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INTERACTIONS OF ORGANIC SOLVENTS WITH PHOTORESPONSIVE CAPPED CYCLODEXTRIN IN AQUEOUS SOLUTION

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Azobenzene-capped β-cyclodextrin (I) forms complexes with organic solvents (methanol, DMSO, DMF, acetone and acetonitrile) according to 1:2 host/guest stoichiometry in its cis state, whereas exhibits nonstoichiometric behavior in its trans state.

Cyclodextrins can form host/guest complexes with a variety of substances in aqueous solution. Furthermore, they act as catalyses for some reactions[1] and as matrices for selective reactions.[2,3] Although these functions have usually been revealed in water solution, there remains a possibility to develope them in organic solvents or aqueous organic solvents.[4] From this point of view, we have examined interactions of some organic solvents with azobenzene-capped β-CD (I)[5] by circular dichroism spectra. The cap azobenzene of I is a useful probe and facilitates the analysis of the phenomena caused by substrate addition. We wish to report here nonstoichiometric behavior of trans-I·organic solvent interactions and 1:2 host/guest complexation of cis-I with the organic solvents.

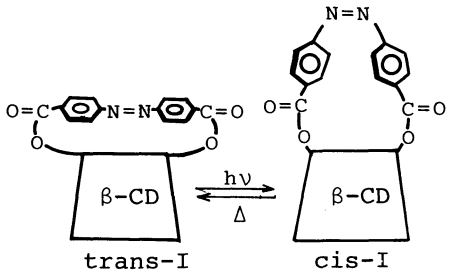

Figure 1 (A) shows variations in molar ellipticity [θ] at 355 nm of trans-I induced by adding organic solvents to the aqueous solution (Tris buffer, pH 7.2). The addition of methanol yields no effect on [θ] until its concentration reaches 14%. On further addition of methanol, a gradual change in [θ] was observed showing the half value of the initial ellipticity at 34.8%. Among the five organic solvents, methanol is the best solvent to keep the conformation of I in the form capable of complex formation. Siegel and Breslow reported complex formation of β-cyclodextrin with some organic substances and remarkably enhanced velocities in cyclodextrin-catalyzed hydrolysis in DMSO and aqueous DMSO solution.[4] In this study, the ellipticity of I was found to diminish with the addition of DMSO, reaching the final value at 40% DMSO. This result indicates that I cannot bind any guest in its cavity at more than 40% DMSO since the change in [θ] should couple with a conformational change between two states capable or incapable to form inclusion complexes.[5-7] It is not clear whether the discrepancy between the results of Breslow et al. and us is or is not due to the perturbed nature of the cyclodextrin moiety of I induced by capping modification. All

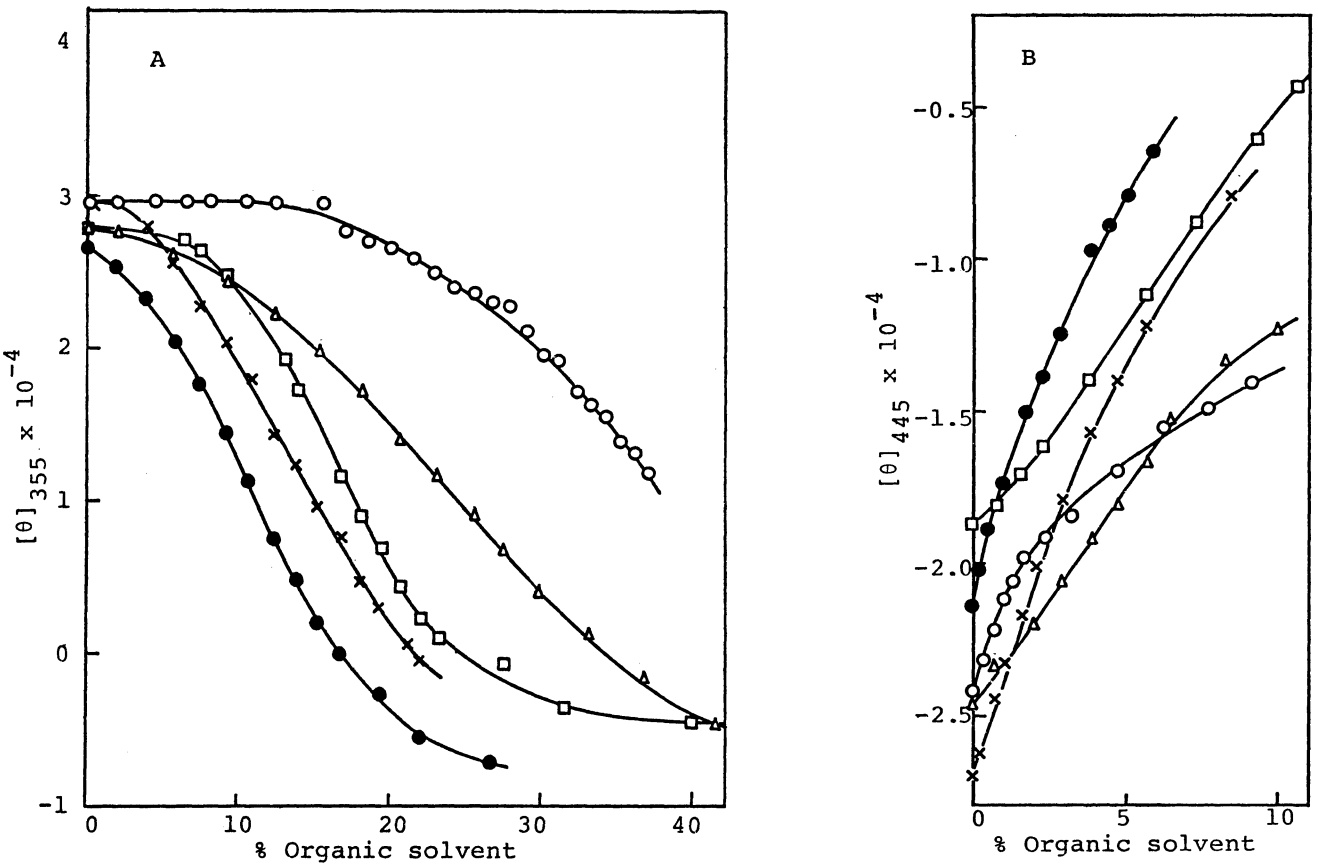

Fig. 1 Variations of the [θ] values at 355 nm and 445 nm before (A) and after (B) photoirradiation respectively induced by organic solvent addition. o: methanol, Δ: DMSO, □: acetonitrile, ×: DMF, ●: acetone.

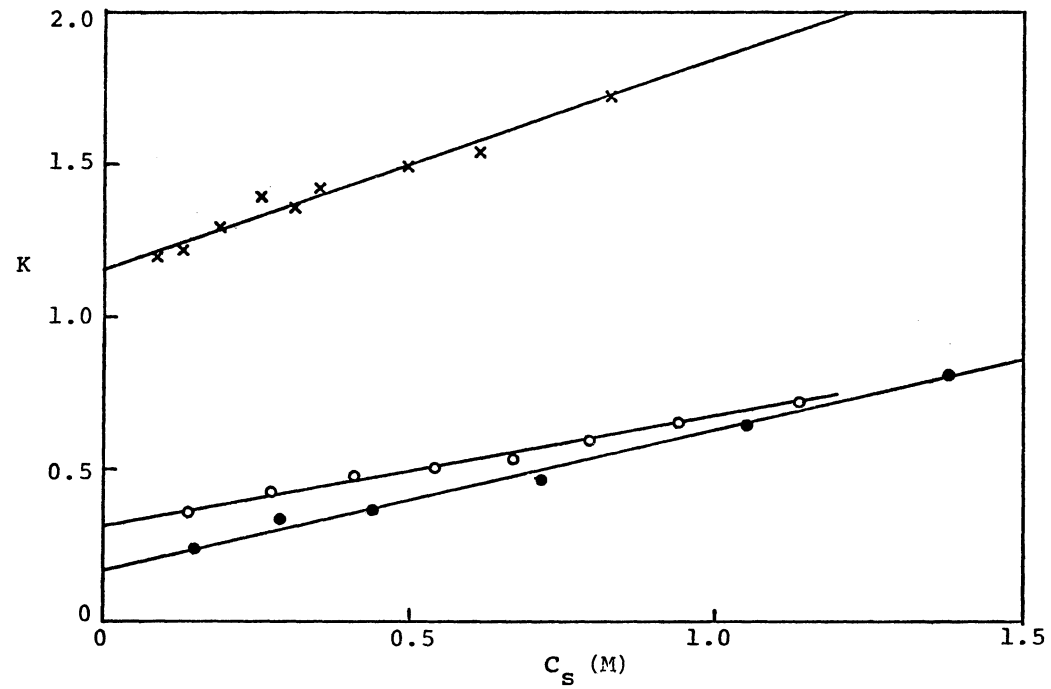

Fig. 2 Plots for determination of K_1 and K_2 values in the case $\theta_1=\theta_2$. ×: DMF, o: DMSO, ●: acetonitrile.

organic solvents examined here do not follow neither 1:1 nor 1:2 host/guest stoichiometry. Therefore, the organic solvent-induced conformational change should be caused according to different inclusion stoichiometries or by the interactions outside the cyclodextrin cavity.

Figure 1 (B) shows the data after photoirradiation. The analysis of these data shows that all the organic solvents (S) form complexes of 1:2 stoichiometry with cis-I having molecular ellipticities θ_1 and θ_2 for I-S and I-S_2 respectively.

$$I + S \underset{}{\overset{K_1}{\rightleftharpoons}} I\text{-}S$$

$$I\text{-}S + S \overset{K_2}{\rightleftharpoons} I\text{-}S_2$$

When a parameter K is defined as shown below

$$K = \frac{\theta_I - \theta_x}{(\theta_x - \theta_s)C_s} \tag{1}$$

where θ=molar ellipticity, θ_x for sample, θ_I for I alone, θ_s for highest substrate excess, C_I=total I concentration, and C_s=total substrate concentration, the following equations hold assuming $\theta_1=\theta_2$ (Eq. (2)) or $\theta_1 \neq \theta_2$ (Eqs. (3) and (4)).[6]

$$K = K_1 + K_2C_s \tag{2}$$

$$\frac{K}{|\theta_I - \theta_x|} = \frac{1}{|\theta_1 - \theta_2|}\frac{1}{C_s} + \frac{K_2}{|\theta_1 - \theta_2|} \tag{3}$$

$$\frac{1 + K_2C_s}{K} = \frac{1}{K_1} + |\theta_1 - \theta_2|\frac{C_s}{|\theta_I - \theta_x|} \tag{4}$$

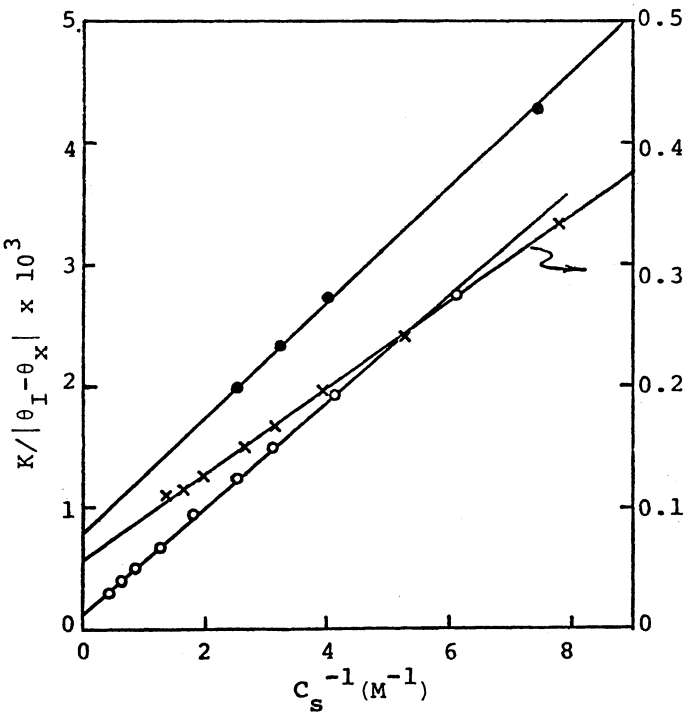

Fig. 3 Plots for determination of K_2 values in the case $\theta_1 \neq \theta_2$. o:methanol, x: DMF, ●: acetone.

Table 1. Complex formation of cis-I with organic solvents (25°C)[a]

Guest	$\theta_1 \neq \theta_2$[b]		$\theta_1 = \theta_2$	
	$K_1(M^{-1})$	$K_2(M^{-1})$	$K_1(M^{-1})$	$K_2(M^{-1})$
Acetone	c)	1.60		
Methanol	c)	0.36		
DMF	c)	1.59	1.14	0.66
DMSO			0.32	1.11
Acetonitrile			0.17	2.70

a) Formation constants were obtained by analyzing the induced circular dichroism of cis-I at 445 nm (Tris buffer, pH 7.2).[5,6] b) $\theta_1 = -4.5 \times 10^4$ for acetone and methanol, -4.8×10^4 for DMF, $\theta_s = \theta_2 = 0, \theta_I = -4.5 \times 10^4$. c) Values are too large to be determined from the plots of Eq. (4) (the plots are not shown here).[6]

Figure 2 shows the plots of K vs. C_s according to Eq. (2). Figure 3 shows the plots of $K/|\theta_I - \theta_x|$ vs. $1/C_s$ according to Eq. (3). By using the K_2 values thus obtained, K_1 can be determined from the plots of $(1+K_2C_s)/K$ vs. $C_s/|\theta_I - \theta_x|$ according to Eq. (4). In Table 1 are given the formation constants of complexation between cis-I and the organic solvents. Methanol and acetone follow the stoichiometry assuming $\theta_1 \neq \theta_2$ whereas DMSO and acetonitrile seem to follow the one assuming $\theta_1 = \theta_2$. There arises a problem in the case of DMF, since DMF follows both stoichiometries. The different behavior of the organic solvents cannot simply be related to their structural characteristics, and indeed some added proofs are necessary to clarify the phenomena. Another aspect of the results is the different behavior of trans-I and cis-I. The complexing ability of cis-I with such small molecules is rather unexpected one because of its expanded hydrophobic cabity. A geometrical perturbation might generate a nallow part in the cavity facilitating complexation with small molecules. Although this is only a preliminary report we are currently investigating in detail the reason for these unique binding behavior of I.

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