215. *The Structure of the Nitrenes.*

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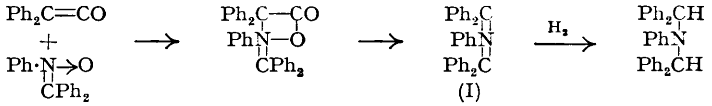
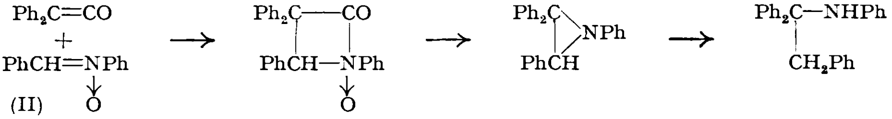
It has been established by degradation and synthesis that nitrenes (Staudinger and Miescher, *Helv. Chim. Acta,* 1919, **2**, 564) should be formulated as *o*-diphenylmethylphenylimino-derivatives. The structure and formation of the precursors of nitrenes, addition products obtained on interaction of *N*-phenylnitrones and diphenylketen, have been discussed.

In studies on the interaction of diphenylketen and various anil *N*-oxides (nitrones), Staudinger and Miescher (*Helv. Chim. Acta,* 1919, **2**, 564) found that *N*-phenylnitrones gave addition compounds which, when heated, decomposed to carbon dioxide and what appeared to be a novel type of product, termed nitrenes. The following course of reaction was proposed :



It was suggested that the nitrene structure (I) accounted for the yellow colour and for the addition of halogens, halogen acids, and hydrogen. In the case of pentaphenylnitrene (I) the dihydro-derivative appeared identical with a product obtained in small yield by heating *N*-diphenylmethylaniline with diphenylmethyl bromide. It did not give a nitroso-derivative.

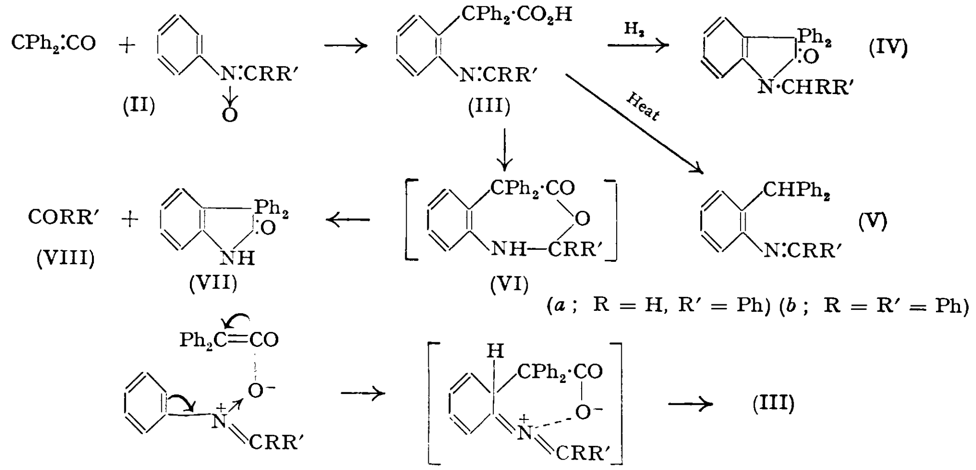
As the quinquecovalent formulation (I) appeared untenable, further investigations were undertaken by Taylor, Owen, and Whittaker (*J.*, 1938, 207), whose evidence led them to an ethyleneimine structure. " Triphenyl-*N*-phenylnitrene," prepared from benzaldoxime *N*-phenyl ether (benzylideneaniline oxide) (II), was obtained colourless. The single product, m. p. 152°, obtained by reduction with aluminium amalgam, gave a nitroso-derivative. The following reactions were suggested :



We have now obtained evidence, from studies on triphenyl-*N*-phenylnitrene and pentaphenylnitrene, which refutes the ethyleneimine formulation. Catalytic hydrogenation of triphenyl-*N*-phenylnitrene gave a single dihydro-compound, m. p. 160—161°; but aluminium amalgam (Taylor, Owen, and Whittaker, *loc. cit.*) gave three products, m. p.s 242°, 160°, and 125°, the principal component being identical with the product of catalytic hydrogenation. Direct comparison showed that these compounds all differed from the two possible reduction products of the ethyleneimine structure, *viz.*, 1-anilino-1 : 2 : 2-triphenylethane (Bergman and Rosenthal, *J. pr. Chem.*, 1933, **135**, 267) and 1-anilino-1 : 1 : 2-triphenylethane prepared by condensation of benzophenone anil with benzylsodium.

It appeared to us that, of the possible modes of reaction of diphenylketen with nitrones, that involving substitution in the *N*-phenyl nucleus was favoured by the observation of the earlier workers that when hydrogen or aliphatic radicals replaced this grouping no nitrene could be obtained. We obtained further support for this view by identifying as 3 : 3-diphenyloxindole the product regularly isolated from the mother-liquors after the interaction of diphenylketen and the *N*-phenylnitrone (Staudinger and Miescher, *loc. cit.*). This compound is also readily obtained, together with benzaldehyde or benzophenone, when the addition products from the *N*-phenyl ethers of benzaldoxime and benzophenone oxime respectively are dissolved in concentrated sulphuric acid or heated in acetic acid or ethanol.

This suggested the possibility of formulating nitrenes as *o*-diphenylmethylphenylimino-derivatives (o-$CHPh_2{\cdot}C_6H_4{\cdot}N{=}$), which was supported by the similarity of the ultra-violet absorption spectrum of pentaphenylnitrene and benzophenone anil and confirmed by synthesis and by acid hydrolysis to *o*-aminophenyldiphenylmethane. The dihydro-derivative of triphenyl-*N*-phenylnitrene was identified as *o*-benzylaminophenyldiphenylmethane, o-$CHPh_2{\cdot}C_6H_4{\cdot}NH{\cdot}CH_2Ph$, by comparison with synthetic material. No nitroso- or acetyl derivative of *o*-diphenylmethylaminophenyldiphenylmethane could be prepared, in agreement with Staudinger and Miescher's observation which led them however to regard this compound as a tertiary amine.



(*a* ; R = H, R′ = Ph) (*b* ; R = R′ = Ph)

The addition products which are precursors of the nitrenes contain one active hydrogen atom and, on hydrogenation, absorb one mol. of hydrogen with loss of an atom of oxygen. The infra-red absorption spectra of these reduction products closely resemble that of 3 : 3-diphenyloxindole : carbonyl absorption at 5·83 μ, typical of carbonyl groups in similar five-membered rings (Witkop and Patrick, *J. Amer. Chem. Soc.*, 1951, **73**, 1289), is present in all of them, but a band at 3·0 μ due to the NH stretching vibration only appears in 3 : 3-diphenyloxindole. Thus the nitrogen atom in the reduction product is tertiary (Randall, Fowler, Fuson, and Dangl, " Infra Red. Determination of Organic Structures," Van Nostrand, New York, 1949). 1-Benzyl-3 : 3-diphenyloxindole, prepared by benzylation of 3 : 3-diphenyloxindole, is identical with the reduction product of the adduct obtained from benzaldoxime *N*-phenyl ether. The evidence favours the formulation of the addition products as derivatives (III) of *o*-aminophenyldiphenylacetic acid. This structure accounts for reduction to a substituted oxindole (IV) (cf. reduction of *o*-nitrophenylacetic acid to oxindole, Bayer, *Ber.*, 1878, **11**, 583), formation of a compound (V) by decarboxylation, and decomposition to 3 : 3-diphenyloxindole (VII). The last reaction is interpreted as proceeding by way of the lactone (VI) which decomposes to (VII) and (VIII). This decomposition would be analogous to, *inter al.*, the hydrolysis of derivatives of benzylideneanthranilic acid (Snyder, Levin, and Wiley, *J. Amer. Chem. Soc.*, 1938, **60**, 2025) and of benzylideneglycine (Bergman, Eusslin, and Zervas, *Ber.*, 1925, **58**, 1034). It is doubtless facilitated by the strong tendency for formation of the oxindole ring. We consider that the similarity of the ultra-violet absorption spectrum to that of the corresponding nitrene and the ease of formation of the water-insoluble monosodium salt favours the formulation of the primary addition product as (III) rather than as (VIII) which could also account for the reaction products obtained. This does not, however, exclude the possibility of an equilibrium mixture containing a proportion of the lactone form, as has been suggested for benzylideneanthranilic acid (Snyder, Levin, and Wiley, *loc. cit.*).

The course of reaction of diphenylketen with an *N*-phenylnitrone is suggested by the structure of the addition product. It appears that the electrophilic character of the nitrogen atom has been transmitted to the *N*-phenyl nucleus, so that the diphenylmethylidene group becomes attached to the *ortho*-position. This is followed by a prototropic change to (III). Although this is in keeping with the known properties of ketens (Staudinger, "Die Ketene," Enke, Stuttgart, 1912) it is an exceptional mode of reaction for nitrones which normally undergo 1 : 3-addition (Smith, *Chem. Reviews*, 1938, **23**, 229).

EXPERIMENTAL

Ultra-violet absorption spectra were obtained with a Beckman D.U. Spectrophotometer. Infra-red absorption spectra were determined with a Baird Associates instrument by Dr. S. M. Nagy, Massachusetts Institute of Technology.

1-*Anilino*-1 : 1 : 2-*triphenylethane*.—This was not obtained on condensation of aniline under forcing conditions with 1 : 1 : 2-triphenylethanol or 1-chloro-1 : 1 : 2-triphenylethane or Clemmensen reduction of α-benzoyldiphenylmethylaniline.

Benzylsodium (Gilman, Pacevitz, and Baine, *J. Amer. Chem. Soc.*, 1940, **62**, 1518) [from sodium (5·75 g.) and chlorobenzene (11·25 g.)] reacted readily with benzophenone anil (13·0 g., 0·05 mol.). The mixture was heated under reflux for 1 hour, treated with ethanol to destroy excess of sodium, and poured into water. The toluene layer was dried and distilled *in vacuo*. The residual *amine* crystallised from ethanol as light brown needles, m. p. 142—143° (7·3 g., 41%) (Found : C, 89·4; H, 6·5; N, 4·0. $C_{26}H_{23}N$ requires C, 89·5; H, 6·6; N, 4·1%).

Attempted Synthesis of Triphenyl-N-*phenylethyleneimine*.—α-Benzoyldiphenylmethylaniline (Cameron, *Trans. R. Soc. Canada*, 1929, 53) (198 mg., 0·54 millimole) in anhydrous ether (25 c.c.) was refluxed with lithium aluminium hydride (268 mg., 7·4 millimole) for 5 hours. The excess of reagent was decomposed with water. 2-*Anilino*-1 : 2 : 2-*triphenylethanol* crystallised from ethanol as prisms (crude yield, 103 mg., 50%), m. p. 176—178° (Found : C, 85·4; H, 6·3; N, 3·8. $C_{26}H_{23}ON$ requires C, 85·5; H, 6·3; N, 3·8%). Attempts to bring about ring closure by heating or by dehydrohalogenation of the chloro-derivative, prepared with thionyl chloride, were not successful.

o-*Benzylideneaminophenyldiphenylmethane* ("*Triphenyl*-N-*phenylnitrene*").—The addition product, o-*benzylideneaminophenyldiphenylacetic acid* (III*a*), prepared from diphenylketen and benzylideneaniline oxide (II*a*) in 44% yield, had m. p. 185—188° (decomp.) (Found : C, 82·5; H, 5·4; N, 3·6. $C_{27}H_{21}O_2N$ requires C, 82·8; H, 5·4; N, 3·6%).

At 215° this rapidly gave carbon dioxide and the *nitrene* (93%). Crystallisation from ethanol and chromatography in benzene–light petroleum (1 : 1) on activated alumina gave needles, m. p. 104—105° [Found : C, 89·9; H, 6·1%; N, 4·1%; *M* (Rast), 355. $C_{26}H_{21}N$ requires C, 90·0; H, 6·1; N, 4·0%; *M*, 347]. Absorption spectrum in EtOH : $\lambda_{\max.}$ 260 (log ε 4·20), and 315 mμ (log ε 3·69).

Hydrolysis. The nitrene (250 mg.) was boiled with 2N-sulphuric acid (5 c.c.) with continuous passage of steam. The distillate yielded benzaldehyde 2 : 4-dinitrophenylhydrazone (97%), m. p. and mixed m. p. 236—238°. The colourless product obtained on neutralisation of the residue in the distillation flask with ammonia was purified by chromatography on activated alumina [50% benzene–light petroleum (b. p. 60—80°); elution, benzene–methanol (9 : 1)] and recrystallisation from ethyl acetate–light petroleum (b. p. 60—80°) needles (Found: C, 88·1; H, 6·5; N, 5·3. Calc. for $C_{19}H_{17}N$: C, 88·0; H, 6·6; N, 5·4%), m. p. and mixed m. p. with authentic *o*-aminophenyldiphenylmethane, 127—128°. It gave an acetyl derivative, m. p. and mixed m. p. 152—155°.

Reduction. (*a*) The nitrene (1·43 g.) was kept with amalgamated aluminium (from 2 g. of aluminium turnings) in moist ether (50 c.c.) at room temperature for 48 hours, then filtered off, and the insoluble material extracted with ether. The pale yellow oil obtained after removal of solvent was chromatographed in benzene on alumina (35 g.). The main product was eluted with benzene and separated by fractional crystallisation into fractions, m. p. 200—210° (289 mg.) and 138—148° (588 mg.). The former on further chromatography and several recrystallisations from ethyl acetate–methanol gave a product, m. p. 242—244°. Insufficient was available to complete the purification.

The low-melting fraction was chromatographed on alumina (Spence Type H; 25 g.). Elution with benzene–light petroleum gave material (268 mg.), fluorescing blue in ultra-violet light, and giving on recrystallisation from ethyl acetate–light petroleum the product (m. p. 160—161°) obtained also on hydrogenation (see below). Benzene containing 1% of ethyl acetate removed non-fluorescent material (221 mg.) which on crystallisation from aqueous alcohol afforded *o*-aminophenyldiphenylmethane, m. p. and mixed m. p. 125—127°.

(*b*) The nitrene (1·985 g.) in ethanol (200 c.c.) was hydrogenated (1·14 mols.) at 1 atm. with Adams's platinum catalyst. The product crystallised from ethanol as prisms, m. p. 160—161° (Found: C, 89·7; H, 6·7; N, 4·3. Calc. for $C_{26}H_{23}N$: C, 89·4; H, 6·6; N, 4·0%).

o-*Benzylaminophenyldiphenylmethane*.—*o*-Aminophenyldiphenylmethane was refluxed for 1 hour with benzyl chloride. The product had m. p. 160—161° alone or mixed with the foregoing reduction product.

Benzylideneaminophenyldiphenylmethane (V*a*).—*o*-Aminophenyldiphenylmethane (Baeyer and Bassett, *Ber.*, 1904, **37**, 3192) (2·54 g.) was heated with benzaldehyde (2·5 g.) on a water-bath for 1 hour. The *product* crystallised from ethanol as needles, m. p. 104—105° alone or mixed with the " nitrene " (Found: C, 90·2; H, 6·4. $C_{26}H_{21}N$ requires C, 89·9; H, 6·1%).

o-*Diphenylmethyleneaminophenyldiphenylmethane* (*Pentaphenylnitrene*) (V*b*).—When the addition product from *N*-diphenylmethylideneaniline oxide and diphenylketen was heated at 215°, the *diphenylmethylene* compound was obtained in 73% yield as yellow needles, m. p. 136—137° (Found: C, 90·9; H, 5·9; N, 3·3. $C_{32}H_{25}N$ requires C, 90·8; H, 5·95; N, 3·3%). Absorption spectrum in ethanol: $\lambda_{max.}$ 250 (log ε 4·13) and 340 mμ (log ε 3·36).

Hydrolysis of this (620 mg.) with N-sulphuric acid during 10 hours gave *o*-aminophenyldiphenylmethane and benzophenone in good yields.

Reduction of the nitrene with aluminium amalgam or hydrogen–platinum as described above gave only o-*diphenylmethylaminophenyldiphenylmethane*, m. p. 158—159·5° [Found: C, 90·7; H, 6·3; N, 3·2%; *M* (Rast), 423. $C_{32}H_{27}N$ requires C, 90·2; H, 6·35; N, 3·3%; *M*, 425].

o-*Benzylideneaminophenyldiphenylacetic Acid*.—When kept, the acid (III*a*) developed a smell of benzaldehyde and gave a compound $C_{20}H_{15}ON$. This reaction occurs more readily in a solvent such as ethanol, acetic acid, or cold, concentrated sulphuric acid.

When the acid (III*a*) (313 mg.) was refluxed for ½ hour with 2 : 4-dinitrophenylhydrazine sulphate in methanol, a precipitate was obtained on cooling. This was separated by recrystallisation from ethanol into benzaldehyde 2 : 4-dinitrophenylhydrazone, m. p. 241°, and a less soluble fraction, 3 : 3-diphenyloxindole, m. p. and mixed m. p. 228° [Found: C, 84·0; H, 5·4; N, 5·0%; *M* (Rast), 288. Calc. for $C_{20}H_{15}ON$: C, 84·0; H, 5·25; N, 4·9%; *M*, 285]; acetyl derivative, m. p. 176—177° (Found: C, 80·6; H, 5·3; N, 4·2. Calc. for $C_{22}H_{17}O_2N$: C, 80·7; H, 5·2; N, 4·3%) (cf. Wegmann and Dahn, *Helv. Chim. Acta*, 1946, **29**, 429).

The acid (III*a*) (136 mg.), suspended in ethyl acetate (50 c.c.), was shaken with hydrogen in presence of Adams's catalyst until dissolved. The residue obtained on distillation of solvent was recrystallised from aqueous methanol and ethyl acetate–light petroleum as plates, m. p. 161—162° (Found: C, 86·7; H, 5·8; N, 3·65. $C_{27}H_{21}ON$ requires C, 86·4; H, 5·6; N, 3·7%). These were identified as 1-*benzyl*-3 : 3-*diphenyloxindole* (IV*a*) by comparison with a sample prepared by heating benzyl chloride (1 c.c.) with 3 : 3-diphenyloxindole (0·70 g.), sodium (204 mg.), and anhydrous benzyl alcohol (25 c.c.). After 4 hours the solvent and excess of reagents were distilled off and the residue treated with water. The product was extracted with chloroform and recrystallised from ethanol as plates (540 mg.), m. p. and mixed m. p. 160—161° (Found: C, 86·4; H, 5·5; N, 3·9%).

o-*Diphenylmethylideneaminophenyldiphenylacetic Acid* (III*b*).—This *acid* was obtained as yellow, crystals, m. p. 170—172° (decomp.) by Staudinger and Miescher's method (*loc. cit.*) (Found: C, 84·3; H, 5·47; N, 2·9; active H, 0·28. $C_{33}H_{25}O_2N$ requires C, 84·8; H, 5·4; N, 3·0; 1 H, 0·22%). Absorption spectrum in EtOH: $\lambda_{max.}$ 250 (log ε 4·38) and 355 mμ (log ε 3·62). The similarity of the absorption spectrum of benzophenone anil, $\lambda_{max.}$ 246 (log ε 4·10) and 335 mμ (log ε 3·36), to that of pentaphenylnitrene (V*b*) is an argument in favour of the presence in this acid of a chromophore containing the $^{-}C{=}N^{-}$ grouping. It is insoluble in water or light petroleum, but somewhat soluble in ethyl acetate, ether, benzene, ethanol, or acetone, and dissolves rapidly in pyridine. It is not soluble in hot aqueous sodium hydroxide or carbonate. When a solution of the acid (268 mg.) in a mixture of N-sodium hydroxide (100 c.c.) and ethanol (100 c.c.) was distilled *in vacuo* at room temperature to remove ethanol a precipitate of *sodium* salt was obtained as a yellow, amorphous powder (279 mg.) (Found: Na, 4·3. $C_{33}H_{24}O_2NNa$ requires Na, 4·8%). Acidification of the aqueous-alcoholic alkaline solution, with cooling, precipitates the original adduct; if the mixture becomes warm, decomposition occurs to 3 : 3-diphenyloxindole.

Decomposition by refluxing with Brady's reagent as described above gave quantitatively 3 : 3-diphenyloxindole and benzophenone 2 : 4-dinitrophenylhydrazone.

Catalytic hydrogenation (uptake, 1·04 mols.) gave 1-*diphenylmethyl*-3 : 3-*diphenyloxindole* as needles, m. p. 219·5—220° (from acetone or ethyl acetate), insoluble in dilute acid or alkali [Found: C, 87·7; H, 5·5; N, 3·0%; *M* (Rast), 411. $C_{33}H_{25}ON$ requires C, 87·8; H, 5·6; N, 3·1%; *M*, 452]. Ultra-violet absorption: $\lambda_{max.}$ 260 mμ (log ε 3·98). The infra-red spectrum is almost identical with that of 1-benzyl-3 : 3-diphenyloxindole.

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