Iron Porphyrins Containing Appended Sulphur Ligands

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Summary Sulphide, sulphoxide, and sulphone ligands were covalently attached to tetraphenylporphyrins and were found to bind to different extents to the iron(II) derivatives.

CYTOCHROME C, an electron transfer agent in the respiratory chain, consists of an iron protoporphyrin IX unit co-ordinated to imidazole (His 18) and sulphide (Met 80) residues in both the reduced and oxidised forms,[1] and there

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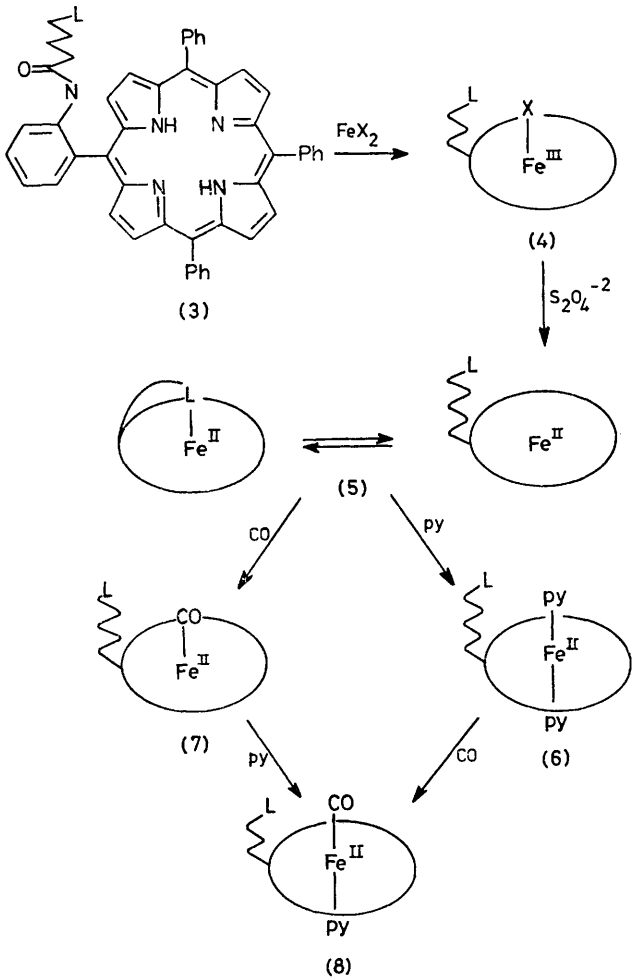
is considerable interest in the redox and electron transfer properties of these molecules. We are studying these properties by constructing simple model porphyrins which contain various sulphur ligands and report here the synthesis of substituted tetraphenylporphyrins containing sulphide, sulphoxide, and sulfone 'tails'; we describe some properties of their iron(III) and iron(II) derivatives.

meso-α-*o*-Aminophenyl-βγδ-triphenylporphyrin (**1**)‡ was prepared by the $SnCl_2$–HCl reduction of the corresponding mononitrophenyltriphenylporphyrin; the latter is available from the mixed condensation of benzaldehyde, *o*-nitrobenzaldehyde, and pyrrole.[2] The axial ligand precursors‡ $L[CH_2]_4CO_2H$ (**2**) [L = SMe (**2a**); S(O)Me (**2b**); SO_2Me (**2c**)] were prepared from commercially available 5-bromovaleric acid.§ The acids (**2a**—**c**) were converted into their anhydrides with *NN'*-dicyclohexylcarbodi-imide, and treatment with (**1**) afforded the 'tailed' porphyrins (**3a**—**c**) [yields based on (**1**), 60—90%].¶

The iron(III) derivatives (**4a**—**c**), were prepared by treating (**3a**—**c**) with anhydrous $FeCl_2$ or $FeBr_2$ in boiling tetrahydrofuran (THF) followed by aerobic oxidation and acidification. The microcrystalline products have spectroscopic properties indistinguishable from those reported[3] for Fe(TPP)Cl or Fe(TPP)Br (Scheme; TPP = αβγδ-tetraphenylporphyrin) indicating that the appended ligands remain unco-ordinated.

However, reduction to iron(II) derivatives (aqueous $Na_2S_2O_4$ or Pd black–CaH_2) gave products (**5a**—**c**) whose electronic spectra (Figure) in toluene vary with the ligand tail (Scheme).** The spectra of the sulphide (**5a**) and the sulphoxide (**5b**) differ appreciably from that of the sulphone (**5c**), which is very similar to that of 4-co-ordinate Fe(TPP),[4] indicating that the sulphone is not co-ordinated. The extent of binding is indicated by the intensities of the Soret band.



SCHEME

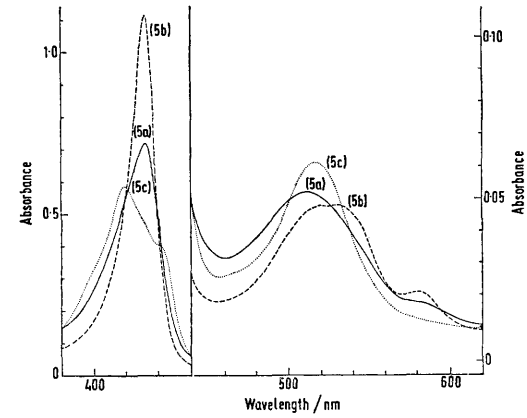


FIGURE. Electronic spectra of (**5a**—**c**) in toluene at 20 °C: ——, (**5a**) ($5{\cdot}95 \times 10^{-6}$ M); – – –, (**5b**) ($5{\cdot}50 \times 10^{-6}$ M); . . . . ., (**5c**) ($5{\cdot}75 \times 10^{-6}$ M).

Spectrophotometric titrations of Fe(TPP) with bases, 2-methylimidazole[5] and 2-methylpyridine, demonstrate that the intensity of the Soret band is directly related to the concentration of the 5-co-ordinate complex, Fe(TPP)L, indicating[6] that the following ordering of ligand affinities for Fe^{II}(TPP) exists: $R_2SO > R_2S > R_2SO_2$; these Fe^{II} derivatives are rapidly oxidised by air.

Some qualitative experiments have been carried out to determine the relative binding properties of the sulphide

‡ Satisfactory elemental analyses, t.l.c., and ^1H n.m.r. and mass spectral data were obtained.

§ Reaction of $Br[CH_2]_4CO_2H$ with an excess of LiSMe (−18 to 25 °C, 6 h, THF) afforded, after acidification, (**2a**) (b.p. 100 °C, 0·7 mmHg); esterification (MeOH–H_2SO_4) gave the ester (b.p. 92—95 °C, 7 mmHg) which, upon oxidation, gave the sulphoxide [1 equiv. *meta*-chloroperbenzoic acid (MCPBA), CH_2Cl_2, 0 °C] and the sulphone (2·2 equiv. MCPBA, CH_2Cl_2) esters; hydrolysis gave (**2b**) (m.p. 55—57 °C) and (**2c**) (m.p. 113—116 °C).

¶ To our surprise, (**3a**) is easily air-oxidised to (**3b**); consequently, (**3a**) must be recrystallised under anaerobic conditions. This air-oxidation is so efficient that it is the preferred method of synthesising (**3b**) [rather than acylating (**1**) with the anhydride of (**2b**)].

** Electronic spectra of the reduced iron porphyrins were measured in toluene (*ca.* 6×10^{-6} M) using modified 1 cm cuvettes. Although both aqueous $Na_2S_2O_4$ and Pd—CaH_2 gave the same products, the former method of reduction is simpler; hydrazine was unsatisfactory and yielded Fe^{II} complexes whose spectra were independent of the ligand tail, suggesting co-ordination of the reducing agent: D. Brault and M. Rougee, *Biochemistry*, 1974, **13**, 4591.

and sulphoxide tails compared to pyridine, CO, and imidazoles. Addition of an excess of pyridine (py) (*ca.* 10^3 excess) to toluene solutions of (**5a**) and (**5b**) (Scheme) gives typical haemochrome spectra;[4] subsequent equilibration with CO results in spectra identical to that obtained from (**5c**) and Fe(TPP) in the presence of pyridine. This implies displacement of the co-ordinated sulphide and sulphoxide groups and formation of Fe(TPP-L)$(py)_2$ (**6**) and Fe(TPP-L)(py)(CO) (**8**), respectively. Equilibration with CO in the absence of pyridine gives identical spectra for (**5a**—**c**) and Fe(TPP), suggesting that CO displaces ligating groups to form the 5-co-ordinate species Fe(TPP-L)(CO) (**7**). This result differs from that found for the appended imidazole tail, where carbonylation results in formation of the 6-co-ordinate Fe(PH-Im)(CO) chromophore {PH–Im = pyrrohaeme-*N*-[3-(1-imidazolyl)-propyl]amide}.[7] As with Fe(TPP), carbonylation is not reversible by freeze–evacuation–thawing procedures, and addition of pyridine results in (**8**). Similar results were obtained with (**5a**) in the presence of 1-methylimidazole.

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[1] R. Swanson, B. L. Trus, N. Mandel, G. Mandel, O. B. Kallai, and R. E. Dickerson, *J. Biol. Chem.*, 1977, **252**, 759; T. Takano, B. L. Trus, N. Mandel, G. Mandel, O. B. Kallai, R. Swanson, and R. E. Dickerson, *ibid.*, p. 776.
[2] J. P. Collman, C. M. Elliot, T. R. Halbert, and B. S. Tovrog, *Proc. Nat. Acad. Sci. U.S.A.*, 1977, **74**, 18.
[3] E. G. Fleischer and T. S. Srivastava, *J. Amer. Chem. Soc.*, 1969, **91**, 2403.
[4] H. Kobayashi and Y. Yanagawa, *Bull. Chem. Soc. Japan*, 1972, **45**, 450.
[5] See J. P. Collman and C. A. Reed, *J. Amer. Chem. Soc.*, 1973, **95**, 2049.
[6] C. A. Adams, D. A. Buckingham, L. M. Engelhardt, and T. B. Rauchfuss, unpublished data.
[7] C. K. Chang and T. G. Traylor, *J. Amer. Chem. Soc.*, 1973, **95**, 8475, 8477.