168.3, 163.6, 156.6, 143.1, 128.4 (2 C), 127.8, 125.6 (2 C), 111.5, 104.6, 72.9, 44.8, 39.6, 27.3, 17.6, 11.4.

Anal. Calcd for $C_{17}H_{20}O_3$: C, 74.97; H, 7.40. Found: C, 74.78; H, 7.45.

6-(1-Methylpropyl)-4-(2-oxo-2-phenylethyl)-2*H*-pyran-2-one (7c). The general procedure was employed, and the enolate (0.20 mmol) was reacted with benzoyl chloride (0.03 mL, 0.26 mmol, 1.3 equiv) at −78 °C, stirred for 15 min, and then quenched with 1 mL of 2 M HCl. Workup and purification by MPLC (R_f 0.28; petroleum ether/20% ethyl acetate, v/v) afforded a 69% yield: IR 3050 (m), 3000 (vs), 2970 (m), 1715 (vs), 1690 (m), 1550 (m), 1520 (m), 1480 (m), 1420 (m) cm^{-1}; NMR δ 0.87 (t, J = 7.32 Hz, 3 H), 1.21 (d, J = 6.84 Hz, 3 H), 1.58 (p, J = 7.08 Hz, 2 H), 2.44 (sext, J = 6.84 Hz, 1 H), 4.08 (s, 2 H), 5.95 (br s, 1 H), 6.05 (br s, 1 H), 7.45–7.65 (m, 3 H), 7.90–8.03 (m, 2 H); ^{13}C NMR δ 194.6, 168.8, 162.7, 152.4, 135.9, 133.7, 128.7 (2 C), 128.2 (2 C), 112.4, 104.1, 44.4, 39.7, 27.3, 17.6, 11.4; mass spectrum, m/e 270.1264 (M^+) (calcd for $C_{17}H_{18}O_3$ 270.1256).

6-Butyl-4-ethyl-2*H*-pyran-2-one (8). The general procedure was employed with the exception that the enolate (0.30 mmol) was treated with methyl iodide (0.06 mL, 0.96 mmol, 3.2 equiv) at −78 °C, warmed to −30 °C over 1 h, and then quenched with 1 mL of 2 M HCl. Workup and MPLC purification (R_f 0.65; petroleum ether/20% ethyl acetate, v/v) afforded an 80% yield: IR 3010 (m), 2970 (s), 2940 (s), 2870 (m), 1715 (br, vs), 1640 (s), 1565 (s), 1465 (m), 1435 (m) cm^{-1}; NMR δ 0.93 (t, J = 6.10 Hz, 3 H), 1.18 (t, J = 7.45 Hz, 3 H), 1.28–1.85 (m, 4 H), 2.17–2.65 (m, 4 H), 5.88 (br s, 1 H), 5.95 (br s, 1 H); ^{13}C NMR δ 164.9, 163.5, 161.5, 108.8, 104.5, 33.3, 28.8, 28.1, 22.0, 13.6, 12.1; mass spectrum m/e 180.1150 (M^+) (calcd for $C_{11}H_{16}O_2$ 180.1160).

5,6-Dimethyl-4-(1-methylethyl)-2*H*-pyran-2-one (9) and 4,6-Diethyl-5-methyl-2*H*-pyran-2-one (10). The general procedure was employed. Workup and MPLC purification (R_f 0.22; hexane/20% ethyl acetate, v/v) afforded a 54% yield of **9** and **10** as a 73:27 mixture determined by the average value obtained from NMR integrations and relative peak heights of three absorption pairs. **9**: IR 1720 (vs) cm^{-1}; NMR (200 MHz) δ 1.17 (d, J = 6.8 Hz, 6 H), 1.97 (s, 3 H), 2.25 (s, 3 H), 2.82 (sept, J = 6.8 Hz, 1 H), 6.06 (s, 1 H); mass spectrum, m/e (relative intensity) 166 (17, M^+), 138 (34, $M^+ - CO$), 123 (75, $M^+ - CO - {}^{\bullet}Me$), 95 (12, $C_7H_{11}^+$; cyclopropenium ion), 43 (100, $C_3H_7^+$). **10**: NMR δ 1.22 (t, partly obscured, 3 H), 1.26 (t, partly obscured, 3 H), 1.95 (s, 3 H), 2.44 (qd, J = 1.08 Hz, J = 7.39 Hz, 2 H), 2.56 (q, J = 7.52 Hz, 2 H), 6.03 (s, 1 H); mass spectrum, m/e (relative intensity) 137 (7, $M^+ - {}^{\bullet}C_2H_5$), 109 (11, $M^+ - CO - {}^{\bullet}C_2H_5$), 81 (6, $C_6H_9^+$; cyclopropenium ion).

4-Ethyl-6-methyl-2*H*-pyran-2-one (11) and 6-Ethyl-2-methyl-2*H*-pyran-2-one (12). The general procedure was employed. Workup and MPLC purification gave a 53% yield of **11** and **12** as a 77:23 mixture determined by the average value obtained from NMR integrations and relative peak heights of six absorption pairs. GC analysis (10 ft, Carbowax 20M, 130–200 °C, 30 mL/min) indicated an 85:15 ratio of products. **11**: NMR (200 MHz) δ 1.18 (t, J = 7.5 Hz, 3 H), 2.23 (s, 3 H), 2.41 (qd, J = 1.01 Hz, J = 7.5 Hz, 2 H), 5.89 (br s, 1 H), 5.97 (br s, 1 H); mass spectrum m/e (relative intensity) 138 (27, M^+), 123 (10, $M^+ - {}^{\bullet}Me$), 110 (56, $M^+ - CO$), 95 (100), 67 (51, ethylcyclopropenium ion). **12**: NMR δ 1.23 (t, J = 7.6 Hz, 3 H), 2.14 (d, J = 1.33 Hz, 3 H), 2.51 (q, J = 7.6 Hz, 2 H), 5.86 (br s, 1 H), 5.97 (br s, 1 H); mass spectrum, m/e (relative intensity) 138 (50, M^+), 109 (100, $M^+ - {}^{\bullet}C_2H_5$), 95 (72), 53 (70, methylcyclopropenium ion).

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Registry No. **1**, 106319-08-8; **2**, 106319-09-9; **3**, 55510-46-8; **4**, 4467-35-0; **5**, 675-09-2; **6a**, 106319-14-6; **6b**, 106319-15-7; **6c**, 106319-16-8; **6d**, 106319-17-9; **6e**, 106319-18-0; **7a**, 106319-10-2; **7b**, 106319-19-1; **7c**, 106319-20-4; **8**, 106319-11-3; **9**, 106319-12-4; **10**, 2551-31-7; **11**, 106319-13-5; **12**, 17422-71-8; PhCHO, 100-52-7.

A Novel Method of Functionalizing the Ethyl Chain of Octaethylporphyrin

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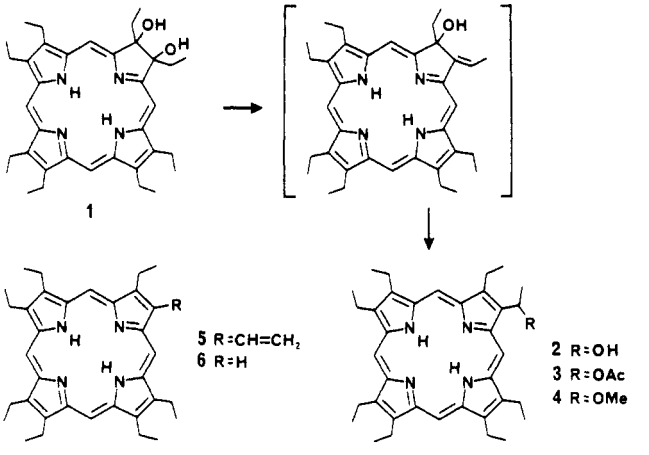
Octaethylporphyrin (OEP), by virtue of its symmetry, high solubility in organic solvents, and excellent spectroscopic correspondence with that of biological heme/porphyrins, has a special place in porphyrin chemistry. Numerous important discoveries concerning heme structure and function can be credited to model studies based on OEP and its metal complexes.[1] The lack of functional groups on OEP, nevertheless, can hinder its application in studies wherein some manipulation of side chains would be required. In such cases, it is often a choice between total synthesis, which is usually lengthy and of low yield, and the natural protoporphyrin or its derivatives, which on the other hand may have too many functional groups all at once. We report here a simple method to functionalize the ethyl chain of OEP so that the broad range of chemical transformations[2] ascribed for the vinyl group of protoporphyrin would become accessible to OEP.

In the study of *vic*-dihydroxychlorins[3] (obtained from OsO_4 oxidation of porphyrins[4]), it was observed that the green pigment often turns grayish brown during heating in aqueous acid. The product is usually a mixture comprising red porphyrins and some purple porphyrinone derived from pinacolic rearrangement of the diol.[5,6] With OEP-diol (**1**), the major porphyrin component is OEP-



alcohol (**2**). This compound is presumably derived via hydration of an ethenylhydroxychlorin intermediate. An analogous reaction has been observed previously in a *vic*-dihydroxybacteriorchlorin.[7] The aqueous acid/dioxane medium employed in the earlier report,[7] however, failed

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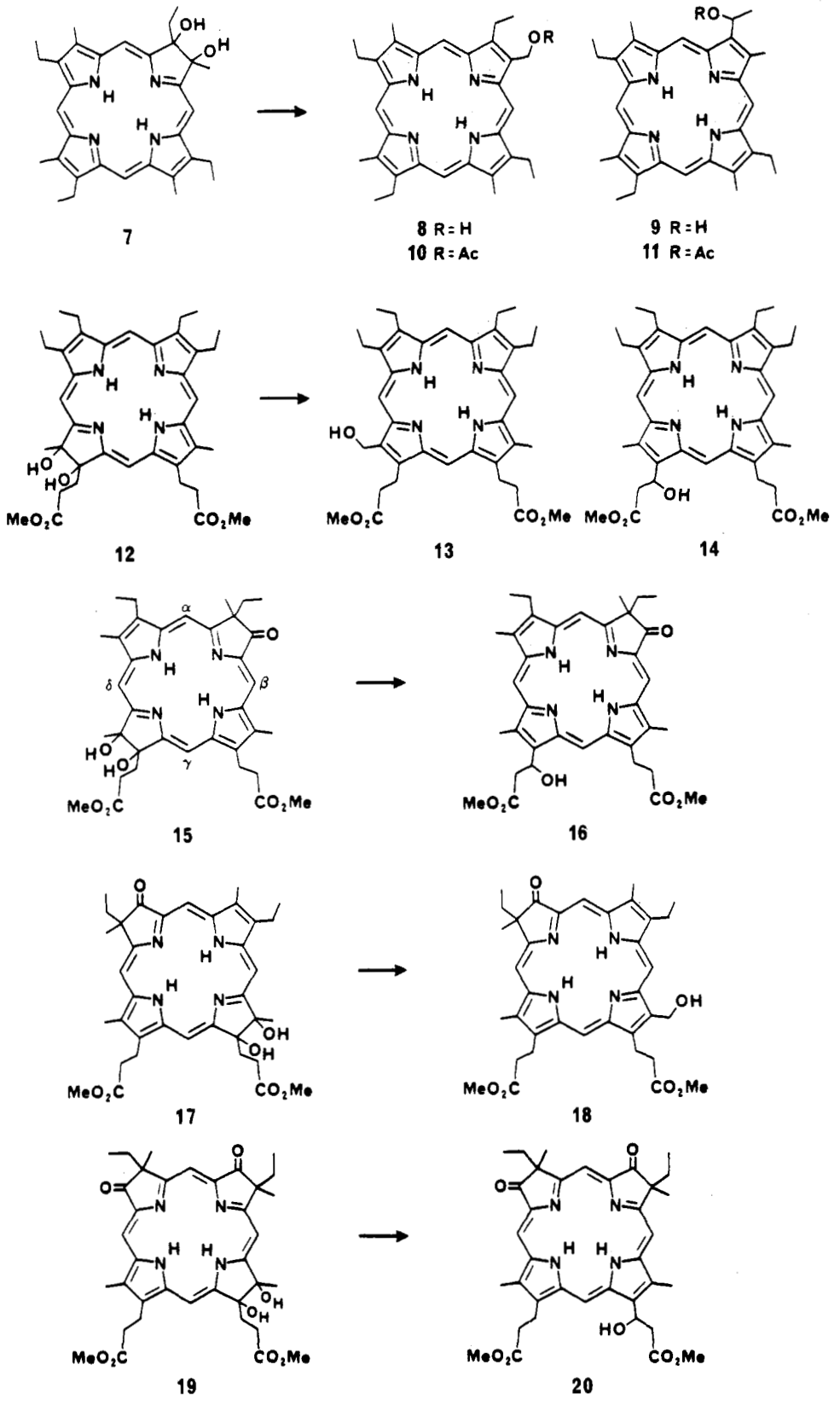
0022-3263/87/1952-0926$01.50/0

Scheme I



to give clean products with a variety of chlorin-*vic*-diols; yields of the porphyrin side-chain alcohols were never greater than 50%. The reaction seemed highly sensitive to the acid concentration: dilute acid gave insufficient reaction while too strong an acid only led to pinacol rearrangement. To improve the reaction, other nucleophilic media were tested. When **1** was dissolved in glacial acetic acid and heated at 90 °C, the acetoxy **3** was obtained withtin 10 min in 85% yield. Likewise, if **1** in methanol was heated in the presence of HCl, the methoxy **4** can be isolated in >75% yields. Both **3** and **4**, of course, can serve as starting point for further derivatizations. Vinylation may also be achieved in a single step (90–95% yield) by heating **1** in benzene containing HCl. As **1** can be prepared readily from OEP by OsO_4 oxidation, the simple preparation of **5** therefore offers expeditious synthetic routes to

a wide range of monosubstituted heptaethylporphyrins having, for instance, Br,[8] CN,[9] CHO,[2,10] $COCH_3$,[2] $CH{=}CHCO_2R$,[9,11] CH_2OH,[12] CH_2CH_2OH,[13] $CH_2CH_2CO_2R$,[13] plus other moieties attached via these groups. The Experimental Section includes a procedure for making **6** by devinylating **5**. It was also observed that the preparation of **2**–**6** can be scaled up without lowering the yield.

When the above procedures are applied to other *vic*-diols with dissimilar alkyl chains, two products are expected. Indeed, dihydroxyetiochlorin (**7**) has been found to yield the two alcohols **8** and **9** or the two acetoxyetioporphyrins **10** and **11** under appropriate conditions. The same is true with porphyrins bearing methyl and propionate substituents (e.g., **13** and **14**). While the ratio of the two possible products, varies from case to case, the methyl group appears to be the more favorable site of attack, at least with common dihydroxychlorins. Such a result would suggest that the reaction is subject more to kinetic control. However, with porphyrinones,[14] the course of reaction can be entirely dependent upon the symmetry of the molecule. For example, diol **15** gave **16** whereas **17** gave **18** (Scheme I); in each case the alternative alcohol was absent. Likewise, in our recently reported synthesis of heme-d_1 analogue, **19** gave *exclusively* **20** before it was dehydrated to the acrylate.[15] In these cases, the stability of the exocyclic alkene intermediate seems to be the determinant factor. The specificity associated with these molecules further suggests that the mild elimination–hydration of *vic*-diol (or an epoxide precursor) may have some biosynthetic significance. We speculate that the acrylate group of heme-d_1 is indeed produced biosynthetically from a propionate side chain by this route. The demonstrated conversion[7] from chlorophyll *a* to chlorophyll *b* via a *vic*-diol could be a viable biosynthetic pathway. As for the heme *a* moiety of cytochrome oxidase,[16] the 8-carboxaldehyde group could come from a CH_3, not by harsh direct oxidation but by way of CH_2OH resulted from the *vic*-diol. These hypotheses possibly can be tested by future experiments.

Experimental Section

NMR spectra ($CDCl_3$, Me_4Si internal standard) were obtained with a Bruker WM-250 instrument. High-resolution mass spectra were obtained with a JEOL HX110-HF instrument equipped with a fast atom bombardment gun. A matrix of thioglycerol–dithioerythreitol–dithiothreitol (2:1:1) containing 0.1% trifluoroacetic acid was used. Visible absorption spectra (in CH_2Cl_2) were measured with a Cary 219 spectrophotometer. Preparative TLC plates were from Analtech (Silica gel G, 1500 μm).

***vic*-Dihydroxyoctaethylchlorine (1).** To a solution of OEP[17] (1.168 g, 2.2 mmol) in CH_2Cl_2 (250 mL) and pyridine (1 mL) was added osmium tetroxide (1.0 g, 3.9 mmol) in diethyl ether (10 mL). The mixture was allowed to stir at room temperature in the dark for 2 days. This mixture was diluted with methanol (50 mL) and was bubbled with H_2S for 15 min. The precipitated osmium sulfide was recovered by filtration, and the solvent was evaporated. The residue was triturated with methanol, which dissolved most of the diol chlorin from unreacted OEP. The solution was filtered, and the product was further purified on a silica gel column, eluting with CH_2Cl_2 containing 0.5% of methanol: yield 827 mg (66.6%) plus unreacted OEP [201 mg (17.1%)]; NMR δ 0.96 (6 H, t, pyrroline Et), 1.74 (18 H, t, Et), 2.55 (4 H, q, pyrroline Et), 3.38 (2 H, s, OH), 3.79, 3.82, 3.91 (12 H, q, Et), 9.00 (2 H, s, meso α,β), 9.68 (2 H, s, meso γ,δ), −2.68 (2 H, br s, NH); UV–vis λ_{max} (ϵ_M) 643 nm (54 000), 590.5 (9700), 523.5 (8700), 496 (19 900), 392 (206 000); MS, found *m/e* 569.3887 for $(M + H)^+$, $C_{36}H_{49}N_4O_2$ requires *m/e* 569.3858. The dihydroxylation of OEP with OsO_4 was found to proceed poorly under catalytic conditions, e.g. using *N*-methylmorpholine oxide.[18]

1-(1-Hydroxyethyl)-2,3,4,5,6,7,8-heptaethylporphine (2). Diol **1** (20 mg, 0.035 mmol) was heated in a mixture consisting of dioxane (6 mL), water (3.5 mL), and concentrated HCl (0.5 mL) on a steam bath for 30 min. The mixture was then evaporated to dryness, and the residue was separated on preparative TLC plates with CH_2Cl_2 as solvent. The major product, **2**, was further crystallized from CH_2Cl_2/hexane: yield 9.7 mg (49%); NMR δ 1.90, 1.91 (21 H, t, Et), 2.34 (3 H, d, $CH(OH)CH_3$), 2.78 (1 H, br s, OH), 4.06, 4.12 (14 H, q, Et), 6.56 (1 H, q, $CH(OH)CH_3$), 10.08 (2 H, s, meso), 10.10, 10.62 (1 H each, s, meso), −3.73 (2 H, br s, NH); UV–vis λ_{max} 620.5 nm, 566.5, 533, 500, 400; MS, found *m/e* 551.3726 for $(M + H)^+$, $C_{36}H_{47}N_4O$ requires *m/e* 551.3753.

1-(1-Acetoxyethyl)-2,3,4,5,6,7,8-heptaethylporphine (3). Diol **1** (20 mg, 0.035 mmol) was heated in glacial acetic acid (5 mL) at 90 °C for 10 min. The reaction mixture was partitioned in CH_2Cl_2 and water; the organic layer was separated and evaporated. The residue was recrystallized from CH_2Cl_2/MeOH: yield 17.8 mg (85%) [note: Upon purification on TLC plates using CH_2Cl_2/MeOH, **3** was largely converted to the methoxide **4**. Silica gel promoted solvolysis is a facile reaction for acetylated hematoporphyrins and, thus, contributes to the complexity in structural analyses of the photodynamic drug hematoporphyrin derivative (HPD).[19]]; NMR δ 1.95 (21 H, t, Et), 2.30 (3 H, s, acetyl), 2.41 (3 H, d, $CHCH_3$), 4.09, 4.16, 4.20 (14 H, q, Et), 7.53 (1 H, q, $CHCH_3$), 10.12 (2 H, s, meso), 10.16, 10.52 (1 H each, s, meso), −3.70 (2 H, br s, NH); UV–vis λ_{max} (ϵ_M) 620 nm (9400), 567 (12 000), 536 (15 300), 500 (17 300), 401 (156 000); MS, found *m/e* 593.3873 for $(M + H)^+$, $C_{38}H_{49}N_4O_2$ requires *m/e* 593.3858.

1-(1-Methoxyethyl)-2,3,4,5,6,7,8-heptaethylporphine (4). Diol **1** (20 mg) was heated to reflux for 1 h in methanol (20 mL) with 1 drop of concentrated HCl. The solvent was then evaporated, and the residue was crystallized from CH_2Cl_2/MeOH: yield 15.4 mg (77.5%); NMR δ 1.93 (21 H, t, Et), 2.32 (3 H, d, $CHCH_3$), 3.62 (3 H, s, OMe), 4.08, 4.14 (14 H, q, Et), 5.96 (1 H, q, $CHCH_3$), 10.10 (2 H, s, meso), 10.12, 10.66 (1 H each, s, meso), −3.70 (2 H, br s, NH); UV–vis λ_{max} (ϵ_M) 620.5 nm (9200), 566.5 (11 500), 533 (14 700), 499 (18 300), 399.5 (172 000); MS, found *m/e* 565.3888 for $(M + H)^+$, $C_{37}H_{49}N_4O$ requires 565.3909.

1-Vinyl-2,3,4,5,6,7,8-heptaethylporphine (5). Diol **1** (100 mg, 0.175 mmol) was heated to reflux in benzene (25 mL) containing 5 drops of concentrated HCl for 3 h. The solvent was evaporated, and the residue was crystallized from CH_2Cl_2/MeOH: yield 85 mg (90%); NMR δ 1.91, 1.93 (21 H, t, Et), 4.09, 4.16, 4.22 (14 H, q, Et), 6.16, 6.38 (2 H, dd, $CH{=}CH_2$), 8.25, 8.31 (1 H, dd, $CH{=}CH_2$), 10.12 (2 H, s, meso), 10.16, 10.28 (1 H each, s, meso), −3.68 (2 H, br s, NH); UV–vis λ_{max} (ϵ_M) 623.5 nm (10 000), 569.5 (14 700), 539 (19 300), 503 (20 000), 402.5 (179 000); MS, found *m/e* 533.3641 for $(M + H)^+$, $C_{36}H_{45}N_4$ requires *m/e* 533.3647.

1,2,3,4,5,6,7-Heptaethylporphine (6). Solid vinylporphyrin **5** (60 mg, 0.113 mmol) was mixed and ground with resorcinol (240 mg, 2.18 mmol) in a mortar. The powder placed in a test tube was swirled over a flame until boiling. The mixture was cooled momentarily and then heated again to boiling. This cycle was

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repeated three times, and the residue, after cooling, was extracted with CH_2Cl_2 and water. The porphyrin in the organic phase was purified by crystallization from CH_2Cl_2/MeOH: yield 51 mg (89%); NMR δ 1.98 (15 H, t, Et), 2.10 (6 H, t, Et), 4.16 (10 H, q, Et), 4.30 (4 H, q, Et), 9.16 (1 H, s, 8-H), 10.11, 10.16, 10.18, 10.20 (1 H each, s, meso); UV-vis λ_{max} (ϵ_M) 618.5 nm (9700), 565 (13 000), 531.5 (16 300), 498 (21 000), 398.5 (215 000); MS, found m/e 507.3457 for $(M + H)^+$, $C_{34}H_{43}N_4$ requires m/e 507.3491.

Reactions of *vic*-Dihydroxyetiochlorin I (7). Diol 7[5] was heated in dioxane/aqueous HCl in the same manner as described above. The overall yield for the two etioporphyrin alcohols was about 50%, with the ratio of 8 to 9 being near 2:1. If the diol 7 was heated in acetic acid, the acetoxy porphyrin 10 was obtained in 67% yield and 11 in 11% yield (6:1 ratio). These ratios can be observed directly by using NMR peaks of CH_2OR vs. CH(OR)Me: δ 6.10 (s, 8):6.52 (q, 9) = 4:1; 6.61 (s, 10):7.55 (q, 11) = 12:1.

Dimethyl 5-(Hydroxymethyl)-8-methyl-1,2,3,4-tetraethyl-6,7-porphinedipropionate (13). Diol 12[3] (40 mg) was heated in dioxane (10 mL)/aqueous HCl (10%, 4 mL) on a steam bath overnight. The solvent was evaporated, and the residue was esterified in $MeOH/H_2SO_4$. The principal product, isolated from TLC plates, was 13: 9.8 mg (~25% yield); NMR δ 1.90 (12 H, t, Et), 3.26 (4 H, t, $CH_2CH_2CO_2$), 3.49 (3 H, s, CH_3), 3.61, 3.66 (3 H each, s, CO_2Me), 4.05, 4.11 (8 H, q, Et), 4.42, 4.45 (2 H each, t, $CH_2CH_2CO_2$), 6.11 (2 H, s, CH_2OH), 10.06 (2 H, s, meso), 10.08, 10.28 (1 H each, s, meso), -3.78 (2 H, br s, NH); UV-vis λ_{max} 621.5 nm, 567, 535.5, 499.5, 402; MS, found m/e 639.3521 for $(M + H)^+$, $C_{38}H_{47}N_4O_5$ requires m/e 639.3549. The alternative alcohol 14 was not detected, but a small amount of acrylic porphyrin [~5% yield; NMR δ 7.05, 7.11, 9.28, 9.36, acrylic] was isolated, which can only result from 14.

Reactions of *vic*-Diols of Porphyrinones 15 and 17 (*Contributed by Weishih Wu*). Diol 15 was obtained by OsO_4 oxidation of 4-mesoporphyrinone dimethyl ester.[14] Like all other "southern" diols, 15 has a tendency to lactonize if left on silica gel; therefore, chromatography was carried out on a short column and as rapidly as possible: MS, found m/e 645.3299 for $(M + H)^+$, $C_{36}H_{45}N_4O_7$ requires m/e 645.3290; NMR δ 0.41 (3 H, t, 3-Et), 1.69 (3 H, t, 2-Et), 1.88 (3 H, d, 8-Me), 2.05 (3 H, s, 3-Me), 2.61 (2 H, m, 3-Et), 2.7-2.9 (4 H, m, 7-$CH_2CH_2CO_2$), 3.03, 4.05 (2 H each, q, 6-$CH_2CH_2CO_2$), 3.28, 3.34 (3 H each, s, 1- and 5-Me), 3.62, 3.65 (3 H each, s, OMe), 3.80 (2 H, q, 2-Et), 8.70, 8.85, 8.88, 9.52 (meso), -2.0 (NH); UV-vis λ_{max} 688 nm, 496, 413, 395. 15 was heated in a mixture of dioxane (6 mL), H_2O (3.5 mL), and concentrated HCl (0.5 mL) on a steam bath for 30 min. Since the resultant alcohol 16 was partially dehydrated, it was heated for further 10 min in the presence of concentrated H_2SO_4 (1 mL) to complete dehydration. The mixture was evaporated in a rotorvap as much as possible, and the residue was diluted in dry methanol (30 mL). After being allowed to overnight at room temperature, the solvent was evaporated and the acrylate ester product was purified by TLC (CH_2Cl_2): yield was about 85% from 15; NMR of the acrylate, δ 0.45 (3 H, t, Et saturated), 1.81 (3 H, t, Et), 2.06 (3 H, s, Me saturated), 2.76 (2 H, q, Et saturated), 3.23 (2 H, t, $CH_2CH_2CO_2$), 3.57, 3.58, 3.62 (3 H each, s, Me), 3.68 (3 H, s, propionate OMe), 3.99 (2 H, q, Et), 4.05 (3 H, s, acrylate OMe), 4.38 (2 H, t, $CH_2CH_2CO_2$), 6.98, 7.04 (1 H, dd, =$CHCO_2$), 9.12 (1 H, s, meso α), 9.19, 9.26 (1 H, dd, CH=$CHCO_2$), 9.80 (1 H, s, meso β), 9.87, 10.02 (1 H each, s, meso γ,δ), -2.89, -2.76 (1 H each, br s, NH); UV-vis λ_{max} 643 nm, 586, 567, 506, 415; MS, found m/e 609.3098 for $(M + H)^+$, $C_{36}H_{43}N_4O_6$ requires m/e 609.3079.

Diol 17 [NMR δ 1.88 (3 H, d, 5-Me), 2.22 (3 H, d, 1-Me), 8.79, 8.95, 8.91, 9.55 (meso); UV-vis λ_{max} 693 nm, 660, 633, 497, 414, 395], obtained from OsO_4 oxidation of 2-mesoporphyrinone dimethyl ester,[14] was heated in dioxane/aqueous HCl as described above. After esterification, the alcohol 18 was isolated from TLC plates: 78% yield; NMR δ 0.41 (3 H, t, Et saturated), 1.81 (3 H, t, Et), 2.06 (3 H, s, Me saturated), 2.76 (2 H, q, Et saturated), 3.29, 3.30 (2 H each, t, $CH_2CH_2CO_2$), 3.58, 3.67 (3 H each, s, Me), 3.68, 3.72 (3 H each, s, CO_2Me), 4.04 (2 H, q, Et), 4.34, 4.40 (2 H each, t, $CH_2CH_2CO_2$), 5.78 (2 H, d, CH_2OH), 9.14 (1 H, s, meso δ), 9.83 (1 H, s, meso α), 9.95, 10.14 (1 H each, s, meso β,γ), -2.93 (2 H, br s, NH); UV-vis λ_{max} 640 nm, 582, 552, 512, 504, 410; MS, found m/e 627.3196 for $(M + H)^+$, $C_{36}H_{43}N_4O_6$ requires m/e 627.3184.

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Kinetics and Mechanisms of Reactions of (Trialkylstannyl)lithiums with Chlorides Bearing Activating α Substituents

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In 1946 Whitmore and Sommer observed that (chloromethyl)trimethylsilane (1) (see Table I for structures) reacted somewhat more rapidly than did 1-chlorobutane with acetate, hydroxide, and ethoxide in protic solvents and with sodium iodide in dry acetone.[1] In contrast, they observed that 1 did not react with aqueous silver nitrate under conditions which led to ready reaction with 1-chlorohexane. Eaborn, in a series of studies,[2] examined the kinetics of the reaction of 1 with sodium iodide in acetone at 49.7 °C and found that its specific rate constant was 16 times that for 1-chlorobutane.[2a] The rate for (chloromethyl)trimethylstannane (2) was 360 times that for 1.[2c] Silylcarbinyl derivatives are generally less reactive than carbon analogues in solvolyses,[2d,3] but the reactivity can be reversed if the solvent is sufficiently nucleophilic.[3] These effects are consistent with theoretical treatments which show that an α-silyl group destabilizes a positive and stabilizes a negative charge on a carbinyl carbon.[3,4]

We have been conducting kinetic studies in connection with research on the mechanisms of reactions of organostannylalkalis with organic halides, eq 1. Such studies

$$RCHR'Cl + R''_3SnLi \rightarrow RCHR'CHSnR''_3 + LiCl \quad (1)$$

should provide information concerning structure/reactivity relationships in nucleophilic substitutions involving nucleophiles with much greater reactivity than those which are normally studied. This reactivity can be maximized for reactions in solution because the dipolar aprotic solvents used have little capacity for solvating anions. It was of particular interest to obtain additional quantitative data concerning the activation by the silyl and stannyl groups and to compare these with other activating groups such as the phenyl and vinyl groups in benzylic and allylic derivatives, respectively. We also report on the enhanced reactivities of geminal and vicinal dichlorides as mechanistic indicators.

The products of the reactions studied were either known or were characterized by standard methods. Rates were measured in a stop-flow system which permitted reliable measurements of bimolecular rate constants in the range 10^{-1} to 10^3 M^{-1} s^{-1}. Pseudo-first-order conditions with excess halide were used and the rate constants were based on data covering more than 4 half-lives in all cases.

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