Reactions of *trans*-Octaethylchlorin with Thallium(III) Trifluoroacetate

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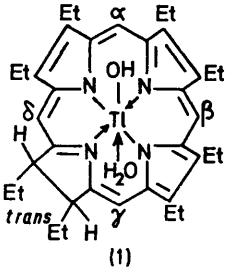
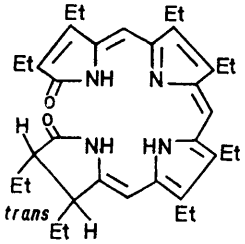
Summary Treatment of *trans*-octaethylchlorin with thallium trifluoroacetate results in oxidative rupture of the macrocycle to give analogues of the bile pigments

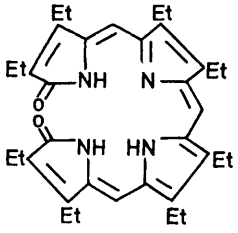
WHEN porphyrins are treated with thallium trifluoroacetate the *corresponding* thallium(III) chelates are obtained, and in the presence of trifluoroacetic acid, further products are produced due to oxidation at the porphyrin *meso*-positions [1] We now report the results of reactions using *trans*-octaethylchlorin[2] as the substrate in order to illuminate an aspect of comparative porphyrin–chlorin chemistry



(1)

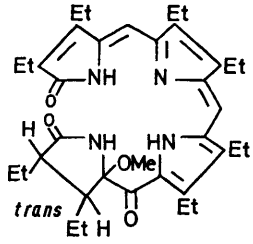


(2)

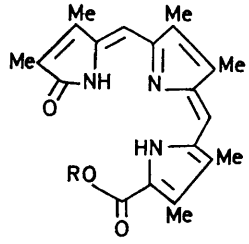


(3)

Treatment of *trans*-octaethylchlorin with an equivalent of thallium trifluoroacetate[3] during 1 5 min, followed by chromatography on alumina gave the required chlorin chelate (1)†‡ (22% yield§) [m p 208—209°, λ_{max} (CH_2Cl_2) 408 nm (ϵ 161,000) 512(5300), 577(5800), and 625 (45,000), i r (KBr) ν_{max} 3430w and 3330m cm^{-1}, OH, mass spectrum *m/e* (%) 774(4), 772(2) P^+ 739(2), 737(1) P^+ $-OH$ $-H_2O$· 536(100), n m r [4] spectrum ($CDCl_3$) τ 0 37 (d, *J* 44 Hz), 0 38 (d, *J* 42 Hz), 1 33 (d, *J* 51 Hz), and 1 35 (d, *J* 46 Hz) (4 *meso-H*)]



(4)



(5)

Small amounts of a more polar blue compound were also isolated from this reaction and the yield of this could be enhanced (to 25%) by use of 4 equiv of thallium trifluoroacetate while maintaining the contact time at 1 5 min The spectroscopic properties of the blue substance showed clearly that the macrocyclic ring had been ruptured, and it was allocated the dihydro-octaethylbiliverdin structure (2)† [m p 219—221°, λ_{max} (CH_2Cl_2) 347 nm (ϵ 45,000) and 591 (18,000), i r (KBr) ν_{max} 1720s and 1685s cm^{-1}, mass spectrum *m/e* 556 (100%), n m r spectrum ($CDCl_3$) τ 1·35 (3 N*H* broad) 3 44, 4 03, and 4 56 (3 methine-*H*)] The formulation (2) with the reduced *terminal* (rather than internal) ring was favoured because of the chemical shifts of the methine protons in the n m r spectrum, and also on the basis of mechanistic arguments, which will be mentioned later Confirmation of structure (2) was obtained, however, by repetition of the reaction using $\gamma\delta$-dideuterio-*trans*-octaethylchlorin[5] which gave a dihydroverdin lacking only the highfield (τ 4 56) methine resonance in its n m r spectrum Further evidence for the gross structure of (2) was provided by its micro-scale chromic acid degradation[6] to diethylmaleimide and a smaller amount of diethylsuccinimide, and also by its ferric chloride oxidation[7] to octaethylbiliverdin (3)† [m p 249—251°, λ_{max} (CH_2Cl_2) 366 nm (ϵ 58,000) and

† New compound which gave a satisfactory elemental analysis

‡ In common with the corresponding porphyrin chelates[1] the precise geometry of the thallium and ligands has yet to be determined. For convenience the chelate is represented as an octahedral species

§ No attempt has been made to maximise this yield The major by-product from these reactions is the porphyrin thallium complex which could presumably be partly eliminated by strict exclusion of oxygen from the reaction This has not been pursued in view of the interesting nature of the further products, which require oxygen for their generation

645 (15,000); i.r. (KBr) ν_{max} 1695sh and 1674s cm^{-1}; mass spectrum *m/e* 554 (100%); n.m.r. spectrum ($CDCl_3$) τ 1·70 (3 N*H*), 3·39 (s, 1 methine-*H*), and 4·13 (s, 2 methine-*H*).] The identity of (3) obtained in this way was established by comparison with an authentic sample prepared unambiguously by coupled oxidation[8] of octaethylhaemin, and by its chromic acid degradation[6] to diethylmaleimide alone.

More prolonged contact of *trans*-octaethylchlorin with thallium trifluoroacetate resulted in the production of a mixture of red pigments with "violinoid"[9a] visible absorption spectra; because of the complexity of this mixture, these were not separated and identified, but if the contact time with the reagent was extended to about 15 min, followed by treatment with methanol and chromatography, the "bilipurpurin"[9b] -type compound (4)† (32% yield) was isolated, [m.p. 198—200°, λ_{max} (CH_2Cl_2) 326 nm (ϵ 52,000), 505 (25,000), and 536 (26,000); i.r. (KBr) ν_{max} 1725s, 1705s, and 1640s cm^{-1}, mass spectrum *m/e*(%) 602(5) P^+ and 570(100) P^+ — MeOH; n.m.r. spectrum ($CDCl_3$) τ — 1·80, 0·78, 3·16 (3 N*H*): 3·30, 4·10 (2 methine-*H*), and 6·63 (s, 3H, O*Me*).] Similar substances have been claimed as intermediates in the well known Gmelin reaction[9c] of the bile pigments and (4) presumably arises by a similar process in this case. Chromic acid degradation[6] of this material gave the same maleimide and succinimide mixture that had earlier been obtained from the dihydroverdin (2). The visible absorption spectrum of the former is also similar to that of the tripyrrenic compounds (5) recently described by Plieninger and Stumpf;[10] both compounds have the same chromophore.

It has been noted earlier[5,11] that chlorins are more susceptible to electrophilic attack at the γ- and δ-positions than are porphyrins. Since the process of electrophilic thallation is also well documented,[3] a likely explanation of the unique course of the ring-opening would appear to be initial thallation at the γ- or δ-position of *trans*-octaethylchlorin [or its thallium chelate (1)] followed by collapse of this highly hindered intermediate (through an unknown mechanism) to give (2). Indeed, a highly labile green material which has not yet been characterised can be isolated from this reaction; on exposure to oxygen it is spontaneously transformed to the dihydroverdin (2). However, the chlorin chelate (1) is not converted into (2) by exposure to oxygen.

In contrast to the chlorin reaction reported here, treatment of porphyrins with thallium trifluoroacetate gives[1] *meso*-oxygenated macrocyclic products which presumably arise by a radical process and does not involve electrophilic thallation on the less activated porphyrin nucleus.

The oxidation of porphyrins to their open-chain bile pigment counterparts is of great biological significance since this is the pathway by which animals dispose of their waste haemoproteins. The method described above is the first example utilising the chlorin macrocycle and it may bear relevance to the catabolism of chlorophylls in the senescent leaf; it represents a useful preparative addition to the very limited number of chemical routes to bile pigments from macrocyclic compounds.[12]

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[12] For a review see K. M. Smith, *Quart. Rev.*, 1971, **25**, 31.