Transport of carbohydrates across a bulk liquid membrane with substituted calyx[8]arenes and phosphoryl-containing podand

I. V. Lyutikova, I. V. Pletnev, I. G. Matveeva, and I. I. Torocheshnikova*

Department of Chemistry, M. V. Lomonosov Moscow State University,
Leninskie Gory, 119899 Moscow, Russian Federation.
Fax: +7 (095) 939 0126

Adamantyl- and *tert*-butyl-substituted calyx[8]arene esters and tripodal podand containing diphenylphosphoryl terminal groups are capable of transporting monosaccharides, but not disaccharides, across a bulk chloroform membrane. Both stoichiometry of complex formation and transport selectivity, in particular, glucose-fructose selectivity, are sensitive to the structure of a carrier.

Key words: transport across a bulk liquid membrane, "host—guest" complexation; substituted calyx[8]arenes, podands; monosaccharides, disaccharides.

Needs of biotechnology and pharmacology motivate interest in novel synthetic reagents for binding polyhydroxy compounds, in particular, monosaccharides and their derivatives. Synthetic membrane systems are of special interest. In our opinion, complex formation of the "host—guest" type is quite promising for creating such systems.[1—5] Certainly, a reagent-"host" has to form firm hydrogen bonds with sugars and be lipophilic enough.

The great majority of investigations in the field of transport across membranes with synthetic reagents is devoted to ionic transport, while data concerning electroneutral compounds, in particular as hydrophilic as sugars, are poorly reported. For example, transport of sugars with derivatives of boric acid has been studied, but this case does not deal with "host—guest" complexation.[6]

Earlier, we used substituted calyx[8]arenes and podands for binding amines.[7] Those reagents are lipophilic and contain functional groups capable of forming hydrogen bonds with sugars. In the present work, we attempted to use them as carbohydrate carriers.

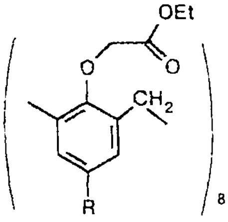
Experimental

Substituted calyx[8]arenes **1** and **2** (Ad means 1-adamantyl) were synthesized by V. V. Kovalev, E. A. Shokova, *et al.* at the Division of the Chemistry of Oil and Organic Catalysis, M. V. Lomonosov Moscow State University. Phosphoryl-containing podand **3** was synthesized by V. E. Baulin in the Institute of Physiologically Active Substances of the Russian Academy of Sciences (Chernogolovka).

Membrane transport was studied in a U-shaped tube (d = 19 mm). The membrane was a solution of a reagent-"host" in chloroform (V = 20 mL, $C = 1 \cdot 10^{-3}$ mol L^{-1}); an aqueous phase: a solution of sugar (V = 10 mL, C = 0.1 mol L^{-1}) was used as a source solution and distilled water (V = 10 mL) was used as a receiving solution. The content of sugar in the receiving solution was controlled photometrically using a reaction with anthrone.[8]

Results and Discussion

Monosaccharides and disaccharides (D-glucose, D-ribose, D-galactose, D-fructose, D-xylose, D-arabinose, maltose, saccharose) cannot be transported across a chloroform membrane without a carrier. The transport also was not observed in the presence of simplest lipophilic reagents capable of forming hydrogen bonds: tetradecyl alcohol and dicyclohexyl-18-crown-6 ether.



1, 2

R = Bu^t (**1**), Ad (**2**)

Substituted calyx[8]arenes **1** and **2** transport monosaccharides (and not disaccharides) across a chloroform membrane. The selectivity of the two reagents is different (Table 1). Thus, when reagent **2** is used, hexoses (fructose, galactose, and glucose), which are more hydrophilic than pentoses, are transported with a lower velocity. The transport of pentoses, in turn, substantially varies in effectiveness. Among hexoses, glucose is trans-

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Table 1. The transport velocity (j) of sugars in the transportation across a chloroform membrane with different reagents-carriers

Sugar	j/μmol h^{-1}		
	1	2	3
D-Glucose	0*	11.4	1.2
D-Fructose	17.0	0*	40.0
D-Galactose	22.8	0*	—
D-Ribose	33.0	63.0	—
D-Xylose	0*	37.2	—
D-Arabinose	0*	20.4	—

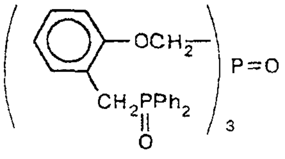
* Was not detected in the receiving solution after 3 h.

ported with a velocity comparable to that of arabinose, a pentose, while fructose and galactose are not transported at all.

In the case of *tert*-butyl-substituted calyx[8]arene **1**, the glucose-fructose selectivity is inverted; the reagent transports well fructose rather than glucose. A sharp difference in the selectivity of calyxarenes, in which only peripheral substituents vary, can be due to either conformational effects or different stoichiometry of complex formation.

To estimate the stoichiometry of complex formation (with fructose for calyxarene **1** and with ribose for reagent **2**), we studied the dependence of the velocity of monosaccharide transport on the concentration. This dependence must be linear in the $C_L/j - 1/C_G$ coordinates (C_L is the "host" concentration in the membrane, C_G is the "guest" concentration in the source solution, and j is the flow velocity) when a "host—guest" complex is formed in the ratio of 1 : 1.[9] The linearity is observed for a complex of ribose with reagent **2**. An experimental dependence for fructose and reagent **1** is different; its character suggests that for each fructose molecule there are two or more molecules of the carrier.

Using phosphoryl-containing podand (reagent **3**) as a monosaccharide carrier accelerates the transport compared to calyxarenes (see Table 1). It is interesting that, like calyxarene **1**, podand **3** discriminates fructose with quite high selectivity.



3

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