# Molecular Design of the Electron-Donating Sidearm of Lariat Ethers: Effective Coordination of the Quinoline Moiety in Complexation toward Alkali-Metal Cations

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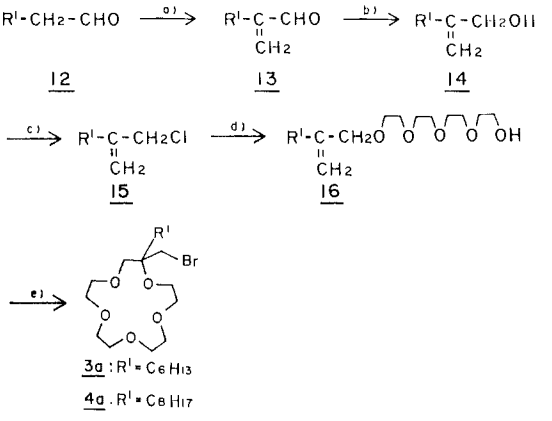
**Abstract:** The electron-donating sidearm of alkyl-substituted lariat ethers based on 15-crown-5, 16-crown-5, and 18-crown-6 was modified to clarify the contribution to the complexation of the sidearm toward alkali-metal cations. A specific coordination property of the quinoline sidearm was shown by measuring the complexing ability in methanol at 25 °C, the change of the chemical shift in the $^1$H NMR spectrum, a characteristic absorption in the UV spectrum, the extractability, and the transport ability. The methyl-substituted lariat ether based on 15-crown-5 or 18-crown-6 displayed an excellent selectivity toward $Na^+$ or $K^+$, respectively, compared with the unsubstituted ethers.

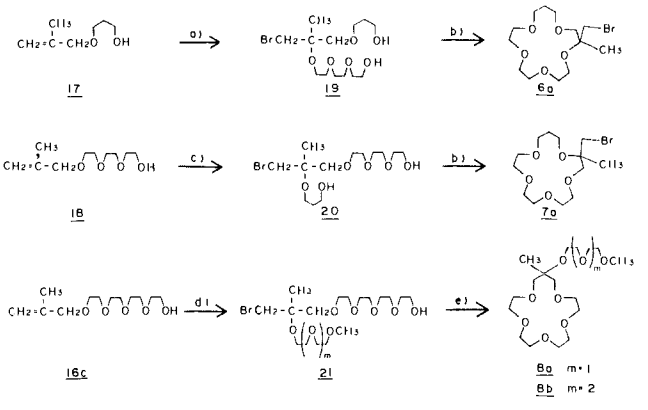
Crown ethers are interesting compounds and are used in many areas because of their selective complexation properties toward specific guest molecules. There are many monographs[1] and reviews[2] concerning their synthesis and complexation properties. Although several factors are considered to affect the complexation of crown ethers toward cations, the relative size of the cation and the cavity of the ring seem to be the most important factors dominating complexation and selectivity.[1-3] For example, 18-crown-6 has an excellent complexing ability and selectivity toward $K^+$. On the other hand, 15-crown-5, which seems to have a suitable ring structure for $Na^+$ among simple crown ethers, does not display sufficient complexing ability toward $Na^+$ and $Na^+/K^+$ selectivity as shown by binding data (see Table I). Accordingly, a ligand suitable for a specific cation is not necessarily obtained by simply changing the ring size. Cryptands having a three-dimensional ring structure or spherands[4] having a preorganized structure are known to display much higher complexing ability and a good selectivity compared with crown compounds.[1,2] However, modification of the ring structure of these ligands is relatively difficult. In addition, too strong complexation is not always desirable, as indicated by some groups[5,6] in membrane transport velocity of cations.

**Scheme I**[a]



[a] (a) Formalin/$Me_2NH$·HCl, (b) $LiAlH_4$/ether, (c) $SOCl_2$/pyridine, (d) tetraethylene glycol/sodium, (e) NBS/1,2-dichloroethane/$NaBF_4$.

**Scheme II**[a]



[a] (a) NBS/triethylene glycol, (b) NaOH/dioxane, (c) NBS/trimethylene glycol, (d) NBS/oligoethylene glycol monomethyl ether, (e) *t*-BuONa/*t*-BuOH.

Lariat ethers, which are crown ether derivatives having an electron-donating sidearm, enable subtle adjustment of complexing ability or selectivity toward a variety of cations.[7] For example,

(1) (a) Izatt, R. M.; Christensen, J. J., Eds. *Synthetic Multidentate Macrocyclic Compounds*; Academic Press: New York, 1978. (b) Lamb, J. D.; Izatt, R. M.; Christensen, J. J.; Eatough, D. J. In *Coordination Chemistry of Macrocyclic Compounds*; Nelson, G. A., Ed.; Plenum Press: New York, 1979; pp 145–217. (c) Vögtle, F., Ed. *Host–Guest Complex Chemistry I*; Springer-Verlag: Berlin, Heidelberg, New York, Tokyo, 1981. (d) Vögtle, F., Ed. *Host–Guest Complex Chemistry II*; Springer-Verlag: Berlin, Heidelberg, New York, Tokyo, 1982. (e) Gokel, G. W.; Korzeniowski, S. H. *Macrocyclic Polyether Syntheses*: Springer-Verlag: Berlin, Heidelberg, New York, Tokyo, 1982. (f) Hiraoka, M., Ed. *Crown Compounds*; Elsevier: Amsterdam, 1982. (g) Vögtle, F.; Weber, E., Eds. *Host–Guest Complex Chemistry III*; Springer-Verlag: Berlin, Heidelberg, New York, Tokyo, 1984. (h) Izatt, R. M.; Christensen, J. J., Eds. *Synthesis of Macrocycles*; Wiley-Interscience: New York, 1986.

(2) (a) Christensen, J. J.; Eatough, D. J.; Izatt, R. M. *Chem. Rev.* **1974**, *74*, 351. (b) Gokel, G. W.; Durst, H. D. *Synthesis* **1976**, 168. (c) Bradshaw, J. S.; Stott, P. E. *Tetrahedron* **1980**, *36*, 461. (d) Jolly, S. T.; Bradshaw, J. S.; Izatt, R. M. *J. Heterocycl. Chem.* **1982**, *19*, 3. (e) Gokel, G. W.; Dishong, D. M.; Schultz, R. A.; Gatto, V. J. *Synthesis* **1982**, 997. (f) Okahara, M. *Kagaku Kogyo* **1982**, 715. (g) Okahara, M. *Yukagaku* **1985**, *34*, 901. (h) Izatt, R. M.; Bradshaw, J. S.; Nielsen, S. A.; Lamb, J. D.; Christensen, J. J.; Sen, D. *Chem. Rev.* **1985**, *85*, 271.

(3) Pedersen, C. J. *J. Am. Chem. Soc.* **1967**, *89*, 7017.

(4) (a) Cram, D. J.; Kaneda, T.; Helgeson, R. C.; Brown, S. B.; Knobler, C. B.; Maverick, E.; Trueblood, K. N. *J. Am. Chem. Soc.* **1985**, *107*, 3645. (b) Cram, D. J.; Lein, G. M. *J. Am. Chem. Soc.* **1985**, *107*, 3657.

(5) Kirch, M.; Lehn, J.-M. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 555.

(6) Lamb, J. D.; Christensen, J. J.; Oscarson, J. L.; Nielsen, B. L.; Asay, B. W.; Izatt, R. M. *J. Am. Chem. Soc.* **1980**, *102*, 6820.

(7) (a) Gokel, G. W.; Dishong, D. M.; Diamond, C. J. *J. Chem. Soc., Chem. Commun.* **1980**, 1053. (b) Dishong, D. M.; Diamond, C. J.; Cinoman, M. I.; Gokel, G. W. *J. Am. Chem. Soc.* **1983**, *105*, 586. (c) Echegoyen, L.; Kaifer, A.; Durst, H.; Schultz, R. A.; Dishong, D. M.; Goli, D. M.; Gokel, G. W. *J. Am. Chem. Soc.* **1984**, *106*, 5100.

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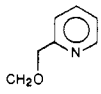
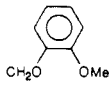
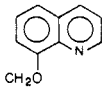
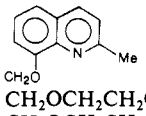
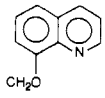
Table I. Stability Constants of Substituted 15-Crown-5

| compd | $R^1$ | $R^2$ | log $K'$ ($Na^+$) | log $K'$ ($K^+$) | selectivity ($Na^+/K^+$) |
|---|---|---|---|---|---|
| **1** | H | H | 3.31 (1.0)[a] | 3.34 (1.0) | 0.93 |
| **2a** | $CH_3$ | $CH_3$ | 2.99 (0.48) | 2.85 (0.32) | 1.4 |
| **2b** | $CH_3$ |  | 3.58 (1.9) | 3.08 (0.55) | 3.2 |
| **2c** | $CH_3$ |  | 4.02 (5.1) | 3.49 (1.4) | 3.4 |
| **2d** | $CH_3$ |  | 3.79 (3.0) | 3.35 (1.0) | 2.8 |
| **2e** | $CH_3$ |  | 4.87 (36.3) | 3.56 (1.7) | 20.4 |
| **2f** | $CH_3$ |  | 4.31 (10.0) | 3.75 (2.6) | 3.6 |
| **2g**[b] | $CH_3$ | $CH_2OCH_2CH_2OMe$ | 3.87 (3.6) | 3.42 (1.2) | 2.8 |
| **2h** | $CH_3$ | $CH_2OCH_2CH_2CH_2OMe$ | 3.48 (1.5) | 3.14 (0.63) | 2.2 |
| **2i** | $CH_3$ | $CH_2OCH_2CH_2OH$ | 3.88 (3.7) | 3.36 (1.0) | 3.3 |
| **2j** | $CH_3$ | $CH_2(OCH_2CH_2)_2OH$ | 3.88 (3.7) | 3.82 (3.0) | 1.1 |
| **2k** | $CH_3$ | $CH_2(OCH_2CH_2)_3OH$ | 3.73 (2.6) | 3.99 (4.5) | 0.5 |
| **2l** | $CH_3$ | $CH_2OC_8H_{17}$ | 3.54 (1.7) | 3.15 (0.41) | 2.5 |
| **2m** | $CH_3$ | $CH_2OCH_2CH_2OC_8H_{17}$ | 3.75 (2.8) | 3.47 (1.3) | 1.9 |
| **2n** | $CH_3$ | $CH_2(OCH_2CH_2)_2OC_8H_{17}$ | 3.88 (3.7) | 3.79 (2.8) | 1.2 |
| **2o** | $CH_3$ | $CH_2OC_{12}H_{25}$ | 3.42 (1.3) | 3.09 (0.56) | 2.1 |
| **2p** | $CH_3$ | $CH_2OCH_2CH_2OC_{12}H_{25}$ | 3.75 (2.8) | 3.42 (1.2) | 2.1 |
| **2q** | $CH_3$ | $CH_2(OCH_2CH_2)_2OC_{12}H_{25}$ | 3.89 (3.8) | 3.78 (2.8) | 1.3 |
| **3a** | $C_6H_{13}$ | $CH_2Br$ | 2.74 (0.27) | 2.55 (0.16) | 1.5 |
| **3b** | $C_6H_{13}$ | $CH_2OC_6H_{13}$ | 3.56 (1.8) | 2.93 (0.38) | 4.3 |
| **3c** | $C_6H_{13}$ | $CH_2OCH_2CH_2OMe$ | 3.90 (3.9) | 3.29 (0.89) | 4.1 |
| **3d** | $C_6H_{13}$ | $CH_2(OCH_2CH_2)_2OMe$ | 3.91 (4.0) | 3.84 (3.2) | 1.2 |
| **3e** | $C_6H_{13}$ | $CH_2(OCH_2CH_2)_3OMe$ | 3.71 (2.5) | 3.72 (2.4) | 1.0 |
| **3f** | $C_6H_{13}$ | $CH_2OC_8H_{17}$ | 3.39 (1.2) | 2.97 (0.43) | 2.6 |
| **3g** | $C_6H_{13}$ | $CH_2OCH_2CH_2OC_8H_{17}$ | 3.62 (2.0) | 3.25 (0.81) | 2.3 |
| **3h** | $C_6H_{13}$ | $CH_2(OCH_2CH_2)_2OC_8H_{17}$ | 3.75 (2.8) | 3.56 (1.7) | 1.5 |
| **3i** | $C_6H_{13}$ |  | 4.85 (34.7) | 3.41 (1.2) | 27.5 |
| **4a** | $C_8H_{17}$ | $CH_2Br$ | 2.79 (0.30) | 2.61 (0.19) | 1.5 |
| **4b** | $C_8H_{17}$ | $CH_2OCH_2CH_2OMe$ | 3.82 (3.2) | 3.17 (0.68) | 4.5 |
| **4c** | $C_8H_{17}$ | $CH_2(OCH_2CH_2)_2OMe$ | 3.86 (3.5) | 3.76 (2.6) | 1.3 |
| **4d** | $C_8H_{17}$ | $CH_2(OCH_2CH_2)_3OMe$ | 3.75 (2.8) | 3.79 (2.8) | 0.9 |

[a] Parentheses denote the relative value toward the stability constant of unsubstituted 15-crown-5 (**1**). [b] Reference 9b.

C-pivot lariat ethers having a 15-crown-5 ring did not remarkably improve the stability constants toward $Na^+$ and $K^+$ or the $Na^+/K^+$ selectivity,[7] though N-pivot lariat ethers were shown to increase the complexation ability toward $Na^+$ and $K^+$.[8] However, the latter compounds show poor $Na^+/K^+$ selectivity. Recently, we could improve the complexation property by introducing a methyl substituent onto the C-pivot position of Gokel's lariat ethers based on 15-crown-5 derivatives compared with the unsubstituted 15-crown-5.[9] Modification of the structure of the electron-donating sidearm should be expected to change their complexation properties. We will report the syntheses and complexation properties of 15-crown-5, 16-crown-5, and 18-crown-6 ethers having an electron-donating sidearm and the effect of the structure of the sidearm on complexation.[10]

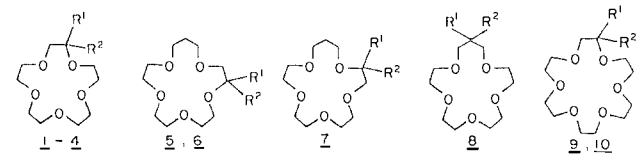
(8) (a) Schultz, R. A.; Dishong, D. M.; Gokel, G. W. *Tetrahedron Lett.* **1981**, *22*, 2623. (b) Masuyama, A.; Nakatsuji, Y.; Ikeda, I.; Okahara, M. *Tetrahedron Lett.* **1981**, *22*, 4665.

(9) (a) Nakatsuji, Y.; Nakamura, T.; Okahara, M.; Dishong, D. M.; Gokel, G. W. *Tetrahedron Lett.* **1982**, *23*, 1351. (b) Nakatsuji, Y.; Nakamura, T.; Okahara, M.; Dishong, D. M.; Gokel, G. W. *J. Org. Chem.* **1983**, *48*, 1237.

(10) A part of this work was published as two communications: (a) Nakatsuji, Y.; Nakamura, T.; Okahara, M. *Chem. Lett.* **1982**, 1207. (b) Nakatsuji, Y.; Yonetani, M.; Okahara, M. *Chem. Lett.* **1984**, 2143.

## Results and Discussion

**Synthesis.** Methyl lariat ethers (**2**) having a 15-crown-5 ring were prepared by reaction of 2-(bromomethyl)-2-methyl-15-crown-5 with an appropriate alkoxide or phenoxide according to

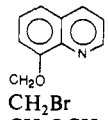
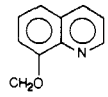


**1** - **4** **5**, **6** **7** **8** **9**, **10**

the previous method.[9] Hexyl or octyl lariat ethers (**3**, **4**) were also obtained from the corresponding 2-(bromomethyl)-2-(long-chain alkyl)-15-crown-5, which was prepared via five steps by using the commercial octanal or decanal as the starting material according to Scheme I.

Lariat ethers having a 16-crown-5 ring possess several positional isomers because of the presence of the trimethylene unit in the ring structure. Accordingly, the position of an electron-donating sidearm, which may affect complexation, should be noted. From this point of view, three kinds of lariat ethers having a 16-crown-5 ring were prepared according to Scheme II. The synthesis of methyl lariat ethers having an 18-crown-6 ring was also carried

Table II. Stability Constants of Substituted 16-Crown-5

| compd | $R^1$ | $R^2$ | log $K'$ ($Na^+$) | log $K'$ ($K^+$) | selectivity ($Na^+/K^+$) |
|---|---|---|---|---|---|
| **5** | H | H | 3.51 (1.0)[a] | 2.63 (1.0) | 7.6 |
| **6a** | $CH_3$ | $CH_2Br$ | 3.31 (0.63) | 2.40 (0.59) | 8.1 |
| **6b** | $CH_3$ | $CH_2OCH_2CH_2OMe$ | 3.60 (1.2) | 2.87 (1.7) | 5.4 |
| **6c** | $CH_3$ | $CH_2(OCH_2CH_2)_2OMe$ | 3.94 (2.7) | 3.40 (5.9) | 3.5 |
| **6d** | $CH_3$ |  | 4.20 (4.9) | 3.10 (3.0) | 12.6 |
| **7a** | $CH_3$ | $CH_2Br$ | 2.59 (0.12) | 2.00 (0.23) | 3.9 |
| **7b** | $CH_3$ | $CH_2OCH_2CH_2OMe$ | 3.00 (0.31) | 2.37 (0.55) | 4.3 |
| **7c** | $CH_3$ | $CH_2(OCH_2CH_2)_2OMe$ | 3.04 (0.34) | 2.76 (1.3) | 1.9 |
| **7d** | $CH_3$ |  | 3.78 (1.9) | 2.66 (0.93) | 13.2 |
| **8a** | $CH_3$ | $CH_2OCH_2CH_2OMe$ | 3.62 (1.3) | 3.51 (7.6) | 1.3 |
| **8b** | $CH_3$ | $CH_2(OCH_2CH_2)_2OMe$ | 3.48 (0.93) | 4.22 (38.9) | 0.2 |

[a] Parentheses denote the relative value toward the stability constant of unsubstituted 16-crown-5 (**5**).

out by a procedure similar to that mentioned above.[10,11] The structures of all new compounds were ascertained by NMR, MS, IR, and elemental analysis (Experimental Section).

**Stability Constants for 15-Crown-5 Derivatives.** The stability constants of new lariat ethers having a 15-crown-5 ring toward $Na^+$ and $K^+$ measured in methanol at 25 °C[12] are summarized in Table I along with data of reference compounds.

In this study, the effect of the electron-donating sidearm on the stability constant was estimated by the relative value to the unsubstituted 15-crown-5 (**1**). The introduction of two methyl groups only works to reduce the stability constants toward $Na^+$ and $K^+$ (see **2a**). On the other hand, all methyl lariat ethers succeeded in raising the stability constant toward $Na^+$. This result clearly demonstrates the importance of the electron-donating sidearm for the coordination toward $Na^+$. In the previous work,[9] binding data obtained for methyl lariat ethers having an oligooxyethylene sidearm at the pivot position showed that one oxyethylene unit increased the complexing ability toward $Na^+$ without the increase of that toward $K^+$. This trend was also observed in other series such as **2i**, **2j**, and **2k**. Gokel and co-workers reported a similar trend in lariat ethers having no methyl group at the pivot position.[13] These findings make clear that the modification of sidearms can improve not only the complexing ability but also the $Na^+/K^+$ selectivity.

The higher binding datum for $Na^+$ obtained for **2c** having a tetrahydrofuran-type sidearm than that for **2g** having a methoxy-type sidearm shows the importance of restricting the interference of the terminal branch movement. As for oligooxyethyleneoxymethyl sidearms, the effect of the terminal group, especially the chain length of the terminal alkoxy group together with the hydroxyl group, on the stability constants was not so remarkable. These compounds having a long-chain terminal group are expected to be promising special nonionic surfactants[14] since such compounds should show a specific behavior in the presence of a variety of cations compared with open-chain analogues.[15] The stability constant of **2h** having a trimethyleneoxy sidearm is relatively lower than that of **2g** having an ethyleneoxy sidearm. This finding demonstrates the importance of an ethyleneoxy unit.

The stability constant of **2e** having a quinoline-type sidearm toward $Na^+$ should be noted. The stability constant (4.87) toward $Na^+$ of **2e** was found to be about 36 times that of unsubstituted 15-crown-5 (**1**) and the $Na^+/K^+$ selectivity exceeded 20 times. The universality of the function of the quinoline sidearm was ascertained in compound **3i**, that is, the corresponding hexyl lariat ethers. The presence of the methyl group on the 2-position of the quinoline moiety of **2f** obviously decreased the stability constant toward $Na^+$ but increased that toward $K^+$. Thus, the $Na^+/K^+$ selectivity for **2f** was remarkably lower than that for **2e**. This result may be explained by considering the steric hindrance between the methyl group of the quinoline moiety and the crown ring and the enlargement of the cavity size. The change of methyl group to hexyl or octyl group contributed toward raising the $Na^+/K^+$ selectivity (compare **2g**, **3c**, and **4b**).

Introduction of two electron-donating sidearms to the crown ring is another interesting problem. The complexing ability of two-armed crown ether having two electron-donating groups on the same carbon of the crown ring is very similar to that of the corresponding methyl lariat ether.[10a] This finding is easily understood because two oxyethylene chains cannot coordinate the cation at the same time as suggested by examination of Corey–Pauling–Koltun molecular models.[10a] Accordingly, two-armed crown ethers having electron-donating groups on different carbons of the crown ring displayed an effective coordination of two electron-donating sidearms.[16]

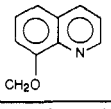
**Stability Constants for 16-Crown-5 Derivatives.** Recently, 16-crown-5 ethers were disclosed to have a higher $Na^+/K^+$ selectivity than 15-crown-5 derivatives.[17] 16-Crown-5 is considered to have an interesting ring structure due to the presence of a trimethylene moiety and affords several positional isomers, which may have different complexation properties, by changing the position of sidearm.

The increase of the $Na^+/K^+$ selectivity was hardly observed in almost all lariat ethers derived from 16-crown-5 ethers because unsubstituted 16-crown-5 (**5**) itself has a good $Na^+/K^+$ selectivity. The introduction of a quinoline sidearm to the crown ring succeeded in increasing the $Na^+/K^+$ selectivity. However, the extent of the increase did not reach that of the corresponding lariat ether having a 15-crown-5 ring (**2e**).

In this case, it should be noted that a large difference between **6** and **7** in the stability constants for both cations was observed. The presence of the substituent on the carbon adjacent to the trimethylene oxygen atom remarkably decreased the stability constants toward $Na^+$ and $K^+$. A CPK model examination suggested the presence of the steric hindrance between the sub-

(11) Nakamura, T.; Nakatsuji, Y.; Okahara, M. *J. Chem. Soc., Chem. Commun.* **1981**, 219.
(12) Frensdorff, H. K. *J. Am. Chem. Soc.* **1971**, *93*, 600.
(13) Goli, D. M.; Dishong, D. M.; Diamond, C. J.; Gokel, G. W. *Tetrahedron Lett.* **1982**, *23*, 5243.
(14) (a) Okahara, M.; Kuo, P.-L.; Yamamura, S.; Ikeda, I. *J. Chem. Soc., Chem. Commun.* **1980**, 586. (b) Kuo, P.-L.; Ikeda, I.; Okahara, M. *Tenside Deterg.* **1982**, *19*, 4. (c) Kuo, P.-L.; Ikeda, I.; Okahara, M. *Tenside Deterg.* **1982**, *19*, 204. (d) Kuo, P.-L.; Tsuchiya, K.; Ikeda, I.; Okahara, M. *J. Colloid Interface Sci.* **1983**, *92*, 463.
(15) (a) Ikeda, I.; Itoh, A.; Kuo, P.-L.; Okahara, M. *Tenside Deterg.* **1984**, *21*, 252. (b) Ikeda, I.; Kuo, P.-L.; Tsuchiya, K.; Okahara, M. *Tenside Deterg.* **1984**, *21*, 255.
(16) Nakatsuji, Y.; Mori, T.; Okahara, M. *Tetrahedron Lett.* **1984**, *25*, 2171.
(17) (a) Ikeda, I.; Katayama, T.; Tsuchiya, K.; Okahara, M. *Bull. Chem. Soc. Jpn.* **1983**, *56*, 2473. (b) Ouchi, M.; Inoue, Y.; Sakamoto, H.; Yamahira, A.; Yoshinaga, M.; Hakushi, T. *J. Org. Chem.* **1983**, *48*, 3168.

Table III. Stability Constants of Substituted 18-Crown-6

| compd | $R^1$ | $R^2$ | log $K'$ ($Na^+$) | log $K'$ ($K^+$) | selectivity ($K^+/Na^+$) |
|---|---|---|---|---|---|
| **9** | H | H | 4.30 (1.0)[a] | 6.02 (1.0) | 52 |
| **10a** | $CH_3$ | $C_3H_7$ | 4.13 (0.68) | 5.38 (0.28) | 18 |
| **10b** | $CH_3$ | $CH_2Br$ | 3.97 (0.47) | 5.31 (0.19) | 22 |
| **10c** | $CH_3$ | $CH_2OC_6H_{13}$ | 4.20 (0.79) | 5.43 (0.26) | 17 |
| **10d** | $CH_3$ | $CH_2SC_6H_{13}$ | 4.01 (0.51) | 5.34 (0.21) | 21 |
| **10e** | $CH_3$ | $CH_2NHC_6H_{13}$ | 3.68 (0.24) | 5.13 (0.13) | 28 |
| **10f** | $CH_3$ | $CH_2OCH_2CH_2OMe$ | 4.09 (0.62) | 5.51 (0.31) | 26 |
| **10g** | $CH_3$ | $CH_2(OCH_2CH_2)_2OMe$ | 4.23 (0.85) | 5.52 (0.32) | 19 |
| **10h** | $CH_3$ | $CH_2(OCH_2CH_2)_3OMe$ | 4.19 (0.78) | 5.51 (0.31) | 21 |
| **10i** | $CH_3$ |  | 4.15 (0.71) | 6.28 (1.8) | 135 |

[a] Parentheses denote the relative value toward the stability constant of unsubstituted 18-crown-6 (**9**).

stituent and the nearest methylene group of the trimethylene unit. Such steric hindrance does not exist in **6** or the alkyl lariat ethers having a 15-crown-5 ring.

On the other hand, the compound having an electron-donating sidearm on the central carbon of the trimethylene unit (**8**) showed an interesting behavior. Especially, the stability constant toward $K^+$ of **8b** was about 40 times that of unsubstituted 16-crown-5 (**5**). This finding showed the selectivity between $Na^+$ and $K^+$ was inverted in this kind of compound. It is noteworthy that the selectivity can dramatically be changed by simply introducing an electron-donating sidearm.

**Stability Constants for 18-Crown-6 Derivatives.** Although modification of 18-crown-6 seemed to be unnecessary because this series of compounds are well-known to have an excellent $K^+/Na^+$ selectivity, we applied this strategy for 18-crown-6 ethers (see Table III).

Attempts to improve the complexation property of 18-crown-6 derivatives by derivatization to lariat ethers, which had succeeded in modifying the complexation property of 15-crown-5 derivatives, were almost unsuccessful (see **10c**, **10f**, **10g**, and **10h**). The coordination of the electron-donating sidearm toward $K^+$ may disturb the suitable positions of the oxygen atoms of the 18-crown-6 ring to decrease the stability constant. However, **10i** displayed a higher complexing ability toward $K^+$ and a higher $K^+/Na^+$ selectivity than the unsubstituted 18-crown-6 (**9**). To the best of our knowledge, this is the first successful example exceeding the complexing ability of an unsubstituted 18-crown-6 toward $K^+$ and the $K^+/Na^+$ selectivity by simply introducing an electron-donating sidearm to the crown ring.

**Chemical Shift in $^1H$ NMR.** A $^1H$ NMR study on the complexation of the 15-crown-5 having a quinoline sidearm (**2e**) and the corresponding 18-crown-6 derivative (**10i**) with NaSCN or KSCN in $CDCl_3$ was carried out because **2e** or **10i** was clarified by the measurement of stability constants in methanol to have a $Na^+/K^+$ selectivity or a $K^+/Na^+$ selectivity, respectively. Since the peaks based on the methylene group on the sidearm adjacent to the crown ring are apart from other peaks, they can easily be compared with each other. For example, the methylene peak of the substituent of **2e** shifted downfield by 0.21 ppm by addition of an equimolar amount of NaSCN, whereas the extent of the shift was only 0.01 ppm with KSCN. The opposite trend was observed for the 18-crown-6 derivative (**10i**): downfield shifts of 0.09 and 0.14 ppm were observed upon addition of NaSCN and KSCN, respectively. These results clearly show the effective coordination of the quinoline sidearm toward a specific alkali-metal cation. Actually, the complex of **2e** with NaSCN (1:1) was isolated as a monohydrate from acetone–toluene. Similarly, the complex of **10i** with KSCN (1:1) was also recrystallized from acetone–toluene.

**UV Spectroscopy.** The position of the UV absorption of the picrate anion is a measure of the type of the ion pair.[18] When

Table IV. UV Absorption Maximum of Picrate Anion in THF

| | $Na^+$ | | $K^+$ | |
|---|---|---|---|---|
| compd | [L]/[P] = 1[a] | [L]/[P] = 5 | [L]/[P] = 1 | [L]/[P] = 5 |
| **2e** | 378[b] | 379 | 355 | 365 |
| **2g** | 351 | 351 | 355 | 357 |
| **10f** | 351 | 359 | 362 | 367 |
| **10i** | 360 | 378 | 378 | 378 |

[a] [L] = [ligand]; [P] = [picrate anion] = $5 \times 10^{-5}$ M. [b] In nm.

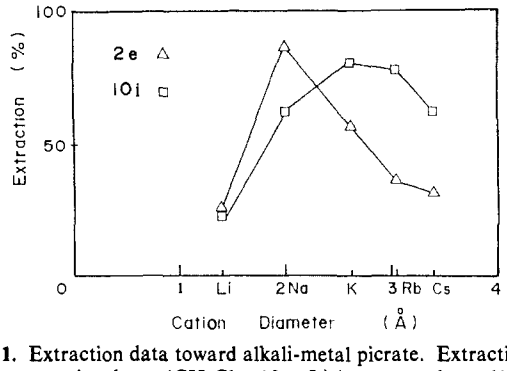



**Figure 1.** Extraction data toward alkali-metal picrate. Extraction conditions: organic phase ($CH_2Cl_2$, 10 mL)/aqueous phase (10 mL); [MOH] = $5 \times 10^{-2}$ M; [extractant] = [picric acid] = $5 \times 10^{-4}$ M; 22 °C; 9 h.

**2e** complexed with sodium picrate in THF, a peak at 378 nm was observed (Table IV). This absorption was assigned to the solvent-separated ion pair. On the other hand, the combination of **2g** and sodium picrate showed the absorption at 351 nm, assigned to the contact ion pair. The large difference between **2e** and **2g** may be attributable to the strong coordination property and the rigid structure of the quinoline moiety as the sidearm of **2e**. Similarly, the UV absorptions of equimolar amounts of **10i** or **10f** and potassium picrate in THF were observed at 378 and 362 nm, respectively. The formation of the solvent-separated ion pair should be useful for generating an activated anion when **2e** or **10i** is used as the phase-transfer catalyst.

**Solvent Extraction.** Although the interesting behavior of **2e** and **10i** having a quinoline sidearm toward $K^+$ and $Na^+$ was disclosed by the experiment mentioned above, the selectivity toward other alkali-metal cations is also considered to be of importance. The complexation property for all alkali-metal cations was estimated by the solvent extraction method.[19] Extraction profiles of **2e** and **10i** are shown in Figure 1.

As expected by the stability constant measured in methanol and the $^1H$ NMR study, a high $Na^+$ selectivity of **2e** over other cations was clearly demonstrated. Although the slight differentiation between $K^+$ and $Rb^+$ observed for **10i** may become a problem in some cases, the $K^+/Na^+$ selectivity is clearly observed.

(18) (a) Wong, K. H.; Bourgoin, M.; Smid, J. *J. Chem. Soc., Chem. Commun.* **1974**, 715. (b) Bourgoin, M.; Wong, K. H.; Hui, J. Y.; Smid, J. *J. Am. Chem. Soc.* **1975**, *97*, 3462.

(19) Pedersen, C. J. *Fed. Proc., Fed. Am. Soc. Exp. Biol.* **1968**, *27*, 1305.

Table V. Competitive Passive Transport Data[a] toward $Li^+$, $Na^+$, and $K^+$

| compd | $Li^+$ | $Na^+$ | $K^+$ | selectivity $Na^+/Li^+$ | selectivity $Na^+/K^+$ | selectivity $K^+/Na^+$ |
|---|---|---|---|---|---|---|
| **2e** | 0.036 | 17.4 | 0.31 | 480 | 56 | |
| **2f** | 0.032 | 12.4 | 0.89 | 340 | 14 | |
| **11**[b] | 0.52 | 7.92 | 2.48 | 15 | 3.2 | |
| **10i** | nd[c] | 0.16 | 9.60 | | | 60 |

[a] $10^6$ mol/h. [b] Dodecyl-15-crown-5. [c] Not determined. Transport conditions: aqueous phase 1 (10 mL) ([LiCl] = [NaCl] = [KCl] = [$Me_4NOH$] = 0.1 M/organic phase ($CH_2Cl_2$, 20 mL) carrier and picric acid ($5 \times 10^{-5}$ mol)/aqueous phase 2 (10 mL) ([HCl] = 0.1 M); 25 °C.

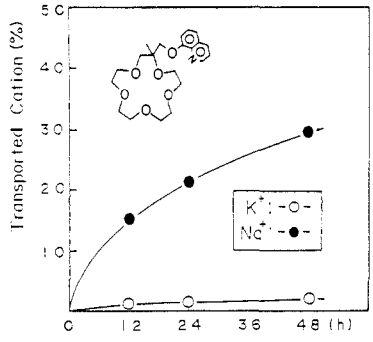



**Figure 2.** Competitive active transport of $K^+$ and $Na^+$ by using **2e**. Transport conditions: aqueous phase 1 (10 mL) ([KSCN] = [NaSCN] = [$Me_4NOH$] = 0.1 M)/organic phase ($CH_2Cl_2$, 20 mL) **2e** ($5 \times 10^{-5}$ mol)/aqueous phase 2 (10 mL) ([KSCN] = [NaSCN] = [HCl] = 0.1 M); 25 °C.

**Bulk Liquid Membrane Transport.** Selective separation of alkali-metal cations was carried out by the liquid membrane transport method.[20] The passive transport conditions and the results are summarized in Table V.

Although it is not proper to compare transport data obtained under different conditions, the $Na^+/K^+$ selectivity (56) of **2e** attained in the liquid membrane system is considered to be among the best for selective carriers.[21] It is clear that compound **2e** possesses a high $Na^+/K^+$ selectivity and $Na^+/Li^+$ selectivity compared with those of dodecyl 15-crown-5 (**11**),[22] which is a lipophilic crown ether. It is interesting that the decrease of the $Na^+/K^+$ selectivity of **2f** compared with that of **2e** is well coincident with the result obtained in the stability constant (see Table I). Compound **10i** was an excellent $K^+$ ionophore as expected.

In addition, compound **2e** can successfully be used as an effective $Na^+$ selective and active transport carrier as shown in Figure 2.

It should be stressed that octylmonoaza-15-crown-5 ether (log $K(Na^+)$ = 3.08) could not selectively transport $Na^+$ over $K^+$ under the same transport conditions.[23] This finding may reflect the difference of the stability constants.

## Conclusion

All data presented in this article strongly demonstrate an effective coordination of a quinoline moiety introduced to the crown ring toward alkali-metal cations. This coordination property of the quinoline moiety will increasingly gain an important position in the molecular design for host molecules.

## Experimental Section

$^1H$ NMR spectra were taken at 100 MHz on a JEOL JNM-PS 100 spectrometer, using tetramethylsilane as the internal standard. IR and UV spectra were obtained on a Hitachi 260-10 spectrometer and a Shimadzu UV-200 spectrophotometer, respectively. Mass spectra were measured with a Hitachi RMU-6E mass spectrometer at an ionization potential of 70 eV. 2-(Bromomethyl)-2-methyl-15-crown-5,[9b,11] 2-(bromomethyl)-2-methyl-18-crown-6 (**10b**),[11] and dialkyl-substituted crown ethers[24] were prepared according to the literature.

**2-Hexylacrolein (13a).** A mixture of octanal (128 g, 1.0 mol), dimethylamine hydrogen chloride (98 g, 1.2 mol), and 37% aqueous formalin (97 g, 1.2 mol) was stirred at 70 °C for 24 h according to the literature procedure.[25] Organic and aqueous phases were separated. The aqueous phase was extracted with hexane (250 mL × 2). The combined organic phase was concentrated and purified by distillation under reduced pressure. Yield 81%; bp 76 °C/20 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 0.96 (t, 3 H), 1.20–1.44 (m, 8 H), 2.16 (t, 2 H), 5.88 (m, 1 H), 6.14 (m, 1 H), 9.48 (m, 1 H); IR 3080, 2950, 2860, 1700, 1630, 1460, 1380, 950, 720 $cm^{-1}$; MS *m/e* 140 ($M^+$, 5), 109 (33), 98 (47), 97 (93), 71 (67), 70 (73), 55 (67), 43 (87), 41 (100).

**2-Octylacrolein (13b).** This compound was prepared by the procedure described in the synthesis of **13a**. Yield 55%; bp 86 °C/8 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 3 H), 1.21–1.40 (m, 12 H), 2.19 (t, 3 H), 5.92 (m, 1 H), 6.17 (m, 1 H), 9.52 (m, 1 H); IR 2930, 2860, 1700, 1630, 1460, 1380, 1330, 940, 720 $cm^{-1}$; MS *m/e* 168 ($M^+$, 13), 137 (25), 111 (33), 98 (67), 97 (100), 71 (79), 57 (96), 55 (96), 43 (75), 41 (96).

**2-Hexylallyl Alcohol (14a).** To a stirred suspension of $LiAlH_4$ (8.12 g, 0.214 mol) in 200 mL of ether was added **13a** by continuing the gentle reflux. After the addition of **13a**, the mixture was stirred for another 3 h. Water (10 mL) was added to the mixture cooled in an ice bath. Then the contents were poured into 100 mL of ice water followed by the addition of 0.5 mL of 10% $H_2SO_4$. The ether layer was separated, and the aqueous layer was extracted with ether (100 mL × 2). The combined organic layer was concentrated and purified by distillation in vacuo. Yield 87%; bp 85 °C/8 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 3 H), 1.20–1.40 (m, 8 H), 1.98 (t, 2 H), 2.50 (s, 1 H), 3.92 (m, 2 H), 4.75 (m, 1 H), 4.91 (m, 1 H); IR 3300, 3080, 2930, 2860, 1650, 1460, 1010, 990 $cm^{-1}$; MS *m/e* 142 ($M^+$, 6), 95 (11), 71 (37), 58 (100), 57 (54), 55 (21), 43 (54), 41 (37).

**2-Octylallyl Alcohol (14b).** This compound was prepared by the procedure described in the synthesis of **14a**. Yield 94%; bp 68 °C/0.2 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 3 H), 1.22–1.42 (m, 12 H), 1.98 (t, 2 H), 3.66 (s, 1 H), 3.92 (m, 2 H), 4.75 (m, 1 H), 4.93 (m, 1 H); IR 3330, 3080, 2950, 2870, 1660, 1460, 1030, 900 $cm^{-1}$; MS *m/e* 170 ($M^+$, 4), 128 (5), 112 (8), 97 (9), 81 (12), 71 (29), 58 (100), 57 (43), 55 (23), 43 (39), 41 (30).

**2-Hexylallyl Chloride (15a).** To a stirred solution of thionyl chloride (82.3 g, 0.692 mol) and pyridine (0.5 mL) was added **14a** (71.5 g, 0.503 mol) at room temperature over a period of 2 h, and the mixture was stirred at 50 °C for another 6 h. After cooling to room temperature, the mixture was neutralized by aqueous $Na_2CO_3$ solution (200 mL). The mixture was extracted with hexane (250 mL × 2) and purified by distillation under reduced pressure. Yield 81%; bp 62 °C/8 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 3 H), 1.20–1.44 (m, 8 H), 2.14 (t, 2 H), 3.95 (s, 2 H), 4.90 (m, 1 H), 5.07 (m, 1 H); IR 3080, 2940, 2860, 1450, 910, 750 $cm^{-1}$; MS *m/e* 162 ($M^+ + 2$, 1), 160 ($M^+$, 2), 101 (14), 95 (22), 90 (30), 70 (70), 69 (66), 56 (84), 55 (100), 43 (97), 42 (63), 41 (71).

**2-Octylallyl Chloride (15b).** This compound was prepared by the procedure described in the synthesis of **15a**. Yield 95%; $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 3 H), 1.20–1.52 (m, 12 H), 2.14 (t, 2 H), 3.94 (m, 2 H), 4.80 (m, 1 H), 5.06 (m, 1 H); IR 3090, 2950, 2870, 1470, 1380, 1260, 910, 750 $cm^{-1}$; MS *m/e* 190 ($M^+ + 2$, 2), 188 ($M^+$, 4), 96 (28), 81 (21), 70 (40), 69 (13), 57 (54), 56 (100), 55 (56) 43 (58), 41 (49).

**General Procedure for Preparing Oligoalkylene Glycol Monoalkylallyl Ether.** The title compound was prepared by the monoalkylation reaction of sodium alkoxide of oligoalkylene glycol with alkylallyl chloride according to the conventional Williamson ether synthesis.[9b]

**Tetraethylene Glycol Mono-2-hexylallyl Ether (16a).** After sodium metal (10.4 g, 0.452 mol) was dissolved in tetraethylene glycol (304 g, 1.57 mol), **15a** (72.6 g, 0.452 mol) was added to the solution over a period of 2 h at 80 °C. Then the mixture was stirred at 80 °C for another 8 h. After the mixture cooled to room temperature, 900 mL of dichloromethane was added to the mixture, which was washed twice with 200 mL

(20) (a) Nakatsuji, Y.; Sakamoto, M.; Okahara, M.; Matsushima, K. *Chem. Express* **1986**, *1*, 431. (b) Nakatsuji, Y.; Sakamoto, M.; Okahara, M.; Matsushima, K. *Nippon Kagaku Kaishi* **1987**, 430. (c) Okahara, M.; Nakatsuji, Y. *Top. Curr. Chem.* **1985**, *128*, 37.

(21) For example: Strzelbicki, J.; Bartsch, R. A. *J. Membr. Sci.* **1982**, *10*, 35. They reported that the $Na^+/K^+$ selectivity obtained by using a kind of carboxylic-type ionophore having a 16-crown-5 ring was 13 in a chloroform bulk membrane.

(22) Ikeda, I.; Yamamura, S.; Nakatsuji, Y.; Okahara, M. *J. Org. Chem.* **1980**, *45*, 5355.

(23) Matsushima, K.; Nakatsuji, Y.; Kobayashi, H.; Okahara, M. *Chem. Lett.* **1983**, 701.

(24) Mizuno, T.; Nakatsuji, Y.; Yanagida, S.; Okahara, M. *Bull. Chem. Soc. Jpn.* **1980**, *53*, 481.

(25) Marvel, C. S.; Myers, R. L.; Sauders, J. H. *J. Am. Chem. Soc.* **1948**, *70*, 1694.

of water. The organic layer was concentrated and distilled in vacuo to give a colorless oil. Yield 64%; bp 130 °C/0.02 mm; $^1$H NMR ($CDCl_3$) $\delta$ 0.87 (t, 3 H), 1.20–1.40 (m, 8 H), 1.98 (t, 2 H), 2.80 (s, 1 H), 3.40–3.60 (m, 8 H), 3.83 (s, 2 H), 4.78 (m, 1 H), 4.90 (m, 1 H); IR 3450, 2950, 1480, 1360, 1310, 1260, 1120, 920 cm$^{-1}$; MS *m/e* 318 ($M^+$, 5), 177 (11), 133 (12), 89 (55), 87 (11), 73 (9), 69 (20), 55 (15), 45 (100).

**Tetraethylene Glycol Mono-2-octylallyl Ether (16b).** This compound was prepared by the procedure described in the synthesis of **16a**. Yield 74%; bp 164 °C/0.06 mm; $^1$H NMR ($CDCl_3$) $\delta$ 0.88 (t, 3 H), 1.20–1.58 (m, 12 H), 2.00 (t, 2 H), 2.80 (s, 1 H), 3.41–3.70 (m, 8 H), 3.94 (m, 2 H), 4.81 (m, 1 H), 4.93 (m, 1 H); IR 3450, 3080, 2940, 2870, 1460, 1350, 1300, 1250, 1120, 910 cm$^{-1}$; MS *m/e* 346 ($M^+$, 6), 177 (10), 133 (16), 89 (52), 71 (15), 69 (13), 57 (18), 55 (21).

**Trimethylene Glycol Mono-2-methylallyl Ether (17).** Since the direct addition of sodium metal to trimethylene glycol was considered to be dangerous, *tert*-butyl alcohol was used for dissolving sodium metal. Yield 72%; bp 95 °C/15 mm; $^1$H NMR ($CDCl_3$) $\delta$ 1.72 (s, 3 H), 1.28–1.92 (m, 2 H), 2.96 (s, 1 H), 3.42–3.74 (m, 4 H), 3.90 (s, 2 H), 4.86 (m, 1 H), 4.94 (m, 1 H); IR 3350, 3080, 2930, 2850, 1650, 1450, 1090, 900 cm$^{-1}$; MS *m/e* 130 ($M^+$, 4), 101 (8), 72 (35), 59 (100), 45 (72).

**Triethylene Glycol Mono-2-methylallyl Ether (18a).** This compound was prepared as described in the synthesis of **16a**. Yield 73%; bp 90 °C/0.05 mm; $^1$H NMR ($CDCl_3$) $\delta$ 1.71 (s, 3 H), 3.38 (s, 1 H), 3.44–3.64 (m, 8 H), 3.84 (s, 2 H), 4.81 (m, 1 H), 4.85 (m, 1 H); IR 3420, 3060, 2900, 1450, 1350, 1260, 1100, 990, 940, 890 cm$^{-1}$; MS *m/e* 204 ($M^+$, 3), 133 (10), 89 (21), 55 (26), 45 (100).

**2-(Bromomethyl)-2-hexyl-15-crown-5 (3a).** The title compound was obtained from a procedure similar to that used for the synthesis of 2-(bromomethyl)-2-methyl-15-crown-5.[9b] Compound **16a** (6.37 g, 0.02 mol) in 1,2-dichloroethane (80 mL) was added dropwise to a stirred suspension of *N*-bromosuccinimide (NBS; 3.56 g, 0.02 mol) and $NaBF_4$ (8.78 g, 0.08 mol) in 1,2-dichloroethane (400 mL) over a 1-h period at 40 °C, and the mixture was stirred at 50 °C for another 6 h. The mixture was filtered and the solvent was evaporated. Water (200 mL) was added to the residue and extracted with ether (200 mL × 3). After evaporation, the viscous brown oil was purified by chromatography over silica gel (5:95 dioxane–benzene) and then distilled to give **3a** as a slightly yellow oil. Yield 25%; bp 150 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 0.86 (t, 3 H), 1.20–1.66 (m, 10 H), 3.32–3.78 (m, 20 H); IR 2930, 2870, 1460, 1360, 1300, 1250, 1130, 990, 940, 680 cm$^{-1}$; MS *m/e* 398 ($M^+$ + 2, 3), 396 ($M^+$), 317 (4), 303 (6), 145 (26), 133 (31), 89 (49), 87 (43), 73 (37), 59 (34), 45 (100), 43 (63).

Anal. Calcd for $C_{17}H_{33}O_5Br$: C, 51.38; H, 8.37; Br, 20.11. Found: C, 51.13; H, 8.53; Br, 19.74.

**2-(Bromomethyl)-2-octyl-15-crown-5 (4a)**: yield 26%; bp 160 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 0.88 (t, 3 H), 1.18–1.66 (m, 14 H), 3.34–3.83 (m, 20 H); IR 2920, 2860, 1460, 1350, 1290, 1250, 1120, 990, 940, 670 cm$^{-1}$; MS *m/e* 426 ($M^+$ + 2, 3), 424 ($M^+$), 345 (4), 331 (5), 199 (10), 159 (23), 145 (25), 133 (39), 89 (53), 87 (43), 73 (38), 59 (33), 57 (31), 55 (30), 45 (100), 43 (48), 41 (28).

Anal. Calcd for $C_{19}H_{37}O_5Br$: C, 53.64; H, 8.77; Br, 18.79. Found: C, 53.34; H, 8.84; Br, 19.86.

**3-(Bromomethyl)-3-methyl-16-crown-5 (6a).** To a stirred suspension of NBS (17.8 g, 0.1 mol) in triethylene glycol (75.1 g, 0.5 mol) was added **17** (13.0 g, 0.1 mol) at 40 °C for a period of 1 h. The resulting mixture was further stirred at 50 °C for 5 h. After cooling to room temperature, the mixture was further cooled in an ice bath to remove the succinimide. The excess triethylene glycol and other byproducts such as succinimide were removed by distillation in a Kugelrohr apparatus (150 °C/0.01 mm). The crude product (**19**) was used for the next step without purification. The cyclization of **19** was done according to the intramolecular procedure developed by us.[26] To a stirred suspension of powdered NaOH (8.4 g, 0.2 mol) in dioxane (150 mL) was added a mixture of **19** (13.1 g, 0.04 mol) and benzenesulfonyl chloride (7.8 g, 0.044 mol) over a period of 5 h at 50 °C. The mixture was stirred for another 10 h. The yield was calculated based on the starting **17**. Yield **24%**; $^1$H NMR ($CDCl_3$) $\delta$ 1.26 (s, 3 H), 1.68–1.92 (m, 2 H), 3.45–3.72 (m, 20 H); IR 2900, 2850, 1450, 1360, 1240, 1120, 940 cm$^{-1}$; MS *m/e* 342 ($M^+$ + 2), 340 ($M^+$), 261 (10), 247 (6), 115 (37), 101 (58), 45 (100).

Anal. Calcd for $C_{13}H_{25}O_5Br$: C, 45.76; H, 7.38; Br, 23.42. Found: C, 45.57; H, 7.53; Br, 23.47.

**2-(Bromomethyl)-2-methyl-16-crown-5 (7a).** The synthetic procedure was almost the same as that used for **6a**. Yield 26%; $^1$H NMR ($CDCl_3$) $\delta$ 1.26 (s, 3 H), 1.68–1.90 (m, 2 H), 3.52–3.60 (m, 20 H); IR 2920, 2880, 1460, 1250, 1110, 960 cm$^{-1}$; MS *m/e* 342 ($M^+$ + 2), 340 ($M^+$), 261 (3), 247 (5), 115 (16), 101 (72), 45 (100).

(26) Kuo, P.-L.; Miki, M.; Okahara, M. *J. Chem. Soc., Chem. Commun.* **1978**, 504.

Anal. Calcd for $C_{13}H_{25}O_6Br$: C, 45.76; H, 7.38; Br, 23.42. Found: C, 46.03; H, 7.66; Br, 23.08.

**General Procedure for the Synthesis of Lariat Ethers.** The details concerning the synthesis have already appeared in the literature.[9b] Basically, a simple substitution reaction of bromomethyl crown ether with an appropriate sodium alkoxide or a potassium phenoxide was used for the synthesis. After sodium metal (0.2 g, 9 mmol) was dissolved in the alcohol (60 mmol), bromomethyl crown ether (3 mmol) was added to the mixture followed by stirring at 120 °C for 24 h. In the reaction with the phenol, potassium metal was employed as an alternate to sodium metal and the mixture was stirred at 140 °C for 48 h. When the alcohol or phenol was solid, 20 mL of diglyme was used to dissolve the compound. After the mixture cooled to room temperature, dichloromethane (20–50 mL) was added to the residue and the insoluble matter was removed by filtration. Then the resulting mixture was concentrated and pyrolyzed under reduced pressure (150–220 °C/0.01 mm). The volatiles were redistilled by using a Kugelrohr apparatus.

**2-Methyl-2-[[(2-pyridinylmethyl)oxy]methyl]-15-crown-5 (2b)**: yield 74%; bp 150 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.24 (s, 3 H), 3.54–3.76 (m, 20 H), 4.67–4.78 (m, 2 H), 7.14–7.81 (m, 3 H), 8.55–8.62 (m, 1 H); IR 3050, 2860, 1590, 1570, 1470, 1430, 1260, 1190, 1150, 1120, 940 cm$^{-1}$; MS *m/e* 355 ($M^+$, 4) 233 (9), 213 (7), 199 (6), 109 (100), 108 (56), 107 (16), 101 (15), 93 (12), 80 (14), 79 (14), 78 (22), 57 (11), 53 (11), 45 (21).

Anal. Calcd for $C_{18}H_{29}O_6N$: C, 60.83; H, 8.22; N, 3.94. Found: C, 60.75; H, 8.30; N, 4.00.

**2-Methyl-2-[[(2-tetrahydrofuranylmethyl)oxy]methyl]-15-crown-5 (2c)**: yield 81%; bp 140 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.16 (s, 3 H), 1.72–1.94 (m, 4 H), 3.43–3.81 (m, 25 H); IR 2850, 1450, 1350, 1290, 1240, 1110, 980, 930, 750 cm$^{-1}$; MS *m/e* 348 ($M^+$, 6), 233 (62), 145 (23), 101 (100), 85 (29), 71 (25), 59 (25), 57 (35), 45 (65), 43 (50).

Anal. Calcd for $C_{17}H_{32}O_7$: C, 58.60; H, 9.26. Found: C, 58.41; H, 9.43.

**2-Methyl-2-[[(2-methoxyphenyl)oxy]methyl]-15-crown-5 (2d)**: yield 71%; bp 140 °C/0.02 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.22 (s, 3 H), 3.45–3.66 (m, 18 H), 3.71–3.98 (m, 5 H), 6.76 (m, 4 H); IR 3080, 2880, 1740, 1600, 1510, 1460, 1360, 1250, 1230, 1180, 1110, 1040, 960, 750 cm$^{-1}$; MS *m/e* 370 ($M^+$, 28), 233 (47), 145 (25), 101 (100), 89 (44), 87 (21), 77 (16), 73 (19), 71 (23), 59 (26), 57 (35), 45 (92), 43 (43).

Anal. Calcd for $C_{19}H_{30}O_7$: C, 61.60; H, 8.16. Found: C, 61.74; H, 8.12.

**2-Methyl-2-[(8-quinolinyloxy)methyl]-15-crown-5 (2e)**: yield 63%; bp 210 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.46 (s, 3 H), 3.60–4.00 (m, 18 H), 4.15 (d, 1 H), 4.34 (d, 1 H), 7.08–7.54 (m, 4 H), 8.00–8.40 (m, 1 H), 8.84–8.90 (m, 1 H); IR 2880, 1510, 1390, 1320, 1270, 1120 cm$^{-1}$; MS *m/e* 391 ($M^+$, 8), 183 (83), 158 (67), 145 (100), 101 (75), 45 (83).

Anal. Calcd for $C_{21}H_{29}O_6N$: C, 64.43; H, 7.47; N, 3.58. Found: C, 64.08; H, 7.65; N, 3.62.

**2-Methyl-2-[[8-(2-methylquinolinyl)oxy]methyl]-15-crown-5 (2f)**: yield 76%; bp 200 °C/0.005 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.48 (s, 3 H), 2.74 (s, 3 H), 3.56–4.00 (m, 18 H), 4.12 (d, 1 H), 4.38 (d, 1 H), 7.04–7.48 (m, 4 H), 7.97 (d, 1 H); IR 2880, 1440, 1120, 1440, 1120, 840, 760 cm$^{-1}$; MS *m/e* 405 ($M^+$, 3), 198 (100), 172 (70), 159 (80), 101 (48).

Anal. Calcd for $C_{22}H_{31}O_6N$: C, 65.16; H, 7.71; N, 3.45. Found: C, 65.20; H, 7.52; N, 3.74.

**2-Methyl-2-[[(3-methoxypropyl)oxy]methyl]-15-crown-5 (2h)**: yield 57%; bp 130 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.14 (s, 3 H), 1.66–1.88 (m, 2 H), 3.28 (s, 3 H), 3.36–3.65 (m, 24 H); IR 2900, 2850, 1450, 1350, 1120 cm$^{-1}$; MS *m/e* 336 ($M^+$, 17), 233 (87), 145 (22), 101 (100).

Anal. Calcd for $C_{16}H_{32}O_7$: C, 57.12; H, 9.59. Found: C, 57.12; H, 9.59.

**2-[(2-Hydroxyethoxy)methyl]-2-methyl-15-crown-5 (2i)**: yield 60%; bp 130 °C/0.03 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.17 (s, 3 H), 1.94 (s, 1 H), 3.40–3.68 (m, 24 H); IR 3420, 2880, 1460, 1360, 1300, 1260, 1110, 960 cm$^{-1}$; MS *m/e* 308 ($M^+$, 8), 233 (47), 145 (15), 133 (8), 101 (100), 89 (23), 87 (25), 73 (28), 59 (42), 57 (38), 45 (98).

Anal. Calcd for $C_{14}H_{28}O_7$: C, 54.53; H, 9.15. Found: C, 54.28; H, 9.26.

**2-[[2-(2-Hydroxyethoxy)ethoxy]methyl]-2-methyl-15-crown-5 (2j)**: yield 60%; bp 150 °C/0.02 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.17 (s, 3 H), 2.16 (s, 1 H), 3.50–3.76 (m, 28 H); IR 3420, 2900, 1460, 1360, 1300, 1260, 1110, 960 cm$^{-1}$; MS *m/e* 352 ($M^+$, 8), 233 (30), 145 (10), 133 (7), 101 (59), 89 (27), 87 (16), 73 (18), 59 (25), 57 (26), 45 (100).

Anal. Calcd for $C_{16}H_{32}O_8$: C, 54.53; H, 9.15. Found: C, 54.47; H, 9.33.

**2-[[2-[2-(2-Hydroxyethoxy)ethoxy]ethoxy]methyl]-2-methyl-15-crown-5 (2k)**: yield 64%; bp 170 °C/0.02 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.18 (s, 3 H), 2.22 (s, 1 H), 3.45–3.76 (m, 32 H); IR 3350,

2900, 1460, 1360, 1300, 1110, 940 $cm^{-1}$; MS *m/e* 396 ($M^+$, 4), 233 (26), 145 (10), 133 (13), 101 (51), 89 (33), 87 (15), 73 (14), 59 (18), 57 (20), 45 (100), 43 (22).

Anal. Calcd for $C_{18}H_{36}O_9$: C, 54.53; H, 9.15. Found: C, 54.43; H, 9.25.

**2-Methyl-2-[(octyloxy)methyl]-15-crown-5 (2l)**: yield 71%; 140 °C/0.02 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.90 (t, 3 H), 1.10 (s, 3 H), 1.25–1.38 (m, 12 H), 3.32 (t, 2 H), 3.42–3.64 (m, 20 H); IR 2930, 2850, 1460, 1360, 1290, 1250, 1110, 930 $cm^{-1}$; MS *m/e* 376 ($M^+$, 4), 233 (57), 145 (24), 103 (17), 101 (100), 89 (13), 87 (14), 73 (13), 71 (17), 59 (28), 57 (33), 45 (39), 43 (28).

Anal. Calcd for $C_{20}H_{40}O_6$: C, 63.80; H, 10.71. Found: C, 63.82; H, 10.83.

**2-Methyl-2-[[2-(octyloxy)ethoxy]methyl]-15-crown-5 (2m)**: yield 86%; bp 150 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.87 (t, 3 H), 1.08 (s, 3 H), 1.22–1.36 (m, 12 H), 3.27–3.66 (m, 26 H); IR 2920, 2860, 1460, 1350, 1290, 1250, 1110, 940 $cm^{-1}$; MS *m/e* 420 ($M^+$, 4), 233 (69), 145 (23), 103 (17), 101 (100), 89 (19), 87 (15), 73 (17), 71 (26), 59 (21), 57 (40), 45 (53), 43 (34).

Anal. Calcd for $C_{22}H_{44}O_7$: C, 62.83; H, 10.55. Found: C, 62.57; H, 10.59.

**2-Methyl-2-[[2-[2-(octyloxy)ethoxy]ethoxy]methyl]-15-crown-5 (2n)**: yield 70%; bp 170 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.88 (t, 3 H), 1.08 (s, 3 H), 1.24–1.35 (m, 12 H), 3.28–3.60 (m, 30 H); IR 2930, 2860, 1460, 1350, 1290, 1250, 1100, 940 $cm^{-1}$; MS *m/e* 464 ($M^+$, 10), 233 (74), 145 (29), 103 (16), 101 (100), 89 (23), 87 (17), 73 (16), 71 (26), 59 (23), 57 (39), 45 (45), 43 (32).

Anal. Calcd for $C_{24}H_{48}O_8$: C, 62.04; H, 10.41. Found: C, 62.09; H, 10.64.

**2-[(Dodecyloxy)methyl]-2-methyl-15-crown-5 (2o)**: yield 67%; bp 150 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.90 (t, 3 H), 1.18–1.60 (s + m, 23 H), 3.36–3.76 (m, 22 H); IR 2930, 2850, 1460, 1350, 1260, 1110, 940 $cm^{-1}$; MS *m/e* 432 ($M^+$, 7), 233 (64), 145 (25), 101 (100), 85 (18), 83 (19), 71 (34), 69 (20), 57 (55), 55 (27), 45 (36), 43 (50), 41 (20).

Anal. Calcd for $C_{24}H_{48}O_6$: C, 66.63; H, 11.18. Found: C, 66.45; H, 11.30.

**2-[[2-(Dodecyloxy)ethoxy]methyl]-2-methyl-15-crown-5 (2p)**: yield 66%; bp 170 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.90 (t, 3 H), 1.10 (s, 3 H), 1.24–1.58 (m, 20 H), 3.18–3.70 (m, 26 H); IR 2920, 2860, 1460, 1350, 1290, 1250, 1120, 940 $cm^{-1}$; MS *m/e* 476 ($M^+$, 4), 233 (62), 145 (23), 101 (100), 73 (19), 71 (25), 59 (15), 57 (44), 55 (18), 45 (36), 43 (37), 41 (15).

Anal. Calcd for $C_{26}H_{52}O_7$: C, 65.51; H, 11.00. Found: C, 65.74; H, 11.29.

**2-[[2-[2-(Dodecyloxy)ethoxy]ethoxy]methyl]-2-methyl-15-crown-5 (2q)**: yield 75%; bp 190 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.88 (t, 3 H), 1.08 (s, 3 H), 1.22–1.56 (m, 20 H), 3.18–3.70 (m, 30 H); IR 2920, 2860, 1460, 1350, 1290, 1250, 1120, 940 $cm^{-1}$; MS *m/e* 520 ($M^+$, 5), 233 (80), 145 (30), 101 (100), 89 (21), 71 (19), 57 (36), 45 (34), 43 (32).

Anal. Calcd for $C_{28}H_{56}O_8$: C, 64.58; H, 10.84. Found: C, 64.71; H, 10.95.

**2-Hexyl-2-[(hexyloxy)methyl]-15-crown-5 (3b)**: yield 72%; bp 150 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.89 (t, 6 H), 1.16–1.66 (m, 18 H), 3.32–3.83 (m, 22 H); IR 2920, 2850, 1450, 1350, 1290, 1250, 1110, 980, 930 $cm^{-1}$; MS *m/e* 418 ($M^+$, 11), 303 (55), 215 (32), 171 (100), 103 (36), 89 (37), 73 (42), 59 (39), 45 (66), 43 (89).

Anal. Calcd for $C_{23}H_{46}O_6$: C, 65.99; H, 11.08. Found: C, 65.80; H, 11.27.

**2-Hexyl-2-[(2-methoxyethoxy)methyl]-15-crown-5 (3c)**: yield 87%; bp 130 °C/0.05 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.84 (t, 3 H), 1.16–1.52 (m, 10 H), 3.32 (s, 3 H), 3.42–3.74 (m, 24 H); IR 2930, 2870, 1460, 1360, 1300, 1260, 1130, 990, 940 $cm^{-1}$; MS *m/e* 392 ($M^+$, 9), 303 (94), 215 (28), 171 (100), 103 (44), 89 (41), 73 (43) 59 (94), 45 (70), 43 (50).

Anal. Calcd for $C_{20}H_{40}O_7$: C, 61.20; H, 10.27. Found: C, 61.26; H, 10.15.

**2-Hexyl-2-[[2-(2-methoxyethoxy)ethoxy]methyl]-15-crown-5 (3d)**: yield 78%; bp 150 °C/0.02 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.86 (t, 3 H), 1.18–1.52 (m, 10 H), 3.36 (s, 3 H), 3.42–3.74 (m, 28 H); IR 2930, 2870, 1460, 1360, 1290, 1250, 1200, 1120, 980, 940 $cm^{-1}$; MS *m/e* 436 ($M^+$, 10), 303 (51), 215 (18), 171 (74), 103 (59), 89 (33), 73 (44), 59 (100), 45 (79), 43 (49).

Anal. Calcd for $C_{22}H_{44}O_8$: C, 60.52; H, 10.16. Found: C, 60.74; H, 9.80.

**2-Hexyl-2-[[2-[2-(2-methoxyethoxy)ethoxy]ethoxy]methyl]-15-crown-5 (3e)**: yield 70%; bp 170 °C/0.02 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.87 (t, 3 H), 1.18–1.52 (m, 10 H), 3.36 (s, 3 H), 3.42–3.78 (m, 32 H); IR 2920, 2850, 1340, 1240, 1190, 1110, 930 $cm^{-1}$; MS *m/e* 480 ($M^+$, 9), 303 (52), 215 (24), 171 (79), 103 (48), 89 (36), 73 (55). 59 (100), 45 (85), 43 (48).

Anal. Calcd for $C_{24}H_{48}O_9$: C, 59.97; H, 10.07. Found: C, 59.85; H, 10.05.

**2-Hexyl-2-[(octyloxy)methyl]-15-crown-5 (3f)**: yield 80%; bp 150 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.86 (t, 6 H), 1.16–1.60 (m, 22 H), 3.30–3.75 (m, 22 H); IR 2920, 2850, 1460, 1350, 1290, 1240, 1200, 1120, 940 $cm^{-1}$; MS *m/e* 446 ($M^+$, 13), 303 (73), 215 (36), 171 (100), 103 (38), 89 (31), 73 (44), 57 (49), 45 (60), 43 (78).

Anal. Calcd for $C_{25}H_{50}O_6$: C, 67.22; H, 11.28. Found: C, 67.12; H, 11.48.

**2-Hexyl-2-[[2-(octyloxy)ethoxy]methyl]-15-crown-5 (3g)**: yield 71%; bp 180 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.88 (t, 6 H), 1.16–1.64 (m, 22 H), 3.36–3.76 (m, 26 H); IR 2920, 2850, 1460, 1350, 1290, 1250, 1120, 980, 940 $cm^{-1}$; MS *m/e* 490 ($M^+$, 13), 303 (77), 215 (31), 171 (100), 103 (38), 89 (31), 73 (49), 71 (44), 45 (69), 43 (69).

Anal. Calcd for $C_{27}H_{54}O_7$: C, 66.08; H, 11.09. Found: C, 65.89; H, 11.25.

**2-Hexyl-2-[[2-[2-(octyloxy)ethoxy]ethoxy]methyl]-15-crown-5 (3h)**: yield 74%; bp 210 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.88 (t, 6 H), 1.18–1.64 (m, 22 H), 3.36–3.78 (m, 30 H); 1R 2920, 2850, 1460, 1350, 1290, 1250, 1120, 990, 940 $cm^{-1}$; MS *m/e* 534 ($M^+$, 8), 303 (60), 215 (30), 171 (100), 103 (35), 89 (40), 73 (40), 71 (39), 59 (36), 57 (48), 45 (77), 43 (60).

Anal. Calcd for $C_{29}H_{58}O_8$: C, 65.13; H, 10.93. Found: C, 65.29; H, 10.98.

**2-Hexyl-2-[(8-quinolinyloxy)methyl]-15-crown-5 (3i)**: yield 70%; bp 180 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.83 (t, 3 H), 1.13–1.52 (m, 10 H), 3.42–3.95 (m, 18 H), 4.12 (d, 1 H), 4.34 (d, 1 H), 7.09–7.49 (m, 4 H), 8.03–8.20 (m, 1 H), 8.87–8.95 (m, 1 H); IR 3050, 2920, 2860, 1620, 1600, 1580, 1500, 1470, 1380, 1320, 1260, 1190, 1120, 940, 830, 800, 760 $cm^{-1}$; MS *m/e* 461 ($M^+$, 15), 386 (11), 317 (12), 303 (15), 254 (46), 171 (58), 158 (35), 145 (100), 89 (58), 73 (33), 55 (38) 45 (99), 43 (62).

Anal. Calcd for $C_{26}H_{39}O_6N$: C, 67.65; H, 8.52; N, 3.03. Found: C, 67.54; H, 8.81; N, 2.99.

**2-[(2-Methoxyethoxy)methyl]-2-octyl-15-crown-5 (4b)**: yield 80%; bp 160 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.85 (t, 3 H), 1.15–1.56 (m, 14 H), 3.35 (s, 3 H), 3.44–3.76 (m, 24 H); IR 2920, 2850, 1460, 1350, 1290, 1250, 1120, 980, 940 $cm^{-1}$; MS *m/e* 420 ($M^+$, 9), 331 (45), 243 (17), 199 (55), 177 (11), 147 (19), 133 (15), 103 (42), 89 (37), 73 (42), 59 (100), 45 (75), 43 (54).

Anal. Calcd for $C_{22}H_{44}O_7$: C, 62.83; H, 10.55. Found: C, 62.57; H, 10.72.

**2-[[2-(2-Methoxyethoxy)ethoxy]methyl]-2-octyl-15-crown-5 (4c)**: yield 64%; bp 170 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.87 (t, 3 H), 1.18–1.52 (m, 14 H), 3.38 (s, 3 H), 3.44–3.76 (m, 28 H); IR 2920, 2850, 1460, 1350, 1290, 1250, 1120, 980, 930 $cm^{-1}$; MS *m/e* 464 ($M^+$, 9), 331 (46), 243 (19), 199 (69), 177 (13), 147 (9), 133 (19), 103 (61), 89 (43), 73 (35), 59 (100), 45 (89), 43 (44).

Anal. Calcd for $C_{24}H_{48}O_8$: C, 62.04; H, 10.41. Found: C, 62.42; H, 10.50.

**2-[[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]methyl]-2-octyl-15-crown-5 (4d)**: yield 75%; bp 190 °C/0.01 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 0.86 (t, 3 H), 1.18–1.52 (m, 14 H), 3.37 (s, 3 H), 3.42–3.74 (m, 32 H); IR 2920, 2860, 1460, 1350, 1300, 1250, 1120, 990, 940 $cm^{-1}$; MS *m/e* 508 ($M^+$, 8), 331 (39), 243 (18), 199 (69), 177 (11), 147 (15), 133 (51), 103 (51), 89 (41), 73 (39), 59 (100), 45 (67), 43 (41).

Anal. Calcd for $C_{26}H_{52}O_9$: C, 61.39; H, 10.30. Found: C, 61.09; H, 10.51.

**3-[(2-Methoxyethoxy)methyl]-3-methyl-16-crown-5 (6b)**: yield 68%; bp 135 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 1.13 (s, 3 H), 1.68–1.96 (m, 2 H), 3.36 (s, 3 H), 3.41–3.74 (m, 24 H); IR 2850, 1440, 1350, 1280, 1240, 1100 $cm^{-1}$; MS *m/e* 336 ($M^+$, 8), 247 (9), 159 (13), 115 (100), 59 (72).

Anal. Calcd for $C_{16}H_{32}O_7$: C, 57.12; H, 9.59. Found: C, 56.92; H, 9.72.

**3-[[2-(2-Methoxyethoxy)ethoxy]methyl]-3-methyl-16-crown-5 (6c)**: yield 83%; bp 145 °C/0.01 mm; $^1H$ NMR ($CDCl_3$) $\delta$ 1.14 (s, 3 H), 1.60–1.90 (m, 2 H), 3.22–3.78 (m, 31 H); IR 2860, 1450, 1360, 1280, 1250, 1110 $cm^{-1}$; MS *m/e* 380 ($M^+$, 12), 247 (35), 191 (10), 145 (10), 133 (18), 101 (80), 59 (76), 45 (100).

Anal. Calcd for $C_{18}H_{36}O_8$: C, 56.82; H, 9.54. Found: C, 57.00; H, 9.84.

**3-Methyl-3-[(8-quinolinyloxy)methyl]-16-crown-5 (6d)**: yield 56%; bp 200 °C/0.005 mm (Kugelrohr); $^1H$ NMR ($CDCl_3$) $\delta$ 1.42 (s, 3 H), 1.64–1.92 (m, 2 H), 3.56–3.84 (m, 18 H), 4.13 (d, 1 H), 4.39 (d, 1 H), 7.08–7.52 (m, 4 H), 8.04–8.16 (m, 1 H), 8.86–8.96 (m, 1 H); IR 2900, 1460, 1380, 1100, 820, 800 $cm^{-1}$; MS *m/e* 405 ($M^+$, 11), 332 (15), 288 (34), 261 (13), 145 (100).

Anal. Calcd for $C_{22}H_{31}O_6N$: C, 65.16; H, 7.71; N, 3.45. Found: C, 64.86; H, 7.84; N, 3.60.

**2-[(2-Methoxyethoxy)methyl]-2-methyl-16-crown-5 (7b)**: yield 70%; bp 140 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.14 (s, 3 H), 1.68–1.94 (m, 2 H), 3.32 (s, 3 H), 3.48–3.78 (m, 24 H); IR 2880, 1440, 1280, 1250, 1100 cm$^{-1}$; MS *m/e* 336 ($M^+$, 6), 287 (82), 159 (16), 115 (100), 59 (65).

Anal. Calcd for $C_{16}H_{32}O_7$: C, 57.12; H, 9.59. Found: C, 56.83; H, 9.77.

**2-[[2-(2-Methoxyethoxy)ethoxy]methyl]-2-methyl-16-crown-5 (7c)**: yield 83%; bp 150 °C/0.02 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.16 (s, 3 H), 1.68–1.90 (m, 2 H), 3.36 (s, 3 H), 3.50–3.78 (m, 28 H); IR 2900, 2870, 1450, 1250, 1110 cm$^{-1}$; MS *m/e* 380 ($M^+$, 8), 247 (90), 191 (11), 145 (12), 133 (15), 101 (100).

Anal. Calcd for $C_{18}H_{36}O_8$: C, 56.82; H, 9.54. Found: C, 56.50; H, 9.72.

**2-Methyl-2-[(8-quinolinyloxy)methyl]-16-crown-5 (7d)**: yield 65%; bp 185 °C/0.005 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.42 (s, 3 H), 1.68–1.92 (m, 2 H), 3.48–3.82 (m, 18 H), 4.07 (d, 1 H), 4.35 (d, 1 H), 7.04–7.52 (m, 4 H), 8.04–8.22 (m, 1 H), 8.90–9.02 (m, 1 H); IR 2880, 1450, 1120, 830, 750 cm$^{-1}$; MS *m/e* 405 ($M^+$, 9), 375 (6), 330 (10), 258 (13), 247 (10), 184 (47), 145 (100), 101 (56).

Anal. Calcd for $C_{22}H_{31}O_6N$: C, 65.16; H, 7.71; N, 3.45. Found: C, 64.98; H, 7.80; N, 3.81.

**15-[(2-Methoxyethoxy)methyl]-15-methyl-16-crown-5 (8a).** The bromoalkoxylation of tetraethylene glycol mono-2-methylallyl ether (**16c**)[9b] using NBS in ethylene glycol monomethyl ether was carried out according to the procedure mentioned above. The crude bromoalkoxylated intermediate (**21a**) was refluxed for 30 h in *tert*-butyl alcohol containing sodium *tert*-butoxide. Yield 32%; bp 120 °C/0.005 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.20 (s, 3 H), 3.38 (s, 3 H), 3.54–3.78 (m, 24 H); IR 2920, 2870, 1450, 1350, 1120 cm$^{-1}$; MS *m/e* 322 ($M^+$, 47), 246 (5), 117 (13), 103 (38), 101 (17), 59 (100).

Anal. Calcd for $C_{15}H_{30}O_7$: C, 55.88; H, 9.38. Found: C, 55.70; H, 9.50.

**15-[[2-(2-Methoxyethoxy)ethoxy]methyl]-15-methyl-16-crown-5 (8b)**: yield 23%; bp 150 °C/0.005 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.17 (s, 3 H), 3.38 (s, 3 H), 3.48–3.80 (m, 28 H); IR 2920, 2870, 1460, 1120 cm$^{-1}$; MS *m/e* 366 ($M^+$, 31), 247 (4), 246 (4), 103 (80), 101 (15), 59 (100).

Anal. Calcd for $C_{17}H_{34}O_8$: C, 55.72; H, 9.35. Found: C, 55.57; H, 9.50.

**2-[(Hexyloxy)methyl]-2-methyl-18-crown-6 (10c)**: yield 60%; bp 120 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 0.90 (t, 3 H), 1.09 (s, 3 H), 1.24–1.40 (m, 8 H), 3.12–3.62 (m, 26 H); IR 2940, 2860, 1460, 1350, 1290, 1250, 1120, 940 cm$^{-1}$; MS *m/e* 392 ($M^+$, 2), 277 (20), 145 (8), 103 (7), 101 (100), 89 (8), 87 (10), 59 (19), 57 (22), 45 (33).

Anal. Calcd for $C_{20}H_{40}O_7$: C, 61.20; H, 10.27. Found: C, 61.31; H, 10.40.

**2-[(Hexylthio)methyl]-2-methyl-18-crown-6 (10d)**: yield 61%; bp 120 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 0.87 (t, 3 H), 1.20–1.34 (s + m, 11 H), 2.50 (t, 2 H), 2.70 (m, 2 H), 3.53 (s, 2 H), 3.59–3.70 (m, 20 H); IR 2940, 2870, 1460, 1350, 1300, 1250, 1120, 950 cm$^{-1}$; MS *m/e* 408 ($M^+$, 1), 291 (6), 277 (16), 145 (17), 101 (100), 57 (26), 45 (48).

Anal. Calcd for $C_{20}H_{40}O_6S$: C, 58.79; H, 9.87; S, 7.85. Found: C, 58.74; H, 10.09; S, 7.71.

**2-[(Hexylamino)methyl]-2-methyl-18-crown-6 (10e)**: yield 84%; bp 125 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 0.88 (t, 3 H), 1.18–1.36 (s + m, 11 H), 2.51–2.69 (m, 5 H), 3.54 (s, 2 H), 3.62–3.70 (m, 20 H); IR 3300, 2920, 2850, 1460, 1350, 1290, 1250, 1120, 940 cm$^{-1}$; MS *m/e* 391 ($M^+$, 6), 291 (8), 277 (6), 133 (26), 114 (100), 101 (48), 89 (55), 57 (32), 45 (42).

Anal. Calcd for $C_{20}H_{41}O_6N$: C, 61.35; N, 10.55; N, 3.58. Found: C, 61.70; H, 10.76; N, 3.85.

**2-Methyl-2-[(2-methoxyethoxy)methyl]-18-crown-6 (10f)**: yield 88%; bp 140 °C/0.04 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.11 (s, 3 H), 3.29 (s, 3 H), 3.42–3.60 (m, 28 H); IR 2900, 1460, 1350, 1290, 1250, 1200, 1100, 960 cm$^{-1}$; MS *m/e* 366 ($M^+$, 5), 277 (30), 145 (10), 103 (14), 101 (100), 89 (18), 87 (18), 73 (18), 59 (59), 45 (52).

Anal. Calcd for $C_{17}H_{34}O_8$: C, 55.72; H, 9.35. Found: C, 55.71; H, 9.44.

**2-Methyl-2-[[2-(2-methoxyethoxy)ethoxy]methyl]-18-crown-6 (10g)**: yield 78%; bp 150 °C/0.02 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.18 (s, 3 H), 3.36 (s, 3 H), 3.43–3.68 (m, 32 H); IR 2900, 1460, 1350, 1300, 1250, 1200, 1100, 950 cm$^{-1}$; MS *m/e* 410 ($M^+$, 8), 277 (45), 145 (14), 103 (32), 101 (100), 89 (19), 87 (20), 59 (73), 45 (57).

Anal. Calcd for $C_{19}H_{38}O_9$: C, 55.59; H, 9.33. Found: C, 55.52; H, 9.47.

**2-Methyl-2-[[2-[2-(2-methoxyethoxy)ethoxy]ethoxy]methyl]-18-crown-6 (10h)**: yield 72%; bp 160 °C/0.01 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.16 (s, 3 H), 3.35 (s, 3 H), 3.42–3.64 (m, 36 H); IR 2900, 1460, 1360, 1300, 1260, 1200, 1100, 960 cm$^{-1}$; MS *m/e* 454 ($M^+$, 6), 277 (25), 145 (12), 101 (100), 59 (56), 45 (51).

Anal. Calcd for $C_{21}H_{42}O_{10}$: C, 55.49; H, 9.31. Found: C, 55.56; H, 9.40.

**2-Methyl-2-[(8-quinolinyloxy)methyl]-18-crown-6 (10i)**: yield 62%; bp 215 °C/0.005 mm (Kugelrohr); $^1$H NMR ($CDCl_3$) $\delta$ 1.45 (s, 3 H), 3.60–3.92 (m, 22 H), 4.15 (d, 1 H), 4.35 (d, 1 H), 7.12–7.60 (m, 4 H), 8.07–8.24 (m, 1 H), 8.86–9.06 (m, 1 H), IR 2870, 1500, 1370, 1320, 1260, 1110 cm$^{-1}$; MS *m/e* 435 ($M^+$, 10), 183 (63), 158 (100), 145 (75), 101 (75), 45 (88).

Anal. Calcd for $C_{23}H_{33}O_7N\cdot H_2O$: C, 60.91; H, 7.78; N, 3.09. Found: C, 61.13; H, 7.70; N, 3.03.

**Complex of 2e with NaSCN.** Compound **2e** (128.4 mg, $3.27 \times 10^{-4}$ mol) and NaSCN (27.0 mg, $3.33 \times 10^{-4}$ mol) were dissolved in 15 mL of acetone. Toluene (15 mL) was added to the solution and the acetone was slowly evaporated to give 144.8 mg (90%) of white needles: mp 182.5–183.7 °C; IR 3450, 2950, 2080, 1490, 1130 cm$^{-1}$.

Anal. Calcd for $C_{22}H_{29}O_6N_2SNa\cdot H_2O$: C, 53.87; H, 6.37; N, 5.71. Found: C, 53.70; H, 6.57; N, 5.52.

**Complex of 2e with NaI**: yield 90%; mp 241.5–242.8 °C; IR 2900, 1460, 1110 cm$^{-1}$.

Anal. Calcd for $C_{21}H_{29}O_6NNaI$: C, 46.59; H, 5.40; N, 2.59. Found: C, 46.30; H, 5.40; N, 2.58.

**Complex of 10i with KSCN**: yield 84%; mp 187.4–188.9 °C; IR 3450, 2900, 2050, 1500, 1110 cm$^{-1}$.

Anal. Calcd for $C_{24}H_{33}O_7N_2SK$: C, 54.11; H, 6.24; N, 5.26. Found: C, 54.06; H, 6.27; N, 5.19.

**Measurement of Stability Constants.** All of the stability constants were determined by using Toko $Na^+$ 1100 and Toko $K^+$ 1200 electrodes for NaCl and KCl, respectively, in anhydrous MeOH at 25 °C. The emf was measured with a Beckman 4500 digital pH meter. The procedures used were those described by Frensdorff.[12] The experimental error is ±0.04 log unit in log $K'$.

**Extraction Procedure.**[19] A mixture of an aqueous solution (10 mL) of alkali-metal hydroxide ($5 \times 10^{-2}$ M) and picric acid ($5 \times 10^{-4}$ M) and a dichloromethane solution (10 mL) of an appropriate extractant ($5 \times 10^{-4}$ M) was shaken at 22 °C for 9 h. The extractability was obtained from the calculation based on the absorption of picrate anion in the aqueous phase at 354 nm in the UV spectrum.

**Liquid Membrane Transport.** Transport experiments were carried out in a U-type cell[20b] at 25 °C. The details for transport conditions are summarized in the footnotes of Table V and the caption of Figure 2. In the case of passive transport, the receiving phase was sampled from four different cells after 6, 12, 18, and 24 h and analyzed for cation concentration using a Nippon Jarrell-Ash AA-8500 atomic absorption spectrophotometer. The value reported in Table V was the mean of four samples. The deviations from the mean were less than ±10%.

**Registry No. 1**, 33100-27-5; **2a**, 74649-90-4; **2b**, 83260-76-8; **2c**, 83260-77-9; **2d**, 83260-78-0; **2e**, 83260-79-1; **2e** complex with NaI, 111719-35-8; **2e** complex with KSCN, 111719-34-7; **2f**, 111719-03-0; **2h**, 111719-04-1; **2i**, 111719-05-2; **2j**, 111719-06-3; **2k**, 111719-07-4; **2l**, 111719-08-5; **2m**, 111719-09-6; **2n**, 111719-10-9; **2o**, 111719-11-0; **2p**, 111719-12-1; **2q**, 111742-56-4; **3a**, 111719-01-8; **3b**, 111719-13-2; **3c**, 83260-81-5; **3d**, 111719-14-3; **3e**, 111719-15-4; **3f**, 111719-16-5; **3g**, 111719-17-6; **3h**, 111719-18-7; **3i**, 83260-80-4; **4a**, 111742-55-3; **4b**, 111742-57-5; **4c**, 111742-58-6; **4d**, 111742-59-7; **6a**, 94703-57-8; **6b**, 111719-19-8; **6c**, 111719-20-1; **6d**, 111719-21-2; **7a**, 94703-58-9; **7b**, 111719-22-3; **7c**, 111719-23-4; **7d**, 111719-24-5; **8a**, 108366-75-2; **8b**, 108366-76-3; **10b**, 78827-96-0; **10c**, 111719-26-7; **10d**, 111719-27-8; **10e**, 111719-28-9; **10f**, 111719-29-0; **10g**, 111719-30-3; **10h**, 111719-31-4; **10i**, 111719-32-5; **10i** complex with KSCN, 111719-37-0; **13a**, 22414-64-8; **13b**, 22418-65-1; **14a**, 37114-55-9; **14b**, 29580-00-5; **15a**, 111718-95-7; **15b**, 111718-96-8; **16a**, 111718-97-9; **16b**, 111718-98-0; **16c**, 78827-93-7; **17**, 111718-99-1; **18a**, 111719-00-7; **19**, 111719-02-9; **21a**, 111719-25-6; $H(OCH_2CH_2)_4OH$, 112-60-7; $H(OCH_2CH_2)_3OH$, 112-27-6; $HO(CH_2)_2OMe$, 109-86-4; $H_3C(CH_2)_6CHO$, 124-13-0.