CHEMISTRY LETTERS, pp. 477-480, 1980.

NMR SPECTROSCOPIC BEHAVIOR OF THE COMPLEXES OF SOME POLYETHYLENE GLYCOL DERIVATIVES WITH ALKALI IONS

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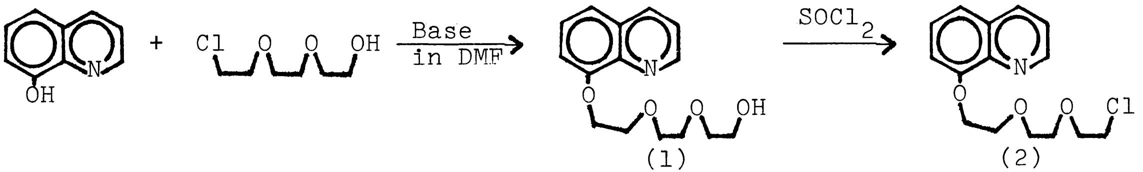
Four triethylene glycol derivatives, which have different end substituents, quinolyl and ortho-substituted phenyl groups, were synthesized in good yields.

The proton NMR spectrum of these compounds and their complexes with alkali and ammonium ions was measured to show that these compounds exhibit complexation specificity for sodium ion.
On complexation, these acyclic polyethers are considered to wrap adequately themselves around sodium ion like a pseudocyclic species.

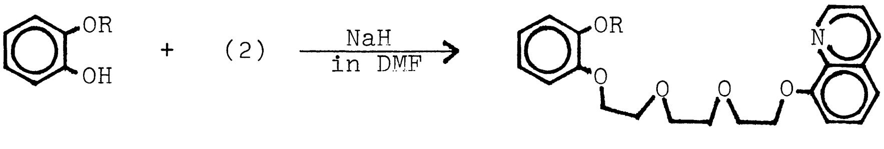
Recently, synthesis of acyclic polyethers and their ability of complexation with cations have increasingly received attention in comparison with cyclic polyethers, so-called "crown ethers",$^{1)}$ and concerning to cation carrier of selective ion transport like monensin$^{2)}$ and nigericin. And various acyclic compounds, e.g., polyethylene glycol derivatives having same end groups by Vögtle et al., have been hitherto synthesized.$^{3)}$ We wish to report here the synthesis of some triethylene glycol derivatives having different two end groups, and the proton NMR spectroscopic behavior of their complexation with alkali and ammonium ions.

In this study, four kinds of triethylene glycol derivatives having 8-quinolyl group as one end group and ortho-substituted phenyl group as the another one were synthesized. 2-[2-(2-(Quinolyl-8-oxy)ethoxy)ethoxy]ethanol (1) was obtained in good yield by the reaction of 8-hydroxyquinoline with 2-[2-(2-chloroethoxy)ethoxy]ethanol in the presence of K_2CO_3 or NaH in DMF. Compound (1) was chlorinated with thionyl chloride to give 8-[2-(2-(2-chloroethoxy)ethoxy)ethoxy]quinoline (2).

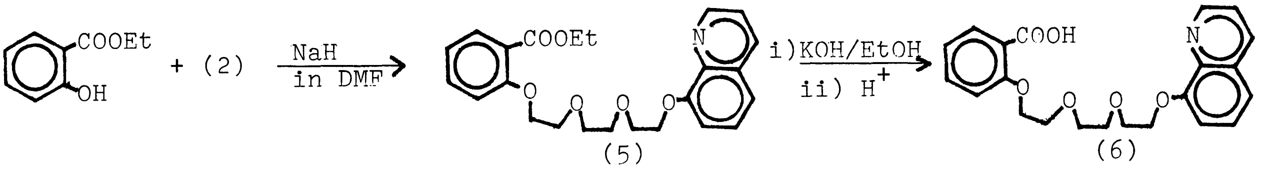


(1) (2)

Compounds (3),$^{4)}$ (4), and (5) were obtained in good yields by the reaction of (2) with o-methoxyphenol, pyrocathechol, and ethyl O-hydroxybenzoate, respectively. Compound (6) was obtained in good yield by the hydrolysis of (5).



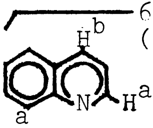
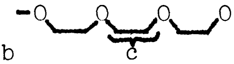
(3) R = Me
(4) R = H



(5) (6)

These compounds were purified by vacuum distillation and/or column chromatography (alumina - $CHCl_3$ or silica gel - $CHCl_3$+ EtOH) and identified with elemental analysis and the NMR, IR, and Mass spectroscopic methods (Table 1).

Table 1. Analytical Data of Triethylene Glycol Derivatives

Polyether	Yield^{*1} %	Elemental Analysis^{*2} C,%	H,%	N,%	60 MHz NMR spectra^{*3} (10% $CDCl_3$ soln., at 21°C)  H^b H^a a	b	 c	others
(3) liquid	95	68.29 (68.91)	6.83 (6.57)	3.48 (3.65)	8.97	8.11	3.83	3.79(OCH_3)
(4) mp,°C 65 - 67	78	67.61 (68.28)	6.35 (6.28)	3.80 (3.79)	8.93	8.06	3.73	4.6(broad, OH)
(5) liquid	74	67.00 (67.75)	6.54 (6.40)	3.28 (3.29)	8.84	8.01	3.77	4.27($OC\underline{H_2}$-CH_3) 1.33(OCH_2-$C\underline{H_3}$)
(6) liquid	69	66.69 (66.49)	5.86 (5.83)	3.34 (3.52)	8.89	8.06	3.75	9.66(COOH)

*1 Yield based on (2). *2 Values in parentheses are calculated ones.
*3 δ ppm from tetramethylsilane as an internal standard.

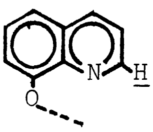
Uptake of cations by these compounds were attempted. When compounds (3), (4),and (5) were stirred in $CHCl_3$ or CH_2Cl_2 in the presence of sodium, potassium, and ammonium thiocyanates, respectively,uptake of each salt into organic solvent was occurred. The complexes of them with NaSCN were obtained as colorless crystals and confirmed to be 1 : 1 complexes with elemental analysis, while the complexes of them with potassium or ammonium thiocyanate became glassy or viscous liquid and did not form any crystalline 1 : 1 complexes in both cases, whose composition ratio of the polyethers to thiocyanate salts was always more than 1 . From these results, the complexes with NaSCN are obviously more stable than the complexes with other thiocyanate salts. The proton NMR spectrum of them was measured under the same conditions and the results are shown in Table 2. For comparison, the chemical shift of the complexes of tetraethylene glycol bis(8-quinolyl)ether (7)$^{5)}$ with thiocyanate salts is also shown in Table 2.

Table 2. 60 MHz NMR Spectroscopic Data of the Complexes
Chemical shift(ppm)^{*1}of the proton^{*2} at the 2-position in the quinoline skelton in $CDCl_3$

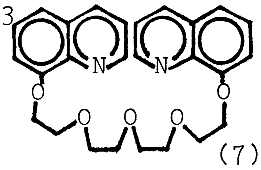
Polyether	without salt	NaSCN	KSCN	NH_4SCN
(3)	8.97	8.41	8.56	8.57
(4)	8.93	8.32	8.72	8.75
(5)	8.93	8.16	8.71	8.77
(7)^{*3}	8.91	8.81	8.43	8.60

*1 Conditions : see Table 1.

*2



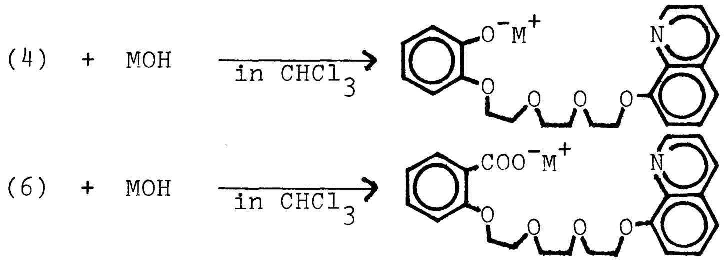
*3



(7)

From Table 2, in the cases of (3), (4), and (5) the chemical shift of the proton at the 2-position in the quinoline skelton of the complexes changes remarkably with the change of cation. The chemical shift of them changes to upfield in comparison with original compounds as follows: $NH_4^+ < K^+ < Na^+$. In compound (3), the signal of the proton on the methoxy group of the another end group shifts similarly to upfield as follows: $NH_4^+ < K^+ < Na^+$. In compound (5) the chemical shift of the methylene and methyl proton of ethoxycarbonyl group changes similarly to upfield. On the contrary, in compound (7) which has one more ethylene oxide chain than (3), (4), and (5), the upfield shift of that proton induced by potassium ion is the largest.[3a, 6] The signal of the proton of ethylene oxide chain of the complexes in all cases, in general, shifts slightly to downfield.[7]

Next, the alkali salts of polyethers (4) and (6) were formed by the reaction with alkali hydroxides. The proton NMR spectrum of them was measured in $CDCl_3$. In Table 3, the chemical shift of the proton at the 2-position in the quinoline skelton are shown.



M = Li, Na, K, Rb, and Cs

Table 3. NMR Spectroscopic Data of the Alkali Salts of (4) and (6)

Polyether	Chemical shift(ppm) of the proton at the 2-position in the quinoline skelton in $CDCl_3$					
	-	LiOH	NaOH	KOH	RbOH	CsOH
(4)	8.93	*	8.59	8.74	8.81	8.79
(6)	8.89	8.77	8.58	*	*	8.82

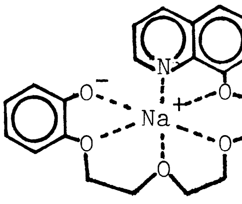
* insoluble in $CDCl_3$

The salt of (4) with LiOH was insoluble in $CHCl_3$. Also the salts of (6) with KOH and RbOH were precipitated in $CHCl_3$, whose NMR spectrum could not be measured in $CDCl_3$. The chemical shift of the salts which are soluble in $CDCl_3$ changes with the change of alkali ion. The upfield shift of that proton induced by sodium ion for both (4) and (6) is the largest of all kinds of the salts as well as in the case of the complexes of (3), (4), and (5) with thiocyanate salts(see Table 2). Here, the quinoline skelton is enoughly remote from ortho-substituted phenyl group beyond three ethylene oxide chains. It means that there is appreciable interaction between sodium ion and the quinolyl group. Sodium ion seems to become most adequately incorporated into these acyclic polyethers.

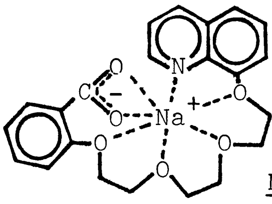
Further, when the mixture of the $CHCl_3$-insoluble white solid of potassium salt and the $CHCl_3$-soluble sodium salt of (6) was stirred in the presence of excess powdered NaOH and KOH mixture, the white solid of the potassium salt became soluble completely into $CHCl_3$. And the chemical shift of the substance from the solution is the same as that of the Na salt only. It means that the K salt was completely exchanged to the Na salt and the Na salt formed became soluble in $CHCl_3$.

$$Na^+\text{-}(6) \quad + \quad K^+\text{-}(6) \quad \xrightarrow[\text{in } CHCl_3]{\text{excess NaOH + KOH}} \quad 2\ Na^+\text{-}(6) \quad + \quad KOH\downarrow$$

The good solubility of the sodium salt in $CHCl_3$ suggests that sodium ion becomes well incorporated into the cavity formed by the acyclic polyether,8) while uptake of potassium ion into that cavity seems to be unfavorable because its ion radius is larger than sodium ion. This is supported by the next experimental fact; both sodium and potassium salts of ortho-ethoxybenzoic acid are insoluble in $CHCl_3$ and their NMR spectra can not be measured in $CDCl_3$. The manner of uptake of sodium ion by (4) and (6) is considered as illustrated schematically below.9)



Na^+-(4)



Na^+-(6)

REFERENCES AND NOTES

1) Reviews: S. Yanagida and M. Okahara, "The Chemistry of Crown Ethers" (Kagaku-zokan 74), ed. by R. Oda, T. Shono, and I. Tabushi, Kagakudojin, Kyoto(1978) p.145 Chap. 4; F. Vögtle and E. Weber, Angew. Chem. Int. Ed. Engl., 18, 753(1979); N. S. Poonia and A. V. Bajaj, Chem. Rev., 79, 389(1979).

2) E.M. Choy, D.F. Evans, and E.L. Cussler, J. Amer. Chem. Soc., 96, 7085(1974).

3 a) E. Weber and F. Vögtle, Tetrahedron Lett., 1975, 2415.
  b) F. Vögtle and H. Sieger, Angew. Chem. Int. Ed. Engl., 16, 396(1977).
  c) B. Tümmler, G. Maass, E. Weber, W. Wehner, and F. Vögtle, J. Amer. Chem. Soc., 99, 4683(1977).
  d) B. Tümmler, G. Maass, F. Vögtle, H. Sieger, U. Heimann, and E. Weber, ibid., 101, 2588(1979).
  e) N.N.L. Kirsch and W. Simon, Helv. Chim. Acta, 59, 357(1976).
  f) R. Büchi and E. Pretsch, ibid., 58, 1573(1975); 60, 1141(1977).
  g) M. Güggi, M. Oehme, E. Pretsch, and W. Simon, ibid., 59, 2417(1976).

4) Known product, see Ref. 3b.

5) Commercially available compound, see Ref. 3a.

6) Tetraethylene glycol derivatives containing the quinolyl group as one end group and o-ethoxycarbonylphenyl group and so on as the another one were also prepared, and from the NMR spectra the chemical shift of the proton at the 2-position in the quinoline skelton changes also to more upfield in K^+-complex than Na^+-complex like the case of (7). Unpublished result.

7) S. Yanagida, K. Takahashi, and M. Okahara, Bull. Chem. Soc. Jpn., 51, 1294, 3111 (1978).

8) It is considered that this phenomenon is the same as the solubilization of inorganic salts into organic solvent in the presence of crown ethers.

9) In the 1 : 1 complex of (7) with RbI it has been confirmed with X-ray analysis that the salt becomes strongly incorporated into the cavity formed by (7). F. Vögtle and E. Weber, Kontakte, 1977, 11.

(Received February 1, 1980)