121. *The Action of Acyl Cyanides on 2- and 1 : 2-Substituted Indoles. Part I.*

By A. K. Kiang and Frederick G. Mann.

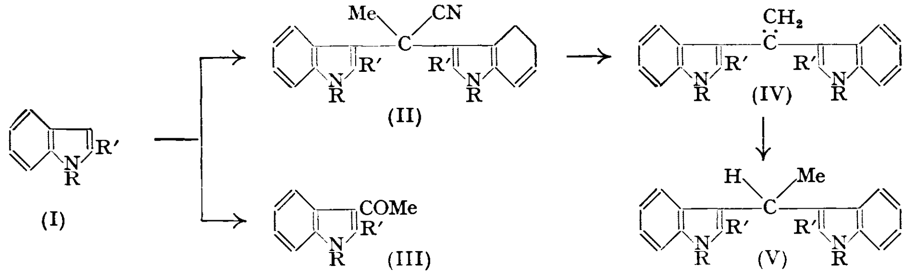
Acetyl and benzoyl cyanides react with the above indoles in the presence of hydrogen chloride usually to give bis-3-indolyl derivatives of type (II) and (IX), whereas in the presence of pyridine the 3-acylindole is formed. No indication that these acyl cyanides undergo a Hoesch-type reaction with the above indoles could be obtained. Acetyl cyanide, however, reacts apparently abnormally with 2-phenylindole to give α-(2-phenyl-3-indolyl)acrylonitrile.

The products obtained by heating the bis-3-indolyl derivatives with soda-lime and with ethanolic potassium hydroxide have been investigated in some detail, particularly with regard to their structure and their behaviour towards acids and alkalis.

In an investigation, to be described in a later paper, on the action of acyl cyanides on substituted indoles which possessed several potential points of reaction, some apparently anomalous results were obtained. It became clear that, before these results could be satisfactorily interpreted, the action of acyl cyanides on simpler indoles containing non-reactive substituents in the 2- and 1 : 2-positions must be studied. The results of this preliminary investigation are recorded in the present paper. The action of acetyl cyanide on certain alkyl- and aryl-indoles is described first, followed by that of benzoyl cyanide.

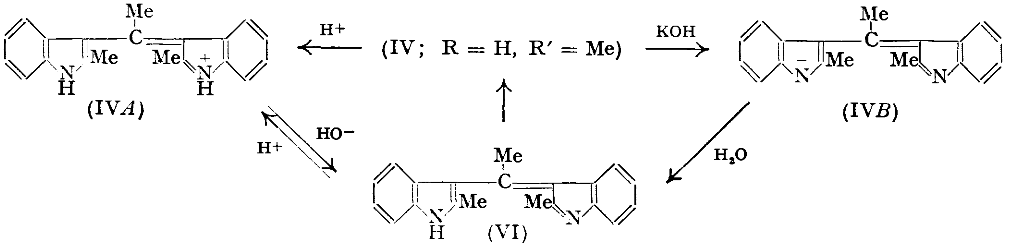
When 2-methylindole (I; R = H, R′ = Me) was treated with an equimolecular quantity of acetyl cyanide in pure chloroform at room temperature for 24 hours or for 40 minutes under reflux, the main product was the colourless crystalline 1-cyano-1 : 1-di-(2-methyl-3-indolyl)ethane (II; R = H, R′ = Me), a smaller quantity of 3-acetyl-2-methylindole (III; R = H, R′ = Me) being also formed. However, in the presence of a small proportion of hydrogen chloride, at room temperature or under reflux, the ethane (II; R = H, R′ = Me) was formed to the apparently complete exclusion of the acetylindole. (When the chloroform solution of the indole and the cyanide was saturated with hydrogen chloride, a heavy tar was deposited, from which no crystalline material could be isolated.)

Conversely, when the original solution in pure chloroform was diluted with a trace of pyridine and then boiled, the acetylindole (III; R = H, R′ = Me) was formed to the exclusion of the ethane. These results clearly indicate the effects of acid and alkali.



The structure of the ethane (II; R = H, R′ = Me) is confirmed by its infra-red spectrum, which shows the characteristic –NH– and –CN absorption bands at 2·9 and 4·53 μ respectively. The compound is unaffected by cold hydrochloric acid: when, however, it is heated in a vacuum (alone or mixed with soda-lime) or boiled with aqueous-ethanolic potassium hydroxide, hydrogen cyanide is lost with the formation of 1 : 1-di-(2-methyl-3-indolyl)ethylene (IV; R = H, R′ = Me), apparently identical with the compound prepared from 2-methylindole by Angeli and Marchetti (*Atti R. Accad. Lincei*, 1907, **16**, ii, 790) by the action of ethyl acetate and sodium ethoxide and by Borsche and Groth (*Annalen*, 1941, **549**, 244) by the action of boiling acetyl chloride, and which has hitherto been considered to be the isomeric 1-(2-methyl-3-indolyl)-1-(2-methyl-3-indoleninylidene)ethane (VI).

The structural identification of our compound rests on the following evidence. It forms colourless crystals, which give deep red salts with acids, and also dissolve in concentrated ethanolic potassium hydroxide to give a deep red solution. When, however, the deep red solution in ethanolic hydrogen chloride was made just alkaline, or the solution in concentrated potassium hydroxide was diluted, the initial pale yellow precipitate changed spontaneously to colourless crystals of the original compound: this change also occurred if the yellow crystals were collected, dried, and recrystallised from benzene. It is suggested that the compound (IV; R = H, R′ = Me) when treated with acids gives the cation (IV*A*) and with concentrated alkalis the anion (IV*B*) (cf. König, *Z. angew. Chem.*, 1925, **38**, 747). Both these ions would be deeply (and similarly) coloured by resonance: the cation (IV*A*) is of course similar in type to that found in many cyanine dyes, *e.g.*, the " rosindoles " of Fischer and Wagner (*Ber.*, 1887, **20**, 815) and later workers. It would be expected that the salts of the cation (IV*A*) would be more stable than those of the anion (IV*B*): hence when solutions of the former are neutralised, or those of the latter diluted with water, the precipitation occurs of the unstable yellow parent compound (VI), which then reverts to the colourless (IV; R = H, R′ = Me), the greater stability of which is due to its more highly aromatic structure. It may be urged that these colour changes are not decisive indications of structure, since the compound (VI) would also give the cation (IV*A*) and the anion (IV*B*) with acids and bases respectively. The structure (VI) would however undoubtedly cause this neutral compound itself to be coloured: compare, for example, the parent compound (2-methyl-3-indolyl)(2-methyl-3-

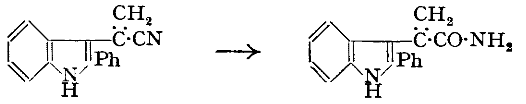


indoleninylidene)methane which Ellinger and Flamand (*Z. physiol. Chem.*, 1911, **71**, 7) and König (*J. pr. Chem.*, 1911, **84**, 194) describe as a bright yellow compound giving red salts with acids; also the orange-red (XI; R = H, R′ = Me) and the deep mauve (XI; R = H, R′ = Ph) (p. 597) which are also of unambiguous structure. It is highly probable therefore that the compound prepared by Angeli and Marchetti and by Borsche and Groth is (IV; R = H, R′ = Me). Unfortunately, the spectroscopic evidence is indecisive: our compound shows a band at 11·25 μ in harmony with the presence of a $>C{:}CH_2$ group, but the corresponding band in the region of 6 μ which this group should show is not apparent.*

The ethylene (IV; R = H, R′ = Me) underwent ready catalytic hydrogenation to the colourless 1 : 1-di-(2-methyl-3-indolyl)ethane (V; R = H, R′ = Me) which Fischer (*Annalen*, 1887, **242**, 372) prepared by the interaction of paraldehyde and 2-methylindole in the presence of zinc chloride. This reduction does not of course distinguish between (IV; R = H, R′ = Me) and (VI).

2-Phenylindole differed from all other indoles investigated in that its reaction with acetyl cyanide did not give a compound of type (II): its apparently abnormal reaction will therefore be discussed at this stage. Equimolecular quantities of the indole and of acetyl cyanide in pure chloroform solution did not interact at room temperature even during 19 days: when the solution was treated with an excess of hydrogen chloride a tar was formed. When however the solution at room temperature was treated with a small quantity of hydrogen chloride, reaction occurred with the formation of the golden-yellow crystalline α-(2-phenyl-3-indolyl)acrylonitrile (VII). The constitution of this compound, which is apparently the first known indole derivative of acrylonitrile, is based on the following evidence. (*a*) Analysis and molecular-weight determinations. (*b*) The compound has no basic properties and is unaffected by cold dilute aqueous or ethanolic hydrogen chloride. (*c*) Its infra-red absorption spectrum shows bands at 3·01, 4·51, and 14·27 μ, corresponding to the –NH–, –CN, and –Ph groups respectively, but that corresponding to the $>C{:}CH_2$ group is rendered uncertain by the phenyl group. (*d*) The compound underwent hydrolysis when its solution in cold concentrated sulphuric acid was poured on ice, with the formation of yellow crystals of α-(2-phenyl-3-indolyl)acrylamide (VIII). The spectrum of this compound showed bands at 2·9, 3·07, and 3·2 μ, due to the –NH– groups, at 14·44 and 13·47 μ due to phenyl and *o*-phenylene groups respectively, and at 5·97 μ due to $>CO$ present as an acid amide group. (*e*) The compound when boiled with ethanolic potassium hydroxide gave (in small yield) 3-acetyl-2-phenylindole (III; R = H, R′ = Ph), previously prepared by Borsche and Groth (*loc. cit.*) by the interaction of acetic anhydride and 2-phenylindole.

(VII)



(VIII)

1-Methyl-2-phenylindole (I; R = Me, R′ = Ph), which is almost insoluble in chloroform, and acetyl cyanide in ether containing hydrogen chloride gave the colourless 1-cyano-1 : 1-di-(1-methyl-2-phenyl-3-indolyl)ethane (II; R = Me, R′ = Ph) which was unaffected by cold hydrochloric acid, but when heated with soda-lime gave 1 : 1-di-(1-methyl-2-phenyl-3-indolyl)ethylene (IV; R = Me, R′ = Ph). This colourless compound gave a deep red solution in ethanolic hydrogen chloride, but the addition of an excess of ammonia to this solution immediately reprecipitated the unchanged ethylene. It should be noted that the constitution of (IV; R = Me, R′ = Ph) is not in doubt, for an isomeric form comparable to (VI) is now not possible; furthermore, the constitution allocated to the anion (IV*B*) now receives indirect support, for the compound (IV; R = Me, R′ = Ph) could not form an anion of this type, and the compound did not in fact give a red solution in potassium hydroxide solution.

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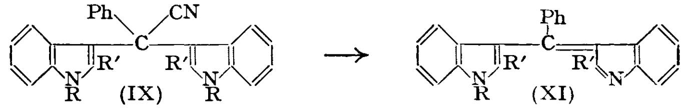
* After this paper was prepared for publication, Saxton (*J.*, 1952, 3592) has briefly discussed the colourless compound which is either (IV; R = R′ = H) or the tautomeric form corresponding to (VI), and considers that the available evidence gives greater support to the latter structure.

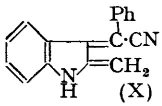
Unexpectedly, it was found that the compound (II; R = Me, R′ = Ph) when boiled with ethanolic potassium hydroxide did not lose hydrogen cyanide, but underwent hydrolysis of the cyano-group followed by decarboxylation, with the formation of the colourless 1 : 1-di-(1-methyl-2-phenyl-3-indolyl)ethane (V; R = Me, R′ = Ph), which was unaffected by hydrochloric acid.

1 : 2-Diphenylindole and acetyl cyanide similarly gave 1-cyano-1 : 1-di-(1 : 2-diphenyl-3-indolyl)ethane (II; R = R′ = Ph), together however with a compound the composition of which indicated that it was α-(1 : 2-diphenyl-3-indolyl)acrylonitrile, but the quantity available was too small for decisive identification. The compound (II; R = R′ = Ph) when heated with soda-lime gave the colourless 1 : 1-di-(1 : 2-diphenyl-3-indolyl)ethylene (IV; R = R′ = Ph) which dissolved in concentrated ethanolic hydrogen chloride to give a deep purplish-red colour which was almost completely discharged by dilution with ethanol; this dissociation of the hydrochloride is not unexpected, however, because the nitrogen atoms in (IV; R = R′ = Ph) would be more feebly basic than those carrying hydrogen or alkyl groups in the previous analogous compounds. The compound (II; R = R′ = Ph) was apparently unaffected by boiling ethanolic potassium hydroxide, in which however it was only slightly soluble.

The products obtained by the action of benzoyl cyanide on 2-methylindole depended markedly on the conditions, as in the case of acetyl cyanide. The indole reacted with benzoyl cyanide in cold chloroform containing a low concentration of hydrogen chloride to give the colourless αα-di-(2-methyl-3-indolyl)benzyl cyanide (IX; R = H, R′ = Me). A higher concentration of hydrogen chloride also led to this compound predominantly, together with a crystalline compound of composition $C_{17}H_{12}N_2$, the spectrum of which showed that it contained the –NH– and –CN groups: this may therefore be α-(2-methylene-3-indolinylidene)benzyl cyanide (X), but the minute yield precluded further investigation. When a chloroform solution of the indole and of benzoyl cyanide was treated with a trace of pyridine and then boiled, only 3-benzoyl-2-methylindole was isolated: Oddo (*Gazzetta*, 1913, **43**, II, 190) has prepared this compound by the action of benzoyl chloride on magnesio-2-methylindole, and Seka (*Ber.*, 1923, **56**, 2058) by subjecting benzonitrile and 2-methylindole to the Hoesch reaction.

The presence of the phenyl group in the compound (IX; R = H, R′ = Me) clearly prevents any reaction of the type (II) ⟶ (IV) when the compound is heated with soda-lime or ethanolic potassium hydroxide; experiment showed that in these circumstances hydrogen cyanide was lost with the formation of orange-red crystalline α-(2-methyl-3-indolyl)-α-(2-methyl-3-indoleninylidene)toluene (XI; R = H, R′ = Me). This compound is identical with that obtained by Fischer and Wagner (*loc. cit.*) by the action of benzoyl chloride on 2-methylindole. It forms fuchsin-red salts with acids, and also when potassium hydroxide is added to its ethanolic solution, in harmony with the mechanism already discussed (p. 595).





(X)

2-Phenylindole did not react with benzoyl cyanide in pure chloroform, but in the presence of hydrogen chloride gave the colourless crystalline αα-di-(2-phenyl-3-indolyl)-benzyl cyanide (IX; R = H, R′ = Ph) which in boiling ethanolic potassium hydroxide similarly furnished α-(2-phenyl-3-indolyl)-α-(2-phenyl-3-indoleninylidene)toluene (XI; R = H, R′ = Ph): this compound formed deep mauve crystals, which gave a bluish-black hydrochloride.

1-Methyl-2-phenylindole and 1 : 2-diphenylindole reacted with benzoyl cyanide in the presence of hydrogen chloride to form the colourless αα-di-(1-methyl-2-phenyl-3-indolyl)-benzyl cyanide and the 1 : 2-diphenyl analogue (IX; R = Me, R′ = Ph; and R = R′ = Ph), respectively. These compounds were unaffected by boiling ethanolic potassium hydroxide, in which however they were only very slightly soluble: the quantities available were insufficient adequately to investigate their reaction with soda-lime.

Although the reactivity of the indoles investigated clearly varied with the nature of the substituents, the following generalisations may be made. (*a*) The interaction of acyl cyanides and indoles is strongly catalysed by a low concentration of hydrogen chloride, which almost invariably caused the cyanides to react as if they were ketones, *i.e.*, to give condensation compounds of type (II) and (IX). (*b*) In weakly basic solution, the cyanides act as acylating agents, giving 3-acylindoles of type (III). (*c*) Even in the presence of a high concentration of hydrogen chloride, the Hoesch reaction, by which the ·CO·COR group should have entered the 3-position of the indole, was never encountered, although the potential presence of such compounds was constantly sought throughout the investigation. It is noteworthy that acetyl and propionyl cyanides with resorcinol give diketones of type $(HO)_2C_6H_3$·CO·COR (Borsche and Diacont, *Ber.*, 1930, **63**, 2740), whilst benzoyl and substituted benzoyl cyanides give polyhydroxy-lactones (Borsche and Walter, *Ber.*, 1926, **59**, 461; Borsche, Walter, and Niemann, *Ber.*, 1929, **62**, 1360). The failure of acyl cyanides to give diketones with indoles may be partly due to the fact that under the most favourable conditions for a Hoesch synthesis, *i.e.*, a high concentration of hydrogen chloride, the reaction often becomes too vigorous, with the production of tars.

EXPERIMENTAL

Many of the compounds obtained in this investigation, particularly those of type (II), (IV), (IX), and (XI), tended to give low and inconsistent analytical values for carbon, a feature which Fischer and Wagner (*loc. cit.*) have already noted. This trouble could usually be obviated by thorough removal of traces of tenaciously occluded solvent, followed by particularly careful analysis.

Acetyl and benzoyl cyanide were freshly prepared and redistilled before use. Pure chloroform was used for the condensations.

Acetyl Cyanide and 2-*Methylindole*.—(*a*) A solution of the indole (1·3 g.) in chloroform (10 c.c.) was diluted with acetyl cyanide (0·75 c.c., 1·05 mol.) and set aside for 24 hours. The crystalline 1-*cyano*-1 : 1-*di*-(2-*methyl*-3-*indolyl*)*ethane* (II; R = H, R′ = Me) (0·9 g., 57%) which had separated was then recrystallised from acetone, giving colourless crystals, m. p. 225—230° (decomp., effervescence) (Found: C, 80·2; H, 6·2; N, 13·6. $C_{21}H_{19}N_3$ requires C, 80·5; H, 6·1; N, 13·4%). Evaporation of the chloroform mother-liquor gave a reddish residue which crystallised when triturated with ethanol; recrystallisation from benzene gave white needles of 3-acetyl-2-methylindole (III; R = H, R = Me), m. p. 200—201°, unchanged by admixture with an authentic sample (Fischer and Pistor, *Ber.*, 1923, **56**, 2318—the action of methyl cyanide and hydrogen chloride on 2-methylindole. They give m. p. 195°; Seka, *loc. cit.*, gives 195—196°).

(*b*) The above solution of reactants was boiled under reflux for 40 minutes. On cooling it deposited the cyano-ethane (1 g., 74%), and the chloroform filtrate on concentration deposited a second crop (0·3 g.).

(*c*) Acetyl cyanide (3 c.c.) and chloroform saturated with hydrogen chloride (5 c.c.) were added in turn to a solution of the indole (5·2 g.) in chloroform (50 c.c.). After 24 hours, the cyano-ethane (5·1 g., 80%) was collected and recrystallised as before (Found: C, 80·6; H, 6·0; N, 13·55%). Concentration of the chloroform gave a small second crop, but the acetylindole could not be detected.

(*d*) A mixture similar to that in (*c*) was boiled under reflux for 30 minutes, during which a copious deposit of the cyano-ethane (5·6 g., 89%) was formed (Found: C, 80·1; H, 6·0%). Again, no acetylindole could be detected.

(*e*) When a slow stream of hydrogen chloride was passed into a solution of the indole and acetyl cyanide, prepared as in (*a*), a tar resulted. No crystalline material could be obtained from this product either directly or after attempted hydrolysis, and no diketone or keto-ketimine had apparently been formed. The chloroform solution which had been decanted from the tar gave a trace of the cyano-ethane.

1 : 1-(*Di*-2-*methyl*-3-*indolyl*)*ethylene* (IV; R = H, R′ = Me).—(*a*) An intimate powdered mixture of the cyano-ethane (1 g.) and soda-lime (2 g.) was heated in a tube, sloping slightly downwards towards the mouth, at 200° rising to 260° at 3 mm. Two layers of sublimate could readily be distinguished. One consisted of 2-methylindole (0·04 g.), identified by mixed m. p. and by its picrate, m. p. 136—137°. The second consisted of yellowish crystals, m. p. 196—200° (0·75 g.), which after repeated recrystallisation from benzene gave the colourless

ethylene (IV; R = H, R′ = Me), m. p. 201—203° (Found: C, 84·0; H, 6·3; N, 9·9. $C_{20}H_{18}N_2$ requires C, 83·85; H, 6·3; N, 9·8%).

(*b*) When the pure cyano-ethane was heated alone, similar results were obtained; a sodium hydroxide trap, placed between the tube and the pump, subsequently contained sodium cyanide, indicating the evolution of hydrogen cyanide.

(*c*) A solution of the cyano-ethane (1 g.) in aqueous-ethanolic 10% potassium hydroxide (20 c.c.) was boiled under reflux for 10 hours. The dark red solution on dilution with water gave an amorphous yellow precipitate which when set aside hardened to the colourless crude ethylene, m. p. 188—190° (0·8 g.), increased by recrystallisation from benzene to 200—202° (Found: C, 84·5; H, 6·4; N, 9·5%). This is the most convenient method of preparing the indolyl-ethylene from the cyano-ethane.

(*d*) 2-Methylindole (1·3 g.), ethyl orthoacetate (0·8 g.), concentrated hydrochloric acid (0·1 c.c.), and zinc chloride (a trace) were heated on a water-bath for 3 hours. The dark red product was extracted with boiling light petroleum (b. p. 60—80°), and the residue dissolved in ethanol and then run into dilute aqueous ammonia. The yellow precipitate when recrystallised as before gave the colourless indolyl-ethylene, m. p. 195—200°, in low yield. This method was based on König's similar preparation (*loc. cit.*) of the lower homologue by the interaction of 2-methylindole and ethyl orthoformate in the presence of acid.

(*e*) Borsche and Groth's preparation (*loc. cit.*) by the interaction of acetyl chloride and 2-methylindole was repeated, and the indolyl-ethylene again obtained as colourless crystals, m. p. 201—203° (Found: C, 83·6; H, 6·8; N, 9·9%).

Our colourless samples of the ethylene (IV; R = H, R′ = Me) slowly became pink on exposure to light and air, which probably explains why Borsche and Groth (*loc. cit.*) describe it as pink.

Hydrochloride. When concentrated hydrochloric acid was carefully added to a concentrated acetone solution of the base, the dark red crystalline hydrochloride was precipitated. It was recrystallised repeatedly from ethanolic hydrogen chloride, but its m. p. remained indefinite and its analyses inconsistent, probably owing to instability, as it readily became brown on exposure to air.

Sulphate. This was similarly prepared, and recrystallised from ethanol, forming dark red crystals, decomp. 236°.

Oxalate. When a concentrated acetone solution of the ethylene and oxalic acid was warmed and stirred, the *oxalate* separated from the deep red solution, and when recrystallised from ethanol formed reddish-orange crystals, m. p. 160—161° (Found: C, 69·2; H, 5·3; N, 7·6. $C_{20}H_{18}N_2,C_2H_2O_4,\frac{1}{2}H_2O$ requires C, 69·4; H, 5·4; N, 7·4%).

Picrate. This was readily prepared in ethanol, and after recrystallisation from ethanol formed dark red crystals, m. p. 195° (decomp., after preliminary darkening) (Found: C, 61·1; H, 4·2; N, 13·6. $C_{20}H_{18}N_2,C_6H_3O_7N_3$ requires C, 60·6; H, 4·1; N, 13·6%).

Attempted Synthesis of (VI).—Angeli and Marchetti (*loc. cit.*) considered that their synthesis of the supposed (VI) depended on the intermediate formation of 3-acetyl-2-methylindole, which underwent condensation with unchanged 2-methylindole. We have failed to condense these compounds in spite of a wide variety of conditions employed: for example, the 3-acetyl-2-methylindole was recovered unchanged after equimolecular mixtures with 2-methylindole had been treated in ethanol with hydrogen chloride or with sodium ethoxide at various temperatures, and when the mixtures had been heated with zinc chloride, or sulphuric acid, or a solution of phosphoric anhydride in syrupy phosphoric acid. This inertness of the acetylindole contrasts sharply with the marked reactivity of indole-3-aldehyde and 2-methylindole-3-aldehyde which condense readily with indoles unsubstituted in the 2- or 3-position (Ellinger and Flamand, *loc. cit.*; König, *loc. cit.*).

2-Methylindole did not react with acetic acid (alone or with hydrochloric acid), although Scholtz (*Ber.*, 1913, **46**, 2138) has shown that it reacts readily with formic acid to give the formate of the orange-yellow lower homologue of (VI).

1 : 1-*Di*-(2-*methyl*-3-*indolyl*)*ethane* (V; R = H, R′ = Me).—A solution of the indolyl-ethylene (IV; R = H, R′ = Me) (2 g.) in ethanol (100 c.c.) was heated with Raney nickel (1 g.), filtered, mixed with more nickel (1 g.), and hydrogenated at room temperature and pressure, one mol. of hydrogen being readily absorbed. Filtration and concentration gave the ethane (V; R = H, R′ = Me), colourless crystals (from benzene), m. p. 209—210° (Found: C, 83·3; H, 6·65; N, 9·7. Calc. for $C_{20}H_{20}N_2$: C, 83·3; H, 7·0; N, 9·7%). Fischer (*loc. cit.*) gives m. p. 191°, but a sample prepared by his method had m. p. 209—210°, unchanged by admixture with the above sample.

Acetyl Cyanide and 2-Phenylindole.—Chloroform (60 c.c.) which had been saturated with hydrogen chloride was added to a solution of 2-phenylindole (5·8 g.) and acetyl cyanide (4·2 c.c., 2 mols.) in chloroform (120 c.c.), and the mixture set aside for 4 days. After filtration to remove a trace of tar, the solvent was evaporated and the red viscous residue rubbed with ethanol. The pale yellow microcrystalline powder (4·1 g.; m. p. 170—172°) thus obtained, when repeatedly recrystallised from ethanol, gave golden-yellow crystals of α-(*2-phenyl-3-indolyl*)*acrylonitrile* (VII), m. p. 174—175·5° (Found: C, 83·4; H, 4·75; N, 11·55%; *M*, ebullioscopic in ethanol, 229. $C_{17}H_{12}N_2$ requires C, 83·6; H, 4·95; N, 11·5%; *M*, 244).

Hydrolysis. (*a*) A solution of the nitrile (VII) in cold sulphuric acid was set aside for 24 hours and then added with stirring to ice-water. The precipitate, when repeatedly recrystallised from ethanol, gave α-(*2-phenyl-3-indolyl*)*acrylamide* (VIII) as yellow crystals, m. p. 203—205° (Found: C, 77·75; H, 5·6; N, 10·6. $C_{17}H_{14}ON_2$ requires C, 77·8; H, 5·4; N, 10·7%).

(*b*) Aqueous-ethanolic 10% potassium hydroxide (20 c.c.) was added to a solution of the nitrile (VII) (1 g.) in boiling ethanol (40 c.c.) which was boiled under reflux for 1 hour, and the dark red solution was then run into dilute acetic acid. The impure yellow precipitate, m. p. 80—135°, on recrystallisation from ethanol furnished 1-acetyl-2-phenylindole, m. p. 220—221° (0·01 g.) (Found: C, 81·7; H, 5·9; N, 6·1. Calc. for $C_{16}H_{13}ON$: C, 81·7; H, 5·6; N, 6·0%). A sample prepared by the method of Borsche and Groth (*loc. cit.*) also had m. p. 220—221°, alone and mixed. No other pure compound could be isolated from the original ethanolic solution.

When a mixture of the nitrile (VII) and soda-lime was heated under pressure, only 2-phenylindole could be isolated from sublimate obtained.

Attempts to prepare the cyanohydrin of 3-acetyl-2-phenylindole were unsuccessful: otherwise, dehydration of this cyanohydrin might have afforded a ready synthesis of the nitrile (VII).

Acetyl Cyanide and 1-Methyl-2-phenylindole (I; R = Me, R′ = Ph).—A solution of the indole (4·14 g.) and acetyl cyanide (1·42 c.c., 1 mol.) in absolute ether (80 c.c.) was saturated with hydrogen chloride and set aside for 24 hours. After filtration from a trace of dark material, and evaporation, the residue was stirred with warm methanol. The colourless solid thus deposited gave, on recrystallisation from benzene, *1-cyano-1 : 1-di-*(*1-methyl-2-phenyl-3-indolyl*)*ethane* (II; R = Me, R′ = Ph), m. p. 237—238° (Found: C, 85·1; H, 6·0; N, 9·1. $C_{33}H_{27}N_3$ requires C, 85·1; H, 5·85; N, 9·0%).

An intimate mixture of the cyano-ethane (1 g.) and soda-lime (2·5 g.) was placed in a sublimation tube, covered with more soda-lime (2·5 g.), and heated at 240—270°/0·5 mm. The main sublimate consisted of colourless plates, which when recrystallised from *cyclo*hexane gave 1 : *1-di-*(*1-methyl-2-phenyl-3-indolyl*)*ethylene* (IV; R = Me, R′ = Ph), m. p. 193—194° (Found: C, 87·6; H, 6·1; N, 6·5. $C_{32}H_{26}N_2$ requires C, 87·6; H, 6·0; N, 6·4%). This compound gave a deep red solution in ethanolic hydrogen chloride, which, however, when poured into an excess of aqueous ammonia, deposited the colourless crystalline ethylene.

A mixture of the cyano-ethane (0·5 g.) and aqueous ethanolic 10% potassium hydroxide (10 c.c.) was diluted with ethanol (20 c.c.) and boiled under reflux for 5 hours, the clear solution slowly becoming turbid. After cooling, the crystalline precipitate, m. p. 210—215°, was recrystallised from aqueous acetone, affording 1 : *1-di-*(*1-methyl-2-phenyl-3-indolyl*)*ethane* (V; R = Me, R′ = Ph), m. p. 212—215° (Found: C, 87·7; H, 6·25; N, 6·1. $C_{32}H_{28}N_2$ requires C, 87·2; H, 6·4; N, 6·4%). This compound remained colourless when treated with hydrochloric acid.

Alternatively, a solution of the cyano-ethane in 70% sulphuric acid was heated until the colour had changed to orange, then red and finally brown, whereupon the solution was chilled and diluted with water. The brown precipitate, when collected and warmed with ethanol, deposited the above ethane, as very pale yellow crystals, m. p. 210—215°, mixed and unmixed.

Acetyl Cyanide and 1 : *2-Diphenylindole* (I; R = R′ = Ph).—A chloroform solution of equimolecular quantities of the indole and the cyanide was saturated with hydrogen chloride, set aside for 48 hours, and filtered, and the chloroform evaporated. The gummy residue was stirred with hot methanol, and the crystalline deposit then quickly filtered from the hot mixture, and washed with more methanol. The deposit, when recrystallised from aqueous acetone, afforded colourless crystals of *1-cyano-1 : 1-di-*(*1 : 2-diphenyl-3-indolyl*)*ethane* (II; R = R′ = Ph), m. p. 214—216° (Found: C, 87·9; H, 5·5; N, 7·1. $C_{43}H_{31}N_3$ requires C, 88·0; H, 5·1; N, 6·9%).

The methanolic filtrate and washings on cooling deposited an oil which slowly solidified, and on recrystallisation from methanol gave colourless crystals, m. p. 150°, presumably of α-(1 : 2-

diphenyl-3-indolyl)acrylonitrile (as VII) (Found : C, 86·2; H, 4·8; N, 8·5. $C_{23}H_{16}N_2$ requires C, 86·25; H, 5·0; N, 8·75%).

The cyano-ethane, when heated as before with soda-lime gradually to 300°/0·5 mm., gave a distillate which readily solidified and when recrystallised from ethyl acetate gave colourless 1 : 1-*di*-(1 : 2-*diphenyl*-3-*indolyl*)*ethylene* (IV; R = R′ = Ph), m. p. 217·5—219·5° (Found : C, 89·2; H, 5·4; N, 5·1. $C_{42}H_{30}N_2$ requires C, 89·6; H, 5·4; N, 5·0%).

The cyano-ethane was recovered unchanged after a suspension in aqueous-ethanolic 10% potassium hydroxide had been boiled under reflux for 10 hours.

Benzoyl Cyanide and 2-Methylindole.—(*a*) Chloroform (2 c.c.), previously saturated with hydrogen chloride, was added to a solution of the indole (2·6 g.) and the cyanide (1·4 g.) in chloroform (20 c.c.), which was set aside for 5 days. The crystals (3·2 g.) which had separated were washed with chloroform and dissolved in a minimum of hot ethanol : water was added dropwise to the hot filtered solution until crystals appeared. On cooling, there were deposited colourless crystals (2·55 g., 68%) of almost pure *αα-di*-(2-*methyl*-3-*indolyl*)*benzyl cyanide* (IX; R = H, R′ = Me), which after crystallisation from aqueous methanol darkened at *ca.* 200°, sintered at 215° and melted at 225° to a red liquid (Found : C, 83·0; H, 5·7; N, 11·4. $C_{26}H_{21}N_3$ requires C, 83·2; H, 5·6; N, 11·2%); this was unaffected by cold hydrochloric acid. A small second crop was isolated from the chloroform filtrate by evaporation, and treatment of the residue with ethanol.

(*b*) The previous experiment was repeated, but with use of chloroform (20 c.c.) saturated with hydrogen chloride. The crystals (2 g.) now collected were apparently a mixture : they were thoroughly triturated with acetone (10 c.c.), collected, and washed again with acetone (5 c.c.). The united acetone filtrates when diluted with water deposited the above crystalline cyanide (1·6 g.), which when heated behaved as before with final melting at 223°. The acetone-insoluble residue appeared to be an unstable hydrochloride; cautious addition of water to its methanolic solution gave colourless chlorine-free crystals (0·1 g.), m. p. 295° (decomp.) after repeated recrystallisation from aqueous acetone. They were apparently α-(2-*methylene*-3-*indolinylidene*)*benzyl cyanide* (X) (Found : C, 83·1; H, 5·0; N, 11·5. $C_{17}H_{12}N_2$ requires C, 83·6; H, 5·0; N, 11·5%).

(*c*) A solution of the indole (1·3 g.), benzoyl cyanide (0·7 g.), and pyridine (1 drop) in chloroform (10 c.c.) was boiled under reflux for 2 hours and the solvent then evaporated. The reddish oily residue when stirred with ethanol gave colourless crystals of almost pure 3-benzoyl-2-methylindole, m. p. 185—186° (from methanol) (Found : C, 81·7; H, 5·6. Calc. for $C_{16}H_{13}ON$: C, 81·7; H, 5·55%). Oddo (*loc. cit.*) gives m. p. 181°; Seka (*loc. cit.*) gives 181—182°.

An intimate mixture of the cyanide (IX; R = H, R′ = Me) and soda-lime was heated at 0·5 mm. A colourless sublimate of 2-methylindole, m. p. 60°, soon formed, and at 210—290° an orange distillate was obtained; this solidified, and when crystallised slowly from a minimum of hot ethanol afforded deep red crystals of α-(2-methyl-3-indolyl)-α-(2-methyl-3-indoleninylidene)-toluene (XI; R = H, R = Me) which darkened at *ca.* 230°, sintered at 244°, and melted at 247°.

The same compound was more readily obtained when a solution of the cyanide (1 g.) in aqueous-ethanolic 10% potassium hydroxide (40 c.c.) was boiled under reflux for 15 minutes, and the hot red solution then run into water (*ca.* 160 c.c.). The initial amorphous, orange precipitate became granular and darker when the mixture was warmed and stirred, and was then collected, washed with water, dried (0·95 g.), and recrystallised as before, deep red crystals of almost identical m. p. being obtained.

For identification, this compound was also prepared by the method of Fischer and Wagner (*loc. cit.*) and an identical product obtained. Our product, like that of these authors, when freshly precipitated from a solution of one of its salts was amorphous and orange, and was freely soluble in ethanol and ether. When however the amorphous material was heated with water or immersed in ethanol, it slowly formed reddish-orange crystals, which were much less soluble in ethanol and almost insoluble in ether. Slow crystallisation from ethanol gave the larger deep red crystals. The addition of solid potassium hydroxide to its ethanolic solution gave the same fuchsin-red colour as that of its salts with acids. The compound retains water and ethanol very tenaciously, and satisfactory carbon analyses were not obtained.

Benzoyl Cyanide and 2-Phenylindole.—Chloroform (20 c.c.), previously saturated with hydrogen chloride, was added to a solution of the indole (1·93 g.) and benzoyl cyanide (1·35 g., 1 mol.) in chloroform (40 c.c.), which was set aside for 4 days. The almost colourless crystals (1·8 g.) were then collected and recrystallised from aqueous ethanol, affording *αα-di*-(2-*phenyl*-3-

indolyl)benzyl cyanide (IX; R = H, R′ = Ph) which became red at *ca.* 200° and melted at 240—242° (decomp.) (Found: C, 84·2; H, 5·3; N, 8·2. $C_{36}H_{25}N_3,0{\cdot}75H_2O$ requires C, 84·3; H, 5·2; N, 8·2%). This compound also retains water very tenaciously: the sample analysed had previously been heated at 60°/0·1 mm. over phosphoric anhydride for 18 hours.

A solution of the cyanide in aqueous-ethanolic 10% potassium hydroxide was boiled under reflux for 3 hours, and the bluish-violet solution then filtered into much water. The amorphous red precipitate became crystalline and mauve when the suspension was warmed and stirred. It was insoluble in most solvents, and was recrystallised by adding water cautiously to a hot solution in ethanolic pyridine (1 : 2) until a turbidity was produced; slow cooling gave fine deep mauve crystals of *α-(2-phenyl-3-indolyl)-α-(2-phenyl-3-indoleninylidene)toluene* (XI; R = H, R′ = Ph), m. p. 320—325° to a red liquid (Found: C, 86·6; H, 5·35; N, 6·05. $C_{35}H_{24}N_2,0{\cdot}75H_2O$ requires C, 86·5; H, 5·3; N, 5·8%). A solution in ethanolic pyridine when run slowly into dilute hydrochloric acid deposited the hydrochloride as bluish-black crystals, which sintered at 220° and melted at 235°.

Benzoyl Cyanide and 1-*Methyl*-2-*phenylindole*.—Ether (40 c.c.), previously saturated with hydrogen chloride, was added to a solution of the indole (2 g.) and benzoyl cyanide (1·3 g., 1 mol.) in dry ether, and the mixture after 2 days was filtered and evaporated. The grey solid residue was triturated with ethanol, and the product (1·9 g.) on recrystallisation from benzene gave colourless crystals of *αα-di-(1-methyl-2-phenyl-3-indolyl)benzyl cyanide* (IX; R = Me, R′ = Ph), m. p. 289—291° (Found: C, 86·4; H, 5·55; N, 7·65. $C_{38}H_{29}N_3$ requires C, 86·5; H, 5·5; N, 8·0%).

Benzoyl Cyanide and 1 : 2-*Diphenylindole*.—A solution of the indole (2 g.) and benzoyl cyanide (1·3 g., 1·35 mol.) in dry chloroform (10 c.c.) was saturated with hydrogen chloride, and after 2 days the solvent was evaporated. The residue was stirred with aqueous sodium hydroxide, collected, washed with water, dried (2·2 g.), and recrystallised from benzene, giving colourless *αα-di-(1 : 2-diphenyl-3-indolyl)benzyl cyanide* (IX; R = R′ = Ph), m. p. 303—304° (Found: C, 88·1; H, 4·9; N, 6·3. $C_{48}H_{33}N_3$ requires C, 88·4; H, 5·1; N, 6·45%).

The above three compounds of type (IX) were unaffected by dilute hydrochloric acid.

The ultra-violet absorption spectra of certain of the above compounds, in ethanolic solution, are recorded in the Table (λ in mμ).

(II; R = H, R′ = Me)	$\lambda_{max.}$	290	282	222		$\lambda_{min.}$	287	247	
	ε	14,110	15,000	65,700		ε	12,500	4200	
(II; R = Me, R′ = Ph)	$\lambda_{max.}$	287	223			$\lambda_{min.}$	258	210	
	ε	18,400	73,500			ε	9200	51,200	
(IV; R = H, R′ = Me)	$\lambda_{max.}$	377	280	275	228	$\lambda_{min.}$	337	278	254
	ε	306	19,280	19,350	50,200	ε	188	19,100	11,500
(IV; R = H, R′ = Me) in EtOH containing 2% of N/10-HCl ...	$\lambda_{max.}$	499	350	285	210	$\lambda_{min.}$	410	325	250
	ε	18,900	1780	17,600	38,100	ε	1080	1400	10,500
(V; R = H, R′ = Me)	$\lambda_{max.}$	291	284	227		$\lambda_{min.}$	289	251	203
	ε	12,360	13,100	58,500		ε	11,700	4200	32,000
(VII)	$\lambda_{max.}$	296	220			$\lambda_{min.}$	256	212	
	ε	16,790	26,350			ε	7076	25,370	

It is noteworthy that König (*loc. cit.*) has recorded that (2-methyl-3-indolyl)(2-methyl-3-indoleninylidene)methane, *i.e.*, the lower homologue of (VI), gives a perchlorate having in ethanolic solution $\lambda_{max.}$ 4820, 3500, and 2900, and a sodium salt having similarly $\lambda_{max.}$ 4820, 3700, and 3000. These red salts must presumably give rise to ions analogous to (IV*A*) and (IV*B*) respectively, and their spectra confirm their closely similar structure.

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