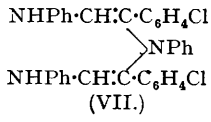

(VII.)

in the presence of aniline hydrobromide (0·01 mol.) gives 2-phenylindole, and when heated with *p*-toluidine (2 mols.) similarly catalysed gives 2-phenyl-5-methylindole. Similarly, phenacylaniline containing aniline hydrobromide (0·01 mol.) reacts with *o*-toluidine (2 mols.) at 180°, giving 2-phenylindole, but with 10 mols. of *o*-toluidine it gives 2-phenyl-7-methylindole. Many similar results are given later (p. 64).

Compounds of the triamine type (V and VI) proved very stable and could not be converted into indoles. There is therefore no evidence for the formation of Bischler's hypothetical diamines from phenacyl primary amines. His results were clearly due to the presence of catalytic impurities. The above results show that a phenacyl primary amine undergoes a slow interchange with a boiling free primary amine (Equation 1), the rate of reaction depending on the active mass and chemical nature of the amine. With pure reagents, the phenacylamine will condense with the free amine present in greatest concentration to give a triamine of type (V) and

(1) $NHPh\cdot CH_2\cdot COPh + o\text{-}C_6H_4Me\cdot NH_2 \longrightarrow o\text{-}C_6H_4Me\cdot NH\cdot CH_2\cdot COPh + NH_2Ph$

2-Phenylindole. 2-Phenyl-7-methylindole.

(VI). In the presence of catalytic impurities, however, each phenacylamine will tend to cyclise to the corresponding indole. Hence in (1) the presence of a small concentration of *o*-toluidine causes the reaction to go so slowly that the main reaction is direct cyclisation of phenacylaniline to 2-phenylindole : a high concentration of *o*-toluidine increases the rate and thus gives a product which is derived mainly from phenacyl-*o*-toluidine and hence on purification gives 2-phenyl-7-methylindole.

It is now clear why 2-arylindoles can always be prepared by heating phenacyl bromide with an excess of the requisite primary amine, since the phenacyl aryl amine first formed will necessarily be accompanied by equivalent quantities of the amine hydrobromide to catalyse its subsequent conversion into the indole.

The reaction of phenacyl primary amines with secondary amines is also of interest. A mixture of pure phenacylaniline and *N*-ethylaniline (5 mols.) when boiled for 4 hours gave a brown oil from which no crystalline product could be isolated. When, however, a trace of aniline hydrobromide was added to the original mixture, boiling then caused a vigorous evolution of water and the product readily yielded 2-phenylindole. Similarly, a mixture of pure phenacylaniline and *N*-ethyl-*p*-toluidine (2 mols.) with a trace of aniline hydrobromide gave 2-phenylindole and aniline. It is clear, therefore, that in the absence of the aniline hydrobromide, a slow interchange between the phenacylamine and the secondary amine occurred (Equation 2) giving a

(2) $NHPh\cdot CH_2\cdot COPh + C_6H_4Me\cdot NHEt \longrightarrow C_6H_4Me\cdot NEt\cdot CH_2\cdot COPh + NH_2Ph$

2-Phenylindole

complex product containing no indole. In the presence of traces of aniline hydrobromide, however, much of the phenacylaniline underwent direct conversion into 2-phenylindole, the phenacyl-*N*-ethyl-*p*-toluidine being unaffected by this catalyst under these conditions (see p. 61); the yields of 2-phenylindole and of aniline in one experiment with *N*-ethyl-*p*-toluidine were 47% and 27% respectively of those indicated by equation (2).

p-*Chlorophenacylaniline* showed one exceptional property. Collet (*Bull. Soc. chim.*, 1899, **21**, 65) claimed

to have prepared this compound, m. p. 187—188°, by heating *p*-chlorophenacyl chloride with aniline. We find that this interaction, when strictly controlled by brief and very gentle warming, gives the true *p*-chlorophenacylaniline, m. p. 113·5°. More vigorous interaction gives Collet's compound, which is actually an ether formed by loss of water from 2 mols. of the enolic form of the true phenacyl derivative, *i.e.*, it is *di*-(β-*phenylamino*-α-p-*chlorophenylvinyl*) *ether* (VIII) : its structure follows from the fact that it gives a *diacetyl* derivative. This ether (VIII) was unchanged when heated with aniline hydrobromide (0·01 mol.) at 200° for 20 minutes; when fused with zinc chloride at 190—200°, extensive decomposition occurred and no indole could be isolated.

$$\begin{matrix} \text{NHPh·CH:C·C}_6\text{H}_4\text{Cl} \\ \diagdown\!\!\diagup\text{O} \\ \text{NHPh·CH:C·C}_6\text{H}_4\text{Cl} \end{matrix}$$
(VIII.)

Before considering possible mechanisms for the above reactions, the behaviour of phenacyl secondary amines when heated similarly with (*a*) possible catalysts, (*b*) primary amines, and (*c*) secondary amines, must be described.

(*a*) Of the many phenacyl secondary amines studied, p-*chlorophenacyl*-N-*ethyl*-p-*toluidine*, $C_6H_4Me\cdot NEt\cdot CH_2\cdot CO\cdot C_6H_4Cl$, has been investigated in greatest detail. When exposed to the air at 100° for 7 hours, this gave appreciable quantities of *p*-chlorobenzoic acid; such oxidative fission of the C–C link is apparently inhibited by sodium acetate, since the phenacylamine, mixed with the acetate, remained unchanged at 140—150° after 8 hours. This phenacylamine when boiled with tetralin (b. p. 206°) or with alcoholic zinc chloride (4 mols.), or fused with zinc chloride at 250°, readily gave 3-p-*chlorophenyl*-5-*methyl*-1-*ethylindole*, *i.e.*, simple cyclisation, corresponding in type to the conversion of the enol (IB) into the indole (II), occurred. All attempts—utilising a variety of conditions—to isomerise this 3-*p*-chlorophenylindole, either *in situ* immediately after its formation or after its subsequent isolation, to the corresponding 2-*p*-chlorophenylindole failed (contrast B.P. 496657). Similar results regarding the cyclisation and attempted isomerisation were obtained with several other phenacyl secondary amines. The only exception was phenacyl-*N*-methylaniline, which, when boiled with alcoholic zinc chloride gave 3-phenyl-1-methylindole, but when fused with zinc chloride gave the 2-phenyl isomeride, as Staedel (*loc. cit.*) and Culmann (*loc. cit.*) had claimed. (Staedel's further claim that alcoholic zinc chloride promotes this isomerisation is incorrect.) As would be expected from these results, 3-phenyl-1-methylindole itself, when fused with zinc chloride, was isomerised to the 2-phenyl compound. It is noteworthy, however, that *p*-chlorophenacyl-*N*-methylaniline, when either boiled with alcoholic zinc chloride or fused with anhydrous zinc chloride, gave only 3-p-*chlorophenyl*-1-*methylindole* : the isomerisation of 3-phenyl-1-methylindole is apparently determined, therefore, both by the nature of the 1-alkyl group and by the absence of substituents in the 3-aryl group. We are now investigating this point in greater detail.

It is particularly noteworthy that phenacyl-*N*-ethylaniline was unaffected by heating with *N*-ethylaniline hydrobromide (0·01 mol.) at 180° for 10 minutes, and *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine was unchanged by similar treatment with *N*-ethyl-*p*-toluidine hydrobromide (0·01 mol.) : the marked catalytic action of these salts on phenacyl primary amines is thus completely absent with the corresponding secondary amines.

(*b*) When phenacyl-*N*-ethylaniline was heated with aniline (1·5 mols.) at 150° for 8 hours, free *N*-ethylaniline and the triamine (V) were obtained; similarly, *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine with aniline yielded *p*-chlorophenacylaniline and the triamine (VII), *i.e.*, NN-*di*-(β-*phenylamino*-α-p-*chlorophenylvinyl*)-*aniline*. It follows that here again a double decomposition occurs (Equation 3), and that the phenacyl primary

$$\text{(3)}\quad \text{NPhEt·CH}_2\text{·COPh} + \text{NH}_2\text{Ph} \longrightarrow \text{NHPh·CH}_2\text{·COPh} + \text{NHPhEt}$$
$$\text{NHPh·CH}_2\text{·COPh} \xrightarrow{\text{NH}_2\text{Ph}} \text{Triamine (V)}$$

amine thus formed condenses with the excess of primary amine as already described (p. 60) to give the corresponding triamine.

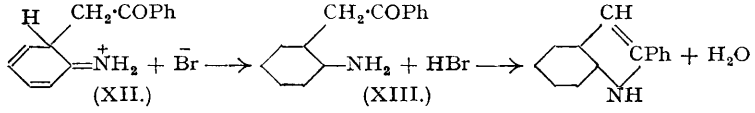
(*c*) To study the interaction of secondary amines with phenacyl secondary amines, mixtures of *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine and free *N*-ethyl-*p*-toluidine have been investigated in greatest detail. This mixture, in equimolecular proportion, when exposed to the air and heated at 100° for 7 hours, gave much *p*-chlorobenzoic acid and 4 : 4′-dichlorobenzil, the fission of the CH_2·CO link being thus again evident. When, however, this mixture was heated in a closed vessel at 140—150° for 7 hours, there was formed, in addition to the above products, p-*chloro*-(αβ-*bis*-p-*tolylethylamino*)*vinylbenzene* (IX). This is the only diamine of Bischler's type obtained in this investigation : it was extremely stable, and could not be converted into an indole in spite of many attempts with various reagents. Its formation was completely inhibited by the presence of sodium acetate in the original mixture, only the acid and the diketone being then isolated.

$$\begin{matrix} \text{C}_6\text{H}_4\text{Me·NEt·CH:C·C}_6\text{H}_4\text{Cl} \\ \qquad\qquad\quad | \\ \qquad\qquad\text{NEt·C}_6\text{H}_4\text{Me} \end{matrix}$$
(IX.)

In contrast to these results, however, when *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine was boiled with an excess (4 mols.) of *N*-ethylaniline, *N*-*iso*butylaniline, or *N*-ethyl-*p*-toluidine, 3-*p*-chlorophenyl-5-methyl-1-ethylindole was obtained in each case. When *p*-chlorophenacyl-*N*-ethylaniline was similarly treated with each of these three secondary amines, 3-p-*chlorophenyl*-1-*ethylindole* was always formed. It is clear, therefore, that at the higher temperature simple cyclisation of the phenacyl secondary amine to the corresponding 3-arylindole occurs, and is independent of the presence of free secondary amines. This is the main reaction : the formation of the diamine—involving a lower temperature and a smaller proportion of secondary amine—must be regarded as exceptional.

Consideration of the above results strongly suggests that the conversion of phenacyl primary arylamines into 2-arylindoles is closely akin to the Hofmann–Martius rearrangement of alkyl anilines and is governed by an ionic mechanism parallel to that suggested by Hickinbottom (J., 1934, 1700) for the latter rearrangement. As the salts which act as catalysts for the conversion of phenacylaniline into 2-phenylindole [Group (a), p. 59] can all give varying quantities of hydrogen bromide or iodide by dissociation or decomposition (see p. 60), we suggest that the first stage consists in the formation of small quantities of the phenacylanilinium cation (X), which on heating gives aniline and the phenacyl ion (XI). The latter then adds on to the aniline to give the *o*-substituted cation (XII), and probably also simultaneously to give the *p*-substituted isomeride.* The cation (XII) then loses a proton to give phenyl *o*-aminobenzyl ketone (XIII), which in turn cyclises with loss

$$\underset{\text{(X.)}}{\overset{+}{N}H_2Ph\cdot CH_2\cdot COPh} + \bar{B}r \longrightarrow NH_2Ph + \underset{\text{(XI.)}}{\overset{+}{C}H_2\cdot COPh} + \bar{B}r \longrightarrow$$



(XII.) (XIII.)

of water to 2-phenylindole (Womack, Campbell, and Dodds, J., 1938, 1402). Any *p*-substituted cation, isomeric with (XII), which may be formed would probably undergo far more complex changes and may well be responsible for the viscous constituents of the final reaction product, from which the 2-phenylindole is isolated by crystallisation.

This mechanism explains the following features: (i) The ready formation of 2-phenylindole, since the ultimate cyclisation is between the enolic hydroxyl group and the amino-group of (XIII), and hence does not involve the replacement of nuclear *o*-hydrogen atoms postulated by previous theories.

(ii) The necessity for traces of hydrogen bromide and iodide, to initiate the ionic process. It does not, however, explain the failure of hydrogen chloride for this purpose. Nevertheless, it is significant that, whereas *N*-methylaniline hydrobromide when subjected to the Hofmann–Martius rearrangement gives *p*-toluidine, yet the hydriodide gives in addition some *o*-toluidine (Hickinbottom, *loc. cit.*); consequently the migration of the phenacyl ion (XI) may be predominantly *para* in the presence of chlorine ions, but become increasingly *ortho* in the presence of bromine and finally iodine ions. Furthermore, the experimental facts show that most amine hydrochlorides [Group (b), p. 59], like the amine salts of other strong acids, promote also an entirely different reaction, *viz.*, the fission of aniline to form diphenacylaniline.

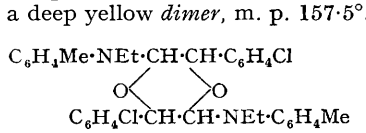
(iii) The fact that acetyl derivatives of phenacyl primary arylamines do not apparently give indoles: clearly these derivatives would not give a cation similar to (X), as the nitrogen atom after acetylation has lost its basic properties. On the other hand, this explanation cannot apply to the similar failure of phenacyl secondary arylalkylamines. It is well known, however, that the Hofmann–Martius rearrangement occurs very much less readily with *NN*-dialkylanilines than with *N*-monoalkylanilines, and in some cases is entirely replaced by other reactions, *e.g.*, dimethylaniline hydrochloride on heating gives methylaniline, and the hydrobromide gives both methylaniline and phenyltrimethylammonium bromide, whilst diethylaniline hydrobromide gives ethylaniline (Hofmann, *Annalen*, 1850, **74**, 137; *Ber.*, 1877, **10**, 600; Staedel, *Ber.*, 1886, **19**, 1947). Hence it is probable that with compounds such as phenacyl-*N*-ethylaniline the Hofmann–Martius rearrangement occurs very slowly (if at all) and that the more rapid cyclisation of the enolic form to give a 3-aryl-1-alkylindole predominates, this reaction being clearly independent of an ionic catalyst.

(iv) The fact that phenacylaniline, heated with excess *o*-toluidine in the presence of aniline hydrobromide, gives 2-phenyl-7-methylindole. There will clearly here be two different primary amines competing for union with the phenacyl ion (XI), and the resulting addition ion (as XII) will depend on the reactivity and active mass of these amines. This of course is merely the ionic interpretation of Equation (1).

The failure of ammonium bromide and iodide to act as catalysts must be attributed to their greater stability compared with that of the corresponding amine salts under the conditions employed.

Certain other noteworthy points have arisen in this investigation. The three types of indole obtained showed characteristic differences with picric acid: the 2-arylindoles gave deep red picrates crystallising readily from benzene; the 2-aryl-1-alkylindoles did not give picrates; the 3-aryl-1-alkylindoles gave deep chocolate-brown (almost black) picrates crystallising well from ethyl alcohol.

p-Chlorophenacyl-*N*-ethyl-*p*-toluidine shows one unique property. The pure pale yellow compound, m. p. 95·5°, is prepared by the interaction of *p*-chlorophenacyl bromide and *N*-ethyl-*p*-toluidine in boiling alcohol in the presence of chalk: when the compound is boiled, however, in alcohol with zinc chloride (1 mol.) it yields a deep yellow *dimer*, m. p. 157·5°. No decisive evidence for the structure of this dimer is at present available. It is possible that the polymerisation has given the dioxan derivative (XIV), and it is significant that Dr. A. Hargreaves and Dr. W. H. Taylor of the Physics Department of the Manchester College of Technology, who have kindly examined the compound crystallographically, find that its molecules do possess the centre of symmetry that the structure (XIV) demands. The existence of a dioxan ring in this compound is not



(XIV.)

* For an example of the migration of a phenacyl group from nitrogen to carbon in a different class of compound, see Thomson and Stevens, J., 1932, 1932.

improbable, as this ring system is known to occur in the " bromodiphenacyls " obtained by the action of sodium ethoxide on phenacyl bromide (Widmann, *Ber.*, 1909, **42**, 3261; *Annalen*, 1913, **400**, 86; Almström, *Ber.*, 1914, **47**, 848).

Campbell and Cooper (*loc. cit.*) and Womack, Campbell, and Dodds (*loc. cit.*) have shown that 2-phenyl-1-methylindole gives a deep green nitroso-compound, which possesses many anomalous properties : they adduce evidence that the nitroso-group is in the 3-position. We find that this is apparently a general reaction for 2-aryl-1-alkyl- and 2-aryl-1 : 5-dialkyl-indoles, and the position of the nitroso-group is thus confirmed. These nitroso-derivatives are of particular value for characterising such indoles, since the latter do not form picrates. We are now investigating the properties of this novel type of nitroso-indole.

In order to prove the identity of some of our 3-aryl-1-alkylindoles, it was necessary to prepare authentic samples of the isomeric 2-aryl analogues by Fischer's hydrazone method. The preparation of the intermediate *as.*-arylalkylhydrazines by reduction of the corresponding nitrosoamines often proved unsatisfactory, and much secondary amine and ammonia were usually formed, particularly with the higher alkyl derivatives. Michaelis (*Ber.*, 1886, **19**, 2448; *Annalen*, 1889, **252**, 266) has, however, shown that phenylhydrazine reacts with sodium to give a derivative $NNaPh{\cdot}NH_2$, which with alkyl halides furnishes the alkyl derivative $NRPh{\cdot}NH_2$ in high yield : the initial reaction with sodium is so violent, however, that the method has been little used. We find that the replacement of sodium by sodamide (Titherley, J., 1897, **71**, 461) in benzene suspension gives a smooth production of the sodium derivative, which without isolation can be treated directly with the alkyl halide. (Substituents in the benzene ring, however, cause very low yields and the method is consequently almost useless with, *e.g.*, *p*-tolylhydrazine.) The *as.*-arylalkylhydrazines thus prepared, when mixed with acetophenone (or other requisite ketone) and then fused with zinc chloride, gave the authentic 2-aryl-1-alkylindoles in good yield.

Experimental.

The names of solvents used for recrystallisation are stated in parentheses after the compounds concerned : when two names are given, as in (acetic acid, alcohol), recrystallisation in each solvent consecutively in this order was performed; when given as in (petrol–benzene), recrystallisation in the mixed solvents was performed.

Phenacyl Primary Amines.—(1) *Preparation.* (For intermediate preparation of phenacyl bromide, *p*-chloroacetophenone, and *p*-chlorophenacyl bromide, see *Organic Syntheses*, 1925, **5**, 19; 1929, **9**, 20; 1939, **19**, 24.) These pure phenacyl derivatives were usually made thus : a solution of phenacyl bromide (100 g.) in alcohol (200 c.c.) was chilled in ice–salt, and the amine (2 mols.) added with vigorous stirring. The bromide, which had crystallised during the initial cooling, rapidly redissolved and was replaced by yellow crystals of the phenacylamine. The mixture was kept cold for 4 hours (occasional stirring) and the phenacylamine then collected, washed with alcohol, mixed with water (1 l.), and vigorously stirred for 3 hours. It was collected, dried, and recrystallised (usually from alcohol).

Phenacylaniline : *hydrobromide*, m. p. 183° (decomp.) (Found : N, 4·9. $C_{14}H_{13}ON,HBr$ requires N, 4·8%); *hydriodide*, m. p. 145° (Found : N, 4·1. $C_{14}H_{13}ON,HI$ requires N, 4·1%); acetyl derivative (alcohol), m. p. 131·5—133° (Found : N, 5·6. Calc. for $C_{16}H_{15}O_2N$: N, 5·5%) (Möhlau, *Ber.*, 1882, **15**, 2470, gives m. p. 126—127°). Phenacyl-2 : 4-dimethylaniline (alcohol), m. p. 96° (Found : C, 80·3; H, 7·4. Calc. for $C_{16}H_{17}ON$: C, 80·3; H, 7·2%) (Kunckell, *Ber.*, 1897, **30**, 575). p-*Chlorophenacylaniline* requires particular care to avoid contamination with the ether (VIII) (p. 65) : aniline (4 g., 2 mols.) was added to a suspension of powdered *p*-chlorophenacyl bromide (5 g., 1 mol.) in alcohol (40 c.c.), and the mixture shaken and warmed very gently until the bromide had dissolved; cooling in ice water for 20 mins. gave yellow needles of the aniline (alcohol), m. p. 113—115°; 2·5 g. (Found : C, 68·4; H, 5·1; N, 5·85; Cl, 14·7; *M*, ebullioscopic in 1·22% acetone solution, 261; in 3·86% solution, 259. $C_{14}H_{12}ONCl$ requires C, 68·4; H, 4·9; N, 5·7; Cl, 14·7%; *M*, 245·6); the filtrate on standing deposited the ether (VIII). The *acetyl* derivative formed colourless crystals (alcohol), m. p. 143° (Found : C, 67·0; H, 5·2; N, 5·2; Cl, 12·8. $C_{16}H_{14}O_2NCl$ requires C, 66·8; H, 4·9; N, 4·9; Cl, 12·4%). p-*Chlorophenacyl*-p-*toluidine* (alcohol), m. p. 148—150° (Found : N, 5·6. $C_{15}H_{14}ONCl$ requires N, 5·4%). p-*Chlorophenacyl*-2 : 4-*dimethylaniline* (alcohol), m. p. 117° (Found : N, 5·4. $C_{16}H_{16}ONCl$ requires N, 5·1%). These phenacylamines varied in colour from pale cream to bright yellow.

(2) *Dry distillation.* (i) Pure phenacylaniline when heated at 12 mm. distilled unchanged, b. p. 208—210°. (ii) When refluxed at 760 mm. for 10 mins. and then distilled at 12 mm., it gave water, aniline (yield, 50% calculated on complete recovery of original aniline), and finally a fraction, b. p. 220—240°/12 mm., which readily solidified. This fraction, crystallised from benzene, gave white crystals, m. p. 127—206°; these were extracted with a small quantity of boiling acetone and the undissolved residue, crystallised from acetic acid, gave 1 : 2 : 5-triphenylpyrrole, m. p. 233—233·5° (Found : C, 89·2; H, 6·5; N, 4·9. Calc. for $C_{22}H_{17}N$: C, 89·4; H, 5·8; N, 4·75%). The acetone mother-liquor was allowed to evaporate, and the final crop gave diphenacyl (acetic acid), m. p. 143—146° (Found : C, 80·7; 6·2. Calc. for $C_{16}H_{14}O_2$: C, 80·7; H, 5·9%). Kapf and Paal (*Ber.*, 1888, **21**, 3056) give m. p.'s 228—229° and 144—145° respectively for these compounds. (iii) When phenacylaniline was destructively distilled at 760 mm. it gave water (37% yield, on the basis of 1 mol. from 1 mol. of phenacylaniline), aniline (35%), and a fraction of b. p. > 300° (33% by weight of original material) which, when diluted with alcohol, gave the crude triphenylpyrrole. The aniline in these decompositions was identified as its *p*-toluenesulphonyl derivative.

When a solution of diphenacyl (0·5 g.) and aniline (0·25 g., 1·2 mols.) in acetic acid (5 c.c.) was refluxed for 45 mins., the boiling solution deposited crystalline 1 : 2 : 5-triphenylpyrrole (acetic acid), m. p. 233—234°, unchanged by admixture with that obtained in the second decomposition above.

(3) *Reaction with catalysts.* The reaction with minute quantities of reagents is considered here, that with molecular quantities of primary and secondary amines under (4) and (5) respectively. Directions for one such experiment suffice for all. (*a*) A powdered mixture of pure phenacylaniline (4·2 g.) and aniline hydrobromide (0·05 g., 0·01 mol.) was placed in an oil-bath at 180° : after 1 min. a vigorous effervescence lasting 2 mins. occurred, and after 6 mins. the heating was stopped. The viscous black product, after dilution with an equal volume of hot benzene, gave on cooling 2-phenylindole (benzene), m. p. 189—190° (unchanged by admixture with authentic sample prepared by Fischer's method : cf. p. 67); yield, 1·2 g. (26%). The other catalysts producing 2-phenylindole are given in Group (a) (p. 59), and their action was always accompanied by the characteristic effervescence. The two times (in mins.) given for the following catalysts are (first) the period of heating before this effervescence started, and (second) the total time of heating : $NPhMe_3I$ (2·5; 6); pyridine methiodide (4; 20); quinoline methiodide (4; 26) and ethiodide (slight effervescence, 8; 35); quinaldine methiodide (vigorous, 6; 25) and ethiodide (vigorous, 4; 25). The times for other catalysts in Group (a) were not

materially different from those with aniline hydrobromide. (*b*) In this group the total heating lasted 7 mins. and only slight effervescence occurred. The orange-coloured product, treated as before with benzene, deposited diphenacylaniline (acetic acid or *n*-propyl alcohol), m. p. 236—238° (dependent on rate of heating); Almström (*Annalen*, 1916, **411**, 371) gives m. p. 236—240° (Found: C, 80·0; H, 6·1; N, 4·2. Calc. for $C_{22}H_{19}O_2N$: C, 80·2; H, 5·84; N, 4·2%). The catalysts $(CO_2H)_2$, NH_2Ph,HCl, and p-$C_6H_4Me{\cdot}NH_2,HCl$ yielded only diphenacylaniline, but $2NH_2Ph,(CO_2H)_2$, $2NH_2Ph,H_2SO_4$, and pyridine ethiodide yielded unchanged material in addition. (*c*) In this group there was no effervescence, and on cooling the product solidified and gave pure phenacylaniline (alcohol), m. p. 97·5—98°. (*d*) These compounds apparently caused extensive decomposition, and thick viscous syrups were obtained, from which no crystalline component could be isolated. Zinc chloride and aluminium chloride gave vigorous effervescence.

To show that the reaction described in (*a*) above, was not peculiar to phenacylaniline, the following comparative experiments were performed. When pure (i) phenacyl-*o*-toluidine, or (ii) *p*-chlorophenacylaniline or (iii) *p*-chlorophenacyl-*p*-toluidine was heated at 180° for 10 mins., it was chemically unchanged; when, however, (i) or (ii) was first mixed with aniline hydrobromide (0·01 mol.), similar treatment gave the characteristic effervescence and the product yielded (i) 2-phenyl-7-methylindole (petrol), m. p. 113°, red picrate (petrol), m. p. 127·5—129° (Bischler, *loc. cit.*, gives m. p.'s 119° and 126° respectively); (ii) 2-*p*-chlorophenylindole (benzene), m. p. 205—206° (Collet, *loc. cit.*, gives m. p. 201—202°), whereas (iii), when previously mixed with *p*-toluidine hydrobromide (0·01 mol.), gave 2-p-*chlorophenyl-5-methylindole* (benzene), m. p. 250·5—251·5° (Found: C, 75·3; H, 5·9; N, 5·6. $C_{15}H_{12}NCl$ requires C, 74·7; H, 5·0; N, 5·8%); *nitroso*-derivative (acetic acid), orange-red powder, m. p. 277° (decomp.) (Found: N, 10·4. $C_{15}H_{11}ON_2Cl$ requires N, 10·4%). The identity of the last two indoles was confirmed by a Fischer synthesis, *p*-chloroacetophenone being condensed with phenyl- and *p*-tolyl-hydrazine respectively (p. 67).

When pure phenacylaniline was fused with zinc chloride (10 mols.) at 190° for 15 mins., and the product digested with warm hydrochloric acid, the insoluble residue on cooling formed an olive-brown solid from which no crystalline substance could be obtained. Pure *p*-chlorophenacylaniline behaved similarly. (Heating at 250° instead of 190° gave a similar result in each case.) On the other hand, acetophenacylanilide, after fusion with zinc chloride (10 mols.) at 195° for 30 mins., and aceto-*p*-chlorophenacylanilide, after similar fusion at 220° for 30 mins., followed by the above extraction, were recovered unchanged.

When diphenacylaniline was heated with aniline hydrobromide (0·01 mol.) at 240° for 7 mins., the black product did not yield any 2-phenylindole, but when it was heated with zinc dust until gentle refluxing occurred, and then further heated under reduced pressure, only a small quantity of acetophenone (semicarbazone, m. p. and mixed m. p. 199—201°) distilled. It is unlikely, therefore, that diphenacylaniline is an intermediate in the conversion of phenacylaniline into 2-phenylindole.

(4) *Reaction with primary amines.* (i) Pure phenacylaniline (5·3 g.) mixed with pure aniline (4·6 g., 2 mols.), was heated at 150° for 8 hours, and the cold product then extracted with dilute hydrochloric acid. The residual syrup crystallised when boiled with alcohol and then gave NN-*di*-(*β*-*phenylamino*-*α*-*phenylvinyl*)*aniline* (V), a white microcrystalline powder (*n*-propyl alcohol), m. p. 205—209° (dependent on rate of heating) (Found: C, 84·8; H, 5·9; N, 8·75; *M*, ebullioscopic in 1·84% acetone solution, 393; in 3·28% solution, 403; in 1·00% benzene solution, 483; in 2·11% solution, 460; cryoscopic in 0·63% ethylene dibromide solution, 506. $C_{34}H_{29}N_3$ requires C, 85·1; H, 6·1; N, 8·8%; *M*, 479·3). The use of aniline (0·5 mol.) gave the same product but less pure. (ii) When the above mixture, containing in addition aniline hydrobromide (0·01 mol.), was heated at 180° for 30 mins., and then extracted with an equal volume of boiling benzene, the solution deposited 2-phenylindole, m. p. and mixed m. p. 189°. (iii) Phenacylaniline (2·8 g.), mixed with *p*-toluidine (14 g., 10 mols.), was refluxed for 4 hours, and most of the free amine then removed by distillation. The dark residue was dissolved in benzene, extracted with dilute hydrochloric acid, dried, and the solvent removed: the residue, which slowly crystallised, was extracted with cold alcohol and then gave NN-*di*-(*β*-*p*-*tolylamino*-*α*-*phenylvinyl*)-p-*toluidine* (VI) (acetic acid; *n*-propyl alcohol), m. p. 175—183° (dependent on rate of heating) (Found: C, 85·5; H, 7·2; N, 7·9. $C_{37}H_{35}N_3$ requires C, 85·2; H, 6·8; N, 8·1%). (iv) A mixture of phenacylaniline, *p*-toluidine (2 mols.), and aniline hydrobromide (0·01 mol.) was heated at 180° for 7 mins., only slight effervescence occurring. The product was boiled with an equal volume of benzene and on cooling gave 2-phenyl-5-methylindole (benzene), m. p. and mixed m. p. 214—216° (Found: C, 86·9; H, 6·25; N, 6·8. Calc. for $C_{15}H_{13}N$: C, 86·9; H, 6·3; N, 6·8%). (v) Phenacylaniline was mixed with *p*-toluidine hydrobromide (1 mol.), heated at 170—180° for 6 mins., and treated as in (iv); the product required repeated crystallisation before 2-phenyl-5-methylindole, m. p. 213—214°, was isolated. The identity of this indole, obtained in (iv) and (v), was confirmed by (*a*) a Fischer synthesis from *p*-tolylhydrazine and (*b*) its conversion into the nitroso-derivative, m. p. and mixed m. p. 266—267°; Bischler (*loc. cit.*) gives m. p.'s 213° and 262° for the indole and its nitroso-derivative respectively. (vi) Phenacylaniline (4·2 g.) mixed with *o*-toluidine (4·3 g., 2 mols.) and aniline hydrobromide (0·01 mol.) was heated at 180° for 8 mins., characteristic effervescence occurring. Treatment as in (ii) gave 2-phenylindole (benzene–*cyclo*hexane), m. p. and mixed m. p. 184—188°. (vii) Repetition of (vi) but with 10 mols. of *o*-toluidine gave a product which after repeated recrystallisation (alcohol, petrol) afforded 2-phenyl-7-methylindole, m. p. and mixed m. p. 112—113°; Bischler (*loc. cit.*) gives m. p. 119°. Its identity was confirmed by conversion into the picrate (petrol), red crystals, m. p. 127·5—129°; Bischler gives m. p. 126°. (viii) Phenacylaniline (4·2 g.), mixed with 2 : 4-dimethylaniline (24·2 g., 10 mols.) and aniline hydrobromide (0·05 g., 0·01 mol.), heated at 180° for 80 mins., and then treated as in (ii), gave a viscous syrup which would not crystallise: treatment with picric acid, however, gave 2-*phenyl*-5 : 7-*dimethylindole picrate* (petrol–benzene), brown crystals, m. p. 156—157·5° (Found: C, 58·3; H, 4·1; N, 12·9. $C_{16}H_{15}N,C_6H_3O_7N_3$ requires C, 58·7; H, 4·0; N, 12·4%). (ix) Phenacyl-*p*-toluidine (4·5 g.), mixed with aniline (3·7 g., 2 mols.) and *p*-toluidine hydrobromide (0·05 g., 0·01 mol.) and heated at 180° for 7 mins., gave ultimately 2-phenyl-5-methylindole (benzene), m. p. 211—213° (mixed with authentic sample, m. p. 215—216°). (x) Repetition of (ix), but with 10 mols. of aniline, gave 2-phenylindole (alcohol), m. p. 186—187° (mixed m. p., 187·5—188·5°).

The above results explain why *p*-chlorophenacyl bromide, heated with aniline (2 mols.) at 100° for 2 mins., gave *p*-chlorophenacylaniline and the chlorophenyl ether (VIII) (cf. p. 65), but when heated with aniline (4 mols.) at 150°, for 7 hours gave 2-*p*-chlorophenylindole (65% yield); in the latter experiment, the aniline hydrobromide present would in conjunction with the longer heating at higher temperature, necessarily cause complete conversion of the phenacyl compound into the 2-arylindole.

Many attempts were made to cyclise the triamine (V) but all failed. Dry distillation gave solely aniline and benzanilide, whilst zinc chloride fusion gave an amorphous product from which no definite compound could be isolated. Heating with aniline hydrobromide (0·01 mol.) at 210° for 7 mins. caused some decomposition, but a portion of the triamine was recovered unchanged.

(5) *Reaction with secondary amines.* (i) A mixture of pure phenacylaniline (8·4 g.) and *N*-ethylaniline (24·2 g., 5 mols.) was refluxed for 4 hours, very little water being evolved. The product was dissolved in ether and then extracted in turn with dilute hydrochloric acid and water. The solution was dried (sodium sulphate), and after removal of the solvent, a dark brown oil (5·0 g.) remained, from which no crystalline substance could be isolated. (ii) On repetition of (i), but using a mixture of phenacylaniline (8·4 g.), *N*-ethylaniline (9·7 g., 2 mols.), and aniline hydrobromide (0·08 g.,

0·01 mol.), water rapidly separated as the mixture boiled. Extraction as above gave a solid residue which readily furnished 2-phenylindole (alcohol), m. p. and mixed m. p. 189—190°. (iii) A repetition of (ii), but with *N*-ethyl-*p*-toluidine (10·8 g., 2 mols.) instead of *N*-ethylaniline, gave 2-phenylindole (crude, 3·6 g., 47% of that possible on Equation 2), m. p. and mixed m. p. 187—189°. The aniline formed was isolated as *p*-toluenesulphonyl derivative (aqueous alcohol), m. p. and mixed m. p. 99—101°; yield, 1·3 g. (27% of that possible on Equation 2).

Di-(β-phenylamino-α-p-chlorophenylvinyl) Ether (VIII).—This was obtained as a by-product in the preparation of *p*-chlorophenacylaniline (p. 63), but the best yield was obtained only by using small quantities of reactants; consequently, to prepare the ether a large number of experiments using aniline (1 g.) were performed, and the products were united and worked up together. The *ether* (VIII) was obtained as bright yellow crystals, m. p. 192—193°, purified by recrystallisation from acetic acid or (rapidly) from acetic anhydride (Found: C, 70·8; H, 5·0; N, 6·2; Cl, 15·1; *M*, ebullioscopic in 0·76% acetone solution, 526; in 1·66% solution, 463. $C_{28}H_{22}ON_2Cl_2$ requires C, 71·0; H, 4·7; N, 5·9; Cl, 15·0%; *M*, 473·2). A mixture of the ether (1 g.) and acetic anhydride (10 g.), boiled for 7·5 hours, deposited on cooling colourless crystals of the *diacetyl* derivative (acetic anhydride), m. p. 232—233° after drying at 100°/15 mm. for 2 hours (Found: C, 68·8; H, 4·6; N, 5·1; Cl, 12·6. $C_{32}H_{26}O_3N_2Cl_2$ requires C, 68·9; H, 4·7; N, 5·0; Cl, 12·7%). When the ether (1 g.) was fused (i) with zinc chloride (5 g.) at 190—200° for 30 mins., extensive decomposition occurred and no definite product could be isolated; (ii) with aniline hydrobromide (0·01 mol.) at 200° for 20 mins., the ether was recovered unchanged (acetic acid), m. p. 190—192°.

Stability of 3-Phenylindole.—This indole was unchanged after being refluxed (i) with aniline (10 mols.) for 8·5 hours, (ii) with a mixture of aniline (2 mols.) and aniline hydrobromide (1 mol.) for 4 hours, (iii) with a solution of zinc chloride (4 mols.) in alcohol (18 mols.) for 5 hours. It was also unchanged when heated with aniline hydrobromide (0·01 mol.) at 200° for 10 mins. When fused with zinc chloride (7 mols.) at 250° for 0·5 hour, however, it was converted quantitatively into 2-phenylindole, m. p. and mixed m. p. 187—189°.

Secondary Amines.—The following arylalkylamines, required for phenacyl derivatives and for Fischer syntheses (p. 67), were prepared by heating the primary amine with the alkyl halide (0·45 mol.) (Hickinbottom, J., 1930, 992) to avoid tertiary amine formation, and then removing unchanged primary amine as its zinc chloride addition product (Morgan, B.P. 102843, 1916): *N*-ethylaniline; *N-iso*butylaniline, b. p. 111·5—113·5°/11·5 mm. (pure *iso*butyl bromide is required for this preparation; cf. "Organic Syntheses," 1933, **13**, 20); *N*-ethyl-*p*-toluidine, b. p. 100°/11 mm., p-*toluenesulphonyl* derivative (alcohol), colourless crystals, m. p. 71° (Found: C, 66·7; H, 7·0. $C_{16}H_{19}O_2NS$ requires C, 66·4; H, 6·6%) (cf. D.R.P. 164130); 2 : 4-*dimethyl*-N-*ethylaniline*, b. p. 229—232°/763 mm. (Found: C, 80·4; H, 10·0. $C_{10}H_{15}N$ requires C, 80·5; H, 10·1%); 2 : 4-dimethyl-*N-iso*butylaniline, b. p. 131—135°/19 mm.; p-*chloro*-N-*ethylaniline*, b. p. 247—250°/760 mm. (Found: N, 9·1. $C_8H_{10}NCl$ requires N, 9·0%) (cf. Hofmann, *Annalen*, 1850, **74**, 143), p-*toluenesulphonyl* derivative (alcohol), m. p. 102·5—104° (Found: C, 58·3; H, 5·3. $C_{15}H_{16}O_2NClS$ requires C, 58·1; H, 5·2%).

4-Ethoxydiphenylamine was prepared by the action of ethyl bromide on an alcoholic solution of the sodium derivative of the hydroxy-compound; colourless crystals, b. p. 196°/11 mm., m. p. 69—71°; yield, 82% (cf., Jacobson, *Ber.*, 1893, **26**, 696). 4 : 4′-*Diethoxydiphenylamine*, similarly prepared and then vacuum distilled, formed colourless crystals (alcohol), m. p. 94° (Found: C, 74·4; H, 7·4. $C_{16}H_{19}O_2N$ requires C, 74·7; 7·4%). The *p*-chlorophenacyl derivatives of these two amines appeared to undergo complete decomposition on attempted cyclisation and were not further investigated.

Phenacyl Secondary Amines.—(1) *Preparation.* The reaction of secondary amines with phenacyl halides is much less vigorous than that of primary amines. These phenacyl derivatives were therefore always prepared by boiling equimolecular quantities of the phenacyl halide and the amine in alcoholic solution with excess of calcium carbonate for 4 hours. [The use of sodium hydroxide (or even carbonate) to absorb the acid is undesirable, as the formation of cyclic "halogen-diphenacyls" may then also occur (Widman, *Ber.*, 1909, **42**, 3261; *Annalen*, 1913, **400**, 86; Almström, *Ber.*, 1914, **47**, 848).] The phenacyl secondary amine, which crystallised after filtration and cooling, was washed with water, and recrystallised (usually from alcohol). The colours of these phenacylamines, like those of the primary derivatives, varied from almost white to deep bright yellow. Phenacyl-*N*-ethylaniline, m. p. 96° (Busch and Hefele, *J. pr. Chem.*, 1911, **83**, 452, give 95°) (Found: C, 80·0; H, 7·7; N, 6·1. Calc. for $C_{16}H_{17}ON$: C, 80·3; H, 7·2; N, 5·9%), has considerable stability; when subjected to steam distillation for 3 hours, a small portion volatilised and the remainder was unchanged: *hydrochloride*, obtained by passing hydrogen chloride into a benzene solution of the amine, colourless crystals, m. p. 158° (Found: N, 5·3. $C_{16}H_{17}ON,HCl$ requires N, 5·1%); *picrate*, deep red crystals (alcohol) becoming yellow when powdered, m. p. 110° (Found: C, 56·7; H, 4·5. $C_{16}H_{17}ON,C_6H_3O_7N_3$ requires C, 56·3; H, 4·6%).

Phenacyl-N-*ethyl*-p-*toluidine* (alcohol), m. p. 110—111° (Found: N, 5·7. $C_{17}H_{19}ON$ requires N, 5·5%). p-*Chlorophenacyl*-N-*methylaniline* (alcohol), m. p. 109·5—110° (Found: C, 69·3; H, 5·5. $C_{15}H_{14}ONCl$ requires C, 69·3; H, 5·5%). p-*Chlorophenacyl*-N-*ethylaniline* (alcohol), m. p. 83° (Found: C, 70·2; H, 5·7; N, 5·2. $C_{16}H_{16}ONCl$ requires C, 70·2; H, 5·85; N, 5·1%); *hydrochloride*, m. p. 169° (Found: N, 4·3. $C_{16}H_{16}ONCl,HCl$ requires N, 4·5%); *picrate*, dark yellow crystals (alcohol), m. p. 116—117° (Found: C, 52·8; H, 4·0. $C_{16}H_{16}ONCl,C_6H_3O_7N_3$ requires C, 52·5; H, 3·8%). p-*Chlorophenacyl*-N-iso*butylaniline* (alcohol), m. p. 91° (Found: N, 4·8. $C_{18}H_{18}ONCl$ requires N, 4·6%). p-*Chlorophenacyl*-N-*ethyl*-p-*toluidine*, yellow needles (alcohol), m. p. 95·5° (Found: C, 70·3; H, 6·1; N, 4·8; *M*, ebullioscopically in 1·12% acetone solution, 273; in 2·20% solution, 248. $C_{17}H_{18}ONCl$ requires C, 70·9; H, 6·3; N, 4·9%; *M*, 287·7); *hydrochloride* (dilute hydrochloric acid), m. p. 177—178° (decomp.) (Found: C, 63·0; H, 5·6. $C_{17}H_{18}ONCl,HCl$ requires C, 63·0; H, 5·9%); *picrate*, yellow crystals (alcohol), m. p. 135—136° (Found: C, 53·2; H, 4·3. $C_{17}H_{18}ONCl,C_6H_3O_7N_3$ requires C, 53·4; H, 4·1%). The pure base is stable at room temperature for several months, whereas crude samples decompose rapidly to a brown viscous syrup. p-*Chloro*-(p′-*chlorophenacyl*)-N-*ethylaniline*, colourless needles (alcohol), m. p. 105—106° (Found: C, 62·6; H, 5·1. $C_{16}H_{15}ONCl_2$ requires C, 62·3; H, 4·9%).

(2) *Reactions with zinc chloride, etc.* (A) (i) When a mixture of phenacyl-*N*-methylaniline (5 g.), powdered zinc chloride (10 g., 4 mols.), and alcohol (22 c.c.) was refluxed for 4 hours, filtered, and set aside, the unchanged phenacyl compound (1·5 g., m. p. 119—120°) crystallised on cooling. On longer standing, crystals of 3-phenyl-1-methylindole (alcohol), m. p. 66°, separated (Found: C, 86·95; H, 6·45; N, 6·9. Calc. for $C_{15}H_{13}N$: C, 86·9; H, 6·3; N, 6·8%); picrate, chocolate-brown crystals (alcohol), m. p. 91—92° (Found: N, 12·9. Calc. for $C_{15}H_{13}N,C_6H_3O_7N_3$: N, 12·8%). Ince (*Annalen*, 1889, **253**, 37) gives m. p.'s 64—65° and 90° respectively.

When a mixture of phenacyl bromide (13 g.) and pure *N*-methylaniline (14 g., 2 mols.) was refluxed, a vigorous reaction occurred; after 1 hour, the product was extracted with hydrochloric acid, and the residue dried and distilled; 3-phenyl-1-methylindole (7·0 g., 52% of theoretical), b. p. 205—215°/12 mm., m. p. 65—66° (alcohol, petrol) was again obtained: picrate, m. p. and mixed m. p. 89—91°. (The use of phenacyl chloride gave a similar result.) This refutes Culmann's statement (*loc. cit.*) that phenacyl bromide and *N*-methylaniline react to give 2-phenylindole, a result which must have been due to the presence of aniline as an impurity in the base.

(ii) When the mixture in (i), but without the alcohol, was heated under reflux at 250° for 40 mins., and the product extracted with hydrochloric acid, the residue gave colourless needles of 2-phenyl-1-methylindole (acetic acid), m. p.

100—100·5° (Found: C, 86·9; H, 6·6; N, 6·8. Calc. for $C_{15}H_{13}N$: C, 86·9; H, 6·3; N, 6·8%); Degen (*Annalen*, 1886, **236**, 155) gives m. p. 100—101°. The indole was characterised as its green 3-nitroso-derivative (alcohol), m. p. 143° (Found: N, 11·4. Calc. for $C_{15}H_{12}ON_2$: N, 11·9%): Campbell and Cooper (*loc. cit.*) give m. p. 144°.

When a mixture of 3-phenyl-1-methylindole (2 g.) and powdered zinc chloride (10 g.) was heated with stirring at 250° for 30 mins., and the product then extracted with warm dilute hydrochloric acid, the insoluble residue became semi-solid on cooling, and, after two recrystallisations from acetic acid, gave pure 2-phenyl-1-methylindole (0·9 g.), m. p. and mixed m. p. 100—101°.

(B) Phenacyl-*N*-ethylaniline in alcoholic solution, when refluxed with zinc chloride (1 mol.) for 4 hours, was unchanged. When similarly refluxed with zinc chloride (4 mols.), or when fused with anhydrous zinc chloride (10 mols.) at 250° for 40 mins., extraction as in (A) (i) or (ii) gave 3-*phenyl*-1-*ethylindole* as a pale yellow oil, b. p. 188—192°/1·5 mm., which did not crystallise (Found: C, 86·4; H, 7·0; N, 6·5. $C_{16}H_{15}N$ requires C, 86·8; H, 6·8; N, 6·3%): *picrate*, dark brown needles from saturated alcoholic picric acid, m. p. 83—83·5° (Found: C, 60·0; H, 4·3; N, 12·4. $C_{16}H_{15}N,C_6H_3O_7N_3$ requires C, 60·0; H, 4·0; N, 12·5%); the picrate slowly decomposes in hot alcohol. A nitroso-compound could not be obtained from the indole. Note: 2-phenyl-1-ethylindole has m. p. 84—84·5° (Fischer, *loc. cit.*), readily gives a green nitroso-compound (see later), and does not form a picrate under the above conditions.

(C) Phenacyl-*N*-ethyl-*p*-toluidine was also unaffected by boiling with zinc chloride (1 mol.) in alcohol, but with zinc chloride (4 mols.) in alcohol (4 hours), or with anhydrous zinc chloride (10 mols.) at 250° for 30 minutes, gave liquid 3-*phenyl*-5-*methyl*-1-*ethylindole*, b. p. 220—222°/17 mm., which did not crystallise (Found: C, 86·6; H, 7·0; N, 5·85. $C_{17}H_{17}N$ requires C, 86·8; H, 7·2; N, 6·0%). It did not give a green nitroso-derivative, but gave a *picrate* (alcohol), dark brown needles, m. p. 107·5—108° (Found: C, 59·6; H, 4·4; N, 12·0. $C_{17}H_{17}N,C_6H_3O_7N_3$ requires C, 59·5; H, 4·35; N, 12·1%).

(D) *p*-Chlorophenacyl-*N*-methylaniline, with alcoholic zinc chloride (4 mols.) or anhydrous zinc chloride (10 mols.), as in (C), gave 3-p-*chlorophenyl*-1-*methylindole* (acetic acid), m. p. 96° (Found: C, 74·1; H, 5·1; N, 6·0; Cl, 14·5. $C_{15}H_{12}NCl$ requires C, 74·5; H, 5·0; N, 5·8; Cl, 14·7%): *picrate* (alcohol), dark brown crystals, m. p. 107—107·5° (Found: C, 53·8; H, 3·3; N, 11·9; Cl, 7·8. $C_{15}H_{12}NCl,C_6H_3O_7N_3$ requires C, 53·6; H, 3·2; N, 11·9; Cl, 7·5%). The pure indole, when fused with anhydrous zinc chloride (10 mols.) at 250°, was, as expected, unchanged.

When a mixture of *p*-chlorophenacyl bromide and *N*-methylaniline (2 mols.) was refluxed, a vigorous reaction occurred, and the product yielded the above indole, m. p. and mixed m. p. 94—95·5°, giving a picrate, m. p. and mixed m. p. 107°.

(E) *p*-Chlorophenacyl-*N*-ethylaniline, fused with zinc chloride (8 mols.) at 250° for 0·5 hour, gave 3-p-*chlorophenyl*-1-*ethylindole* (alcohol), m. p. 81°, b. p. 168°/0·1 mm. (Found: C, 75·0; H, 5·75. $C_{16}H_{14}NCl$ requires C, 75·15; H, 5·5%).

(F) *p*-Chlorophenacyl-*N*-*iso*butylaniline, treated as in (E), gave 3-p-*chlorophenyl*-1-*isobutylindole* (alcohol), m. p. 71—72°, b. p. 245°/15 mm. (Found: C, 76·25; H, 6·3. $C_{18}H_{18}NCl$ requires C, 76·2; H, 6·4%).

(G) *p*-Chlorophenacyl-*N*-ethyl-*p*-toluidine (i) when heated in an open dish at 100° for 7 hours yielded much unchanged material and also a small quantity of *p*-chlorobenzoic acid, m. p. and mixed m. p. 238° (Found: C, 53·7; H, 3·6; Cl, 21·9. Calc.: C, 53·7; H, 3·2; Cl, 22·7%). (ii) When mixed with powdered anhydrous sodium acetate (3 mols.) and heated in an open dish at 145° for 8·5 hours was unchanged and did not contain *p*-chlorobenzoic acid. (iii) When refluxed with tetralin (b. p. 206°) for 3 hours gave water and a small quantity of unchanged material; distillation removed the solvent and then gave 3-p-*chlorophenyl*-5-*methyl*-1-*ethylindole* (alcohol, acetic acid), m. p. 92° (Found: C, 75·3; H, 5·73; N, 5·2. $C_{17}H_{16}NCl$ requires C, 75·7; H, 5·9; N, 5·2%): *picrate* (alcohol) dark brown needles, m. p. 102·5—103·5° (Found: N, 11·5. $C_{17}H_{16}NCl,C_6H_3O_7N_3$ requires N, 11·2%); the tetralin distillate slowly deposited *p*-chlorobenzoic acid, m. p. and mixed m. p. 239—240°. (iv) When refluxed with alcoholic zinc chloride (1 mol.) for 4 hours, gave on cooling much unchanged material; the filtrate, set aside overnight, deposited bright yellow crystals of the *dimer* (acetone–alcohol), m. p. 157·5° (Found: C, 71·1; H, 6·2; N, 5·0; Cl, 12·2; *M*, ebullioscopic in 0·33% acetone solution, 564; in 0·63% solution, 534. $C_{34}H_{36}O_2N_2Cl_2$ requires C, 70·9; H, 6·3; N, 4·9; Cl, 12·4%; *M*, 575·4). For crystallographic data, see p. 68. (v) When refluxed with alcoholic zinc chloride (4 mols.) for 4 hours, gave, after filtration and cooling, the above indole, m. p. and mixed m. p. 91—92°. (vi) When fused with zinc chloride (10 mols.) at 250° for 30 mins. also gave this indole.

The preparation of the above 3-aryl-1-alkylindoles (B—G) was also performed in one operation by heating a mixture of the secondary amine, phenacyl bromide, chlorobenzene, zinc oxide, and zinc chloride in an autoclave at 190° for 6 hours, as stated in B.P. 496657.

It is clear from the above results that 3-aryl-1-alkylindoles, with the exception of the phenylmethyl member, are not isomerised by fusion with zinc chloride. This was confirmed by (i) fusing 3-*p*-chlorophenyl-1-ethylindole (10 g.) with zinc chloride (50 g.) for 0·5 hour at 250°; (ii) heating this indole (10 g.) with zinc chloride (10 g.) and concentrated hydrochloric acid (20 c.c.) in a sealed tube at 190° for 18 hours; (iii) heating the indole (10 g.) with zinc chloride (25 g.) and chlorobenzene (50 c.c., previously saturated with hydrogen chloride) in a sealed tube at 170° for 8 hours. In all three cases, the indole was recovered unchanged, contrary to the statements in B.P. 496657.

(3) *Reactions with primary amines.* (A) (i) A mixture of phenacyl-*N*-ethylaniline (12 g.) and aniline (7·0 g., 1·5 mols.) was heated at 150° for 8 hours, and the free amines, removed by steam-distillation, gave *p*-toluenesulphonanilide (1 g.), m. p. 101°, and *p*-toluenesulphonethylanilide (4·1 g.), m. p. 86·5—87°: these correspond to aniline (0·6 g., 12% recovery of amine used) and *N*-ethylaniline (2·9 g., 48% of that present originally as phenacylamine). The dark brown residue from the distillation solidified on cooling (9·3 g.) and was pulverised, thrice extracted with boiling alcohol, and then recrystallised (acetic acid, *n*-propyl alcohol), the triamine (V), m. p. 206—209° (shrinking at 195°), being thus obtained (Found: C, 85·2; H, 6·0; N, 9·0%). The three united alcoholic extracts, which smelt strongly of phenyl *iso*cyanide, gave on cooling a second crop of (V); this was removed, the alcohol evaporated, and the residue distilled, benzanilide, b. p. 210—220°/25 mm., m. p. and mixed m. p. 161—163°, being thus obtained (Found: C, 79·1; H, 5·7; N, 7·0. Calc.: C, 79·1; H, 5·6; N, 7·1%).

(ii) Repetition of (i), but with *p*-chloroaniline (9·6 g., 1·5 mols.) instead of aniline, gave on steam-distillation mixed amines (6·7 g.) which furnished *p*-toluenesulphon-ethylanilide (4·0 g.) and -*p*-chloroanilide (1·4 g.); the latter, after one and two crystallisations from aqueous alcohol, had m. p. 91—94° and 120—121° respectively (Found: C, 55·2; H, 4·65. Calc. for $C_{13}H_{12}O_2NClS$: C, 55·4; H, 4·3%). Since Chattaway (J., 1904, **85**, 1184) gives m. p. 95° and D.R.-P. 164130 gives m. p. 119°, the compound is clearly dimorphous. The residue from the steam-distillation could not be purified, but the experiment proves the interchange of amines.

(B) When a mixture of phenacyl-*N*-ethyl-*p*-toluidine (12·8 g.) and aniline (7 g., 1·5 mols.) was treated as in (A) (i), steam-distillation gave aniline and *N*-ethyl-*p*-toluidine (identified as *p*-toluenesulphonyl derivatives, 1·0 g., m. p. 100—101°, and 4·1 g., m. p. 71—71·5°, respectively) and a strong odour of phenyl *iso*cyanide. The residue, purified as before, gave the triamine (V) (acetic acid, *n*-propyl alcohol), m. p. 200—205°, softening at 195° (m. p. 200—210° mixed with authentic sample) (Found: C, 85·4; H, 5·8; N, 8·9%).

(C) (i) A mixture of *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine (10·3 g.) and aniline (4·9 g., 1·5 mols.) treated as in (A) (i), gave mixed bases (2·1 g.), proved as above to be aniline and ethyl-*p*-toluidine; the residue gave NN-*di*-(β-*phenylamino*-α-p-*chlorophenylvinyl*)*aniline* (VII) (acetic acid, *n*-propyl alcohol) as a buff-coloured, microcrystalline powder, m. p.

172—180° dependent on rate of heating (Found: C, 74·6; H, 5·1; N, 6·9; Cl, 13·45; *M*, cryoscopic in 0·92% ethylene dibromide solution, 512. $C_{34}H_{27}N_3Cl_2$ requires C, 74·4; H, 5·0; N, 7·65; Cl, 12·9%; *M*, 548·3). (ii) The same mixture, heated as before and then extracted with alcohol, gave ultimately the *p*-chloro-ether (VIII), m. p. 191·5—192°, thus proving the intermediate formation of *p*-chlorophenacylaniline. (iii) A mixture of the phenacylamine with aniline (4 mols.), refluxed for 6·5 hours, gave a solid product contaminated with *N*-ethyl-*p*-toluidine; this solid on recrystallisation gave *p*-chlorobenzanilide (alcohol), m. p. and mixed m. p. 199—200° (Found: C, 67·6; H, 4·5; N, 6·1; Cl, 15·4. Calc.: C, 67·4; H, 4·35; N, 6·05; Cl, 15·3%).

(4) *Reactions with secondary amines.* (A) (i) A mixture of *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine (10 g.) and *N*-ethyl-*p*-toluidine (4·7 g., 1 mol.) was heated in an open basin at 100° for 7 hours, during which crystals formed around the melt. The cold, almost solid product, dissolved in hot alcohol, deposited 4 : 4′-dichlorobenzil (alcohol), 0·8 g., m. p. 199° (Found: C, 60·2; H, 3·0; Cl, 25·8. Calc. for $C_{14}H_8O_2Cl_2$: C, 60·2; H, 2·9; Cl, 25·4%), unchanged by admixture with an authentic sample prepared by Gomberg and Natta's method (*J. Amer. Chem. Soc.*, 1929, **51**, 2241): The alcoholic mother-liquors slowly deposited 2·0 g. of *p*-chlorobenzoic acid (alcohol), m. p. and mixed m. p. 238°.

(ii) The above mixture was heated in a loosely-plugged flask at 140—150° for 7 hours, and the product then mixed with acetic acid (40 c.c.); the residual crystals were *p*-chlorobenzoic acid (alcohol), m. p. and mixed m. p. 238°; yield 0·5 g. The acetic acid liquor, when set aside, slowly deposited p-*chloro*-(*αβ-bis*-p-*tolylethylamino*)*vinylbenzene* (IX) (alcohol), colourless needles, m. p. 123—123·5° (Found: C, 77·0; H, 6·9; N, 7·1; Cl, 9·0; *M*, cryoscopic in 0·62% ethylene dibromide solution, 396; in 1·15% solution, 398; ebullioscopic in 1·75% acetone solution, 388; in 3·06% solution, 376. $C_{26}H_{29}N_2Cl$ requires C, 77·1; H, 7·2; N, 6·9; Cl, 8·8%; *M*, 404·8); yield, 0·7 g.

As an alternative treatment, a solution of the above crude reaction product in ether (100 c.c.) was extracted in turn with dilute sodium hydroxide solution, dilute hydrochloric acid, and water, dried (sodium sulphate), the solvent removed, and the residue distilled. A dark red, viscous fraction, b. p. 140—240°/0·1 mm., was dissolved in hot acetic acid, and slowly deposited 0·1 g. of the above diamine (IX), m. p. and mixed m. p. 119—120°. On one occasion, a repetition of this experiment gave a viscous distillate, b. p. 100—220°/0·1 mm., which, however, furnished 4 : 4′-dichlorobenzil (alcohol–acetone) (0·05 g.), m. p. and mixed m. p. 198°.

The diamine (IX) was recovered unchanged after it had been (*a*) refluxed at 760 mm. for 5 mins., (*b*) heated with zinc oxide at 140—150° for 7 hours, with zinc chloride at 220° for 0·5 hour, or with alcoholic hydrogen chloride at 120—125° for 32 hours, (*c*) boiled with concentrated hydrochloric acid for 2·5 hours, (*d*) dissolved in excess methyl iodide at room temperature for 3 days, (*e*) dissolved in alcoholic picric acid for 1 week, (*f*) shaken in acetic acid solution with hydrogen and Adams's platinum oxide catalyst, and (*g*) similarly treated in the presence of a palladium–charcoal catalyst.

(iii) When the above mixture, (A) (i), contained powdered anhydrous sodium acetate (3 mols.), heating at 140—150° for 10 hours gave small quantities of *p*-chlorobenzoic acid and dichlorobenzil, much unchanged phenacyl compound, but no diamine. (iv) When experiment (ii) was repeated in a carbon dioxide or a hydrogen atmosphere, the mixture was unchanged; the production of the acid and the diketone is therefore due to atmospheric oxidation.

(v) When the phenacylamine (9·6 g.) was heated with 2 : 4-dimethyl-*N*-ethylaniline (5 g., 1 mol.) at 140—150° for 7 hours, *p*-chlorobenzoic acid (1·7 g., 32% of theoretical) and 4 : 4-dichlorobenzil (*ca.* 0·2 g.) were isolated; repetition, but with *N-iso*butylaniline (5·2 g., 1 mol.), gave the acid but no diketone.

(vi) When the phenacylamine (2·5 g.) and *N*-ethylaniline (4·5 g., 4 mols.) were refluxed together for 3·5 hours, and the product extracted with dilute hydrochloric acid, the insoluble residue furnished 3-*p*-chlorophenyl-5-methyl-1-ethyl indole (alcohol), m. p. and mixed m. p. 90·5—91°. Repetition, but with replacement of the *N*-ethylaniline by *N-iso*-butylaniline (5·2 g., 4 mols.) or *N*-ethyl-*p*-toluidine (4·7 g., 4 mols.), gave the same result.

(B) When mixtures of *p*-chlorophenacyl-*N*-ethylaniline (2·7 g.) and *N*-ethylaniline (4·8 g., 4 mols.), or *N-iso*butylaniline (6·0 g., 4 mols.) or *N*-ethyl-*p*-toluidine (5·4 g., 4 mols.) were refluxed for 5 hours, treatment as in (A) (vi) gave always 3-*p*-chlorophenyl-1-ethylindole (alcohol; acetic acid), m. p.'s (in the 3 experiments) 80°, 79°, 74—75°, undepressed by admixture with an authentic sample.

Syntheses by Fischer's Method.—(a) *Secondary amines* (see p. 65). (b) *Nitrosoamines.* These were prepared by usual methods; p-*chlorophenyl*-*N*-*ethylnitrosoamine* (alcohol), colourless needles, m. p. 58—59° (Found: N, 15·3. $C_8H_9ON_2Cl$ requires N, 15·2%). (c) *Hydrazines.* (i) Monoarylhydrazines were prepared by reducing the diazo-salts with sodium sulphite and sulphur dioxide, better yields being thus obtained than by Thomson's hydrosulphite method (*J. Soc. Dyers Col.*, 1921, **37**, 7). (ii) *as.*-Arylalkylhydrazines were prepared by (*a*) reduction of the nitrosoamine, or (*b*) through the sodium derivative of the monoarylhydrazine (p. 63).

The following directions illustrate method (*b*). Sodamide (42 g.) was pulverised under benzene, the mixture transferred to a flask, the total benzene made up to 250 c.c., warmed under reflux, and phenylhydrazine (108 g.) added. Yellow needles separated, and after 1·5 hours' boiling, the mixture was allowed to cool, ethyl bromide (110 g., 1 mol.) added, and, when the vigorous reaction had subsided, refluxing was continued for another hour. The mixture was filtered, and the benzene distilled; the residual oil was dissolved in chloroform (500 c.c.), and dry hydrogen chloride passed in to precipitate unchanged phenylhydrazine as its hydrochloride, which was collected. The chloroform filtrate was then shaken in turn with aqueous sodium hydroxide and water, dried (sodium sulphate), the solvent removed, and the free phenylethylhydrazine distilled; b. p. 133°/19 mm.; yield, 67 g. (50%). The following b. p.'s were recorded: phenyl-*n*-propylhydrazine, 137°/25 mm.; phenyl*iso*butylhydrazine, 140°/22 mm. (acetyl derivative, m. p. 115—116°); *p*-tolylethylhydrazine, 122—124°/12 mm. (cf. Hegel, *Annalen*, 1886, **232**, 214; Michaelis *et al.*, *ibid.*, 1889, **252**, 270; *Ber.*, 1897, **30**, 2815).

(d) *Hydrazones.* These were seldom isolated [see (e) below]. p-*Chloroacetophenonephenylhydrazone* (alcohol), m. p. 112—113° (Found: N, 11·8. $C_{14}H_{13}N_2Cl$ requires N, 11·5%).

(e) *Indoles.* Fischer (*Annalen*, 1886, **236**, 133) and Fischer and Schmidt (*loc. cit.*) have shown that acetophenonephenylhydrazone on fusion with zinc chloride gives 2-phenylindole, m. p. 186°, but that phenylacetaldehydephenylhydrazone when boiled with alcoholic hydrogen chloride gives 3-phenylindole, m. p. 89°, and when fused with zinc chloride gives 2-phenylindole, isomerisation occurring in the last case. We have confirmed the formation of 3-arylindoles by the use of alcoholic hydrogen chloride. For the preparation of authentic 2-aryl-1-alkylindoles, however, we have employed zinc chloride, without isolating the intermediate hydrazone. The general method consisted in heating a mixture of the *as.*-arylalkylhydrazine, acetophenone (or the *p*-chloro-derivative), and excess of zinc chloride at *ca.* 200° for 10—15 mins.; the product was poured into hot dilute hydrochloric acid, and the liberated indole extracted with benzene, dried, distilled when necessary, and crystallised. For the preparation of the 3-nitroso-2-aryl-1-alkylindoles, sodium nitrite (2 mols.) was added to a cold solution of the indole in acetic acid; after several hours, the solution was slowly diluted with water; the green nitroso-compound crystallised on stirring. 2-*Phenyl*-1-*ethylindole* (alcohol, acetic acid), b. p. 207—209°/19 mm., m. p. 84—84·5° (Found: C, 87·0; H, 7·0; N, 6·4. $C_{16}H_{15}N$ requires C, 86·8; H, 6·85; N, 6·35%) (cf. Baeyer and Co., D.R.-P. 128660); 3-*nitroso*-derivative, m. p. 130—131° (Found: N, 11·5. $C_{16}H_{14}ON_2$ requires N, 11·2%). 2-*Phenyl*-5-*methyl*-1-*ethylindole*, b. p. 171—173°/0·2 mm., m. p. 70·5° (Found: C, 86·6; H, 7·0; N, 6·5. $C_{17}H_{17}N$ requires C, 86·8; H, 7·2; N, 6·0%) (Baeyer and Co., *ibid.*); 3-*nitroso*-derivative, m. p. 161—162° (Found: C, 76·8; H, 6·4; N, 10·8. $C_{17}H_{16}ON_2$ requires C, 77·3; H, 6·1; N, 10·6%). 2-p-*Chlorophenyl*-1-*ethylindole*, b. p. 171°/0·2 mm.,

m. p. 86—87° (Found: C, 74·9; H, 5·8. $C_{16}H_{14}NCl$ requires C, 75·15; H, 5·5%); 3-*nitroso*-derivative, m. p. 138—139° (Found: C, 67·3; H, 4·9. $C_{16}H_{13}ON_2Cl$ requires C, 67·5; H, 4·6%). 2-p-*Chlorophenyl*-1-n-*propylindole*, b. p. 222—225°/15 mm., m. p. 54° (Found: C, 76·2; H, 6·2; N, 5·0. $C_{17}H_{16}NCl$ requires C, 75·7; H, 5·9; N, 5·1%); 3-*nitroso*-derivative, m. p. 137—138° (Found: C, 68·0; H, 5·1; N, 9·7. $C_{17}H_{15}ON_2Cl$ requires C, 68·3; H, 5·1; N, 9·4%). 2-p-*Chlorophenyl*-1-iso*butylindole*, b. p. 173—178°/0·3 mm., 230—232°/13 mm., m. p. 87—87·5° (Found: C, 76·5; H, 6·0; N, 4·8. $C_{18}H_{18}NCl$ requires C, 76·5; H, 6·3; N, 4·9%); 3-*nitroso*-derivative, m. p. 93° (Found: N, 9·0. $C_{16}H_{17}ON_2Cl$ requires N, 9·0%). 2-p-*Chlorophenyl*-5-*methyl*-1-*ethylindole*, b. p. 239°/13 mm., m. p. 127—128·5° (Found: C, 75·9; H, 6·0; N, 5·2; Cl, 13·3. $C_{17}H_{16}NCl$ requires C, 75·7; H, 5·9; N, 5·1; Cl, 13·2%). All the above indoles were colourless and their 3-nitroso-derivatives deep green. The indoles were usually crystallised from alcohol or acetic acid, and their nitroso-derivatives from alcohol or light petroleum.

Drs. Hargreaves and Taylor report on the dimeric polymeride obtained from *p*-chlorophenacyl-*N*-ethyl-*p*-toluidine:

"*Physical and Optical Properties.*—The material recrystallises from acetone in the form of large thick yellow plates. The shape of the plate face is usually that of a parallelogram. Slight pleochroism is observed when plane polarised light is transmitted through the plate face, maximum and minimum absorption occurring for directions of variation of the light which are inclined to the edges of the parallelogram. Examination between crossed Nicols with the light transmitted normally through the plate face reveals that the extinction direction is also inclined to the side of the parallelogram.

In some crystals, faces are developed at right angles to the plate face. When light is passed normally through these faces, and between crossed Nicols, extinction occurs parallel and perpendicular to the edges lying in the plate face.

The density of the crystals, measured by flotation in an aqueous solution of strontium bromide, is 1·24.

X-ray Data. X-ray rotation, oscillation, and Weissenberg photographs reveal that the crystals are monoclinic, with the symmetry axis normal to the plate face. This is in agreement with the observations on extinction directions.

The unit cell dimensions are: $a = 9{\cdot}7$ A., $b = 18{\cdot}1_3$ A., $c = 10{\cdot}35$ A., $\beta = 57°$.

The density of the crystals, calculated from the contents and dimensions of the unit cell, is

$$\Delta = \frac{1{\cdot}65 \times 575 \times \text{No. mols. per unit cell}}{18{\cdot}1_3 \times 9{\cdot}7 \times 10{\cdot}35 \times 0{\cdot}839} = 0{\cdot}62_1 \times \text{No. mols. per unit cell.}$$

With two mols. in the unit cell the calculated density is $1{\cdot}24_2$, in agreement with the observed density of 1·24.

Indexing of the oscillation and Weissenberg photographs indicates that all reflections of type $\{hkl\}$ are present, reflections $\{h0l\}$ are present only when h is even, and reflections $\{0k0\}$ are present only when k is even. The $\{h0l\}$ halving has been firmly established by examination of the $\{h0l\}$ reflections recorded on a zero-layer line Weissenberg photograph taken with the crystal rotating about the asymmetry axis. The $\{0k0\}$ halving is based on the absence of all odd orders of $\{0k0\}$ up to $k = 17$.

The space group is therefore $C_{2h}^5 - P_{2_1}/a$.

There are 4 equivalent general positions per unit cell in a lattice with the space group P_{2_1}/a, and it is only possible to have 2 molecules per unit cell if the molecules are centro-symmetrical and lie with their symmetry centres on symmetry centres in the space lattice. As the unit cell of the material under investigation has been found to contain only 2 molecules, it is clear that these molecules must therefore be centro-symmetrical."

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