Synthesis and Properties of 1-(Tropon-2-yl)-1-aza-4,7,10,13-tetraoxacyclopentadecanes. Preferential Complexation of Lithium Salt among the Alkali Salts

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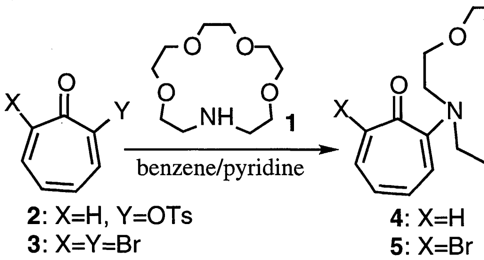
1-(Tropon-2-yl)-1-aza-15-crown-5 ether and 1-(7-bromotropon-2-yl)-1-aza-15-crown-5 ether were prepared by condensation of 1-aza-15-crown-5 ether and appropriate derivatives. Spectrophotometric titration of the 1:1-complexes of these crown derivatives showed a preferential complexation with lithium salt over other alkali metal salts. Thus, structural modification by capping with tropone system altered the selectivity.

Recently, we have prepared several mercurophilic dithiocrown derivatives having tropones and dicyanoheptafulvene systems incorporated.[1-4] In view of their outstanding features, we have extended the study to *aza*-crown derivatives having a troponoid pendant.



Scheme 1.

Reflux of a 1:1-mixture of 1-aza-4,7,10,13-tetraoxacyclopentadecane (**1**) and 2-(*p*-tolylsulfonyloxy)tropone (**2**) or 2,7-dibromotropone (**3**) in benzene and pyridine (9:1) for 20 h gave 1-(tropon-2-yl)-1-aza-4,7,10,13-tetraoxacyclopentadecane (**4**, 85% yield) or 1-(7-bromotropon-2-yl)-1-aza-4,7,10,13-tetraoxacyclopentadecane (**5**, 89% yield).[5]

Complexation behaviors of **4** with various metal salts were analyzed by ^{1}H NMR spectroscopy; in $CDCl_3$, $Hg(SCN)_2$ revealed no change, but LiSCN, NaSCN, and KSCN showed a change of the chemical shifts of certain signals. For the cases of RbSCN, CsSCN, CdI_2, $Mg(SCN)_2$, $Ca(SCN)_2$, $Ba(SCN)_2$, and $Zn(SCN)_2$, the complexation in $CDCl_3$ was evident from the formation of precipitates.

By additions of metal salts, the UV spectral of **4** changed dramatically; the spectrum of free **4** was typical as that of 2-aminotropone derivative, having two strong absorption bands at a longer wavelength region, 385 and 430 nm, which were disappeared by addition of cations other than mercury(II). Figure 1 shows the UV spectra of **4** with and without (solid line) added metal ions (100 molar equivalent).

Using this spectral change, the association constants (*Ka*) of complexes were determined by both Benesi-Hildebrand method[6] and the curve-fitting method.[7] For alkaline earth metals, the measurements in MeCN were out of range, and the solvent was changed to a mixture of $CHCl_3$ and MeOH (7:1). The results are compiled in Table 1. The ratio of metal salt to **4** were 1:1 for all according to both measurements.

It is interesting that the order of *Ka* of **4** with alkali ions was $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$; it is known that with the series of crown ethers, Li^+ and Na^+ preferably form the complexes with 12-crown-4 and 15-crown-5 derivatives, respectively.[8] This Na^+ ion selectivity was commonly observed for several modified 1-aza-15-crown-5 derivatives, such as **A**, **B**, and **C** (Chart 1);[9] i.e., **A**, in which the substituent on the nitrogen is the aryl group, showed a distinct band shift of a donor-acceptor-type chromoionophore, and the order was $Na^+ > Li^+ > K^+$,[10] and **B** and **C**, whose chromophores are bound with inserted *sp*^{3}-carbon unit, showed an order of $Na^+ > K^+ > Li^+$.[11]

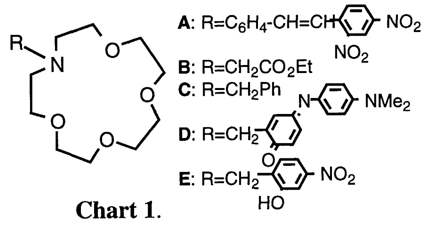
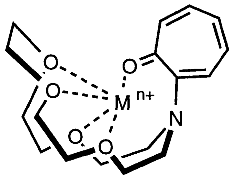


Chart 1.

On the other hand, the quinone imine ligand (**D**) was Li^+ ion selective in CH_3CN, $Li^+ > Na^+ > K^+$. This Li^+ ion selectivity was explained in terms of the flexible cavity.[12] The present troponoid ionophore **4**, of which a type of the substituent on the nitrogen is also like **A**, the aryl group, but its Li^+ ion selectivity is similar to **D**. It is interesting that the compound **E**, together with several other analogs having *o*-hydroxybenzyl groups, revealed a same order of extraction coefficients (from H_2O to CH_2Cl_2) for alkali ions, Li^+, Na^+, and K^+.[13] As the capping agent, the phenolic hydroxyl and aromatic carbonyl behaved differently.

The order of K_a of **4** with alkaline earth ions, was just opposite to that for **D**; in **4**, the larger *Ka*, the larger ionic radii of metals, $Ba^{2+} > Ca^{2+} > Mg^{2+}$, and indeed, the largest K_a was observed for Ba^{2+}. This can be explained in terms of strong solvation of cations. For complexation, the solvated ions have to be desolvated, and solvation energy is larger in smaller metal ions.[14] However, discussions should not be further extended since the solvent systems were different with **A** and **D**.

The UV-spectral behavior of **4** indicates, except for the case of Hg (II), a change of conformation by complexation. As shown in Scheme 2, should the tropone carbonyl and four ethereal oxygen constitute the coordination form, the robe of the unshared electron pair of the nitrogen should become perpendicular to the π-axis of the seven-membered ring.



Scheme 2.

This makes effective size of the crown cavity smaller than the parent *aza*-crown ether, and the fixed conformation gives the observed electronic structure of the host molecule.

In a sharp contrast, the UV spectral band structures of **4** and its Hg(II) complex are same. This indicates that tropone carbonyl of **4** is essentially not coordinated with Hg^{2+} to change the con-

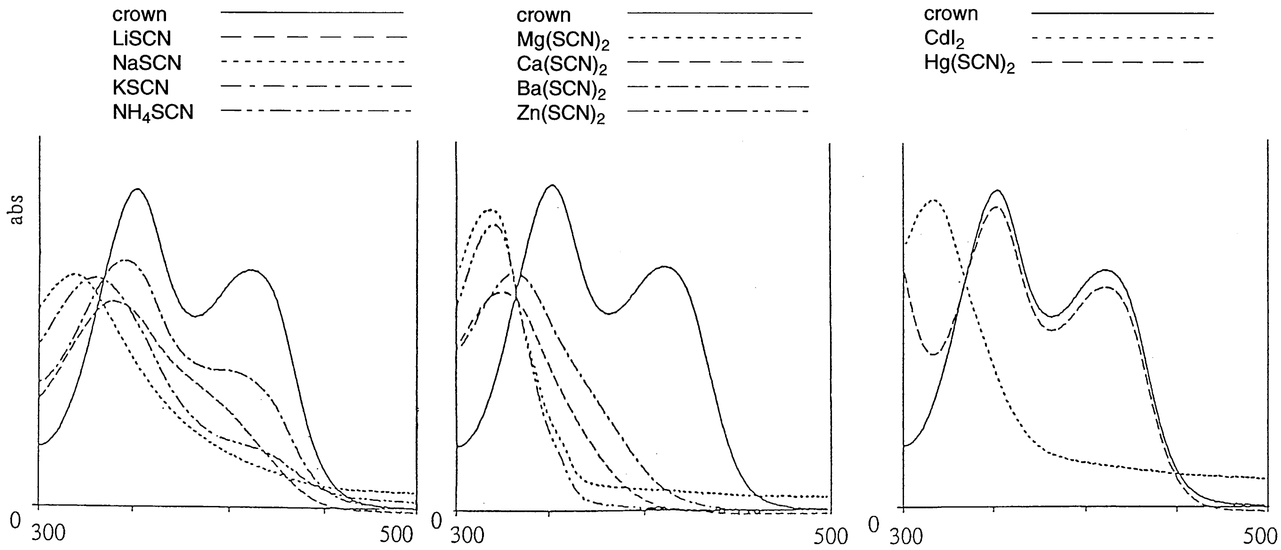


Figure 1. The UV spectra of **4** with (100 mole equivalent) and without (solid line) added metal ions.

Table 1. Association constants for 1:1 complexes of **4** with various cations

Cations	log K MeCN[a]	 $CHCl_3$-MeOH(7:1)[a]	 MeCN[b]
Li^+	4.81±0.12	2.17±0.02	4.60±0.10
Na^+	3.55±0.07		3.70±0.03
K^+	2.54±0.05		2.70±0.04
$(NH_4)^+$	2.28±0.05		2.17±0.02
Rb^+	1.95±0.03		1.90±0.03
Cs^+	1.91±0.04		1.88±0.06
Hg^{2+}	1.51±0.02		1.33±0.06
Mg^{2+}		1.41±0.09	
Ca^{2+}		3.25±0.04	
Ba^{2+}		3.81±0.04	
Cd^{2+}		3.06±0.04	5.54±0.10
Zn^{2+}			5.99±0.20

[a]Obtained by Benesi-Hildebrand method.
[b]Obtained by curve-fitting method.

formation; previously, we noticed that there is only a slight change in the spectral properties of the carbonyl group of troponoid crown derivatives by complexation.[15]

Finally, it should be pointed out that **4** is readily soluble not only in water but in the most of solvents, and can be a useful reagent for analyses. Further studies including a fixation on polymers of **5** are in progress.

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5 The following ^1H NMR data (270 MHz in $CDCl_3$) were obtained: **4**: δ=3.62-3.68(12H, m), 3.75-3.84(8H, m), 6.53 (dd, *J*=10.6, 8.1 Hz), 6.66(d, *J*=10.6 Hz), 6.86(dd, *J*= 12.1, 1.1 Hz), 7.02(t, *J*=10.6 Hz), and 7.05(ddd, *J*=12.1, 8.1, 1.1 Hz); **5**: δ=3.57-3.66(12H, m), 3.80(8H, s), 6.33 (t, *J*=9.9 Hz), 6.71(d, *J*=10.6 Hz), 7.06(dd, *J*=10.6, 9.9 Hz), and 7.88(d, *J*=9.9 Hz).
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15 However, this does not apply for the side-on complexes, e.g., one from 5-oxa-2,8-dithiabicyclo[7.4.1]tetradeca-1(13), 9,11-trien-14-one.[4]