CHEMISTRY LETTERS, pp. 1227-1230, 1988.

Stabilization of a Labile cis-Azobenzene Derivative with Amphiphilic Cyclodextrins

Hiroyuki NIINO,* Akira YABE, Akihiko OUCHI, Motoo TANAKA, Yasujiro KAWABATA, Shoji TAMURA,† Tomohiro MIYASAKA,† Waichiro TAGAKI,† Hiroo NAKAHARA,†† and Kiyoshige FUKUDA††

National Chemical Laboratory for Industry, Tsukuba, Ibaraki 305

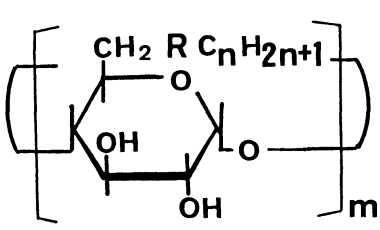
†Department of Applied Chemistry, Faculty of Engineering, Osaka City University, Sumiyoshiku, Osaka 558

††Department of Chemistry, Faculty of Science, Saitama University, Urawa, Saitama 338

The cis-isomer of p-Methyl Red (**cis-p-MR**) was appreciably stabilized by inclusion in equimolar amphiphilic heptakis(6-alkylamino-6-deoxy)cyclodextrins (C_nN**-CDs**) in either chloroform solution or the Langmuir-Blodgett (LB) films, as compared with that in the isolated state. Amino moieties in the cyclodextrin derivatives were found to be essential for a tight inclusion of **p-MR** and also for the stabilization of cis-isomer.

It is widely known that cyclodextrins (**CDs**) form inclusion complexes with a number of organic molecules without any covalent bonds. **α-CDs** and **ß-CDs**, which are composed of six and seven glucopyranose units respectively, have different internal diameters of the cavity (**α-CDs**:ca.0.5 nm and **ß-CDs**:ca.0.7 nm) for the selective inclusion. These host-guest compounds, therefore, have aroused an increasing interest in wide fields of science and technology.[1)]

Recently, we have reported a new type of photoreactive LB films which is composed of $C_{12}N$**-ßCD** including such azobenzenes without long alkyl chains as **p-MR**, Methyl Orange, and p-(phenylazo)benzoic acid.[2,3)] During the experiments, considerable stabilization for unstable cis-isomers of azobenzenes was observed in



abbreviation

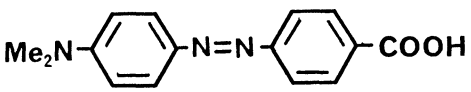
$C_{12}N$**-ßCD** : n=12, m=7, R=NH

$C_{16}N$**-αCD** : n=16, m=6, R=NH

$C_{16}S$**-ßCD** : n=16, m=7, R=S

$C_{12}SO$**-ßCD** : n=12, m=7, R=SO

Amphiphilic cyclodextrins



p-Methyl Red (**p-MR**)

these LB films. Although the cis-isomer of **p-MR** having electron push-pull substituents (dimethylamino and carboxyl groups) was extremely labile in chloroform solution at room temperature, it was significantly stabilized by inclusion in the LB films of C_{12}**N-ßCD.**[3,4] However, not all of **CDs** have exhibited the stabilization effect. It seems to be important for extensive utilizations of **CDs** to reveal the factors which have influence on the stabilization phenomena. This report describes the effects on the stabilization of labile **cis-p-MR** by forming the inclusion complex with **CDs** in LB films and chloroform solution.

The trans-isomer of **p-MR** (**trans-p-MR**) was irradiated with a monochromatic light at its absorption maximum until the photostationary state (PSS) was reached, and then kinetics of thermal cis-to-trans isomerization in the LB films and chloroform solution was investigated by UV-visible spectroscopy. Fast decay of the cis-isomer in solution was measured by a flash photolysis system consisted of a storage scope and a pulsed dye laser (full width at half-maximum : 20 ns).[5] In the case of slow decay, the isomerization was monitored with a spectrophotometer at the absorption maximum of the trans-isomer after its PSS on irradiation with a 500 W super-high pressure xenon lamp through a monochromator.

Figure 1 shows plots of the first order kinetics for thermal cis-to-trans isomerization of the inclusion complexes in solution and the LB films. In the chloroform solution of complexes, the cis-isomers reverted thermally to their trans-isomers by first order processes at room temperature, while deviation from the first-order kinetics was observed in the LB films of C_n**N-CDs.**[3,4] The rate constants and half-lifes for the thermal cis-to-trans isomerization of the inclusion complexes are summarized in Table 1.

Although **trans-p-MR** in C_{16}**N-αCD** was less converted into **cis-p-MR** than in C_{12}**N-ßCD** at PSS, **cis-p-MR** was considerably stabilized in the LB films which is shown in

Table 1. Rate constants and half-lifes of **p-MR** in LB films and $CHCl_3$ at 25 °C

Run	CD	LB or $CHCl_3$[a]	First-order rate constant k / s^{-1}	Half-life $T_{1/2}$
1	none	$CHCl_3$	1.2×10^{2}	6.0 ms
2	C_{12}**N-ßCD**[b]	LB		55 s [c]
3	C_{16}**N-αCD**	LB		68 s [c]
4	C_{12}**N-ßCD**	$CHCl_3$	1.3×10^{-3}	9.1 min
5	C_{16}**N-αCD**	$CHCl_3$	8.7×10^{-4}	13.6 min
6	C_{16}**S-ßCD**	$CHCl_3$	1.1	640 ms
7	C_{12}**SO-ßCD**	$CHCl_3$	4.2	160 ms
8	**TriMe-ßCD**	$CHCl_3$	1.4×10^{2}	4.9 ms
9	**DiMe-ßCD**	$CHCl_3$	94	7.4 ms

a) [**CD**] = [**p-MR**] = 2.5×10^{-5} mol dm^{-3}.

b) Ref. 3.

c) At 20 °C.

Table 1 (Run 2 and 3). Conversions of **trans-p-MR** into the cis-isomer included in C_{16}**N-αCD** and C_{12}**N-βCD** at PSS were estimated to be 8% and 30%, respectively, from the absorbance. It is attributed to difference in the cavity diameters of C_n**N-CDs** and also probably to morphological characteristics of the LB films.

In dilute chloroform solution, the stability of **cis-p-MR** in C_n**N-CDs** (molar ratio **p-MR:**C_n**N-CD** = 1:1, 2.5×10^{-5} mol dm^{-3}) was about 100 000-fold more stable in comparison with that of free **cis-p-MR** (Run 4 and 5). As shown in Fig.2, a hypsochromic shift was observed in the UV-visible spectra of **trans-p-MR** in C_n**N-CDs.** These results indicate specific interactions between **p-MR** and **CDs** having possess hydrophobic cavities, in a non-aqueous solution.[6] Conversions of **trans-p-MR** into **cis-p-MR** in C_{16}**N- CD** and C_{12}**N-βCD** at PSS were estimated to be about 60% in both **CDs.**[7]

On the other hand, an equimolar addition of amphiphilic heptakis(6-hexadecylthio-6-deoxy)-ß-cyclodextrin (C_{16}**S-βCD**) or heptakis(6-dodecylsulfinyl-6-deoxy)-ß-cyclodextrin (C_{12}**SO-βCD**) without amino moieties to the solution had only a slight effect on the stability of **cis-p-MR** (Run 6 and 7). The hypsochromic shift was not observed in these solutions. The inclusion of **p-MR** in LB films was not achieved with C_{16}**S-βCD** and C_{12}**SO-βCD** by the procedure as in the previous papers.[2,8] Furthermore, in the case of equimolar mixtures of **p-MR** and chloroform-soluble methylated **ß-CDs** such as heptakis(2,3,6-tri-O-methyl)-ß-cyclodextrin (**TriMe-βCD**) and heptakis(2,6-di-O-methyl)-ß-cyclodextrin (**DiMe-βCD**), the rate of thermal isomerization resembled to that of isolated **p-MR** in chloroform solution (Run 8 and 9).

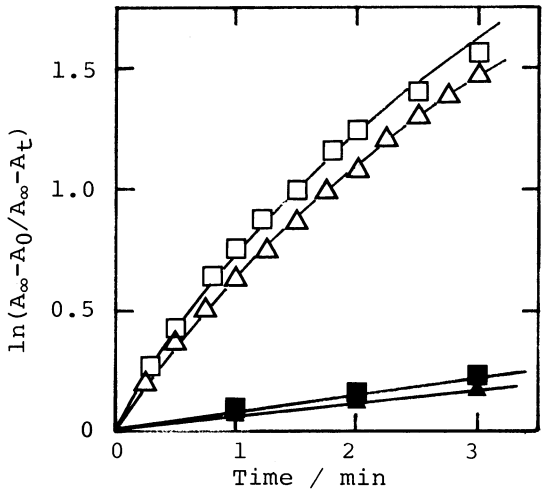


Fig.1. The first order kinetics plots for cis-to-trans thermal isomerization. A_0, A_t, and A_∞: absorbance at initial state, after t and ∞ min, respectively.

□:the LB film of **p-MR** in C_{12}**N-βCD**
△:the LB film of **p-MR** in C_{16}**N-αCD**
■:the solution of **p-MR** in C_{12}**N-βCD**
▲:the solution of **p-MR** in C_{16}**N-αCD**

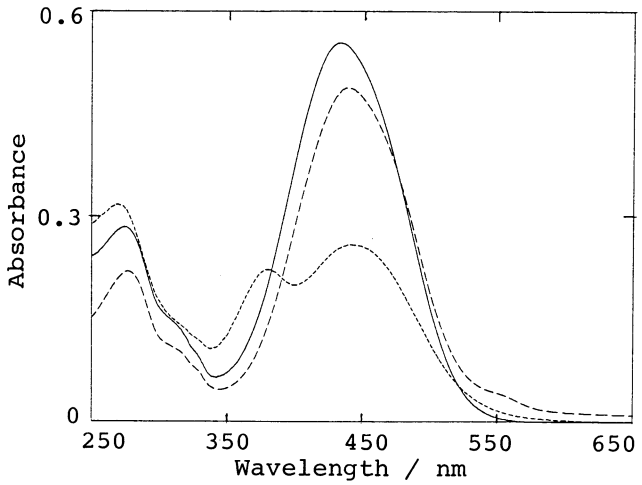


Fig.2. UV-Vis spectra of **p-MR**, and the complex of **p-MR** and C_{12}**N-βCD** (1:1), $CHCl_3$.

(----): **p-MR**
(——):the complex before irradiation
(------):the complex at PSS

Study of inclusion complexes on irradiation has indicated the ejection of the cis-isomer of azobenzenes from non-substitued **ß-CD** in an aqueous solution.[9,10] Our experiments have shown the abilities of **C_nN-CDs** for the inclusion of **p-MR** in chloroform solution and LB films, while the examination of molecular models suggested that the geometry of cis-isomer disfavored a stable complex with **ß-CD**.

In conclusion, the present study has revealed that the amino moiety in **CD** derivatives of **C_nN-CDs** plays an important role for the complexation between **C_nN-CDs** and **p-MR**, and also for the stabilization of **cis-p-MR** in the inclusion complexes, in chloroform solution and LB films. In the case of **C_{16}S-ßCD** and **C_{12}SO-ßCD**, the high rate constants suggest that the complex formation with **p-MR** is weaker than in the case of **C_nN-CDs**. Further investigations on detailed functions of amino groups in **CDs** are now in progress.

The authors wish to thank Professor Shogo Saito of Kyushu University for the experimental suggestions on the flash photolysis technique.

References

1) M. L. Bender and M. Komiyama, "Cyclodextrin Chemistry," Springer-Verlag, New York (1978).
2) M. Tanaka, Y. Ishizuka, M. Matsumoto, T. Nakamura, A. Yabe, H. Nakanishi, Y. Kawabata, H. Takahashi, S. Tamura, W. Tagaki, H. Nakahara, and K. Fukuda, Chem. Lett., 1987, 1307.
3) A. Yabe, Y. Kawabata, H. Niino, M. Tanaka, A. Ouchi, H. Takahashi, S. Tamura, W. Tagaki, H. Nakahara, and K. Fukuda, Chem. Lett., 1988, 1.
4) A. Yabe, Y. Kawabata, H. Niino, M. Matsumoto, A. Ouchi, H. Takahashi, S. Tamura, W. Tagaki, H. Nakahara, and K. Fukuda, Thin Solid Films, in press.
5) P. D. Wildes, J. G. Pacifici, G. Irick, Jr., and D.G. Whitten, J. Am. Chem. Soc., 93, 2004 (1971).
6) J. L. Lach and T-F. Chin, J. Pharm. Sci., 53, 69 (1964).
7) The trans-isomer of isolated **p-MR** in solution was not completely converted into its cis-isomer at PSS, because **cis-p-MR** absorbed light at the corresponding absorption maximum of **trans-p-MR**. Conversion to **cis-p-MR** in **C_nN-CDs** was not so small in chloroform solution.
8) Y. Kawabata, M. Matsumoto, M. Tanaka, H. Takahashi, Y. Irinatsu, S. Tamura, W. Tagaki, H. Nakahara, and K. Fukuda, Chem. Lett., 1986, 1933.
9) A. Ueno, K. Takahashi, and T. Osa, J. Chem. Soc., Chem. Commun., 1980, 837.
10) P. Bortolus and S. Monti, J. Phys. Chem., 91, 5046 (1987).

(Received April 7, 1988)