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A NOVEL TYPE OF PSEUDOCRYPTAND FOR SIMULTANEOUS RECOGNITION OF HEAVY AND ALKALI METALS

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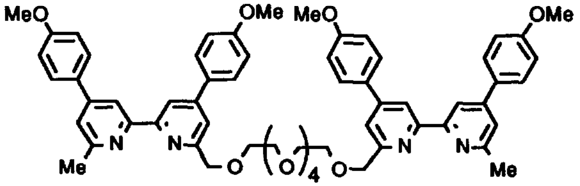
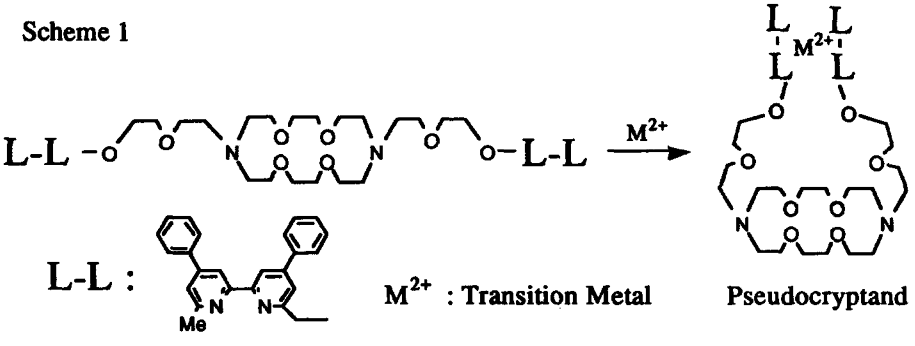
Abstract: Simultaneous and stable recognition for two different metals, e.g. Cu^+ and K^+, has been achieved by using diazacrown ether with 2,2-bipyridine moieties. Formation of pseudocrown structure of the Cu^+ complexes provides a suitable recognition cavity for alkali metal ion.

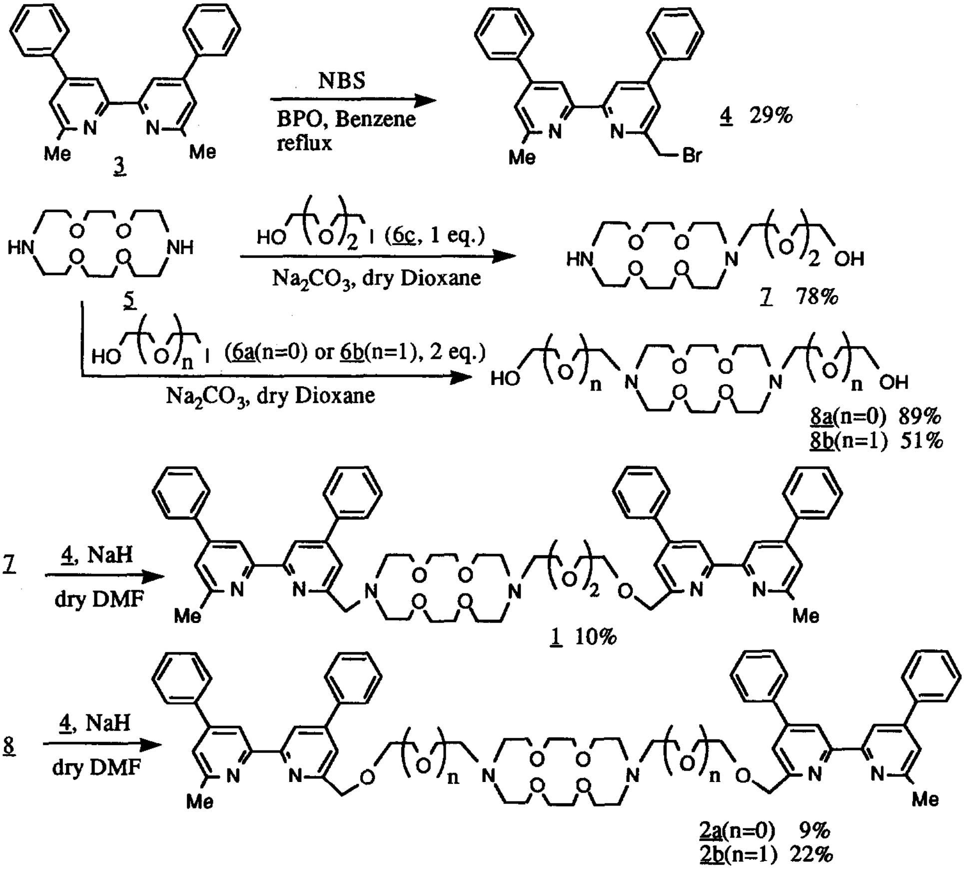
In biological systems allosterism and cooperativity of enzymes are due to the conformational change of the apoproteins,[1)] which should be also very useful to construct an artificial switching system for a molecular function. Recently we have reported synthesis and binding properties to alkali metal ions of an artificial ionophore 6-O-bpy with two kinds of recognition sites for metal ions.[2)] On the addition of Cu^+, 6-O-bpy is immediately converted to the tetrahedral complex, accompanying conformational change of the polyether chain to cyclic (pseudocrown) structure, which can dramatically enhance the selectivity on transport of alkali metal ion across liquid membrane.[2,3)] In other words selective and simultaneous recognition of two different metals, which is one of the most important and


6-O-bpy

Scheme 1



Scheme 2



useful means to construct a heterotropic coreceptor,[4] was achieved by utilizing conformational change induced by an external stimulus. In the system of 6-O-bpy - Cu^+, however, the rate of the transport is heavily diminished because of electrostatic repulsion between Cu^+ and alkali metal cation, compared to the ionophore itself. Taking these facts into accounts, we designed diazacrown ethers 1, 2 with two bipyridine moieties and their binding properties for heavy and alkali metals. In complexation with heavy metals, formation of pseudocryptand structure (Scheme 1) is expected, promising to inhibit the diminishment of the binding strength due to the large macrobicyclic effect of the cryptand.[5]

Synthetic routes to ionophores 1 or 2 are depicted in Scheme 2. 4, 13-Diaza-18-crown-6[6] was treated with 1 eq. or 2 eq. amount of monoiodide 6 and Na_2CO_3 in dry dioxane to afford 7 or 8 crown ethers with oligoethylene glycol as a side arm, in moderate yields, respectively. The desired ionophores were obtained by reaction of 7 or 8 with NaH and 6-bromomethyl-6'-methyl-4,4'-diphenyl-2,2'-bipyridine 4, which was prepared by bromination of the corresponding dimethyl derivative 3[7] by NBS and BPO in benzene.

Table 1 Extractability of Transition and Heavy Metals by 2

	E(%)			
	Fe^{3+}	Co^{2+}	Ni^{2+}	Zn^{2+}
2a	0	0	1	74
2b	0	0	4	75

aqueous phase (10 ml) containing 0.01M metal nitrate, adjusting the pH at 5.5 by using bis-tris buffer; organic phase (CH_2Cl_2, 10ml) containing 5 x 10^{-5}M ionophore at 25°C.

Both 1 and 2 formed red complexes with Cu^+ in organic solvents, such as CH_2Cl_2. The absorption spectra of the solution possess characteristic λ_{max} at 474 nm (metal-to-ligand charge transfer band), which supports two bipyridines bind to Cu^+ with the tetrahedral geometry.[8)] Mole ratio method by using absorption or ^1H NMR spectroscopy monitoring the change of chemical shifts of the methylene and the methyl protons adjacent to the pyridine ring (e.g. in 2b, 4.84→4.45 ppm and 2.71→2.35 ppm, respectively) indicated that 2 readily generates stable and tetrahedral 1 : 1 complex with Cu^+. In contrast, tetrahedral complex of 1 was found to decompose abruptly in the presence of slightly excess of Cu^+, possibly because of the rather strained structure from inspection of the CPK model. Therefore it was concluded that 1 is an unfavorable candidate for a host used for simultaneous metal recognition. In 2, solvent extraction experiment was also carried out to determine the binding ability to heavy and transition metal ions. As shown in Table 1, Zn^{2+} was extracted selectively (74% in 2a and 75% in 2b). Since solubility of CuCl to water is extremely low, Cu^+-2 complex prepared in $CHCl_3$-CH_3CN was dissolved in CH_2Cl_2 and then mixed vigorously with an equal amount of aqueous bis-tris buffer solution (pH 5.5) for 12 h at 25°C to estimate the binding ability. Analysis of UV-VIS spectra of the organic phase revealed that ca. 80% of Cu^+ still remained as the complex. The fact exhibits that 2 captures Cu^+ quite tightly, though the extractability can not be compared directly to those in the other metals. The selectivity of 2 for Zn^{2+} and Cu^+ may be attributed to tendency that the tetrahedral structure is preferably formed due to substituents at 6 and 6' positions of the bipyridines.

Binding of alkali metal ions in 2 was also ascertained by ^1H NMR spectroscopy. In 2a clear shifts of the signals by the addition of Na^+ were observed for methylene protons adjacent to the pyridine ring(4.72→4.79 ppm) and the pivot nitrogen atoms(2.80→2.56 ppm), and aromatic protons(e.g. $H^{3'}$, 8.41→8.32 ppm), indicating 1) occurrence of conformational change of the ionophore and/or 2) co-ordination of Na^+ with lone pairs of oxygen atoms in 2a. Change of the chemical shifts when complexed with alkali metal ion is a well-known phenomenon for cryptand and cryptate.[9)]

Possibility of the simultaneous recognition for metal ions was examined by extraction experiment of alkali metal ion by 2b and 2b-Cu^+(Table 2). It should be noted that 2b has

Table 2 Extractability of Alkali Metal Ions by 2b and 2b-Cu^+ Complex at 25°C

	Ex(%)$^{a)}$	
	Na^+	K^+
2b$^{b)}$	23	50
2b-$Cu^{+,c)}$	21	51

a) determined by flame spectrometry; Ex(%)=$[M^+Pic^-]_{org}/[\text{ionophore}]_0 \times 100$; organic phase($CH_2Cl_2$, 10ml) containing 5×10^{-5} M ionophore.

b) aqueous layer(10ml) containing 5×10^{-5} M metal picrate and 0.1 M MNO_3 in phosphate buffer(pH 7.1).

c) $[2b]_0=5 \times 10_{-5}$ M; $[Pic^-]_{aq,0}= 1 \times 10^{-4}$ M; $[M^+Pic^-]_{org}$=conc. of metal picrate in the organic phase; $[\text{ionophore}]_0$=initial conc. of ionophore(2b or 2b-Cu^+); $[Pic^-]_{aq,0}$=initial conc. of picrate anion in the aqueous phase.

higher affinity to K^+(50%) over Na^+(23%) and there is no effect of Cu^+ on the extractability(51% for K^+, and 21% for Na^+). In other words, simultaneous and selective recognition for two different metal ions, Cu^+ and K^+, is achieved successfully in spite of the fact that the binding site in 2b for Cu^+ is as close as that in pseudocrown 6-O-bpy - Cu^+ to the recognition site for alkali metal ions. The ineffectiveness of Cu^+ suggests that pseudocryptand structure in 2b-Cu^+, whose macrobicyclic effect is considered to cause larger stabilization of the metal complex than macrocyclic effect of the pseudocrown, compensates the electrostatic disadvantage effectively. Therefore it is concluded that the pseudocryptand should be quite a convenient and suitable host molecule to construct a sophisticated metal catalyst having recognition site for cationic guests.

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