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Selective Arylation of β-Cyclodextrin with an Ethylenediamino Group and Characteristics of Arylated β-Cyclodextrin Derivatives in Host–Guest Complexation

AI-YOU HAO* and JI-MAO LIN
College of Chemistry, Shandong University, Jinan 250100, P.R. China.

LIN-HUI TONG
Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, P.R. China.

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Abstract. Mono-3-deoxy-(N'-benzoyl-ethylenediamino)-β-CD, mono-3-deoxy-(N'-benzylidene-ethylenediamino)-β-CD and mono-3-deoxy-(N'-salicylidene-ethylenediamino)-β-CD, each having a flexible chain that bonds the aryl moiety on the secondary side of β-CD, were prepared. The reaction processes might involve the formation of mono-(2,3-manno-epoxide)-β-CD as an intermediate under our reaction conditions. Further experiments showed that the aryl moiety which was bonded as a functional group on the primary side of β-CD or on the secondary side of β-CD with or without an ethylenediamino chain show remarkably different complexation properties in the complexation with small molecular guests such as alkanes, cycloketones etc.

Key words: selective arylation, flexible chain, host–guest complexation, β-cyclodextrin.

1. Introduction

Cyclodextrins (CDs, including α-, β-, γ-CD etc.) have gained prominence in recent years because their torus-shaped cavity, which is hydrophilic outside and hydrophobic inside, is ideal for constructing efficient artificial enzymes, molecular recognition sensors and other functional models [1–3]. For building more efficient artificial enzymes and molecular recognition sensors, we have prepared a series of β-CD derivatives bearing chromophores [3–6], including mono-2-*O*-benzoyl-β-CD (**E**), mono-3-O-benzoyl-β-CD (**F**) and mono-6-*O*-benzoyl-β-CD (**G**), and found [3, 5–7] that an aryl modification moiety could act as a spectroscopic probe as well as a functional group. For example [7], mono-(6-deoxy-6-monosalicylidene-polyethylenepolyamino)-β-CD, which has a flexible chain, could accept guest molecules during host–guest complexation, excellently simulating the 'induced fit' of enzymes.

* Author for correspondence.

Since models constructed by modeling the more open secondary side of CDs usually result in largely increased complexation ability, water solubility etc. [8], we prepared mono-3-deoxy-(N'-benzoyl-ethylenediamino)-β-CD (**A**), mono-3-deoxy-(N'-benzylidene-ethylenediamino)-β-CD (**B**) and mono-3-deoxy-(N'-salicylidene-ethylenediamino)-β-CD (**C**), each having a flexible chain that bonded the aryl moiety on the secondary side of β-CD. Further experiments showed that the aryl moiety which was bonded as a functional group on the primary side of β-CD, or on the secondary side of β-CD with or without an ethylenediamino chain shows remarkably different complexation properties in the complexation with small molecular guests such as alkanes, cycloketones etc. Furthermore, a hydroxyl substitution group on the aryl moiety could act as a recognition probe in host–guest complexation.

2. Experimental

2.1. MATERIALS AND INSTRUMENTS

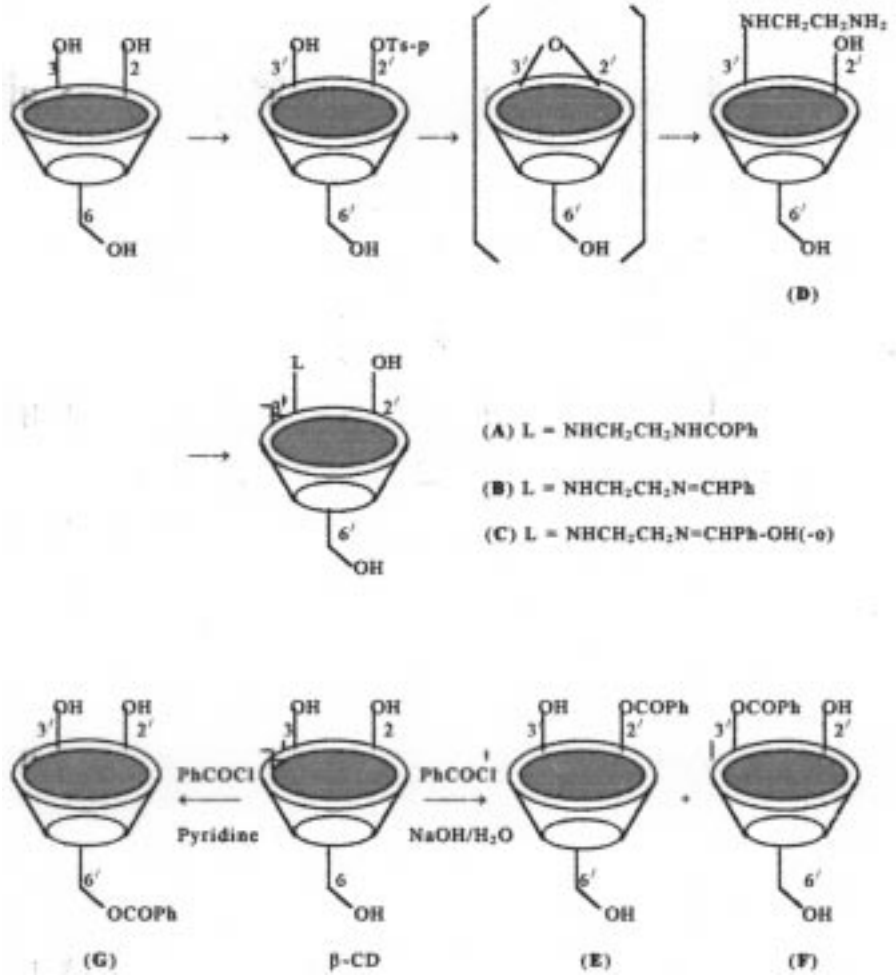
β-CD was a product of Suzhou Gourmet Powder Plant, China, recrystallized from water and dried for 4 h at 110–120 °C. *p*-Tosylchloride, ethylenediamine, benzoyl chloride, benzaldehyde, salicylic aldehyde, methanol, ethanol, acetonitrile, acetone and DMF etc. were analytical grade reagents, and were used directly. Guest molecules pentane, hexane, heptane, cyclopentanone, cyclohexanone and cycloheptanone were analytical grade reagents, and were distilled before use.

Carlo-Erba 1106 elemental analytical instrument; Bruker AM-400 NMR spectrometer (Me_4Si used as an internal reference in DMSO-d_6); German DC-Plastikfolien kieselgel60 F_{254} 0.2 mm silica TLC plates; Shimadzu UV-240 spectrophotometer.

2.2. PREPARATION OF THE HOSTS

Host compounds (**A**), (**B**) and (**C**) were prepared according to the route in Scheme 1.

10 mmol mono-2-*O*-*p*-tosyl-β-CD (prepared according to reference [9]) was dissolved in a solution of 30 mL ethylenediamine with 2 mL water. After stirring for 4 h at 80 °C under nitrogen, most of the ethylenediamine (about 28 mL) was evaporated at 80 °C in vacuo, and then a Sephadex G-25 column ($\Phi = 3.5 \times 50$ cm, distilled water eluent) was used with silica TLC as a monitor for the purity of the product (the eluent was PrOH—$CH_3COOC_2H_5$—H_2O, 4 : 3 : 2 vol.), to furnish pure mono-3-deoxy-ethylenediamino-β-CD (**D**) as a white solid. In order to obtain pure product, column chromatographic purification was repeated three or four times. Yield 19% (2.2 g). R_f = 0.10 (the eluent was PrOH—$CH_3COOC_2H_5$—NH_3 (28%)—H_2O, 3 : 3 : 3 : 2 vol.). δ_H: 5.90–5.52 (br, O(2)H, O(3)H); 5.05–5.02 (d, 1H, H-1′); 4.85–4.78 (m, 6H, H-1); 4.62–4.59 (m, O(6)H); 3.84–3.20 (m, 41H, H-2, 4, 6, 5, 3); 3.11–2.59 (m, 7H, H-3′, —CH_2CH_2—, —NH_2); 2.08 (s, 1H, —NH—)



Scheme 1. Preparation route of host compounds.

ppm. δ_C: 101.9 (C-1); 101.0, 100.5 (C-1′); 81.6 (C-4); 79.6 (C-4′); 73.0 (C-3); 72.4 (C-2); 72.1 (C-5); 71.8 (C-5′); 70.0 (C-2′); 61.0 (C-3′); 59.9 (C-6); 59.8 (C-6′); 39.2 (—$NHCH_2$—); 36.5 (—CH_2NH_2) ppm. *Anal. found:* C 42.35; H 6.48; N 2.36 (*calc.* for $C_{44}H_{76}O_{34}N_2 \cdot 4H_2O$: C 42.77; H 6.72; N 2.24).

Compound (**D**) (2.5 mmol) was dissolved in a solution of 40 mL newly distilled pyridine with 60 mL water, then 5 mmol benzoylchloride in 10 mL acetonitrile was added dropwise in 10 minutes. After stirring for 12 h, the reaction solution was evaporated to about 5 mL under 50 °C in vacuo, then a Sephadex G-25 column (Φ = 3.5 × 50 cm) was used as in the preparation of (**D**) to furnish pure (**A**) as a white solid. Yield 42% (1.34 g). R_f = 0.36 (the eluent was PrOH—$CH_3COOC_2H_5$—H_2O, 4 : 3 : 2 vol.). δ_H: 8.82 (s, 1H, —NHCO—); 8.10–7.41 (m, 5H, aromatic protons); 5.90–5.41 (br, O(2)H, O(3)H); 5.01–4.90 (d, 1H, H-1′); 4.80–4.58 (m,

12H, H-1, O(6)H); 4.14–3.12 (m, 46H, —CH_2CH_2—, H-2, 2′, 4, 4′, 6, 5, 5′, 3, 3′); 2.10 (s, 1H, —NH—) ppm. δ_C: 165.6 (—CO—); 144.4, 133.4, 129.5, 128.7 (aromatic carbons); 102.0 (C-1); 102.6, 100.0 (C-1′); 81.5 (C-4); 82.4, 79.2 (C-4′); 73.1 (C-3); 72.4 (C-2); 72.1 (C-5); 71.7 (C-5′); 69.1 (C-2′); 64.2 (C-3′); 59.9 (C-6); 59.6 (C-6′); 56.1 (—CH_2—NH—carbonyl linkage); 37.8 (—$NHCH_2$—) ppm *Anal. found:* C 45.35; H 6.29; N 2.12 (*calc.* for $C_{51}H_{80}O_{35}N_2 \cdot 4H_2O$: C 45.27; H 6.55; N 2.07).

Compound **D** (0.5 mmol) and 0.8 mmol benzaldehyde were dissolved in 10 mL DMF and stirred for 2 h. HCl solution of pH = 5 (2 mL) was added dropwise and stirred for another 2 h. The reaction solution was concentrated to about 5 mL under 50 °C in vacuo, and then a Sephadex G-25 column ($\Phi = 3.5 \times 50$ cm) was used as in the preparation of (**D**) to furnish pure (**B**) as a white solid. Yield 48% (0.30 g). R_f = 0.30 (the eluent was PrOH—$CH_3COOC_2H_5$—H_2O, 4 : 3 : 2 vol.). δ_H: 8.34 (s, 1H, —NHCO—); 7.75–7.35 (m, 5H, aromatic protons); 5.98–5.41 (br, O(2)H, O(3)H); 5.02–4.97 (m, 1H, H-1′); 4.84 (s, 6H, H-1); 4.11–3.02 (m, O(6)H, H-2, 2′, 4, 4′, 6, 5, 5′, 3, —CH_2CH_2—); 2.89–2.87 (m, 1H, H-3′); 1.89 (s, 1H, —NH—) ppm. δ_C: 162.1 (—CO—); 136.1, 130.7, 128.5, 127.7 (aromatic carbons); 102.0 (C-1); 100.7 (C-1′); 81.6 (C-4); 80.1 (C-4′); 73.1 (C-3); 72.5 (C-2); 72.1 (C-5); 71.8 (C-5′); 69.8 (C-2′); 62.5 (C-3′); 61.0 (—CH_2N=); 59.9 (C-6); 59.7 (C-6′); 38.9 (—$NHCH_2$—) ppm. *Anal. found:* C 46.98; H 6.52; N 2.08 (*calc.* for $C_{51}H_{80}O_{34}N_2 \cdot 2H_2O$: C 47.08; H 6.46; N 2.15).

Compound **D** (0.5 mmol) and 0.8 mmol salicyclic aldehyde were dissolved in 10 mL DMF, then the reaction was treated similarly to that of the preparation of (**B**) to get (**C**) as a white solid. Yield 46% (0.29 g). R_f = 0.24 (the eluent was PrOH—$CH_3COOC_2H_5$—H_2O, 4 : 3 : 2 vol.). δ_H: 8.56–7.55 (m, salicyl protons); 5.99–5.48 (br, O(2)H, O(3)H); 5.11–4.90 (m, 1H, H-1′); 4.80–4.44 (m, 12H, H-1, O(6)H); 3.97–2.98 (m, 46H, —CH_2CH_2—, H-2, 2′, 4, 4′, 6, 5, 5′, 3, 3′); 2.14 (s, 1H, —NH—) ppm. δ_C: 167.8 (—CO—); 162.9, 133.3, 129.0, 128.0, 127.7, 124.1 (salicyl carbons); 101.9 (C-1); 101.5, 101.0 (C-1′); 81.6 (C-4); 79.4 (C-4′); 73.0 (C-3); 72.5 (C-2); 72.1 (C-5); 71.7 (C-5′); 70.2 (C-2′); 60.8 (—CH_2N=); 60.5 (C-3′); 59.9 (C-6); 59.7 (C-6′); 36.7 (—$NHCH_2$—) ppm. *Anal. found:* C 45.61; H 6.62; N 2.02 (*calc.* for $C_{51}H_{80}O_{35}N_2 \cdot 4H_2O$: C 45.27; H 6.55; N 2.07).

Host compounds mono-2-*O*-benzoyl-β-CD (**E**), mono-3-*O*-benzoyl-β-CD (**F**) and mono-6-*O*-benzoyl-β-CD (**G**) were prepared according to references [4] and [5]. Their ^{1}H NMR, ^{13}C NMR as well as the elemental analysis data of (**E**), (**F**) and (**G**) conform exactly with those reported in references [4] and [5].

2.3. COMPLEXATION OF THE HOSTS WITH SMALL MOLECULAR GUESTS

The concentration $[H]_0$ of the host was fixed at 6.0×10^{-5} M in a water–methanol (3 : 1 v : v) solvent, in which the inclusion compounds of the host and guest molecules would be soluble. The absorption and difference absorption spectra were measured as a function of the concentration $[G]_0$ of a guest, such as cyclopen-

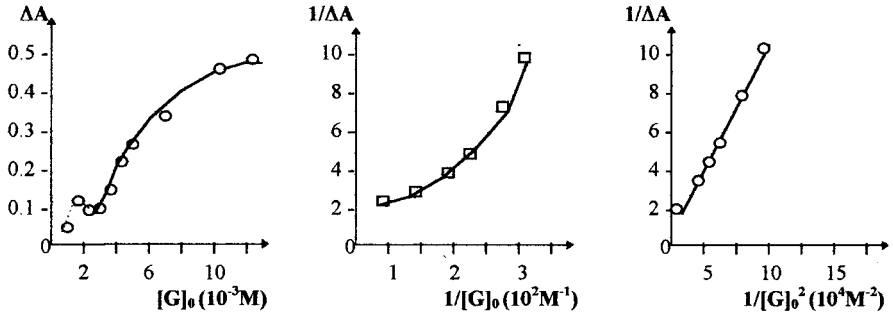


Figure 1. Difference absorption ΔA of 6.0×10^{-5} M mono-2-*O*-benzoyl-β-CD(**E**) in water–methanol (3 : 1 v : v) as a function of the concentration $[G]_0$ of hexane at 235.0 nm.

tanone, cyclohexanone, cycloheptanone, hexane, heptane, pentane etc. using host : guest concentration ratios of 1 : 10, 20, 30, ..., 200. Figure 1 shows the difference absorption, ΔA, of 6.0×10^{-5} M (**E**) as a function of the concentration of hexane at 235.0 nm in water–methanol (3 : 1 v : v) solvent.

3. Results and Discussion

3.1. THE STRUCTURE OF HOSTS (**A**), (**B**), (**C**) AND (**D**)

The reaction of mono-2*O*-*p*-tosyl-β-CD with ethylenediamine has two possible routes [11]: (i) obtaining mono-2-deoxy-ethylenediamino-β-CD by a direct S_N2 reaction; (ii) first forming the intermediate mono-(2,3-manno-epoxide)-β-CD from mono-2-*O*-*p*-tosyl-β-CD, then obtaining mono-3-deoxy-ethylenediamino-β-CD (**D**) by an S_N2 reaction of the intermediate with ethylenediamine. Comparison of the corresponding ^{13}C-NMR spectra of unsubstituted glucoses and the product molecule shows that the 1-carbon (C-1′) has a smaller chemical shift change than that of the 4-carbon (C-4′), which could be separated clearly from the other carbons. The modification of a hydroxyl group of CDs usually leads to a downfield chemical shift change of the carbon carrying the hydroxyl (α-carbon) but a smaller chemical shift change of the β-carbon and a still smaller shift of the γ-carbon [12]. It was clear that we obtained the 3-position modified product (**D**) by the second reaction route under our experimental conditions. Thus, the 3-carbon (C-3′) of the substituted glucose of the product has the largest chemical shift change, the 2-, 4- and 1-carbons (C-2′, C-4′ and C-1′) have relatively smaller chemical shift changes, and the 5- and 6-carbons (C-5′ and C-6′) have the smallest chemical shift changes (Table I). This may result from the fact that the direct S_N2 reaction route of mono-2-*O*-tosyl-β-CD with ethylenediamine needs a configurational reversion and this process requires a higher activation energy than that of the second reaction route.

Products (**A**), (**B**) and (**C**) prepared from (**D**) should also be 3-position modified products. Their structures conform with their ^{13}C-NMR spectra (Table I).

Table I. Some of the ^{13}C-NMR shifts ($\Delta\delta$ ppm) of the substituted glucose in the product molecules

	C-1	C-2	C-3	C-4	C-5	C-6
(**A**)	2.0	3.3	8.9	2.3	0.4	0.3
(**B**)	1.3	2.7	10.6	1.5	0.3	0.3
(**C**)	0.9	2.3	12.5	2.2	0.4	0.2
(**D**)	1.4	2.4	12.0	2.0	0.3	0.1

3.2. CHARACTERISTICS OF THE HOSTS IN HOST–GUEST COMPLEXATION

The observed difference absorption spectral changes of the host (**E**) in Figure 1 should arise from the changes of the guest concentration $[G]_0$, the guest–host molecular ratio n in the host–guest inclusion compound, and their complexation constant K_n.

$$H + H \overset{K_a}{\rightleftharpoons} H_2$$

$$H + G \overset{k'_1}{\rightleftharpoons} H\text{—}G$$

$$H\text{—}G + G \overset{k'_2}{\rightleftharpoons} H\text{—}2G$$

. . . . . .

$$H\text{—}(n-1)G + G \overset{k'_n}{\rightleftharpoons} H\text{—}nG.$$

The host–guest complexation constant $K_n = k'_1 \cdot k'_2, \ldots, k'_n$

$$= \frac{[H\text{—}nG]}{[H]\cdot[G]^n} = \frac{[H\text{—}nG]}{([H]_0 - [H\text{—}nG] - 2[H_2])\cdot([G]_0 - n[H\text{—}nG])^n}. \quad (1)$$

Where K_a is the association constant of the host; [H], [G], $[H_2]$ and [H—nG] are the corresponding concentrations of the host, the guest, the associated molecule H_2 and the inclusion compound H—nG in the complexation system. Since $[G]_0 \gg [H]_0$, $[H_2]$ and [H—nG] should be very small compared to $[H]_0$ and $[G]_0$ when n is not too large, thus:

$$K_n = \frac{[H\text{—}nG]}{([H]_0 - [H\text{—}nG])\cdot[G]_0^n} \quad (2)$$

$$\frac{1}{K_n} = \frac{[H]_0\cdot[G]_0^n}{[H\text{—}nG]} - [G]_0^n \quad (3)$$

Table II. Complexation abilities of the hosts and guests in water–methanol (3 : 1, v : v) [1 : n is the molecular ratio host : guest, and K_n is the complexation constant of the inclusion compound]

Host	Guest	Wavelength analyzed (nm)	$[G]_0/[H]_0$	$1:n$	K_n
	Cyclopentanone	234	>40	1 : 2	6.8×10^3 M^{-2}
	Cyclohexanone	234	>10	1 : 1	7.2×10^2 M^{-1}
(**A**)	Cycloheptanone	235	∼	1 : 1	6.9×10^2 M^{-1}
	Pentane	233	30 ∼ 100	1 : 2	1.0×10^4 M^{-2}
	Hexane	230	>30	1 : 2	8.2×10^3 M^{-2}
	Heptane	228	∼	1 : 1	8.8×10^2 M^{-1}
	Cyclopentanone	240	>30	1 : 2	8.5×10^3 M^{-2}
	Cyclohexanone	244	>20	1 : 1	7.8×10^2 M^{-1}
(**B**)	Cycloheptanone	246	∼	1 : 1	7.2×10^2 M^{-1}
	Pentane	240	30 ∼ 100	1 : 2	4.2×10^4 M^{-2}
	Hexane	246	20 ∼ 160	1 : 2	1.5×10^4 M^{-2}
	Heptane	242	∼	1 : 1	1.4×10^2 M^{-1}
	Cyclopentanone	232	>30	1 : 2	2.2×10^3 M^{-2}
	Cyclohexanone	234	∼	1 : 1	2.2×10^2 M^{-1}
(**C**)	Cycloheptanone	242	∼	1 : 1	1.9×10^2 M^{-1}
	Pentane	238	30 ∼ 100	1 : 2	6.2×10^3 M^{-1}
	Hexane	240	>40	1 : 2	4.8×10^3 M^{-2}
	Heptane	242	>20	1 : 2	3.7×10^3 M^{-2}
	Cyclopentanone	234	>20	1 : 2	7.8×10^3 M^{-2}
	Cyclohexanone	234	>40	1 : 2	3.8×10^3 M^{-2}
(**E**)	Cycloheptanone	234	∼	1 : 1	1.1×10^3 M^{-1}
	Pentane	236	40 ∼ 150	1 : 3	5.6×10^6 M^{-3}
	Hexane	235	>30	1 : 2	2.1×10^4 M^{-2}
	Heptane	236	>20	1 : 2	1.9×10^4 M^{-2}
	Cyclopentanone	232	>60	1 : 3	4.2×10^5 M^{-3}
	Cyclohexanone	232	>50	1 : 2	1.7×10^4 M^{-2}
(**F**)	Cycloheptanone	232	>50	1 : 2	3.8×10^4 M^{-2}
	Pentane	230	50 ∼ 120	1 : 3	1.8×10^5 M^{-3}
	Hexane	232	20 ∼ 140	1 : 2	6.1×10^3 M^{-2}
	Heptane	232	>50	1 : 2	6.8×10^3 M^{-2}
	Cyclopentanone	232	>20	1 : 2	4.2×10^4 M^{-2}
	Cyclohexanone	232	>50	1 : 2	3.8×10^4 M^{-2}
(**G**)	Cycloheptanone	234	>50	1 : 2	2.8×10^4 M^{-2}
	Pentane	236	20 ∼ 120	1 : 3	8.2×10^3 M^{-3}
	Hexane	232	>50	1 : 2	1.0×10^4 M^{-2}
	Heptane	232	>50	1 : 2	8.4×10^3 M^{-2}

Under the condition of $[G]_0 \gg [H]_0$, not only $[H_2]$ but also $[H]$ should be very small compared to $[H]_0$. On the other hand, the association of the host could not be significant under the same condition [10]. ϵ_H, ϵ_{H_2}, and ϵ_{H_n} are the corresponding absorbancy indexes of the host, the associated molecule H_2 and the inclusion compound H—nG in the complexation system; L is the thickness of the measuring cell; $[H]'$ and $[H_2]'$ are the concentrations of the host and the associated molecule H_2 before the guest is added. The difference absorption ΔA at a predetermined wavelength where the guest has no absorption is:

$$\begin{aligned} \Delta A &= (\epsilon_H[H] + \epsilon_{H_n}[H—nG] + \epsilon_{H_2}[H_2]) \cdot L - (\epsilon_H[H]' + \epsilon_{H_2}[H_2]') \cdot L \\ &\approx \epsilon_{H_n}[H—nG] \cdot L - \epsilon_H[H]' \cdot L \\ &\approx \Delta\epsilon \cdot [H—nG] \cdot L \end{aligned} \tag{4}$$

where $\Delta\epsilon = \epsilon_{H_n} - \epsilon_H$. Combining Equation (3) with (4):

$$\frac{1}{K_n} = \frac{\Delta\epsilon \cdot L \cdot [H]_0 \cdot [G]_0^n}{\Delta A} - [G]_0^n. \tag{5}$$

Assuming that $\Delta\epsilon \cdot L \cdot [H]_0 = \alpha$, which is a constant in the experimental condition, the equation relating the complexation constant K_n and the guest : host molecular ratio n in the host : guest inclusion compound is then:

$$\frac{1}{\Delta A} = \frac{1}{\alpha \cdot K_n} \cdot \frac{1}{[G]_0^n} + \frac{1}{\alpha}. \tag{6}$$

When $n = 1$, $1/\Delta A$ and $1/[G]_0$ are linearly correlated. This indicates the host and the guest form a 1 : 1 type inclusion compound with the corresponding complexation constant K_1.

From Figure 1, it can be seen that host (**E**) forms a 1 : 2 type inclusion compound with guest hexane in the range of >1 : 30 by concentration ratio of the host and guest, and the corresponding complexation constant K_2 could be calculated as 2.1 $\times 10^4$ M^{-2} according to Equation (6). When the host and guest concentration ratio is <1 : 30, it would be difficult to describe the complexation of the host (**E**) with the guest hexane, because it might be relatively easier for (**E**) to form the associated molecule [10] rather than mixed inclusion compounds of 1 : 1 type and 1 : 2 type with hexane at the same time in this experimental condition. When using pentane as the guest, the appropriate concentration range is 40–150 by concentration ratio of the host and guest, in which the difference absorption ΔA shows a regular change dependence on the concentration changes of pentane, indicating that (**E**) formed a 1 : 3 type inclusion compound with pentane.

The complexation constants of hosts (**A**), (**B**), (**C**), (**E**), (**F**) and (**G**) with the guests cyclopentanone, cyclohexanone, cycloheptanone, hexane, heptane, or pentane were calculated according to Equation (6) in a similar fashion (Table II).

Comparing the experimental data in Table II, the following results could be found.

(1) Hosts (**A**), (**B**) and (**C**) containing the aryl moieties in a chain show very different characteristics in comparison with hosts (**E**) and (**F**), particularly (**F**), in the host–guest complexation. For example, (**A**), (**B**) and (**C**) form a 1 : 2 type but (**E**) and (**F**) form 1 : 2 type inclusion compounds when using cyclohexanone as the guest. The aryl moieties in (**A**), (**B**) and (**C**) might act as a 'Wedge' which could get in and narrow the cavity of β-CD itself. The aryl moieties in (**E**) and (**F**) prefer to act as a 'Cap' at the opening of β-CD which could enlarge the hydrophobic cavity of β-CD itself. Wedged hosts tend to form inclusion compounds with a relatively small n value with guests, but capped hosts tend to form inclusion compounds with a relatively large n value with guests. Furthermore, when the hosts and guests form inclusion compounds with the same n value, the complexation constants of the wedged hosts decrease but those of the capped hosts usually increase with the increasing stereo bulk of the guests.

(2) When different aryl moieties were bonded on the same position of β-CD by the same method, the aryl moieties could show different characteristics in the host–guest complexation. For example, (**A**) and (**B**) form a 1 : 1 type but (**C**) forms a 1 : 2 type inclusion compound when using heptane as the guest. Compared with the benzoyl moiety in (**A**) or the benzylidene moiety in (**B**), the salicylidene moiety in (**C**) might show some capped action because of its α-hydroxyl group which could retard the aryl moiety getting into the hydrophobic cavity of β-CD itself

(3) When the same aryl moiety was bonded on the different positions of β-CD, the aryl moiety could also show different characteristics in the host–guest complexation. For example, though (**E**), (**F**) and (**G**) form the same 1 : 2 type inclusion compound when using hexane or heptane as the guest, the complexation constants of (**E**) and (**G**) decrease but those of (**F**) increase with the increasing stereo bulk of the guests. Compared with the benzoyl moiety bonded on the 3-position of β-CD in (**F**), which prefers to act as a cap, the benzoyl moiety bonded on the 2-position of β-CD in (**E**) or bonded on the 6-position of β-CD in (**G**) shows some wedge action, particularly the benzoyl moiety in (**G**), which has a much greater tendency to show a wedge action. The results above might be based on the different stereo structures of the benzoyl moiety on β-CD: the benzoyl moiety in (**E**) or (**G**) in some way could get into the cavity of β-CD itself, but the benzoyl moiety in (**F**) could hardly get into the cavity of β-CD itself because the 3-hydroxyl bond joined to the benzoyl moiety is further away from the opening of β-CD itself in comparison with the 2- and 6-hydroxyl bonds.

(4) The aryl moieties with a chain in hosts (**A**), (**B**) and (**C**) might show some 'induced fit' action when the hydrophobic guests enter the β-CD cavity of the hosts in the host–guest complexation. For example, when the host and guest concentration ratio is $<1:30$ in the complexation of (**A**) with hexane, it might firstly form an inclusion compound of the 1 : 1 type with part of the aryl moiety of the host included in the cavity of β-CD itself. However, when the host and guest

concentration ratio is $>1:30$, the aryl moiety of the host would then leave the cavity of β-CD itself and act in some way as a cap on the opening of β-CD which could enlarge its cavity effectively, and at the same time the other guest molecules would be included in the enlarged cavity of the host. This characteristic might be used for building enzyme models which have an ability to self-assemble.

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