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Amide-armed Azamacrocycles as a New Series of Synthetic Carriers for Alkali and Alkaline Earth Metal Cations

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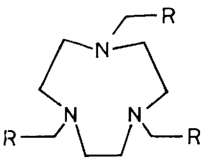
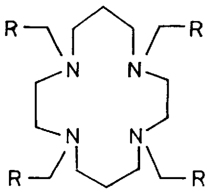
Novel azamacrocycles having amide-functionalized arm groups have been shown to mediate selective and efficient transport of 'hard' alkali and alkaline earth metal cations *via* three-dimensional complexations, while the parent azamacrocycles favour 'soft' metal cations.

Armed macrocyclic host molecules, characterized by parent macrocyclic ligands and flexible cation-ligating arm groups, have attracted much attention.[1] They form three-dimensional but kinetically labile complexes with several metal cations, and mediate effective transport of them.[2–4] Since their cation-binding and transport properties are essentially controlled by the natures of the macrocyclic skeletons and ligating side-arms, structural combinations suitable for new and specific carriers can be designed.

Here we report the remarkable cation-binding and transport properties of amide-armed azamacrocycles. Parent azamacrocycles are known to act as powerful ligands for 'soft' transition metal cations,[5] but we found that some amide-armed azamacrocycles specifically formed encapsulated complexes with 'hard' Ba^{2+} and Li^{+} ions and effectively transported them. Since their guest-selectivities were rather different from those of simple azamacrocycles, crown- and cryptand-type carriers, the present study provides a new series of host compounds exhibiting selective transport abilities for alkali and alkaline earth metal cations.



(1) R = $CONEt_2$
(2) R = CO_2Et



(3) R = $CONEt_2$
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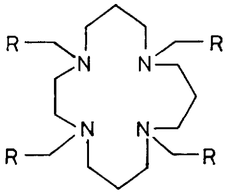

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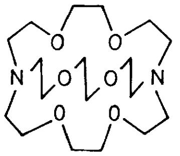
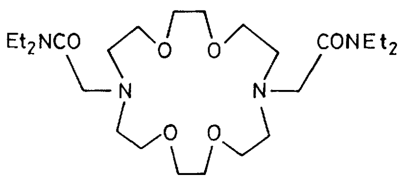


(7)



(6)

Table. Cation transport profiles of amide-armed macrocycles and related carriers[a]

Carrier	Transport rate × 10^6 (mol h^{-1}) Li^+	Na^+	K^+	Cs^+	Mg^{2+}	Ca^{2+}	Ba^{2+}
(1)	2.5	1.4	*	*	*	1.9	2.4
(2)	*	*	*	*	*	*	*
(3)	1.4	0.8	*	*	*	*	8.9
(4)	*	*	*	*	*	*	*
(5)	*	*	*	*	*	*	*
(6)	1.5	4.3	7.0	2.2	*	1.9	0.6
(7)	0.8	6.5	1.2	1.4	*	0.4	3.7

[a] Transport conditions; Aq. I: Guest perchlorate, 0.50 mmol/H_2O, 5 ml. Membrane: Carrier, 0.0372 mmol/$CHCl_3$, 12 ml. Aq. II: H_2O, 5 ml. Initial transport rates of guest cations were indicated. * Below limit of detection ($<0.3 \times 10^{-6}$ mol h^{-1}).

We prepared a series of amide- and ester-armed azamacrocycles (**1**)—(**5**) having 9-, 14-, and 15-membered rings from the corresponding polyamine macrocycles and alkyl chlorides, and compared their transport properties with those of the amide-armed crown ether (**6**)[6] and the bicyclic cryptand (**7**). The liquid membrane transport of various metal perchlorates was achieved in a U-tube glass cell (2.0 cm, i.d.) as described previously,[3] the transported amounts of guest cations and co-transported ClO_4^- anion being individually determined by atomic absorption and ion-selective electrode techniques.

Amide-armed 14-membered azamacrocycle (**3**) transported Ba^{2+} ion effectively, but failed to do so for K^+ and Na^+ ions though they are of similar ion-sizes (see Table). Since ester-armed azamacrocycle (**4**) could not act as a carrier for any of the alkali and alkaline earth cations examined, introduction of an amide-functionalized arm into the azamacrocyclic skeleton significantly enhanced the transport ability for the hard Ba^{2+} cation. In contrast, the crown ether (**6**) and the cryptand (**7**) carried Na^+ and/or K^+ ions more effectively than Ba^{2+} ion,

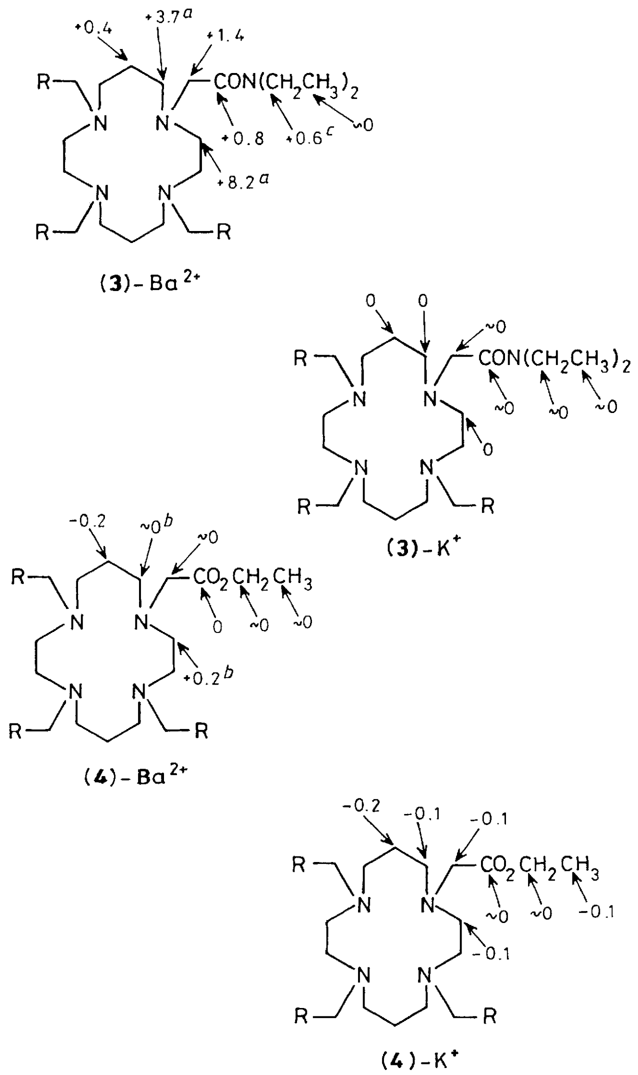


Figure. Ba^{2+}- and K^+-induced changes in ^{13}C n.m.r. chemical shift of the armed azamacrocycles (**3**) and (**4**) (p.p.m.). Conditions: azamacrocycle (0.050 mmol), $Ba(ClO_4)_2$ or $KClO_4$ (0.050 mmol), MeCN–D_2O (4:1) (1.0 ml). [a,b] These signals could not be unequivocally assigned. [c] Calculated from the averaged values of two signals.

and selective transport of the latter ion was not achieved with these conventional carriers. The moderate transport efficiency of the amide-armed triazamacrocycle (**1**) for Li^+, Na^+, Ca^{2+}, and Ba^{2+} ions contrasted with that of the tetra azamacrocycle (**5**) for which it was very low. Thus, the cation transport profile of these amide-armed azamacrocycles is clearly dependent on the ring-size of the parent azamacrocycle as well as the nature of the ligating side-arm group.

The cation-binding properties of the azamacrocycles (**3**) and (**4**) were investigated by ^{13}C n.m.r. spectroscopy (see Figure). Thus, addition of $Ba(ClO_4)_2$ (1 mol equiv.) to the amide-armed azamacrocycle (**3**) solution led to significant spectral changes upon complexation,* whereas $KClO_4$ induced no spectral change. Since the signals for the carbons on both the amide arm and the polyamine ring of the azamacrocycle (**3**) shifted considerably, it is suggested that co-operative action of the amide-arm and parent polyamine ring led to the selective and complete inclusion of the guest Ba^{2+} ion.† The ^{13}C n.m.r. spectrum of the ester-armed azamacrocycle (**4**) was only slightly changed in the presence of Ba^{2+} or K^+ cations, indicating that no stable complexation occurred. These results clearly revealed that a combination of an amide-functionalized arm and an azamacrocyclic skeleton offered selective three-dimensional complexations as well as unique and efficient transport for hard metal cations.‡ Further variation of the arm-donor group and parent macrocyclic ligand may provide new possibilities in design of specific ligands and/or carriers for a new series of guest cations.§

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References

1 Review: H. Tsukube, *J. Coord. Chem., Sect. B*, 1987, **16**, 101.
2 H. Tsukube, *J. Chem. Soc., Chem. Commun.*, 1984, 315.
3 H. Tsukube, K. Takagi, T. Higashiyama, T. Iwachido, and N. Hayama, *J. Chem. Soc., Perkin Trans. 1*, 1986, 1033.
4 H. Tsukube, K. Yamashita, T. Iwachido, and M. Zenki, *Tetrahedron Lett.*, 1988, **29**, 569.
5 R. M. Izatt, J. S. Bradshaw, S. A. Nielsen, J. D. Lamb, and J. J. Christensen, *Chem. Rev.*, 1985, **85**, 271.
6 H. Tsukube, H. Adachi, and S. Morosawa, *J. Chem. Soc., Perkin Trans. 1*, 1989, 89.
7 S. Buon, J. Dale, P. Groth, and J. Kran, *J. Chem. Soc., Chem. Commun.*, 1982, 1178.
8 E. Metzger, R. Aeschimann, M. Egli, G. Suter, R. Dohner, D. Ammann, M. Dobler, and W. Simon, *Helv. Chim. Acta*, 1986, **69**, 1821; K. Matthes, D. Parker, H. J. Buschmann, and G. Ferguson, *Tetrahedron Lett.*, 1987, **28**, 5573; P. D. Beer, H. Sikanyika, C. Blackburn, and J. F. McAleer, *J. Organomet. Chem., Sect. C*, 1988, **350**, 15.
9 T. A. Kaden, 'Topics in Current Chemistry,' Springer-Verlag, Berlin, vol. 121, p. 157; E. Kimura, *Pure Appl. Chem.*, 1986, **58**, 1461.

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* ^{13}C N.m.r. spectral changes supported 1:1 complexation between the azamacrocycle (**3**) and Ba^{2+} ion.

† 1,4,7,10-Tetrahydroxyethyl-1,4,7,10-tetra-azacyclododecane is known to accommodate a three-dimensional cavity for guest cation.[7]

‡ Some amide-containing acyclic and cyclic host molecules have recently been characterized.[8]

§ Several types of armed azamacrocycles form characteristic encapsulated complexes with 'soft' transition metal cations.[9]