

## Synthesis and Structure of *N,N'*-Bridged Porphycene

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Porphycene, a structural isomer of porphyrin, reacts with the Vilsmeier reagent (DMF-POCl<sub>3</sub>) to give a one-carbon bridge between two pyrrolic nitrogens; this new structure is characterized by NMR and X-ray crystallography.

Porphycene, a structural isomer of porphyrin, was first synthesized in 1986.<sup>1,2</sup> While this aromatic tetrapyrrolic macrocycle resembles porphyrin in many chemical and spectroscopic aspects, it possesses a smaller cavity size in comparison with porphyrin. In porphycene the four nitrogen atoms form a rectangle, the sides of which are 2.83 and 2.63 Å in length, as compared to a typical porphyrin's 2.89 Å square.<sup>2</sup> The unique shape and size of the porphycene core may therefore be the cause of interesting properties of its metal complexes as well as of the ligand.<sup>3</sup> We here report an unusual reactivity of porphycene toward the Vilsmeier reagent.

When the cupric complex of 2,7,12,17-tetrapropylporphycene (PPc) was treated with the Vilsmeier reagent prepared from DMF and POCl<sub>3</sub>, instead of the expected formylation product(s), a blue-green compound was isolated which contained no copper ion and which exhibited sharp <sup>1</sup>H NMR signals in the upfield region. This same product could also be obtained in 92% yield by reacting free base PPc and DMF-POCl<sub>3</sub>. Mass spectral analysis of this product gave a *m/z* of 534 (*M* + 1) and <sup>1</sup>H NMR data [ $\delta$  -5.06 (s, 1 H), -1.78 (s, 6 H), 1.29 (t, 12 H), 2.40 (m, 8 H), 3.98 (t, 4 H), 4.15 (t, 4 H), 9.67 (s, 2 H), 9.98 (s, 2 H), 10.07 (s, 2 H), 10.34 (s, 2 H)] supportive of the *N,N'*-bridged structure **1**. *N,N'*-Methylene bridged porphyrins have been prepared previously either from reactions between porphyrins and dichlorocarbene<sup>4</sup> or by a rearrangement of the diazoacetate adduct of Co<sup>II</sup> porphyrins.<sup>5</sup> Yields of such products are not high and the bridging group is rather labile, having a tendency to cleave one or both N-C bonds. In contrast,

the *ortho*-amidate structure of PPc is quite stable in the presence of aqueous acids and bases; only concentrated sulfuric acid could destroy the bridging group. This bicyclic macrocycle has a very low affinity for metal chelation. In an effort to prepare a Cu<sup>II</sup> complex, **1** was heated to reflux with Cu(ClO<sub>4</sub>)<sub>2</sub> in acetonitrile. After the solvent was evaporated, the macrocycle was found to be unchelated. However, this treatment resulted in the production (85%) of a new compound **2** with only one methyl group left on the protruding nitrogen. The loss of one methyl group may be analogous to the metal-assisted demethylation observed in *N*-methyl Cu<sup>II</sup> porphyrins.<sup>6</sup> The structure of this monomethyl-substituted bridging PPc has been characterized by single crystal X-ray diffraction method. The X-ray structure† (Fig. 1) revealed a relatively strain-free seven-membered ring created by the bridging carbon. While the N(2)-N(3) distance of 2.53(3) Å is not significantly different from the non-bridging N(1)-N(4) distance of 2.38(4) Å, it is much shorter than the N(1)-N(2) [2.95(5) Å] or the N(3)-N(4) [3.02(5) Å] separation. The excellent fit of the bridging carbon with the pair of closely spaced pyrrolic nitrogen atoms helps the porphycene macrocycle to retain a high degree of planarity. The bridgehead H on C(33) is only 0.89(7) Å above the centre of the porphycene core, which explains the extreme upfield NMR shift for this proton.

We discovered that this reaction is generally applicable when substituted formamides are used to prepare the Vilsmeier reagent. For example, the reaction with *N*-methylformanilide-POCl<sub>3</sub> gave **3** (95% yield); <sup>1</sup>H NMR  $\delta$  -5.99 (s, 1H), -2.11 (s, 3 H), 3.07 (d, 2 H), 5.92 (t, 2 H) and 6.41 (t, 1 H) for the bridging moiety. The reaction worked equally well with 4-formylmorpholine and POCl<sub>3</sub> in dichloroethane to give **4** (93% yield); <sup>1</sup>H

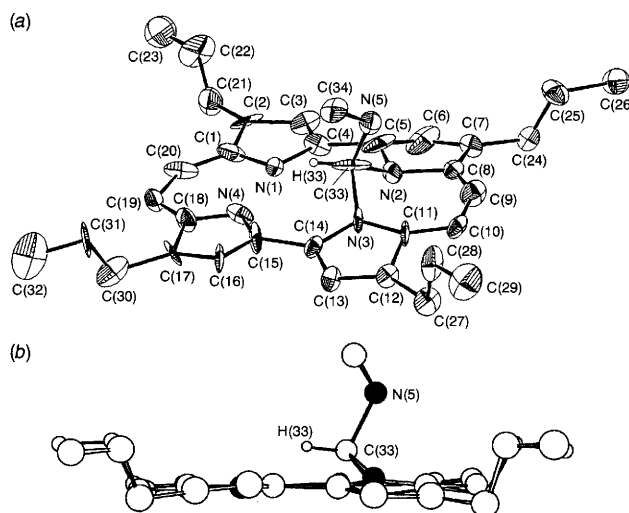
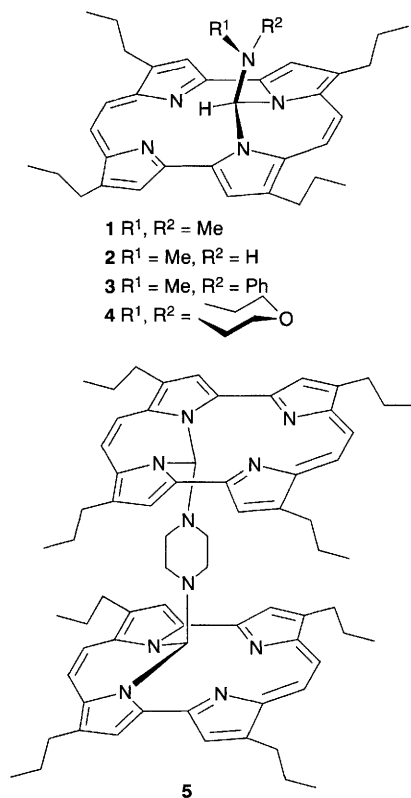


Fig. 1 (a) ORTEP drawing and numbering scheme for **2**. (b) Side view showing the macrocyclic planarity. The *N*-alkylated porphycenes tend to form a greasy film; the crystal used was obtained by slow evaporation of benzene solution and was not of very high quality. Selected bond distances (Å) and angles (°): N(2)-C(33) 1.47(4), N(3)-C(33) 1.669(24), N(5)-C(33) 1.514(24), N(2)-C(33)-N(3) 107.4(16), N(2)-C(33)-N(5) 112.8(20), N(3)-C(33)-N(5) 94.0(13). The dihedral angle between the plane defined by N(1)-C(1)-C(20)-C(19)-C(18)-N(4) and the pyrrole ring N(2)-C(5)-C(6)-C(7)-C(8) is 4.6(8)°, that between the pyrrole ring N(3)-C(11)-C(12)-C(13)-C(14) and the ring N(2)-C(5)-C(6)-C(7)-C(8) is 15.9(9)°.

NMR  $\delta$   $-5.02$  (s, 1 H),  $-2.25$  (br s, 4 H) and  $1.82$  (br s, 4 H) for the bridging methine and the morpholine methylenes, respectively. Another example is the reaction with 1,4-piperazinedicarboxaldehyde- $\text{POCl}_3$  in dichloroethane to yield an interesting doubly bridged dimer **5**. The ratio of the Vilsmeier reagent to PPc was varied from 1 : 2 to 1.6 : 2 but the yield of the dimer was typically less than 40%. Dimer **5** was characterized by FAB-MS (*p*-nitrobenzoic acid matrix,  $m/z$  1063) and NMR; the methine protons were found near  $\delta$   $-5.9$  and the piperazine methylenes were at  $\delta$   $-2.1$ . The two porphycene rings are apparently separated far enough that they do not exhibit any significant rotational barrier about the piperazine bridge as evidenced by NMR, nor do they show the presence of ring-to-ring exciton coupling in the absorption spectrum. We have also examined the reaction of PPc with Vilsmeier reagents prepared from *N,N'*-acetamide or higher carboxamide homologues but found that they are completely unreactive, giving some indication about the limitation of steric bulk that can be tolerated on the bridging carbon.

The visible absorption spectrum of the bridged PPc has an overall appearance of a divalent metal complex of porphycene, particularly that of  $\text{Cu}^{\text{II}}\text{PPc}$ .<sup>3</sup> For example, **1** exhibits (in  $\text{CH}_2\text{Cl}_2$ ) a broadened Soret band near 380 nm ( $\epsilon = 130\,000\text{ dm}^3\text{ mol}^{-1}\text{ cm}^{-1}$ ) and an intense absorption peak at 618 nm ( $\epsilon = 57\,000\text{ dm}^3\text{ mol}^{-1}\text{ cm}^{-1}$ ). The strong absorbance in the visible wavelength combined with the good chemical and photochemical stability should make such simply functionalized derivatives (hydrophilic, cationic, etc.) attractive as photodynamic therapeutic (PDT) reagent.<sup>7</sup>

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### Footnote

† Crystal data for  $(\text{C}_{34}\text{H}_{42}\text{N}_5)^+(\text{ClO}_4)^-\cdot\text{C}_6\text{H}_6$ ; monoclinic, space group  $P2_1/n$ ,  $a = 1.2386(19)$ ,  $b = 19.3352(23)$ ,  $c = 20.250(4)$  Å,  $\beta = 103.547(17)^\circ$ ,  $V = 3897.3(12)$  Å<sup>3</sup>,  $Z = 4$ ; final  $R = 0.125$  and  $R_w = 0.097$ . Protonation was assumed to be at N5, but could take place at other N's. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Information for Authors, Issue No. 1.

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