

Werner Löwe*, Stefanie Brätter and Christoph Dietrich

Institut für Pharmazie I, Freie Universität Berlin, Königin-Luise-Str. 2+4, D-14195 Berlin, Germany

Manuela Weber and Peter Luger

Institut für Kristallographie, Freie Universität Berlin, Takustr. 6, D-14195 Berlin, Germany

Received April 21, 1997

Dedicated to Professor W. Wiegrebe, Regensburg, on the occasion of his sixty fifth birthday

We report here the syntheses and characterization of new crown-type compounds **8** and **9** incorporated with one and two 4-pyrone units. The reaction of compound **3** with 1,5-bis(2-hydroxyphenoxy)-3-oxapentane or catechol gave the desired molecules **8** and **9** in 65% and 25% yields, respectively. Compound **3** resulted from **1** by Wohl-Ziegler bromination in small amounts and could be separated from five bromination by-products by column chromatography. For example, **8** binds K^+ and a pyrylium salt **11** (single crystal X-ray structure analysis) can also be prepared starting from **3** by treatment of the latter with perchloric acid in the presence of acetonitrile.

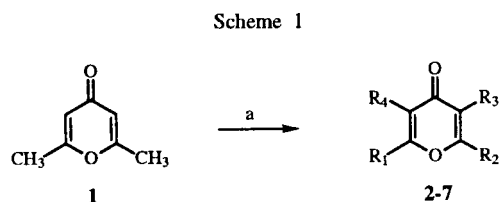
J. Heterocyclic Chem., **34**, 1173 (1997).

Heteroaromatic components can assume donor positions in crown ethers. Furano-, pyridino- and thiophenocompounds are well known representatives of these crown-type compounds [1,2]. To our knowledge, the 4-pyrones have not yet been used for syntheses of such oxa rings. Furthermore their functionalities may permit a wide range of reactions that would make them available for the synthesis of a number of 4-pyrone derivatives and other macrocycles after ring opening of the 4-pyrone system.

Bromination of 2,6-Dimethyl-4-pyrone **1** (Scheme 1, Table 1).

The synthesis of crown-type compounds **8** and **9** requires prior preparation of a 4-pyrone derivative **3**, which must have symmetrically substituted bromomethyl groups at positions 2 and 6. These bromomethyl functions could basically be obtained from the appropriate primary alcohol groups by reaction with hydrogen bromide. A 4-pyrone with this type of hydroxymethyl substituents at positions 2 and 6 has been reported in the literature [3]. It is synthesized *via* sodium borohydride reduction of the appropriate dicarboxylate. However, the yields are very small, and the technique for separating the compound from three other byproducts is very time-consuming.

As a result we have tried to synthesize 2,6-bisbromomethyl-4-pyrone **3** from 2,6-dimethyl-4-pyrone **1** by



a: *N*-bromosuccinimide, dibenzoyl peroxide/tetrachloromethane

Table 1

| Compounds | R ₁ | R ₂ | R ₃ | R ₄ | tlc R _f (ethyl acetate) |
|-----------|--------------------|--------------------|----------------|----------------|---------------------------------------|
| 2 | CH ₃ | CH ₂ Br | H | H | 0,18 |
| 3 | CH ₂ Br | CH ₂ Br | H | H | 0,31 |
| 4 | CH ₃ | CHBr ₂ | H | H | 0,40 |
| 5 | CH ₂ Br | CHBr ₂ | H | H | 0,55 |
| 6 | CHBr ₂ | CHBr ₂ | H | H | 0,65 |
| 7 | CHBr ₂ | CHBr ₂ | Br | Br | 0,72 |

means of Wohl-Ziegler bromination [4], although the published data on this preferred method is very misleading [5,6]. Both Buu-Hoi and Yamamoto were only able to document the formation of the singly brominated compound **2**. If, in accordance with the Yamamotos report, bromination were performed by reacting excess *N*-bromosuccinimide in the presence of dibenzoyl peroxide in tetrachloromethane, one would obtain the bromination products **2-7**, one of which is the target compound **3**. Three fractions are first isolated *via* column chromatography (tlc R_f 0.55-0.72: **5,6,7**; tlc R_f 0.31-0.41: **3,4**; tlc R_f 0.18: **2**), then separated again into the individual components. Although the yield of **3** is very small, and also separation of the bromination products is very time-consuming, multiple repetition of the technique yields enough compound **3** for obtaining crown ether prototypes **8** and **9**, and for performing sample reactions with **8**.

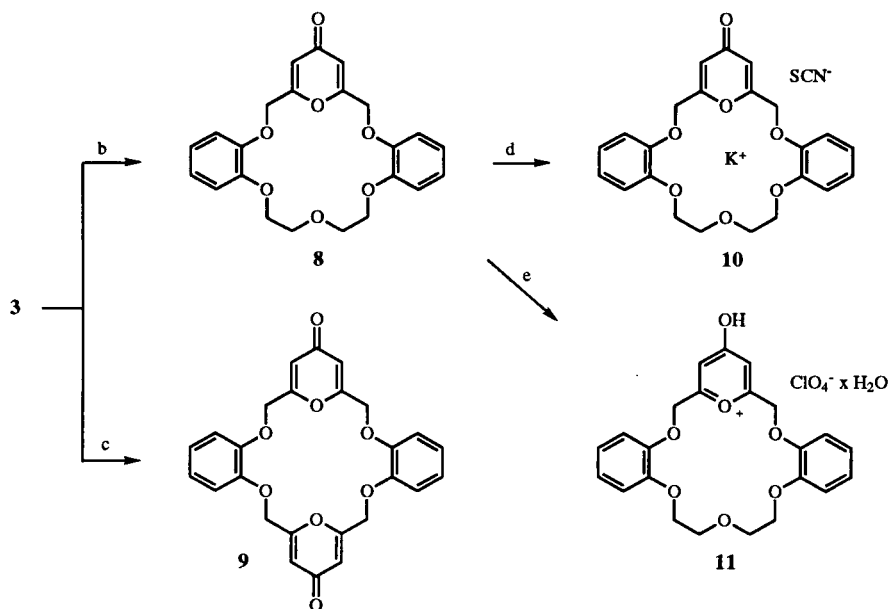
Syntheses of Polyethers **8** and **9** (Scheme 2).

Compound **8** is prepared according to the two component dilution principle [7]. Since 4-pyrone **3** is not stable in bases the potassium salt of 1,5-bis(2-hydroxyphenoxy)-3-oxapentane is separately prepared from the diphenol with ethanolic potassium hydroxide. This potassium salt as well as the 4-pyrone **3** were dissolved in *tert*-butyl alcohol and allowed

to drop simultaneously and continuously into boiling *tert*-butyl alcohol. After such standard preparation, good yields (65%) of **8** are obtained. Its structure is clearly confirmed by elemental analyses and spectral data.

Compound **9** with two 4-pyrone units was synthesized by means of phase transfer catalysis [8] from **3** and catechol. The reaction of the latter is carried out in a solution containing aqueous sodium hydroxide and dichloro-

Scheme 2



b: potassium salt of 1,5-bis(2-hydroxyphenoxy)-3-oxapentane, dimethylformamide/ H_2O /*tert*-butyl alcohol; c: catechol, NaOH/tetrabutylammonium hydrogen sulfate/dichloromethane, N_2 ; d: KSCN, dichloromethane; e: $HClO_4$ (70%), acetonitrile

methane in the presence of catalytic amounts of tetrabutylammonium hydrogen sulfate. A 25% yield of **9** was obtained and its structure likewise is confirmed by elemental analyses and spectral data.

Reactions with Compound **8** (Scheme 2).

Polyether **8** was reacted by adding sodium thiocyanate in dichloromethane. Inclusion of potassium ion can be shown by isolating compound **10**. Compound **10** can be easily identified by a strong SCN^- band at 2054 cm^{-1} in the infrared spectrum. From our prior knowledge by reacting **8** with perchloric acid in acetonitrile, it was shown for the first time that umpolung of the crown type ligands takes place. After protonation of the carbonyl group, the 4-pyrone structure is transformed into a pyrylium salt **11**. Its pyrone ring protons (7.36 ppm) show significantly more down-field shift than the comparable signal (6.45 ppm) of **8**. The structure of the salt **11** is confirmed by means of X-ray crystal structure analysis.

X-ray Analysis of Compound **11**.

The structure of compound **11** as obtained from the X-ray analysis is displayed in Figure 1, together with the chosen numbering scheme. There is a disorder in the macrocycle (see Experimental) causing the two atoms

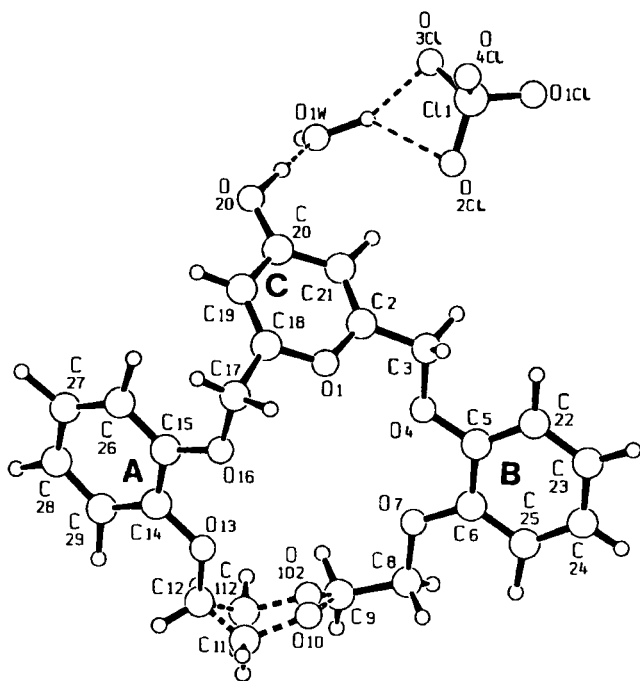


Figure 1. Structure of compound **11** in the crystal, generated with SCHAKAL [12]).

Table 2

Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($\text{Å}^2 \times 10^3$) for Compound 11. U (eq) is defined as one third of the trace of the orthogonalized Uij tensor

| | x | y | z | U(eq) | pp |
|---------|-----------|-----------|------------|---------|--------|
| O (1) | 8739 (2) | 2284 (2) | -376 (2) | 52 (1) | |
| C (2) | 8228 (3) | 3047 (2) | -431 (3) | 52 (1) | |
| C (3) | 7689 (3) | 3344 (2) | -1601 (4) | 61 (1) | |
| O (4) | 6904 (2) | 2708 (2) | -2189 (2) | 70 (1) | |
| C (5) | 6461 (3) | 2792 (3) | -3315 (3) | 59 (1) | |
| C (6) | 5728 (3) | 2141 (3) | -3873 (3) | 59 (1) | |
| O (7) | 5566 (3) | 1497 (2) | -3220 (2) | 74 (1) | |
| C (8) | 4775 (4) | 845 (4) | -3749 (4) | 88 (2) | |
| C (9) | 4816 (7) | 160 (5) | -2937 (6) | 112 (2) | |
| O (10) | 5933 (10) | -400 (7) | -2786 (10) | 69 (3) | 0.5214 |
| C (11) | 6110 (9) | -1191 (6) | -2190 (8) | 69 (2) | 0.5352 |
| O (102) | 5650 (11) | -161 (8) | -2548 (12) | 75 (3) | 0.4679 |
| C (112) | 5628 (9) | -841 (8) | -1843 (11) | 88 (3) | 0.4811 |
| C (12) | 6513 (6) | -1167 (4) | -1135 (8) | 156 (4) | |
| O (13) | 7453 (3) | -625 (2) | -639 (3) | 94 (1) | |
| C (14) | 7871 (4) | -545 (3) | 486 (5) | 75 (1) | |
| C (15) | 8727 (3) | 52 (2) | 908 (4) | 64 (1) | |
| O (16) | 9023 (2) | 477 (2) | 111 (2) | 66 (1) | |
| C (17) | 9875 (3) | 1119 (2) | 463 (4) | 62 (1) | |
| C (18) | 9385 (3) | 1963 (2) | 607 (3) | 51 (1) | |
| C (19) | 9519 (3) | 2378 (2) | 1560 (3) | 57 (1) | |
| C (20) | 8924 (3) | 3146 (2) | 1524 (3) | 58 (1) | |
| O (20) | 8996 (3) | 3495 (2) | 2459 (3) | 79 (1) | |
| C (21) | 8282 (3) | 3484 (2) | 483 (3) | 56 (1) | |
| C (22) | 6692 (3) | 3462 (3) | -3904 (4) | 68 (1) | |
| C (23) | 6204 (4) | 3485 (3) | -5047 (4) | 76 (1) | |
| C (24) | 5478 (4) | 2846 (4) | -5594 (4) | 80 (1) | |
| C (25) | 5220 (4) | 2180 (4) | -5016 (4) | 71 (1) | |
| C (26) | 9227 (4) | 168 (3) | 2035 (4) | 71 (1) | |
| C (27) | 8850 (5) | -298 (3) | 2762 (5) | 88 (2) | |
| C (28) | 8012 (5) | -884 (4) | 2342 (6) | 103 (2) | |
| C (29) | 7508 (5) | -1001 (4) | 1213 (6) | 98 (2) | |
| Cl (1) | 8409 (1) | 6411 (1) | 476 (1) | 78 (1) | |
| O (1Cl) | 7789 (5) | 6993 (3) | -315 (4) | 143 (2) | |
| O (2Cl) | 8100 (5) | 5574 (3) | 53 (4) | 133 (2) | |
| O (3Cl) | 8178 (4) | 6495 (3) | 1473 (4) | 121 (2) | |
| O (4Cl) | 9546 (3) | 6529 (3) | 721 (4) | 152 (2) | |
| O (1W) | 7816 (5) | 4777 (3) | 2280 (7) | 205 (4) | |

Table 3

Bond Lengths [Å] and Angles [deg] for Compound 11

| | | | |
|-------------------|------------|----------------------------|------------|
| O (1) - C (18) | 1.341 (4) | C (22) - C (5) - C (6) | 120.0 (4) |
| O (1) - C (2) | 1.344 (4) | O (7) - C (6) - C (25) | 124.8 (4) |
| C (2) - C (21) | 1.343 (5) | O (7) - C (6) - C (5) | 115.7 (4) |
| C (2) - C (3) | 1.493 (6) | C (25) - C (6) - C (5) | 119.5 (4) |
| C (3) - O (4) | 1.421 (5) | C (6) - O (7) - C (8) | 117.6 (3) |
| O (4) - C (5) | 1.365 (5) | O (7) - C (8) - C (9) | 109.5 (4) |
| C (5) - C (22) | 1.384 (6) | O (102) - C (9) - C (8) | 115.0 (8) |
| C (5) - C (6) | 1.394 (6) | C (8) - C (9) - O (10) | 106.0 (6) |
| C (6) - O (7) | 1.372 (5) | C (11) - O (10) - C (9) | 119.2 (9) |
| C (6) - C (25) | 1.386 (6) | C (12) - C (11) - O (10) | 118.5 (8) |
| O (7) - C (8) | 1.423 (5) | C (9) - O (102) - C (112) | 112.8 (11) |
| C (8) - C (9) | 1.484 (9) | C (12) - C (112) - O (102) | 123.0 (10) |
| C (9) - O (102) | 1.123 (14) | C (11) - C (12) - O (13) | 117.0 (8) |
| C (9) - O (10) | 1.627 (13) | C (112) - C (12) - O (13) | 118.7 (6) |
| O (10) - C (11) | 1.430 (2) | C (14) - O (13) - C (12) | 118.8 (5) |
| C (11) - C (12) | 1.274 (12) | O (13) - C (14) - C (29) | 125.3 (5) |
| O (102) - C (112) | 1.400 (2) | O (13) - C (14) - C (15) | 115.6 (4) |
| C (112) - C (12) | 1.280 (12) | C (29) - C (14) - C (15) | 119.1 (5) |

Table 3 (continued)

| | | | |
|------------------------|-----------|----------------------------|-----------|
| C (12) - O (13) | 1.422 (6) | C (26) - C (15) - O (16) | 125.2 (4) |
| O (13) - C (14) | 1.364 (6) | C (26) - C (15) - C (14) | 120.3 (4) |
| C (14) - C (29) | 1.384 (8) | O (16) - C (15) - C (14) | 114.5 (4) |
| C (14) - C (15) | 1.391 (6) | C (15) - O (16) - C (17) | 118.6 (3) |
| C (15) - C (26) | 1.377 (7) | O (16) - C (17) - C (18) | 110.2 (3) |
| C (15) - O (16) | 1.386 (5) | O (1) - C (18) - C (19) | 121.5 (3) |
| O (16) - C (17) | 1.429 (5) | O (1) - C (18) - C (17) | 110.7 (3) |
| C (17) - C (18) | 1.495 (5) | C (19) - C (18) - C (17) | 127.8 (4) |
| C (18) - C (19) | 1.346 (5) | C (18) - C (19) - C (20) | 119.1 (4) |
| C (19) - C (20) | 1.409 (5) | O (20) - C (20) - C (21) | 124.0 (4) |
| C (20) - O (20) | 1.297 (5) | O (20) - C (20) - C (19) | 117.8 (4) |
| C (20) - C (21) | 1.404 (6) | C (21) - C (20) - C (19) | 118.2 (3) |
| C (22) - C (23) | 1.384 (7) | C (2) - C (21) - C (20) | 118.8 (3) |
| C (23) - C (24) | 1.372 (7) | C (5) - C (22) - C (23) | 120.2 (4) |
| C (24) - C (25) | 1.386 (7) | C (24) - C (23) - C (22) | 119.7 (4) |
| C (26) - C (27) | 1.403 (7) | C (23) - C (24) - C (25) | 120.8 (4) |
| C (27) - C (28) | 1.366 (8) | C (24) - C (25) - C (6) | 119.7 (4) |
| C (28) - C (29) | 1.380 (9) | C (15) - C (26) - C (27) | 120.0 (5) |
| Cl (1) - O (1Cl) | 1.384 (4) | C (28) - C (27) - C (26) | 119.3 (5) |
| Cl (1) - O (4Cl) | 1.389 (4) | C (27) - C (28) - C (29) | 120.9 (5) |
| Cl (1) - O (2Cl) | 1.412 (4) | C (28) - C (29) - C (14) | 120.4 (5) |
| Cl (1) - O (3Cl) | 1.429 (4) | O (1Cl) - Cl (1) - O (4Cl) | 111.1 (4) |
| C (18) - O (1) - C (2) | 120.2 (3) | O (1Cl) - Cl (1) - O (2Cl) | 108.0 (3) |
| C (21) - C (2) - O (1) | 121.9 (3) | O (4Cl) - Cl (1) - O (2Cl) | 109.7 (4) |
| C (21) - C (2) - C (3) | 126.4 (3) | O (1Cl) - Cl (1) - O (3Cl) | 110.9 (3) |
| O (1) - C (2) - C (3) | 111.5 (3) | O (4Cl) - Cl (1) - O (3Cl) | 108.8 (3) |
| O (4) - C (3) - C (2) | 108.1 (3) | | |
| C (5) - C (4) - C (3) | 116.7 (3) | | |
| O (4) - C (5) - C (22) | 124.7 (4) | | |
| O (4) - C (5) - C (6) | 115.4 (3) | | |

Table 4

Hydrogen Coordinates ($\times 10^4$) and Isotropic Displacement Parameters ($\text{Å}^2 \times 10^3$) for Compound 11

| | x | y | z | U(eq) | pp |
|---------|-------|-------|-------|-------|--------|
| H (31) | 7461 | 3992 | -1650 | 50 | |
| H (32) | 8326 | 3401 | -1890 | 50 | |
| H (81) | 4010 | 1096 | -4109 | 50 | |
| H (82) | 4991 | 568 | -4367 | 50 | |
| H (91) | 4804 | 482 | -2245 | 50 | |
| H (92) | 4093 | -172 | -3235 | 50 | |
| H (111) | 6795 | -1433 | -2359 | 50 | 0.5352 |
| H (112) | 5245 | -1510 | -2500 | 50 | 0.5352 |
| H (11A) | 5309 | -413 | -1485 | 50 | 0.4811 |
| H (11B) | 5056 | -1281 | -2156 | 50 | 0.4811 |
| H (121) | 6711 | -1768 | -837 | 50 | |
| H (122) | 5883 | -957 | -895 | 50 | |
| H (171) | 10197 | 1228 | -190 | 50 | |
| H (172) | 10492 | 950 | 1167 | 50 | |
| H (19) | 10000 | 2155 | 2366 | 50 | |
| H (20) | 8468 | 4097 | 2371 | 50 | |
| H (21) | 7939 | 4100 | 380 | 50 | |
| H (22) | 7260 | 3971 | -3427 | 50 | |
| H (23) | 6392 | 3967 | -5545 | 50 | |
| H (24) | 5065 | 2897 | -6395 | 50 | |
| H (25) | 4750 | 1613 | -5402 | 50 | |
| H (26) | 9842 | 715 | 2309 | 50 | |
| H (27) | 9479 | -294 | 3750 | 50 | |
| H (28) | 7622 | -1261 | 2852 | 50 | |
| H (29) | 6954 | 1534 | 725 | 50 | |
| H (11W) | 7810 | 5395 | 1771 | 50 | |
| H (12W) | 7143 | 4703 | 2500 | 50 | |

Table 5
Intra- and Intermolecular Bonds of Compound 11

| D-H...A | D...A | D-H | H...A | D-H-A angle | Sym.op.for A |
|-----------------------|----------|----------|----------|-------------|----------------------|
| O(20)-H(20)...O(1W) | 2.463(6) | 1.137(3) | 1.327(5) | 177.2(3) | <i>x,y,z</i> |
| O(1W)-H(11W)...O(2Cl) | 3.272(9) | 1.162(6) | 2.396(5) | 130.4(3) | <i>x,y,z</i> |
| O(1W)-H(11W)...O(3Cl) | 2.964(7) | 1.162(6) | 1.852(5) | 158.5(4) | <i>x,y,z</i> |
| O(1W)-H(12W)...O(10) | 2.58(1) | 1.162(6) | 1.82(1) | 129.0(5) | <i>x,1/2-y,1/2+z</i> |
| O(1W)-H(12W)...O(102) | 2.93(1) | 1.008(4) | 2.02(1) | 148.0(5) | <i>x,1/2-y,1/2+z</i> |
| O(1)...O(4Cl) | 3.023(5) | - | - | - | <i>2-x,1-y,-z</i> |

O 10 and C 11 being distributed on two positions each (O 10 and O 102 and C 11 and C 112, respectively). The conformation of an 18-crown-6 type macrocycle type can be described by six O-C-C-O fragments. In the mostly occurring D_{3h} symmetric 18-crown-6 each of these segments has a *t/g/t* (*t* = *trans*, *g* = *gauche*) conformation. In the crown of the present structure only the four segments O1-C2-C3-O4 (*t/g/t*), O4-C5-C6-O7 (*t/c/t*, *c* = *cis*), O1-C18-C17-O16 (*t/g/g*), O16-C15-C14-O13 (*t/c/t*) are properly defined whereas the segments O13-C12-C11-O10 and O7-C8-C9-O10 are affected by the disorder and should not be discussed in detail.

While from the chemical formula the 18 membered macrocycle could have a twofold symmetry with respect to a line through the atoms O1 and O10 this is not realized in this structure, not even for the ordered part of the crown,

being easily visible from the conformational differences of the fragments O1-C2-C3-O4 (*t/g/t*) and O1-C18-C17-O16 (*t/g/g*). The presence of the two phenyl rings A and B requires a zero torsion hence a *cis* situation along the two C-C-bonds C5-C6 and C14-C15. Least-squares planes were calculated through the planar rings A, B and C differing by $\sigma = 0.007, 0.007, 0.028 \text{ \AA}$ (for A, B, C, σ = average deviation of contributing atoms from the least-square plane) from planarity. While the phenyl rings A and B are almost coplanar (planes A/B = $15.6(2)^\circ$), ring C forms angles of $76.3(1)^\circ$ and $62.2(2)^\circ$ with rings A and B.

The size of the open space inside the crown can be estimated by some intramolecular O...O contacts, being O1...O13 = $4.79(1) \text{ \AA}$, O1...O7 = $4.57(1) \text{ \AA}$, O7...O13 = $4.70(1) \text{ \AA}$, so that a spherical space in the crown of an approximate diameter of $4.5\text{--}4.7 \text{ \AA}$ is available.

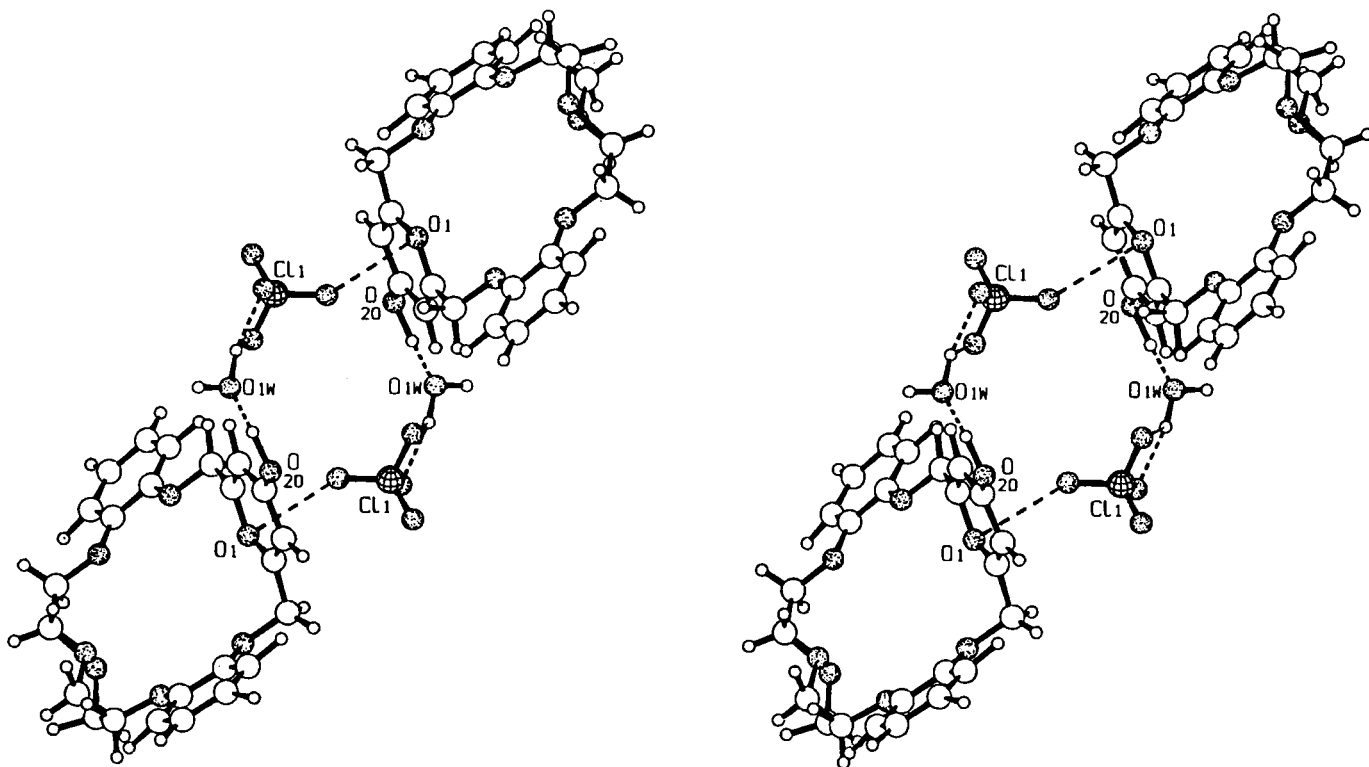


Figure 2. Dimeric cluster consisting of the crown-type compound 11, water and ClO_4^- -fragments connected via a crystallographic inversion center (stereo representation [12])

The one water molecule located in this crystal structure connects the crown with the perchlorate group by the sequence O20-H20...O1W-H11W...O2Cl/O3Cl (contact distances, see Table 5). The second water hydrogen makes another intermolecular hydrogen bond to the disordered oxygen O10 of a crown related by the twofold screw axis. A short O...O contact O1...O4Cl' = 3.023 (5) (symmetry operation for the primed atom: 2-x, 1-y, -z) is seen, establishing a kind of dimer of the constituents crown-water ClO₄-crown'-water'-ClO₄'-(crown) (Figure 2) via the inversion center at (1;0.5,0).

EXPERIMENTAL

General Methods.

Melting points were determined on a Linström apparatus and are uncorrected. The ir spectra were recorded on a Perkin-Elmer 297 spectrometer. The ¹H-nmr spectra were recorded on a Bruker AC 300 spectrometer. Mass spectra were obtained on a Finnigan MAT Bremen CH-7A spectrometer and Finnigan MAT Bremen CH-5DF. Elemental analyses were performed by the Institut für Pharmazie Analytical Service Laboratory.

General Procedure for the Preparation of the Compounds 2-7.

A mixture of compound 1 (10.0 g, 80.64 mmoles), *N*-bromosuccinimide (30 g, 169.0 mmoles) and dibenzoyl peroxide (2.0 g) in tetrachloromethane (250 ml) was heated under reflux for 24 hours. After cooling the precipitate was filtered and the remaining solution was washed with two 120 ml portions of water and two 120 ml portions of a saturated sodium chloride solution. The organic phase was dried over anhydrous sodium sulfate, filtered and evaporated *in vacuo*. The remaining brown oil (11.2 g) was flash chromatographed (column 4.5 cm x 40 cm, silica gel, ethyl acetate) to yield three fractions in order to their tlc R_f-values (fraction I: R_f 0.55-0.72, compounds 7, 6 and 5; fraction II: R_f 0.31-0.42, compounds 4 and 3; fraction III: R_f 0.18, compound 2). The three higher brominated products were obtained by further column chromatography of fraction I (silica gel, ethyl acetate). Fraction II was chromatographed again to obtain compounds 4 and 3 (silica gel, ethyl acetate/chloroform v/v 1:1). All bromination products 2-7 were recrystallized from ethanol.

2-Bromomethyl-6-methyl-4-pyranone (2).

This compound was obtained as beige crystals in 6.7% yield (1.1 g), mp 107° (lit [6] 109°); ir (potassium bromide): ν 1667 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 2.27 (s, 3H), 4.52 (s, 2H), 6.16 (s, 1H), 6.41 (s, 1H); ms: (m/z) 204/202 (M⁺).

Anal. Calcd. for C₇H₇BrO₂ (202.1): C, 41.60; H, 3.49. Found: C, 41.51; H, 3.59.

2,6-Bisbromomethyl-4-pyranone (3).

This compound was obtained as light-brown crystals in 3.2% yield (0.71 g), mp 91°; ir (potassium bromide): ν 1662 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 4.56 (s, 4H), 6.50 (s, 2H); ms: (m/z) 284/282/280 (M⁺).

Anal. Calcd. for C₇H₆Br₂O₂ (280.1): C, 30.01; H, 2.16. Found: C, 29.94; H, 2.15.

2-Dibromomethyl-6-methyl-4-pyranone (4).

This compound was obtained as light-yellow crystals in 10% yield (2.3 g), mp 132°; ir (potassium bromide): ν 1660 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 2.35 (s, 3H), 6.23 (s, 1H), 6.40 (s, 1H), 7.20 (s, 1H); ms: (m/z) 284/282/280 (M⁺).

Anal. Calcd. for C₇H₆Br₂O₂ (280.1): C, 30.01; H, 2.16. Found: C, 29.92; H, 2.23.

6-Bromomethyl-2-dibromomethyl-4-pyranone (5).

This compound was obtained as colorless crystals in 3.1% yield (0.9 g), mp 85°; ir (potassium bromide): ν 1662 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 4.63 (s, 2H), 6.50 (s, 1H), 6.55 (s, 1H), 7.22 (s, 1H); ms: (m/z) 364/362/360/358 (M⁺).

Anal. Calcd. for C₇H₅Br₃O₂ (358.1): C, 23.48; H, 1.41. Found: C, 23.29; H, 1.43.

2,6-Bisdibromomethyl-4-pyranone (6).

This compound was obtained as colorless crystals in 3.4% yield (1.2 g), mp 161°; ir (potassium bromide): ν 1660 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 6.53 (s, 2H), 7.27 (s, 2H); ms: (m/z) 444/442/440/438/436 (M⁺).

Anal. Calcd. for C₇H₄Br₄O₂ (436.1): C, 19.28; H, 0.92. Found: C, 19.53; H, 1.06.

3,5-Dibromo-2,6-bisdibromomethyl-4-pyranone (7).

This compound was obtained as light-yellow crystals in 0.3% yield (0.15 g), mp 207°; ir (potassium bromide): ν 1662 (CO) cm⁻¹; ¹H-nmr (DMSO-d₆): δ 7.49 (s, 2H); ms: (m/z) 604/602/600/598/596/594/592 (M⁺).

Anal. Calcd. for C₇H₂Br₆O₂ (592.1): C, 14.20; H, 0.34. Found: C, 14.47; H, 0.53.

2,9,12,15,22-Pentaoxa[2.7]orthocyclo[2](2,6)pyranophan-28-one (8).

First, the di-potassium salt of 1,5-bis(2-hydroxyphenoxy)-3-oxapentane was prepared by dissolving sodium hydroxide (2.25 g, 56.25 mmoles) in a mixture of water (5 ml) and ethanol (250 ml). After that the diphenol (206 mg, 0.71 mmole) is dissolved in a mixture of the above prepared ethanolic potassium hydroxide (10 ml) and dimethylformamide (10 ml) and the resulting solution was allowed to react at room temperature over 24 hours under continuous stirring. The solutions of the di-potassium salt (20 ml) and compound 2 (200 mg, 0.71 mmole) in *tert*-butyl alcohol (20 ml) are added dropwise, simultaneously and continuously to 120 ml of boiling *tert*-butyl alcohol over 45 minutes according to the two component dilution principle. After an additional reaction time of 1 hour the precipitated potassium bromide was filtered, the solution was removed by evaporation and the residue was purified by column chromatography (silica gel, ethyl acetate). Pure fractions were combined and concentrated to afford 170 mg (42%) of 8 as a white solid. Colorless crystals were obtained from ethyl acetate, mp 104°; ir (potassium bromide): ν 1671 (CO) cm⁻¹; ¹H-nmr (deuterioacetonitrile): δ 3.83 (t, 4H), 4.10 (t, 4H) 4.84 (s, 4H), 6.45 (s, 2H), 6.94-7.02 (m, 8H); ms: (m/z) 410 (M⁺).

Anal. Calcd. for C₂₃H₂₂O₇ (410.4): C, 67.31; H, 5.40. Found: C, 67.15; H, 5.37.

2,9,18,25-Tetraoxa[2.2]orthocyclo[2.2](2,6)pyranophan-15,31-dione (9).

Under nitrogen compound 2 (200 mg, 0.71 mmole), catechol (110 mg, 1.42 mmoles) and tetrabutylammonium hydrogen

sulfate (24.1 mg, 0.071 mmole) are dissolved in dichloromethane (60 ml), followed by the dropwise addition of 0.5 N sodium hydroxide (7.1 ml, 3.55 mmoles). The mixture was stirred at room temperature for 24 hours and then a solution of **2** (200 ml, 0.71 mmole) tetrabutylammonium hydrogen sulfate (24.1 mg, 0.071 mmole) in dichloromethane (10 ml) was added again to this mixture. After stirring at room temperature 7 hours, the organic layer was separated, washed with 0.5 N sodium hydroxide (20 ml) and successively with saturated sodium chloride solution (20 ml). The organic layer was dried and the solvent was evaporated to give a solid which was chromatographed (silica gel, ethyl acetate) and white crystals were obtained from ethyl acetate, yield 81 mg (25%), mp 259; ir (potassium bromide): ν 1670 (CO) cm^{-1} ; $^1\text{H-nmr}$ (deuteriochloroform): δ 4.95 (s, 8H), 6.52 (s, 4H), 7.02-7.07 (m, 8H); ms: (m/z) 460 (M^+).

Anal. Calcd. for $\text{C}_{26}\text{H}_{20}\text{O}_8$ (460.4): C, 67.83; H, 4.38. Found: C, 67.63; H, 4.45.

Potassium Thiocyanate Complex 10.

Potassium thiocyanate (100 mg, 1.03 mmoles) was added in small portions to a solution of **8** (100 mg, 0.244 mmole) in dry dichloromethane (30 ml). After stirring at room temperature for 24 hours the excess potassium bromide residue was removed by filtration and then the filtrate was evaporated to give 14 mg (11%) as pale yellow crystals, mp 178°; ir (potassium bromide): ν 1671 (CO), 2054 (SCN) cm^{-1} ; $^1\text{H-nmr}$ (deuteriochloroform): δ 3.95 (t, 4H), 4.20 (t, 4H) 4.98 (s, 4H), 6.46 (s, 2H), 6.89-7.01 (m, 8H).

Anal. Calcd. for $\text{C}_{23}\text{H}_{22}\text{O}_7 \cdot \text{KSCN} \cdot 1/2\text{H}_2\text{O}$ (516.6): C, 55.80; H, 4.49; N, 2.71. Found: C, 55.67; H, 4.43; N, 2.65.

2,9,12,15,22-Pentaoxa[2.7]orthocyclo[2]-28-hydroxy-(2,6)-pyrylophanium Perchlorate (**11**).

Perchloric acid (2 ml, 70%) was added to compound **8** (100 mg, 0.244 mmole) and the resulting pale yellow solution was kept at room temperature for 1 hour to form a suspension of the pyrylium perchlorate. The mixture was diluted with acetonitrile (3 ml) and allowed to cool to 5° overnight. The crystalline product was filtered, washed with acetonitrile and dried to give 38 mg (29%). An analytical sample was prepared by twice recrystallizing a portion from acetonitrile. The pale yellow crystals had mp 172° dec; ir (potassium bromide): ν 1089 (ClO_4) cm^{-1} ; $^1\text{H-nmr}$ (deuterioacetonitrile): δ 3.01 (s, br OH, H_2O) 3.74 (t, 4H), 4.11 (t, 4H) 5.24 (s, 4H), 6.94-7.08 (m, 8H), 7.36 (s, 2H).

Anal. Calcd. for $\text{C}_{23}\text{H}_{23}\text{ClO}_{11} \cdot \text{H}_2\text{O}$ (528.9): C, 52.23; H, 4.76. Found: C, 51.91; H, 4.61.

Single Crystal X-ray Analysis of Compound 11.

Crystals of $\text{C}_{23}\text{H}_{25}\text{O}_7 \cdot \text{ClO}_4 \cdot \text{H}_2\text{O}$ were grown from acetonitrile and perchloric acid. Precise lattice parameter (from 77 high-order reflections with $40^\circ \leq 2\theta \leq 70^\circ$) and three-dimensional intensity data were measured on a STOE diffractometer using Ni-filtered $\text{CuK}\alpha$ -radiation ($\lambda = 1.5418 \text{ \AA}$). A single crystal with

approximate dimensions 0.68 x 0.45 x 0.25 mm was used to collect the intensity data of 4211 reflections of one quadrant ($2\theta \leq 128^\circ$, $\pm h, k, l$) by using the ω - 2θ scan technique. No significant intensity variations monitored *via* three check reflections, were observed. Merging gave 3985 unique reflections ($R_{\text{int}} = 1.0\%$, $R_\sigma = 2.0\%$) of which 3116 reflections had $F_o > 4\sigma(F_o)$.

Crystal Data of 11.

Molecular formula is $\text{C}_{23}\text{H}_{25}\text{O}_7 \cdot \text{ClO}_4 \cdot \text{H}_2\text{O}$ ($M_r = 528.88$), space group, monoclinic $P2_1/c$, unit cell $a = 12.826(1)$, $b = 15.547(2)$, $c = 12.927(1) \text{ \AA}$, $\beta = 110.98(1)^\circ$, $V = 2406.8 \text{ \AA}^3$, $Z = 4$, $\rho_x = 1.460 \text{ g} \cdot \text{cm}^{-3}$, $\mu(\text{CuK}\alpha) = 19.9 \text{ cm}^{-1}$. Phase determination was made with direct methods (program SHELXS 86 [9]), refinement was done with the corresponding least squares program of the SHELXL program system [10]. Absorption correction was made with XTAL [11]. All hydrogens were located from difference syntheses. In the course of the refinement a disorder in the crown was observed, of which the two atoms O10 and C11 were affected. An inspection of the difference synthesis suggested to refine two positions of each of these atoms with population parameters of approximately 50%. After convergence R-value of $R_1 = 6.7\%$ and $wR_2 = 18.7\%$ (based on F^2) were obtained. A list of anisotropic displacement parameters and F_o - F_c -tables are in the deposition material.

REFERENCES AND NOTES

- [1] G. R. Newkome, J. D. Sauer, J. M. Roper and D. C. Hager, *Chem. Rev.*, **77**, 513 (1977).
- [2] V. K. Majestic and G. R. Newkome, *Top. Curr. Chem.*, **106**, 79 (1982).
- [3] D. H. R. Barton, B. D. Brown, D. D. Ridley, D. A. Widdowson, A. J. Keys and C. J. Leaver, *J. Chem. Soc., Perkin Trans. I*, 2069 (1975).
- [4a] A. Wohl, *Ber.*, **52**, 51 (1919); [b] K. Ziegler, A. Späth, E. Schaaf, W. Schumann and F. Winkelmann, *Liebigs Ann. Chem.*, **551**, 80 (1942).
- [5] N. P. Buu-Hoi and J. Lecocq, *C. R. Hebd. Seances Akad. Sci.*, **222**, 1441 (1946); *C. R. Hebd. Seances Akad. Sci.*, **224**, 937 (1947).
- [6] M. Yamamoto, S. Iwasa, K. Takatsuki and K. Yamada, *J. Org. Chem.*, **51**, 346 (1986).
- [7] F. Vögtle, *Chem. Ztg.*, **96**, 396 (1972).
- [8] E. V. Dehmow, *Angew. Chem.*, **86**, 187 (1974).
- [9] G. M. Sheldrick, in *Crystallographic Computing 3*; R. Goddard, and C. Krüger, eds; Oxford University Press; Oxford 1985, pp 175-189.
- [10] G. M. Sheldrick, SHELXL-93, A Program for Refinement Structures; Universität Göttingen, 1997, publication is in preparation for *J. Appl. Cryst.*
- [11] S. R. Hall, H. D. Flack and J. M. Stewart, eds, XTAL Program System 3.2, Users Manual, Universities of Western Australia, Geneva and Maryland, 1992.
- [12] E. Keller, SCHAKAL 88, A Fortran Program for the Graphical Representation of Molecular and Crystallographic Models, University Freiburg, Germany, 1988.