# Synthesis of novel modified β-cyclodextrins and their fluorescence studies of inclusion complexation with Rhodamine B

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**Three novel β-cyclodextrin derivatives have been synthesized and their inclusion complexation behavior with Rhodamine B (RhB) was investigated by the fluorescence spectroscopy.**

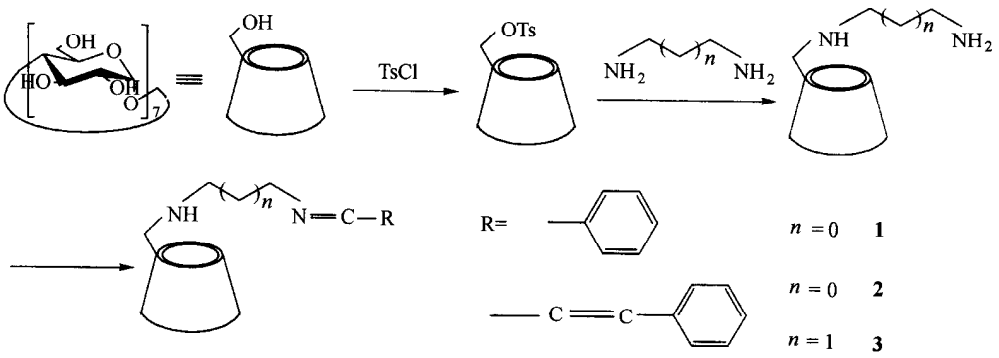
**Keywords** β-Cyclodextrin derivatives, Rhodamine B, inclusion complexation

## Introduction

One of the most important properties of cyclodextrins (CDs) is its ability to form inclusion complexes with a variety of organic compounds via molecular recognition.[1] To improve the original molecular binding abilities of the native CDs, a great deal of effort has been concentrated on the design and syntheses of novel CD derivatives in recent years.[2] It has been demonstrated that several weak interactions, including van der Waals, hydrophobic, electrostatics dipole-dipole, and hydrogen bonding interactions, cooperatively govern the inclusion complexation behavior of CDs hosts. We have reported the syntheses and molecular recognition of a series of modified CDs in the previous study and found that the type of substituent introduced to CDs drastically affects the molecular binding ability and selectivity.[3,4]

In order to further study the effects of the sidearm chain attached to β-CD on the inclusion complexation of β-CD with the guests, as well as improve our understanding of several weak interactions between them, we report our study on the syntheses and inclusion complexation of the novel β-cyclodextrin derivatives, *i.e.* mono-[6-[[(benzylideneamino) ethyl] amino]-6-deoxy]-β-cyclodextrin (**1**), mono-[6-[[(cinnamylideneamino)-ethyl] amino]-6-deoxy]-β-cyclodextrin (**2**), and mono-[6-[[(cinnamylideneamino) propyl] amino]-6-deoxy]-β-cyclodextrin (**3**), shown in Scheme 1.

**Scheme 1**

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The inclusion complexation behavior of three modified β-cyclodextrins with Rhodamine B (RhB) was studied in phosphate buffer solution (pH 7.20, methanol: water($V/V$) = 1:2) by the fluorescence spectroscopy.

## Experimental

*Synthesis*

Mono-(6-*O*-tolylsulfonyl)-β-cyclodextrin (6-OTs-β-CD) was synthesized as reported recently.[5] Three novel β-CD derivatives (**1**—**3**) were prepared according to the synthetic route shown in Scheme 1.

**1** $\nu_{max}$: 3401, 2927, 1636, 1598, 1560, 1387, 1300, 1254, 1156, 1079, 1032, 945, 756, 704, 580 $cm^{-1}$. $\lambda_{max}$ ($CH_3OH$: $H_2O$ = 1:2) ($\varepsilon$/$dm^3 \cdot mol^{-1} \cdot cm^{-1}$): 305(4100) nm. $\delta_H$($D_2O$, TMS): 2.65—3.17(m, 4H), 3.53—3.77(m, 42H), 4.98(s, 7H), 7.45—7.87(m, 6H). Anal. $C_{51}H_{80}O_{34}N_2 \cdot 5H_2O$. Calcd: C, 45.2; H, 6.69; N, 2.06. Found: C, 44.98; H, 7.12; N, 1.94.

**2** $\nu_{max}$: 3412, 2929, 1637, 1561, 1410, 1335, 1246, 1155, 1080, 1032, 946, 849, 755, 704, 580 $cm^{-1}$. $\lambda_{max}$ ($CH_3OH$: $H_2O$ = 1:2) ($\varepsilon$/$dm^3 \cdot mol^{-1} \cdot cm^{-1}$): 290(6258) nm. $\delta_H$($D_2O$, TMS): 2.67—3.15(m, 4H), 3.44—3.67(m, 42H), 4.97(s, 7H), 6.80—7.39(m, 8H). Anal. $C_{53}H_{82}O_{34}N_2 \cdot 4H_2O$. Calcd: C, 46.69; H, 6.65; N, 2.05. Found: C, 46.57; H, 7.15; N, 2.31.

**3** $\nu_{max}$: 3400, 2929, 1686, 1639, 1406, 1370, 1331, 1238, 1156, 1079, 1031, 945, 756, 704, 578 $cm^{-1}$. $\lambda_{max}$ ($CH_3OH$: $H_2O$ = 1:2) ($\varepsilon$/$dm^3 \cdot mol^{-1} \cdot cm^{-1}$): 292(4348) nm. $\delta_H$($D_2O$, TMS): 2.83(m, 6H), 3.62—3.90(m, 42H), 5.03(s, 7H), 6.80—7.70(m, 8H). Anal. $C_{54}H_{84}O_{34}N_2 \cdot 4H_2O$. Calcd: C, 47.09; H, 6.73; N, 2.03. Found: C, 46.71; H, 7.13; N, 2.08.

*Fluorescence measurements*

Fluorescence spectra were measured using a JASCO FP-750 spectrofluorometer in a conventional 1 × 1 cm quartz cell at 25℃ in an air-conditioned room. The excitation and emission slits were 5 nm. The sample solutions with $1.0 \times 10^{-5}$ mol·$dm^{-3}$ of RhB were excited at 540 nm.

## Results and discussion

As shown in Scheme 1, the modified cyclodextrins (**1**—**3**) were synthesized starting from 6-*O*-monotosylcyclodextrin and characterized by $^1$H NMR, FT-IR, UV-visible spectrometry and elementary analysis.

In the fluorescence experiments, the emission intensity of RhB gradually decreased upon the addition of varying concentration of β-CDs.

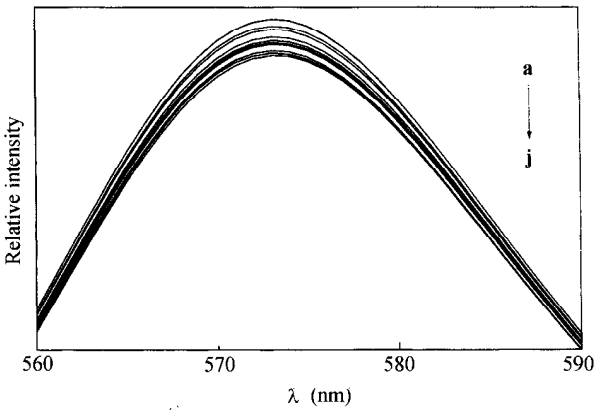


**Fig. 1** Fluorescence spectra of RhB ($1.0 \times 10^{-5}$ mol/L) in phosphate buffer solution (pH 7.20) in the presence of **1** at various concentrations, which increase in the range of 0—$2.8 \times 10^{-4}$ mol/L from **a** to **j**. The excitation wavelength was 540 nm.

Fig. 1 shows the fluorescence spectral changes of RhB with increasing β-CD derivative **1**. These results indicated that inclusion complexes have been formed by complexation of the modified β-CD with RhB.[6] Meanwhile, this fluorescence spectral change can be used to determine the complex stability constants.[7] Table 1 shows the binding constants of the inclusion complexation

**Table 1** Stability constants ($K_s$) and the free-energy change ($-\Delta G°$, J·$mol^{-1}$) for the inclusion complexation of the modified β-CD (**1**—**3**) with RhB in the phosphate buffer (pH = 7.2)[a]

| Host | $K_s$ | $-\Delta G°$ |
|---|---|---|
| **1** | 1169 | 17472 |
| **2** | 1352 | 17848 |
| **3** | 1970 | 18768 |

[a] The $K_s$ values are the average of two or three independent runs: error < 5% of the reported values.

of the modified β-CDs **1**, **2** and **3** with RhB. The data indicate that the binding ability of **1**—**3** is different, and the inclusion complexation with β-CD derivative **3** gives the biggest binding constant for the guests used. Among the β-CD derivatives of **1**, **2** and **3**, the benzene moiety is linked to the β-CD through a flexible chain, and the length of the flexible chain is **3** > **2** > **1**. From the viewpoint above, we considered that these β-CD derivatives offered the different microenvironment upon guest addition, and resulted in the different binding ability. It was shown that the length of the sidearm chain attached to the edge of β-CD appeared to be the predominant factor that determines the binding ability of guest by β-CD derivatives. The detailed study of inclusion behavior is in progress.

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