436. *Peroxides of Tetrahydrocarbazole and Related Compounds. Part I. Tetrahydrocarbazolyl Hydroperoxide.*

By R. J. S. Beer, L. McGrath, and Alexander Robertson.

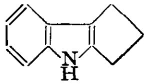
The preparation and properties of 1 : 2 : 3 : 4-tetrahydrocarbazolyl hydroperoxide are described. With aqueous sodium hydroxide this peroxide gave a compound, m. p. 340°, along with a small amount of *cyclo*pentane*spiro*-2-ψ-indoxyl, which was also formed by treatment with ferrous ions in acid solution. With sodium hydrosulphite (dithionite) it gave a compound, m. p. 153°, identical with so-called " 10-hydroxy-1 : 2 : 3 : 10-tetrahydrocarbazole " of Plant and Tomlinson (*J.*, 1933, 298). Reduction of the peroxide over a palladium catalyst regenerated 1 : 2 : 3 : 4-tetrahydrocarbazole whilst a platinum catalyst gave rise to the same hydroxy-hexahydrocarbazole as was obtained by hydrogenation of the compound, m. p. 153°. The structures of the peroxide and of the related compound, m. p. 153°, are discussed and possible mechanisms for the peroxidation process elaborated.

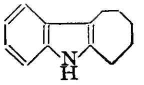
Catalytic hydrogenation of *cyclo*pentane*spiro*-2-ψ-indoxyl afforded a tetrahydro-derivative which readily forms a peroxide.

The compound, m. p. 115°, regarded by Plant and Tomlinson (*loc. cit.*) as 11-hydroxy-2 : 3 : 4 : 11-tetrahydrocarbazole, is shown to be 1-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole.

In the course of attempts to purify 6 : 7-dimethoxy-1 : 2 : 3 : 4-tetrahydrocarbazole by crystallisation from light petroleum–ethyl acetate it was found that the compound readily absorbed atmospheric oxygen, giving rise to a crystalline peroxide. This unexpected and surprisingly ready reaction leading to a relatively stable peroxide was subsequently found to occur also with 1 : 2 : 3 : 4-tetrahydrocarbazole and its 6 : 7-methylenedioxy-derivative (*J.*, 1949, 2061; *Nature*, 1949, **164**, 362) and the present communication deals with the results of our preliminary examination of the chemical properties of 1 : 2 : 3 : 4-tetrahydrocarbazole peroxide which, on account of its accessibility, was an obvious choice for initial study.

The formation of 1 : 2 : 3 : 4-tetrahydrocarbazole peroxide takes place in light petroleum in the absence of a catalyst and, although it appears to be accelerated by irradiation with ultra-violet light, proceeds as satisfactorily in darkness as in laboratory illumination. Although the average yield of purified peroxide is about 40%, the yield of crude product is generally much higher. Of considerable interest is the observation that 9-methyl- and 9-acetyl-1 : 2 : 3 : 4-tetrahydrocarbazole appear to resist attack under the conditions employed in this work.


(I.)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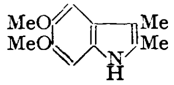
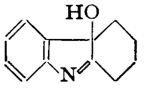

(III.)

Curiously, 2 : 3-*cyclo*penteno- (I) and 2 : 3-*cyclo*hepteno-indole (II) (Perkin and Plant, *J.*, 1923, **123**, 3244; 1928, 2586) have not yielded crystalline peroxides under our conditions although in experiments with added catalysts (*e.g.*, traces of a peroxide of tetrahydrocarbazole, cobalt stearate) decomposition of these indoles occurs and the amorphous products obtained have sometimes given feebly positive tests for peroxides. Similarly, 5 : 6-dimethoxy-2 : 3-dimethylindole (III) (*J.*, 1949, 2061) has afforded a product containing traces of peroxide and it seems likely that, with the discovery of appropriate conditions, simple indoles and even pyrroles may be induced to yield isolable peroxides. In this connection it may be noted that peroxide formation by this type of compound may possibly be of considerable biological significance in the phytochemical production of complex basic substances as well as in the formation of the melanins (*J.*, 1948, 2223).

1 : 2 : 3 : 4-Tetrahydrocarbazole peroxide, $C_{12}H_{13}O_2N$, which melts between 124° and 129° with vigorous decomposition accompanied by the emission of a vivid blue flash, liberates iodine immediately from acidified aqueous potassium iodide and differs from the parent tetrahydrocarbazole and the indoles generally in being readily soluble in dilute aqueous mineral acids. With nitrous acid the peroxide appears to behave as a secondary amine. It also shows weakly acidic properties and although it is rapidly decomposed by alkalis some peroxidic material can be recovered from an alkaline solution, indicating that the compound is, in fact, a hydroperoxide containing the group ·O·OH. From the reaction of the peroxide with aqueous sodium hydroxide two products have been isolated, the chief of which is a high-melting substance, $C_{12}H_{11}ON$, m. p. about 330°, showing both basic and acidic properties. This compound, which will be discussed in a later communication, is accompanied by small amounts of a yellow compound identical (*Nature, loc. cit.*) with the " 11-hydroxytetrahydrocarbazolenine," m. p. 79°, (IV) or (V), of Perkin and Plant (*J.*, 1923, **123**, 689) which has recently been formulated as the *cyclo*pentane*spiro*-2-*ψ*-indoxyl (VI) by Plant and Robinson (*Nature*, 1950, **165**, 36) and by Witkop (*J. Amer. Chem. Soc.*, 1950, **72**, 614). The same compound, m. p. 79°, was obtained in low yield by the action of acetic acid and iron powder on the peroxide but in this case it was accompanied by the colourless " 2 : 3-dihydrocarbazole," m. p. 293—295°, formulated as (VII) by Plant and Tomlinson (*J.*, 1931, 3324; 1933, 298) together with a second, yellow substance, m. p. 245°, which appears to have the empirical formula $C_{24}H_{24}ON_2$ or $C_{24}H_{26}ON_2$.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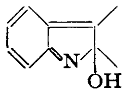
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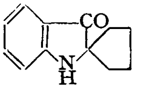
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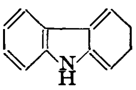
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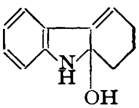
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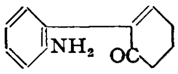

(IX.)

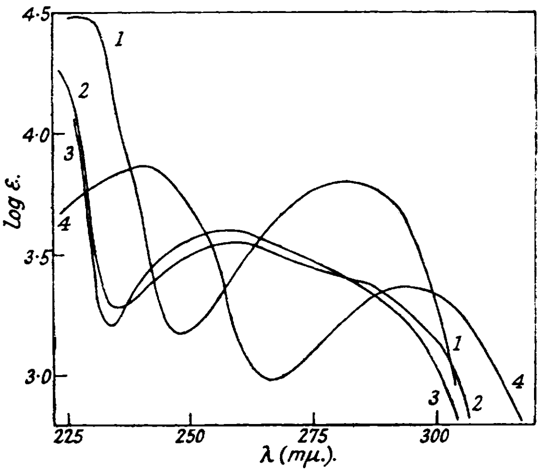
With alkaline aqueous sodium hydrosulphite (dithionite), tetrahydrocarbazolyl hydroperoxide gave rise to a compound, m. p. 153°, which was identical with the so-called 10-hydroxy-1 : 2 : 3 : 10-tetrahydrocarbazole (VIII) of Plant and Tomlinson (*loc. cit.*). Like the parent peroxide this compound is also basic and decomposes in dilute sulphuric acid to mixed products from which the " 2 : 3-dihydrocarbazole," m. p. 293—295°, can be isolated in small yield. In addition, the acidic decomposition of the peroxide has afforded a small amount of a non-basic substance, m. p. about 150°, which has not yet been obtained pure.

Reduction of tetrahydrocarbazolyl hydroperoxide with hydrogen and a palladium–charcoal catalyst regenerated 1 : 2 : 3 : 4-tetrahydrocarbazole but with a platinum oxide catalyst a compound $C_{12}H_{15}ON$ was obtained, identical with the hydrogenation product of the compound,

m. p. 153°. This product is clearly a hydroxyhexahydrocarbazole since on treatment with mineral acids it readily lost water giving rise to 1 : 2 : 3 : 4-tetrahydrocarbazole.

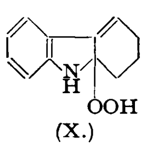
From the foregoing results it is apparent that 1 : 2 : 3 : 4-tetrahydrocarbazolyl hydroperoxide and the compound, m. p. 153°, are structurally very closely related, a view supported by the close similarity of their ultra-violet absorption curves (see Fig. 1) which differ markedly from that of 1 : 2 : 3 : 4-tetrahydrocarbazole. Further, it is clear that in the formation of the peroxide some modification of the conjugated system present in the parent tetrahydrocarbazole takes place, in keeping with the appearance of basic properties in the peroxide. The formula (VIII) was assigned to the compound, m. p. 153°, by Plant and Tomlinson (*loc. cit.*) to account for its behaviour as an aromatic primary amine which could be diazotised, *i.e.*, the compound behaved as the isomeride (IX) in mineral acid solution and on this basis 1 : 2 : 3 : 4-tetrahydrocarbazolyl hydroperoxide and its hydrogenation product, which is also obtained from the compound, m. p. 153°, would be represented respectively by formulæ (X) and (XI). The formulæ (VIII), (X), and (XI) for these compounds are in agreement with their instability in mineral acid solution.

FIG. 1.

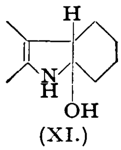


1, 1 : 2 : 3 : 4-*Tetrahydrocarbazole.* 2, 1 : 2 : 3 : 4-*Tetrahydrocarbazole peroxide.* 3, *Compound, m. p.* 153° (11-*hydroxytetrahydrocarbazolenine or* 10-*hydroxy*-1 : 2 : 3 : 10-*tetrahydrocarbazole*). 4, *Dihydro-derivative of* 3.

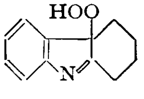
(*All spectroscopic measurements were made in alcoholic solution.*)



(X.)



(XI.)



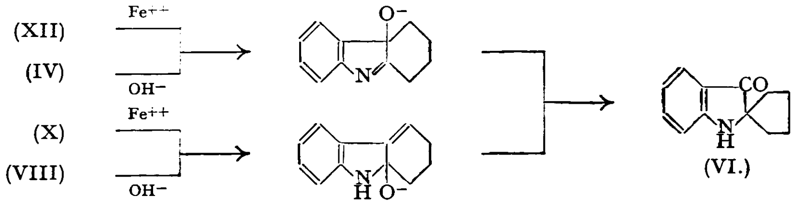
(XII.)

In a recent communication Patrick and Witkop (*J. Amer. Chem. Soc.*, 1950, **72**, 633) have briefly described the preparation of a compound, m. p. 159°, by catalytic oxidation of tetrahydrocarbazole followed by mild hydrogenation. From the data for its ultra-violet absorption spectrum this compound, which the foregoing authors regard as being identical with the so-called 10-hydroxy-1 : 2 : 3 : 10-tetrahydrocarbazole, would appear to be identical with the product of m. p. 153° obtained by us. In this connection it is of interest that, prepared by the method of Plant and Tomlinson (*loc. cit.*), this compound was found to have m. p. 153° except on one occasion when a sample was obtained with m. p. 158·5°. On being kept overnight, however, this material reverted to the lower-melting form, but it is not yet clear whether the compound is dimorphic since the melting point seems to vary somewhat with the rate of heating. On the basis of its infra-red absorption spectrum Patrick and Witkop (*loc. cit.*) regard this compound as being authentic 11-hydroxytetrahydrocarbazolenine (IV) and it is clear that if this view proves to be correct then 1 : 2 : 3 : 4-tetrahydrocarbazole peroxide must have the corresponding structure (XII). Without giving experimental details Patrick and Witkop (*loc. cit.*) state that on decomposition with acid, heat, or acetic anhydride, their compound, m. p. 159°, affords an 85% yield of *cyclo*pentane*spiro*-2-ψ-indoxyl (VI) together with a substance, m. p. 255° (and after resolidification m. p. 313°), which they regard as being identical with " 2 : 3-dihydrocarbazole," m. p. 293—295° (Plant and Tomlinson, *loc. cit.*), and to which they assign the empirical formula $C_{24}H_{18}N_2$ despite the fact that their analytical results [*] are in better agreement with $C_{24}H_{22}N_2$. In our experiments we have invariably failed to isolate *cyclo*pentane*spiro*-2-ψ-indoxyl by the action of acids under a wide variety of conditions (except in the presence of iron) either from the peroxide of 1 : 2 : 3 : 4-tetrahydrocarbazole or from the compound m. p. 153°, and on the view, which we maintain, that this compound, m. p. 153°, is identical with Patrick and Witkop's substance, m. p. 159°, we are unable at present to account for the findings of these authors. Moreover, specimens of the so-called 2 : 3-dihydrocarbazole prepared by the method of Plant and Tomlinson (*loc. cit.*) and from the peroxide have had the m. p. 293—295° reported by the original authors.

In the decomposition of 1 : 2 : 3 : 4-tetrahydrocarbazolyl hydroperoxide with alkali, and with acetic acid and iron powder, it seemed feasible that the *cyclo*pentane*spiro*-2-ψ-indoxyl, which in neither case is the major product, is formed by way of the compound, m. p. 153°. Whilst under alkaline conditions this mechanism may obtain since, as Plant and Tomlinson (*loc. cit.*) showed, " 10-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole " readily yields the ψ-indoxyl with alkalis, it seems to be highly improbable when the medium is acetic acid containing iron powder because with hot acetic acid the compound, m. p. 153°, as well as the peroxide of tetrahydrocarbazole, rapidly form the " 2 : 3-dihydrocarbazole," m. p. 293—295°, unaccompanied by detectable amounts of the ψ-indoxyl. Since the difference in behaviour of 1 : 2 : 3 : 4-tetrahydrocarbazolyl hydroperoxide towards acetic acid in the presence or absence of iron might be due to the action of the ferrous ion which is known to catalyse the decomposition of peroxides (see Waters, *Ann. Reports*, 1945, **47**, 136) the peroxide was treated with cold dilute sulphuric acid containing ferrous sulphate. A rapid reaction ensued and the *spiro*-ψ-indoxyl was isolated in approximately the same yield as in the experiments with iron powder and alcoholic acetic acid On the other hand, the presence of ferrous sulphate did not materially affect the action of cold dilute sulphuric acid on the compound, m. p. 153°. By analogy with the Haber–Weiss theory of the metal-catalysed decomposition of hydrogen peroxide (see, *e.g.*, Waters, *loc. cit.*) the action of ferrous ions on the peroxide of 1 : 2 : 3 : 4-tetrahydrocarbazole may be considered to be :

$$R{\cdot}O{\cdot}OH + Fe^{++} \longrightarrow (R{\cdot}O)^{-} + {\cdot}OH + Fe^{+++}$$

The subsequent rearrangement of the anion $(R{\cdot}O)^-$, which presumably is also formed by the action of alkali on the compound, m. p. 153° (the alcohol R·OH), to give *spiro*-ψ-indoxyl (VI) is more easily understandable on the basis of formula (XII) rather than (X) for the peroxide :



Thus the metal-catalysed decomposition of the peroxide may be considered to afford indirect support for the carbazolenine structure (XII) for this compound. Additional indirect support for this structure can be adduced from a consideration of the mechanism of peroxidation which, in common with other autoxidation processes, may be assumed to be a radical chain reaction. For this, two mechanisms are envisaged of which one (*A*) leads to structure (X) for the peroxide and the other (*B*) to (XII).

The mechanism (*B*) provides a feasible explanation of the observation that peroxidation of *N*-substituted 1 : 2 : 3 : 4-tetrahydrocarbazoles, *e.g.*, 9-methyl and 9-acetyl derivatives, does not occur. Nevertheless, on the basis of structure (XII) for the peroxide two difficulties arise. In the first place the peroxide appears to behave as a secondary amine towards nitrous

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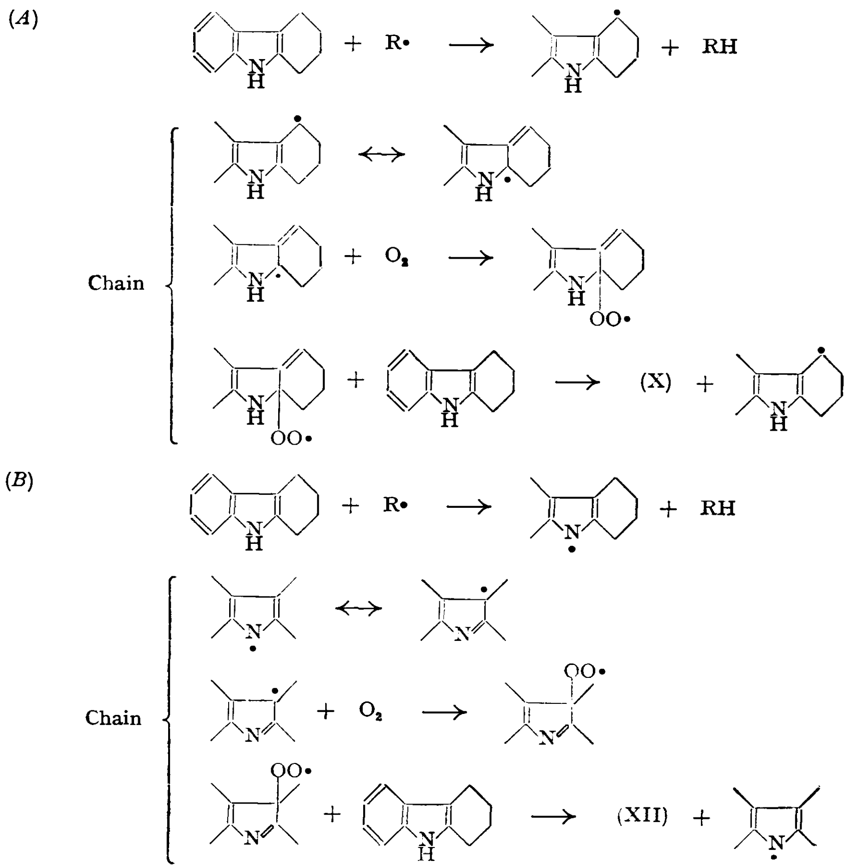
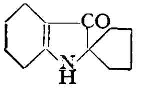
[*] Patrick and Witkop state that calculated values for $C_{24}H_{18}N_2$ are C, 85·25; H, 6·51; N, 8·3%, whereas these should be C, 86·23; H, 5·39; N, 8·4%.

acid and, in the second, the corresponding alcohol, m. p. 153°, behaves as a primary amine towards the same reagent. Further experiments designed to resolve these difficulties and to lead to a final decision between the two structures (X) and (XII) for the peroxide are in progress.

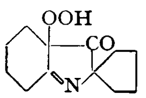


During our examination of *cyclo*pentane*spiro*-2-ψ-indoxyl (VI) we found that, as expected, the compound can be readily oximated and, like Witkop (*J. Amer. Chem. Soc.*, 1950, **72**, 614), we observed that on hydrogenation it formed a tetrahydro-derivative (XIII). In benzene solution this tetrahydro-compound readily forms a peroxide which has not yet been fully investigated but its ultra-violet absorption spectrum has been compared with that of related compounds (see Fig. 2).

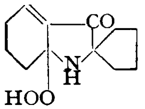
It appears that, as in the formation of tetrahydrocarbazole peroxide, peroxidation is accompanied by a double-bond shift and we suggest two possible structures (XIV) or (XV) for this new peroxide, the former being favoured on spectroscopic grounds.



(XIII.)



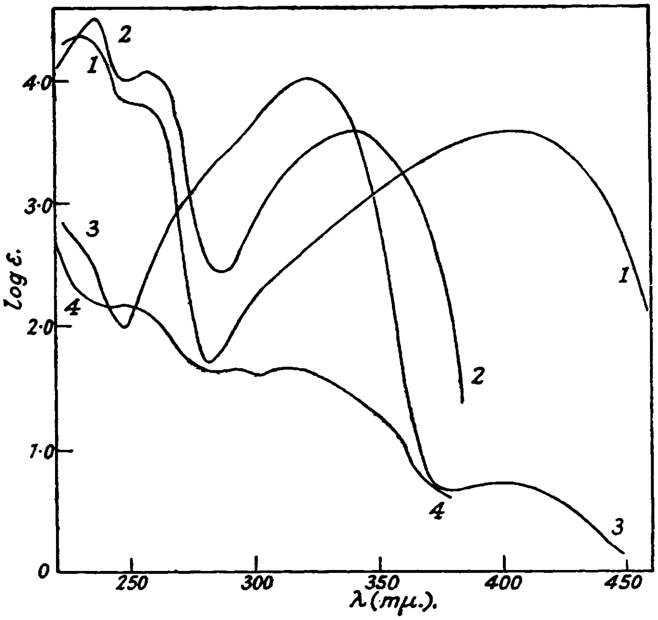
(XIV.)



(XV.)

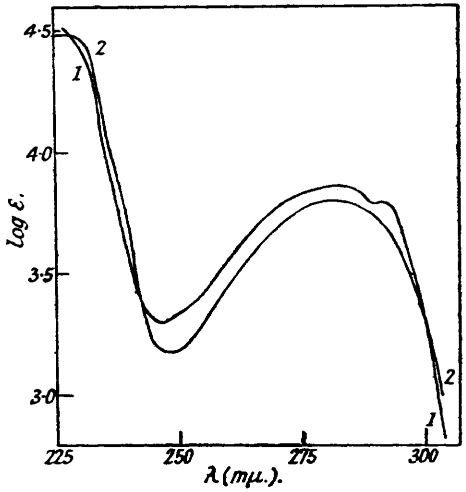
For comparison with the compound, m. p. 153°, (VIII) or (IV), we prepared the isomeric compound, m. p. 115°, from 9-benzoyl-1 : 2 : 3 : 4-tetrahydrocarbazole by the method of Plant and Tomlinson (*loc. cit.*) who ascribed to it formula (XVI). The ultra-violet absorption spectrum of this compound, however, closely resembled that of 1 : 2 : 3 : 4-tetrahydrocarbazole (see Fig. 3) and hence it seemed that in all probability the compound was (XVII) or (XVIII)

FIG. 2.



1, cyclo*Pentane*spiro-2-ψ-*indoxyl*. 2, N-*Acetyl*cyclo*pentane*spiro-2-ψ-*indoxyl*. 3, *Tetrahydro*cyclo*pentane*spiro-2-ψ-*indoxyl*. 4, *Peroxide of* 3.

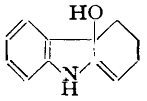
FIG. 3.



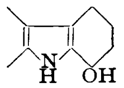
1, " 11-*Hydroxy*-2 : 3 : 4 : 11-*tetrahydrocarbazole*," *m. p.* 115° (1-*hydroxy*-1 : 2 : 3 : 4-*tetrahydrocarbazole*). 2, 1 : 2 : 3 : 4-*Tetrahydrocarbazole*.

rather than (XVI). That it is 1-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole (XVII) is shown by the fact that it is formed by reduction with lithium aluminium hydride of 1-keto-1 : 2 : 3 : 4-tetrahydrocarbazole (XIX), which was prepared by the unambiguous method of Coffey (*Rec. Trav. chim.*, 1923, **42**, 528) as modified by Kent (*J.*, 1935, 976).

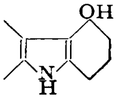
The conversion of 9-benzoyl-1 : 2 : 3 : 4-tetrahydrocarbazole into 1-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole, by treatment with bromine and then aqueous ammonia followed by debenzoylation, finds a close analogy in the production of 3-methyl-2-hydroxymethylindole from 9-acetyl-2 : 3-dimethylindole by a similar series of reactions (Plant and Tomlinson, *J.*, 1933, 955; cf. Taylor, *Helv. Chim. Acta*, 1950, **33**, 168).



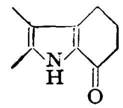
(XVI.)



(XVII.)



(XVIII.)



(XIX.)

EXPERIMENTAL.

1 : 2 : 3 : 4-*Tetrahydrocarbazolyl Hydroperoxide* (X or XII).—(*a*) A warm filtered solution of 1 : 2 : 3 : 4-tetrahydrocarbazole (Rogers and Corson, *J. Amer. Chem. Soc.*, 1947, **69**, 2910) (2 g.) in light petroleum (b. p. 60—80°) (200 ml.) was allowed to cool in the presence of atmospheric oxygen. After a somewhat variable period (generally about ½ hour) the solution became opaque and then began to deposit the crystalline *peroxide* on the sides of the containing flask. 18 Hours later the solid (1·5—1·9 g.) was dislodged and isolated without disturbing the thin layer of resinous material which had formed on the bottom of the flask. Recrystallisation of the peroxide was effected as rapidly as possible by the addition of hot ethyl acetate to a suspension of the solid in boiling light petroleum until a clear solution was obtained. On cooling this solution deposited the compound in large, almost colourless shining tablets, which decomposed violently at temperatures varying from 124° to 129°, the decomposition being accompanied by a flash of blue light (Found : C, 70·7; H, 6·7; N, 7·0. $C_{12}H_{13}O_2N$ requires C, 70·9; H, 6·4; N, 6·9%). The yield of recrystallised product varied considerably. A high yield of the crude peroxide was associated with a comparatively high yield of purified material (*e.g.*, 0·95 g. of recrystallised peroxide from 1·9 g. of crude product) and, as sometimes happened, when the crude product was obtained in poor yield, this gave a relatively much lower yield of purified peroxide.

(*b*) A current of air was aspirated through a solution of 1 : 2 : 3 : 4-tetrahydrocarbazole (2 g.) in light petroleum (200 ml.) kept at just below its boiling point for 1 hour. The crystalline peroxide usually separated after about 30 minutes' aeration and in favourable cases the yield of purified product was equal to the optimum yields obtained by method (*a*). Occasionally, however, extensive decomposition of the carbazole or its peroxide took place and an amorphous tan powder was obtained which could not be crystallised and had a low and indefinite m. p. For routine preparations method (*a*) was preferred.

In these experiments commercial samples of light petroleum were employed and, although the use of other solvents has not yet been extensively investigated, it has been found that peroxidation proceeded normally in re-distilled *n*-hexane whereas in benzene only small amounts of a very crude peroxide were obtained. With ether as solvent in method (*a*) very slight peroxidation occurred.

1 : 2 : 3 : 4-Tetrahydrocarbazole hydroperoxide liberates iodine instantaneously from acidified aqueous potassium iodide and dissolves easily in dilute aqueous mineral acids, forming yellow solutions which rapidly become opaque and then deposit a brown amorphous precipitate. Addition of sodium nitrite to a solution of the peroxide in dilute hydrochloric acid at 0° causes the separation of a bright yellow viscous oil which can be extracted with ether. Although large crystals of the peroxide are only slowly attacked by aqueous sodium hydroxide the finely powdered compound readily forms a faintly yellow solution.

Decomposition of 1 : 2 : 3 : 4-*Tetrahydrocarbazolyl Hydroperoxide*.—(a) *With alkali*. Rapid dissolution of the peroxide in 2N-aqueous sodium hydroxide followed by immediate neutralisation with 2N-sulphuric acid gives a sticky precipitate which, on being thoroughly washed with water, is obtained as a tan-coloured powder giving a positive peroxide reaction with acidified aqueous potassium iodide.

When a solution of the peroxide (2·8 g.) in aqueous sodium hydroxide (100 ml.) was kept at room temperature for 14 hours and then neutralised with dilute sulphuric acid and the resulting microcrystalline precipitate (2·5 g.) crystallised from hot alcohol, a *substance* was obtained in shining light brown rectangular plates, m. p. 330° (decomp.), which retained their colour on repeated recrystallisation (Found : C, 77·8, 77·6; H, 5·9, 6·5; N, 7·4. $C_{12}H_{11}ON$ requires C, 77·8; H, 5·9; N, 7·6%). This product is soluble in both dilute mineral acids and aqueous alkalis but is very sparingly soluble in water or in aqueous sodium hydrogen carbonate. The neutral liquor left on the separation of this ampholyte showed the characteristic green fluorescence of *cyclo*pentane*spiro*-2-ψ-indoxyl (VI) (Perkin and Plant, *loc. cit.*). This indoxyl was isolated from another experiment in which the peroxide (1 g.) was warmed with 2N-sodium hydroxide (25 ml.) on the steam-bath for 20 minutes. The yellow solution quickly became opaque and then deposited brown resinous material. Repeated extraction of the cooled reaction mixture with ether gave a yellow gum from which the ψ-indoxyl was extracted by boiling light petroleum. Recrystallised from the same solvent, it formed bright yellow, compact prismatic needles (50 mg.), m. p. 78—79°, undepressed on admixture with an authentic specimen (Found : C, 77·05; H, 6·9; N, 7·5. Calc. for $C_{12}H_{13}ON$: C, 77·0; H, 6·95; N, 7·5%). On filtration and neutralisation, the alkaline liquor left after the separation of *cyclo*pentane*spiro*-2-ψ-indoxyl deposited a microcrystalline powder (600 mg.) which, on crystallisation from hot alcohol, gave the substance, m. p. 330° (decomp.).

(b) *With alkaline sodium dithionite*. When a mixture of powdered peroxide (1 g.), ether (50 ml.), and N-sodium hydroxide (20 ml. containing 2 g. of sodium dithionite) was agitated, the solid dissolved in the course of 10 minutes. One hour later the ethereal layer was separated and the aqueous liquor extracted several times with fresh ether. Concentration of the combined, dried ethereal solutions gave colourless crystals (550 mg.), m. p. 147—149°, followed by a further small amount of less pure material. Recrystallised from benzene this product gave " 10-hydroxy-1 : 2 : 3 : 10-tetrahydrocarbazole " (VIII or IV) in colourless prisms, m. p. 153—154°, identical with an authentic specimen (Plant and Tomlinson, *loc. cit.*) (Found : C, 77·2; H, 7·0; N, 7·4. Calc. for $C_{12}H_{13}ON$: C, 77·0; H, 6·95; N, 7·5%). Like the authentic compound this product from the peroxide was readily soluble in dilute mineral acids, and in acid solution behaved as a primary aromatic amine.

(c) *With alcoholic acetic acid and iron.* The reaction between the peroxide (1 g.), iron powder (5 g.), and acetic acid (20 ml.) in alcohol (25 ml.) was initiated by gentle warming and then allowed to proceed spontaneously until it subsided in about 5 minutes. After having then been heated on the steam-bath for 7 minutes the reaction mixture was filtered and the residue of iron and ferrous acetate was well washed with several small portions of hot alcohol. The combined filtrates and washings were diluted with water and extracted several times with ether, and the ethereal extracts were concentrated until solid began to separate. After cooling, the yellow product (0·36 g.) was collected and crystallised from much benzene, giving a mixture (50 mg.) of colourless and yellow crystals. The colourless material was separated manually and then recrystallised from benzene, giving " 2 : 3-dihydrocarbazole," m. p. 293—295°, identical with an authentic specimen (Plant and Tomlinson, *loc. cit.*)(Found : C, 85·15; H, 6·5; N, 8·1. Calc. for $C_{12}H_{11}N$ or $C_{24}H_{22}N_2$: C, 85·2; H, 6·5; N, 8·3%).

Concentration of the benzene mother-liquor left on separation of the mixed crystals gave a homogeneous yellow product (0·25 g.), m. p. 238—240°, which on recrystallisation from the same solvent furnished a *substance* in bright yellow prisms, m. p. 245° [Found : C, 79·8, 79·9; H, 6·1, 6·5; N, 8·4. *M* (Rast), 367. $C_{24}H_{24}ON_2$ requires C, 80·9; H, 6·7; N, 7·9%; *M*, 356. $C_{24}H_{26}ON_2$ requires C, 80·4; H, 7·3; N, 7·8%; *M*, 358].

Evaporation of the aqueous alcohol–acetic acid liquor left after separation of the crude mixed solid, followed by distillation of the product in a high vacuum, gave *cyclo*pentane*spiro*-2-ψ-indoxyl as a yellow oil (0·2 g.) (bath-temp. 115—130°/0·5 mm.) which solidified and then formed yellow prisms, m. p. and mixed m. p. 79°, from light petroleum.

(d) *With dilute sulphuric acid.* On being heated on the steam-bath the pale yellow solution of the powdered peroxide (2 g.) in 2N-sulphuric acid (200 ml.) rapidly darkened and deposited a reddish-black resin. One hour later the solution was decanted, filtered, cooled, and extracted with ether. Evaporation of the ethereal extracts left a crystalline product which, after trituration with benzene to remove traces of resin, had m. p. 147—149° after sintering at about 130°. Recrystallisation of this substance (0·34 g.) has not as yet given a compound with a well-defined m. p.; nevertheless, it is distinguished from " 10-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole," m. p. 153°, in being non-basic.

The dark resin obtained in the foregoing experiment was washed and triturated with warm alcohol, which removed tarry impurities and gave a yellow solid from which " 2 : 3-dihydrocarbazole " was isolated by repeated extraction with boiling benzene, followed by concentration of the combined extracts. The compound formed colourless prisms (140 mg.), m. p. 289—292° undepressed on admixture with the authentic compound.

When a solution of the peroxide (1 g.) in 2N-sulphuric acid was kept at room temperature for 24 hours, filtered from the brown amorphous resin, and extracted with ether, a colourless product (250 mg.), m. p. 125° to 140°, was obtained which, on recrystallisation from benzene, formed colourless prisms, m. p. about 148° after sintering at 130°. Detectable amounts of the *cyclo*pentane*spiro*-2-ψ-indoxyl were not present in the reaction product.

(e) *With dilute sulphuric acid containing ferrous sulphate.* The powdered peroxide (1 g.) dissolved rapidly in an agitated solution of ferrous sulphate (1 g.) in 2N-sulphuric acid (50 ml.), and the resulting turbid yellow solution soon became green and deposited a solid. 15 Minutes later this product was isolated and washed with water, and the combined filtrate and washings were extracted with ether. Evaporation of the dried extracts gave *cyclo*pentane*spiro*-2-ψ-indoxyl (160 mg.), m. p. 78—79° after purification from light petroleum.

Action of 2N-*Sulphuric Acid on Compound, m. p.* 153°.—On being kept at room temperature for 1 hour a solution of this compound (0·9 g.) in 2N-sulphuric acid (50 ml.) deposited an amorphous yellow solid (0·52 g.) which was collected and 18 hours later a further quantity (0·3 g.) separated. The acidic filtrate was then extracted with ether but evaporation of the extracts gave only a trace of gummy product.

The first crop of solid was extracted with boiling ether and the filtered extract evaporated leaving a yellow gum which was then extracted with several portions of boiling light petroleum (b. p. 60—80°). On concentration the combined light petroleum extracts gave a yellow powder, melting indistinctly from 120° to 200°, and further concentration of the mother-liquor afforded a second crop of similar appearance which softened at about 80° and melted at about 120°. Spontaneous evaporation of the residual light petroleum liquors left only a trace of a yellow gum. The second crop of yellow reaction product contained similar material, m. p. 120—150°, but the ψ-indoxyl was not isolated in this experiment or when the compound, m. p. 153°, was allowed to react with 2N-sulphuric acid for 15 minutes.

In a third experiment the compound of m. p. 153° (0·5 g.) was heated with 2N-sulphuric acid (25 ml.) on the steam-bath for one hour and the resulting deep-red insoluble resin digested with warm alcohol. The granular product was recrystallised from benzene, forming colourless prisms (80 mg.), m. p. 288—290°, identical with " 2 : 3-dihydrocarbazole." Further extraction of the original aqueous solution gave only a trace of yellow gum.

Action of Hot Alcoholic Acetic Acid on 1 : 2 : 3 : 4-*Tetrahydrocarbazolyl Hydroperoxide and on Compound, m. p.* 153°.—When a solution of the peroxide (1·0 g.) in a mixture of alcohol (25 ml.) and acetic acid (20 ml.) was heated on the steam-bath for 10 minutes a colourless crystalline solid began to separate from the dark red liquid. On isolation and washing with a little alcohol this compound (0·12 g.) had m. p. 293—295°, undepressed on admixture with " 2 : 3-dihydrocarbazole," m. p. 293—295°. Evaporation of the dark filtrate followed by distillation of the residue in a high vacuum gave a yellow oil (0·22 g.), b. p. 160—180°/0·4 mm., which yielded only a small amount of a colourless solid, m. p. 236—238° (decomp.).

When the peroxide was replaced by the compound of m. p. 153° in the foregoing experiment the " dihydrocarbazole " (0·32 g.), m. p. 293—295°, separated and then distillation of the alcohol and acetic acid liquor left a gum from which a trace of the colourless compound, m. p. 236—238°, was obtained. The reaction mixture did not contain detectable amounts of *cyclo*pentane*spiro*-2-ψ-indoxyl.

Catalytic Reduction of 1 : 2 : 3 : 4-*Tetrahydrocarbazolyl Hydroperoxide.*—Reduction of the hydroperoxide (0·95 g.) in methanol (50 ml.) with hydrogen and a palladium charcoal catalyst gave a good yield of 1: 2 : 3 : 4-tetrahydrocarbazole, m. p. and mixed m. p. 117—118°.

A solution of the peroxide (1 g.) in methanol (70 ml.) containing Adams's platinum catalyst (0·1 g.) was agitated with hydrogen for 1¼ hours. On isolation the product slowly solidified and, after being washed with a little ether, was recrystallised from the same solvent, giving the *hydroxyhexahydrocarbazole* in colourless needles, m. p. 104—105°, which in contact with the mother-liquor slowly changed to colourless prisms (0·68 g.), m. p. 110° (Found : C, 76·1; H, 8·3; N, 7·1. $C_{12}H_{15}ON$ requires C, 76·2; H, 7·9; N, 7·4%). Recrystallisation of the prismatic form from ether and seeding with the needle form gave the compound as a mixture of needles and prisms which on being kept changed completely into the prismatic form. This product is slightly soluble in light petroleum, moderately soluble in benzene, and readily soluble in methanol or alcohol. On treatment with dilute hydrochloric acid the compound was dehydrated, giving 1 : 2 : 3 : 4-tetrahydrocarbazole.

Reduction of the compound, m. p. 153°, with Adams's catalyst gave rise to the same hydroxyhexahydrocarbazole, m. p. 109—110°.

Derivatives of cyclo*Pentane*spiro-2-ψ-*indoxyl* (VI).—Specimens of this compound prepared by the methods of Perkin and Plant (*J.*, 1923, **123**, 689) and Plant and Tomlinson (*J.*, 1933, 298) were readily oximated in pyridine, giving the *oxime* which formed pale yellow, rectangular prisms, m. p. 158°, from aqueous methanol (Found : N, 14·1. $C_{12}H_{14}ON_2$ requires N, 13·9%). The *oxime* of the *N*-acetyl derivative of the ψ-indoxyl was prepared by the same method and separated from benzene–light petroleum (b. p. 60—80°) in colourless irregular prisms, m. p. 168° (Found : N, 11·5. $C_{14}H_{16}O_2N_2$ requires N, 11·5%).

Hydrogenation of the ψ-indoxyl (1·22 g.) in methanol (50 ml.) with hydrogen and a platinum catalyst during 9 hours gave rise to a greenish-brown oil which partly crystallised and was repeatedly extracted with boiling light petroleum (b. p. 60—80°) to remove unchanged material. Crystallised from ethyl acetate, the residue (0·72 g.) gave *cyclo*pentane*spiro*-2-(4 : 5 : 6 : 7-tetrahydro-ψ-indoxyl) (XIII) in very pale green rods, m. p. 190° (Found : C, 75·2; H, 8·8. Calc. for $C_{12}H_{17}ON$: C, 75·4; H, 8·9%) (cf. Witkop, *loc. cit.*, who gives m. p. 193°). This compound readily dissolved in dilute mineral acids and behaved with nitrous acid as a secondary amine. It sublimed unchanged at 160—165°/0·03 mm.

In an attempt to crystallise this tetrahydro-derivative from benzene the compound absorbed oxygen giving a *peroxide* which separated in colourless prisms, m. p. 125° (decomp.) (Found : C, 64·7; H, 7·7; N, 6·4. $C_{12}H_{17}O_3N$ requires C, 64·6; H, 7·6; N, 6·3%). This compound, which was much less soluble in benzene than the parent tetrahydro-ψ-indoxyl, readily dissolved in dilute mineral acids, and liberated iodine from acidified aqueous potassium iodide.

1-*Hydroxy*-1 : 2 : 3 : 4-*tetrahydrocarbazole* (XVII).—1-Keto-1 : 2 : 3 : 4-tetrahydrocarbazole (Kent, *J.*, 1935, 976) (1·95 g.) in ether (220 ml.) was gradually added to a solution of lithium aluminium hydride (0·40 g.) in ether (75 ml.). Ten minutes later ice-cold water (20 ml.) was added, followed by 10% sulphuric acid (10 ml.). The resulting crude 1-hydroxy-1 : 2 : 3 : 4-tetrahydrocarbazole (1·64 g.), m. p. 82—100°, isolated with ether and recrystallised from acetone–light petroleum (b. p. 60—80°), formed colourless rectangular tablets, m. p. 115°, identical with a specimen of so-called " 11-hydroxy-2 : 3 : 4 : 11-tetrahydrocarbazole," m. p. 115° (Plant and Tomlinson, *J.*, 1931, 3324) (Found : C, 77·1; H, 6·7; N, 7·55. Calc. for $C_{12}H_{13}ON$: C, 77·0; H, 6·95; N, 7·5%).

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