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COMPLEXATION PROPERTIES OF MACROCYCLIC POLYETHER-DIESTER COMPOUNDS CONTAINING FURAN AND BENZENE SUBCYCLIC UNITS

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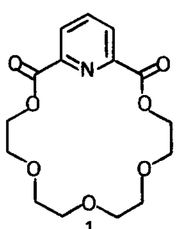
A new series of macrocyclic polyether-diester ligands containing a furan subcyclic unit is reported. In contrast to other macrocyclic ligands, the twenty-four membered ring diester compounds containing either a furan or benzene subcyclic unit complex more strongly with benzylammonium perchlorate than do the eighteen membered ring compounds.

We have a continuing interest in the synthesis and cation complexation properties of macrocyclic polyether-diester compounds.[2-6] The pyridino diester compound **1** is an excellent ligand for complexing various metal[3] and alkylammonium[6] cations and is extremely easy to synthesize.[3,5] We now report unusual complexing properties of some macrocyclic polyether-diester compounds containing furan and benzene subcyclic units (compounds **2**-**13**).

The furan compounds (**2**-**7**) were prepared from 2,5-furandicarbonyl chloride[7] or its 3,4-dimethoxy derivative[8] and the appropriate glycol.[3,5] For example, reaction of 3,4-dimethoxy-2,5-furandicarbonyl chloride with tetraethylene glycol yielded **5** as white needles (67%)[9]; m.p. 167-167.5°C: δ 3.76 (s, 8H, $OC\underline{H}_2$), 3.80 (m, 4H, $OC\underline{H}_2$), 4.12 (s, 6H, $OC\underline{H}_3$), 4.46 (m, 4H, $COOC\underline{H}_2$). The remaining furan compounds were similarly prepared: **2**[9], 60%, m.p. 117-118°C; **3**, 27% m.p. 133-134°C; **4**, 30%, m.p. 93.5-95°C; **6**, 31%, m.p. 84-85°C, **7**, 14%, m.p. 67-67.5°C. The benzene compounds (**8**-**13**) have been reported previously.[4]

Formation of the alkylammonium-ligand complex is accompanied by significant chemical shift changes in the 'H n.m.r. spectra in CD_2Cl_2. The free energy of activation ($\Delta G^{\neq}$) for the dissociation of the alkylammonium complexes of compounds **1**-**13** are shown in Table I.[10] The furan and benzo diester ligands complexed with benzylammonium cations in an unusual manner. Specifically, in contrast to the pyridine diester ligands of type (**1**) where the complexes of the eighteen membered ring ligands were the most kinetically stable[6], the benzylammonium cation complexes of the twenty-four membered diester rings containing furan (**4**, **7**) or benzene (**10**, **13**) subcyclic units were the most kinetically stable (see Table I). Indeed the most significant chemical shift changes in the 'H n.m.r. spectra were shown by the complexes of compounds **4**, **7**, **10** and **13**. The 'H n.m.r. spectral patterns



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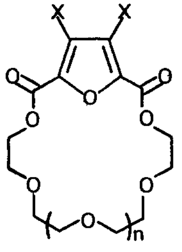
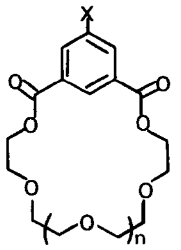


2 X=H, n=1
3 X=H, n=2
4 X=H, n=3
5 X=OCH$_3$, n=1
6 X=OCH$_3$, n=2
7 X=OCH$_3$, n=3



8 X=H, n=1
9 X=H, n=2
10 X=H, n=3
11 X=NO$_2$, n=1
12 X=NO$_2$, n=2
13 X=NO$_2$, n=3

Table I. Free Energy of Activation ($\Delta G^{\neq}$) for the Complexation of Primary Alkylammonium Perchlorate ($RNH_3\ ClO_4$) with Compounds 1-13.[a]

Compd.		$PhCH_2NH_3^+$(1:1)		$PhCH_2CH_2NH_3^+$(1:1)		$tBuNH_3^+$(1:1)	
	Ring mbrs	T_c ± 3°C	$\Delta G_c^{\neq}$ + 0.3 kcal/mole	T_c ± 3°C	$\Delta G_c^{\neq}$ + 0.3 kcal/mole	T_c ± 3°C	$\Delta G_c^{\neq}$ + 0.3 kcal/mole
1	18	+10	13.0	---	---	-20	11.8
2	18	-60	9.7	-65	9.5	-80	8.7
3	21	-47	10.7	-51	10.4	<-100	<8
4	24	-40	10.9	-58	10.3	<-100	<8
5	18	-47	10.2	-63	9.6	-73	9.1
6	21	-44	10.7	-50	10.5	<-100	<8
7	24	-34	11.1	-55	10.3	<-100	<8
8	18	No complex		No complex		No complex	
9	21	-75	9.3	---	---	<-100	<8
10	24	-46	10.5	-65	10.0	<-100	<8
11	18	No complex		No complex		No complex	
12	21	-80	9.0	---	---	<-100	<8
13	24	-53	10.2	---	---	<-100	<8

[a] $\Delta G^{\neq}$ values were obtained in the usual manner (reference 10).

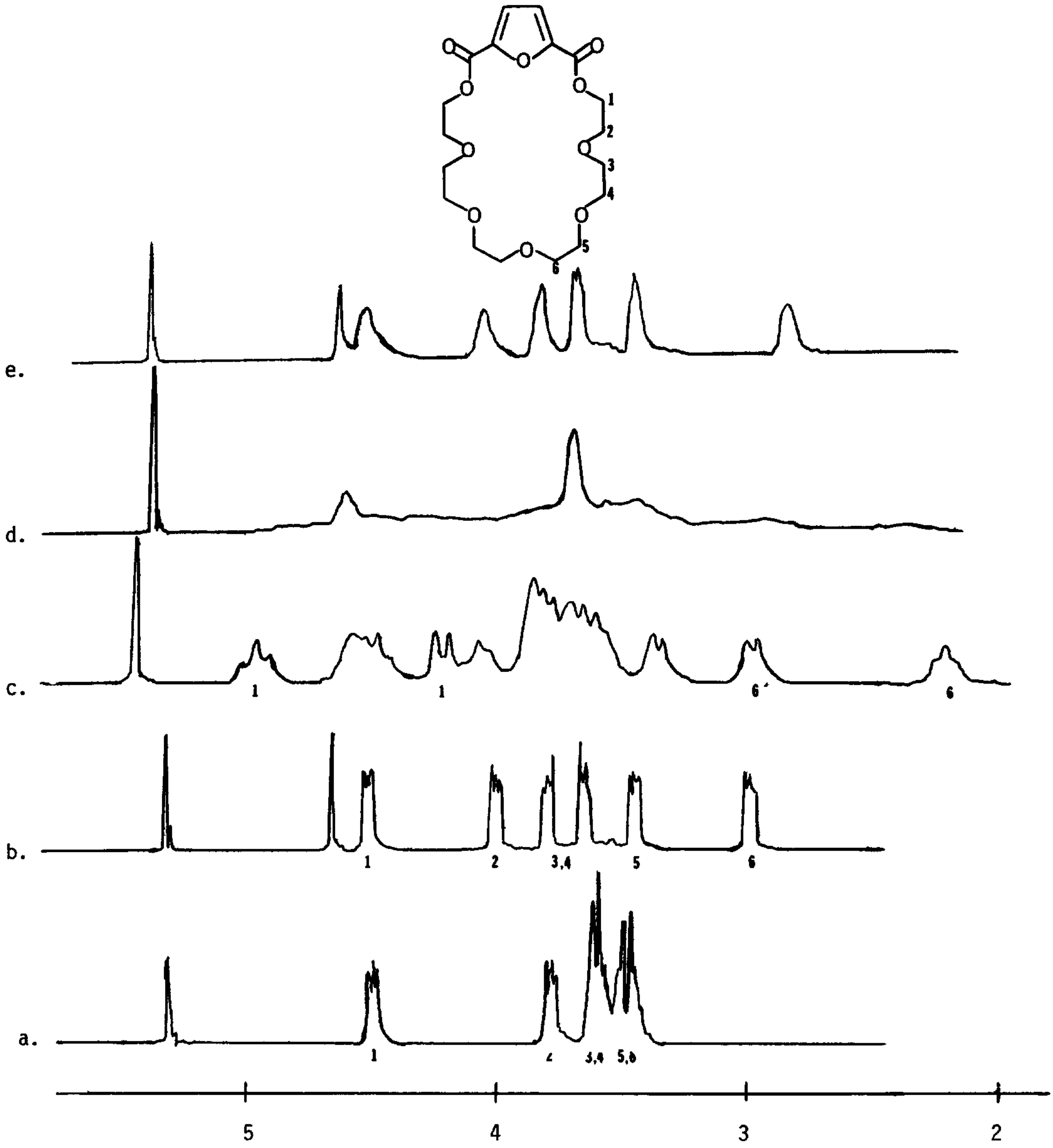
Table II. Log K, ΔH, and TΔS for the Reaction of Compounds 2, 3, and 4 with Ammonium, Methylammonium and Benzylammonium Chlorides in a 50% v/v Chloroform/Methanol Mixture at 25°C[a]

Ligand	Value	NH_4^+	$CH_3NH_3^+$	$PhCH_2NH_3^+$
2	Log K	1.61 ± .01	1.12 ± .03	0.5
	ΔH	-6.4 ∓ .8	-7.0 ∓ .8	---
	TΔS	-4.2	-4.9	---
3	Log K	2.51 ± .01	1.76 ± .01	1.36 ± .12
	ΔH	-4.9 ∓ .2	-5.5 ∓ .4	-8.3 ∓ 1.0
	TΔS	-1.6	-3.1	-6.4
4	Log K	1.29 ± .12	1.60 ± .11	1.40 ± .07
	ΔH	-2.8 ∓ .5	-4.2 ∓ .6	-10.2 ∓ .7
	TΔS	-1.0	-2.0	-8.3

[a] Error limits are given as the average deviation from the mean determined from two or more independent experiments.

for each of these complexes were almost the same (see Figure 1). The absence of any change in the frequency of the carbonyl infrared band or the maximum in the furan (or benzene) ultraviolet spectrum upon complexation indicates that the furan (or benzene) dicarbonyl group is not involved in complexation. The 200 Hz upfield shift of the protons on macroring positions 11 and 13 (the carbons opposite the furan ring) in the 'H n.m.r. spectrum suggests that the benzene ring of the benzyl ammonium cation is centered over the ether part of the macrocycle (see Figure 1). At very low temperatures the macroring protons on the same side as the benzene ring of the ammonium salt should shift even higher upfield as was observed (Figure 1, compare c to b). CPK models show that this structure is indeed possible. Supporting this type of structure is the knowledge that the furan oxygen is the weakest hydrogen bond acceptor[13] so that one would expect complexation to take place in the polyether portion of the molecule. The pyridine compounds[6] on the other hand would complex differently since the pyridine nitrogen is the best hydrogen bond acceptor. In this case complexation ability would be expected to fall off for the larger rings.

The complexes with the β-phenylethylammonium cations show nearly the same kinetic stability order while those with t-butylammonium cations do not (see Table I). The t-butylammonium cations appear to follow the same kinetic stability order with these ligands as with the pyridine ligands previously reported.[6] We



igure 1. 'H n.m.r. spectra for the complexation of compound 4 with Benzylammonium Perchlorate i Methylene Chloride D_2: a. compound 4 at 25°C; b. the 4-$PhCH_2NH_3\ ClO_4^-$ complex at 25°C; c. the complex at -100°C; d. the complex at -40°C (Tc); and e. the complex at -10°C.

'H n.m.r. signal at 5.3 ppm is solvent and signal at 4.6 in b. and e. is the benzyl CH_2.

also observed that the methoxy groups on the furan ring enhance kinetic stability while the nitro group on the benzene ring retards stability. These results are in keeping with the electronic donating effect of the methoxy group and withdrawing effect of the nitro group.

Titration calorimetry for the reaction of ligands **2**-**4** with ammonium, methylammonium and benzylammonium cations in a mixture of chloroform and methanol were also carried out (Table II). Again the benzylammonium cation complexes show an unusual stability order with the twenty-four membered ring ligand (**4**) forming a more stable complex than the eighteen membered ring (**2**). This phenomenon is also observed with the methylammonium cation complexes but not in the case of the ammonium complex where ligand **2** formed a more stable complex than ligand **4**. In both of these latter two cases, the complexes with the twenty-one membered ring ligand (**3**) were the most stable.

Liquid membrane experiments similar to those performed previously[14] were conducted using these ligands. In the transport of metal cations using chloroform, the furan compound **5** showed poor carrie ability compared to **1**. However, compounds **6** and **7** showed ten times greater transport selectivity for Cs^+ over Rb^+ than was found for 21-crown-7 which itself shows good $Cs^+ > Rb^+$ selective transport. In addition, compound **6** transported Cs^+ more rapidly than any of thirty other macrocyclic ligands studied Details of these liquid membrane transport experiments will be presented in a subsequent publication. The superior capacity of **6** as a Cs^+ selective carrier warrants further investigation.

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