SYNTHESIS OF PORPHYRIN HETEROBINUCLEAR LIGANDS

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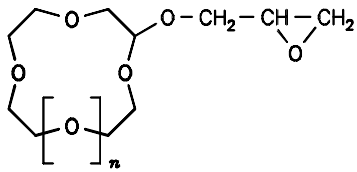
A series of mono- or biscrown and azacrown ether porphyrin derivatives *IIIb – IIIi*, *IVb* and *IVc* were synthesized as model systems for cytochrome c oxidase. The arrangement of the porphyrin and the crown ether subunits and their spatial relation has been investigated by ^{1}H NMR spectroscopy. The complexation properties of the synthesized ligands have also been studied.

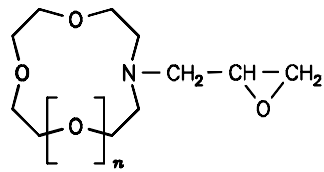
The recent growing interest in the synthesis of heterobinuclear ligands[1,2] is connected with the clarification and application of recognition processes, synthesis of artificial receptors[3], multistep catalysis processes and, last but not least, also biomimetic models of some enzymatic systems[4].

From this viewpoint the most interesting seem to be the heterobimetallic complexes of two transition metals, the special attention being paid[5] to complexes of Fe(III) and Cu(II) as systems analogous to cytochrome c oxidase. No doubt, the investigation of relationships between the structure and function of this bimetallic hemoprotein is of great importance because it represents the terminal enzyme of the respiratory chain. The significance of model structures mimicking this system consists in the attempted clarification of mechanism of activation of molecular oxygen and multiple catalysis processes in this so far little explored system. For this reason, several model systems have been synthesized which, thanks to their simplicity, could make some investigations easier[1 – 3,5].

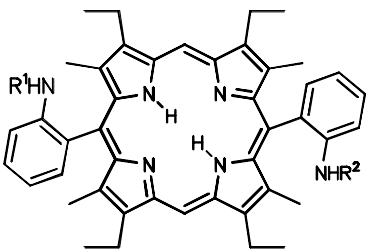
As models of this type we synthesized crown or azacrown ethers bonded by one[5] or two[1,2] spacers to the porphyrin subunit. In the synthesis of these compounds two basic approaches are employed: (i) the crown ether unit is combined with the starting benzaldehyde which is used for the construction of the porphyrin macrocycle in the Rothemund reaction[6,7] or (ii) the pre-synthesized suitably substituted crown ether and porphyrin building blocks are linked by means of a spacer with an appropriate reactive group[1,2,8,9]. The latter approach has been used in the present study. Compounds *IIIb – IIIi*, *IVb*, and *IVc* were synthesized by aminolysis of epoxyalkyl crown or azacrown ethers[10] *Ia*, *Ib* and *IIa*, *IIb* with amino- or bisaminoporphyrins *IVa* and *IIIa*,



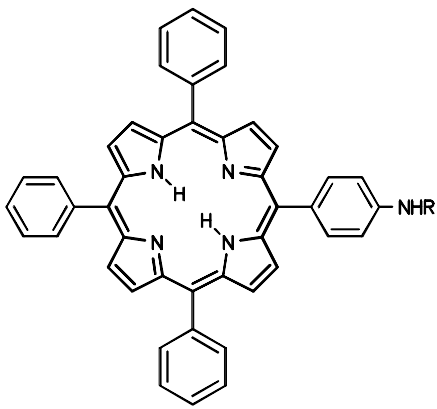
Ia, $n = 2$
Ib, $n = 3$



IIa, $n = 2$
IIb, $n = 3$

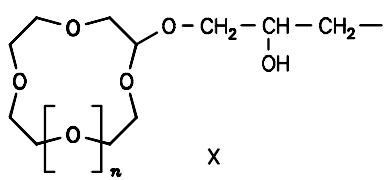


IIIa, $R^1 = R^2 = H$
IIIb, $R^1 = H$; $R^2 = X$; $n = 2$
IIIc, $R^1 = R^2 = X$; $n = 2$
IIId, $R^1 = H$; $R^2 = X$; $n = 3$
IIIe, $R^1 = R^2 = X$; $n = 3$
IIIf, $R^1 = H$; $R^2 = Y$; $n = 2$
IIIg, $R^1 = R^2 = Y$; $n = 2$
IIIh, $R^1 = H$; $R^2 = Y$; $n = 3$
IIIi, $R^1 = R^2 = Y$; $n = 3$

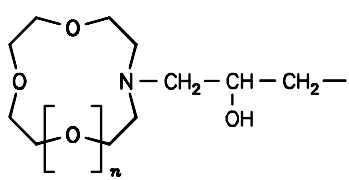


IVa, R = H
IVb, R = X; $n = 3$
IVc, R = Y; $n = 2$

In formulae *III*, *IV*:

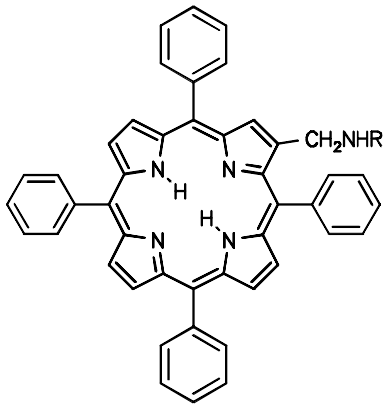


X



Y

prepared according to the literature[11]. Porphyrins *Va* and *Vb* were obtained by reductive amination of 3-formyl-5,10,15,20-tetraphenylporphyrin[12]. Metallation of porphyrin crown ether derivatives was carried out according to ref.[13]. The possibility of subsequent metallation was tested with two selected compounds *IIId* and *IIIe* where the porphyrin ligand was selectively metallated with Cu(II) and the crown ether ligand with K(I) as described in Experimental.



Va, R = CH_3

Vb, R = $CH_2C_6H_5$

EXPERIMENTAL

^{1}H NMR spectra were obtained with a Varian XL-200 (200 MHz) instrument at 23 °C in deuteriochloroform with tetramethylsilane as internal standard, chemical shifts are given in ppm (δ scale). Mass spectra were obtained with VG Analytical ZAB EQ spectrometer (FAB method). IR spectra were obtained with a Brucker ISS 88 spectrometer in chloroform, wavenumbers are given in cm^{-1}. UV-VIS spectra were obtained with Varian DMS 200 spectrophotometer in chloroform, absorption maxima are given in nm. Thin-layer chromatography (TLC) was performed on Kieselgel GF_{254} (Merck). Preparative flash column chromatography was performed on silica gel Merck H (for TLC). Potentiometric measurements were carried out on Radelkis digital OP-208/1 pH-meter with ion selective electrode (Monokrystaly, Turnov) and Ag/AgCl/LiCl as the reference.

Starting crown and azacrown ethers 2-(4,5-epoxy-2-oxa-1-pentyl)-1,4,7,10,13-pentaoxacyclopentadecane (*Ia*), 2-(4,5-epoxy-2-oxa-1-pentyl)-1,4,7,10,13,16-hexaoxacyclooctadecane (*Ib*), *N*-(2,3-epoxy-1-propyl)-1,4,7,10-tetraoxa-13-azacyclopentadecane (*IIa*), *N*-(2,3-epoxy-1-propyl)-1,4,7,10,13-pentaoxa-16-azacyclooctadecane (*IIb*) were prepared according to the previously published procedures[10].

Starting porphyrin derivatives 5,15-bis(2-aminophenyl)-2,8,12,18-tetraethyl-3,7,13,17-tetramethylporphyrin (*IIIa*), 5-(4-aminophenyl)-10,15,20-triphenylporphyrin (*IVa*), Cu(II)2-methylaminomethyl-

5,10,15,20-tetraphenylporphyrin (*Va*), Cu(II)2-phenylaminomethyl-5,10,15,20-tetraphenylporphyrin (*Vb*) were synthesized according to the literature methods[11,12,14].

General Procedure for Preparation of Porphyrin Crown and Porphyrin Azacrown Ether Ligands *IIId*, *IVb* and *IVc*

The porphyrin derivative (0.10 mmol) and the crown ether (0.11 mmol) were dissolved in absolute ethanol (15 ml) and the obtained solution was refluxed under argon for 48 h. The reaction was followed by TLC (2 – 5% of methanol in dichloromethane). The solvent was evaporated in vacuo and the product was purified by preparative TLC (2 – 5% of methanol in dichloromethane).

Compound IIId. Porphyrin *IIIa* (66 mg) and epoxy crown ether *Ib* (40 mg) gave after chromatography 46 mg (46%) of product. For $C_{60}H_{78}N_6O_8$ (1 011.3) calculated: 71.26% C, 7.77% H, 8.31% N; found: 71.06% C, 7.59% H, 8.23% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 392 (OH); 3 224 (NH); 2 931 (CH_2); 1 612, 1 603, 1 581 (C=C); 1 354 (C–N); 1 113 (CH_2–O). UV spectrum: 407.2, 506.2, 539.8, 571.8, 653.7.

Compound IVb. Porphyrin *IVa* (63 mg) and epoxy crown ether *Ib* (40 mg) gave after chromatography 60.0 mg (62%) of product. For $C_{60}H_{61}N_5O_8$ (980.2) calculated: 73.52% C, 6.27% H, 7.14% N; found: 73.33% C, 6.23% H, 7.01% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 390 (OH); 2 925, 2 855 (CH_2); 1 605, 1 585, (C=C); 1 460 (CH_2); 1 354 (C–N); 1 115, 1 060 (CH_2–O).

Compound IVc. Porphyrin *IVa* (63 mg) and epoxy crown ether *IIa* (30 mg) gave after chromatography 40 mg (45%) of product. For $C_{57}H_{56}N_6O_5$ (905.1) calculated: 75.64% C, 6.24% H, 9.28% N; found: 75.80% C, 6.21% H, 9.24% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 660 (OH); 3 425 (NH); 1 613, 1 603, 1 581, 1 516 (C=C); 1 113 (CH_2–O).

General Procedure for Preparation of Porphyrin Crown and Porphyrin Azacrown Ether Ligands *IIIb*, *IIId*, *IVb*, and *IVc*

The porphyrin derivative (0.10 mmol) and the crown ether (0.11 mmol) were dissolved in absolute *N*,*N*-dimethylformamide (15 ml) and the obtained solution was heated with stirring at 130 °C under argon for 6 h. The reaction was followed by TLC (2 – 5% of methanol in dichloromethane). The solvent was evaporated in vacuo and the product was purified by preparative TLC (3 – 10% of methanol in dichloromethane).

Compound IIIb. Porphyrin *IIIa* (66 mg) and epoxy crown ether *Ia* (33 mg) gave after chromatography 41 mg (43%) of product. For $C_{58}H_{74}N_6O_7$ (967.3) calculated: 72.02% C, 7.71% H, 8.69% N; found: 71.91% C, 7.73% H, 8.52% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 392 (OH); 2 927, 2 857 (CH_2); 1 603, 1 583 (C=C); 1 457 (CH_2); 1 354 (C–N); 1 122, 1 061 (CH_2–O). UV spectrum: 407.5, 506.2, 540.2, 573.8, 654.3.

Compound IIId. Porphyrin *IIIa* (66 mg) and epoxy crown ether *Ib* (40 mg) gave after chromatography 47.5 mg (47%) of product identical with compound *IIId* described above.

Compound IVb. Porphyrin *IVa* (63 mg) and epoxy crown ether *Ib* (39 mg) gave after chromatography 54 mg (55%) of product identical with compound *IVb* described above.

Compound IVc. Porphyrin *IVa* (63 mg) and epoxy crown ether *IIa* (30 mg) gave after chromatography 43 mg (48%) of product identical with compound *IVc* described above.

General Procedure for Preparation of Porphyrin Crown and Porphyrin Azacrown Ether Ligands *IIIb – IIIi*, *IVb*, and *IVc*

The porphyrin derivative (0.10 mmol) and the crown ether (0.50 mmol) were dissolved in absolute chloroform (15 ml) and the obtained solution was stirred at 40 °C under argon for 15 min. The chlo-

roform was distilled off and the reaction mixture was heated with stirring at 130 °C for 6 h. The pure product was obtained by flash column chromatography (3 – 10% of methanol in dichloromethane).

Compounds IIIb *and* IIIc. Porphyrin *IIa* (66 mg) and epoxy crown ether *Ia* (150 mg) gave after chromatography 74 mg (58%) of product *IIIc* and 37 mg (38%) of compound *IIIb*. Compound *IIIc*: For $C_{72}H_{100}N_6O_{14}$ (1 273.6) calculated: 67.90% C, 7.91% H, 6.66% N; found: 67.81% C, 7.78% H, 8.52% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 391 (OH); 2 922, 2 855 (CH_2); 1 613 (C=C); 1 462 (CH_2); 1 354 (C–N); 1 110, 1 060 (CH_2–O). UV spectrum: 410.1, 506.5, 541.5, 574.2, 655.0. The data for *IIIb* see above.

Compounds IIIe *and* IIId. Porphyrin *IIIa* (66 mg) and epoxy crown ether *Ib* (175 mg) gave after chromatography 52 mg (38%) of product *IIIe* and 48 mg (47%) of *IIId*. Compound *IIIe*: For $C_{76}H_{108}N_6O_{16}$ (1 361.7) calculated: 67.03% C, 7.99% H, 6.17% N; found: 67.12% C, 7.83% H, 6.08% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 669, 3 410 (OH); 3 232 (NH); 2 927, 2 856 (CH_2); 1 627 (C=C); 1 354 (C–N); 1 113 (CH_2–O). UV spectrum: 410.1, 506.5, 541.5, 574.2, 655.0. The data for *IIId* see above.

Compounds IIIh *and* IIIi. Porphyrin *IIIa* (66 mg) and epoxy crown ether *IIa* (160 mg) gave after chromatography 49 mg (38%) of product *IIIi* and 28 mg (28%) of *IIIh*. Compound *IIIi*: For $C_{74}H_{106}N_8O_{12}$ (1 299.7) calculated: 68.39% C, 8.22% H, 8.62% N; found: 68.30% C, 8.17% H, 8.53% N. IR spectrum: 3 446 (OH); 3 223 (NH); 1 750 – 1 550 (C=C); 1 354 (C–N); 1 111, 1 052 (CH_2–O). UV spectrum: 409.9, 506.2, 540.5, 574.2, 654.2. Compound *IIIh*: For $C_{59}H_{77}N_7O_6$ (930.3) calculated: 72.29% C, 7.92% H, 10.00% N; found: 72.20% C, 7.85% H, 9.97% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 400 (OH); 2 928, 2 856 (CH_2); 1 603 (C=C); 1 352 (C–N). UV spectrum: 406.9, 505.5, 540.5, 575.1, 656.0.

Compounds IIIf *and* IIIg. Porphyrin *IIIa* (66 mg) and epoxy crown ether *IIa* (140 mg) gave after chromatography 48 mg (40%) of product *IIIg* and 44 mg (47%) of *IIIf*. Compound *IIIg*: For $C_{70}H_{98}N_7O_{10}$ (1 197.6) calculated: 70.20% C, 8.25% H, 8.19% N; found: 70.43% C, 8.22% H, 8.27% N. IR spectrum: 3 576 (OH); 3 423 (NH); 1 620, 1 605, 1 568, 1 518 (C=C); 1 113 (CH_2–O). UV spectrum: 408.0, 506.8, 541.5, 575.3, 659.5. Compound *IIIf*: For $C_{57}H_{73}N_7O_5$ (936.3) calculated: 73.12% C, 7.86% H, 10.47% N; found: 73.08% C, 7.74% H, 10.28% N. For ^{1}H NMR and MS spectra see Table I. IR spectrum: 3 666 (OH); 3 425 (NH); 3 390 (OH, NH); 1 613, 1 603, 1 581, 1 516 (C=C); 1 113 (CH_2–O). UV spectra: 407.8, 506.2, 540.5, 574.2, 657.7.

Compound IVb. Porphyrin *IVa* (63 mg) and epoxy crown ether *Ib* (175 mg) gave after chromatography 64 mg (65%) of product identical with compound *IVb* described above.

Compound IVc. Porphyrin *IVa* (63 mg) and epoxy crown ether *IIa* (137 mg) gave after chromatography 57 mg (63%) of product identical with compound *IVc* described above.

General Procedure for Metallation of Porphyrin Crown Ether Compounds

Porphyrin crown ether compound *IIId* (30 mg, 0.030 mmol) or *IIIe* (30 mg, 0.022 mmol) was dissolved in absolute chloroform (5 ml) and copper(II) acetate monohydrate 100 mg (0.5 mmol) was added. Reaction mixture was refluxed for 3 h, the salts were filtered off, the filtrate was washed with water and dried over anhydrous magnesium sulfate. Pure products were obtained after flash column chromatography (8% of methanol in dichloromethane). In both cases the yield of the Cu(II) complex was 95%.

Compound Cu . IIId. Mass spectrum, *m*/*z* (%): calculated 1 072.85; found: 1 073 (100), 1 072 (90), 1 074 (70), 1 071 (50). IR spectrum: 3 392 (OH); 2 928, 2 855 (CH_2); 1 638, 1 603, 1 585 (C=C); 1 353 (C–N); 1 109, 1 061 (CH_2–O). UV spectrum: 403.9, 530.6, 565.6.

TABLE I
^{1}H NMR and MS spectral characteristics of compounds *IIIb – IIIi*, *IVb*, and *IVc*

Compound	^{1}H NMR spectrum		Mass spectrum *m/z* (%)
	porphyrin subunit	crown ether subunit	
IIIb	–2.43 s, 2 H (NH pyrrole)	1.65 – 1.90 m, 5 H	967 (100)
	1.79 t, 12 H (CH_3–Et)	2.10 – 2.30 m, 3 H	968 (90)
	2.7 s, 12 H (Me)	2.50 – 2.65 m, 4 H	876 (80)
	4.04 q, 8 H (CH_2–Et)	3.40 – 3.85 m, 14 H	585 (30)
	7.05 – 7.55 m, 8 H (aryl)		429 (40)
	10.25 s, 2 H (methine)		
IIIc	–2.45 s, 2 H (NH pyrrole)	1.55 – 1.85 m, 10 H	1 274 (100)
	1.76 t, 12 H (CH_3–Et)	2.00 – 2.75 m, 6 H	1 275 (80)
	2.68 s, 12 H (Me)	3.00 – 3.25 m, 8 H	1 273 (50)
	4.0 q, 8 H (CH_2–Et)	3.40 – 3.90 m, 28 H	995 (30)
	7.06 – 7.55 m, 8 H (aryl)		967 (70)
	10.13 s, 2 H (methine)		645 (30)
IIId	–2.43 s, 2 H (NH pyrrole)	1.55 – 1.90 m, 7 H	1 011 (100)
	1.75 t, 12 H (CH_3–Et)	2.55 – 3.05 m, 3 H	1 010 (50)
	2.70 s, 12 H (Me)	3.10 – 3.35 m, 4 H	1 012 (82)
	4.05 q, 8 H (CH_2–Et)	3.45 – 3.90 m, 16 H	922 (70)
	7.03 – 7.65 m, 8 H (aryl)		775 (28)
	10.12 s, 2 H (methine)		673 (30)
IIIe	–2.50 s, 2 H (NH pyrrole)	1.60 – 2.10 m, 14 H	1 361 (100)
	1.70 t, 12 H (CH_3–Et)	2.55 – 2.65 m, 3 H	1 362 (80)
	2.65 s, 12 H (Me)	2.90 – 3.10 m, 8 H	1 360 (60)
	3.95 q, 8 H (CH_2–Et)	3.35 – 3.85 m, 32 H	1 011 (90)
	7.05 – 7.60 m, 8 H (aryl)		1 013 (50)
	10.13 s, 2 H (methine)		409 (75)
IIIf	-2.46 s, 2 H (NH pyrrole)	1.55 – 1.80 m, 12 H	1 199 (100)
	1.77 t, 12 H (CH_3–Et)	2.20 – 2.80 m, 6 H	1 200 (40)
	2.72 s, 12 H (Me)	3.00 – 3.30 m, 12 H	1 198 (70)
	4.07 q, 8 H CH_2–Et)	3.50 – 3.85 m, 20 H	1 197 (30)
	7.00 – 7.70 m, 8 H (aryl)		
	10.14 s, 2 H (methine)		
IIIg	–2.46 s, 2 H (NH pyrrole)	1.55 – 1.80 m, 6 H	936 (100)
	1.71 t, 12 H (CH_3–Et)	2.25 – 2.80 m, 3 H	937 (90)
	2.65 s, 12 H (Me)	3.10 – 3.30 m, 6 H	938 (80)
	3.99 q, 8 H (CH_2–Et)	3.55 – 3.85 m, 10 H	
	7.03 – 7.65 m, 8 H (aryl)		
	10.17 s, 2 H (methine)		

TABLE I
(*Continued*)

Compound	^{1}H NMR spectrum		Mass spectrum *m/z* (%)
	porphyrin subunit	crown ether subunit	
IIIh	–2.46 s, 2 H (NH pyrrole)	1.65 – 1.95 m, 6 H	981 (100)
	1.71 t, 12 H (CH_3–Et)	2.20 – 2.30 m, 3 H	980 (72)
	2.65 s, 12 H (Me)	2.52 m, 4 H	953 (40)
	3.99 q, 8 H CH_2–Et)	3.10 m, 4 H	912 (50)
	7.03 – 7.65 m, 8 H (aryl)	3.45 – 3.85 m, 12 H	830 (75)
	10.17 s, 2 H (methine)		
IIIi	–2.40 s, 2 H (NH pyrrole)	1.69 – 1.90 m, 12 H	1 300 (100)
	1.75 t, 12 H (Et)	2.05 – 2.25 m, 3 H	1 301 (70)
	2.70 s, 12 H (Me)	2.6 m, 8 H	1 299 (45)
	3.97 q, 8 H (Et)	3.15 m, 8 H	1 003 (40)
	7.05 – 7.75 m, 8 H (aryl)	3.45 – 3.85 m, 24 H	661 (28)
	10.19 s, 2 H (methine)		
IVb	–2.73 s, 2 H (NH pyrrole)	2.60 – 2.85 m, 4 H	981 (100)
	7.06 d, 2 H (4-aminophenyl)	3.00 – 3.20 m, 2 H	982 (70)
	8.00 d, 2 H (4-aminophenyl)	3.55 – 3.70 m, 20 H	980 (60)
	7.76 m, 9 H (phenyl)		
	8.82 m, 6 H (phenyl)		
	8.95 m, 8 H (C–H pyrrole)		
IVc	–2.80 s, 2 H (NH pyrrole)	2.25 – 3.40 m, 9 H	906 (100)
	7.10 d, 2 H (4-aminophenyl)	3.60 – 3.94 m, 16 H	907 (70)
	8.08 d, 2 H (4-aminophenyl)		905 (60)
	7.76 m, 9 H (phenyl)		613 (35)
	8.82 m, 6 H (phenyl)		
	8.93 m, 8 H (C–H pyrrole)		

Compound Cu . IIIe. Mass spectrum, *m/z* (%): calculated 1 423.3; found: 1 424 (100), 1 423 (90), 1 425 (30). IR spectrum: 3 660 (OH); 2 930, 2 860 (CH_2); 1 635 (C=C); 1 353 (C–N); 1 110, 1 070 (CH_2–O). UV spectrum: 405.9, 530.9, 567.2.

General Procedure for Insertion of Potassium Ion into the Crown Ether Subunit Ligand

Preparation of KCu . *IIId* and KCu . *IIIe* complexes was carried out by refluxing Cu . *IIId* (30 mg, 0.028 mmol) or Cu . *IIIe* (30 mg, 0.021 mmol) complexes with potassium bromide (30 mg, 0.25 mmol) and potassium carbonate (5 mg, 0.036 mmol) in absolute methanol (50 ml) for 2 h. The Cu(II)/K(I) heterobimetallic complexes were characterized by MS (FAB), the presence of stoichiometric amount of potassium ion was detected by potentiometric measurements.

Compound KCu . IIId. Mass spectrum, *m*/*z* (%): calculated 1 111.95; found: 1 112 (100), 1 113 (80). UV spectrum: 404.0, 530.6, 565.6.

Compound KCu . IIIe. Mass spectrum, *m*/*z* (%): calculated 1 462.40; found 1 463 (100), 1 464 (60). UV spectrum: 405.9, 530.9, 567.1.

RESULTS AND DISCUSSION

The opening of the epoxide ring was first studied using the simplest porphyrin *IVa* in which the amino group is not sterically hindered. The reaction gave the porphyrins *IVb* and *IVc*. Then the method was applied to porphyrines *IIIa*, *Va* and *Vb*; here our interest focused on the mutual interaction between the porphyrin and crown ether subunits. In spite of considerable steric hindrance of the amino groups, the best results were obtained with the porphyrin *IIIa*. Using appropriate reaction conditions, it was possible to obtain either products of monosubstitution (*IIIb*, *IIId*, *IIIg* and *IIIh*) or disubstitution (*IIIc*, *IIIe*, *IIIf*, *IIIi*). In prolonged reaction with a large excess of the epoxy crown ether we observed a compound that was probably the product of a triple aminolysis in which one of the amino groups in the porphyrin *IIIa* reacted with two molecules of the epoxy crown ether. Whereas with derivatives *IIIa* and *IVa* the epoxide opening proceeded in the expected manner, porphyrins *Va* and *Vb* did not react at all even on prolonged treatment with the epoxide. There are probably two reasons for this behaviour: (i) the amino group in porphyrins *Va* and *Vb* is directly attached to the porphyrin macrocycle

TABLE II
^{1}H NMR spectra of starting crown ether epoxides *Ia* – *Id* and *IIa* – *IIb*

Compound	^{1}H NMR spectrum
Ia	2.62 – 2.74 m, 2 H (H-5) 3.11 – 3.18 m, 2 H (H-3) 3.60 – 3.70 m, 22 H (CH, CH_2)
Ib	2.62 – 2.73 m, 2 H (H-5) 3.11 – 3.18 m, 2 H (H-3) 3.60 – 3.70 m, 26 H (CH,CH_2)
IIa	2.30 – 2.35 m, 9 H (H-2, H-3, CH_2N) 3.65 – 3.75 m, 16 H (CH_2O)
IIb	2.30 – 2.35 m, 9 H (H-2, H-3, CH_2N) 3.65 – 3.75 m, 20 H (CH_2O)

which markedly reduces its nucleophilicity and moreover, (ii) it is sterically hindered by the neighbouring substituents.

In accord with the accepted reaction mechanism[15], the epoxide ring was opened by the nucleophilic attack at the primary carbon atom under formation of a six-membered spacer between the crown ether and the porphyrin moiety in the reaction of crown ethers *Ia* and *Ib*, and a four-membered one with azacrown ethers *IIa* and *IIb*. The spacer allows considerable flexibility of the porphyrin crown ether complex. The mutual influence and position of both parts of the molecule were studied by ^{1}H NMR spectra (see Table I).

The spatial arrangement between the porphyrin and crown ether parts of the molecule can be analyzed on the basis of the porphyrin ring current-induced chemical shift of the crown ether protons. The widening and upfield shift of some methylene signals of the spacer and of the crown ether proper (compared with those of the starting epoxides; see Table II) indicates an important interaction with the porphyrin. The large upfield shift (up to 1 ppm) of some crown ether signals gives evidence that a part of the crown ether ligand is situated above the plane of the porphyrin macrocycle.

The porphyrin crown ether ligands make possible a subsequent metallation with two different metal ions. As follows from the absorption spectra and from potentiometric measurements[16], incorporation of Cu(II) into the porphyrin ring does not principally affect complexation properties of the crown ether ligand.

The obtained crown ether derivatives will be further studied from the viewpoint of the possible application to the porphyrin mediated redox catalysis and mimicking processes related to structure and function of cytochrome c oxidase.

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