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LARIAT ETHERS. VI. EVIDENCE FOR INTRAMOLECULAR CHELATION IN SODIUM AND POTASSIUM CATION BINDING BY 15-CROWN-5, CARBON-PIVOT LARIAT ETHERS

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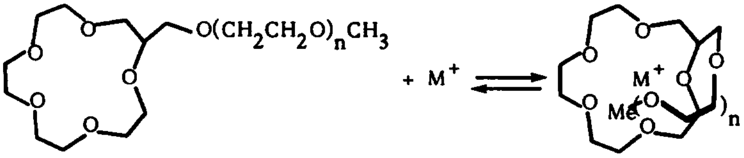
Summary: The first compelling evidence for intramolecular sidearm involvement in sodium and potassium cation complexation by carbon-pivot lariat ethers is presented.

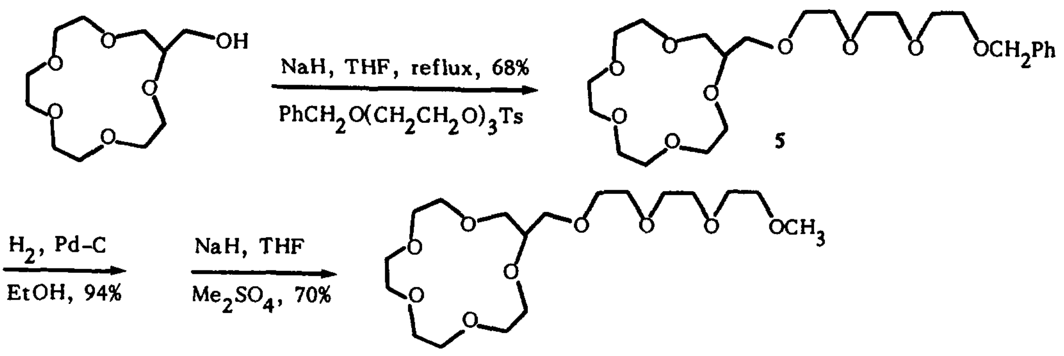
We have recently presented evidence for intramolecular participation by the donor-containing sidearm in nitrogen-pivot lariat ethers.[1] Participation by the sidearm when it is attached at the non-invertable carbon atom has proved more difficult to document, although strong presumptive evidence has accumulated on this subject.[2-5] We have made several comparisons of sodium and potassium cation binding strengths[6] using a group of carbon-pivot 15-crown-5 lariat ethers having sidechains of differing lengths, and have drawn inferences from this. The binding data presented for this group of compounds confirms the "lariat conformation" in carbon-pivot lariat ethers.



1 n = 0; **2** n = 1
3 n = 2; **4** n = 3

The carbon-pivot lariat ethers having 15-membered rings and methoxymethyl- (**1**), 2,5-dioxahexyl- (**2**) or 2,5,8-trioxanonyl- (**3**) sidechains have been reported previously.[2,3] They were made from the glycidyl ether of the incipient sidechain by treatment of the oligoethylene glycol monomethyl ether with epichlorohydrin. Hydrolytic conversion of the oxirane to the vicinal diol followed by cyclization with tetraethylene glycol ditosylate (NaH, THF) afforded the macrocycles **1-3** in 23%, 61%, and 48% yields, respectively.[2] 2-(2,5,8,11-Tetraoxadodecyl)-15-crown-5 (4) was prepared by a somewhat different method than that used for 1-3. 2-[2-(2-Benzyloxyethoxy)ethoxy]ethyl p-toluenesulfonate was condensed (THF) with the anion (NaH) of 2-hydroxymethyl-15-crown-5[8,9] to give the benzyl-protected crown (5) as a colorless oil [68%, ^{1}H-NMR($CDCl_3$): 3.66 (bs, 33H), 4.53 (s, 2H), 7. s, 5H); Anal. calcd for $C_{24}H_{40}O_9$: C, 61.00; H, 8.53. Found: C, 61.28; H, 8.77]. Hydrogenolysis of 5 (23 h, Parr bottle, EtOH, 10% Pd on C) gave hydroxycrown-6 (94%) as a nearly colorless oil. Treatment of 6 with NaH and then Me_2SO_4 in THF, followed by alumina chromatography gave 4 (70%) as a colorless oil [^{1}H-NMR($CDCl_3$): 3.37 (s, 3H), 3.68 (m, 33H); Anal. calcd for $C_{18}H_{36}O_9$: C, 54.53; H, 9.15. Found: C, 54.25; H, 9.40]. The approach is summarized below in the scheme.

Scheme



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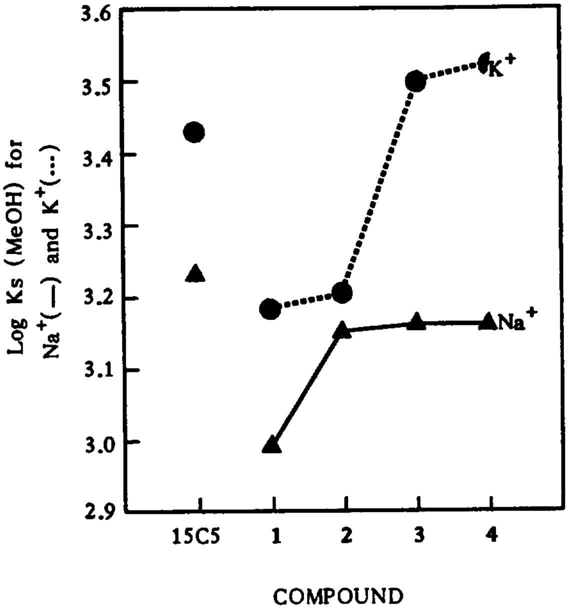
The sodium (solid line) and potassium (dashed line) binding constants are summarized in the table and graphically in the figure. The expected[10] trend of stronger K^+ than Na^+ binding is observed for this series of compounds. The more important result is that there is a significant discontinuity in each curve and this discontinuity is of a similar magnitude in both cases. Moreover, the discontinuity is offset by one ethyleneoxy unit in going from Na^+ to K^+. This suggests (A) that considerable stabilization is gained in going from two-dimensional to three-dimensional binding; and (B) that (as expected) the solvation sphere required by K^+ is larger than that required by Na^+ although the detailed ligand array is not known for either system and the symmetries may differ as well. These observations are in accord with intramolecular solvation of the alkali metal cations, a phenomenon previously confirmed in the solution phase only for nitrogen-pivot lariat ethers and

Table. Sodium and Potassium Cation Binding by Lariat Ethers[a]

Crown	Log Ks[b] Na^+	Log Ks[b] K^+
15-crown-5	3.23	3.43
1	2.99	3.18
2	3.15	3.20
3	3.16	3.50
4	3.16	3.52

[a] In MeOH at 25.0°C, see ref. 6

[b] Errors in log Ks are of the order ±0.01 log unit



ammonium ions.[1]

In considering possible binding mechanisms for complexation by these lariat ethers, it seems quite possible that binding of cations might occur by either a "sandwich type of association" (two rings and one cation) or the arm might be utilized intermolecularly to stabilize a ring-bound cation in another species. The steric demand of the ammonium cation clearly demonstrates that this is not the case for nitrogen-pivot lariat ethers having 18-membered rings, and inferentially for the smaller-ring species.

For the 15-membered ring carbon-pivot lariat ethers, the large increment in binding at distances which seem appropriate to accommodate the differently sized cations is strongly suggestive of intramolecular participation by the sidearm, if not confirmation of this fact.

ACKNOWLEDGEMENTS

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