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Complexation of acyclic ligands having two terminal quinoline units with alkali metal cations

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Acyclic multidentate ligands consisting of an oligooxyethylene chain (di-, tri-, tetra-, and penta-) and two terminal rigid quinaldate end groups were newly prepared and their complexation properties with alkali metal cations were estimated by the solvent extraction method to indicate a better affinity for K^+. Among them, the tetraethylene glycol derivative showed the highest K^+ binding on about the same level as 18-crown-6. Their conformations in solution and in the solid state were examined by using ^1H- and ^{13}C-NMR spectroscopy and X-ray crystal analyses, respectively. The better binding of K^+ in comparison with the corresponding glymes or analogues having the same donor sites was reasonably explained by considering the effective co-ordination of the carbonyl oxygen of the ester groups and the parallel π-stacking interaction between two quinaldate surfaces.

INTRODUCTION

Increasing attention has been focused on molecular recognition concerning specific ions or substances. A variety of artificial host compounds such as crown ethers, cryptands, spherands, cavitands, carcerands, and calixarenes has been developed and successfully modified with respect to the structures of the guest molecules.[1] High selectivity or specificity has been attained by recent remarkable progress in synthetic organic chemistry, while the structures of the host compounds mentioned above have become increasingly complicated. On the other hand, generally speaking, acyclic host compounds have an advantage in their simple synthetic routes but their complexing ability and selectivity are often poor. From this perspective, molecular design of a new type of acyclic host molecule having favourable complexing abilities has been noted.[2]

Concerning specific hosts suitable for alkali metal cations, Vögtle and Weber[3] reported excellent complexing abilities for the oligoethylene glycol derivatives having quinolinyloxy moieties among a number of acyclic host compounds. We also found a good relationship between the extraction ability of acyclic multidentate ligands towards alkali metal cations and the extent of stacking interaction of the two quinoline rings.[4] An efficient function of the quinoline moiety was also observed in complexation with alkali metal cations when used as the substituent of lariat ethers.[5] Based on these findings, further addition of the secondary donor site to an appropriate position of the quinoline ring of Vögtle's ligands is promising to improve their complexation ability.

We described here the design of efficient acyclic host compounds having quinaldate moieties which work as both co-ordination sites and stacking surfaces.[6] The ester group was used as the secondary donor site of the quinoline ring for alkali metal cations because it is known to be one of the most important co-ordinating groups in the case of natural antibiotics such as valinomycin and enniatin.[7] Correlation between complexing ability and structure is also discussed in terms of solvent extraction, NMR measurements, and X-ray crystal data.

RESULTS AND DISCUSSION

A series of acyclic multidentate ligands (**1**–**4**) having a di-, tri-, tetra-, or pentaoxyethylene bridge and two quinaldate moieties at either end were prepared by reaction of the corresponding oligoethylene glycol dichloride and methyl 8-hydroxyquinaldate[8] in the presence of K_2CO_3 and tetrabutylammonium chloride (as a phase transfer catalyst) in CH_3CN. The aminolysis of **1** with morpholine at 95°C for 24 h gave the corresponding amide compound **5**. Compound **6**

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was also synthesized by the reaction of 2-(hydroxymethyl)-8-methoxyquinoline, which was obtained by the reduction of methyl 8-methoxy quinaldate with tetraethylene glycol ditosylate under basic conditions. The structures of all new compounds were confirmed by NMR, mass spectrometry, IR spectroscopy and elemental analysis (see the Experimental section).

The complexing properties of this new series of acyclic hosts (**1–4**) and the related compounds (**5**, **6**) towards alkali metal cations were evaluated by the solvent extraction method using equimolar amounts of the extractant and the alkali metal picrate. The extraction data are summarized in Table 1 along with some reference data. These acyclic host compounds (**1–4**) showed much better extraction ability that their corresponding analogues (**7** and **8**)[4] having no donor site on the 2-position of the quinoline ring or heptaglyme (**11**). The amide derivative (**5**) showed disappointingly lower values. The extractability of a different type of ligand **6** was also moderate in comparison with that of **3** which contains the same donor atoms. Ligand **3**, having a tetraoxyethylene bridge between two rigid aromatic groups, was the best among them. It is especially noteworthy that its K^+ extraction ability is approximately the same as that of 18-crown-6 (**10**). Both **1** and **7** possess the same (seven) donor atoms and the former extracted more

Table 1 Extraction data for alkali metal pictrates[a]

	Extraction (%)				
Compound	Li^+	Na^+	K^+	Rb^+	Cs^+
1	<1	12	40	33	20
2	<1	20	54	40	25
3	<1	18	67	66	50
4	<1	12	56	61	60
5	<1	2	<1	<1	1
6	<1	5	21	17	11
7[b]	3	8	15	5	5
8[b]	1	9	36	33	18
10	1	5	68	63	45
11	1	2	14	14	10

[a] Organic phase (CH_2Cl_2, 10 ml)/aqueous phase (10 ml); [MOH] = 50 mM; [extractant] = [picric acid] = 0.5 mM; 22°C, 9 h. [b] Ref 4.

K^+ than the latter. The same trend in extraction abilities between **2** and **8** was also observed. These results suggest that the ester group on the quinoline ring plays an important role in forming the complex with KSCN.

The X-ray crystal structure of **7**·RbI[9] was reported to be substantially different from that of **9**·RbI[10] having the methyl substituent on the 2-position of the quinoline ring (quinaldine). In particular, parallel stacking between the two quinoline rings was observed only in the latter complex. Our ligands (**1–4**) are different from these two types of ligands (**7** and **9**) because they have further additional donor sites on the quinoline rings (quinaldate). If these additional donor sites co-ordinate to K^+ as suggested by the extraction data, an alternate structure to those reported previously[9,10] should be observed. In order to elucidate the structural features in the solid state, single crystal X-ray structure analyses of the complexes of **2** and **3** with KSCN were carried out. Table 2 shows the crystal data and selected refinement parameters. Figures 1 and 2 illustrate their ORTEP views.[11] The **2**·KSCN complex clearly shows the effective co-ordination of both carbonyl oxygen atoms to K^+. The ligand is co-ordinated to K^+ by eight heteroatoms (two N, four ether-O, two C=O). Since K^+ is completely enclosed by the ligand and thus shielded, it cannot interact with SCN^-. This is probably the reason for it being somewhat disordered. Parallel stacking interaction between two quinaldate surfaces (2.4°, 3.4 Å) was observed in the crystal structure of the **3**·KSCN complex. One of the ester groups and the thiocyanate anion are not involved in co-ordination to K^+, so the co-ordination number is 8 in analogy with the case of the **2**·KSCN complex. Another ester group co-ordinates to K^+ by the carbonyl oxygen but not the methoxy oxygen.

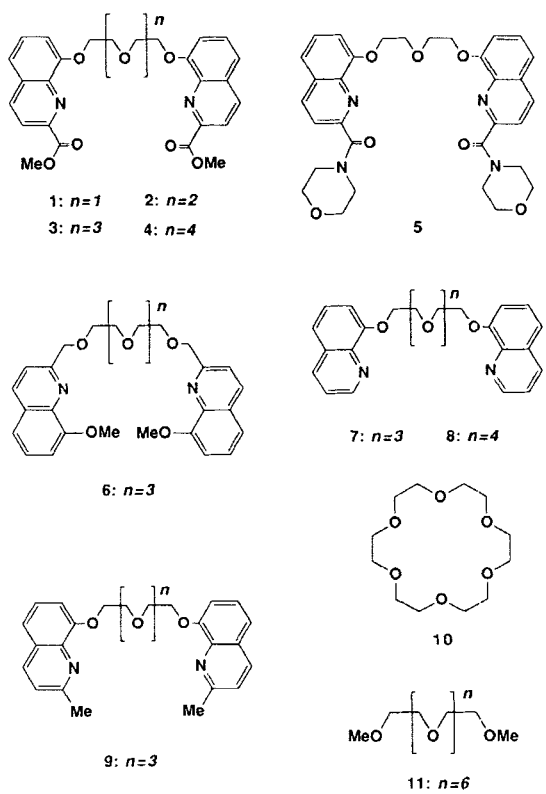

Table 2 Crystal data and selected refinement parameters for X-ray analysis of the KSCN complexes of **2** and **3**

Compound	*2·KSCN*	*3·KSCN*
Formula	$C_{28}H_{28}N_2O_8$·KSCN	$C_{30}H_{32}N_2O_9$·KSCN
Crystal system	monoclinic	triclinic
Space group	$C2/c$	$P\bar{1}$
Cell constants		
a, Å	18.597(5)	11.400(4)
b, Å	14.236(2)	14.466(4)
c, Å	12.140(2)	10.834(2)
α, deg	–	111.63(2)
β, deg	113.72(1)	91.46(2)
γ, deg	–	107.05(2)
V, Å^3	2943(1)	1569.8(8)
Z	4	2
d_{calc}, g cm^{-3}	1.394	1.400
No. of data collected	3525	7193
R	0.052	0.108
R_w	0.035	0.144

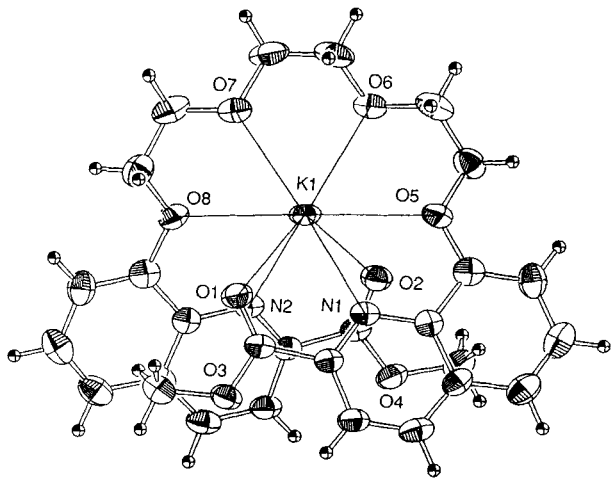

Figure 1 ORTEP drawing of complex **2**·KSCN. Ellipsoids are shown at the 30% level. The SCN anion is omitted for clarity.

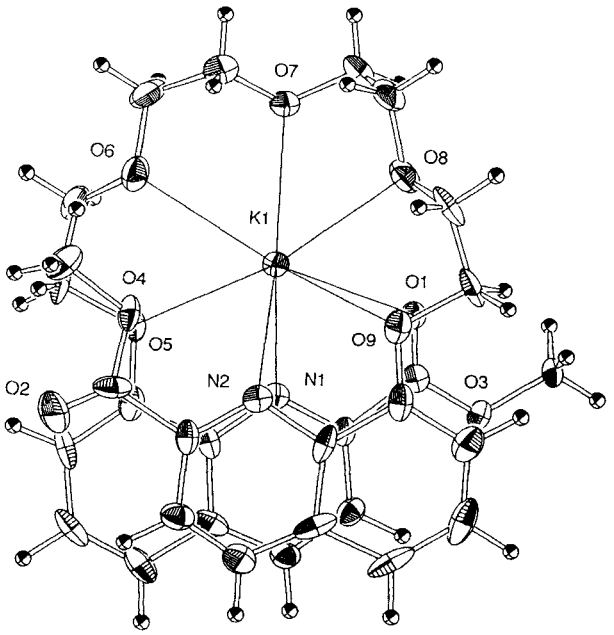

Figure 2 ORTEP drawing of complex **3**·KSCN. Ellipsoids are shown at the 30% level. The SCN anion is omitted for clarity.

In order to evaluate the detailed conformations of the ionophores in solution, changes in the chemical shifts upon the addition of potassium thiocyanate were measured with 400 MHz ^{1}H-NMR.[4] The results are shown in Table 3.[12]

An interesting trend was observed in the chemical shifts of the ^{1}H-NMR spectra of **1–4** upon complexation with KSCN, which is regarded as a measure of the extent of the stacking between the two aromatic rings. In particular, the upfield shifts of the H3 and H4 protons of **3** are significant. As previously described,[4] **7**, which showed characteristic upfield shifts for H2, H3, and H4, and **8**, which exhibited the same for H5, H6, and H7, were considered to form pseudo-cyclic structures like that of 18-crown-6 based on the partial stacking interaction between the quinoline rings.[3,4] The tendency of the shift of **3** was very similar to that of **7** which has the same tetraoxyethylene bridge. This finding suggests the conformational resemblance between them. Accordingly, **3** is also considered to assume a pseudo-cyclic structure when it complexes with K^+.

NOE difference spectroscopy is one of the best techniques for obtaining information with regard to conformation in solution.[13] The ester group possess plural donor sites for K^+, that is, the carbonyl oxygen and the methoxy oxygen. It is interesting to clarify whether or not the carbonyl oxygen participates in the co-ordination to K^+ in solution by using this

Table 3 Changes in chemical shifts of noncyclic multidentate ligands with equimolar additions of KSCN[a]

Compound	*H1*	*H2*	*H3*	*H4*	*H5*	*H6*	*H7*
1 (EO2)	−0.12	–	−0.05	0.03	0.04	0.06	−0.01
2 (EO3)	−0.94	–	−0.44	0.02	0.12	0.15	0.19
3 (EO4)	0	–	−0.89	−0.47	−0.15	−0.02	−0.05
4 (EO5)	0.05	–	−0.17	−0.07	−0.11	−0.22	−0.57
7 (EO4)[b]	–	−0.40	−0.45	−0.37	−0.18	−0.09	−0.07
8 (EO5)[b]	–	−0.05	0.09	−0.04	−0.17	−0.31	−0.73

[a] $\Delta\delta$ (ppm) = $\delta_{KSCN} - \delta_{None}$; [Ligand] = 0.05 M; $CDCl_3$; 27°C. [b] Ref 4.

Table 4 NOE values[a] observed by irradiating methoxy protons

Compound	*Salt*	*H3*	*H4*	*H5*	*H6*	*H7*
1	–	0	0	0	0	0
1	KSCN	2.0	~0	~0	~0	~0
2	–	0	0	0	0	0
2	KSCN	1.5	0.4	1.1	0.5	0.5
3	–	0	0	0	0	0
3	KSCN	0	0	0	0	0

[a] Relative intensity (%).

technique, though X-ray crystal data for the complexes of **2** and **3** with KSCN supported the view that it was responsible for the complexation in the solid state. The NOE difference spectra of **1–3** were measured in the presence and absence of KSCN. The data are summarized in Table 4. Irradiation of the methoxy protons of **1–3** led to no detectable enhancements; whereas, characteristic NOE enhancements were observed for the complexes of **1** and **2** with KSCN. For ligand **1** having the shortest bridge (EO 2), irradiation of the methoxy protons gave an ehancement of 2% at the H3 proton of the quinoline ring, which means that the methoxy group is in the vicinity of H3. Taking this NOE enhancement and the CPK model examination into account, the possibility of the co-ordination of the methoxy group to K^+ is excluded in this case. As for **2**, several NOE enhancements were observed upon irradiation of the methoxy protons. The methoxy group is deduced to be fixed near the quinoline ring by complexation with K^+. This coincides well with the finding of the remarkable upfield shift of the methoxy protons upon the addition of KSCN, as disclosed by the ^{1}H-NMR study (Table 3). The CPK model examinations and the NOE data make co-ordination of the methoxy oxygen very unlikely in accordance with the case of **1**.

The spin-lattice relaxation times (T_1) of ^{13}C-NMR give important information concerning the molecular mobility of the host compounds in solution.[14,15] The ^{13}C relaxation times determined in $CDCl_3$ for **1–4** with and without KSCN are summarized in Table 5. Individual carbon assignments were done on the basis of 2-dimensional C–H COSY spectra. Although all T_1 values of carbons were determined, the T_1 data for the quinoline ring and oxyethylene carbons are shown as averages to simplify the discussion. The difference between T_1 values before and after the addition of KSCN is demonstrated as the percentage by which the relaxation time decreased.[15] All T_1 values for **1–4** were decreased by the addition of KSCN. This result

Table 5 ^{13}C-NMR relaxation times for **1–4** and their complexes[a]

Carbon	*Cation*	*Compound*			
		1	*2*	*3*	*4*
C=O	–	12.32	11.76	12.25	9.33
	KSCN	5.60 (55%)	5.40 (54%)	5.27 (60%)	6.62 (29%)
MeO	–	2.74	2.82	3.35	2.66
	KSCN	1.52 (45%)	1.59 (44%)	1.87 (44%)	1.85 (30%)
Quinoline-	–	7.48	8.56	8.10	5.86
quaternary-C[b]	KSCN	3.46 (54%)	4.01 (53%)	3.94 (51%)	4.05 (31%)
Quinoline-	–	0.77	0.80	0.88	0.86
methine-C[b]	KSCN	0.41 (47%)	0.52 (35%)	0.49 (44%)	0.51 (41%)
EO-C[b]	–	0.67	0.75	0.85	0.88
	KSCN	0.25 (61%)	0.32 (57%)	0.35 (59%)	0.35 (60%)

[a] All T_1 values are in seconds and values in parentheses are the percentage decreases in T_1 after the addition of KSCN. [b] Average of T_1 values of the indicated carbons.

suggests that the complexation of the ligand with KSCN restricts its molecular movement. A certain trend was observed in the extent of the decrement of T_1 values. In the cases of **1–3**, the T_1 values of the carbonyl carbons were reduced more than those of the methoxy carbons upon addition of KSCN. This result may be explained by considering that the carbonyl oxygen takes part in the complexation with K^+ rather than the methoxy oxygen. The decrement in the T_1 value of the carbonyl carbons (54–60%) is almost the same as that for the oxyethylene carbons (57–61%), except for ligand **4**. In other words, the decrement in the T_1 value of the carbonyl carbon of **4** (29%) was rather less than that of the other ligands **1–3**. As shown in the extraction experiment, the extraction ability of **4** is inferior to that of **3**. This is further evidence that all donor atoms of **4** do not simultaneously co-ordinate to K^+.

CONCLUSIONS

The tetraethylene glycol derivative with a quinaldate group at either end (**3**) was revealed to have a high K^+ extraction ability of about the same level as 18-crown-6 (**10**). NMR measurements and X-ray analyses evidently demonstrated that this better K^+ binding ability of **3** is due not only to the effect of structural fixation based on the parallel stacking between two quinoline rings but also to the supplementary co-ordination of the donor group (ester group) at the 2-position of the quinoline ring. These findings should contribute to the molecular design of new open-chain host compounds.

EXPERIMENTAL SECTION

NOE experiments were measured at 27°C in $CDCl_3$. Samples consisted of approximately 0.7 ml of solution (containing 3×10^{-5} mol of ionophore in the presence of an equimolar amount of KSCN) in 5 mm o.d. tubes which were carefully degassed by at least three freeze-pump-thaw cycles.

Relaxation times (T_1) were measured under proton-noise-decoupling conditions by the inversion-recovery technique at 27°C. ^{13}C-NMR spectra were completely assigned using 2-dimensional C–H COSY spectra. A waiting time (t_w) of 10 s, 40 s, or 60 s was used. T_1 values were determined by non-linear least-squares. A theoretically meaningless T_1 value which exceeded $t_w/5$ was not accepted.

General procedure for the preparation of ionophores (1–4)

The ionophores (**1–4**) were prepared by the reaction of the potassium salt of methyl 8-hydroxyquinaldate[8] with the corresponding chlorides.

2,2′-Bis(methoxycarbonyl)-8,8′-[oxybis(2,1-ethanediyloxy)]bisquinoline (1)

A mixture of methyl 8-hydroxyquinaldate (6.0 g, 30 mmol), K_2CO_3 (7.8 g, 56 mmol) and n-Bu_4NBr (tetrabutylammoniumbromide, 0.96 g, 3.0 mmol, as a phase transfer catalyst) in acetonitrile (100 ml) was stirred at room temperature for 2 h. Ethylene glycol dichloride (**12**) (2.1 g, 15 mmol) was then added at 40°C, and the mixture was refluxed for 40 h. After the solvent was evaporated, the residue was dissolved in CH_2Cl_2 (100 ml). Insoluble matter was removed by filtration. The CH_2Cl_2 solution was washed with H_2O (70 ml) and dried over $MgSO_4$. The solvent was evaporated and the residue was dissolved in methanol (70 ml). The methanol solution was refluxed for 20 h in the presence of a few drops of H_2SO_4 and then neutralized with aq. 15% $NaHCO_3$. After the methanol was evaporated, H_2O (50 ml) was added to the residue which then extracted with CH_2Cl_2 (150 ml × 2). The combined organic layer was dried over $MgSO_4$, concentrated and purified by recrystallization (CH_3OH/H_2O = 10/1). The yield was calculated based on the starting material, **12** (3.8 g, 54%): m.p. 53–54°C; IR 3400, 2800, 1720, 1610, 1500, 1320, 1130, 1105 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 4.00 (s, 6H), 4.30 (t, J = 5.1 Hz, 4H), 4.50 (t, J = 5.1 Hz, 4H), 7.16 (dd, J = 7.8, 1.0 Hz, 2H), 7.41 (dd, J = 8.3, 1.0 Hz, 2H), 7.50 (dd, J = 8.3, 7.8 Hz, 2H), 8.19 (d, J = 8.3 Hz, 2H), 8.25 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 476 (M^+, 2.7), 230 (75), 172 (100).

Anal. calcd for $C_{26}H_{24}O_7N_2 \cdot H_2O$: C, 63.15; H, 5.30; N, 5.67. Found: C, 63.35; H, 5.15; N, 5.59.

2,2′-Bis(methoxycarbonyl)-8,8′-[1,2-ethanediylbis(oxy-2,1-ethanediyloxy)]bisquinoline (2)

The synthetic procedure was almost the same as that used for **1**. The purification was performed by chromatography on silica gel (chloroform/methanol = 99/1) to give a slightly yellow viscous liquid. Yield 21%: IR 3400, 2950, 1720, 1610, 1500, 1330, 1120, 1110, 1070 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 3.90 (s, 4H), 4.02 (s, 6H), 4.13 (t, J = 5.1 Hz, 4H), 4.42 (t, J = 5.1 Hz, 4H), 7.14 (dd, J = 7.3, 1.0 Hz, 2H), 7.45 (dd, J = 8.3, 1.0 Hz, 2H), 7.52 (dd, J = 8.3, 7.3 Hz, 2H), 8.20 (d, J = 8.3 Hz, 2H), 8.25 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 520 (M^+, 3.5), 318 (27), 230 (100), 203 (58), 170 (46).

Anal. calcd. for $C_{28}H_{28}O_2N_2 \cdot H_2O$: C, 62.45; H, 5.61; N, 5.20. Found: C, 62.45; H, 5.78; N, 5.07.

2,2′-Bis(methoxycarbonyl)-8,8′-[oxybis(2,1-ethanediyloxy-2,1-ethanediyloxy)]bisquinoline (3)

The synthetic procedure was almost the same as that used for **2**. A slightly yellow viscous liquid was produced. Yield 40%: IR 3500, 2900, 1720, 1600, 1500, 1330, 1130, 1100 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 3.73 (t, J = 6.0 Hz, 4H), 3.83 (t, J = 6.0 Hz, 4H), 4.04 (s, 6H), 4.10 (t, J = 5.4 Hz, 4H), 4.41 (t, J = 5.4 Hz, 4H), 7.14 (d, J = 7.3 Hz, 2H), 7.43 (d, J = 8.3 Hz, 2H), 7.54 (dd, J = 8.3, 7.3 Hz, 2H), 8.20 (d, J = 8.3 Hz, 2H), 8.26 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 564 (M^+, 3.5), 362 (33), 230 (100), 203 (58), 170 (44).

Anal. calcd for $C_{30}H_{32}O_9N_2 \cdot H_2O$: C, 61.84; H, 5.88; N, 4.81. Found: C, 61.96; H, 5.79; N, 4.79.

2,2′-Bis(methoxycarbonyl)-8,8′-[1,2-ethanediylbis(oxy-2,1-ethanediyloxy-2,1-ethanediyloxy)]bisquinoline (4)

The synthetic procedure was almost the same as that for **2**. A slightly yellow viscous liquid was produced. Yield 33%: IR 3550, 2900, 1730, 1670, 1500, 1330, 1130, 1100 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 3.66 (s, 4H), 3.69 (t, J = 5.6 Hz, 4H), 3.82 (t, J = 5.6 Hz, 4H), 4.04 (s, 6H), 4.09 (t, J = 5.1 Hz, 4H), 4.42 (t, J = 5.1 Hz, 4H), 7.15 (d, J = 7.3 Hz, 2H), 7.43 (d, J = 8.3 Hz, 2H), 7.55 (dd, J = 8.3, 7.3 Hz, 2H), 8.20 (d, J = 8.3 Hz, 2H), 8.26 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 608 (M^+, 2.3), 406 (34), 230 (100), 203 (54), 170 (33).

Anal. calcd for $C_{32}H_{36}O_{10}N_2 \cdot H_2O$: C, 61.33; H, 6.11; N, 4.47. Found: C, 61.41; H, 5.89; N, 4.44.

2,2′-Bis(morpholinocarbonyl)-8,8′-[1,2-ethanediylbis(oxy-2,1-ethanediyloxy)]bisquinoline (5)

A mixture of **1** (0.5 g, 1.1 mmol) and morpholine (3 g, 34 mmol) was stirred at 95°C for 24 h. Excess morpholine was removed by distillation in a Kugelrohr apparatus (50°C/0.1 Torr). The residue was dissolved in chloroform (100 ml) and washed twice with water (100 ml × 2). The organic layer was dried over $MgSO_4$ and concentrated to give 0.7 g of a brown solid. The purification was performed by chromatography over silica gel [chloroform/methanol = 99/1 (v/v)] to give **5** (0.2 g, 32%) as a white solid: IR 3550, 2950, 1640 ($\nu_{C=O}$), 1450, 1330, 1120, 870, 750 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 3.75–3.97 (m, 16H), 4.17 (t, J = 4.9 Hz, 4H), 4.42 (t, J = 4.9 Hz, 4H), 7.14 (d, J = 7.3 Hz, 2H), 7.42 (d, J = 7.3 Hz, 2H), 7.48 (t, J = 7.3 Hz, 2H), 7.86 (d, J = 8.3 Hz, 2H), 8.23 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 586 (M^+, 44), 413 (24), 387 (46), 359 (100), 285 (34).

Anal. calcd for $C_{32}H_{34}O_7N_4$: C, 65.51; H, 5.84; N, 9.55. Found: C, 65.37; H, 5.78; N, 9.39.

8,8′-Dimethoxy-2,2′-[oxybis(2,1-ethanediyloxy-2,1-ethanediyloxymethyl)]bisquinoline (6)

A mixture of methyl-8-methoxyquinaldate (1.0 g, 4.6 mmol) and $NaBH_4$ (2.6 g, 69 mmol) in methanol (20 ml) was refluxed for 2 h. After cooling to room temperature, 5 ml of water was added to the mixture. The solvent was evaporated and then 100 ml of water was added to the resulting residue. The mixture was extracted with dichloromethane (100 ml × 2). The organic layer was dried over $MgSO_4$ and concentrated to quantitatively give 2-hydroxymethyl-8-methoxyquinoline (**13**) as a slightly yellow solid. This compound was used for the next reaction without further purification. A suspension of NaH (*ca.* 6.0 g in mineral oil, washed by hexane) in THF (25 ml) was mixed with a solution of **13** (1.3 g, 6.9 mmol) in THF (25 ml) at −78°C. After the temperature was gradually raised to room temperature, the mixture was further stirred at that temperature for 1.5 h. After the temperature was again cooled to −78°C, a solution of tetraethylene glycol ditosylate (0.8 g, 1.7 mmol) in THF (5 ml) was slowly added to the resulting suspension over a period of 1 h. After the temperature was gradually raised to room temperature, the mixture was stirred for 2 days at that temperature. Methanol was added to the mixture in order to deactivate excess NaH and the solvent was evaporated. Dichloromethane was added to the residue and insoluble matter was removed by filtration. The crude product was purified by alumina short column chromatography using dichloromethane as the eluent to give a white solid (0.53 g, 58%): IR 2900, 1610, 1330, 1270, 1130, 1010, 830, 760 cm^{-1}; ^{1}H-NMR ($CDCl_3$) δ 3.60–3.80 (m, 16H), 4.07 (s, 6H), 4.94 (s, 4H), 7.04 (d, J = 7.8 Hz, 2H), 7.36–7.45 (m, 4H), 7.71 (d, J = 8.3 Hz, 2H), 8.14 (d, J = 8.3 Hz, 2H); MS *m/e* (relative intensity) 536 (M^+, 32), 364 (38), 188 (50), 173 (100).

Anal. calcd for $C_{30}H_{36}O_7N_2 \cdot 0.5H_2O$: C, 66.04; H, 6.84; N, 5.14. Found: C, 65.80; H, 6.47; N, 5.19.

Complex of 2 with KSCN

Equimolar amounts of compound **2** and KSCN were dissolved in chloroform. Toluene was added to the solution and the chloroform was slowly evaporated to give white crystals for an X-ray analysis; m.p. 167–170°C.

Anal. calcd for $C_{28}H_{28}O_8N_2 \cdot KSCN$: C, 56.38; H, 4.57; N, 6.80; S, 5.19. Found: C, 56.25; H, 4.61; N, 6.90; S, 5.14.

Complex of 3 with KSCN

The complex was prepared as described for the isolation of the complex of **2** with KSCN; m.p. 194–196°C.

Anal. calcd for $C_{30}H_{32}O_9N_2 \cdot KSCN$: C, 56.26; H, 4.87; N, 6.35; S, 4.85. Found: C, 55.91; H, 5.00; N, 6.61; S, 4.79.

X-ray analyses

Data for unit cell determinations and also for the structural studies were collected by utilizing a Rigaku AFC5R diffractometer with graphite monochromated Mo K_α radiation. Lattice parameters for each structure were determined by a least-squares technique involving centred 2θ values. The structures were determined by direct methods.[16] All non-hydrogen atoms were refined anisotropically. Positions for all hydrogens were calculated on the basis of stereochemical considerations and were allowed to ride on the carbon atoms to which they were bonded during the refinement process. All calculations were performed using the TEXAN[17] crystallographic software package from Molecular Structure Corporation.

Extraction procedure[18]

A mixture of an aqueous solution (10 ml) of alkali metal hydroxide (5×10^{-2} M) and picric acid (5×10^{-4} M) with a dichloromethane solution (10 ml) of an appropriate extractant (5×10^{-4} M) was shaken at 22°C for 9 h. The extractability was obtained from the calculation based on the absorption of picrate anion in the aqueous phase at 354 nm in the UV spectrum.

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