Electronic Supplementary Information of

Thermosensitive Hydrogels Composed of Cyclodextrin Pseudorotaxanes. Role of [3]Pseudorotaxane in the Gel Formation

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Experimental Section

General. Cl(CH2)10OC6H3-3,5-(OMe)2 was prepared by the literature method. Other chemicals were commercially available. NMR spectra (1H, 13C {1H}) were recorded on Varian MERCURY300 spectrometer, JEOL EX-400 spectrometer or JEOL JNM La-500 spectrometer. 13C CP/MAS NMR spectra were recorded on JEOL JNM La-500. Fast atom bombardment mass spectra (FABMS) were obtained from a JEOL JMS-700 (matrix, (2-nitrophenyl)(n-octyl) ether (NPOE) or 3-nitrobenzyl alcohol (NBA)) spectrometer. Matrix assisted laser desorption ionization time of flight mass spectra (MALDI-TOFMS) were obtained from a Shimadzu AXIMA-CFR Plus (matrix, 2-hydroxy-5-methoxybenzoic acid (super DHB); cationization agent, silver trifluoroacetate) spectrometer. Elemental analyses were carried out with a Yanaco MT-5 CHN autorecorder. The absorption spectrum were recorded using JASCO V-530 UV/Vis spectrometer. Before measuring, the samples were stored at an adequate temperature using a JASCO EHC-477 peltire-type thermostated cell holder.

Cl(CH2)3OC6H3-3,5-(OMe)2: A solution of 3,5-dimethoxyphenol (8.0 g, 52 mmol) and NaOH (3.2 g, 80 mmol) in DMF (35 mL) was stirred for 8 h at room temperature, followed by the addition of 1,8-dichlorooctane (18.0 mL, 95 mmol). The mixture was stirred for 24 h at 110 °C. The reaction was quenched by addition of 1 M HCl, and the organic product was extracted with CH2Cl2 and dried over MgSO4. Evaporation of the solvent give a crude product which was
purified by SiO$_2$ column chromatography (hexane/CH$_2$Cl$_2$ = 5/1). Further purification of the product by recrystallization from solution at 3 °C and washing with cold hexane yield Cl(CH$_2$)$_8$C$_6$H$_3$-3,5-(OMe)$_2$ as white solid (1.67 g, 5.6 mmol, 11%). $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ 1.24–1.57 (8H, CH$_2$), 1.69–1.85 (4H, CH$_2$), 3.54 (t, 2H, $J$ = 7 Hz, ClCH$_2$), 3.77 (s, 6H, OCH$_3$), 3.91 (t, 2H, $J$ = 6 Hz, OCH$_2$), 6.08 (3H, ortho-, para-C$_6$H$_3$). $^{13}$C{$^1$H} NMR (75.5 MHz, CDCl$_3$): $\delta$ 25.8 (CH$_2$), 26.7 (CH$_2$), 28.7 (CH$_2$), 29.0 (CH$_2$), 29.1 (CH$_2$), 32.5 (CH$_2$), 44.9 (ClCH$_2$), 55.1 (OCH$_3$), 67.7 (OCH$_2$), 92.6 (C$_6$H$_3$), 93.1 (C$_6$H$_3$), 160.9 (C$_6$H$_3$), 161.3 (C$_6$H$_3$).

Anal. calcd. for C$_{16}$H$_{25}$ClO$_3$: C, 63.88; H, 8.38; Cl, 11.79. Found: C, 63.59; H, 8.62; Cl, 12.08. FABMS: $m/z$ = 301 [M+H]$^+$. 

Br(CH$_2$)$_{12}$OC$_6$H$_3$-3,5-(OMe)$_2$: An acetone (30 mL) solution containing 3,5-dimethoxyphenol (4.1 g, 27 mmol), K$_2$CO$_3$ (3.4 g, 25 mmol) and 1,12-dibromododecane (17 g, 52 mmol) was refluxed for 21 h. Evaporation of the solvent give a crude product which was purified by SiO$_2$ column chromatography (hexane/CH$_2$Cl$_2$ = 2/1) to yields Br(CH$_2$)$_{12}$OC$_6$H$_3$-3,5-(OMe)$_2$ as white solid (6.0 g, 15 mmol, 56%). $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ 1.19–1.51 (16H, CH$_2$), 1.76 (m, 2H, OCH$_2$CH$_2$), 1.85 (m, 2H, BrCH$_2$CH$_2$), 3.40 (t, 2H, $J$ = 7 Hz, ClCH$_2$), 3.76 (s, 6H, OCH$_3$), 3.91 (t, 2H, $J$ = 6 Hz, OCH$_2$), 6.08 (3H, ortho-, para-C$_6$H$_3$). $^{13}$C{$^1$H} NMR (75.5 MHz, CDCl$_3$): $\delta$ 26.0 (CH$_2$), 28.1 (CH$_2$), 28.7 (CH$_2$), 29.2 (2C, CH$_2$), 29.3 (CH$_2$), 29.4 (2C, CH$_2$), 29.5 (2C, CH$_2$), 32.8 (CH$_2$), 34.0 (BrCH$_2$), 55.2 (OCH$_3$), 67.9 (OCH$_2$), 92.7 (C$_6$H$_3$), 93.2 (C$_6$H$_3$), 161.0 (C$_6$H$_3$), 161.4 (C$_6$H$_3$). Anal. calcd. for C$_{20}$H$_{33}$BrO$_3$+0.25(H$_2$O): C, 59.18; H, 8.32; Br, 19.69. Found: C, 59.43; H, 8.39; Br, 19.48. FABMS: $m/z$ = 401 [M+H]$^+$. 

[py-N-(CH$_2$)$_8$OC$_6$H$_3$-3,5-(OMe)$_2$]$^+(Cl^-)$ (1a): A DMF solution (5 mL) of Cl(CH$_2$)$_8$OC$_6$H$_3$-3,5-(OMe)$_2$ (1.0 g, 3.3 mmol) and pyridine (1.3 mL, 16 mmol) was stirred at 110 °C for 27 h. The solution was poured into di ethyl ether (200 mL). The precipitate was collected by filtration and washed with diethyl ether to yield 1a as a white solid (1.27 g, 3.3 mmol, quant.). $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ 1.18–1.39 (8H, CH$_2$), 1.62 (m, 2H, CH$_2$), 1.95 (m, 2H, CH$_2$), 3.66 (s, 6H, OCH$_3$), 3.78 (t, 2H, $J$ = 6 Hz, OCH$_2$), 4.88 (t, 2H, $J$ = 7 Hz, NCH$_2$), 5.96 (3H, ortho-, para-C$_6$H$_3$), 8.07 (t, 2H, $J$ = 7 Hz, C$_5$H$_5$N), 8.42 (t, 1H, $J$ = 7 Hz, C$_5$H$_5$N), 9.44 (d, 2H, $J$ = 7 Hz, C$_5$H$_5$N). $^{13}$C{$^1$H} NMR (75.5 MHz, CDCl$_3$): $\delta$ 25.6 (CH$_2$), 25.7 (CH$_2$), 28.7 (CH$_2$), 28.8 (CH$_2$), 28.9 (CH$_2$), 31.7 (CH$_2$), 55.1 (OCH$_3$), 61.7 (NCH$_2$), 67.6 (OCH$_2$), 92.6 (ortho-C$_6$H$_3$), 93.1 (para-C$_6$H$_3$), 128.3 (C$_5$H$_5$N), 144.9 (C$_5$H$_5$N), 145.0 (C$_5$H$_5$N), 160.7 (meta-C$_6$H$_3$), 161.2 (ipso-C$_6$H$_3$). Anal. calcd. for C$_{21}$H$_{30}$ClNO$_3$+(H$_2$O): C, 63.38; H, 8.11; N, 3.52; Cl, 8.91. Found: C, 63.45; H, 8.21; N, 3.59; Cl, 9.31. FABMS: $m/z$ = 344 [M-Cl]$^+$. 

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[py-N-(CH2)10OC6H3-3,5-(OMe)2]+(Cl-) (1b): A DMF solution (10 mL) of Cl(CH2)10OC6H3-3,5-(OMe)2 (2.1 g, 6.4 mmol) and pyridine (2.5 mL, 31 mmol) was stirred at 110 °C for 24 h. The solution was poured into diethyl ether (200 mL). The precipitate was collected by filtration and wash with diethyl ether to yield 1b as a white solid (2.0 g, 4.9 mmol, 77%). 1H NMR (300 MHz, DMSO-d6): δ 1.20–1.42 (12H, CH2), 1.65 (m, 2H, CH2), 1.89 (m, 2H, CH2), 3.68 (s, 6H, OCH3), 3.88 (t, 2H, J = 6 Hz, OCH2), 4.57 (t, 2H, J = 7 Hz, NCH2), 6.05 (3H, ortho-, para-C6H3), 8.14 (t, 2H, J = 8 Hz, C5H5N), 8.59 (t, 1H, J = 8 Hz, C5H5N), 9.08 (d, 2H, J = 6 Hz, C5H5N). 13C{1H} NMR (75.5 MHz, DMSO-d6): δ 25.5 (CH2), 25.6 (CH2), 28.5 (CH2), 28.7 (CH2), 28.8 (2CH2), 28.9 (CH2), 30.9 (CH2), 55.2 (OCH3), 60.6 (NCH2), 67.4 (OCH2), 92.7 (ortho-C6H3), 93.2 (para-C6H3), 128.1 (C5H5N), 144.9 (C5H5N), 145.5 (C5H5N), 160.6 (meta-C6H3), 161.2 (ipso-C6H3). Anal. calcd. for C23H34ClNO3+1.3(H2O): C, 64.04; H, 8.55; N, 3.25. Found: C, 63.95; H, 8.71; N, 3.32. FABMS: m/z = 372 [M-Cl]+.

[py-N-(CH2)12OC6H3-3,5-(OMe)2]+(Br-) (1c): A DMF solution (20 mL) of Br(CH2)12OC6H3-3,5-(OMe)2 (3.0 g, 7.5 mmol) and pyridine (3.0 mL, 39 mmol) was stirred at 110 °C for 16 h. The solution was poured into diethyl ether (300 mL). The precipitate was collected by filtration and wash with diethyl ether to yield 1c as a white solid (3.5 g, 7.3 mmol, 97%). 1H NMR (300 MHz, CDCl3): δ 1.11–1.40 (16H, CH2), 1.65 (m, 2H, CH2), 1.97 (m, 2H, CH2), 3.67 (s, 6H, OCH3), 3.81 (t, 2H, J = 6 Hz, OCH2), 4.91 (t, 2H, J = 7 Hz, NCH2), 5.97 (3H, ortho-, para-C6H3), 8.09 (t, 2H, J = 7 Hz, C5H5N), 8.45 (t, 1H, J = 7 Hz, C5H5N), 9.50 (d, 2H, J = 6 Hz, C5H5N). 13C{1H} NMR (75.5 MHz, CDCl3): δ 25.7 (CH2), 25.8 (CH2), 28.8 (CH2), 28.9 (CH2), 29.1 (2C, CH2), 29.2 (3C, CH2), 31.8 (CH2), 55.1 (OCH3), 61.7 (NCH2), 67.8 (OCH2), 92.5 (ortho-C6H3), 93.1 (para-C6H3), 128.3 (C5H5N), 144.9 (2C, C5H5N), 160.8 (meta-C6H3), 161.2 (ipso-C6H3). Anal. calcd. for C25H38BrNO3+0.25(H2O): C, 64.04; H, 8.55; N, 3.25. Found: C, 61.82; H, 8.11; N, 2.93; Br, 16.48. FABMS: m/z = 400 [M-Br]+.

**Xerogel of 1b and α-CD:** A H2O solution (5 mL) of 1b (220 mg, 0.5 mmol) and α-CD (1.0 g, 1.0 mmol) was stirred at 70 °C for 20 min. The solution was cooled to 4 °C for 32 h gave hydrogel. Addition of acetone (5 mL) to the hydrogel formed white precipitate. The precipitate was collected by filtration and washed with acetone (30 ml) to yield xerogel as a white solid. The xerogel was also obtained by slow evaporation of the hydrogel.

**The reaction of urea with hydrogel containing 1b and α-CD:** Heating of an aqueous solution of 1b (14 mg, 0.04 mmol) and α-CD (68 mg, 0.07 mmol) at 60 °C and subsequent cooling to room temperature gave hydrogel. Addition of urea (64 mg, 1.1 mmol) to the hydrogel and heating at 60 °C. The solution was cooled to room temperature to give transparent solution.
1. $^{13}$C CP/MAS NMR spectra of Xerogel of 1b and $\alpha$-CD

Figure S1. $^{13}$C CP/MAS NMR spectra (100 MHz, RT) of (a) $\alpha$-CD, (b) xerogel of 1b and $\alpha$-CD, and (c) 1b. Peaks with an asterisk are assigned to C-1 and C-4 with a conformationally strained glycoside linkage.
2. 2D ROESY $^1$H NMR Spectrum of 1b and α-CD

Figure S2. 2D ROESY $^1$H NMR spectrum (500 MHz, 30 °C) of 1b (100 mM) and α-CD (50 mM) in D$_2$O (mixing time = 400 ms).

Reference