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Pseudo Cyclic Ionophores: 'Binary-Effect' of Quinolinyloxy Groups at Both Ends of Oligoethylene Glycols on the Conformational Stabilization of Their Complexes with Alkali Metal Salts

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Abstract. A series of noncyclic neutral ionophores has been synthesized by the reaction of oligoethylene glycol dihalides with 8-quinolinol. Complexation properties for alkali metal picrates were evaluated from solvent extraction and bulk liquid membrane transport experiments. Complexation profiles of the newly synthesized ionophores with a hexyl chain were similar to those of their homologues without the hexyl chain in the extraction experiments. Among them, the pentaethylene glycol derivatives showed the highest extraction efficiency and selectivity towards potassium ion. From the ^{1}H NMR spectra (400 MHz), the change in chemical shifts of the aromatic protons upon the addition of alkali metal thiocyanates suggested the existence of a stabilization effect which is caused by intramolecular stacking conformations between the quinoline rings during complexation. Aryl stacking interactions depend on the size of the cations and on the chain length of the oligoethylene glycol. The relationship between transport ability towards alkali metal cations and lipophilicity of these ionophores is also discussed.

Key words. Noncyclic ionophore, solvent extraction, membrane transport, ^{1}H NMR.

1. Introduction

Numerous ionophores are responsible for the molecular recognition in a biomembrane [1]. In order to attain better binding properties, naturally occurring polyether antibiotics possess a characteristic structure which contributes to the stereochemically reinforced preorganization [2].

Generally, the oxyethylene chain of common glymes affords the low complexing ability which is ascribed to its conformational freedom. However, oligoethylene glycol derivatives with aromatic donor groups at both ends were found to possess better complexing abilities in comparison with common glymes [3, 4]. In particular, the compound having quinolinyloxy moieties, **2a**, showed an excellent complexing ability [5]. This type of acyclic ionophore is considered to have intermediate properties between crown ethers and common glymes.

On the other hand, increasing attention has been recently focused on the studies that treat 'structural effects' of semirigid host compounds which incorporate a π-stacking component (aromatic moiety) [6].

From the viewpoint of constructing highly efficient neutral ionophores with an acyclic structure, we describe the relationship between the complexing abilities

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(extraction efficiency and transport ability) towards alkali metal cations and the structural properties of both series of quinolinyloxy ionophores, **1a**–**4a** and **1b**–**4b**.

2. Results and Discussion

2.1. SYNTHESIS

All ionophores were prepared by the reaction of the corresponding dihalide with 8-quinolinol in the presence of potassium hydroxide (see the experimental section). The structures of all new compounds were ascertained by NMR and IR spectroscopy, mass spectrometry, and elemental analysis.

2.2. SOLVENT EXTRACTION

Extraction profiles conducted under the conditions using equimolar amounts of ionophore and picrate are shown in Figure 1.

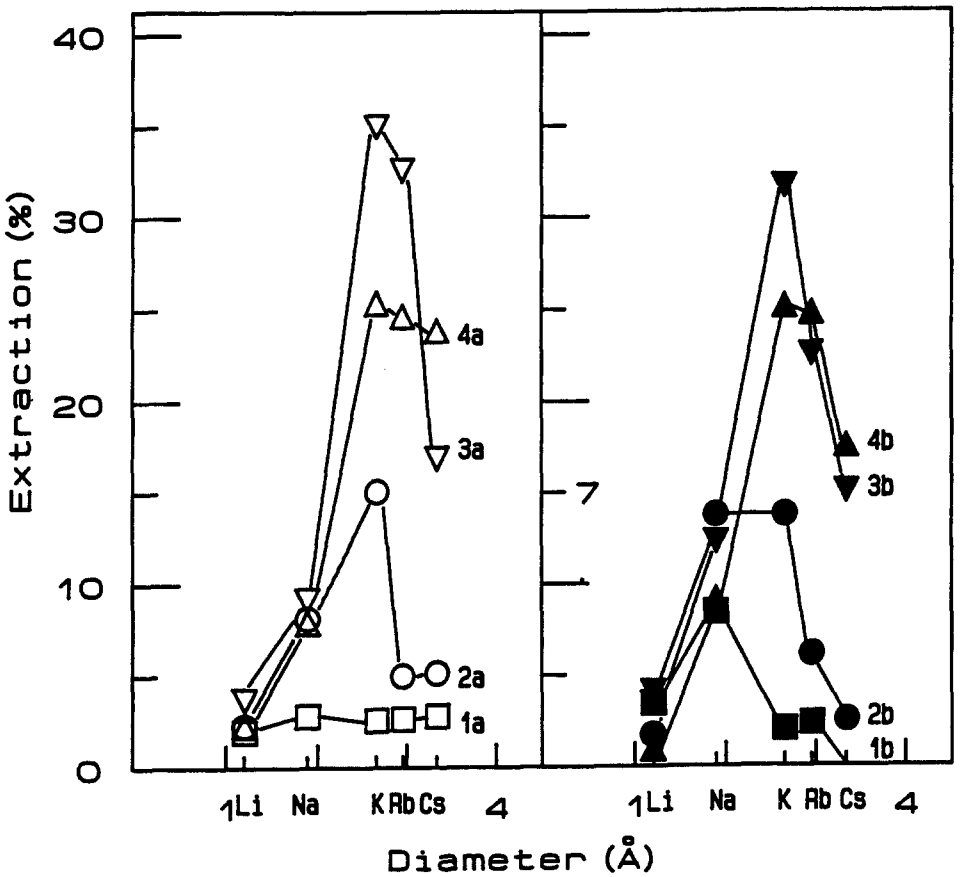
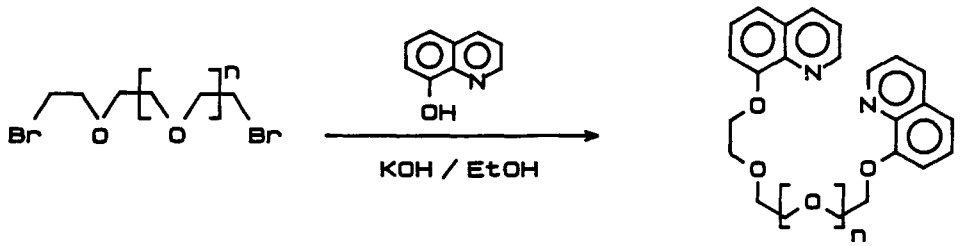
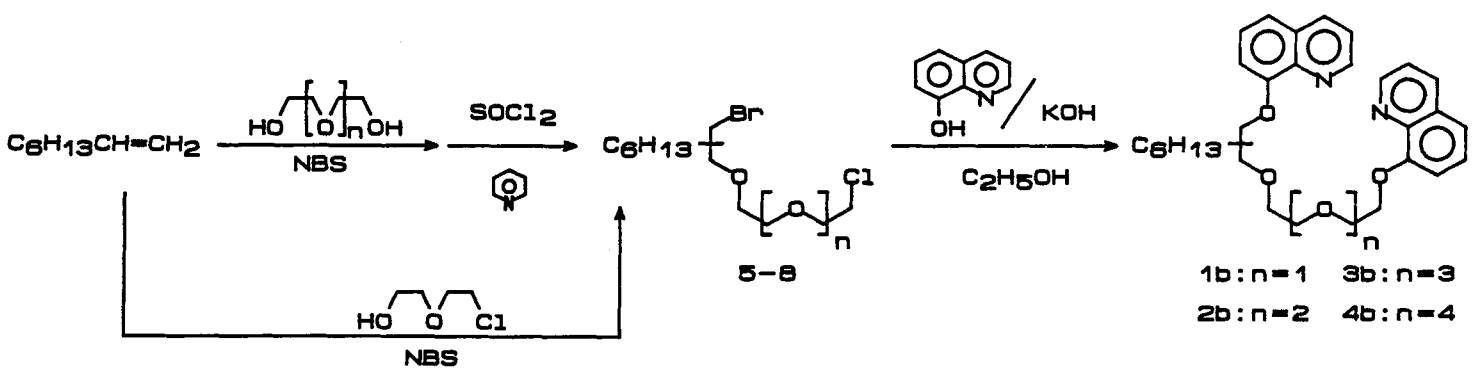


Fig. 1. Solvent extraction of alkali metal picrate by acyclic ionophores: organic phase (CH_2Cl_2, 10 mL)/aqueous phase (10 mL); [MOH] = 50 mM; [Extractant] = [Picric acid] = 0.5 mM; 22°C; 9 h.

Scheme 1



1a: n=1 3a: n=3
2a: n=2 4a: n=4



1b: n=1 3b: n=3
2b: n=2 4b: n=4

Both types of ionophores (without or with the hexyl chain) showed almost the same extraction efficiency. This fact suggests that the attachment of a hexyl chain does not hinder the formation of a complex.

Focusing on the difference in the length of the oxyethylene chain, a maximum extraction efficiency for potassium picrate was observed in the pentaethylene glycol type ionophores, **3a** and **3b**. In previous works [5], a tetraethylene glycol type ionophore, **2a**, seemed to be considered as the most efficient ionophore in the series of their homologues which consist of an oligoethylene glycol and two quinoline moieties. In the solvent extraction experiment, however, **3a** showed significantly better complexing ability than **2a**.

Hexaethylene glycol-type ionophores, **4a** and **4b**, showed decreased complexing ability for potassium picrate compared with **3a** and **3b**, in spite of the increment in the donor atom number. Generally, common glyme-type ionophores show an increase in their complexing abilities simply with a change in the number of donor atoms [7]. The presence of a maximum extraction efficiency as a result of changing the length of the ionophore strongly suggests that these ionophores with quinolinyl end groups are stabilized not only by a spherical wrapping effect (shown by many glyme-type ionophores) but also by an additional effect (π-stacking effect [8]) based on the aromatic end groups.

2.3. EFFECT OF QUINOLINYLOXY END GROUP ON THE STABILITY OF THE COMPLEX

^{1}HNMR spectra give much information concerning the conformations of the ionophore in solution. Vögtle *et al.* have reported that the conformation of **2a** in $CDCl_3$ changed remarkably upon the addition of KSCN [9]. However, a systematic study concerning the behavior of this type of acyclic ionophores in solution has not been performed. Their tentative suggestion of a type of stabilization effect based on the interaction between both aromatic end groups was not carefully considered, because such ionophores gave good single crystals with cations which made it possible to determine their crystal structures [10]. Thus, the correlation between the complexing ability of an ionophore and the structure of the complex in the crystal state had been brought into focus.

In order to evaluate the detailed conformations of quinolinyl ionophores and to relate these conformations to the complexing abilities determined by solvent extraction, we measured changes in the chemical shifts of the protons on the quinoline moiety of the ionophores upon the addition of equimolar amounts of alkali metal thiocyanates. The typical NMR spectra are shown in Figure 2. Chemical shifts of all quinoline protons in $CDCl_3$ are listed in Table I and the change in chemical shifts upon addition of alkali metal thiocyanates are shown in Figure 3 [11].

When a donor atom participates in coordination with metal ions, chemical shifts of neighboring protons generally tend to move downfield. By contrast, aryl π-stacking produces an upfield shift. In Figure 3, the quinoline protons of all ionophores show charactistic changes in chemical shifts which are ascribed to the partial stacking by the quinoline rings.

Compounds **3a** and **3b**, which are the ionophores displaying a favorable selectivity for potassium ion, showed a fairly large upfield shift in H5, H6, H7 when KSCN was added. This result suggests the existence of the complex proposed in Figure 4.

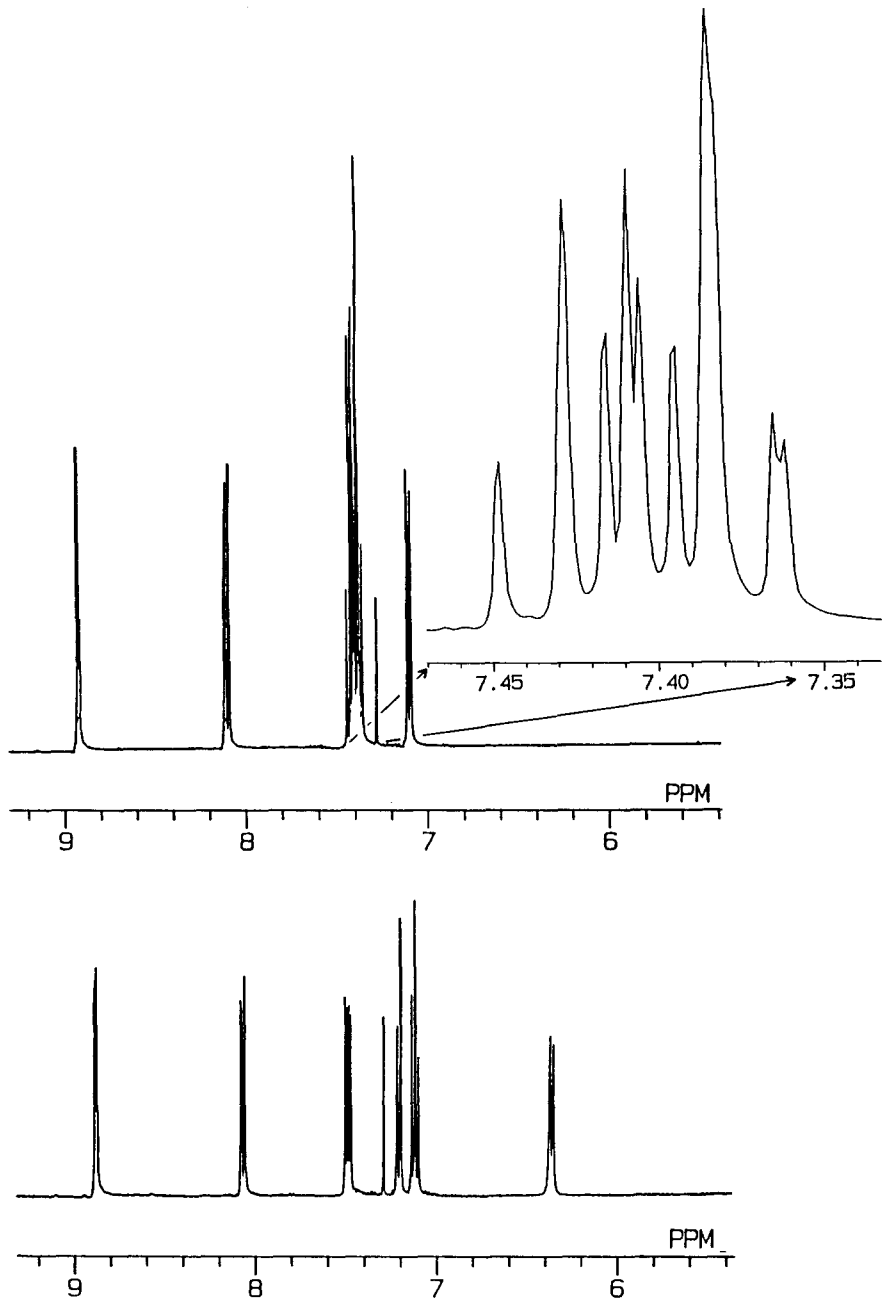


Fig. 2. Typical NMR spectra of quinolinyl protons: **3a** (above); **3a** + KSCN (below); 0.05 M; in $CDCl_3$; 27°C.

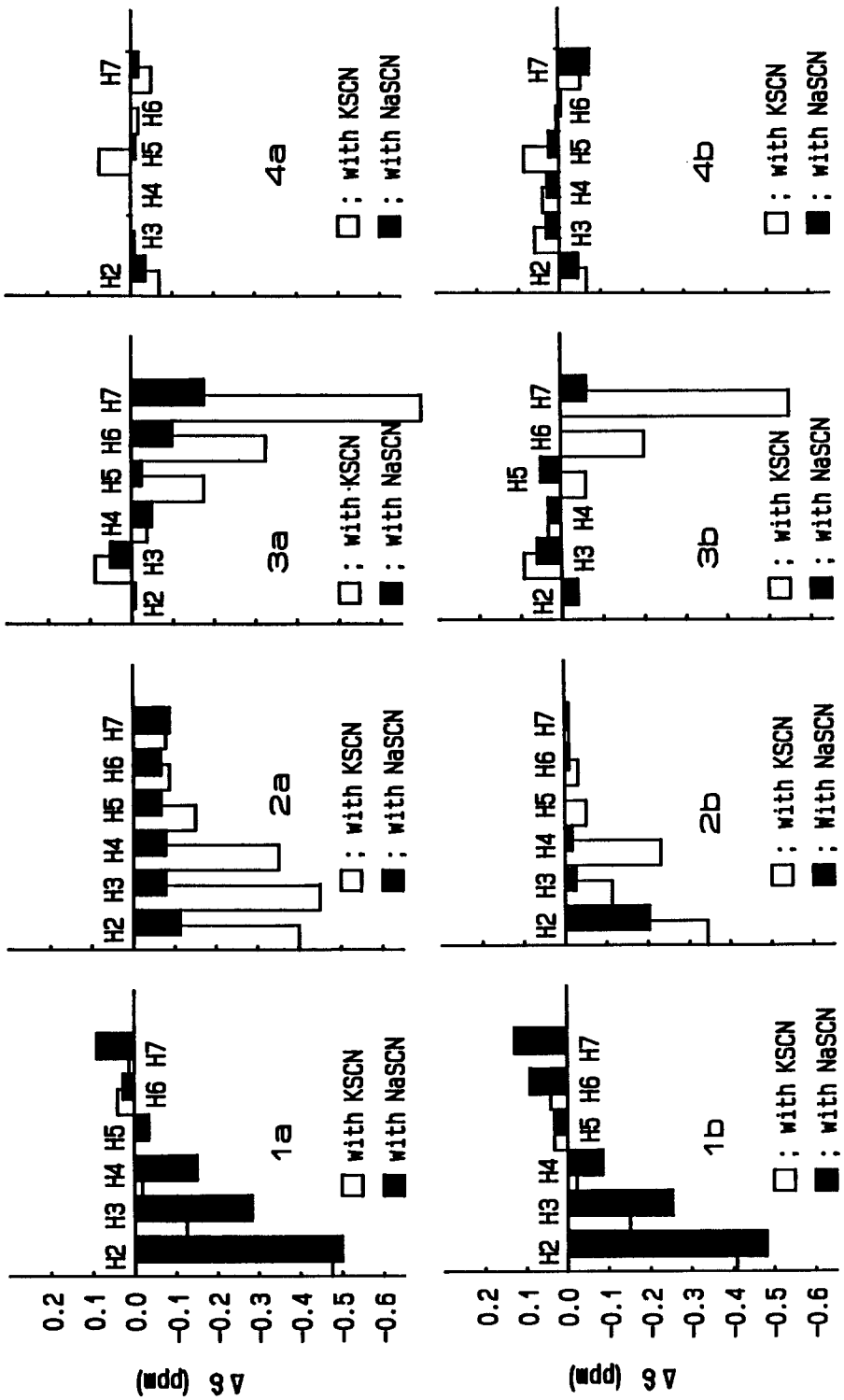
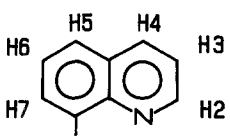


Fig. 3. Changes in chemical shifts of quinolinyl protons by the addition of metal thiocyanate: $\Delta\delta = \delta_{MSCN} - \delta_{None}$; 27°C.

Table I. Chemical shifts of quinoline-protons[a] in the presence or absence of metal thiocyanate

Compd	MSCN	Chemical shift (ppm)					
		H2	H3	H4	H5	H6	H7
1a	None	8.93	7.38	8.12	7.41	7.43	7.10
	NaSCN	8.42	7.11	7.97	7.38	7.45	7.21
	KSCN	8.46	7.25	8.10	7.41	7.46	7.11
2a	None	8.93	7.41	8.12	7.38	7.43	7.09
	NaSCN	8.82	7.34	8.04	7.32	7.37	7.00
	KSCN	8.53	6.96	7.75	7.20	7.34	7.02
3a	None	8.93	7.40	8.11	7.38	7.43	7.10
	NaSCN	8.85	7.38	8.06	7.35	7.34	6.94
	KSCN	8.88	7.49	8.07	7.21	7.12	6.37
4a	None	8.93	7.42	8.12	7.39	7.44	7.11
	NaSCN	8.89	7.42	8.13	7.39	7.44	7.09
	KSCN	8.87	7.43	8.12	7.45	7.43	7.06
1b	None	8.91	7.39	8.09	7.36	7.40	7.08
	NaSCN	8.43	7.15	8.01	7.41	7.49	7.25
	KSCN	8.50	7.24	8.07	7.39	7.44	7.08
2b	None	8.92	7.39	8.10	7.38	7.42	7.10
	NaSCN	8.72	7.37	8.09	7.38	7.41	7.09
	KSCN	8.58	7.27	7.87	7.33	7.39	7.09
3b	None	8.92	7.40	8.10	7.38	7.43	7.11
	NaSCN	8.89	7.46	8.13	7.42	7.43	7.06
	KSCN	8.92	7.49	8.13	7.32	7.23	6.56
4b	None	8.92	7.41	8.11	7.38	7.44	7.11
	NaSCN	8.86	7.44	8.14	7.42	7.43	7.04
	KSCN	8.88	7.47	8.15	7.45	7.45	7.09

[a]in $CDCl_3$; 27°C. TMS was used for the internal standard. Assignment of quinoline protons were as follows.



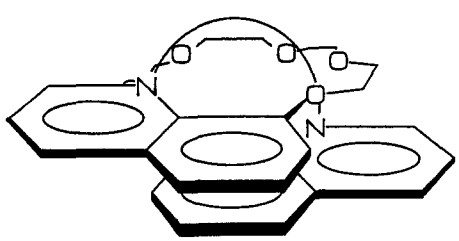


Fig. 4. Proposed conformation of the **3a**—K^+ complex.

In this complex, an oxyethylene chain comprising six oxygen atoms surrounds the potassium ion with a pseudo-ring conformation, similar to the way an 18-crown-6 with six oxygen atoms coordinates to a potassium ion. Quinolinyl groups act not only as the coordination site but also as the stabilizer of such pseudo-ring structures, like an 18-crown-6 ring. The downfield shift of H3 may indicate that the nitrogen atoms of the quinoline moieties also effectively participate in the coordination. The maximum complexation ability attained by **3a** or **3b** for potassium ion may be explained by considering the 'binary-effect' consisting of conformational stabilization induced by π-stacking of the end groups and by supplementary donation of nitrogen atoms toward the metal cation.

All aromatic protons of **2a** and **2b** showed upfield shifts, especially in the case of the K^+ complexes, but their complexation abilities were not extreme. Triethylene glycol derivatives, **1a** and **1b**, achieved a better stabilization effect in the Na^+ complexes than in the K^+ ones because of the difference in the extent of overlap of the quinoline hetero-ring edges. It is noted that **4a** and **4b**, having six oxyethylene units, showed no stacking effect with either cation. Taking the extraction result into account, this supports the importance of the stabilization effect by aromatic stacking.

All ionophores tend to form a pseudo-cyclic coordination field which is stabilized by the aryl stacking effect for complexation. However, too long or too short an oxyethylene chain disturbs the formation of π-stacking between quinoline rings placed at both ends of the ionophore. In the shortest ionophores, **1a** or **1b**, complexation forms a relatively small cavity in comparison with **3a** or **3b** because of the shorter oxyethylene chain and the lower number of donor atoms (4O, 2N). This is the reason that they show a selectivity towards sodium ions rather than towards potassium ions. In the case of the longest ionophores, **4a** or **4b**, sufficient donor ability (7O, 2N) spoils the 'binary-effect' of the quinolinyl end groups. Since the pseudo-cyclic conformation, which diminishes both the entropic and enthalpic disadvantages during complexation, cannot be invoked in **4a** or **4b**, they show a lower complexing ability for potassium ions than do **3a** or **3b**.

2.4. BULK LIQUID MEMBRANE TRANSPORT

Competitive passive transport experiments were performed in order to examine the function of the introduced alkyl chain. Transport experiments were carried out in a U-shaped cell at 25°C [12]. The source phase and receiving phase were arranged to be basic and acidic, respectively. The amounts of transported cations are summarized in Table II. The transport velocity of **3b** for potassium ion is about 4.4 times as fast as that of **3a** in spite of its having about the same extraction efficiency during solvent extraction. It is clear that the lipophilicity of the ionophores significantly affects the transport velocity. Under these transport conditions using protonation to the nitrogen atom of the ionophore in the release process, the reverse transport of protons must be considered. When the nitrogen atom of the ionophore is protonated in the acidic phase, the increased hydrophilicity should reduce the concentration of the ionophore in the organic membrane. The hexyl side chain of **2b** and **3b** should prevent the loss of the ionophore from the organic phase to the acidic phase.

Table II. Competitive passive transport data for Li^+, Na^+, K^+, Rb^+, and Cs^+.

Compd	Transported Cation (%)				
	Li^+	Na^+	K^+	Rb^+	Cs^+
2a	0.09	0.68	2.0	0.59	0.18
3a	0.06	0.24	3.5	2.1	0.56
2b	0.35	4.5	10.5	6.1	2.5
3b	0.29	2.8	15.2	9.4	4.2

Transported conditions: aqueous phase 1 (10 mL), [LiCl] = [NaCl] = [KCl] = [RbCl] = [CsCl] = [Me_4NOH] = 0.1 M; organic phase (CH_2Cl_2, 20 mL) carrier and picric acid, 5×10^{-5} M; aqueous phase 2 (10 mL) [HCl] = 0.1 M; 25°C; 24 h.

3. Conclusions

A series of ionophores having two quinolinyloxy moieties and a variable oxyethylene chain was synthesized as a model of natural ionophores and the relationship between their complexation properties and conformations in solution was discussed. It was shown that **3a** and **3b** had the best extraction efficiency for K^+ among these series and the aliphatic side chain equipped on **2b** and **3b** afforded the increment of transport abilities. It is interesting that synthesized ionophores seem to perform as good ionophores when they are able to keep their conformations on a pseudo cyclic structure like an 18-crown-6. For the molecular design of effective synthetic ionophores, introduction of aromatic moieties to the structure will be convenient and is an effective way instead of an elaborate preorganization of the structure.

4. Experimental

^{1}HNMR spectra were measured at 400 MHz on a JEOL JNM-GSX-400 spectrometer, using tetramethylsilane as the internal standard. IR and UV spectra were obtained on a Hitachi 260-10 spectrometer and Hitachi U-2000 spectrometer, respectively. Mass spectra were measured with a JEOL JMS-DX 303 HF spectrometer.

4.1. GENERAL PROCEDURE FOR THE SYNTHESIS OF OLIGOETHYLENE GLYCOL DIHALIDE HAVING A HEXYL GROUP (5–8) [13]

Bromoalkoxylation of 1-octene with *N*-bromosuccinimide (NBS) and oligoethylene glycol or diethylene glycol monochloride were used for the synthesis. The intermediate compounds having a hydroxyl group were converted to the corresponding dihalide by treatment with thionyl chloride. Merck silica gel 60 (70–230 mesh) or Merck aluminium oxide 90 active, neutral (70–230 mesh) was used for the chromatography.

4.1.1. *1-Bromo-8-chloro-2-hexyl-3,6-dioxaoctane* (**5**) [13]

A mixture of 1-octene (13.47 g, 0.12 mol), diethylene glycol monochloride (199.31 g, 1.60 mol), and NBS (7.12 g, 0.04 mol) was stirred at 50°C for 7 h. After cooling to room temperature, excess diethylene glycol monochloride was evaporated and the residue was extracted with ether (300 mL × 3) after addition of water (100 mL). The combined organic layer was dried over $MgSO_4$, concentrated, and purified by distillation under reduced pressure. This compound was used for the next step without further purification. Yield 82%; bp 85°C/0.05 mm (Kugelrohr); ^{1}H NMR ($CDCl_3$) δ0.88 (t, 3H), 1.22–1.98 (m, 10H), 3.46–3.52 (m, 2H), 3.60–3.68 (m, 2H), 3.76–3.92 (m, 7H); IR 2950, 1470, 1300, 1120 cm^{-1}; MS *m/z* 221 (49), 107 (100), 69 (49), 63 (80).

4.1.2. *1-Bromo-11-chloro-2-hexyl-3,6,9-trioxaundecane* (**6**) [13]

A mixture of 1-octene (10.1 g, 0.09 mol), triethylene glycol (180.2 g, 1.2 mol), and NBS (5.34 g, 0.03 mol) was stirred at 55°C for 4 h. After cooling to room temperature, water (250 mL) was added to the mixture. The mixture was extracted with ether (250 mL × 3). The combined organic layer was dried over $MgSO_4$, concentrated, and purified by distillation under reduced pressure (120°C/0.05 mm). The monohalide was prepared in 88% yield. To a mixture of monohalide (6.83 g, 0.02 mol) and pyridine (a few drops) was gradually added thionyl chloride (3.57 g, 0.03 mol) at a temperature of less than 10°C. After the addition of thionyl chloride, the system was gradually heated to reflux and stirred for 7 h. After cooling to room temperature, the mixture was neutralized with 15% Na_2CO_3 and extracted with ether (200 mL × 2). The combined organic phase was dried over $MgSO_4$, concentrated, and purified under reduced pressure. This compound was used for the next step without further purification. Yield 79%; bp 130°C/0.05 mm (Kugelrohr); ^{1}H NMR ($CDCl_3$) δ 0.78–1.92 (t, 3H), 1.16–1.68 (m, 10H), 3.40–3.48 (m, 2H), 3.56–3.88 (m, 13H); IR 2940, 1460, 1350, 1300, 1100 cm^{-1}; MS *m/z* 361 ($M^+ + 3$, 1), 359 ($M^+ + 1$, 1) 141 (96), 110 (96), 87 (96), 75 (100).

4.1.3. *1-Bromo-14-chloro-2-hexyl-3,6,9,12-tetraoxatetradecane* (**7**) [13]

Compound **7** was prepared by the procedure described in the synthesis of **6** and was used for the next step without further purification. Yield 78%; bp 150°C/0.07 mm (Kugelrohr); ^{1}H NMR ($CDCl_3$) δ 0.78–1.02 (t, 3H), 1.18–1.76 (m, 10H), 3.40–3.48 (m, 2H), 3.52–3.90 (m, 17H); IR 2930, 1460, 1350, 1300, 1120 cm^{-1}; MS *m/z* 405 ($M^+ + 3$, 1), 403 ($M^+ + 1$, 1), 195 (100), 151 (94), 111 (99), 87 (98).

4.1.4. *1-Bromo-17-chloro-2-hexyl-3,6,9,12,15-pentaoxaheptadecane* (**8**) [13]

Compound **8** was prepared by the procedure described in the synthesis of **6**. Its purification was performed by chromatography over silica gel. This compound was used for the next step without further purification. Yield 73%; ^{1}H NMR ($CDCl_3$) δ 0.79–1.00 (t, 3H), 1.16–1.80 (m, 10H), 3.36–3.60 (m, 4H), 3.60–3.84 (m, 19H); IR 2940, 1470, 1120 cm^{-1}; MS *m/z* 449 ($M^+ + 3$, 1), 447 ($M^+ + 1$, 1), 151 (97), 107 (100), 87 (100), 69 (100).

4.2. GENERAL PROCEDURE FOR SYNTHESIS OF 'PSEUDO CYCLIC IONOPHORES' **1a–4a** AND **1b–4b**

All ionophores were synthesized by reaction of the potassium salt of 8-hydroxyquinoline with the dihalide according to the conventional Williamson ether synthesis.

4.2.1. *8,8′-[1,2-Ethanediylbis(oxy-2,1-ethanediyloxy)]bisquinoline* (**1a**) [14]

8-Hydroxyquinoline (4.54 g, 0.031 mol) and KOH (1.77 g, 0.031 mol) were dissolved in ethanol (60 mL). The mixture was refluxed for 1 h and then triethylene glycol dibromide (4.3 g, 0.0155 mol) was added dropwise over a period of 50 min. The mixture was stirred for another 3 h. After cooling to room temperature, the mixture was filtered and evaporated. The residue was dissolved in $CHCl_3$ (150 mL) and washed with aq. NaOH and then water. The organic layer was dried over $MgSO_4$, concentrated, and purified by chromatography over alumina (CH_2Cl_2). Yield 48%; ^{1}H NMR ($CDCl_3$) δ 3.81 (s, 4H), 4.07 (t, 4H), 4.41 (t, 4H), 7.10 (d, 2H), 7.38 (dd, 2H), 7.41 (t, 2H), 7.43 (t, 2H), 8.12 (dd, 2H), 8.93 (dd, 2H); IR 2900, 1570, 1500, 1110 cm^{-1}; MS *m/z* 404 (M^+, 0.8), 259 (50), 172 (100).

4.2.2. *8,8′-[Oxybis(2,1-ethanediyloxy-2,1-ethanediyloxy)]bisquinoline* (**2a**) [9]

The synthetic procedure was almost the same as that used for **1a**. Yield 77%; ^{1}H NMR ($CDCl_3$) δ 3.68–3.80 (m, 8H), 4.05 (t, 4H), 4.39 (t, 4H), 7.09 (dd, 2H), 7.38 (dd, 2H), 7.41 (t, 2H), 7.43 (t, 2H), 8.12 (dd, 2H), 8.93 (dd, 2H); IR 2900, 1570, 1500, 1110 cm^{-1}; MS *m/z* 448 (M^+, 0.8), 304 (22), 172 (100).

4.2.3. *8,8′-[1,2-Ethanediylbis(oxy-2,1-ethanediyloxy-2,1-ethanediyloxy)]bisquinoline* (**3a**)

The synthetic procedure was almost the same as that used for **1a**. Yield 50%; ^{1}H NMR ($CDCl_3$) δ 3.63–3.68 (m, 8H), 3.74–3.76 (m, 4H), 4.04 (t, 4H), 4.41 (t, 4H), 7.10 (dd, 2H), 7.34 (t, 2H), 7.38 (dd, 2H), 7.43 (t, 2H), 8.11 (dd, 2H), 8.93 (dd, 2H); MS *m/z* 492 (M^+, 1), 348 (2.2), 172 (100).

Anal. Calcd for $C_{28}H_{32}O_6 \cdot 2\,H_2O$: C, 63.62; H, 6.86; N, 5.30. Found: C, 63.49; H, 6.48; N, 5.28.

4.2.4. *8,8′-[3,6,9,12,15-Pentaoxaheptadecane-1,17-diylbis(oxy)]bisquinoline* (**4a**) [14]

The synthetic procedure was almost the same as that for **1a**. Yield 68%; ^{1}H NMR ($CDCl_3$) δ 3.55–3.75 (m, 12H), 3.74–3.76 (m, 4H), 4.04 (t, 4H), 4.41 (t, 4H), 7.11 (dd, 2H), 7.39 (dd, 2H), 7.42 (t, 2H), 7.44 (dd, 2H), 8.12 (dd, 2H), 8.93 (dd, 2H); MS *m/z* 536 (M^+, 0.13), 392 (23), 172 (100).

4.2.5. *1,8-bis(8-quinolinyloxy)-2-hexyl-3,6-dioxaoctane* (**1b**) [15]

8-Hydroxyquinoline (4.79 g, 0.033 mol) and KOH (1.85 g, 0.033 mol) were dissolved in ethanol (15 mL). Under refluxing conditions, **5** (4.73 g, 0.015 mol) in

ethanol (15 mL) was added dropwise over a period of 50 min. The mixture was then stirred for another 36 h. A considerably longer reaction time was necessary for the chloride moiety to react, since it is less reactive than the bromide. After the mixture was cooled to room temperature, water (200 mL) was added. The mixture was then extracted with methylene chloride (50 mL × 5). The combined organic layer was dried over $MgSO_4$, concentrated, and purified by chromatography on alumina (benzene/dioxane). Yield 55%; ^{1}H NMR ($CDCl_3$) δ 0.70–0.96 (t, 3H), 1.12–1.92 (m, 10H), 3.56–4.22 (m, 11H), 7.07–7.09 (m, 2H), 7.35–7.37 (m, 2H), 7.38–7.40 (m, 2H), 7.39–7.41 (m, 2H), 8.08–8.10 (m, 2H), 8.90–8.92 (m, 2H); IR 2940, 1600, 1570, 1500, 1120 cm^{-1}; MS *m/z* 488 (M^+, 1), 343 (31), 257 (38), 172 (100), 145 (89).

Anal. Calcd for $C_{30}H_{36}O_4N_2 \cdot 0.5\,H_2O$: C, 72.41; H, 7.49; N, 5.63. Found: C, 72.08; H, 7.74; N, 5.48.

4.2.6. *1,11-Bis(8-quinolinyloxy)-2-hexyl-3,6,9-trioxaundecane* (**2b**) [15]

The synthetic procedure was almost the same as that used for **1b**. Yield 30%; ^{1}H NMR ($CDCl_3$) δ 0.74–0.98 (t, 3H), 1.14–1.80 (m, 10H), 3.60–4.44 (m, 15H), 7.09–7.11 (m, 2H), 7.37–7.39 (m, 2H), 7.39–7.41 (m, 2H), 7.41–7.43 (m, 2H), 8.09–8.11 (m, 2H), 8.90–8.92 (m, 2H); IR 2940, 1600, 1570, 1500, 1120 cm^{-1}; MS *m/z* 532 (M^+, 2), 388 (56), 256 (39), 172 (100), 145 (73).

Anal. Calcd for $C_{32}H_{40}O_5N_2 \cdot 0.5\,H_2O$: C, 70.95; H, 7.63; N, 5.17. Found: C, 70.55; H, 7.74; N, 5.14.

4.2.7. *1,14-Bis(8-quinolinyloxy)-2-hexyl-3,6,9,12-tetraoxatetradecane* (**3b**) [15]

The synthetic procedure was almost the same as that used for **1b**. Yield 28%; ^{1}H NMR ($CDCl_3$) δ 0.72–0.98 (t, 3H), 1.16–1.92 (m, 10H), 3.60–4.43 (m, 19H), 7.10–7.12 (m, 2H), 7.37–7.39 (m, 2H), 7.39–7.41 (m, 2H), 7.42–7.44 (m, 2H), 8.09–8.11 (m, 2H), 8.91–8.93 (m, 2H); IR 2940, 1600, 1570, 1500, 1120 cm^{-1}; MS *m/z* 576 (M^+, 3), 432 (50), 256 (45), 172 (100), 145 (79).

Anal. Calcd for $C_{34}H_{44}O_6N_2 \cdot H_2O$: C, 68.66; H, 7.80; N, 4.71. Found: C, 68.43; H, 7.53; N, 4.75.

4.2.8. *1,17-Bis(8-quinolinyloxy)-2-hexyl-3,6,9,12,15-pentaoxaheptadecane* (**4b**) [15]

The synthetic procedure was almost the same as that used for **1b**. Yield 34%; ^{1}H NMR ($CDCl_3$) δ 0.68–1.00 (t, 3H), 1.04–1.88 (m, 10H), 3.48–4.68 (m, 23H), 7.10–7.12 (m, 2H), 7.37–7.39 (m, 2H), 7.40–7.42 (m, 2H), 7.43–7.45 (m, 2H), 8.10–8.12 (m, 2H), 8.91–8.93 (m, 2H); IR 2940, 1570, 1500, 1120 cm^{-1}; MS *m/z* 620 (M^+, 6), 476 (58), 255 (32), 172 (100), 158 (40), 145 (89).

Anal. Calcd for $C_{36}H_{48}O_7N_2 \cdot H_2O$: C, 67.69; H, 7.89; N, 4.39. Found: C, 67.55; H, 7.65; N, 4.47.

4.3. EXTRACTION PROCEDURE

A mixture of an aqueous solution (10 mL) of alkali metal hydroxide (50 mM) and picric acid (0.5 mM) and a dichloromethane solution (10 mL) of an appropriate

extractant (0.5 mM) was shaken at 22°C for 9 h. The percent of cation extracted was calculated from the absorption of picrate anion in the aqueous phase at 354 nm in the UV spectrum: Extraction(%) = $100 \times [1 - Abs_{354}(Host)/Abs_{354}(Blank)]$.

4.4. LIQUID MEMBRANE TRANSPORT

Transport experiments were carried out in a U-shaped cell at 25°C. The details of the transport conditions are summarized in the footnotes of Table II. The receiving phase was sampled after 24 h and analyzed for cation concentration using a Nippon Jarrel-Ash AA-8500 atomic absorption spectrometer.

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Notes and References

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