159. *The Proton Magnetic Resonance Spectra of Porphyrins. Part III.*[1] meso-*Substituted Porphyrins.*

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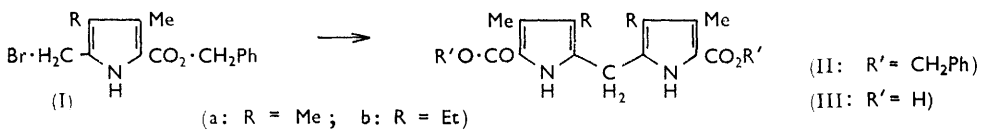
Proton magnetic resonance spectra of the dications of some simple *meso*-methylporphins, γ-phylloporphyrin XV, phylloerythrin, and *meso*-tetraphenylporphin have been measured in trifluoroacetic acid. Comparison of these spectra with those of the corresponding *meso*-unsubstituted porphyrins shows that introduction of a methyl group at a *meso*-position shifts the resonances of protons in nearby β-substituents to higher field and of N–H protons to lower field. These effects are explained in terms of reduction in the ring current and, in some instances, of non-planarity of the aromatic system.

Proton magnetic resonance spectra of dications of porphyrins dissolved in trifluoroacetic acid were described in Part I,[2] and were interpreted in terms of additive effects of β-substituents on the chemical shifts of the *meso* and N–H protons. In Part II [1] the observed chemical shifts were accounted for by a semi-classical calculation of ring currents. This paper is concerned with the influences exerted by some *meso*-substituents on the chemical shifts of all the other protons. The new results cannot be accommodated in a simple additive hypothesis, but they can be explained qualitatively, and for the present tentatively, on the basis of two effects: (1) a general decrease in ring current caused by a *meso*-substituent, and (2) a local effect due to distortion of the macrocycle by repulsions between the *meso*-substituent and neighbouring β-substituents.

Most of the porphyrins examined were prepared by published methods, but the *meso*-monomethyl and -dimethyl derivatives of octamethylporphin and ætioporphyrin were new compounds, synthesised from symmetrical dipyrrolylmethanes (III). The latter were prepared by hydrogenolysis of the corresponding benzyl esters (II) which could be obtained by the action of boiling ethanol on the bromomethylpyrroles (I). When an



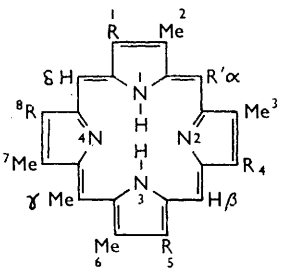
acetic acid solution of the diacid (IIIa) and acetyl chloride was heated and then aerated, a mixture of porphyrins was formed in low yield. They were isolated from the crude product (obtained on basification of the reaction mixture) by Soxhlet extraction of methenes

[1] Part II, Abraham, *Mol. Phys.*, 1961, **4**, 145.
[2] Abraham, Jackson, and Kenner, *J.*, 1961, 3468.

and other soluble by-products with methanol. The residual, extremely insoluble mixture of octamethylporphin and its *meso*-mono- and -di-methyl derivatives was separated and purified by extraction into *o*-dichlorobenzene followed by countercurrent distribution between the *o*-dichlorobenzene and sulphuric acid.

The action of acetyl chloride in acetic acid on the dipyrrolylmethane diacid (IIIb) likewise gave a mixture of porphyrins, and these were separated from the crude reaction product in the same way. The final purification was effected by countercurrent distribution between benzene and 10% sulphuric acid which yielded three fractions. The first band contained ætioporphyrin, the second the *meso*-monomethyl-, and the last the *meso*-dimethyl-ætioporphyrin. They were readily distinguished from each other by their colours, particularly in acidic solution in which they appeared red, violet, and blue, respectively.

Originally it had been supposed that the action of acetyl chloride on the dipyrrolylmethanes (III) would yield exclusively the symmetrical *meso*-dimethylporphyrins (IV). Mixtures of porphyrins were actually formed in both cases, and the additional porphyrins must have arisen by fission of the dipyrrolylmethanes and recombination of the individual pyrrole units with formaldehyde (or its equivalent) formed from the methane bridges. Reactions of this type have recently been reported by Mauzerall; [3] an earlier example is the reaction of acetic acid alone on the dipyrrolylmethane (IIIa) to give octamethylporphin



(IV: R' = Me)
(V : R' = H)

(a : R = Me;
b : R = Et)

and 2-acetyl-3,4,5-trimethylpyrrole.[4] (This pyrrole was not isolated in our experiments with acetyl chloride–acetic acid mixtures.) In view of these unexpected complexities, it is not possible to infer the precise structure of the ætioporphyrin derivatives, although the *meso*-dimethyl-compound is in fact the obvious product with the orientation (IVb).[5] Although previous work had shown that isomeric ætioporphyrins could not be separated by countercurrent distribution, the *meso*-monomethylætioporphyrin was separated into two components by 600 transfers between benzene and 9% sulphuric acid (Fig. 1), confirming that fission of the dipyrrolylmethanes and rearrangement of the pyrrole rings had occurred. The proton magnetic resonance spectra of the two *meso*-monomethyl compounds were identical, as expected from our earlier investigation of β-alkylporphyrins.[2] Consequently this structural problem, interesting though it is in its own right, is irrelevant to this particular study; only one entry is made in Table 1, and the orientation is arbitrarily assigned as shown in (Vb). The proton magnetic resonance spectrum of the *meso*-dimethylætioporphyrin confirms the symmetrical disposition (αγ rather than αβ) of the *meso*-substituents, and this is also true of the *meso*-dimethyloctamethylporphin (IVa). There can be no ambiguity about the structure (Va) of *meso*-monomethyloctamethylporphin.

[3] Mauzerall, *J. Amer. Chem. Soc.*, 1960, **82**, 2601.
[4] Fischer, Halbig, and Walach, *Annalen*, 1927, **452**, 276.
[5] Structures (IV) and (V) and the nomenclature in the Tables and text are arranged with a *meso*-methyl-group in the γ-position in order to facilitate comparison with degradation products of chlorophyll. On the other hand, if this *meso*-dimethylætioporphyrin was to be related to ætioporphyrin II with the more usual numbering, it would be regarded as the βδ-derivative of 2,3,6,7-tetraethyl-1,4,5,8-tetramethylporphin instead of the αγ-derivative of 1,4,5,8-tetraethyl-2,3,6,7-tetramethylporphin.

Assignments of peaks in the spectra to different types of substituent follow almost entirely from the classification in Part I.[2] The chief fresh structural feature is the *meso*-methyl group which has a signal at 5·1—5·3 τ, about 1 p.p.m. below that of a β-methyl group. This difference is expected because the *meso*-substituent is closer to the ring current, and it corresponds to the difference between *meso*- and β-protons.[1,2] In broad

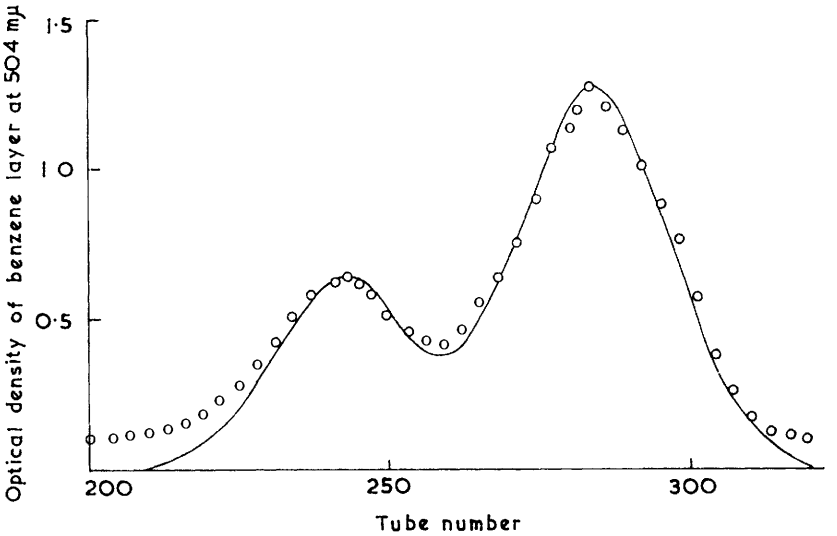


FIG. 1. Countercurrent distribution curve for *meso*-monomethylætioporphyrins B_1, and B_2, between benzene and 9% (w/v) sulphuric acid.

outline, the data in Table 1 resemble those reported in Part I, but the effects of *meso*-substituents differ very significantly from those of β-substituents. Thus, substitution of methyl groups at all eight β-positions shifts the N–H peaks in porphin by +0·42 p.p.m. and the *meso*-proton peaks by +0·24 p.p.m.; in contrast, substitution of methyl groups at all four *meso*-positions in porphin shifts the N–H peaks by −1·42 p.p.m. and the β-proton peaks by +0·36 p.p.m. The effects of the *meso*-methyl groups are qualitatively different from, as well as greater than, those of the β-substituents. The usual explanations of the effects of substituents on chemical shifts, such as those given in Part I,[2] cannot account for the data, because inductive, hyperconjugative, and dipolar effects, for example, would cause a shift of the N–H resonance, like that of the β-protons, to high field. We conclude that *meso*-methyl groups decrease the ring current. A 10% decrease would shift the N–H protons by −1·1 p.p.m. (downfield) and the β-protons by +0·38 p.p.m. (upfield). In view of the assumptions made in this calculation (*e.g.*, that the current decreases uniformly over the ring) and that the methyl groups will presumably also affect the ring by the mechanisms invoked [2] to account for the results of β-substitution, the agreement with observation is good. The causes of decrease in ring current cannot be completely defined theoretically at present, but the existence of such a decrease is supported by parallel observations of Pople, Schneider, and Bernstein [6] in the benzene series. They found that the signals of protons both directly attached to the ring and in methyl substituents are moved to high field by increasing methyl substitution. The shift of the ring protons could be accounted for *qualitatively* by increasing electron density in the ring, but this would not explain the effect on methyl protons. On the other hand, a decrease in

[6] Pople, Schneider, and Bernstein, " High-resolution Nuclear Magnetic Resonance," McGraw-Hill, New York, 1959, p. 263.

ring current provides a reasonable explanation for the direction of these shifts and their size. The resonance of the methyl groups in 1,3,5-trimethylbenzene is 0·15 p.p.m. upfield of that in toluene, which has a shift of 1·46 p.p.m. from ring current,[7] and hence a 10% decrease in ring current would be concordant. It is only by chance that this decrease is identical with that postulated for *meso*-tetramethylporphin, but it does appear that the effect could be general.

TABLE 1.

Chemical shifts in proton magnetic resonance spectra of *meso*-substituted porphyrins.

Solutions in trifluoroacetic acid or deuterotrifluoroacetic acid.

		meso-Substituents		β-Substituents			
Compound	N–H	H	Me	H	Me	Et	Others
Porphin	14·40	−1·22		0·08			
Octamethylporphin	14·82	−0·98			6·23		
meso-Tetramethylporphin	13·01		5·27	0·45			
αγ-*meso*-Dimethyloctamethylporphin	13·66	−0·39	5·34		6·61		
αγ-*meso*-Dimethylætioporphyrin	13·46	−0·38	5·34		6·57	6·07 8·46	
γ-*meso*-Monomethyloctamethylporphin	13·57 (3,4)	−0·62 (βδ)	5·17		6·52 (5,6,7,8)		
	14·33 (1,2)	−0·48 (α)			6·38 (1,2,3,4)		
γ-*meso*-Monomethylætioporphyrin	13·47 (3,4)	−0·63 (βδ)	5·15		6·50 (5,8)	5·95 8·35 (6,7)	
	14·19 (1,2)	−0·49 (α)			6·34 (1,4)	5·83 8·20 (2,3)	
γ-Phylloporphyrin XV	13·54 (3)	−0·77 (βδ)	5·14	0·58	6·40 (8)	5·80 8·21	CH_2–CH_2–CO_2H 5·48 6·94
	13·80 (4)	−0·65 (α)			6·31 (1,3,5)		
	14·25 (2)						
	14·35 (1)						
γ-Phylloporphyrin XV methyl ester	13·63 (3)	−0·80 (βδ)	5·14	0·54	6·39 (8)	5·78 8·20	CH_2–CH_2–CO_2Me 5·50 6·88 6·29
	13·75 (4)	−0·68 (α)			6·29 (1,3,5)		
	14·31 (1,2)						
Phylloerythrin methyl ester	12·67 (β)	−1·02 (βδ)			5·99 (5)	~5·7	CH_2–CH_2–CO_2Me ~5·55 6·62 6·26
	13·48	−0·81 (α)			6·20 6·25	8·13 8·20	$-CH_2\cdot CO-$ 3·57
Pyrroætioporphyrin VII †	14·57 *	−1·05 *		0·35	6·09 (6)	5·65 8·13	
	14·72 *				6·17		
	14·82 *				(1,4,7)		
Deuteroætioporphyrin IX ‡	14·64 * (1,2)	−1·09 (αβ)		0·33	6·12 (1,3)	5·67 8·15	
	14·79 * (3,4)	−1·02 (γδ)			6·19 (5,8)		
meso-Tetraphenylporphin	12·07			1·15			*ortho*-H 1·41 *meta*- and *para*-H 1·92

* Broad and poorly resolved. † 2,3,8-Triethyl-1,4,6,7-tetramethylporphin. ‡ 6,7-Diethyl-1,3,5,8-tetramethylporphin.

A question, which arises from acceptance of the hypothesis that *meso*-substitution decreases ring current, is why β-substitution should not act similarly. The difference is that the current can flow past the nitrogen atom and the β-carbon atoms in parallel, and

[7] Johnson and Bovey, *J. Chem. Phys.*, 1958, **29**, 1012.

therefore β-substitution alters the distribution between these parallel paths while a *meso*-substituent controls the whole flow. An alternative way of formulating this idea is in terms of a network comprising the macrocycle and four five-membered rings; β-substituents directly affect the currents in the small rings and the effect on the macrocycle is of the second order.

The spectra of *meso*-dimethyloctamethylporphin (IVa) and the correspondin gætioporphyrin (IVb) are quite similar to that of *meso*-tetramethylporphin. They show, in addition, the effects of *meso*-methylation on chemical shifts of *meso*-protons and β-alkyl groups (see Table 2). The peaks are moved upfield like those of β-protons, and a 12%

TABLE 2.

The effects of *meso*-methyl-substitution on proton shifts.

	Proton shifts compared with the corresponding *meso*-unsubstituted porphyrins			
Compound	N–H	*meso*-H	β-Me	β-CH_2Me
meso-Tetramethylporphin	−1·42			
meso-Dimethyloctamethylporphin	−1·16	+0·59	+0·38	
meso-Dimethylætioporphyrin	−1·35	+0·64	+0·38	+0·38 +0·30
meso-Monomethyloctamethylporphin.....	−1·25	+0·36	+0·27	
	(3,4)	(βδ)	(5,6,7,8)	
	−0·49	+0·50	+0·15	
	(1,2)	(α)	(1,2,3,4)	
meso-Monomethylætioporphyrin	−1·34	+0·39	+0·31	+0·26 +0·19
	(3,4)	(βδ)	(5,8)	(6,7)
	−0·62	+0·52	+0·15	+0·14 +0·04
	(1,2)	(α)	(1,4)	(2,3)
γ-Phylloporphyrin XV methyl ester	−1·01	+0·20	+0·18	+0·09 +0·05
	(3)	(βδ)	(8)	
	−0·84	+0·32	+0·08	
	(4)	(α)	(1,3,5)	
	−0·18			
	(1,2)			

decrease in ring current would account quite well for the results. It is, however, unlikely to be the sole large factor in determining the chemical shifts, because scale drawings reveal severe crowding of the *meso*-methyl groups and neighbouring β-alkyl groups. These repulsions, which have been very clearly noted by Woodward,[8] could distort the otherwise planar macrocycle and thus alter the deshielding and shielding of protons by the ring current. Some light is thrown on this problem by the spectra of the *meso*-monomethylporphyrins.

The spectra (Fig. 2) of the *meso*-monomethyl derivatives (Va and Vb) of octamethylporphin and ætioporphyrin show double peaks for N–H and *meso*-protons and for the β-alkyl groups. [The complex fine structure (Fig. 2b) in the spectrum of (Vb) is due to overlapping of two normal ethyl spectra; for instance the two triplets from the outer methyl protons form a quartet at 8·28.] Only one of these sets, that for the *meso*-protons, can be assigned unequivocally; this shows one peak corresponding to two protons, and another, at higher field, corresponding to one proton, which must for reasons of symmetry be in the α-position. Thus, quite surprisingly, it is that *meso*-proton, farthest from the *meso*-methyl groups, which is affected more than the other two. Four of the β-alkyl-substituents have chemical shifts like those of the eight β-substituents in the *meso*-dimethylporphyrins (IVa and IVb), and the other four have chemical shifts closer to those of the eight in the *meso*-unsubstituted porphyrins. *A priori* the former could be assigned to the 5,6,7,8-positions near the *meso*-substituent and the latter to the 1,2,3,4-positions on the far side of the macrocycle, and this agrees with deductions (see below) from the spectrum of γ-phylloporphyrin XV. It is easy to see how repulsions between the *meso*-methyl group and the neighbouring β-substituents could be relieved by slight folding of

[8] Woodward, *Angew. Chem.*, 1960, **72**, 652.

the porphyrin ring about an axis through the methyl group, and that folding in the moiety under direct strain would be greater than in the other half of the macrocycle. It is more difficult to assess the spectroscopic consequences of this distortion because the resonance frequency of a proton is determined by its location with respect to the ring current and

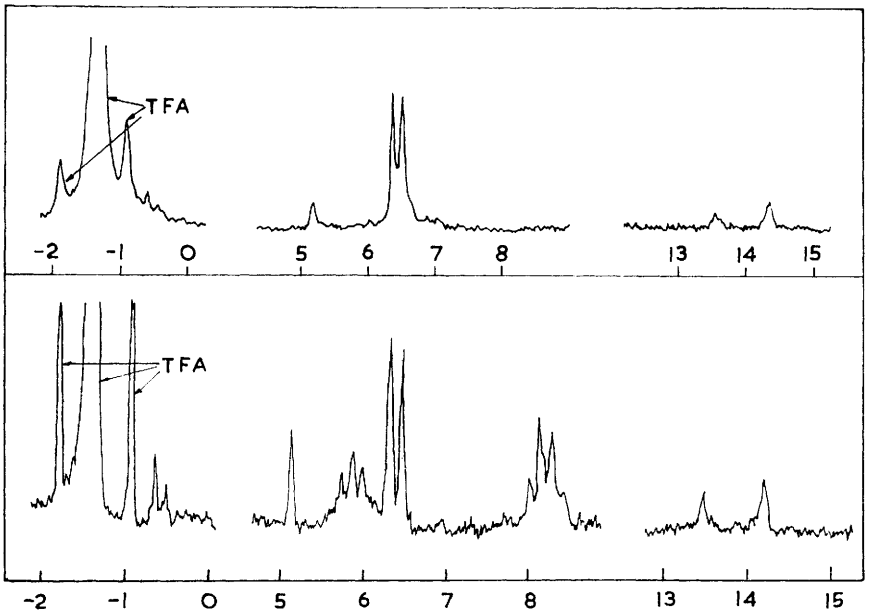
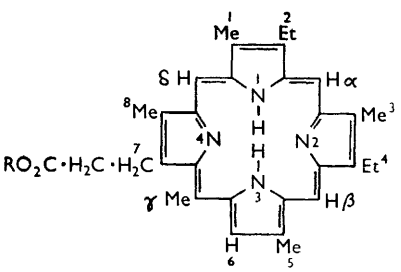


FIG. 2. Proton magnetic resonance spectra of (upper) *meso*-monomethyloctamethylporphin and (lower) *meso*-monomethylætioporphyrin in trifluoroacetic acid (TFA) at 60 Mc./sec.

the strength of the current in the network in the vicinity; both factors could be altered by the hypothetical folding. The situation could doubtless be clarified by examination of a wider variety of *meso*-substituted porphyrins than is accessible to us at the present time.



(a: R = H;
b: R = Me)

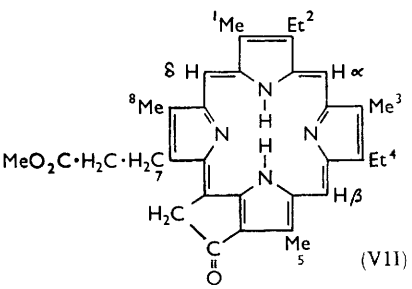
(VI)

The spectra of γ-phylloporphyrin XV (VIa) and its methyl ester (VIb) accord with those of the simpler, synthetic *meso*-monomethylporphyrins, and present some additional features. The four N–H protons in the dication formed from the acid (VIa), when it is dissolved in trifluoroacetic acid, produce separate peaks, but the two at higher field coalesce in the ester (VIb). These peaks can be assigned to the protons attached to N-1 and N-2 because their environments are similar to each other and also to those of N–H protons in *meso*-unsubstituted porphyrins, which have signals at about 14·7. By analogy this assignment allocates the higher N–H peak in the simpler compounds (Va and Vb) to the protons more remote from the *meso*-group. The doublet (area 2 : 1) near −0·7 can be assigned to the *meso*-protons and, as in the simpler compounds, it is the α-proton, more *remote*

from the *meso*-methyl group, which is shifted to higher field. The lone β-proton has a peak appreciably higher than those in the *meso*-unsubstituted hexa- and hepta-alkylporphins (deuteroætioporphyrin and pyrroætioporphyrin). This shift corresponds to that already noted in passing from porphin to *meso*-tetramethylporphin, but it is only half as great. Distinction between the four β-methyl groups is slightly more complicated. The resonance of one stands out at higher field than those of the other three which coincide with that of the methoxyl group in the ester (VIb). Obviously this lone methyl must be either that at position 5 or 8, and we place it definitely at 8; in agreement, the resonances of the methylene groups in the propionate chain at position 7 are also at slightly higher field than in *meso*-unsubstituted porphyrins (5·27—5·33 and 6·65—6·72 [2]). In fact the methyl group at position 5 has suffered a similar shift, because in *meso*-unsubstituted compounds a methyl group with a hydrogen atom as its immediate neighbour has a *down*field shift (see deutero- and pyrro-ætioporphyrin) which has been neutralised in this case. Thus, fundamentally, these spectra show the same division as do those of the other *meso*-monomethylporphyrins.

Phylloerythrin methyl ester (VII) is bound to behave differently because its *meso*-substitution takes the form of a fused ring which will cause coplanarity rather than buckling of the macrocycle. The carbonyl group also has a powerful influence and consequently the peak due to the 5-methyl group is shifted to lower field. The spectrum of the same compound, dissolved in deuterochloroform, has been recorded.[9] As in other instances, the spectrum of the free porphyrin covers a narrower range than does that of the dication, and there is a very large shift in the CH_2–CO peak [at 5·57 (δ 4·43) instead of 3·59].

The spectrum of *meso*-tetraphenylporphin shows the greatest difference from that of *meso*-unsubstituted porphyrins. The phenyl substituents might affect the resonance of the N–H and β-protons in three ways, namely by conjugation with the macrocycle, through direct ring-current effects of the benzene rings, and by altering the ring current of the macrocycle. The first effect can be safely neglected because it is not marked even in biphenyl (which shows a complex multiplet at 2·4—2·8 in deuterochloroform solution), and the phenyl rings cannot be coplanar with the porphyrin ring. It has been suggested that the angle of twist is as much as 60°,[10] but we estimate it to be nearer to 50° by assuming that the macrocycle remains planar and by employing the dimensions of ætio-



(VII)

porphyrin II [11] with an effective radius of 0·6 Å for the β-protons.[12] The assumption that the macrocycle retains planarity is probably incorrect (see below) but this calculation is sufficiently accurate to permit an estimate of the shifts to low and high field, respectively, of the N–H and β-proton resonance caused by the currents in the benzene rings. With the aid of Johnson and Bovey's tables,[13] we deduce values of about 0·45 p.p.m. for each of these shifts, and therefore this effect accounts for only a fraction of the differences between the spectra of *meso*-tetraphenylporphin and porphin itself. There remain shifts

[9] Becker, Bradley, and Watson, *J. Amer. Chem. Soc.*, 1961, **83**, 3743.
[10] Thomas and Martell, *J. Amer. Chem. Soc.*, 1956, **78**, 1338.
[11] Crute, *Acta Cryst.*, 1960, 12.
[12] Braude and Waight, *Progr. Stereochem.*, 1954, **1**, 146.
[13] Johnson and Bovey, *J. Chem. Phys.*, 1958, **29**, 1012.

of −1·9 and +0·6 p.p.m. in the positions of the resonance from N–H and β-protons, and these correspond to an 18% decrease in the current of the porphyrin ring. We think that this diminution in ring current is so great that at any rate a considerable part must be due to non-planarity of the macrocycle caused by repulsions between the *meso*-phenyl groups and the β-hydrogen atoms. Finally, the unusually low positions of the phenyl resonances can be satisfactorily ascribed to the effect of the current in the porphyrin ring.

The visible and ultraviolet absorption spectra of the various *meso*-methylporphyrins show that introduction of one methyl group into the *meso*-position of an octa-alkylporphyrin causes an overall bathochromic shift, and that introduction of a second *meso*-methyl group is responsible for a further bathochromic shift. These effects are paralleled by the successive increases in basicity which occur on substitution with one and two methyl groups and which are clearly shown in countercurrent distribution.

Experimental

Dibenzyl Di-(3,4-dimethyl-2-pyrrolyl)methane-5,5′-dicarboxylate (IIa) (with Dr. J. Ellis).—Benzyl 5-bromomethyl-3,4-dimethylpyrrole-2-carboxylate (15 g.) was heated with methanol (75 ml.) under reflux for 4 hr. The *product* (8·2 g.; 75%) crystallised from the cooled solution as buff needles, m. p. 176—177°. Recrystallisation from petroleum (b. p. 100—120°) gave colourless needles, m. p. 179° (Found: C, 74·2; H, 6·5; N, 5·9. $C_{29}H_{30}N_2O_4$ requires C, 74·0; H, 6·4; N, 5·95%).

Di-(3-ethyl-4-methyl-2-pyrrolyl)methane-5,5′-dicarboxylic Acid (IIIb) (with Dr. J. Ellis).—The corresponding dibenzyl ester [14] (2 g.) in ethyl acetate (50 ml.) was hydrogenated over 10% palladium–charcoal (0·2 g.) at room temperature and pressure for 18 hr. The catalyst was removed and washed with a little warm methanol to extract a small amount of the product which had crystallised. The combined filtrates were evaporated to dryness under reduced pressure (N_2 leak) at $\leqslant 35°$. The pale pink crystalline residual diacid (1·2 g.; 95%), m. p. 166° (with effervescence) (lit.[15] m. p. 170°), was used directly for conversion into porphyrin without further purification.

Di-(3,4-dimethyl-2-pyrrolyl)methane-5,5′-dicarboxylic Acid (IIIa).—This preparation was similar to the preceding one, except that a larger amount of ethyl acetate (150 ml.) was necessary for the hydrogenolysis of the corresponding dibenzyl ester (2·0 g.). The required *diacid* (1·2 g., 95%) crystallised as pale pink needles, used without further purification in succeeding stages. It formed colourless needles, m. p. 196—198° (with effervescence) (from aqueous methanol) (Found: C, 62·1; H, 6·6; N, 9·6. $C_{15}H_{18}N_2O_4$ requires C, 62·05; H, 6·25; N, 9·65%).

meso-*Methylætioporphyrins*.—A mixture of the dicarboxylic acid (IIIb) (1·2 g.), glacial acetic acid (5 ml.), and acetyl chloride (1·5 ml.) was heated under reflux for 4 hr. The cooled mixture was then aerated overnight, neutralised with dilute ammonium hydroxide, and extracted with chloroform (3 × 100 ml.). The chloroform extracts were washed with water, dried ($MgSO_4$), evaporated to small bulk, and chromatographed twice on alumina, first with chloroform as eluant, and secondly with benzene to remove pyrromethenes and polymeric products.

The porphyrin-containing eluates were evaporated to dryness and the residue was distributed between benzene and sulphuric acid (10% w/v) in a small hand-operated countercurrent machine (20 ml. top and bottom phases). After 30 transfers the mixture had separated into three distinctly coloured fractions, which were combined with the products of seven similar experiments and purified separately.

Fraction (1). Tubes 1—5, deep blue in the acid layer and pink in the benzene (maximum at tubes 1—2), were combined and the acid was neutralised with dilute ammonium hydroxide. The benzene layer was separated, and precipitated porphyrin was extracted with warm benzene after filtration. The combined benzene extracts, after being washed with water, were dried ($MgSO_4$) and evaporated to small volume. βδ-meso-*Dimethylætioporphyrin* II crystallised as blue-violet needles; more was obtained on evaporation of the mother liquors (total yield 105 mg., 1·4%) (Found: C, 80·1; H, 8·5; N, 11·3. $C_{34}H_{42}N_4$ requires C, 80·6; H, 8·4; N, 11·1%), $\lambda_{max.}$ (in benzene) 412, 510, 545, 584, 630 mμ (log ε 5·31, 4·22, 3·61, 3·75, 2·76), $\lambda_{max.}$ (in trifluoroacetic acid) 416, 575, 627 mμ (log ε 5·35, 4·03, 3·76).

[14] Johnson, Kay, Markham, Price, and Shaw, *J.*, 1959, 3416.
[15] Fischer and Orth, "Die Chemie des Pyrrols," Akademische Verlag, Leipzig, 1934, Vol. I, p. 344.

Fraction (2). Tubes 6—18, pink in each layer (maximum at tube 11), were worked up in the same way as the first fraction. The *meso*-monomethylætioporphyrin crystallised from chloroform–methanol as purple needles (110 mg., 1·4%). This material, dissolved in benzene (60 ml.), was introduced into the first three tubes of a 120-tube automatic Craig machine (20 ml. phases) and further purified by recycling countercurrent distribution between benzene and sulphuric acid (9% w/v). After 600 transfers almost complete separation into two distinct fractions had occurred, with maxima at tubes 243 and 283 (cf. Fig. 1). The contents of tubes 209—254 (B_1) and 267—314 (B_2) were collected separately, worked up in the usual manner, and the porphyrins recrystallised from chloroform–methanol (B_1, 46 mg.; B_2, 51 mg.). The components gave identical nuclear magnetic resonance spectra, indicating that they were *meso*-monomethylætioporphyrins (cf. Table 1 and Fig. 2), $\lambda_{max.}$ (in benzene) B_1, 409, 506, 539, 579, 630 mμ (log ε 5·01, 3·94, 3·54, 3·52, 2·99); B_2, 408, 505, 539, 579, 630 mμ (log ε 5·14, 4·04, 3·63, 3·62, 3·06); $\lambda_{max.}$ (in trifluoroacetic acid) B_1, 407, 562, 608 mμ (log ε 5·17, 3·86, 3·39); B_2, 407, 562, 608 mμ (log ε 5·23, 3·94, 3·47).

Fraction (3). Tubes 25—30, red in acid and brown in benzene, contained a small amount of ætioporphyrin, and were therefore discarded.

meso-*Methyloctamethylporphyrins*.—The dipyrrolylmethane diacid (IIIa) (1·2 g.) in glacial acetic acid (10 ml.) was heated with acetyl chloride (3 ml.) for 4 hr. under reflux. Air was blown through the cooled mixture, and next day it was neutralised with dilute ammonium hydroxide. The dark brown precipitate was filtered off, washed with water, and dried in air, before being extracted (Soxhlet) successively with methanol, chloroform, and *o*-dichlorobenzene. Spectroscopic examination of the extracts showed that no porphyrin had been extracted by the methanol, and only a trace by the chloroform, whereas a small amount of fairly pure porphyrins was extracted by the *o*-dichlorobenzene. The conditions were varied in attempts to increase the yield of porphyrin, *e.g.*, by the use of a larger excess of acetyl chloride in the initial reaction, longer reflux time, or the addition of more acetyl chloride during the reaction, but there was no significant improvement. The *o*-dichlorobenzene extracts from all these experiments were combined and evaporated to small volume; a crude mixture of mono- and di-*meso*-methyloctamethylporphin crystallised as deep purple needles (300 mg., ~2%, from a total of 19·2 g. of the diacid).

This mixture of porphyrins was redissolved in *o*-dichlorobenzene (100 ml.) by Soxhlet extraction, allowed to cool, and shaken with sulphuric acid (100 ml., 5% w/v). After filtration from a small amount of interfacial matter (shown spectroscopically to be the *meso*-dimethyloctamethylporphin) the solutions were introduced (20 ml. of each layer) into the first five tubes of the 120-tube automatic Craig machine and distributed between *o*-dichlorobenzene and sulphuric acid (5% w/v). After 60 transfers the mixture had separated into three distinct bands.

Fraction (1). Tubes 1—8 (max. at tube 3), brown in the lower dichlorobenzene layer, contained a small amount of octamethylporphin, and this was therefore discarded.

Fraction (2). Tubes 19—39 (max. at 29), pink in both layers, were combined, diluted with *o*-dichlorobenzene, and slowly neutralised with dilute ammonium hydroxide whilst the mixture was stirred vigorously. The *o*-dichlorobenzene was separated and washed with water, the aqueous extracts being re-extracted with fresh *o*-dichlorobenzene. The combined organic extracts were dried ($MgSO_4$) and evaporated to dryness. The residual *meso*-monomethyloctamethylporphin formed purple needles (*ca.* 15 mg., 0·1%) which were used directly for visual spectroscopic and nuclear magnetic resonance determinations, $\lambda_{max.}$ (in benzene) 410, 506, 539, 578, 630 mμ (log ε 5·16, 4·06, 3·72, 3·71, 3·27).

Fraction (3). Tubes 46—58 (max. at 53), blue in acid and pink in *o*-dichlorobenzene, were bulked and worked up in the same way as fraction (2). Recrystallisation of the residue, obtained on evaporation of the *o*-dichlorobenzene, from *o*-dichlorobenzene gave deep purple needles of the *meso*-dimethyloctamethylporphin (30 mg. 0·2%), dried *in vacuo* at 100° for visible spectroscopy and nuclear magnetic resonance determinations, $\lambda_{max.}$ (in benzene) 416, 512, 547, 584, 632 mμ (log ε 5·17, 4·06, 3·49, 3·65, 2·82).

Pyrroætioporphyrin VII (2,3,8-*Triethyl*-1,4,6,7-*tetramethylporphin*) (with Mr. P. A. Burbidge). —4-Ethyl-3,3′,5,5′-tetramethylpyrromethene hydrochloride [16a] (0·50 g.), 5,5′-dibromo-3,3′-diethyl-4,4′-dimethylpyrromethene (0·85 g.), and succinic acid (6·0 g.) were ground intimately together in a mortar. The mixture was dried *in vacuo* overnight, and then heated (stirring

[16] Fischer and Orth, " Die Chemie des Pyrrols," Akademische Verlag, Leipzig, 1937, Vol. II, Part 1, (*a*) p. 13, (*b*) p. 10.

occasionally with a glass rod) in an oil-bath at 200° for 35 min. The cooled mixture was extracted with boiling water (500 ml.), and made just alkaline with sodium hydroxide. The dark residue was filtered off, dried in air, and extracted (Soxhlet) with chloroform. The extracts were evaporated to small bulk and chromatographed twice on alumina, first with chloroform and secondly with benzene–chloroform (70 : 30 v/v). The porphyrin-containing eluates were evaporated to dryness, and the residue was dissolved in a small amount of chloroform. On addition of hot methanol the pyrroætioporphyrin (19 mg., 2·2%) crystallised as purple needles, m. p. 290° (decomp.), $\lambda_{max.}$ 497, 528, 573, 622 mμ.

Deuteroætioporphyrin IX (6,7-*Diethyl*-1,3,5,8-*tetramethylporphin*) (with Mr. P. A. BURBIDGE). —An intimate mixture of 3′,4,5,5′-tetramethylpyrromethene hydrochloride [16b] (0·40 g.) and 5,5′-dibromo-3,3′-diethyl-4,4′-dimethylpyrromethene hydrobromide (0·90 g.) was heated with succinic acid (6 g.) and worked up for porphyrin as in the foregoing preparation. The deuteroætioporphyrin crystallised from chloroform–methanol as purple needles (19 mg., 2·7%), m. p. 270—280°.

meso-*Tetraphenylporphin*.—This compound was prepared by Ball, Dorough, and Calvin's method,[17] and the crude product, partially purified by chromatography in chloroform solution on alumina, was introduced into the first two tubes (20 mg. in each tube) of an automatic Craig machine (20 ml. top and bottom phases) and distributed between benzene–isobutyl methyl ketone (1 : 3 v/v) and hydrochloric acid (90% w/v). After 75 transfers the porphyrin band (green in both layers and maximum at tube 33) was well separated from a dark coloured impurity running at the solvent front and a yellow impurity running between it and the solvent front. The contents of tubes 5—45 were combined, neutralised with dilute ammonium hydroxide, and the organic layer was separated and evaporated to dryness. The residue was recrystallised from chloroform–methanol to give purple micro-needles (20 mg.) of spectroscopically pure [17] *meso*-tetraphenylporphin.

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[17] Ball, Dorough, and Calvin, *J. Amer. Chem. Soc.*, 1946, **68**, 2276.