performed on all reaction mixtures.

Di-*n*-butyl Sulfoxide (4). Sodium hydroxide pellets (13.9 g, 287 mmol) were added to a mixture containing water (50 mL), chloroform (50 mL), and TBAC (500 mg). Di-*n*-butyl sulfide (4.2 g, 290 mmol) was added to the mixture at ambient temperature which was stirred vigorously for 23 h. GLC analysis of an aliquot of the organic layer indicated the presence of 4 (18%) and a number of minor components arising from catalyst (TBAC) degradation within the injection port and on the GLC column. Separation of these components was accomplished with column chromatography. The dark red-brown chloroform solution was concentrated to dryness (rotary evaporator), and a 5-mL aliquot was pipetted onto a column (1 in. o.d. × 15 in.) containing neutral aluminum oxide (50 g). Elution with a mixture of hexanes afforded homogeneous **14**; elution with chloroform gave pure **4**; elution with methanol gave TBAC. The identity of each substance was confirmed by ^{13}C NMR (Table III) and GLC retention time comparisons with authentic samples.

Dichloromethyl Methyl Sulfide (21). Dimethyl sulfide (31.7 g, 50 mmol) was added to a dry 500-mL, three-necked flask equipped with an addition funnel (250 mL), an overhead stirrer, a condenser, and a drying tube (Drierite). The reaction flask was cooled to approximately −10 °C (ice–salt bath), and thionyl chloride (119 g, 71.9 mL, 100 mmol) was added dropwise over a 3-h period. The solution was then heated to reflux (steam bath) and allowed to stir overnight. The remaining yellow liquid was decanted from a yellow solid and distilled to afford 42.3 g of a liquid. A second distillation (8-in. Vigreux column) gave 14.0 g (21%) of a yellow homogeneous liquid: bp 130–133 °C [lit.[34] bp 137 °C (742 torr)], ^1H NMR (neat) δ 2.70 (s, 3 H, SCH_3), 7.08 (s, 1 H, Cl_2CHS).

(Dichloromethyl)dimethylsulfonium Tetrafluoroborate (22). A solution of **21** (6.5 g, 50 mmol) in 20 mL of dichloromethane was added to a dry, round-bottomed flask fitted with a reflux condenser and a drying tube. Methyl iodide (7.1 g, 3.1 mL, 50 mmol) was added in one portion, and the solution was heated to reflux (steam bath) for 12 h. An ^1H NMR analysis of an aliquot indicated that no reaction had occurred. Trimethyloxonium tetrafluoroborate (7.4 g, 50 mmol) was added, and the solution was again heated to reflux for 2 h. The lower brown viscous phase was pipetted into 50 mL of anhydrous diethyl ether where it crystallized. Recrystallization of this solid from a 1:1 solution of diethyl ether and acetone gave 6.1 g (52%) of a colorless solid: mp 45 °C; ^1H NMR (D_2O) δ 3.4 (s, 6 H, $S(CH_3)_2$), 7.6 (s, 1 H, Cl_2CHS). Anal. Calcd for $C_3H_7SCl_2BF_4$: C, 17.19; H, 3.03. Found: C, 17.27; H, 3.16.

(Dichloromethyl)dimethylsulfonium Tetrafluoroborate in Aqueous Sodium Hydroxide. A solution of **22** (2.33 g, 10.0 mmol) in 5 mL of water was added to a round-bottomed flask equipped with a reflux condenser. A solution of 50% aqueous sodium hydroxide (0.50 mL, 13 mmol) was added in one portion with rapid stirring. A transient yellow color appeared immediately following the addition, and in less than 3 s the solution turned dark brown. The solution was extracted in approximately 2 mL of $CDCl_3$ and analyzed by NMR: ^1H NMR ($CDCl_3$) δ 2.11 (0.33 H, CH_3SCH_3), 2.52 ($CH_3S(O)CH_3$), 5.3 (0.67 H, CH_2Cl_2).

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Registry No. **1**, 67-68-5; **2**, 70-29-1; **3**, 2211-89-4; **4**, 2168-93-6; **5**, 2180-20-3; **6**, 833-82-9; **7**, 2211-92-9; **8**, 21892-75-1; **9**, 621-08-9; **10**, 945-51-7; **11**, 10133-81-0; **12** (isomer 1), 67530-09-0; **12** (isomer 2), 67530-10-3; **13**, 75-18-3; **14**, 544-40-1; **15**, 831-91-4; **16**, 139-66-2; **17**, 6294-31-1; **18**, 625-80-9; **19**, 261-31-4; **20**, 54340-73-7; **21**, 2032-76-0; **22**, 62425-75-6; diethyl sulfide, 352-93-2; di-*tert*-butyl sulfide, 107-47-1; dibenzyl sulfide, 538-74-9; dichlorocarbene, 1605-72-7; tetrabutylammonium chloride, 1112-67-0.

Synthesis of Substituted Crown Ethers from Oligoethylene Glycols

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A convenient synthetic method for preparing 12-crown-4, 15-crown-5, 18-crown-6, and 21-crown-7 bearing various substituents by intramolecular cyclization of the corresponding substituted oligoethylene glycols in high yields is described. Substituents include modifiable pendent groups such as phenyl and hydroxymethyl, as well as various alkyl groups. Stability constants for the new substituted crown ethers with sodium and potassium ions in methanol were determined by potentiometric titration. The absolute effect of pendent groups on stability constants was insignificant.

Since the discovery of macrocyclic polyethers and their complexing ability toward metal and ammonium cations, numerous papers and books have been published on their synthesis, properties, and applications.[1-4] For the most part, interest has been directed to the synthesis of new macrocyclic compounds with higher complexing ability and selectivity, rather than more practical methods suitable for their industrial production.

Although some of the alkyl crown ethers reported in this study have already been synthesized and reported to be effective as phase-transfer catalysts,[5-8] they were previously

(1) J. S. Bradshaw and P. E. Stott, *Tetrahedron*, **36**, 461 (1980), and references therein.
(2) M. Hiraoka, "Crown Compounds", Kodansha Scientific, Tokyo, 1978.
(3) R. M. Izatt and J. J. Christensen, "Synthetic Multidentate Macrocyclic Compounds", Academic Press, New York, San Francisco, London, 1978.
(4) R. M. Izatt and J. J. Christensen, "Progress in Macrocyclic Chemistry", Vol. 1, Wiley, New York, 1979.
(5) D. Landini, F. Montanari, and F. M. Pirisi, *J. Chem. Soc., Chem. Commun.*, 879 (1974).
(6) M. Cinquini and P. Tundo, *Synthesis*, 516 (1976).
(7) J. J. Christensen, J. D. Lamb, S. R. Izatt, S. E. Starr, G. C. Weed, M. S. Astin, B. D. Stitt, and R. M. Izatt, *J. Am. Chem. Soc.*, **100**, 321 (1978).
(8) W. W. Parish, P. E. Stott, C. W. McCausland, and J. S. Bradshaw, *J. Org. Chem.*, **43**, 4577 (1978).

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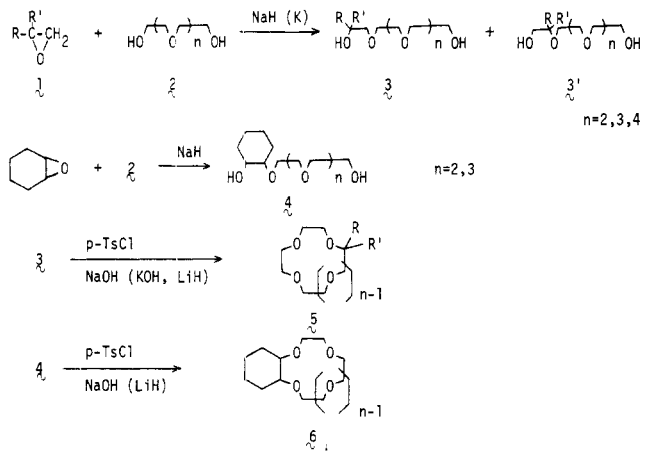
Scheme I



obtained via rather tedious routes and therefore are of limited availability.

We previously reported the synthesis of unsubstituted and alkyl-substituted crown ethers.[9-13] However, this paper deals with a far more practical method for the preparation of a wide variety of substituted crown ethers starting from epoxy compounds and oligoethylene glycols. Thus, the emphasis of this study is the demonstration of a synthetic design utilizing convenient synthons applicable to the industrial production of crown ethers. A further advantage of this design is that the pendent groups so conveniently introduced onto the crown ether moiety may serve to improve the physical properties of the crown ethers as catalysts, or further chemistry may be conducted on the substituents for entirely new applications.

Results and Discussion

Instead of ethoxylation of substituted glycols by addition of ethylene oxide,[10] the reaction of epoxy compounds with oligoethylene glycol monanions prepared from the glycols and 0.5 molar equiv of sodium hydride or potassium was employed for the preparation of substituted oligoethylene glycols as the starting compounds for synthesis of the crown ethers (Scheme I).

The crude glycol product, obtained as viscous brown liquid, is possibly composed of two isomers (**3** and **3'**). It was purified without mixture separation by thin-film molecular or Kugelrohr distillation, because both isomers should afford the same substituted crown ether by intramolecular cyclization. The S_N2 character of the ring opening of epoxides under basic conditions has been illustrated convincingly by many investigations to involve unsymmetric epoxides. Thus, substituted epoxides, such as propylene oxide, are attacked predominantly at the least substituted ring carbon atom.[14,15] In the present investigation, however, no attempt was made to clarify the isomer distribution of **3** and **3'**.

Table I. Preparation of Substituted Oligoethylene Glycol (3, 3', or 4)

3, 3', or 4	R	R'	n	yield, %	thin-film molecular distillation, °C (torr)
a	CH_3	H	3	29	137-139 (0.1)[a]
b	CH_3	CH_3	3	17	146-147 (0.3)[a]
c	C_2H_5	H	3	64	153-157 (0.04)[a]
d	n-C_6H_{13}	H	3	56	140 (0.001)
e	n-C_8H_{17}	H	3	73[b]	150 (0.003)
f	n-$C_{10}H_{21}$	H	3	54	170 (0.001)
g	n-$C_{12}H_{25}$	H	3	56	190 (0.03)
h	Ph	H	3	59[c]	
i	$PhOCH_2$	H	3	55	200 (0.02)
j	$PhCH_2OCH_2$	H	3	58	200 (0.04)
k	CH_2=$CHCH_2OCH_2$	H	3	57[b]	160 (0.03)
l	n-$C_4H_9OCH_2$	H	3	59	140 (0.001)
m	Ph	H	2	68[c]	
n	$PhCH_2OCH_2$	H	2	72[b]	140 (0.002)
o	Ph	H	4	69[b]	180 (0.015)
p	n-C_8H_{17}	H	4	73[b]	190 (0.005)
q	n-$C_{10}H_{21}$	H	4	68[b]	200 (0.005)[d]
r	n-$C_{10}H_{21}$	H	5	53[b]	200 (0.0015)[d]
s	n-$C_{12}H_{25}$	H	5	64[b]	220 (0.0007)[d]
t	1,2-cyclohexanediyl		2	70[c]	
u	1,2-cyclohexanediyl		3	57	140 (0.001)

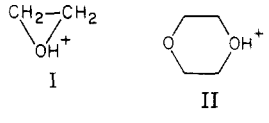
[a] Fractional distillation with a Widmer spiral. [b] Potassium metal was used instead of NaH. [c] Only low-boiling-point materials (solvent, unreacted raw materials) were removed by distillation at reduced pressure. [d] Waxy white solid at 20 °C.

The substituted tetra-, penta-, hexa-, and heptaethylene glycols were thus prepared from the corresponding epoxy compounds with tri-, tetra-, penta-, and hexaethylene glycol, respectively (Table I). No attempt was made to optimize the reaction conditions. Low yields in the cases of methyl and dimethyl derivatives may be due to the low boiling points of propylene and isobutylene oxides.

The synthesis of substituted crown ethers from the corresponding substituted oligoethylene glycols was achieved by our previously reported synthetic method.[9,13] Treatment of the substituted pentaethylene glycols with *p*-toluenesulfonyl chloride in the presence of pulverized sodium hydroxide in dioxane gave the corresponding substituted 15-crown-5 compounds in good yields. The crude products were purified under pyrolyzing conditions by Kugelrohr or thin-film molecular distillation under reduced pressure or purified by fractional distillation after removal of salts by methylene chloride–water extraction of the crude products. By the same procedure, substituted 12-crown-4, 18-crown-6, and 21-crown-7 compounds were prepared from the substituted tetra-, hexa-, and heptaethylene glycols with *p*-toluenesulfonyl chloride and lithium hydride or potassium hydroxide. The results of synthesis are listed in the Experimental Section.

The yields of cyclohexano-15-crown-5 (**6u**) and 2,2-dimethyl-15-crown-5 (**5b**) are practically equal to those of the other substituted 15-crown-5 compounds, showing that substituted pentaethylene glycols which have a secondary or tertiary hydroxyl group successfully cyclize to give the corresponding crown ethers.

The crown ethers prepared are all colorless, hygroscopic liquids, and thus their elemental analyses deviate due to trace contamination of water. Mass spectral analysis revealed m/e = 45 (I) for the hydroxymethyl crown ethers



I II

(9) M. Okahara, M. Miki, S, Yanagida, I. Ikeda, and K. Matsushima, *Synthesis*, 854 (1977).
(10) P.-L. Kuo, M. Miki, and M. Okahara, *J. Chem. Soc., Chem. Commun.*, 504 (1978).
(11) N. Kawamura, M. Miki, I. Ikeda, and M. Okahara, *Tetrahedron Lett.*, 535 (1979).
(12) T. Mizuno, Y. Nakatsuji, S. Yanagida, and M. Okahara, *Bull. Chem. Soc. Jpn.*, **53**, 481 (1980).
(13) P.-L. Kuo, N. Kawamura, M. Miki, and M. Okahara, *Bull. Chem. Soc. Jpn.*, **53**, 1689 (1980).
(14) R. J. Gritter in "The Chemistry of the Ether Linkage", S. Patai, Ed., Wiley-Interscience, New York, 1967, p 390.
(15) N. Schachat and H. L. Greenwald in "Nonionic Surfactant", M. J. Schick, Ed., Marcel Dekker, New York, 1967, p 12.

Scheme II

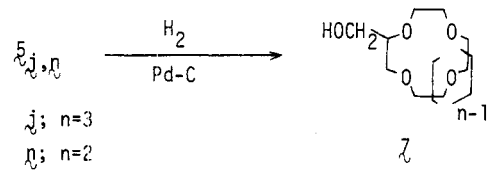


Table II. Stability Constants in Methanol at 25 °C

crown ether	log K_1' Na⁺	log K_1' K⁺
15-crown-5	3.3	3.3
C_6H_{13}-15-crown-5	3.2	3.0
C_8H_{17}-15-crown-5	3.2	3.1
$C_{10}H_{21}$-15-crown-5	3.2	3.2
Ph-15-crown-5	3.3	3.4
18-crown-6	4.3 (4.32)[17]	6.0 (6.10)[17]
C_8H_{17}-18-crown-6	3.9	5.1

and m/e 89 (II) for all of the remaining crown ethers as the expected base peaks. Parent peaks were observed for all of the crown ethers. The characteristic split of the ν_{C-O} band (1100 and 1130 cm^{-1}) for the 12-crown-4 compounds was observed in the IR spectra. Conversely, the 15-crown-5, 18-crown-6, and 21-crown-7 compounds possess only a broad single absorption band.

The crown ethers **5** with the pendent phenyl group should differ from benzo crown ethers in complexing properties. Other derivatives should be obtainable by modification of the phenyl group. Reductive debenzylation of (benzyloxy)methyl crown ethers gave the corresponding hydroxymethyl-substituted crown ethers (Scheme II). These in turn can potentially be converted to various substituted crown ethers by esterification, etherification, or oxidation or may be immobilized on polymer matrices.[16-18]

The stability constants for the new crown ethers with sodium and potassium cations in methanol are listed in Table II. The effect of the substituents on stability constants is insignificant within each series of both 15-crown-5 and 18-crown-6 ligands.

Experimental Section

Proton NMR spectra were recorded at 100 MHz on a JEOL JNM-PS 100 spectrometer. Infrared spectra were taken on either a JASCO IR-E or Hitachi 260-10 spectrometer. Mass spectral data were obtained with a Hitachi RMU-6E mass spectrometer at an ionization potential of 70 eV. GLC analyses were performed on a Schimadzu GC-3A using 1 m × 3 mm column packed with 10% silicone SE-30 on 60-80-mesh Celite 545. Stability constants were measured with a Beckman 4500 digital pH meter and calculated by the reported method.[19]

Hexylpentaethylene Glycol (3d). Procedure A. To a mixture of 150 mL of dioxane and 12.0 g (0.25 mol) of 50% oil-suspended NaH stirred at 20 °C was slowly added 97.0 g (0.50 mol) of tetraethylene glycol. After the evolution of hydrogen gas had ceased, 32.0 g (0.25 mol) of 1,2-epoxyoctane was added to the mixture which was heated under reflux for 24 h. After cooling, the reaction mixture was neutralized with 22 mL of concentrated HCl, and sodium chloride was filtered off. Evaporation of the solvents and excess tetraethylene glycol under reduced pressure gave 70 g of crude product as a viscous brown liquid. An aliquot (65 g) of the crude product was purified by thin-film molecular distillation at 140 °C (0.001 torr) to give 41 g (56%) of GLC-pure **3d** as a pale yellow liquid.

Octylpentaethylene Glycol (3e). Procedure B. Into 50 mL of dioxane containing 9.8 (0.25 mol) of potassium in lumps was added dropwise under stirring 97.0 g (0.50 mol) of tetraethylene glycol at 50 °C. After the potassium metal had dissolved, 39.0 g (0.25 mol) of 1,2-epoxydecane was added to the solution, and the mixture was heated under reflux for 12 h. The same workup technique as for procedure A was adopted to give 81 g of crude product as viscous brown liquid. The crude product (76 g) was purified by molecular distillation at 150 °C (0.003 torr) to give 62 g (73%) of **3e** as a pale yellow liquid.

Hexyl-15-crown-5 (5d). This procedure is typical for the preparation of crown ethers. To a suspension of 20 g (0.48 mol) of pulverized NaOH in 600 mL of dioxane was added a solution of 39 g (0.12 mol) of **3d** and 23 g (0.12 mol) of *p*-toluenesulfonyl chloride in 360 mL of dioxane dropwise over a period of 10 h under stirring at 60 °C. After the addition was complete, the mixture was stirred at 60 °C for an additional 10 h and cooled to room temperature. The precipitate was filtered off and washed with CH_2Cl_2. Evaporation of the solvent from the combined solution under reduced pressure gave 40 g of crude product as a viscous yellow liquid. The crude product (36 g) was purified by molecular distillation under reduced pressure at 120 °C (0.03 torr) to give 23 g (62%) of GLC-pure **5d**: ^1H NMR (CCl_4) δ 0.88 (t, CH_3, 3 H), 1.28 (s, CH_2, 10 H), 3.20–3.80 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H); IR (neat film) 2920, 2860, 1470, 1350, 1290, 1250, 1130, 990, 940 cm^{-1}. Anal. Calcd for $C_{16}H_{32}O_5$: C, 63.05; H, 10.80. Found: C, 63.13; H, 10.59.

Methyl-15-crown-5 (5a): bp 100–120 °C (0.09 torr; Kugelrohr distillation); colorless liquid; 70% yield; ^1H NMR (CCl_4) δ 1.05 (d, CH_3, 2.9 H), 3.25–3.64 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H). Anal. Calcd for $C_{11}H_{22}O_5$: C, 56.39; H, 9.46. Found: C, 55.47; H, 9.52.

Dimethyl-15-crown-5 (5b): bp 126–129 °C (0.25 torr; Kugelrohr distillation); colorless liquid; 40% yield; ^1H NMR (CCl_4) δ 1.14 (s, CH_3, 6 H), 3.35 (s, $OCCH_2O$, 2 H), 3.42–3.61 (m, OCH_2CH_2O, 16 H). Anal. Calcd for $C_{12}H_{24}O_5$: C, 58.04; H, 9.74. Found: C, 57.38; H, 10.04.

Ethyl-15-crown-5 (5c): bp 80 °C (0.02 torr; molecular distillation); 65% yield; ^1H NMR (CCl_4) δ 0.90 (t, CH_3, 2.8 H), 1.28–1.56 (m, CH_2, 1.9 H), 3.42–3.61 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H). Anal. Calcd for $C_{12}H_{24}O_5$: C, 58.04; H, 9.74. Found: C, 57.13; H, 9.94.

Octyl-15-crown-5 (5e): bp 140 °C (0.003 torr; molecular distillation); 62% yield; ^1H NMR (CCl_4) δ 0.88 (t, CH_3, 3 H), 1.22 (s, CH_2, 14 H), 3.16–3.84 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H). Anal. Calcd for $C_{18}H_{36}O_5$: C, 65.00; H, 11.17. Found: C, 65.03; H, 10.91.

Decyl-15-crown-5 (5f): bp 140 °C (0.002 torr; molecular distillation); 48% yield; ^1H NMR (CCl_4) δ 0.90 (t, CH_3, 3 H), 1.28 (s, CH_2, 18 H), 3.20–3.78 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H). Anal. Calcd for $C_{20}H_{40}O_5$: C, 66.63; H, 11.18. Found: C, 66.58; H, 11.47.

Dodecyl-15-crown-5 (5g): bp 160 °C (0.01 torr; molecular distillation); 48% yield; ^1H NMR (CCl_4) δ 0.90 (t, CH_3, 3 H), 1.28 (s, CH_2, 22 H), 3.20–3.78 (m, OCH_2CH_2O, $OCHCH_2O$, 19 H). Anal. Calcd for $C_{22}H_{44}O_5$: C, 68.00; H, 11.41. Found: C, 67.69; H, 11.62.

Phenyl-15-crown-5 (5h): bp 150–162 °C (0.02 torr; Kugelrohr distillation); 40% yield; ^1H NMR (CCl_4) δ 3.41–3.70 (m, OCH_2CH_2O, CH_2CPhO, 18 H), 4.57 (dd, OCCHPhO, 1 H), 7.24 (s, C_6H_5, 5 H); IR (neat film) 2940, 2860, 1460, 1350, 1295, 1250, 1120, 980, 930, 750, 690 cm^{-1}. Anal. Calcd for $C_{16}H_{24}O_5$: C, 64.85; H, 8.16. Found: C, 63.91; H, 8.23.

[(Phenyloxy)methyl]-15-crown-5 (5i): bp 170 °C (0.03 torr; molecular distillation); 49% yield; ^1H NMR (CCl_4) δ 3.20–4.24 (m, OCH_2CH_2O, $PhOCH_2CHCH_2O$, 21 H), 6.64 (m, C_6H_5, 5 H). Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.30; H, 8.12.

[(Benzyloxy)methyl]-15-crown-5 (5j): bp 150 °C (0.02 torr; molecular distillation); 50% yield; ^1H NMR (CCl_4) δ 3.28–3.88 (m, OCH_2CH_2O, $BzOCH_2CHCH_2O$, 2 H), 4.48 (s, $PhCH_2O$, 2 H), 7.20 (s, C_6H_5, 5 H). Anal. Calcd for $C_{18}H_{28}O_6$: C, 63.51; H, 8.29. Found: C, 63.60; H, 8.33.

[(Allyloxy)methyl]-15-crown-5 (5k): bp 100 °C (0.001 torr; molecular distillation); 60% yield; ^1H NMR (CCl_4) δ 3.30–3.80 (m, OCH_2CH_2O, $OCH_2CHCH_2OCC{=}C$, 21 H), 3.86–3.98 (m, $C{=}CCH_2O$, 2 H), 5.00–5.34 (m, $CH_2{=}$, 2 H), 5.64–6.00 (m, =CH,

(16) M Tomoi, O. Abe, M. Ikeda, K. Kihara, and H. Kakiuchi, *Tetrahedron Lett.*, 3031 (1978).
(17) F. Motanari, *Tetrahedron Lett.*, 5055 (1979).
(18) K. Hiratani, P. Reuter, and G. Manecke, *J. Mol. Catal.*, 241 (1979).
(19) J. K. Frensdorff, *J. Am. Chem. Soc.*, **93**, 600 (1971).

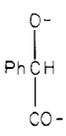
1 H). Anal. Calcd for $C_{14}H_{26}O_6$: C, 57.91; H, 9.03. Found: C, 57.87; H, 9.20.

[(Butyloxy)methyl]-15-crown-5 (51): bp 100 °C (0.005 torr; molecular distillation); 69% yield; ^{1}H NMR (CCl_4) δ 0.93 (t, CH_3, 3 H), 1.16–1.76 (m, CH_2, 4 H), 3.24–3.84 (m, OCH_2CH_2O, $PrCH_2OCH_2CHCH_2O$, 23 H). Anal. Calcd for $C_{15}H_{30}O_6$: C, 58.80; H, 9.87. Found: C, 58.74; H, 9.93.

Phenyl-12-crown-4 (5m): bp 88–93 °C (0.01 torr; Kugelrohr distillation); 19% yield; ^{1}H NMR (CCl_4) δ 3.16–4.44 (m, OCH_2CH_2O, 14 H), 4.66 (t, CPhHO, 1 H), 7.20 (s, C_6H_5, 5 H); IR (neat film) 2920, 2880, 1500, 1455, 1365, 1310, 1295, 1250, 1200, 1130, 1095, 1025, 1005, 920, 855, 755, 695 cm^{-1}. Anal. Calcd for $C_{14}H_{20}O_4$: C, 66.65; H, 7.99. Found: C, 66.66; H, 8.19.

[(Benzyloxy)methyl]-12-crown-4 (5n): bp 140–165 °C (0.1 torr; Kugelrohr distillation); 62% yield; ^{1}H NMR (CCl_4) δ 3.16–3.90 (m, OCH_2CH_2O, $BzOCH_2CHCH_2O$, 17 H), 4.44 (s, $PhCH_2$, 2 H), 7.20 (m, C_6H_5, 5 H). Anal. Calcd for $C_{16}H_{24}O_5$: C, 64.84; H, 8.16. Found: C, 65.06; H, 8.35.

Phenyl-18-crown-6 (5o): bp 120 °C (0.002 torr; molecular distillation); 50% yield; ^{1}H NMR (CCl_4) δ 3.36–3.80 (m, OCH_2CH_2O, 22 H), 4.54 (dd, III, 1 H), 7.24 (s, C_6H_5, 5 H). Anal. Calcd for $C_{18}H_{28}O_6$: C, 63.51; H, 8.92. Found: C, 62.73; H, 8.29



III

Octyl-18-crown-6 (5p): bp 150 °C (0.003 torr; molecular distillation); 56% yield; ^{1}H NMR (CCl_4) δ 0.88 (t, CH_3, 3 H), 1.26 (s, CH_2, 14 H), 3.24–3.88 (m, OCH_2CH_2O, $OCHCH_2O$, 23 H); IR (neat film) 2920, 2850, 1460, 1340, 1290, 1240, 1120, 980, 940 cm^{-1}. Anal. Calcd for $C_{20}H_{40}O_6$: C, 63.80; H, 10.71. Found: C, 63.49; H, 10.98.

Decyl-18-crown-6 (5q): bp 160 °C (0.004 torr; molecular distillation); 56% yield; ^{1}H NMR (CCl_4) δ 0.88 (t, CH_3, 3 H), 1.28 (s, CH_2, 18 H), 3.28–3.92 (m, OCH_2CH_2O, $OCHCH_2O$, 23 H). Anal. Calcd for $C_{22}H_{44}O_6$: C, 65.31; H, 10.96. Found: C, 64.98; H, 11.02.

Decyl-21-crown-7 (5r): bp 160 °C (0.002 torr; molecular distillation); 59% yield; ^{1}H NMR (CCl_4) δ 0.86 (t, CH_3, 3 H), 1.25 (s, CH_2, 18 H), 3.20–3.90 (m, OCH_2CH_2O, $OCHCH_2O$, 27 H). Anal. Calcd for $C_{24}H_{48}O_7$: C, 64.25; H, 10.78. Found: C, 63.65; H, 11.03.

Dodecyl-21-crown-7 (5s): bp 180 °C (0.001 torr; molecular distillation); 47% yield; ^{1}H NMR (CCl_4) δ 0.88 (t, CH_3, 3 H), 1.26 (s, CH_2, 22 H), 3.20–3.90 (m, OCH_2CH_2O, $OCHCH_2O$, 27 H). Anal. Calcd for $C_{26}H_{52}O_7$: C, 65.51; H, 10.99. Found: C, 65.22; H, 11.11.

Cyclohexano-12-crown-4 (6t): bp 120–140 °C (0.07 torr; Kugelrohr distillation); 30% yield; ^{1}H NMR (CCl_4) δ 0.80–2.12 (m, CH_2, 8 H), 2.84–3.32 (m, OCHCHO, 2 H), 3.36–4.00 (m, OCH_2CH_2O, 12 H). Anal. Calcd for $C_{12}H_{22}O_4$: C, 62.58; H, 9.63. Found: C, 62.36; H, 9.72.

Cyclohexano-15-crown-5 (6u): bp 110 °C (0.001 torr; molecular distillation); 61% yield; ^{1}H NMR (CCl_4) δ 1.04–2.00 (m, CH_2, 8 H), 3.04–3.42 (m, OCHCHO, 2 H), 3.48–3.68 (m, OCH_2CH_2O, 16 H). Anal. Calcd for $C_{14}H_{28}O_5$: C, 61.29; H, 9.55. Found: C, 60.96; H, 9.79.

(Hydroxymethyl)-12-crown-4 (7n). Into a solution of 1.66 g (5.6 mmol) of **5n** in 10 mL of dioxane including 160 mg of 5% palladium on carbon and 160 mg of *p*-toluenesulfonic acid was bubbled a stream of hydrogen gas at room temperature for 3 h. After debenzylation was complete, which was monitored by the dissappearance of **5n** with GLC, the catalyst was removed by filtration, and the solvent was evaporated to give 1.12 g (97%) of GLC-pure **7n** as a pale yellow residue. Distillation of the residue (0.35 g) with a Kugelrohr distillation apparatus gave 0.30 g of (hydroxymethyl)-12-crown-4 as a colorless liquid: bp 115 °C (0.04 torr); ^{1}H NMR (CCl_4) δ 2.75 (s, 1 H), 3.4–3.8 (m, 17 H); mass spectrum, *m/e* (relative intensity) 206 (M^+, 0.5), 188 ($M^+ - H_2O$), 175 ($M^+ - CH_2OH$, 22); IR (neat film) 3300, 2920, 2860, 1440, 1360, 1290, 1240, 1130, 1100, 1030, 910, 850 cm^{-1}. Anal. Calcd for $C_9H_{18}O_5$: C, 52.41; H, 8.80. Found: C, 51.99; H, 8.84.

[(Trifluoroacetoxy)methyl]-12-crown-4. Hydroxymethyl compound **7n** was heated with an excess amount of trifluoroacetic anhydride at 90–100 °C for 1 h. Low-boiling materials were distilled off in vacuo, and the objective compound was isolated from the distillation residue with GLC: ^{1}H NMR (CCl_4) δ 4.4 (m, 2 H), 3.9–4.4 (m, 15 H); mass spectrum, *m/e* 302 (M^+).

(Hydroxymethyl)-15-crown-5 (7j). The procedure for **7n** was adopted: bp 113 °C (0.01 torr; Kugelrohr distillation apparatus); 89% yield; ^{1}H NMR (CCl_4) δ 2.75 (s, 1 H), 3.40–3.82 (m, 2 H); mass spectrum, *m/e* (relative intensity) 250 (M^+, 0.5), 232 ($M^+ - H_2O$, 0.7), 219 ($M^+ - CH_2OH$, 15). Anal. Calcd for $C_{11}H_{22}O_6$: C, 52.79; H, 8.86. Found: C, 52.74; H, 8.90.

Registry No. **1** (R = CH_3; R′ = H), 75-56-9; **1** (R = R′ = CH_3), 558-30-5; **1** (R = C_2H_5; R′ = H), 106-88-7; **1** (R = *n*-C_6H_{13}; R′ = H), 2984-50-1; **1** (R = *n*-C_8H_{17}; R′ = H), 2404-44-6; **1** (R = *n*-$C_{10}H_{21}$; R′ = H), 2855-19-8; **1** (R = *n*-$C_{12}H_{25}$; R′ = H), 3234-28-4; **1** (R = Ph; R′ = H), 96-09-3; **1** (R = $PhOCH_2$; R′ = H), 122-60-1; **1** (R = $PhCH_2OCH_2$; R′ = H), 2930-05-4; **1** (R = $CH_2{=}CHCH_2OCH_2$; R′ = H), 106-92-3; **1** (R = *n*-$C_4H_9OCH_2$; R′ = H), 2426-08-6; **2** (*n* = 2), 112-27-6; **2** (*n* = 3), 112-60-7; **2** (*n* = 4), 4792-15-8; **2** (*n* = 5), 2615-15-8; **3a**, 75506-76-2; **3b**, 75506-77-3; **3c**, 75506-78-4; **3d**, 75506-79-5; **3e**, 75506-80-8; **3f**, 75506-81-9; **3g**, 75506-82-0; **3h**, 75506-83-1; **3i**, 75506-84-2; **3j**, 75506-85-3; **3k**, 75506-86-4; **3l**, 75506-87-5; **3m**, 75506-88-6; **3n**, 75506-89-7; **3o**, 75506-90-0; **3p**, 75506-91-1; **3q**, 75506-92-2; **3r**, 75506-93-3; **3s**, 75506-94-4; **3′a**, 75506-95-5; **3′b**, 75506-96-6; **3′c**, 75506-97-7; **3′d**, 75506-98-8; **3′e**, 75506-99-9; **3′f**, 75507-00-5; **3′g**, 75507-01-6; **3′h**, 75507-02-7; **3′i**, 75507-03-8; **3′j**, 75507-04-9; **3′k**, 75507-05-0; **3′l**, 75507-06-1; **3′m**, 75507-07-2; **3′n**, 75507-08-3; **3′o**, 75507-09-4; **3′p**, 75507-10-7; **3′q**, 75507-11-8; **3′r**, 75507-12-9; **3′s**, 75507-13-0; **4t**, 74262-29-6; **4u**, 75507-14-1; **5a**, 68167-84-0; **5b**, 74649-90-4; **5c**, 75507-15-2; **5d**, 65743-07-9; **5e**, 74649-87-9; **5f**, 74649-88-0; **5g**, 74649-89-1; **5h**, 68756-67-2; **5i**, 75507-166-3; **5j**, 75507-17-4; **5k**, 68167-86-2; **5l**, 75507-18-5; **5m**, 75507-19-6; **5n**, 75507-20-9; **5o**, 75507-21-0; **5p**, 75507-22-1; **5q**, 60742-60-1; **5r**, 75507-23-2; **5s**, 75507-24-3; **6t**, 17454-42-1; **6u**, 17454-48-7; **7j**, 75507-25-4; **7n**, 75507-26-5; [(trifluoroacetoxy)-methyl]-12-crown-4, 75507-27-6; 7-oxabicyclo[4.1.0]heptane, 286-20-4; 15-crown-5, 33100-27-5; 18-crown-6, 17455-13-9.