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FUNCTIONALIZATIONS OF THE ALKYL SUBSTITUENTS IN OCTA-ALKYLPORPHYRINS

M Graça H Vicente and Kevin M Smith*

Department of Chemistry, University of California, Davis, California 95616

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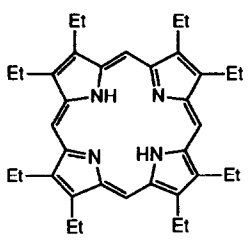
Abstract Treatment of octaethylporphyrin (OEP, **1**) with N-bromosuccinimide in the presence of 2,2'-azobis(2-methylpropionitrile) (AIBN) affords the trans-(2-bromovinyl)-heptaethylporphyrin **10** in high yield When primary and secondary alcohols are present in the reaction mixture the corresponding (1-alkoxyethyl)-heptaethylporphyrins are formed The trans-(2-bromovinyl)-heptaethylporphyrin undergoes some of the reactions characteristic of the vinyl groups in porphyrins and several reactions of this compound are described.

The porphyrin macrocycle provides an excellent system for spectroscopic and synthetic studies of organic and organometallic chemistry, and also for related investigations of a number of biological phenomena and natural products In this regard, octaethylporphyrin (OEP, **1**) has been used extensively as a probe for chemical, physical, and biological properties of the free base and a plethora of metal complexes [1] Numerous important discoveries concerning heme structure and function can be credited to model studies using octaethylporphyrin and its metal complexes [2] In addition, the reactions of porphyrin substituents are of considerable chemical interest since the fundamental properties of the porphyrin macrocycle can be altered by small changes in these substituents However, with the exception of meso-substitution,[3] methods for functionalization of octaethylporphyrin (**1**), the prototypical alkylporphyrin, appear to have fallen behind.



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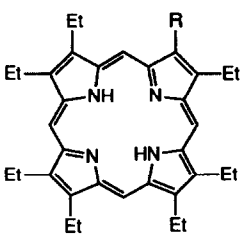
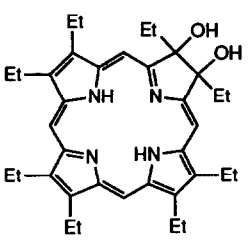


2 R = $CH(Cl)CH_3$
3 R = $CH{=}CH_2$
4 R = $CH(OH)CH_3$
5 R = $CH(OCH_2CH_3)CH_3$
6 R = CH=CH-Cl
8 R = $CH(OAc)CH_3$
9 R = $CH(OCH_3)CH_3$



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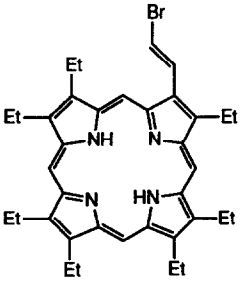

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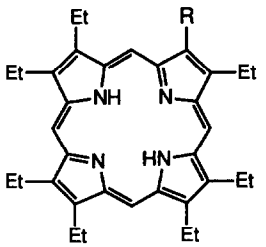
OEP (**1**) reacts[4] with tert-butyl hypochlorite and 2,2'-azobis(2-methylpropionitrile) (AIBN) in chloroform to give a low yield of a mixture of products which have undergone reaction at an ethyl group From the reaction mixture,

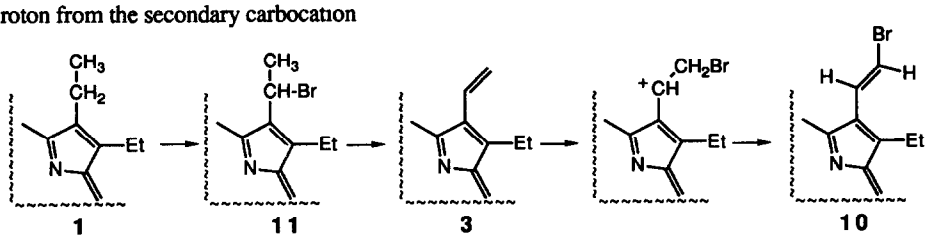
7% of 1-(1-chloroethyl)-heptaethylporphyrin **2**, 37% of 1-vinyl-heptaethylporphyrin **3**, 4% of 1-(1-hydroxyethyl)-heptaethylporphyrin **4** and 7% of 1-(1-ethoxyethyl)-heptaethylporphyrin **5** were isolated In a related reaction, treatment of OEP **1** with sodium chloroaurate(III) in pyridine was shown to give[5] the 1-(2-chlorovinyl)-heptaethylporphyrin **6** in 15% yield Another method[6] for the functionalization of an ethyl group of OEP has also been described, the dihydroxychlorin **7** was prepared from oxidation of OEP with osmium tetroxide, in 67% yield,[7] and upon heating in the presence of acid, the mono-(1-hydroxyethyl) derivative **4** was obtained in 49% yield When glacial acetic acid or methanol were used, the mono-(1-acetoxyethyl)-porphyrin **8** or the mono-(1-methoxyethyl)-porphyrin **9** were produced in 85% and 78% yield, respectively The 1-vinyl-heptaethylporphyrin **3** was also obtained in 90% yield, by heating compound **7** in benzene containing HCl In the present paper we describe a number of efficient procedures for the functionalization of OEP, with the keystone intermediate being the (2-bromovinyl)-heptaethylporphyrin **10** Recently, bromination of OEP with Br_2, H_2O_2/HBr, or NBS has recently been investigated[8] in the case of NBS, a high yielding route to the (1-ethoxyethyl)-heptaethylporphyrin **5** was described, but because of the different reactions conditions employed, the trans-(2-bromovinyl)-porphyrin **10** was not observed [8]

The Reaction of OEP with N-Bromosuccinimide



10 R = CH=CH-Br
11 R = CH(Br)CH_3
12 R = CH(OCH$_2$CH$_2$CH$_3$)CH_3
13 R = CH(OCH$_2$CH$_2$SiMe$_3$)CH_3
14 R = CH[OCH(Me$_2$)]CH_3

Treatment of OEP with two molar equiv of N-bromosuccinimide in the presence of AIBN produced the corresponding trans-(2-bromovinyl)-heptaethylporphyrin **10** in 85% yield (93% based on recovered starting material) The structure of compound **10** was assigned initially on the basis of the proton NMR spectrum which showed two vinylic protons at (8 67 ppm and 7.33 ppm) coupled to each other with J=14 1 Hz, confirming the trans arrangement at the olefinic double bond The proposed mechanism for the formation of the trans compound **10**, the thermodynamically most stable isomer, is shown in Scheme 1, after benzylic bromination of OEP to give **11**, elimination of hydrogen bromide presumably occurs to produce the mono-vinyl derivative **3** Addition of bromonium ion to the vinyl group would yield the bromovinyl derivative **10** after loss of a proton from the secondary carbocation



1 **11** **3** **10**

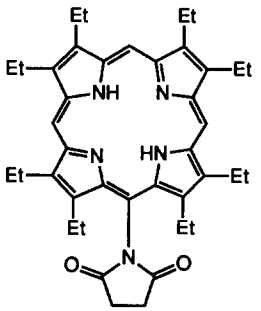
Scheme 1 Proposed mechanism for transformation of OEP (**1**) into trans-(2-bromovinyl)-heptaethylporphyrin (**10**)

When the reaction was carried out under the same conditions, using commercial chloroform (containing 0 75% of ethanol as a stabilizer) as the solvent, no trans-(2-bromovinyl)-heptaethylporphyrin **10** was formed The main product obtained under these conditions was (1-ethoxyethyl)-heptaethylporphyrin **5** obtained in 47% yield (73% based on recovered OEP), and also 1-vinyl-heptaethylporphyrin **3** in 10% yield Presumably, the ethanol displaces the bromine atom in the initial product **11** to form compound **5**, while **5** simply eliminates ethanol under the reaction

conditions to give product **3** We have also shown that compound **5** gives **3** upon refluxing in toluene When the same reaction was carried out in the presence of 1-propanol (3% of 1-propanol in dichloromethane), compound **12** was obtained in 82% yield In this case, no 1-vinyl-heptaethylporphyrin **3** was detected since 1-propanol does not eliminate under these reaction conditions In the presence of 2-(trimethylsilyl)ethanol, the trimethylsilylethoxy derivative **13** was obtained in 50% yield (83% based on recovered OEP) Compound **13** did not react with tetra n-butylammonium fluoride in tetrahydrofuran[9] but treatment of the trimethylsilylethoxy-porphyrin **13** with an excess of trimethylsilyl iodide gave a 50% yield of the (1-hydroxyethyl)-porphyrin **4** (85% based on recovered starting material) Compound **4** was dehydrated by heating in toluene for 3 h, to provide an almost quantitative yield of the mono-vinyl-porphyrin **3**

Use of a secondary alcohol, such as 2-propanol, in place of 1-propanol afforded porphyrin **14** in 40% yield (89% based on recovered OEP) In this case a longer reaction time is needed and the yield obtained for the ether derivative was lower When tert-butyl alcohol was used the corresponding tert-butyl ether was not detected and the trans-(2-bromovinyl)-porphyrin **10** was the only product, obtained in 77% yield Use of 1% of water in dichloromethane as the solvent also afforded the trans-(2-bromovinyl)-compound **10** as the only product, and in 77% yield

The zinc(II) complex of OEP behaved differently from the free-base **1** under the same conditions, treatment of zinc(II) OEP with N-bromosuccinimide in the presence of AIBN afforded product **15** in 28% yield (72% based on recovered starting material) after removal of the chelated zinc Only a trace of the trans-(2-bromovinyl)-porphyrin (**10**) was produced Addition of primary alcohols to the reaction mixture did not affect the formation of **15** The reaction mechanism may involve formation of the π-cation radical of zinc(II) OEP **1**, followed by attack of succinimide as a nucleophile Similar zinc(II) porphyrin cation radical reactions with nucleophiles have been reported in the literature [10]



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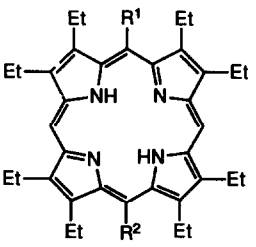
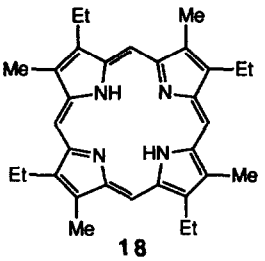


16 $R^1 = R^2 = Cl$
17 $R^1 = Cl, R^2 = H$

When OEP **1** was reacted under the same reaction conditions, but with N-chlorosuccinimide in place of N-bromosuccinimide, the meso-dichloro-porphyrin **16** was the main product (obtained in 30% yield), along with 17% of the mono meso-chlorinated porphyrin **17** and a 50% recovery of OEP The structures of compounds **16** and **17** were assigned on the basis of their mass spectra and proton NMR spectra (presence of only two or three meso protons, respectively) The two chlorine atoms of compound **16** are sited in opposite meso positions as indicated in the symmetric proton NMR spectrum

Treatment of etioporphyrin-I (**18**) with N-bromosuccinimide gave only a complex mixture of polar decomposition materials However, in the presence of ethanol, compounds **19** and **20** were obtained in the ratio of 3 1, respectively Upon heating in toluene, compound **20** gave the mono-vinyl derivative **21** in good yield



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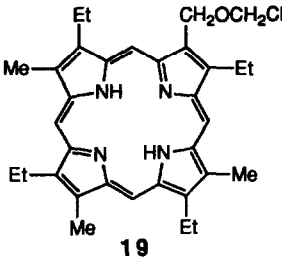

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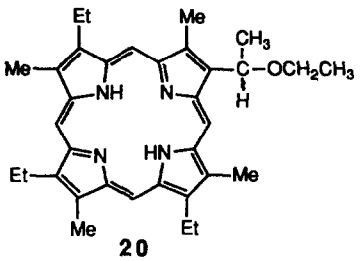

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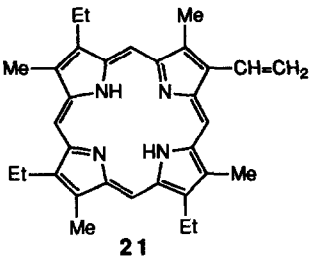

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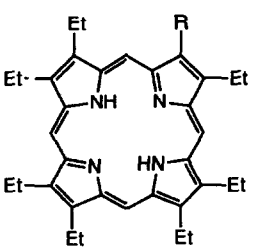
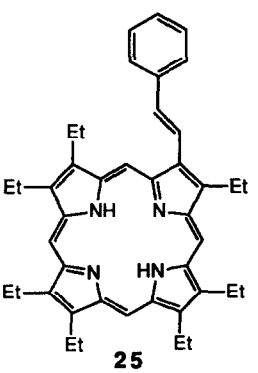
Compound **10** is very stable, is resistant to many reagents and reaction conditions (e g. high temperatures) with very little decomposition, and so proved to be a keystone intermediate for further transformations Attempts to obtain the saturated (2-bromoethyl)-porphyrin **22**, a useful vinylporphyrin precursor, by hydrogenation of **10** were unsuccessful However, the trans-(2-bromovinyl)-heptaethylporphyrin **10** underwent several of the reactions known to the vinyl group of porphyrins [11] Thus, compound **10** reacted with osmium tetroxide in the presence of sodium periodate[12] to give the β-formylporphyrin **23** in 62% yield (97% based on recovered OEP precursor) The iron(III) complex from compound **10** also reacted with resorcinol in the classical Schumm protiodevinylation[13] to give the β-unsubstituted porphyrin **24** in 68% yield, after demetalation Both compounds **23** and **24** can be further functionalized and used in the preparation of numerous other OEP derivatives [14]

The zinc(II) complex of **10** reacted with nickel(II) chloride, triphenylphosphine, and phenyl magnesium chloride[15] at -3°C, to give compound **25** in 50% yield after removal of the chelating zinc A number of different OEP derivatives can be obtained using different Grignard reagents, only typical examples are given here Treatment of zinc(II) **10** with benzaldehyde or 4-(dimethylamino)-benzaldehyde in the presence of anhydrous chromium(II) chloride[16] gave low yields (5-12%) of compounds **26** and **27**, respectively



22 R = CH_2CH_2Br
23 R = CHO
24 R = H



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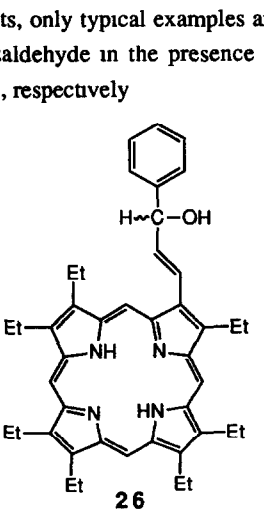

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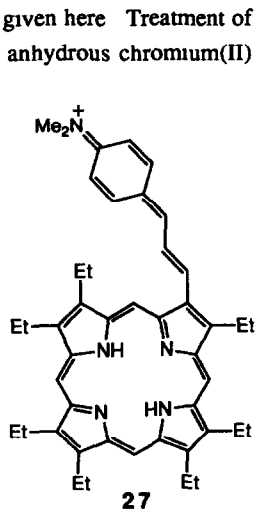

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1-Vinyl-heptaethylporphyrin **3** was obtained from reaction of zinc(II) **10** with tert-butyl or n-butyl lithium (at -78°C and -39°C, respectively) followed by quenching of the resulting vinyl anion with water However, the yield of 1-vinyl-heptaethylporphyrin **3** never exceded 35% and decomposition products were invariably observed

Experimental

Melting points were measured on a Thomas/Bristoline microscopic hot stage apparatus and were uncorrected Silica gel 60 (70-230 and 230-400 mesh, Merck) or neutral alumina (Merck; usually Brockmann Grade III, i e. deactivated with 6% water) were used for column chromatography Preparative thin layer chromatography was carried out on 20 x 20 cm glass plates coated with Merck G 254 silica gel (1 mm thick). Analytical thin layer chromatography was performed using Merck 60 F254 silica gel (precoated sheets, 0 2 mm thick) Reactions were monitored by thin layer chromatography and spectrophotometry and were carried out under nitrogen and in the dark Proton and carbon-13 NMR spectra were obtained in deuterochloroform solution at 300 MHz using a General Electric QE300 spectrometer; chemical shifts are expressed in ppm relative to chloroform (7 258 ppm) Elemental analyses were performed at the Midwest Microlab, Ltd , Indiana, and at the Microchemical Analysis Laboratory, U C Berkeley Electronic absorption spectra were measured in dichloromethane solution using a Hewlett-Packard 8450A spectrophotometer Mass spectra were obtained at the Mass Spectrometry Facility, University of California, San Francisco

1-Vinyl-2,3,4,5,6,7,8-heptaethylporphyrin (3). 1-(1-Hydroxyethyl)-2,3,4,5,6,7,8-heptaethylporphyrin (**4**) (20 mg, 0 04 mmol) was heated at reflux in toluene for 2 h The solvent was removed under vacuum and the product was recrystallized from dichloromethane/methanol to give 18 mg (95% yield) of the title compound, mp 294-295°C (lit [8] 296-298°C) UV-Vis λ_{max} 402 (ε 149 400), 502 (18 400), 538 (17 900), 570 (13 600) and 622 nm (10 400), NMR δ_H 10 30 and 10 18 (s, 1 H each, 2 meso-H), 10 12 (s, 2 meso-H), 8 33 and 8 27 (dd, 1 H, C<u>H</u>=CH_2, J = 11 7 Hz), 6 40 and 6 19 (dd, 1 H each, CH=C<u>H_2</u>, J = 11 7 Hz, J' = 1 2 Hz), 4 13 (overlapping q, 14 H, CH_2 of Et), 1 96 (overlapping t, 21 H, CH_3 of Et), -3 66 (s, br, 2 NH), Anal calcd for $C_{36}H_{44}N_4$. C, 81 16, H, 8 32, N, 10 52 Found C, 81 54, H, 8 40, N, 10 39, HRMS m/e (%), $C_{36}H_{44}N_4$ requires 532 3566, Found 532 3566

1-(1-Hydroxyethyl)-2,3,4,5,6,7,8-heptaethylporphyrin (4) Trimethylsilyl iodide (0.06 mL, 0 44 mmol) was added dropwise to a solution of 1-[1-(2-trimethylsilyl)ethoxy]-2,3,4,5,6,7,8-heptaethylporphyrin (**13**) (17 3 mg, 0 03 mmol) in chloroform (10 mL) at 0°C The reaction mixture was allowed to warm up slowly to room temperature and then heated to 30°C for 24 h It was washed with 20% aqueous $NaHCO_3$ (1x100 mL) and with water (2x100 mL) The organic mixture was dried over anhydrous sodium sulfate, the solvent was evaporated under vacuum and the residue was chromatographed on an alumina (Brockmann Grade III) column, using dichloromethane for elution The major band was collected and recrystallized from dichloromethane/hexane to yield 7 5 mg (50%) of the title compound, mp > 250°C (dec) UV-Vis λ_{max} 400 (ε 159 100), 498 (15 400), 534 (12 700), 566 (9 600) and 620 nm (7 200), NMR δ_H 10 64 and 10 12 (s, 1 H each, 2 meso-H), 10 10 (s, 2 meso-H), 6 58 (q, 1 H, C<u>H</u>(OH)CH_3), 4 14 and 4 10 (overlapping q, 14 H, CH_2 of Et), 2 86 (s, br, 1 OH), 2 36 (d, 3 H, CH(OH)C<u>H_3</u>), 1 92 and 1 93 (overlapping t, 21 H, CH_3 of Et), -3 75 (s, br, 2 NH) HRMS m/e (%), $C_{36}H_{46}N_4O$ requires 550 3671, Found 550 3626

1-(1-Ethoxyethyl)-2,3,4,5,6,7,8-heptaethylporphyrin (5). N-Bromosuccinimide (33 1 mg, 0 186 mmol) was dissolved in commercial chloroform (5 mL) and added to a solution of octaethylporphyrin (**1**) (90.1 mg, 0 168 mmol) in chloroform (75 mL) AIBN (3.74 mg, 0 023 mmol) was dissolved in chloroform (2 mL) and added to the reaction mixture with continous stirring. The final mixture was refluxed for 4 h, concentrated and chromatographed in preparative TLC silica gel plates using dichloromethane for elution The major band was collected and recrystallized from dichloromethane/petroleum ether to give 46 mg (47%) of the title compound (73% based on recovered starting material that was obtained in 35% yield) 1-Vinyl-heptaethylporphyrin (**3**) was a minor product obtained in this reaction in 10% yield For the title compound, mp > 260°C (dec) UV-Vis λ_{max} 390 (ε 198 600), 498 (19 550), 532 (15 700), 566 (11 900) and 620 nm (6 800), NMR δ_H 10 80 and 10 15 (s, 1 H each, 2 meso-H), 10 17 (s, 2 H, 2 meso-H), 6 11 (q, 1 H, C<u>H</u>(OEt)CH_3), 4 18 and 4 16 (overlapping q, 14 H, CH_2 of Et), 3 86 (q, 2 H, CH_2 of ethoxy gp), 2 38 (d, 3 H, CH(OEt)C<u>H_3</u>), 1 99 (t, 21 H, CH_3 of Et), 1 40 (t, 3 H, CH_3 of ethoxy gp), -3 65 (s, br, 2 NH), MS m/e (%) 578 8 (66) and 534 7 (100), Anal calcd for $C_{38}H_{50}N_4O$ C, 78 84, H, 8 70, N, 9 67 Found C, 78 65, H, 8 70, N, 9 60

trans-(2-Bromovinyl)-2,3,4,5,6,7,8-heptaethylporphyrin (10). N-Bromosuccinimide (39 5 mg, 0 22 mmol) was dissolved in 1,2-dichloroethane (3 mL) and added to a solution of OEP (61 4 mg, 0 12 mmol) in 1,2-dichloroethane (40 mL) AIBN (2 7 mg, 0 02 mmol) was dissolved in 1,2-dichloroethane (0 5 mL) and added to the OEP solution with continuous stirring The reaction mixture was refluxed for 5 h and then after evaporation of the solvent the residue was chromatographed on preparative TLC silica gel plates using 30% petroleum ether in dichloromethane for elution The front-running band was collected, evaporated to dryness, and recrystallized from dichloromethane/methanol to give 57 9 mg (83% yield) (92% based on recovered starting material) of the title compound, mp > 350°C UV-Vis λ_{max} 402 (ε 192 400), 504 (24 300), 542 (26 200), 570 (19 300) and 624 nm (13

900), NMR δ_H 10 15 and 10 11 (s, 1 H each, 2 meso H), 10 10 (s, 2 H, 2 meso-H), 8 67 (d, 1-H of vinyl, J = 14 1 Hz), 7 33 (d, 2-H of vinyl, J = 14 1 Hz), 4 16 (10 H) and 4.05 (4 H) (q, CH_2 of Et), 1 94 and 1 91 (21 H, overlapping t, CH_3 of Et), -3 71 (s, broad, 2 NH), δ_C 18 20, 18 55 and 19 70 (q, CH_3 of Et), 18 70, 19.85 and 20 40 (t, CH_2 of Et), 96 50 (d, 2 meso-C), 97.05 and 97 30 (d, 1 meso-C each), 109 10 (dd, 1 vinyl-C, J^1 = 185.9, J^2 = 9 2), 131.30 (dd, 1 vinyl-C, J^1 = 153.8, J^2 = 4 3), 135.20-149 80 (br, ring Cs), MS m/e (%) 612.9 (99.7), 611 9 (84.6), 610.9 (100) and 531 0 (40 8), Anal calcd for $C_{36}H_{43}BrN_4$: C, 70.69; H, 7 09, N, 9 16 Found C, 70.30, H, 7 03, N, 9.09.

1-(1-n-Propoxyethyl)-2,3,4,5,6,7,8-heptaethylporphyrin (12). The same procedure was followed as for the synthesis of compound 5 OEP (35 8 mg, 0.07 mmol), NBS (26 0 mg, 0 14 mmol) and AIBN (2 8 mg, 0.02 mmol) in 3% 1-propanol/dichloromethane were used. The reaction mixture was refluxed for 3 h, then the solvent was removed under vacuum and the residue chromatographed on an alumina, Brockmann Grade V, column (elution with dichloromethane). The main product was further purified by chromatography on preparative TLC silica gel plates, using 20% petroleum ether/dichloromethane for elution The above compound was collected and recrystallized from dichloromethane/methanol to give 32 mg (82% yield) For the title compound, mp > 250°C (dec.) UV-Vis λ_{max} 400 (ε 168 400), 498 (18 900), 534 (15 700), 566 (12 500) and 620 nm (9 600), NMR δ_H 10 72 and 10 10 (s, 1 H each, 2 meso-H), 10.11 (s, 2 H, 2 meso-H), 6.02 (q, 1 H, C<u>H</u>(OR)CH_3), 4.05-4 22 (overlapping q, 14 H, CH_2 of Et), 3 68 (t, 2 H, O<u>C</u>$H_2CH_2CH_3$), 2 32 (d, 3 H, CH(OR)C<u>H</u>$_3$), 1.93 (t, 21 H, CH_3 of Et), 1 77 (m, 2 H, OCH_2C<u>H</u>$_2CH_3$), 0.88 (t, 3 H, OCH_2CH_2C<u>H</u>$_3$), -3 72 (s, br, 2 NH), HRMS m/e (%), $C_{39}H_{52}N_4O$ requires 592 4141, Found 592 4153 (100)

1-[1-(2-Trimethylsilyl)ethoxy]-2,3,4,5,6,7,8-heptaethylporphyrin (13). N-Bromosuccinimide (60 1 mg, 0 34 mmol) was dissolved in 2% 2-(trimethylsilyl)-ethanol/dichloromethane and added to a solution of OEP (85 0 mg, 0 16 mmol) in the same solvent (70 mL) AIBN (5 3 mg, 0 03 mmol) was dissolved in the same solvent (2 mL) and added to the reaction mixture with continous stirring After 48 h stirring at room temperature the solvent was evaporated under vacuum and the residue was passed through an alumina column to remove the excess NBS The residue was chromatographed on preparative TLC silica gel plates using 1 1 petroleum ether/dichloromethane for elution The major product was collected and recrystallized from dichloromethane/methanol, giving 50 mg (50%) of the title compound (85% based on recovered starting materialrecovered in 41% yield), mp > 300°C (dec) UV-Vis λ_{max} 400 (ε 190 700), 498 (16 600), 532 (13 800), 566 (10 550) and 618 nm (7 200); NMR δ_H 10 95, 10 31, 10 28 and 10.27 (all s, 1 H each, 4 meso-H), 6 24 (q, 1 H, C<u>H</u>(OR)CH_3), 4 29 and 4 26 (overlapping q, 14 H, CH_2 of Et), 4 02 (m, 2 H, O<u>C</u>H_2CH_2TMS), 2 50 (d, 3 H, CH(OR)C<u>H</u>$_3$), 2.09 (overlapping t, 21 H, CH_3 of Et), 1.46 and 1 28 (m, 1 H each, OCH_2C<u>H</u>$_2$TMS), 0 06 (s, 9 H, Si(CH_3)$_3$), -3.52 (s, br, 2 NH); δ_C 19 00 (q, 3 Si-CH_3), 19 06, 19 19, 19 99, 20 20 and 20 25 (overlapping t and q, peripheral CH_2 and CH_3), 26 96 (d, <u>C</u>H(OR)CH_3), 66 87 (t, OCH_2<u>C</u>H_2TMS), 73 11 (t, O<u>C</u>H_2CH_2TMS), 96 72, 96 86, 96.95 and 99 44 (all d, 4 meso-C), 140.20-147 20 (br, ring Cs), MS m/e (%) 650 9 (100), 534 8 (42), 533 8 (47) and 267 4 (43), Anal calcd for $C_{41}H_{58}N_4OSi$ C, 75 64, H, 8 98, N, 8 61 Found C, 75 73, H, 8 85, N, 8 90

1-[1-(i-Propoxy)ethyl]-2,3,4,5,6,7,8-heptaethylporphyrin (14). The same procedure as above was followed OEP (50.4 mg, 0 09 mmol), NBS (48 9 mg, 0 27 mmol) and AIBN (3 9 mg, 0.02 mmol) were used, in 3% 2-propanol/dichloromethane. The reaction mixture was refluxed for 5 h, the solvent was removed under vacuum and the residue chromatographed on an alumina, Brockmann Grade V, column (elution with dichloromethane) The products were further purified by chromatography on preparative TLC silica gel plates, using 20% petroleum ether/dichloromethane for elution The above compound was collected and recrystallized from dichloromethane/methanol to give 22 mg (40% yield) along with 27 mg (54%) recovery of OEP For the title compound, mp > 260°C (dec) UV-Vis λ_{max} 400 (ε 161 900), 498 (15 100), 532 (12 050), 566 (9 400) and 620 nm (6 500), NMR δ_H 10 77 and 10 10 (s, 1 H each, 2 meso-H), 10 09 (s, 2 H, 2 meso-H), 6.14 (q, 1 H, C<u>H</u>(OR)CH_3), 4 03-4 20 (overlapping q, 14 H, CH_2 of Et), 3 97 (m, 1 H, O<u>C</u>H(CH_3)$_2$), 2 30 (d, 3 H, CH(OR)C<u>H</u>$_3$), 1 92 (t, 21 H, CH_3 of Et), 1.45 and 1 16 (both d, 3 H each, OCH(C<u>H</u>$_3$)$_2$), -3 73 (s, br, 2 NH), HRMS m/e (%), $C_{39}H_{52}N_4O$ requires 592 4141, Found 592 4167 (100) and 532 3611 (35), Anal calcd for $C_{39}H_{52}N_4O$ C, 79 01, H, 8 84, N, 9 45 Found C, 78 90, H, 8 88, N, 9 41

Meso-(N-succinimidyl)-octaethylporphyrin (15). N-Bromosuccinimide (57 mg, 0.32 mmol) was dissolved in dichloromethane (4 mL) and added to a solution of the zinc(II) OEP (101.6 mg, 0.170 mmol) in dichloromethane (200 mL) AIBN (4 4 mg, 0 027 mmol) was dissolved in dichloromethane (1 mL) and added to the zinc(II) OEP solution The reaction mixture was refluxed for 20 h, cooled down to room temperature, and then the solvent was removed under vacuum The residue was chromatographed on a silica gel column, using 10% petroleum ether in dichloromethane for elution. The product was collected and recrystallized from dichloro-methane/methanol to give 30 mg (27%) of the title compound (72% based on recovered starting material, recovered in 65% yield), mp = 259-260°C UV-Vis λ_{max} 402 (ε 161 000), 502 (16 100), 536 (12 050), 572 (9 100) and 624 nm (8 100), NMR δ_H 10 21 (s, 2 meso-H), 10 02 (s, 1 meso-H), 4 05-4 16 (overlapping q, 12 H, CH_2 of Et), 3 65 (q, 4 H, CH_2 of Et),

3 46 (s, 4 H, CH_2 of succinimide), 1 94 (t, 18 H, CH_3 of Et), 1 62 (t, 6 H, CH_3 of Et), -3 21 and -3.30 (br, 1 H each, 2 NH); δ_C 17 11, 18 88, 18 96, 20 12, 20 19, 20 29, 22 27 and 30 17 (peripheral Et), 30.22 (t, CH_2 of succinimide), 97 55 (d, 1 meso-C), 97 88 (d, 2 meso-C), 106 33 (s, quaternary meso-C), 138 89, 142 01, 142 52, 142 83, 143 85, 145 96 and 146 00 (all s, ring Cs), 180 14 (s, CO of succinimide); MS m/e (%), $C_{40}H_{49}N_5O_2$ requires 631 3886 Found 631 3844 (100), Anal calcd for $C_{40}H_{49}N_5O_2\ H_2O$ C, 73 93, H, 7 91, N, 10 78 Found C, 74 03, H, 7 82, N, 10 70

1-Formyl-2,3,4,5,6,7,8-heptaethylporphyrin (23). trans-(2-Bromovinyl)-2,3,4,5,6,7,8-heptaethylporphyrin (**10**) (88 mg, 0 144 mmol) was dissolved in tetrahydrofuran (12 mL) and 1,4-dioxane (8 0 mL) and the resulting solution was added to a stirring solution of osmium tetroxide (4 6 mg, 0 018 mmol) in diethylether (0 4 mL) The mixture was stirred at room temperature, under argon, for 5 min before a solution of sodium periodate (60 mg, 0 28 mmol) in 2 mL of water was added Another solution of sodium periodate (100 mg, 0 47 mmol) in 2 mL of water was added after a period of 12 h The final reaction mixture was heated to 50°C for another 12 h The solution was washed with 20% acetic acid/water and extracted with diethylether (3 x 50 mL) The organic extracts were washed with water (3 x 200 mL), dried over anhydrous sodium sulfate, and the solvent was evaporated under vacuum The residue was chromatographed on a silica gel column, using 30% petroleum ether in dichloromethane for elution The desired product was collected and recrystallized from dichloromethane/methanol to yield 48 mg (62%) of the title compound (97% based on recovered starting material, obtained in 36% yield), mp = 298-299°C UV-Vis λ_{max} 412 nm (ε 189 500), 516 (14 700), 556 (28 000), 578 (19 700) and 636 nm (4 900), NMR δ_H 11 47 (s, 1 H, CHO), 10 95, 10 01, 9 95 and 9 93 (all s, 4 meso-H), 4 33 (q, 2 H, 2-CH_2 of Et), 3 98-4 15 (overlapping q, 12 H, CH_2 of Et), 1 89-1 97 (overlapping t, 21 H, CH_3 of Et), -3 65 (s, br, 2 NH), δ_C 18 76, 18 93, 20 01, 20 05, 20 22 and 30 17 (peripheral Et), 96 40, 96 82, 98 56 and 101 26 (d, 4 meso-C), 133 94-145 20 (br, ring C's), 188 67 (d, CHO), MS m/e (%), $C_{35}H_{42}N_4O$ requires 534 3358 Found 534 3363 (100) and 505 2755 (10), Anal calcd for $C_{35}H_{42}N_4O\ H_2O$ C, 76 05, H, 8 02, N, 10 13 Found C, 76 35, H, 7 87, N, 9 81

2,3,4,5,6,7,8-Heptaethylporphyrin (24). The iron(III) chloride complex of trans-(2-bromovinyl)-heptaethylporphyrin (**10**) (154 3 mg, 0 23 mmol) was added to resorcinol (430 mg, 3 83 mmol) and the two solids were stirred to mix well, under argon With continuous stirring, the reaction mixture was heated to 140°C until both solids melted and then to 165°C for 1 h The dark reaction mixture was allowed to cool down to room temperature before it was dissolved in 10% sulfuric acid/TFA and poured into water The aqueous layer was extracted with dichloromethane (6 x 50 mL) and the organic extracts were neutralized with 20% aqueous sodium bicarbonate (100 mL) and washed with water (3 x 200 mL) After drying over anhydrous sodium sulfate the solvent was evaporated under vacuum and the residue was chromatographed on an alumina (Brockmann Grade V) column (elution with 1 1 petroleum ether/dichloromethane) The main red fraction was collected and crystallized from dichloromethane/methanol to give 80 mg (68%) of the title compound, mp = 266-267°C UV-Vis λ_{max} 399 (ε 183 400), 498 (15 900), 532 (12 000), 566 (9 100) and 618 nm (6 300), NMR δ_H 10 28, 10 26, 10 25 and 10 19 (all s, 4 meso-H), 9 23 (s, br, 1 H, β-H), 4.37 (q, 2 H, CH_2 of Et), 4 23 (overlapping q, 12 H, CH_2 of Et), 2 21 (t, 3 H, CH_3 of Et), 2 05-2 19 (overlapping t, 18 H, CH_3 of Et), -3 62 (s, br, 2 NH), MS m/e (%) 506 5 (100), Anal calcd for $C_{34}H_{42}N_4$ C, 80 59, H, 8 35, N, 11 06 Found· C, 80 55, H, 8 30, N, 11 02

trans-(2-Phenylvinyl)-2,3,4,5,6,7,8-heptaethylporphyrin (25). To a solution of the zinc(II) complex of trans-(2-bromovinyl)-2,3,4,5,6,7,8-heptaethylporphyrin (**10**) (37 5 mg, 0 056 mmol) in dry THF at -78°C under nitrogen, was added anhydrous nickel(II) chloride (0 75 mg, 0 006 mmol), triphenyl phosphine (3 0 mg, 0 01 mmol), and phenyl magnesium chloride (0 70 ml of a 2 M solution in THF, 1 40 mmol) The reaction mixture was allowed to warm up to -3°C and was kept at this temperature for 38 h, under nitrogen and with continous stirring The reaction mixture was quenched with water and the aqueous layer was extracted with dichloromethane (4 x 50 mL) After drying the organic extracts over anhydrous sodium sulfate and evaporation of the solvent under vacuum, the final residue was chromatographed on a silica gel column using 1 2 petroleum ether/dichloromethane for elution The major fast-running red compound was further purified on preparative TLC silica gel plates The title compound was collected and recrystallized from dichloromethane/methanol to give 16 5 mg (50%), mp = 238-239°C UV-Vis λ_{max} 404 (ε 163 900), 506 (14 000), 544 (17 400), 572 (11 300) and 628 nm (6 100), NMR δ_H 10 35 and 10 18 (s, 1 H each, 2 meso-H), 10.11 (s, 2 meso-H), 8 66 (d, 1 H, C<u>H</u>=CH-Ph, J = 16 5 Hz), 7 79 (d, 1 H, CH=C<u>H</u>-Ph, J = 16 5 Hz), 7 99 (d, 2 H, *ortho*-phenyl H's, J = 7 2 Hz), 7 63 (t, 2 H, *m*-phenyl H's, J = 7 5 Hz), 7 48 (t, 1 H, *p*-phenyl H, J = 7 2 Hz), 4 06-4 32 (overlapping q, 14 H, CH_2 of Et), 1 90-2 05 (overlapping t, 21 H, CH_3 of Et), -3.62 (br, 2 NH), δ_C 18 51, 18 89, 18 99, 20 16, 20 24 and 20 86 (overlapping t and q, CH_2 and CH_3 of Et), 96 80 (d, 2 meso-C), 97 33 and 98 20 (d, 2 meso-C), 122 91 and 135 34 (d, 2 vinyl C's), 127 15 and 129 39 (d, 2 C each, *o*- and *m*-Cs of phenyl), 128 19 (d, *p*-C of phenyl), 138 99 (s, C-1 of phenyl), 134 50-144 00 (br, ring Cs), HRMS m/e (%), $C_{42}H_{48}N_4$ requires 608 3879 Found 608 3863 (100), Anal calcd for $C_{42}H_{48}N_4$ C, 82 84, H, 7 95, N, 9 20 Found C, 82 67, H, 7 96, N, 9 13

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