The Chemistry of 1,3,4,7-Tetramethylisoindole and a Route to the Tetrabenzporphyrin System

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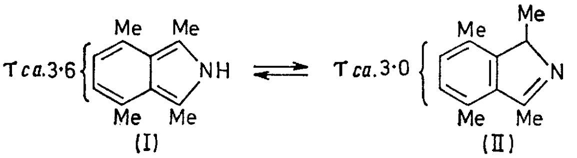
Various reactions of 1,3,4,7-tetramethylisoindole are described. The tautomerism with the corresponding 1*H*-isoindole in various solvents is examined. Autoxidation leads to two compounds which are formulated as 1-hydroxy- and 1-hydroperoxy-1*H*-isoindole derivatives. The addition of dienophiles is complex: maleic anhydride gives the Diels–Alder adduct (IX) which subsequently isomerises (on melting, or in solution) to give (X). Dimethyl acetylenedicarboxylate gives both 1 : 1 and 1 : 2 adducts: structures are proposed for these compounds. When heated with a metal powder or a metal salt 1,3,4,7-tetramethylisoindole gives the metallo-octamethyltetrabenzporphyrins.

RECENTLY, *N*-unsubstituted *C*-alkylisoindoles have become available.[1] This paper reports on aspects of the fundamental chemistry of such systems, with 1,3,4,7-tetramethylisoindole † as the principle example.

Tautomerism.—It has been shown[1] that in chloroform this compound behaves as a tautomeric mixture of the isoindole (I) and 1*H*-isoindole (II) forms, with the latter predominant. The tautomeric ratio has now been determined for the isoindole in a variety of solvents by comparing the areas of the n.m.r. signals at τ *ca.* 3·6 and *ca.* 3·0.‡ Solutions used were moderately concentrated (*ca.* 0·5M) in order to minimise the effects of autoxidation (see later): experiments in which concentrations were varied (0·1—1M in deuteriochloroform) did not reveal a marked dependence of either chemical shift or tautomeric ratio on concentration in the range studied. The results are presented in Table 1: the n.m.r. spectra of solutions in chloroform and in pyridine, which represent the predominance of an individual tautomer (1*H*-isoindole and isoindole, respectively) are shown in Figures 1 and 2.



(I) (II)

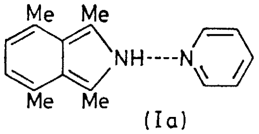
TABLE 1

Tautomeric composition of the 1,3,4,7-tetramethylisoindole–1*H*-isoindole system (I,II) in various solvents (*ca.* 0·5M; 32 ± 1°)

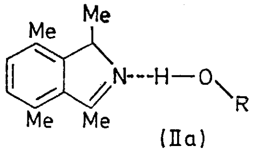
Solvent type	Solvent	Chemical shift (τ) of 5- and 6-protons (I)	(II)	Isoindole (% ± 5)
Nonpolar	CCl_4	3·82	3·10	20
	C_6D_6	3·42	3·16	24
	CS_2	3·86	3·10	28
Polar; hydrogen bonding as proton source	$CDCl_3$	3·66	3·00	10
	MeOH	3·82	2·96	16
	EtOH	3·79	2·95	15
Polar; hydrogen bonding as electron source	Et_2O	3·77	3·04	43
	2,6-Lutidine	3·54	†	60
	Me_2CO	3·76	3·01	72
	C_5D_5N	3·45	3·01	84
	$(CD_3)_2SO$	3·82	2·98	95

† Obscured by solvent.

There appears to be no simple relationship between the observed tautomeric ratios and either the dielectric constants or the dipole moments of the solvents. For the three nonpolar solvents studied the ratio appears to be fairly constant (*ca.* 25% isoindole). For the hydroxylic solvents the proportion of isoindole is lower; this is attributed to the stabilisation of the 1*H*-isoindole by hydrogen bonding (solvent H-donor) as in (IIa). It appears that solvents which can contribute only a lone pair to a hydrogen bond tend to stabilise the other tautomer [see (Ia)]. This interaction is subject to steric effects: thus, although 2,6-lutidine is a stronger base than is pyridine it is less effective in stabilising the isoindole form.



(Ia)



(IIa)

Similar equilibria have been reported for 1-arylisoindoles,[2] but in those compounds the isoindole form was generally observed to predominate (*e.g.* 1-*p*-dimethylaminophenylisoindole: *ca.* 50% isoindole in $CDCl_3$; *ca.* 100% isoindole in pyridine). The importance of the 1*H*-isoindole form in the present example is attributed to two effects: (i) electron-releasing groups [Me in (I) and (II)] are found to favour the 1*H*-isoindole tautomer (*e.g.*[2] for 1*H*-isoindole in $CDCl_3$: 3-phenyl, 9%; 3-*p*-methoxyphenyl, 31%; 3-ethoxy, 100%) and (ii) in the 1*H*-isoindole (II) one of the *peri*-interactions in structure (I) is eliminated.

Autoxidation.—1,3,4,7-Tetramethylisoindole is readily autoxidised, and chemical investigations must normally be conducted in an inert atmosphere. Although the

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† This name will be used for convenience: its use does not imply the absence of the tautomeric form.

‡ Except for the case of 2,6-lutidine as solvent, where the signal at τ *ca.* 3 is obscured. Here the doublet at τ 8·6 (1*H*-isoindole) was compared with the signal at τ 3·54.

[1] C. O. Bender and R. Bonnett, *J. Chem. Soc.* (*C*), 1968, 3036.

[2] D. F. Veber and W. Lwowski, *J. Amer. Chem. Soc.*, 1964, **86**, 4152.

autoxidation products resulting from isoindole–1*H*-isoindole systems have not been identified,* *N*-substituted isoindoles have been studied in this respect. Photo-oxidation of 1,2,3-triphenylisoindole is reported[4] to give the *endo*-peroxide (III), and *N*-butyl-2,3-dihydroisoindol-1-one, *N*-butyl-2,3-dihydro-3-hydroxyisoindol-1-one, and *N*-butylphthalimide result from the autoxidation of *N*-butylisoindole in isopropyl methyl ketone.[5]

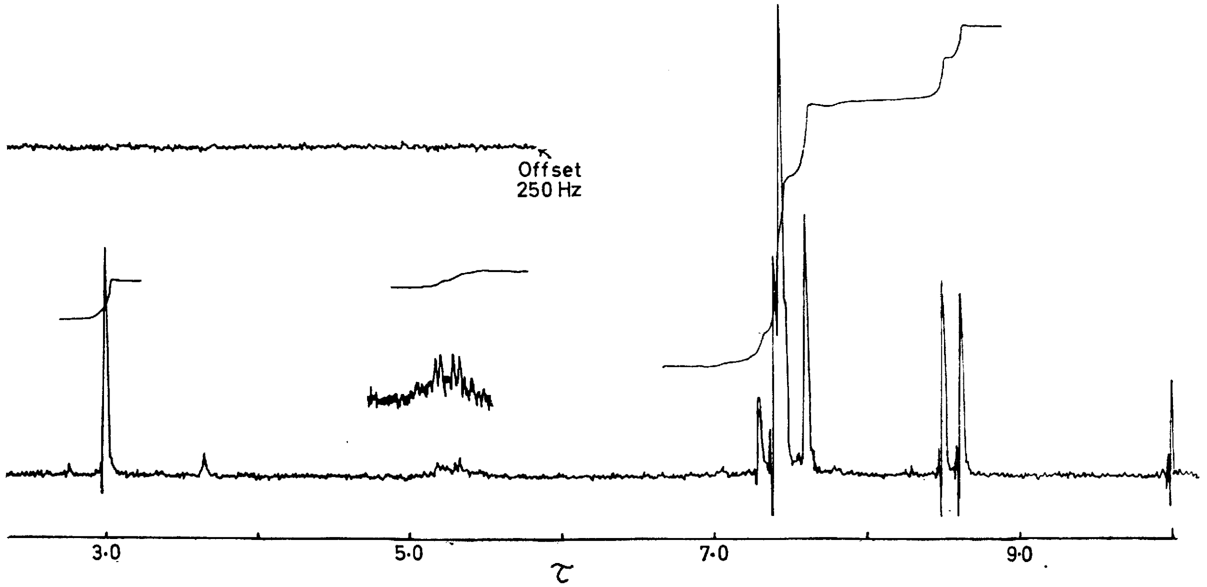

FIGURE 1 N.m.r. spectrum (60 MHz) of 1,3,4,7-tetramethylisoindole in deuteriochloroform, in which solvent the 1*H*-isoindole tautomer predominates. The signal due to the C-1 proton at τ 5·27 appears as a multiplet (probably two sets of quartets, see inset) owing to a small further splitting (*ca.* 2 Hz) arising from MeC:C. Double irradiation at τ 7·46 causes collapse of this signal to the expected quartet

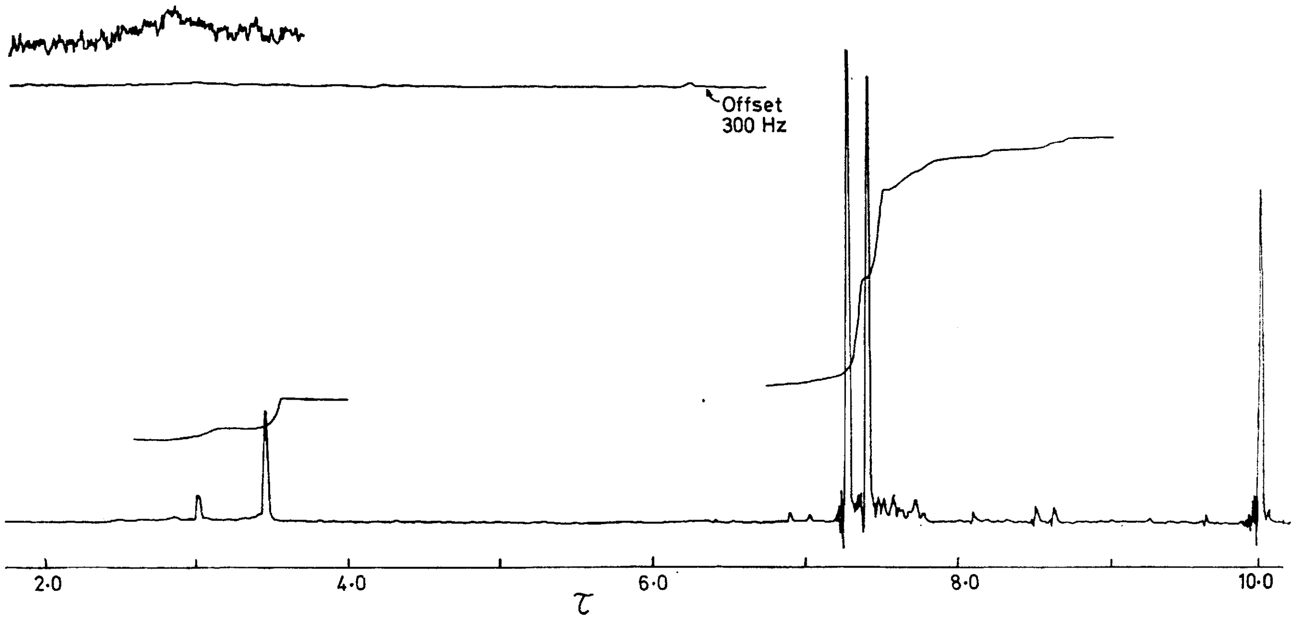

FIGURE 2 N.m.r. spectrum (60 MHz) of 1,3,4,7-tetramethylisoindole in $[^2H_5]$pyridine, in which solvent the isoindole form predominates (see text)

Two compounds have been isolated from the autoxidation of 1,3,4,7-tetramethylisoindole. A hot solution of this compound in light petroleum (b.p. 60—80°) in the presence of air gradually deposited a white granular precipitate. This could be recrystallised from ether, and analysis figures, molecular weight (osmometry), and n.m.r. spectrum were consistent with the structure

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* Emmett and Lwowski[3] report that 1,3-diphenylisoindole reacts with air to give an oxygen-free pale yellow polymer.

[3] J. C. Emmett and W. Lwowski, *Tetrahedron*, 1966, **22**, 1011.

[4] W. Theilacker and W. Schmidt, *Annalen*, 1957, **605**, 43.

[5] J. K. Kochi and E. A. Singleton, *Tetrahedron*, 1968, **24**, 4649.

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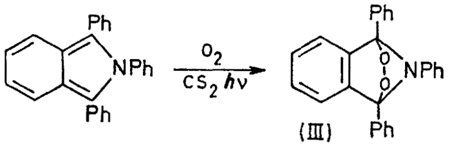
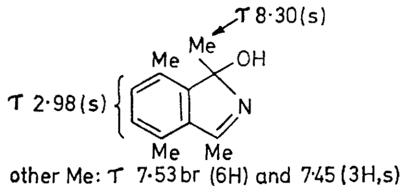
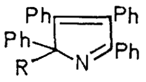
1-hydroxy-1,3,4,7-tetramethyl-1*H*-isoindole (IV). The mass spectrum showed the molecular ion at *m/e* 189 (25%) and losses of water (171; 100%) and methyl (174; 85%) from this; this last fragmentation was confirmed by a metastable peak at 160·1. The i.r. spectrum ($CHCl_3$) revealed signals at 3590 (OH), and 1620 and 1595 (conjugated azomethine) cm.$^{-1}$ [*cf.*[6] (V; R = OH): $\nu_{max.}$ ($CHCl_3$) 3560 and 1630 cm.$^{-1}$]; in the solid a broad band appeared at 3100 cm.$^{-1}$ [*cf.*[7] (V; R = OH): $\nu_{max.}$ (KBr) 3050 cm.$^{-1}$], which was shifted in the deuteriated compound (Et_2O–D_2O) to 2290 cm.$^{-1}$ ($\nu_{OH}/\nu_{OD} = 1{\cdot}35$). The u.v. spectrum closely resembled that of 1-benzyl-1,3,4,7-tetramethyl-1*H*-isoindole.[1] Reduction with zinc and hydrochloric acid gave a mixture of *cis*- and *trans*-1,3,4,7-tetramethylisoindolines.[8]



(III)

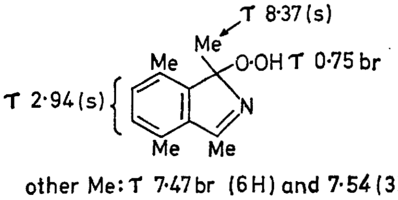


(IV)



(V)

Passage of a vigorous stream of oxygen through a cold solution of the isoindole (I,II) in ether–benzene gave a different autoxidation product. This process was originally thought to be a photo-oxidation,[9] but has subsequently been shown to occur in the dark. The product analysed as a dioxy-derivative, and is formulated as the hydroperoxide (VI) on the basis of the following evidence. The molecular weight (osmometry) and the n.m.r. spectrum [see (VI)] agreed with the structure shown. The spectrum resembles that of the hydroxy-compound (IV): again the 1-methyl group gives a singlet, and again it is deshielded with respect to the corresponding signal (τ 8·56) of 1,3,4,7-tetramethyl-1*H*-isoindole by the oxygen function at the quaternary position [*cf.*[10] $PhCMe_2O{\cdot}OH$: $\tau(CCl_4)$ 8·44 (Me); $PhCHMe_2$: 8·77 (Me)]. The i.r. maxima ($CHCl_3$) observed at 2790 (H-bonded OH) and 1625 (C=N) cm.$^{-1}$ may be compared with those[6] for (V; R = O·OH), 2800 and 1630 cm.$^{-1}$. Again the OH stretching mode was shifted to lower frequency on deuteriation ($\nu_{OH}/\nu_{OD} = 1{\cdot}35$). The u.v. spectrum was consistent with the presence of the 1*H*-isoindole chromophore.[1] As might be expected from the structural assignments the spectroscopic properties of (IV) and (VI) were confusingly alike: however, characteristic bands in the i.r. spectra of the solids were observed [*e.g.* 1240 and 810 cm.$^{-1}$ for (IV); 930 and 830 cm.$^{-1}$ for (VI)] and there were, in addition, several minor but characteristic differences (in intensity and exact wavelength) between bands common to both. The hydroperoxide gave an immediate positive test with hydrochloric acid and starch-iodide paper, which the hydroxy-compound did not; and mild reduction of the former compound with dithionite gave the latter in good yield. The chemistry of the two autoxidation products is being studied further.



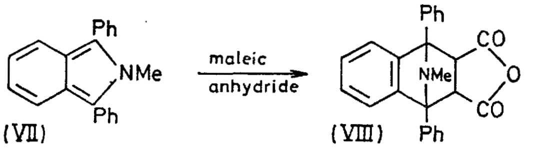
(VI)

The hydroperoxide is considered to arise by a radical-type autoxidation process: the reaction occurs in the dark and evidently involves the ground electronic states of both oxygen and the 1*H*-isoindole. The hydroperoxide is probably an intermediate in the generation of the 1-hydroxy-compound, which is formed when the supply of oxygen is limited. Strong evidence for this view comes from the observation that when the hydroperoxide was refluxed with an excess of the isoindole *under nitrogen* the 1-hydroxy-compound was isolable in 75% yield.

$$(II) + (VI) \xrightarrow[\text{petroleum}]{\Delta,\ N_2} (IV)$$

The reagents were unchanged when submitted individually to the conditions of this reaction.

Diels–Alder Reactions.—Isoindoles react with dienophiles in one of two ways, both of which have analogies in pyrrole chemistry. Diels–Alder addition, uncommon with the pyrroles, is perhaps the more typical reaction here, *e.g.*[3,11] reaction (1), but substitution at α-carbon (common in the pyrrole series) has also been observed *e.g.*[12] reaction (2).



(1)

With 1,3,4,7-tetramethylisoindole and maleic anhydride the particularly interesting situation arises where *both* types of reaction occur: this might not have been recognised but for the relative insolubility of the

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[6] C. Dufraisse, G. Rio, A. Ranjon, and O. Pouchot, *Compt. rend.*, 1965, **261**, 3133.

[7] R. E. Lutz and D. W. Boykin, *J. Org. Chem.*, 1967, **32**, 1179.

[8] C. O. Bender and R. Bonnett, *J. Chem. Soc.* (*C*), 1968, 2186.

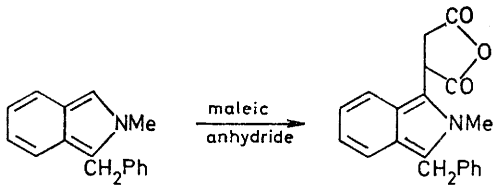
[9] C. O. Bender and R. Bonnett, *Chem. Comm.*, 1966, 198.

[10] G. V. D. Tiers, 'Summary of N.m.r. Values,' Minnesota Mining and Manufacturing Co., St. Paul,

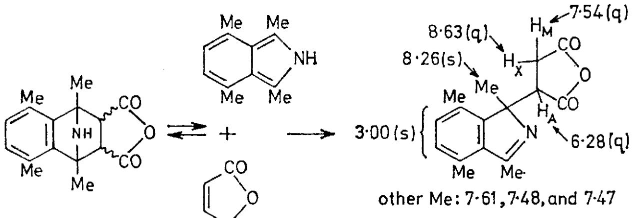
[11] W. Theilacker and W. Schmidt, *Annalen*, 1955, **597**, 95.

[12] G. Wittig and H. Streib, *Annalen*, 1953, **584**, 1.

Diels–Alder adduct (IX). In benzene at room temperature the reactants deposited a colourless crystalline 1 : 1 adduct. The i.r. spectrum of the solid showed maxima at 3290 (NH) and 1860, 1830, and 1770 cm.$^{-1}$ (anhydride C=O), and the u.v. spectrum [again of the solid (KBr)] had a maximum at 270·5 and an inflection at 278 nm., in the region where benzenoid absorption appropriate to structure (IX) would be expected. Solutions of the adduct had markedly different light absorption: in ethanol, maxima were observed initially at 252, 293, 301, and 348 nm. The last band, which suggested that the isoindole chromophore was present,[1] and hence that the addition was readily reversible [as has been observed in certain other examples, *e.g.*[11] (VII) $\rightleftharpoons$ (VIII)], disappeared within a few minutes, leaving a spectrum of the alkyl-1*H*-isoindole type.



(2)



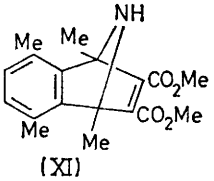
(IX)

(X; τ values indicated)

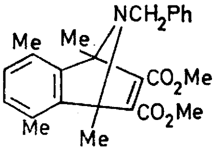
The n.m.r. spectrum taken within five minutes of dissolution (CDCl$_3$) corresponded to a mixture of (IX) (*endo*- and *exo*-isomers,[13] 53%) and (X) (47%). After 2 hr. the spectrum had changed: no signals were now attributable to (IX) and the spectrum corresponded cleanly to structure (X).

When the Diels–Alder adduct (IX) was heated it melted (132°) and then resolidified, remelting at 171—173°. The new compound so formed, which could also be obtained by heating (IX) in benzene–hexane, had properties which agreed with structure (X). Thus it analysed as a 1 : 1 adduct, the i.r. spectrum had no NH band, but possessed maxima at 1855 and 1770 (anhydride C=O), and 1615 and 1580 (C=N and C=C) cm.$^{-1}$, and the u.v. spectrum was of the alkyl-1*H*-isoindole type. In the n.m.r. spectrum [see (X)] the three protons of the anhydride ring give rise to an AMX system with one of the signals (presumably that due to H$_X$, the effect being caused by shielding by the benzene ring) at the high τ value of 8·63 (J_{AX} 4, J_{MX} 18·5, and J_{AM} 9·5 Hz). The nature of the coupling between these protons was confirmed by double irradiation experiments: the sign of the geminal coupling constant (J_{MX}) was opposite to that of the vicinal coupling constants, as expected.

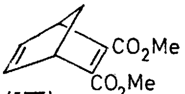
Dimethyl acetylenedicarboxylate gave a Diels–Alder adduct (XI) which was not observed to undergo the retro-reaction in solution. The i.r. and n.m.r. spectra were in accord with this formulation. The electronic spectrum, however, showed unexpected absorption bands [$\lambda_{\text{max.}}$ (EtOH) 241infl. (ϵ 4200) and 300 (2100) nm.], and the analogous adduct (XII) with 2-benzyl-1,3,4,7-tetramethylisoindole showed a similar spectrum, apparently due to orbital overlap between the benzenoid and maleic ester chromophores. The disposition of the relevant π-orbitals rather resembles that in the cyclopentadiene–acetylenedicarboxylic acid adduct (XIII), which has an absorption band[14] at $\lambda_{\text{max.}}$ (EtOH) 247 nm. (ϵ 5150), *i.e.* at much lower energy than expected for the unperturbed maleic acid chromophore [$\lambda_{\text{max.}}$ (EtOH) 210 nm. (ϵ 13,800)].[15]



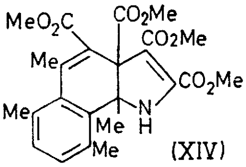
(XI)



(XII)



(XIII)



(XIV)

The 1 : 1 adduct (XI) reacted further with dimethyl acetylenedicarboxylate to give a 1 : 2 adduct, which is formulated as (XIV). The i.r. spectrum showed NH and carbonyl absorptions, and the electronic spectrum was that expected for a *trans*-cinnamic acid chromophore. The n.m.r. spectrum showed signals corresponding to the four methoxy-groups in different environments (all singlets, τ 6·26, 6·28, 6·33, and 6·37), three MeC:C groups (all singlets, τ 7·51, 7·54, and 7·64), one deshielded *Me*C$\leqslant$ group [τ 8·36 (s)] and two aromatic protons [τ 3·03 (s)]. The signal at τ 4·80 br attributed to NH disappeared in the presence of deuterium oxide.

The formation of the 1 : 2 adduct (XIV) finds a close analogy in the reaction of *N*-methylpyrrole with dimethyl acetylenedicarboxylate.[16] In that case the 1 : 1 adduct was not isolated, but the formation of the product (XV) was rationalised in terms of it and a similar addition–rearrangement process, summarised in (XVI), can be visualised in the present example.

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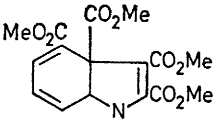
[13] A. mixture of *endo*- and *exo*-isomers has also been reported to be formed on cycloaddition of 2-*p*-tolylisoindole and *N*-phenylmaleimide (R. Kreher and J. Seubert, *Angew. Chem. Internat. Edn.*, 1966, **5**, 967).

[14] E. R. H. Jones, G. H. Mansfield, and M. C. Whiting, *J. Chem. Soc.*, 1956, 4073.

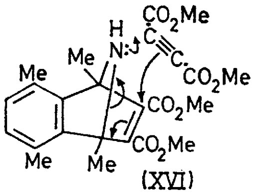
[15] E. A. Braude, *Ann. Reports*, 1945, **42**, 105.

[16] R. M. Acheson and J. M. Vernon, *J. Chem. Soc.*, 1962, 1148.

Octamethyltetrabenzporphyrins.—Early attempts to synthesise tetrabenzporphyrins were based on the self-condensation of units of the isoindole type. At that time (*ca.* 1937) the isoindoles were unknown, but it was found (Linstead and Helberger) that low to moderate yields of the metallotetrabenzporphyrins could be obtained by heating various 2,3-dihydroisoindol-1-one derivatives with metal powders or metal salts.[17]

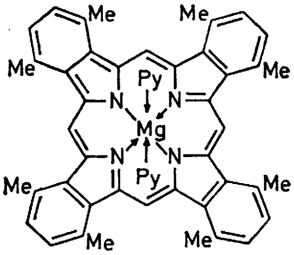


(XV)



(XVI)

When 1,3,4,7-tetramethylisoindole was heated (*ca.* 350°) with magnesium powder (or refluxed in 1,2,4-trichlorobenzene under nitrogen with magnesium acetate) a dark blue-green pigment was formed.[18] After preliminary washing with hexane and benzene the pigment from the sealed tube reaction was extracted with pyridine and was crystallised from pyridine–light petroleum. The same pigment was obtained when the hydroxy-compound (IV) or the hydroperoxy-compound (VI) was employed in place of the isoindole. The pigment showed the gross physical properties typical of the porphyrin system—considerable thermal stability, an intense Soret band, and a brilliant scarlet fluorescence in solution under u.v. irradiation. Analysis indicated an N_6 formula, and agreed with the assigned structure (XVII), the bis-pyridine complex of octamethyltetrabenzporphyrin. Demetallation with trifluoracetic acid gave the free base, octamethyltetrabenzporphyrin. Oxidation of the latter with cerium(IV) sulphate gave a titration value of 15 oxygen atom equivalents:[19] from this oxidation 3,6-dimethylphthalimide, isolated in moderately good yield, was the only observed product.



(XVII)

The most convincing evidence for the tetrabenzporphyrin structure was the electronic spectrum: the spectrum of the metal-free compound had four strong bands, two in the Soret region and two at *ca.* 650 nm. As expected, the metal complex, a more symmetrical chromophore, had a simpler spectrum with strong bands at *ca.* 420 and 650 nm. Besides the main bands several minor peaks and inflections were observed. A comparison with the spectrum[20] of tetrabenzporphyrin itself in 1-chloronaphthalene is given in Table 2. The correspondence between the main absorption bands is good. The spectrum of the octamethyl compound shows a small bathochromic shift with respect to the parent tetrabenzporphyrin which is attributed to the effect[21] of the alkyl groups.

TABLE 2

Spectra of tetrabenzporphyrins in 1-chloronaphthalene
(values in parenthesis refer to inflections)

		Parent compound (ref. 20)			
$\lambda_{max.}$ (nm.)	367	392	421	437	476
$10^{-3}\varepsilon$	23	43	180	235	3·7
$\lambda_{max.}$ (nm.)	493	530	572	609·5	665
$10^{-3}\varepsilon$	3·4	5·1	16	66	50
		Octamethyl derivative			
$\lambda_{max.}$ (nm.)	375	400	428	445	540
$10^{-3}\varepsilon$	14·1	35·2	173·4	236·3	3·4
$\lambda_{max.}$ (nm.)	(574)	582	(602)	(614)	(620)
$10^{-3}\varepsilon$	12·6	14·9	13·4	32·6	52·6
$\lambda_{max.}$ (nm.)	627	674			
$10^{-3}\varepsilon$	83	47·8			

EXPERIMENTAL

Electronic spectra (Unicam SP 800B) were calibrated against a holmium filter. I.r. spectra (Perkin-Elmer 257) were calibrated against polystyrene. Values of λ(nm.) and ν(cm.$^{-1}$) refer to maxima unless otherwise stated: molecular extinctions are given in parentheses. N.m.r. spectra (Varian A60 or Varian HA100) were referred to internal tetramethylsilane. Mass spectra were measured with an MS902 instrument (A.E.I.). All reactions (except autoxidation) with isoindoles were carried out under oxygen-free nitrogen.

1-*Hydroxy*-1,3,4,7-*tetramethyl*-1H-*isoindole* (IV).—1,3,4,7-Tetramethylisoindole (1·89 g.) and light petroleum (b.p. 60—80°; 150 ml.) were refluxed (in air). During 10 min. the solid dissolved, and the colour of the solution changed from yellow to pink. When the stirred mixture was allowed to cool to room temperature during 1 hr. a white precipitate gradually formed, and was filtered off to give 1-*hydroxy*-1,3,4,7-*tetramethyl*-1H-*isoindole* (1·40 g., 68%), m.p. 163—165° (decomp.). Recrystallisation from ether raised the m.p. to 169—171° (decomp.); m.p. *in vacuo* 170—172° (decomp.) [Found: C, 76·0; H, 7·8; N, 7·4%; M^+, 189·1149; *M*(osmometry), 207. $C_{12}H_{15}NO$ requires C, 76·15; H, 8·0; N, 7·4%; *M*, 189·1154], ν($CHCl_3$) 3590, 3150, 2870, 1620, and 1595, ν(Nujol) 3100, 1620, 1595, 1285, 1260, 1240, 1200, 1160, 1120, and 810, λ(EtOH) 256 (4780), 294·5 (1860), and 305 (1360). The compound (10 mg.) was shaken with ether (20 ml.) and deuterium oxide (1 ml.) for 2 hr. and the dried solution was concentrated; the product had ν($CHCl_3$) 2650 and 2330, ν(Nujol) 2290.

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[17] For review see T. S. Stevens, *Ann. Reports*, 1940, **37**, 312.

[18] Preliminary communication, C. O. Bender, R. Bonnett, and R. G. Smith, *Chem. Comm.*, 1969, 345.

[19] The theoretical value is 17, but experimental values lower than this have been encountered by others (R. P. Linstead and F. T. Weiss, *J. Chem. Soc.*, 1950, 2981).

[20] M. Whalley, unpublished observations. We thank Professor J. A. Elvidge for bringing these results to our attention.

[21] *Cf.* A. Stern and H. Wenderlein, *Z. phys. Chem.* (*Leipzig*), 1936, *A*, **175**, 405.

Reduction of the 1-hydroxy-1*H*-isoindole with zinc dust and 6N-hydrochloric acid (reflux; 4·5 hr.), followed by decomposition of the zinc complex with aqueous sodium hydroxide, extraction with ether, drying ($MgSO_4$), and distillation, gave a colourless solid (50%) with an i.r. spectrum similar to that of *trans*-1,3,4,7-tetramethylisoindoline. The n.m.r. spectrum ($CF_3{\cdot}CO_2H$) indicated that the product was a mixture of *cis*- (20%) and *trans*- (80%) isomers. Crystallisation from hexane gave a product identical [i.r. spectrum, mixed m.p. 70—71° (lit.,[8] 72—73°)] with the *trans*-isoindoline.

1-*Hydroperoxy*-1,3,4,7-*tetramethyl*-1H-*isoindole* (VI).—Oxygen was bubbled through a solution of 1,3,4,7-tetramethylisoindole (157 mg.) in benzene (40 ml.) and ether (40 ml.) for 6 hr. Concentration of the solution and crystallisation from benzene–hexane gave 1-*hydroperoxy*-1,3,4,7-*tetramethyl*-1H-*isoindole* (86 mg., 46%), m.p. *in vacuo* 146—147° (decomp.), mixed m.p. *in vacuo* with the 1-hydroxy-compound, 134—144° (decomp.), mixed m.p. *in vacuo* with parent base, 103—104° [Found: C, 70·45; H, 7·4; N, 7·1%; *M*(osmometry), 248. $C_{12}H_{15}NO_2$ requires C, 70·2; H, 7·35; N, 6·8%; *M*, 205) ν($CHCl_3$) 3050infl, 2790, 1625, and 1595, ν(Nujol) 3060, 2780, 1625, 1595, 1285, 1270, 1210, 1175, 1160, 1115, 1095, 930, and 830; after deuteriation (C_6H_6–D_2O), ν(Nujol) 2250 and 2100, λ(EtOH) 257 (4920), 296 (2090), and 306 (1630).

Reactions of 1-*Hydroperoxy*-1,3,4,7-*tetramethyl*-1H-*isoindole*.—(*a*) Reduction (zinc dust; 6N-hydrochloric acid; reflux 4 hr.) gave 1,3,4,7-tetramethylisoindoline (38%; *cis–trans ca.* 1 : 2). Recrystallisation (ethanol) of the phenylsulphonamido-derivative gave *trans*-1,3,4,7-tetramethyl-2-phenylsulphonylisoindoline, mixed m.p. 136—138° (lit.,[22] 139°).

(*b*) The hydroperoxide (0·050 g.) in chloroform (10 ml.) was stirred with alkaline sodium dithionite solution (0·50 g. in 5 ml. N-sodium hydroxide) for 1 hr. at room temperature. The layers were separated and the aqueous one was re-extracted with chloroform (10 ml.). The combined organic extract was washed, dried ($MgSO_4$), and concentrated to give a pink solid (46 mg.), m.p. 168—170°, which had an i.r. spectrum identical to that of the hydroxy-compound. Recrystallisation from ether afforded a white solid (55%), m.p. *in vacuo* 173—174° (decomp.).

(*c*) Oxidation (aq. $KMnO_4$–K_2CO_3) and extraction at pH 1 by the method already described,[22] followed by methylation (CH_2N_2) gave tetramethylbenzene-1,2,3,4-tetracarboxylate (30%), mixed m.p. 128—130° (lit.,[22] 129—131°).

(*d*) The hydroperoxide (0·050 g., 0·24 mmole) and the parent isoindole (0·10 g., 0·58 mmole) were refluxed in light petroleum (b.p. 60—80°; 10 ml.), for 30 min. The cold mixture was filtered to give a pale pink solid (0·068 g., 74%), m.p. *in vacuo* 172—174° (decomp.), the i.r. spectrum of which was identical with that of an authentic sample of 1-hydroxy-1,3,4,7-tetramethyl-1*H*-isoindole.

Diels–Alder Adduct (IX) *from* 1,3,4,7-*Tetramethylisoindole and Maleic Anhydride*.—A solution of 1,3,4,7-tetramethylisoindole (0·56 g.) and maleic anhydride (0·34 g.) in benzene (20 ml.) was swirled under nitrogen for 5 min. During this time a white solid crystallised out, and was removed and washed with benzene to give the *adduct* (IX) (0·20 g., 23%), m.p. 132°, solidifying and remelting at 171—173° (decomp.) (Found: C, 70·8; H, 6·4; N, 5·3. $C_{16}H_{17}NO_3$ requires C, 70·85; H, 6·3; N, 5·15%), ν(Nujol) 3290, 1860, 1770, 1240, 1090, 1070, and 930, λ(KBr) 270·5 and 278infl., λ(EtOH): time dependent, finally (20 min.) 252 (6450), 292 (1800), and 301 (1575). τ($CDCl_3$) (*a*) within 5 min. (i) signals due to (IX) (53%): 3·21 (s, ArH), 6·46 (s, NH), 7·08 (s, bridgehead H), 7·64 and 7·68 (each s, *exo*- and *endo*-ArMe), and 7·98 and 8·06 (each s, *exo*- and *endo*-*Me*C$\leqslant$); (ii) signals due to (X) (47%): 2·98, 7·44, 7·47, 7·61, and 8·26; (*b*) after 2 hr. (i) no signals due to (IX); (ii) signals due to (X): see structure (X) in Discussion.

(1,3,4,7-*Tetramethyl*-1H-*isoindol*-1-*yl*)*succinic Anhydride* (X).—(*a*) An attempt to recrystallise the Diels–Alder adduct (IX) from benzene–hexane gave two crystalline compounds, which were separated by hand-picking. One was identical with the starting material (i.r.); the other was a new 1 : 1 adduct, (1,3,4,7-*tetramethyl*-1H-*isoindol*-1-*yl*)*succinic anhydride*, m.p. 174—176° (Found: C, 70·7; H, 6·45; N, 5·3%), ν(Nujol) 1855, 1770, 1615, and 1580, λ(EtOH) 252 (6740), 292 (1725), and 301 (1565).

(*b*) The Diels–Alder adduct (IX) was heated at 136° for 2 min. The crude material, m.p. 167—170° (decomp.), was crystallised from acetone to give the isomer (X), m.p. and mixed m.p. 177—179°. The n.m.r. spectrum ($CDCl_3$) was identical with that recorded in the previous section under (*b*) (ii).

The Diels–Alder Adduct (XI) *of* 1,3,4,7-*Tetramethylisoindole and Dimethyl Acetylenedicarboxylate*.—Dimethyl acetylenedicarboxylate (0·456 g., 0·0032 mole) in dimethyl sulphoxide (10 ml.) was added during 30 min. to a stirred solution of 1,3,4,7-tetramethylisoindole (0·539 g., 0·0031 mole) in dimethyl sulphoxide (20 ml.) at room temperature under nitrogen. After a further 1 hr. the mixture was poured into water (350 ml.), the suspension was extracted with ether (4 × 30 ml.), and the extract was washed with water (2 × 20 ml.), dried ($MgSO_4$), and concentrated. The residue gave the Diels–Alder *adduct* (XI) as colourless crystals (0·577 g., 59%), m.p. 137—139° (from hexane) (Found: C, 68·6; H, 6·8; N, 4·4. $C_{18}H_{21}NO_4$ requires C, 68·55; H, 6·7; N, 4·45%), ν(Nujol) 3260, 1725, 1705, and 1630, λ(EtOH) 241infl. (4200) and 300 (2100), τ($CDCl_3$) 3·37 (s, ArH) 6·28 (s, OMe), 7·16br (NH, exchangeable) 7·73 (s, ArMe), and 8·04 (s, *Me*C$\leqslant$).

The Diels-Alder Adduct (XII) *of* 2-*Benzyl*-1,3,4,7-*tetramethylisoindole and Dimethyl Acetylenedicarboxylate*.—2-Benzyl-1,3,4,7-tetramethylisoindole (0·212 g.), dimethyl acetylenedicarboxylate (0·180 g.), and hexane (10 ml.) were stirred for 20 hr. under nitrogen. The solvent was removed and the residue gave the *adduct* (XII) as colourless crystals (0·195 g., 60%), m.p. 110—112° (from ethanol–water) (Found: C, 74·4; H, 6·8; N, 3·5. $C_{25}H_{27}NO_4$ requires C, 74·05; H, 6·7; N, 3·45%), ν(Nujol) 1725, 1710, 1640, 1600, and 1495, λ(EtOH) 239infl. (6300) and 302 (1900), τ($CDCl_3$) 2·5—2·9 (m, Ph), 3·34 (s, remaining ArH), 6·28 (s, OMe), 6·48 (s, PhC*H*$_2$), 7·66 (s, ArMe), and 8·24 (s, MeC$\leqslant$).

Tetramethyl 3a,9b-*Dihydro*-5,6,9,9b-*tetramethylbenz*[g]*indole*-2,3,3a,4-*tetracarboxylate* (XIV).—(*a*) 1,3,4,7-Tetramethylisoindole (0·79 g.) was added in portions to dimethyl acetylenedicarboxylate (1·07 g.). An exothermic reaction occurred. Benzene (5 ml.) was added. After 20 min. the precipitated solid was removed and washed with ether (10 ml.) to give the 1 : 2 *adduct* (XIV) (0·68 g., 32%), m.p. 170—177° (m.p. 180—182° from benzene–ether).

(*b*) The Diels–Alder adduct (XI) (95 mg., 0·0003 mole)

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[22] R. Bonnett and J. D. White, *J. Chem. Soc.*, 1963, 1648.

was refluxed with dimethyl acetylenedicarboxylate (61 mg., 0·0004 mole) in benzene (15 ml.) for 8 hr. The solution was concentrated and treated with hexane to give white crystals (56 mg., 41%), m.p. 170—173° (m.p. 180—182° from hexane). Samples prepared by routes (*a*) and (*b*) were identical (i.r. and mixed m.p.) (Found: C, 62·95; H, 6·1; N, 3·3. $C_{22}H_{27}NO_8$ requires C, 63·0; H, 5·95; N, 3·05%), ν(Nujol) 3300, 1730, 1710, and 1665, λ(EtOH) 217 (17,900) and 283·5 (16,000), τ($CDCl_3$) 3·03 (s, ArH), 4·80b, (NH, exchangeable), 6·26, 6·28, 6·33, and 6·37 (all s, OMe) 7·51, 7·54, and 7·64 (all s, MeC:C), and 8·36 (s, *Me*C<).

Dipyridinemagnesium Octamethyltetrabenzporphyrin (XVII).—A mixture of 1,3,4,7-tetramethylisoindole (1·32 g.) and magnesium powder (2·48 g.) in a sealed tube was heated at 400° for 3 hr. The mixture was extracted (Soxhlet) with light petroleum (b.p. 60—80°) (3 hr.), benzene (4 hr.), and then pyridine (7 hr.). The deep green pyridine solution was filtered hot, and the filtrate was diluted with light petroleum (b.p. 60—80°). Dark blue crystals (1·27 g., 81%) of *dipyridinemagnesium octamethyltetrabenzporphyrin*, m.p. >360°, formed gradually. The material was homogeneous on t.l.c. [on alumina; irrigated with 10% pyridine in light petroleum (b.p. 60—80°)] (Found: C, 80·85; H, 6·05; Mg, 3·2; N, 10·9. $C_{54}H_{46}MgN_6$ requires C, 80·75; H, 5·75; Mg, 3·05; N, 10·45%), ν(CsBr) 1605, 1590, 1580, 1535, 1490, 1470, 1445, 1320, 1230, 1190, 1050, 1040, 1020, 910, 820, and 800, λ(pyridine; major bands only) 422 (61,400), 449 (628,000), 595 (16,900), and 642 (127,000).

Oxidation of Dipyridinemagnesium Octamethyltetrabenzporphyrin.—Dipyridinemagnesium octamethyltetrabenzporphyrin (61 mg.) was added to cerium(IV) sulphate solution (0·1N; 100 ml.) and warmed at 88° for 35 min. after which time the green colour of the tetrabenzporphyrin was no longer visible. Excess of aqueous iron(II) sulphate was added to the cool solution, which was then continuously extracted with ether (12 hr.). The ether was removed and water was added, whereupon a solid formed. This gave 3,6-dimethylphthalimide (36 mg., 67%), m.p. 230—232° (from ethanol), identical with an authentic sample prepared by treating 3,6-dimethylphthalic anhydride with aqueous ammonia (50°; 2 days) and then heating the product. The 3,6-*dimethylphthalimide* thus obtained was purified by preparative t.l.c. (silica irrigated with 3% acetone in chloroform) to give colourless needles, m.p. 231—232° (from ethanol) (Found: C, 68·6; H, 5·1; N, 7·95. $C_{10}H_9NO_2$ requires C, 68·55; H, 5·2; N, 8·0%), ν(Nujol) 3250, 1760, and 1700, τ($CDCl_3$) 2·66 (s, ArH) and 7·36 (s, ArMe).

Octamethyltetrabenzporphyrin.— Dipyridinemagnesium octamethyltetrabenzporphyrin (0·30 g.) was stirred in trifluoroacetic acid (20 ml.) at room temperature for 1·5 hr. The mixture was filtered through a sintered pad into water (100 ml.) whereupon a green precipitate formed. This was filtered off and washed with water and with pyridine to give *octamethyltetrabenzporphyrin* (0·22 g., 94%), m.p. >360° (Found: C, 84·65; H, 6·3; N, 8·8. $C_{44}H_{38}N_4$ requires C, 84·85; H, 6·15; N, 9·0%), λ(CF_3·CO_2H with excess of pyridine) 394 (51,600), 422 (211,000), 440 (271,000), 576 (17,200), 610infl. (41,000), 618infl. (60,000), 624 (81,700), and 671 (49,500), λ(CF_3·CO_2H) 414 (73,600), 438 (312,000), 532 (4000), 628 (11,600), and 690 (95,500).

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