p-(4-Nitrophenylazo)phenol Dye-bridged Permethylated *α*-Cyclodextrin Dimer: Synthesis and Self-aggregation in Dilute Aqueous Solution

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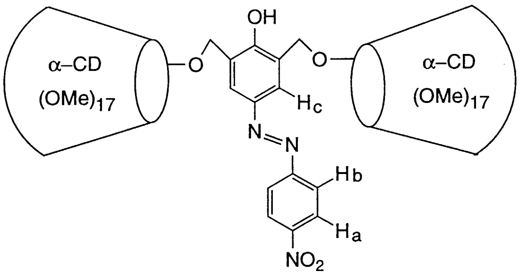
The title compound **1** exhibited the time-dependence of the VIS and ^{1}H-NMR spectra in aqueous solution at room temperature in the dark. These phenomena were interpreted in terms of the self-aggregation involving intermolecular inclusion of the *p*-(4-nitrophenylazo)phenol group with one of the two permethylated α-cyclodextrins of **1**.

In order to examine the host-guest color complexation defined as complexation causing synchronous coloration, we have dealt with chromogenic crown ethers and spherands, and reported that the better host-guest complementarity in the colored complexes tends to bring about blue shift of the absorption bands.[1] In this connection, we were interested in an azophenolic, lipophilic, and dimeric cyclodextrin (CD) **1** as a prototype of chromogenic CDs taking into account the inclusion ability of CDs. Recently, the fascinating works on chromogenic CDs have been developed by Ueno and Toda and their co-workers.[2] Their indicator functions involve the "intramolecular" inclusion of the dye group into the CD cavity. We describe here the "intermolecular" inclusion or the self-aggregation of **1** in dilute aqueous solution.

Permethylated α-cyclodextrin 6^A-monoalcohol[3] was benzylated with 2,6-bis(bromomethyl)-1,4-dimethoxybenzene[4] to yield the corresponding *m*-xylene-bridged permethylated α-CD dimer in 50% yields. The oxidation of the CD dimer with cerium(IV) ammonium nitrate followed by treatment with *p*-nitrophenylhydrazine gave the title compound **1**[5] in 70% yields via quinone hydrazone-azophenol tautomerization.

In preliminary experiments for color complexation, we encountered a strange time-dependence of visible spectra of **1** in an aqueous neutral solution (~1x10^{-5} mol dm^{-3}). The time-dependent spectra became much simpler under acidic and basic conditions as shown in Figure 1. Thus, it was found that the absorption bands of azophenol and the corresponding phenolate were gradually red-shifted from 380 to 390 nm and 520 to 540 nm, respectively, during 2 h at room temperature in the dark. Further, it is noteworthy that two independent isosbestic points appear in the spectra (Figure 1(b)) of **1** in an aq NaOH and the original spectrum was reproduced by heating at 80 °C for 1 h. These findings suggest that two different and reversible chemical processes are involved in the time-dependence. Similar red-shifts were found on the titration experiments for some azophenol dye-α-CD systems and interpreted in terms of 1:1 inclusion complex formation,[6,7] however, there are no description regarding the time-dependency.



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According to examination of CPK molecular models, the dye

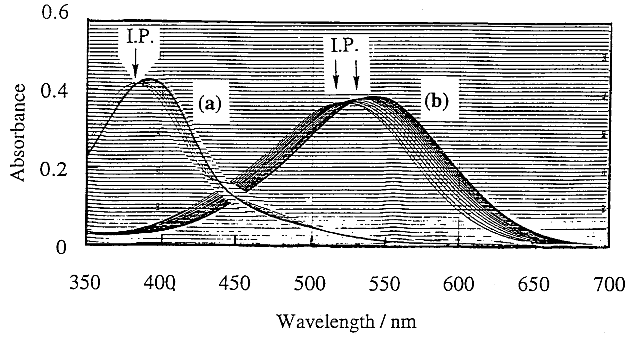
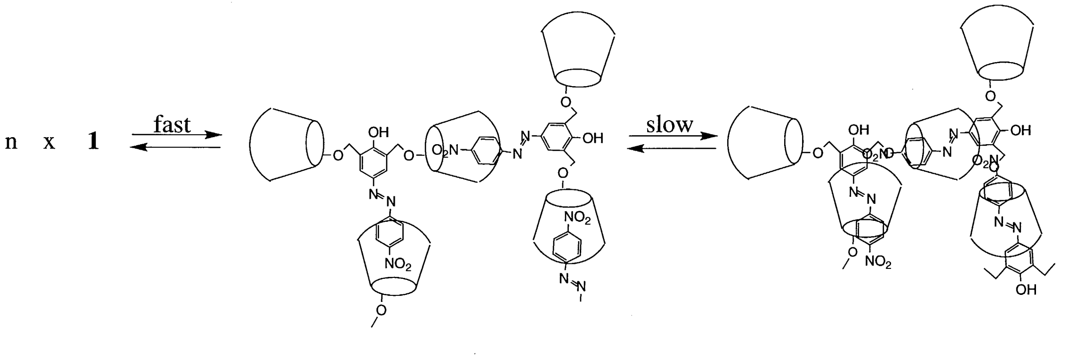


Figure 1. The time-dependent VIS-spectra of **1** (~1x10^{-5} mol dm^{-3}) in (a) acidic and (b) basic aqueous solution. I.P. : isosbestic piont.



Scheme 1. A postulated mechanism for the self-aggregation of **1** in aqueous solution.

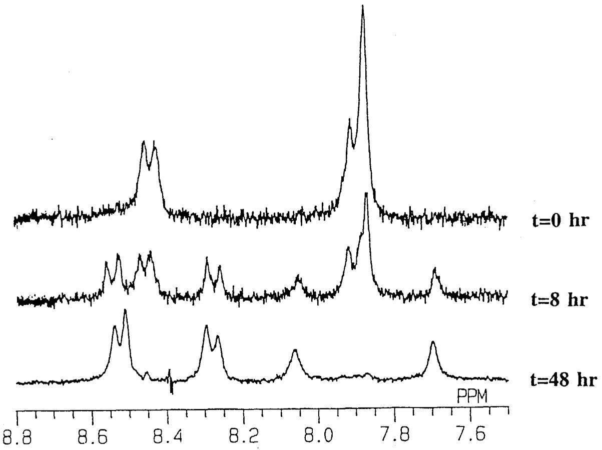


Figure 2. The time-dependent ^{1}H-NMR spectra of **1** in D_2O (270 MHz, DSS as an internal standard).

group of **1** can enter neither α-CD cavity of the same molecule, because of its long and azobenzene-like rigid geometry. Therefore, the red shifts of 10 and 20 nm observed with **1** must be attributed to intermolecular inclusion of the *p*-(4-nitrophenylazo)phenol group with one of the two permethylated α-CD units or the self-aggregation of **1** as illustrated in Scheme 1 where the first fast step gives so-called loose aggregates **2** and the second slow step does tight aggregates **3**. The self-aggregation is compatible with the observation of concentration-dependence, acceleration of the first step by a factor of about 1.5 in a higher concentration (~2x10^{-4} mol dm^{-3}) of **1** (and almost no influence on the second step). There have been some reports about such a two-step mechanism by which azo-dyes interact with α-CD.[7,8]

Alternative evidence supporting the self-aggregation of **1** was provided by ^{1}H-NMR spectrometry. As shown in Figure 2, the new signals ascribed to tight aggregates **3** appeared gradually at 8.53 ppm (d, J=8.7 Hz, Ha), 8.27 (d, J=8.7 Hz, Hb), 8.06 (bs, Hc), and 7.68 (bs, Hc) with disappearance of the original peaks for Ha (8.45 ppm, d, J=6.9 Hz), Hb(7.90, d, J=6.9 Hz), and Hc (7.88, s) of uncomplexed **1**. The unequivalent behavior of the two Hc protons in **3** suggests the restraint of free rotation about the C-N bond between the *p*-hydroxyphenyl and *p*-nitrophenylazo groups. The appearance of the separated signals of the complexed and uncomplexed species demonstrates that the chemical exchange is slow compared with the NMR time scale. A similar phenomenon was observed with a complex of α-CD with *p*-(3-t-butyl-4-hydroxyphenylazo)benzenesulfonic acid.[7c]

The present work may provide an approach to construct a "supercyclodextrin" with a ring structure of many CD inclusion complex units.

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References and Notes

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