

Electronic supplementary information

Synthesis of a cationic water-soluble pillar[6]arene and its effective complexation towards naphthalenesulfonate guests

Wei Chen, Yanyan Zhang, Jian Li, Xiaobing Lou, Yihua Yu, Xueshun Jia* and
Chunju Li,*

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Materials and methods.

General Experimental Procedures. Fluorescence titrations were measured in a conventional rectangular quartz cell ($10 \times 10 \times 45 \text{ mm}^3$) with the excitation and emission slits at a width of 5 nm on a Shimadzu spectrofluorometer model FP-5301PC, which was kept at 25 °C through a temperature controller. The excitation wavelengths for 2,6-NDS and 2-NS were 302 nm and 275 nm, respectively. ^1H NMR, ^{13}C NMR, and 2D ROESY spectra were recorded on a 500 MHz NMR instrument. Mass spectra were performed on a Bruker MicroTOF II spectrometer.

Materials. All commercial reagents were used as purchased from commercial sources without further purification. The phosphate buffer solution of pH 7.2 was prepared by dissolving disodium hydrogen phosphate (25.79 g) and sodium dihydrogen phosphate (4.37 g) in distilled, deionized water (1000 mL) to make a 0.1 mol dm^3 solution. The pH value of the buffer solution was verified on a pH-meter calibrated with two standard buffer solutions. Compounds **3** were prepared according to previously reported procedures.^[S1]

Synthesis and characterization of compounds.

Synthesis of compound **2** and **2'**.

To a solution of **3** (3.0g, 8.0 mmol) in chloroform (150 mL), paraformaldehyde (0.48 g, 16 mmol) and Boron trifluoride etherate (2.3 g, 16 mmol) were added under argon atmosphere. The mixture was then stirred at 25 °C for about 2 hours. The reaction mixture was then washed with water and dried with Na₂SO₄. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel (petroleum ether/CH₂Cl₂) to afford pillar[6]arene **2** (0.45g) and pillar[5]arene **2'** (0.85g).

Pillar[6]arene **2**. Colorless oil, yield: 15%. ¹H NMR (500 MHz, CDCl₃): δ (ppm) = 6.67 (s, 12H), 3.81 (t, *J* = 6.0 Hz, 24H), 3.79 (s, 12H), 3.39 (t, *J* = 6.5 Hz, 24H), 1.96 (m, 24H), 1.83 (m, 24H); ¹³C NMR (CDCl₃, 125 MHz): δ (ppm): 150.4, 127.9, 114.9, 67.7, 33.9, 30.9, 29.6, 28.3; HRMS (ESI-TOF): *m/z* calcd for [C₉₀H₁₂₀O₁₂Br₁₂Na]⁺: 2374.8755; found 2374.8779.

Pillar[5]arene **2'** Colorless solid, yield: 27%. Mp: 91–92 °C. ¹H NMR (500 MHz, CDCl₃): δ (ppm) = 6.83 (s, 10H), 3.95 (t, *J* = 5.7 Hz, 20H), 3.78 (s, 10H), 3.46 (t, *J* = 6.6 Hz, 20H), 2.07 (m, 20H), 1.94 (m, 20H); ¹³C NMR (CDCl₃, 125 MHz): δ (ppm): 149.8, 128.3, 115.0, 67.6, 33.8, 29.8, 29.6, 28.5; HRMS (ESI-TOF): *m/z* calcd for [C₇₅H₁₀₀O₁₀Br₁₀Na]⁺: 1982.8946; found 1982.8962.

Synthesis of compound 1.

A solution of **2** (1.2 g, 0.50 mmol) and pyridine (1.2 g, 15 mmol) in CH₃CN (50 ml) was refluxed for 25 hours. The precipitate was then filtered, washed with CH₃CN and dried to give a light yellow solid **1** (1.5 g, 91 %). Mp: 165–167 °C. ¹H NMR (500 MHz, D₂O): δ (ppm) = 8.65 (s, 24H), 8.48 (t, *J* = 7.7 Hz, 12H), 7.94 (s, 24H), 6.61 (s, 12H), 4.51 (s, 24H), 3.80 (s, 24H), 3.70 (s, 12H), 2.07 (s, 24H), 1.73 (s, 24H); ¹³C NMR (D₂O, 125 MHz): δ (ppm): 149.8, 145.7, 144.0, 128.6, 128.2, 116.1, 68.3, 61.4, 30.5, 27.3, 25.4; HRMS (ESI-TOF): *m/z* calcd for [M – 2Br]²⁺: 1570.7805; found 1570.7780; *m/z* calcd for [M – 3Br]³⁺: 1020.2149; found 1020.2184. Elem Anal. Calcd for C₁₅₀H₁₈₀O₁₂Br₁₂N₁₂·H₂O: C 54.27, H 5.53, N 5.06. Found: C 54.19, H 5.60, N 4.98.

Copies of ^1H NMR and ^{13}C NMR spectra of 1–3.

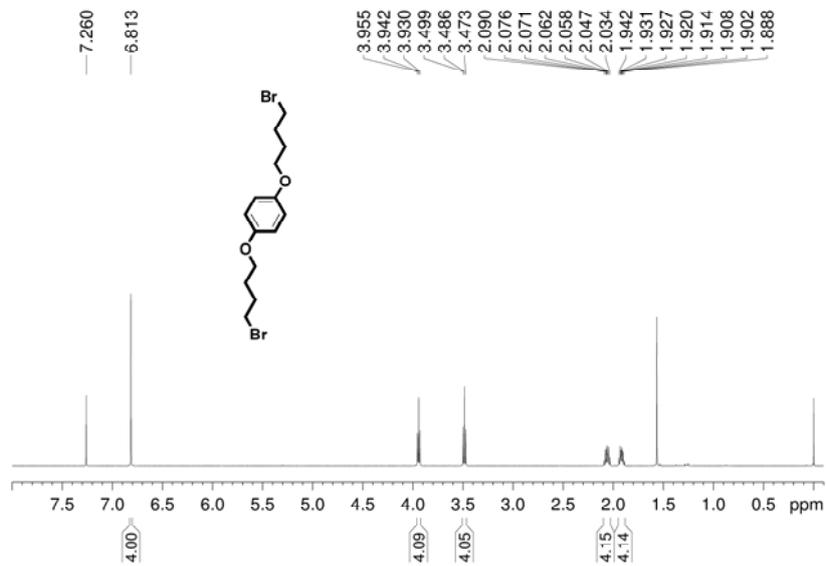


Figure S1. ^1H NMR spectrum (500 MHz) of 3 in CDCl_3 .

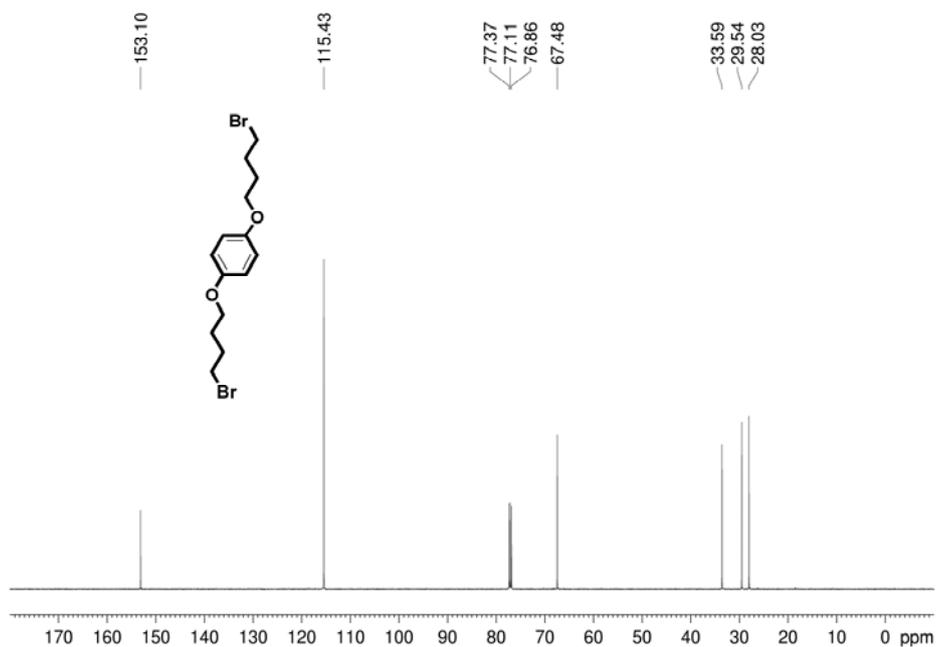
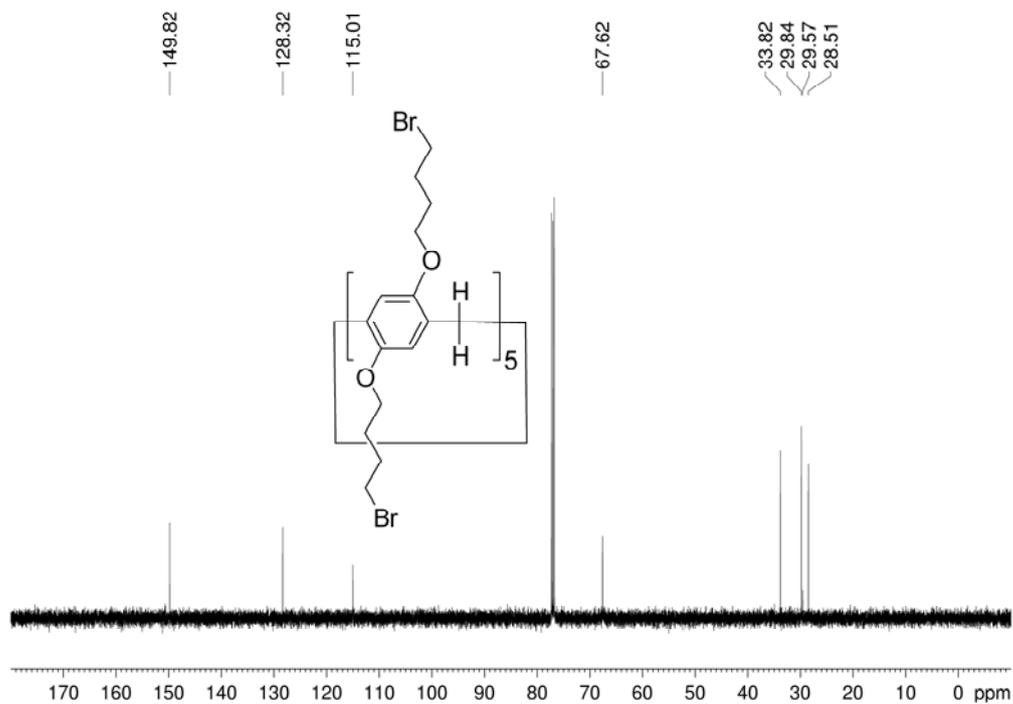
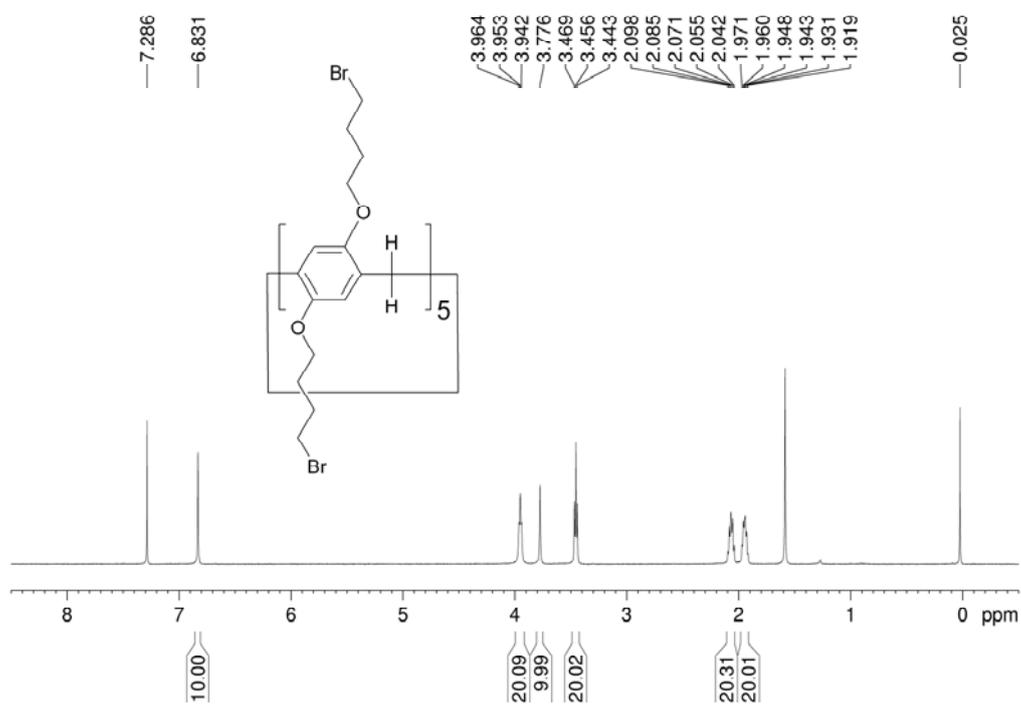


Figure S2. ^{13}C NMR spectrum (125 MHz) of 3 in CDCl_3 .



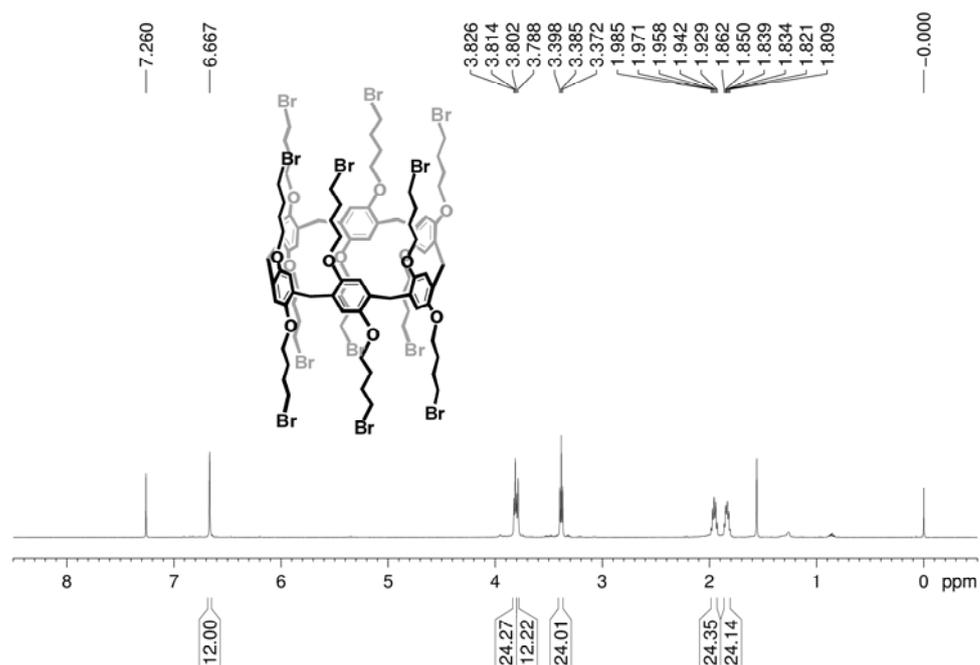


Figure S5. ^1H NMR spectrum (500 MHz) of **2** in CDCl_3 .

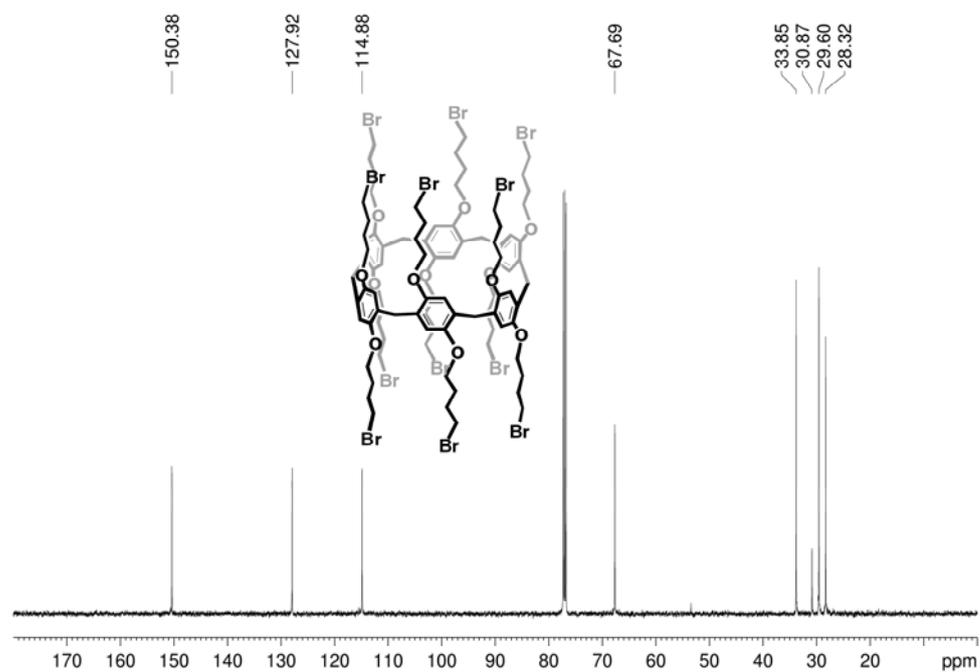


Figure S6. ^{13}C NMR spectrum (125 MHz) of **2** in CDCl_3 .

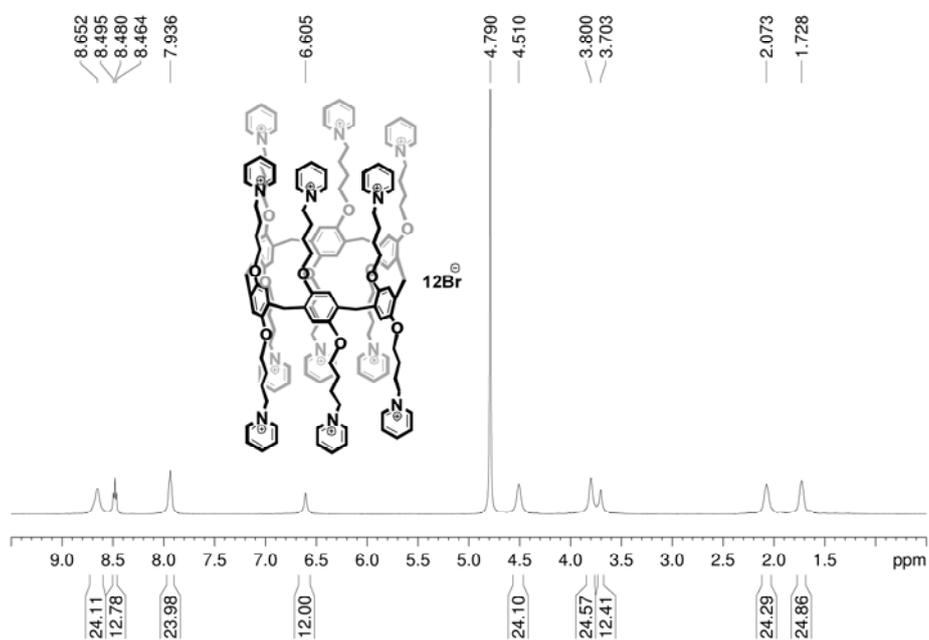


Figure S7. ¹H NMR spectrum (500 MHz) of **1** in CDCl₃.

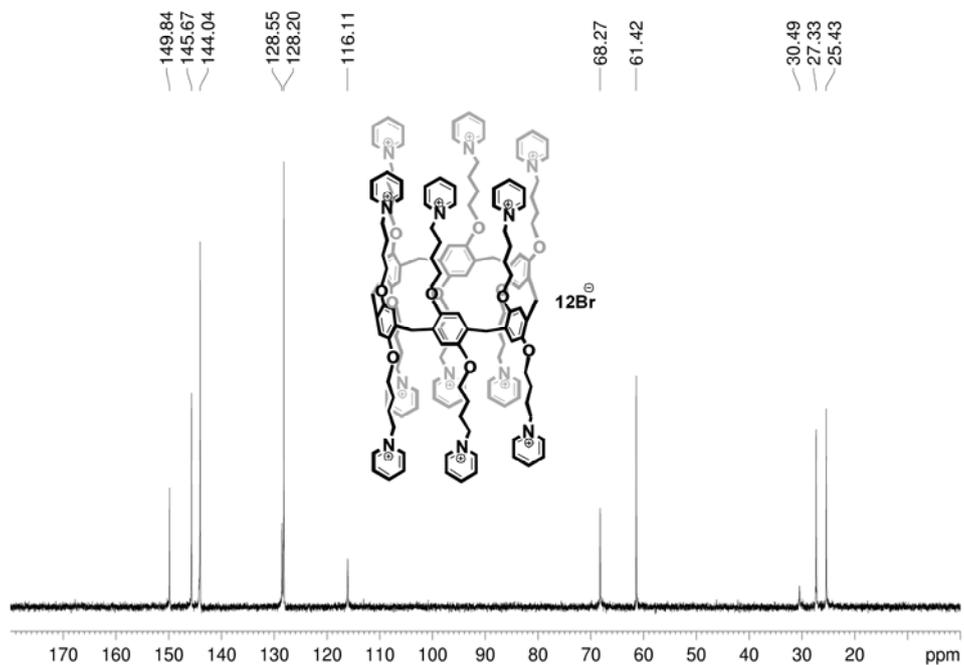


Figure S8. ¹³C NMR spectrum (125 MHz) of **1** in CDCl₃.

^1H NMR spectra of 2-NS guest in the absence and presence of host 1.

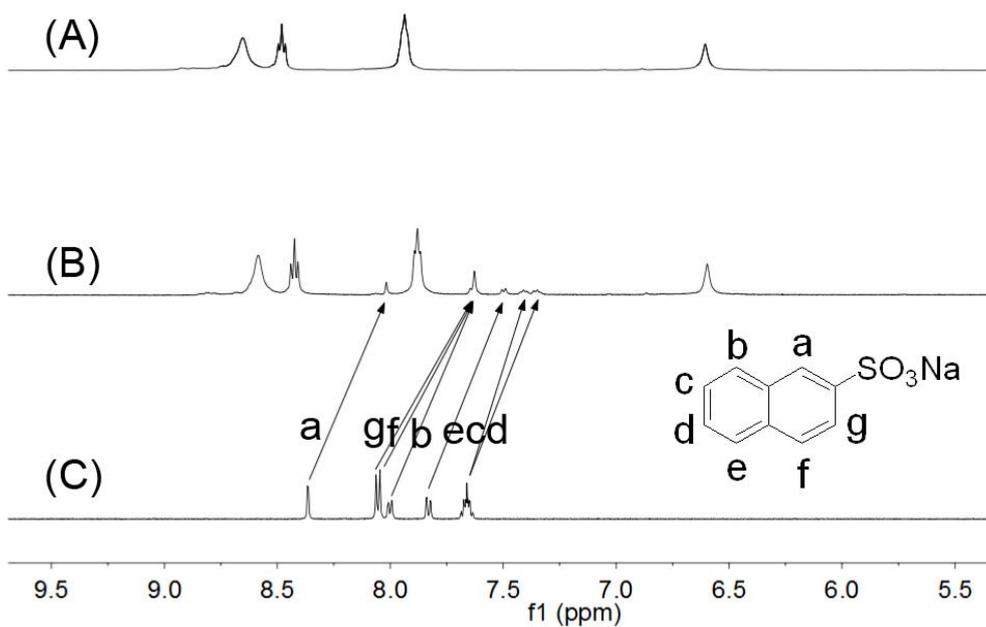


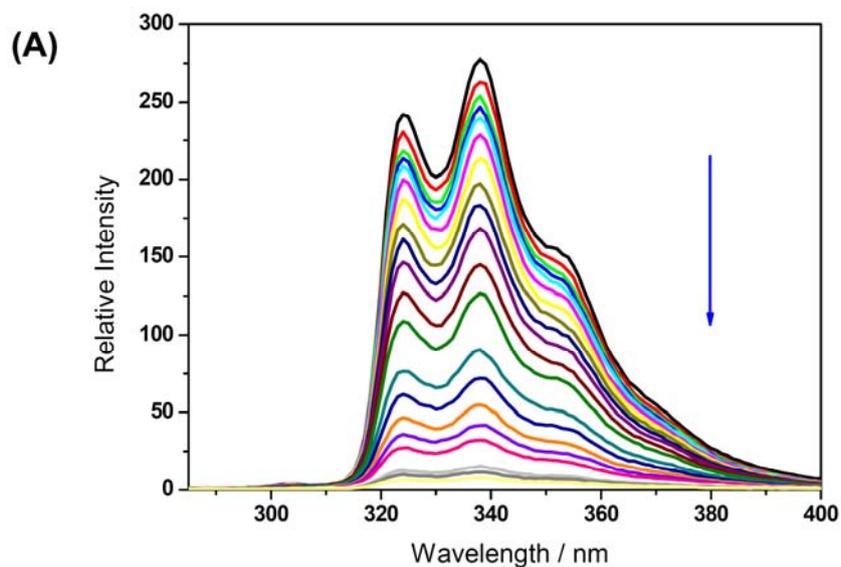
Figure S9. ^1H NMR spectra (500 MHz, 298 K) of (A) 1; (B) 1+2-NS; (C) 2-NS in D_2O at 5.9–6.1 mM.

Determination of the association constants.

To quantitatively assess the inclusion complexation behavior of these compounds, fluorescence titrations of water-soluble pillar[6]arene **1** with 2-NS and 2,6-NDS guests were performed at 298 K in a phosphate buffer solution of pH 7.2. Using a nonlinear least-squares curve-fitting method,^[S2] the association constant was obtained for each host-guest combination from the following equation:

$$F = I_0 - (0.5 * (\alpha) * ((G_0/2 + H_0 + (1/K_a)) - (\sqrt{((G_0/2 + H_0 + (1/K_a)) * (G_0/2 + H_0 + (1/K_a)) - 4 * G_0/2 * H_0}))))$$

Where F is the fluorescence intensity of guest at $[H]_0$, $[G]_0$ is the fixed initial concentration of the guest, and $[H]_0$ is the initial concentration of host. Typical fluorescence spectrum changes and curve-fitting plots are shown in Figure S10.



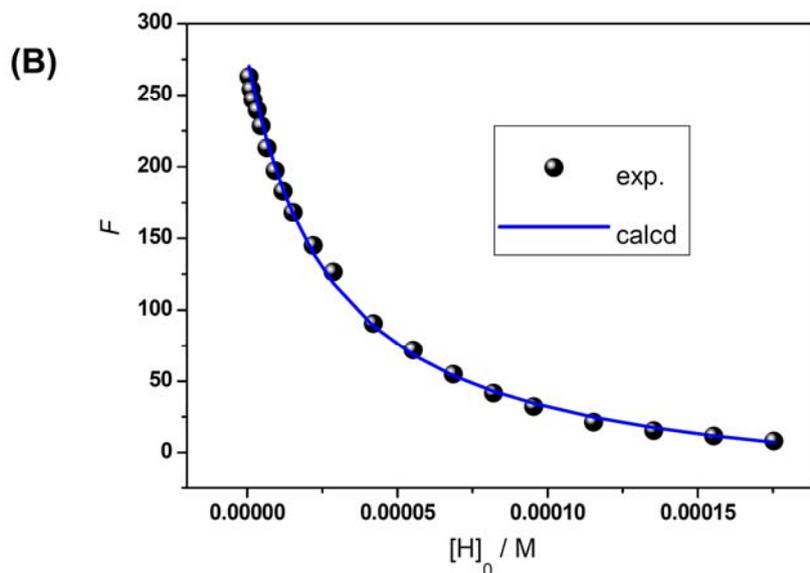


Figure S10. (A) Fluorescence spectra of 2-NS ($5.0 \times 10^{-6} \text{ mol}\cdot\text{dm}^{-3}$) in the presence and absence of pillar[6]arene **1** in aqueous phosphate buffer solution (pH 7.2) at 298 K. (B) The nonlinear least-squares analysis to calculate the association constant (K_a).

ESI mass spectrum of 2-NS \subset 1.

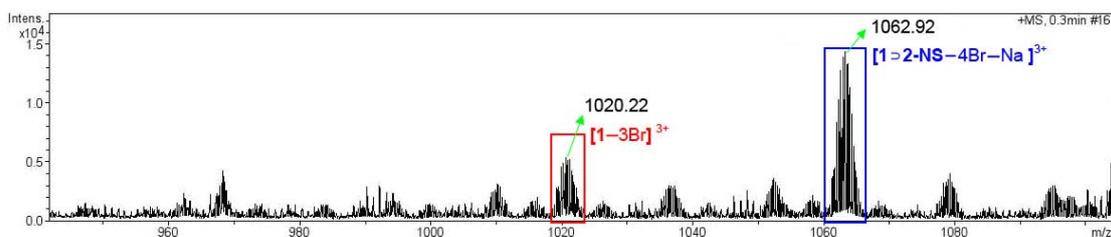


Figure S11. ESI mass spectrum of an equimolar mixture of 2-NS and host **1** in water. The concentration of host/guest is about $0.5 \mu\text{mol/L}$.

The concentration-dependent ^1H NMR studies of **1**.

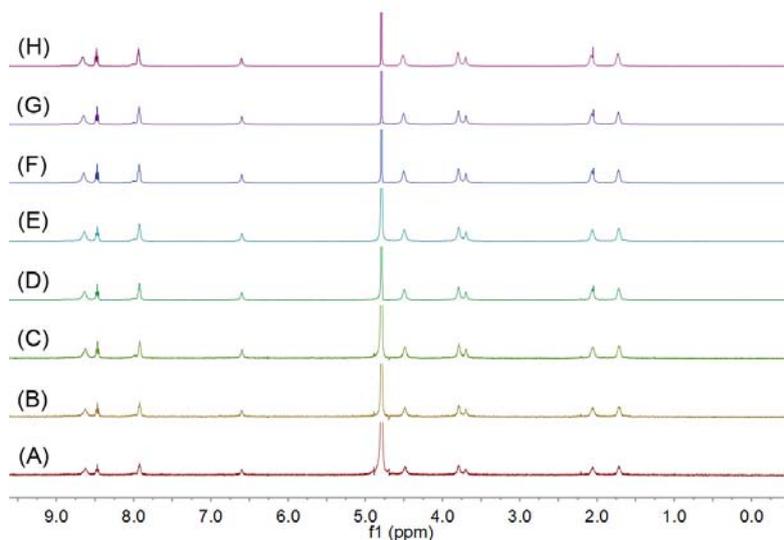


Figure S12. ^1H NMR spectra of **1** (D_2O , 298 K, 500 MHz) at various concentrations: (a) 0.30 mM, (b) 0.61 mM, (c) 1.0 mM, (d) 2.0 mM, (e) 3.0 mM, (f) 6.0 mM, (g) 10 mM, (h) 15 mM.

As shown in Figure S12, no obvious differences were observed for the ^1H NMR spectra of **1** over a concentration range of 0.3 – 15 mM. These results indicate that the pyridinium moieties do not insert into the pillararene cavity, and the host does not aggregate in solution or at least the aggregating is unremarkable.

References

- [S1] W. Wang, C. Sheng, X. Che, H. Ji, Y. Cao, Z. Miao, J. Yao and W. Zhang, *Bioorg. Med. Chem. Lett.*, 2009, **19**, 5965.
- [S2] (a) K. A. Connors, *Binding Constants*; Wiley: New York, 1987. Corbin, P. S. Ph.D. Dissertation, University of Illinois at Urbana-Champaign, Urbana, IL, 1999; (b) R. P. Ashton, R. Ballardini, V. Balzani, M. Belohradsky, M. T. Gandolfi, D. Philp, L. Prodi, F. M. Raymo, M. V. Reddington, N. Spencer, J. F. Stoddart, M. Venturi, D. J. Williams, *J. Am. Chem. Soc.*, 1996, **118**, 4931; (c) Y. Inoue, K. Yamamoto, T. Wada, S. Everitt, X.-M. Gao, Z.-J. Hou, L.-H. Tong, S.-K. Jiang and H.-M. Wu, *J. Chem. Soc., Perkin Trans. 2*, 1998, 1807.