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Enhanced Transport Through Binding Cooperativity in a Circulating System

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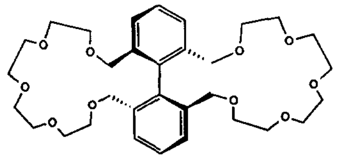
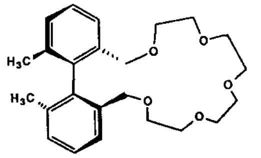
Summary: Allosteric cooperativity in a multiphase circulating system is shown to enhance ion transport when long contact times are involved.

Some time ago we introduced[1] the crown system **1** as a model for allosteric behavior. Positive cooperativity is shown by **1** in binding of certain metal derivatives such as mercury salts. That is, **1** shows higher affinity for the salts than does its monomeric counterpart the crown ether **2**. The cooperativity arises as follows: binding of the metal at one site fixes the dihedral angle defined by the aromatic ring planes, which to a small extent, organizes the second site for binding. The intrinsic (or statistically corrected) association constants for the binding of $Hg(SCN)_2$ in methanol are as shown.



1 $K_1 = 156\ M^{-1}$
$K_2 = 632\ M^{-1}$



2 $K = 172\ M^{-1}$

The effect of binding cooperativity on the rate of transport in a circulating system was the subject of a recent study.[2] In a relatively rapidly circulating system we found that the cooperative carrier was *less effective per site* than the monomeric system, presumably because of the slower release of metal ion by the cooperative crown. In the current study we show that enhanced transport rates can be observed with a cooperative carrier under conditions where longer contact times in the trapping phase are available to the circulating solution.

The experimental setup is one described recently[3] in which a peristalic pump circulates solvents between two polymer-bound phases. The first is composed of solid $Hg(SCN)_2$ adsorbed on unfunctionalized, crosslinked polystyrene. It is the source phase of metal ions and releases the metal at a constant rate to the circulating solution. The trapping phase is the covalently bound dibenzo-18-crown-6 derivative[3] of crosslinked polystyrene **3**. The loading level of the crown ether was determined to be 0.44 meg/g using titrimetric procedures. The uptake of mercuric ions by this polymer-bound crown was followed by IR and calibrated against combustion analysis as previously described.[3]

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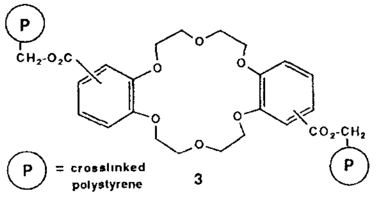
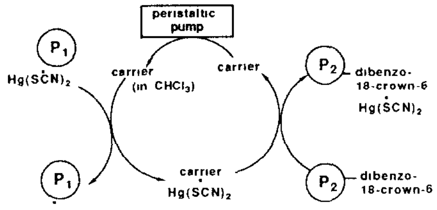


3

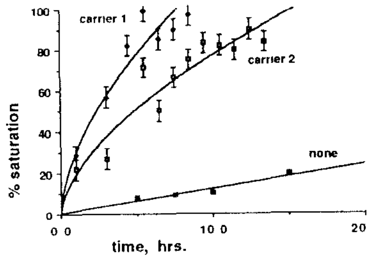
Three-phase system



The enhanced contact time was ensured by creating a large reservoir of solvent kept in contact with the resin 3; under these experimental conditions the contact time could be estimated as 180 ± 10 minutes. Thus, the solutions of the ether complexes have enough time to release the metal to the polymer-bound crown. (The latter has a much higher affinity for mercury salts).

The experimental results are shown graphically in the figure. The fraction saturation as a function of time is given for the two carriers as well as for the run using solvent only. This last value represents the low background solubility of $Hg(SCN)_2$ in $CHCl_3$. It is seen that the cooperative crown **1** is about twice as effective *per site* as the single site system (the lines are drawn merely to distingush the data sets)

Three phase transport



In an admittedly abstract way this system reflects the conditions of a circulatory system in mammals[4] A relatively short contact time of the hemoglobin carrier with oxygen in the lung requires rapid uptake of oxygen The longer the contact time in the muscle tissues permits efficient release. To be sure, the cooperativity of hemoglobin is not of the same sort as the system here in hemoglobin the nature of the subunit contacts *reduces* the intrinsic affinity of the individual subunits in the fully assembled tetramer.[5] In conclusion, we have shown here that binding cooperativity provides enhanced transport in a circulating system when sufficient contact times are allowed.

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