Promoted Binding Ability of γ-Cyclodextrin Appended by a Space-regulating Naphthalene Moiety

Akihiko Ueno,* Yoko Tomita, and Tetsuo Osa*

Pharmaceutical Institute, Tohoku University, Aobayama, Sendai 980, Japan

Narrowing of the large cavity of γ-cyclodextrin by an appended naphthalene moiety enables it to become a good host for small molecules.

Cyclodextrins are toroidal cyclic oligosaccharides and extensive studies of binding and catalysis by them and their derivatives have been described.[1] Most investigations have been confined to α-cyclodextrin (cyclohexa-amylose) and β-cyclodextrin (cyclohepta-amylose) which have suitable cavity sizes for many organic compounds. Recently γ-cyclodextrin (cyclo-octa-amylose, γ-CD) has excited much attention because of the inclusion of two guests in its large cavity.[2–11] We previously described[3] a space-regulating molecule which narrows the large γ-CD cavity to allow the inclusion of another kind of molecule. We report here that the attachment of a naphthalene moiety to γ-CD enables it to become a good host for small molecules by an induced-fit type of complexation as shown in Figure 1.

γ-CD was sulphonated at the 6-hydroxy-position by reaction with naphthalene-2-sulphonyl chloride in pyridine, affording (**1**). This sulphonated γ-CD was transformed into the ester (**2**) by a replacement reaction with sodium 2-naphthylacetate. Both compounds were identified by ^{1}H n.m.r., ^{13}C n.m.r., u.v., i.r., and elemental analyses.†

The γ-CD derivatives possess an appended naphthalene moiety which can be used as a probe to monitor its environment. In fact, an induced-fit type of complexation of (**2**) with cyclohexanol, (+)-fenchone, and (−)-borneol was proved to occur by c.d. measurements in the absorption regions of the chromophore. The molecular ellipticity of (**2**) was markedly enhanced by the addition of guests in the regions of the ^1B_b and ^1L_a transitions of the naphthalene moiety (Figure 2). This phenomenon may be ascribed to the limited mobility of the naphthalene moiety when involved together with a guest molecule in the chiral γ-CD cavity. The c.d. behaviour was analysed by using an equation for 1 : 1 complexation,[12] the binding constants being 55, 1270, and 5670 l mol^{-1} at 25 °C for cyclohexanol, (+)-fenchone, and (−)-borneol, respectively. In the case of (**1**), the ellipticity was scarcely affected by the addition of the guests probably owing to its negligible binding ability as a host.

Other evidence for the space-regulating effect of the appended naphthalene moiety was obtained by the fluorescence enhancement of (**2**) in the presence of cyclohexanol. The enhancement is caused by a change in the environment around the fluorophore from the polar to less polar medium,[13] resulting from the fact that the appended naphthalene moiety

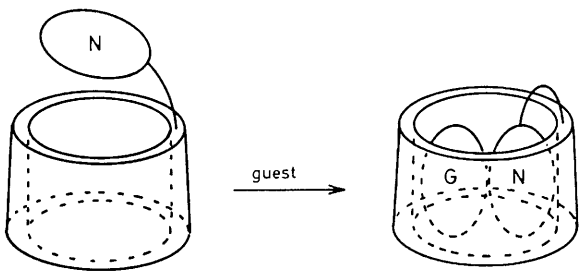
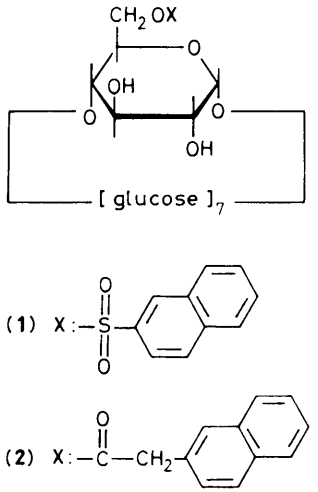


Figure 1. Induced-fit type of space regulation by the appended naphthalene moiety (N) for inclusion of a guest molecule (G) in the γ-CD cavity.



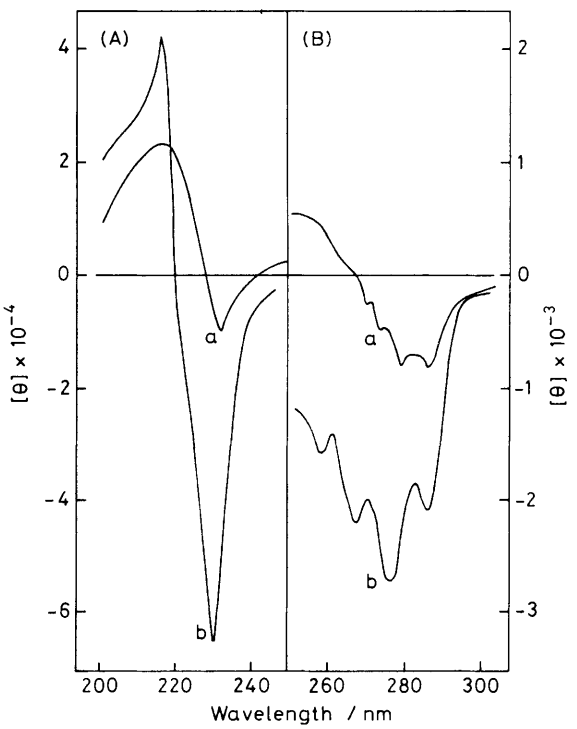


Figure 2. Circular dichroism spectra of (**2**) (A, 7.5 × 10^{-6} M; B, 1.5 × 10^{-4} M) in water at 25 °C, alone (a) or in the presence of cyclohexanol (b, 0.086 M).

† Synthetic and analytical details of compounds (**1**) [6-*O*-(2-naphthylsulphonyl)cyclo-octa-amylose] and (**2**) [6-*O*-(2-naphthylacetyl)cyclo-octa-amylose] will be reported elsewhere.

is sandwiched between the guest and the hydrophobic wall of γ-CD.

The different binding abilities of (**1**) and (**2**) suggest that the longer linkage of (**2**) between the naphthalene moiety and γ-CD facilitates the simultaneous involvement of the naphthalene moiety and a guest molecule in the cavity as shown by examination of Corey–Pauling–Koltun (CPK) molecular models. These models also show that the guests used here are too small to form any complex with γ-CD without such a space-regulating moiety. Therefore, the attachment of a space regulating moiety is important to enable complexes to be formed with molecules which are too small to complex with native γ-CD.

The idea of a space-regulating effect will obviously lead to the design of hydrophobic cavities of various sizes by changing the size of the appended moiety. Furthermore, unique catalytic reactions will become possible through face-to-face interactions between catalyst and substrate in the γ-CD cavity when the space-regulating moieties are replaced by various catalytic ones.

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