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Effects of Cation on Transport Efficiency and Selectivity of Amino Acid Derivative Anions through Macrocyclic Carrier-containing Liquid Membrane

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Synopsis. New aspects of amino acid transport mediated by macrocyclic carriers were reported. Its transport "efficiency" and "selectivity" were demonstrated to be controlled by the appropriate choice of co-transported cation and employed carrier-type.

Recently we demonstrated that several macrocyclic crown ethers[1)] and their derivatives[2)] effectively mediate the passive and active transport of amino acid and oligopeptide derivative anions. In this transport system (see Fig. 1), the macrocyclic carrier, dissolved in the membrane, facilitates the transport of guest anion and co-transported cation from the source phase through the membrane to the receiving phase by solubilizing co-transported cation and guest anion into the membrane.

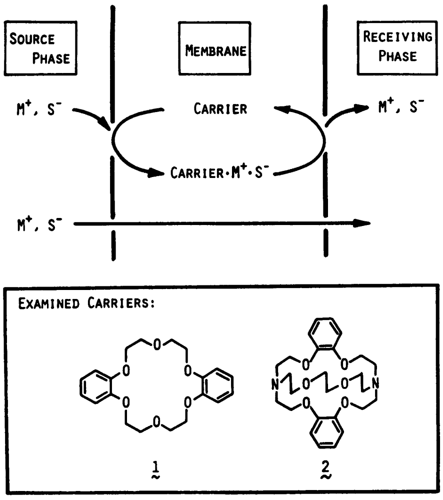
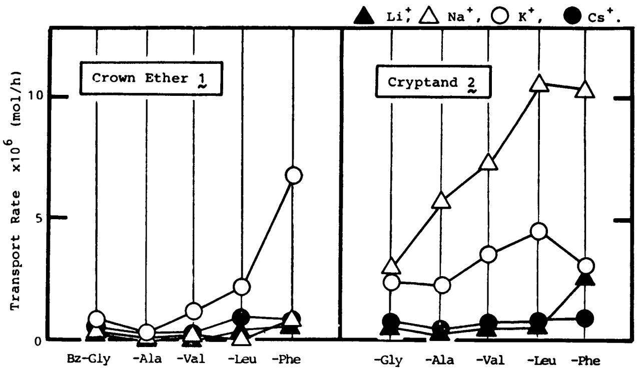


Fig. 1. Liquid membrane and macrocyclic carriers for transport of amino acid derivatives. M^+: Co-transported cation, S^-: guest anion.

(a) In the presence of "alkali metal cation"



(b) In the presence of "alkaline earth metal cation"

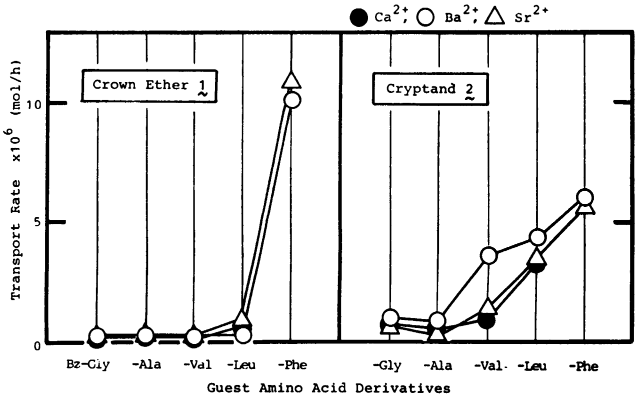


Fig. 2. Transport rates of several *N*-benzoyl amino acid anions by macrocyclic carriers **1** and **2**.
Transport conditions: Source phase; *N*-benzoyl amino acid, 0.250 mmol co-transported cation chloride, 2.50 mmol/0.05 mol dm^{-3} LiOH, 5 ml. Membrane; carrier, 0.0557 mmol/CHCl$_3$, 12 ml. Receiving phase; distilled water, 5 ml. Other conditions were indicated in Experimental.

In the previous publications,[1,2)] we showed that the transport rates of some guest anions were largely influenced by the natures and concentrations of co-transported cations. Here we report a further detailed study of co-transported cation effects on the transport phenomena, and provide a new possibility of controlling the transport "selectivity." By using typical two macrocyclic carriers **1** and **2**, we measured the transport rates of amino acid derivatives in the presence of various metal cations (Li^+, Na^+, K^+, Cs^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}), and found that the natures of these cations significantly governed both the transport "selectivity" and "efficiency." Typical results are illustrated in Fig. 2.

Figure 2(a) clearly shows that alkali metal cation has a large effect on the transport "selectivity" and "efficiency" for amino acids. When the crown ether **1** was employed as carrier, Bz–Phe and Bz–Leu anions (Bz= benzoyl) were effectively transported, together with K^+ cation. These transport properties were found to simply depend on the stability constant of crown ether **1**·metal cation complex ($Li^+ < Na^+ < K^+ > Cs^+$)[3] and hydrophobicity of guest anion (Bz–Gly$\lesssim$Bz–Ala<Bz–Val<Bz–Leu<Bz–Phe). Similar conclusions have been presented in the crown ether-mediated transport of alkali metal-inorganic anion salts by Lamb *et al.*[4)] In a marked contrast, the cryptand carrier **2** exhibited unique and interesting transport property. Its transport selectivity was largely affected by the natures of co-transported metal cations: For Li^+; Bz–Gly$\approx$Bz–Ala$\approx$Bz–Val$\approx$Bz–Leu<Bz–Phe. For Na^+; Bz–Gly<Bz–Ala<Bz–Val<Bz–Leu$\approx$Bz–Phe. For K^+; Bz–Gly$\approx$Bz–Ala$\lesssim$Bz–Val$\lesssim$Bz–Leu>Bz–Phe. It was of particular interest that Bz–Leu anion was more effectively transported with K^+ cation than Bz–Phe and other guest anions.

Since the cryptand **2** is a much stronger complexing agent for Na^+ and K^+ cations than the crown ether **1**,[5] highly hydrophobic Bz–Phe anion could be accumulated into the membrane as very stable cryptand–cation–guest anion complex rather than being transported. Recently some transition metal complexes were found to successfully mediate the artificial transport of amino acid derivatives anions.[6] In such systems, the amino acid anions with lower hydrophobicities allowed fast transport: Bz–Gly>Bz–Ala>Bz–Val>Bz–Leu>Bz–Phe. Thus, transport selectivity could be dramatically modified and controlled by alterations of the employed metal cation and ligating agent.

The effects of alkaline earth metal cations on this transport process were also examined (Fig. 2(b)). Both two macrocyclic carriers **1** and **2** selectively transported hydrophobic guest anions (Bz–Phe and Bz–Leu), together with Ba^{2+} and Sr^{2+} cations, while they hardly transported hydrophilic anions (Bz–Gly and Bz–Ala). Several investigators have studied the crown ether-mediated transport of alkaline earth metal salts, and found that their transport rates were generally much lower than those of alkali metal salts.[7] Although crown ethers form highly stable complexes with alkaline earth metal cations in the solution systems,[3,5] the heterogeneous complexation reactions at the water/membrane interfaces slowly occurred.[8] Probably, hydrophobic Bz–Phe and Bz–Leu anions could promote the heterogeneous complexation and provide higher transport rates.

These results obtained here clearly show that there is an optimum combination of carrier and metal cation for efficient and selective transport of a given guest anion. This principle[6,9] could be used for effective control of the transport "selectivity" and "efficiency."

Experimental

Materials. The macrocyclic carriers **1** and **2** were purchased from Merck Japan Ltd. The used *N*-benzoyl amino acids were obtained from Nakarai Chem. Ltd. and Tokyo Chem. Ltd. All other chemicals were of analytical grade and employed as received.

Transport Procedure. The transport experiments (Fig. 2) were carried out at room temperature in an U-shaped glass cell (2.0 cm, i.d.) as described before.[6] The carrier in chloroform (12 ml) was placed in the base of the U-tube, and two aqueous phases (5 ml, each) were placed in the arms of the U-tube, floating on the chloroform membrane.The membrane phase was stirred with a magnetic stirrer. The transport rates were calculated from the initial rates of appearance of guest anions into the receiving phase, which were determined spectroscopically. Reproducibility was confirmed as ±15% or better.

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