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Synthesis and X-ray characterization of a new bis-crown ether porphyrin

Lydie Michaudet, Philippe Richard and Bernard Boitrel*

Laboratoire de Synthèse et d'Electrosynthèse Organométalliques, UMR CNRS 5632, 6 Boulevard Gabriel, 21000 Dijon, France

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Abstract

The easy one-step synthesis of a new bis-diaza crown ether porphyrin starting from the widely used αβαβ-tetrakis (*o*-aminophenyl)porphyrin (TAPP αβαβ) allows access to a new family of potential multisite complexing agents. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: crown ethers; general synthesis; ureas; cofacial structure; X-ray crystallography.

Considerable interest has already been devoted to the study of multisite receptors,[1] of cation/anion binding[2] and of the mechanism of single and multimetallic enzymes.[3] Among all the different types of synthetic analogs, a remarkable class is represented by the combination of a porphyrin and a crown ether or related compounds.[4] We ourselves have reported the first synthesis of cyclam-strapped porphyrins, targeting new models of the resting state of cytochrome *c*-oxidase.[5] The most interesting feature with these 'crown-ether porphyrins' is the fact that most of the structural parameters can be changed and adapted almost at will: e.g. the size of the crown ether, the number of oxygen and/or nitrogen atoms, the number of links between the porphyrin and the crown ether, the length of the links and even the size of the porphyrin.[4g] We wish to report herein the synthesis of a novel ligand in which the two sides of the porphyrin are identically functionalized[6] and the crown ether is tethered by only two very short linkers (Scheme 1).

Indeed, the very simple synthesis of porphyrin **2** makes use of a previously published method,[7] which has been shown to be a versatile strategy for attaching to porphyrins different nucleophilic compounds such as diamines, tripodal triamines and alcoholates but surprisingly, no statement about the reaction of cyclic compounds such as cyclam, cyclen or diaza-crown ethers was made. This report outlines the fact that two molecules of diaza-crown ethers can be

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* Corresponding author. E-mail: bboitrel@satie.u-bourgogne.fr

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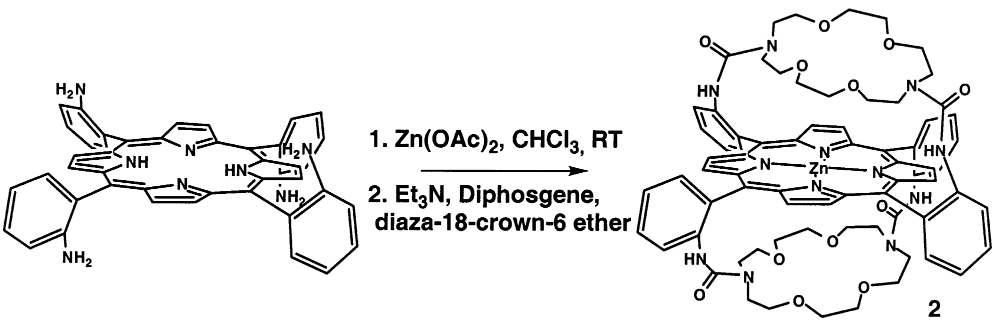

Scheme 1. Synthesis of the Zn bis-crown ether porphyrin **2**

attached to the porphyrin cycle, thus forming a macropentacycle inducing a significant distortion of the porphyrin.

Briefly, as shown above, the atropisomer αβαβ of TAPP was activated by reaction of diphosgene and Et_3N in dry THF as described in the original report, and then condensed with three equivalents of the diaza-18-crown-6 ether. After evaporation of the reactional mixture, the compound was purified by flash chromatography on 15 μm silica gel and eluted as the major band (yield = 30%). Both the free-base and the zinc complex have been synthesized, but in the latter case zinc was firstly introduced at room temperature into the starting TAPP before the final strapping reaction could be achieved. According to the literature,[4f] strongly upfield-shifted chemical shifts should be expected for the different protons of the aliphatic macrocycle. Actually, the three aliphatic resonances usually observed for this type of structure are in our case downfield-shifted. Indeed, when one compares the analogs of porphyrin **2** with either two or one methylene groups in the linker[4f]—instead of zero methylene group in the present case—the three signals are upfield-shifted by at least 1 ppm when the length of the linker decreases by one methylene group. This apparent inconsistency could have a plausible explanation. In our case, the diaza-crown ether is so closely linked to the porphyrin that its (peripheral) protons go through the porphyrin 'magic angle' and are therefore, spatially localized in the downfield-shifting part of the ring current. This observation in solution can be confirmed by the solid-state structure (Fig. 1).

The molecule is located on a fourfold crystallographic rotoinversion axis.[†] The diaza crown ether straps pulling the *meso* carbon atoms (Cm) out of the porphyrin plane, the macrocycle

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[†] Compound **2** crystallized in space group $P4_2/n$ with $a = b = 15.438(1)$, $c = 13.337(1)$ Å. A red crystal with dimensions 0.22×0.07×0.05 mm was mounted on a Nonius kappa-CCD diffractometer. 14 371 reflections (3632 unique, $R_{\mathrm{int}} = 0.047$) were measured at 110 K. The structure was solved by a combination of direct and Patterson methods[8] and all non-hydrogen atoms were refined anisotropically, while all hydrogen atoms were refined with riding isotropic temperature factors. The oxygen atom of the water molecule is located on a fourfold rotoinversion axis and its multiplicity refined to 0.25. This latter value implies that only one water molecule is coordinated to the Zn atom and is disordered over two positions, each on one side of the macrocycle. Hence, the five-coordinated Zn atom is also disordered over both sides of the rotoinversion center (1/2,1/2,1/2) on the –4 axis. However, when refining simultaneously the positional and the anisotropic thermal parameters, the two Zn atoms collapsed to the center of the macrocycle leading to a non-satisfactory chemical model and furthermore, strong residual peaks in the $\Delta\rho$ map indicated a wrong refinement. This difficulty was circumvented by a two-step refinement; the positional and the isotropic thermal parameters of the Zn atom were first successfully refined followed by an anisotropic refinement with fixed coordinate parameters for the Zn atom (during these steps all other non-hydrogen atoms were anisotropically refined). The final refinement residual are $wR2 = 0.099$ (on F^2, all data, 229 parameters), $R1 = 0.050$ (2695 $I > 2\sigma(I)$), G.O.F. = 1.057, and $\Delta\rho = 0.38$ and -0.34 e Å^{-3}.

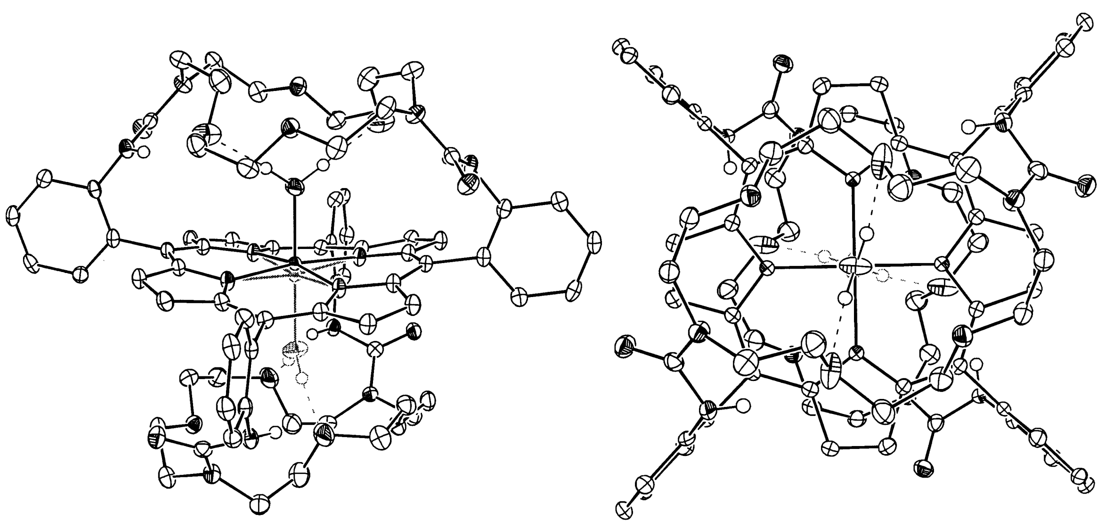

Figure 1. Side view (a) and top view (b) of the molecular structure of porphyrin **2**

adopts a ruffled conformation. The Cm deviation is ±0.333(2) Å with respect to the 24-atom least-squares plane and the dihedral angle of two symmetrically related opposite pyrrole planes is 21.70(4)°. The five-coordinated central Zn atom is bound to an axial H_2O molecule (vide infra footnote † for the description of the observed disorder) and is located 0.156 Å above the porphyrin mean plane. The average Zn–N bond length is 2.044(2) Å and the Zn–Ow bond length is 2.060(4) Å. The axial H_2O is hydrogen bound to two oxygen atoms of one diaza crown ether ring (2.786 Å for Ow···O and 1.92 Å for H···O). The same coordination scheme was observed for the single-strapped diaza crown ether zinc porphyrin **MSPZn**.[4f] In this latter compound the bridging spacers are longer in one methylene group than those of **2**. However, the distances between the center of the diaza crown ring from the porphyrin 4-N center are similar: 4.30 Å for **MSPZn** and 4.34 Å for **2**. This similarity could be explained by the existence, in both cases, of the hydrogen bonds Ow···O in the solid state, but is not evidenced by the NMR data in solution. In **2**, the diaza crown ethers, which are symmetrically related, adopt the same conformation whether a water molecule is coordinated to the Zn atom or not. This observation can be explained as the deformation induced by the inclusion of the water molecule on one side of the porphyrin is transmitted on the other side of the porphyrin more especially as the strap is highly rigid.

In conclusion, we have reported the synthesis of a new bis-aza crown ether porphyrin and its characterization in the solid state. Its X-ray structure shows that the porphyrin macrocycle is distorted in a ruffled conformation. The coordination properties of this ligand, particularly vis-a-vis cations such as lanthanides are under investigation.

Note

All the new compounds described in this work gave satisfactory spectroscopic data (^{1}H NMR, MS) and consistent elemental analyses; the chemical shifts are given in ppm and are referenced to the protonated residual solvent; **TUPPαβCEH$_2$ 1** (tetra urea phenyl porphyrin αβ crown ether): anal. calcd for $C_{72}H_{78}N_{12}O_{12}\cdot 2H_2O$: C, 64.56; H, 6.17; N, 12.55; found: C, 64.77; H, 6.12; N, 12.18; ^{1}H NMR (500 MHz, $CDCl_3$, 300 K): $\delta = 8.89$ (s, 8H); 8.43 (d, 4H, $J = 7.46$ Hz, $J = 1.47$

Hz); 7.95 (d, 4H, $J=8.31$ Hz, $J=1.22$ Hz); 7.76 (t, 4H, $J=7.83$ Hz, $J=1.71$ Hz); 7.57 (t, 4H, $J=7.46$ Hz, $J=1.34$ Hz); 5.92 (s, 4H); 2.63 (broad s, 16H); 2.05 (broad s, 16H); 0.76 (broad s, 16H); −2.15 (s, 2H); HR-MS (LSI-MS) *m*/*z* calcd: 1325.5760 $[M+Na]^+$ for $C_{72}H_{78}N_{12}O_{12}Na$; found: 1325.5777; **TUPPαβCEZn 2**: anal. calcd for $C_{72}H_{76}N_{12}O_{12}Zn\cdot MeOH$: C, 62.68; H, 5.76; N, 12.02; found: C, 62.79; H, 5.60; N, 11.75; ^1H NMR (500 MHz, $CDCl_3$, 300 K): $\delta=8.92$ (s, 8H); 8.43 (d, 4H, $J=7.21$ Hz); 7.99 (d, 4H, $J=8.19$ Hz); 7.77 (t, 4H, $J=7.7$ Hz); 7.58 (t, 4H, $J=7.46$ Hz); 5.75 (s, 4H); 2.36 (broad s, 16H); 1.86 (broad s, 16H); 1.2 (broad s, 16H).

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