Electronic Supplementary Material (ESI) for ChemComm.

Electronic Supplementary Information (ESI)

Selective precipitation of alkyl dihalides using a newly synthesized water-soluble bisphosphorylpillar[5]arene

Wenjin Cheng,[a] Hao Tang,*[b] Rongrong Wang,[a] Lingyun Wang,[a] Herbert Meier[c] and Derong Cao*[a]

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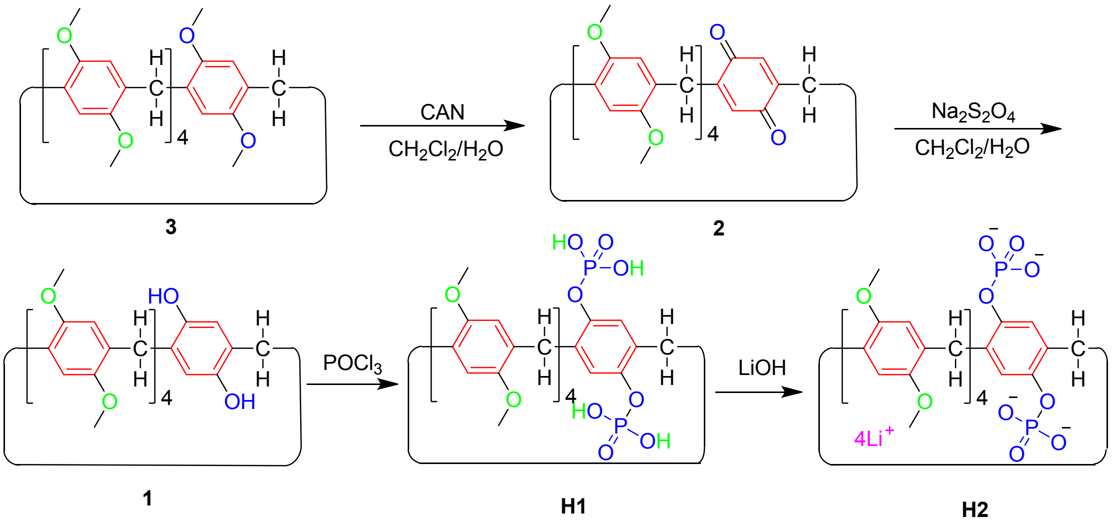
1. *Materials and instruments*

Phosphorus oxychloride, trimethylamine and lithium hydroxide monohydrate were reagent grade and commercially available. Pillar[5]arene **1** was prepared according to the literature procedure.[S1] All solvents were either purchased from commercial sources or dried according to the standard solvent manual. ^{1}H NMR, ^{13}C NMR and ^{31}P NMR spectra were collected on a Bruker DRX 400 spectrometer with internal standard TMS. The melting points were recorded on a SWG X-4B microscopic melting point meter. Matrix-assisted laser desorption ionization time-off flight (MALDI-TOF) mass measurements were performed with an Autoflex III smart-beam spectrometer. The isothermal titration calorimetry (ITC) was measured with NanoITC LV – 190 μL (Waters GmbH, TA Instruments, Eschborn, Germany).

2. *Synthesis and characterization of compounds*



Scheme S1. Synthetic route to **H1** and **H2**

Synthesis of H1: $POCl_3$ (0.23 mL, 2.46 mmol) and trimethylamine (0.23 mL, 1.53 mmol) were added to a solution of **1** (342 mg, 0.47 mmol) in anhydrous $CHCl_3$ (35 mL) under argon atmosphere at 0 °C. The mixture was stirring for 2.5 h and then 6 mL of aqueous HCl (2.5%) was added to the mixture. The reaction mixture was kept stirring for 2 d at room temperature, followed by the evaporation of $CHCl_3$. The mixture was washed several times with aqueous HCl (2.5%), and dried in vacuo. Yield: 400 mg (0.45 mmol, 95.8%) of H1 as bright ocher solid. M.p.168.9-169.7. NMR spectra of H1 were shown in Figures S1 – S3. ^{1}H NMR (400 MHz, $CDCl_3/CD_3OD$ (1:1), 298 K), δ (ppm): 7.37 (s, 2H), 6.93 (s, 2H), 6.85 (s, 2H), 6.83 (s, 2H), 6.82 (s, 2H), 3.79-3.70 (m, 34H). ^{13}C NMR (100 MHz, $CDCl_3/CD_3OD$ (1:1), 298 K), δ (ppm): 154.38, 154.38, 154.36, 154.27, 148.84, 148.78, 135.28, 135.28, 135.21, 135.21, 132.79, 132.59, 132.57, 131.18, 125.19, 125.19, 117.74, 117.46, 117.46, 117.05, 59.41 (3C), 59.14, 33.45, 33.45, 32.97, 32.97, 32.87. ^{31}P NMR (162 MHz, $CDCl_3/CD_3OD$), δ (ppm): -1.65; MS (MALDI-TOF): m/z calcd. for $[M+Na]^+$ $C_{43}H_{48}O_{16}P_2$: 905.2315; found 905.2363 (100%).

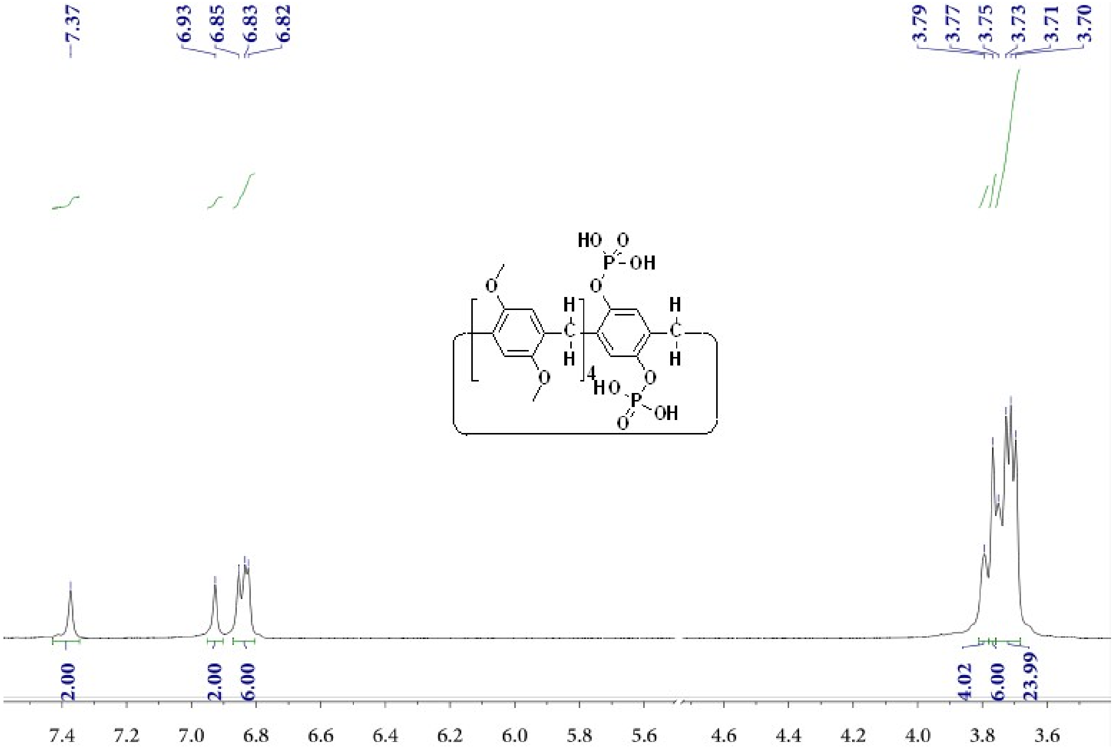


Figure S1. ^{1}H NMR spectrum (400 MHz, $CDCl_3/CD_3OD$ (1:1)) of **H1**

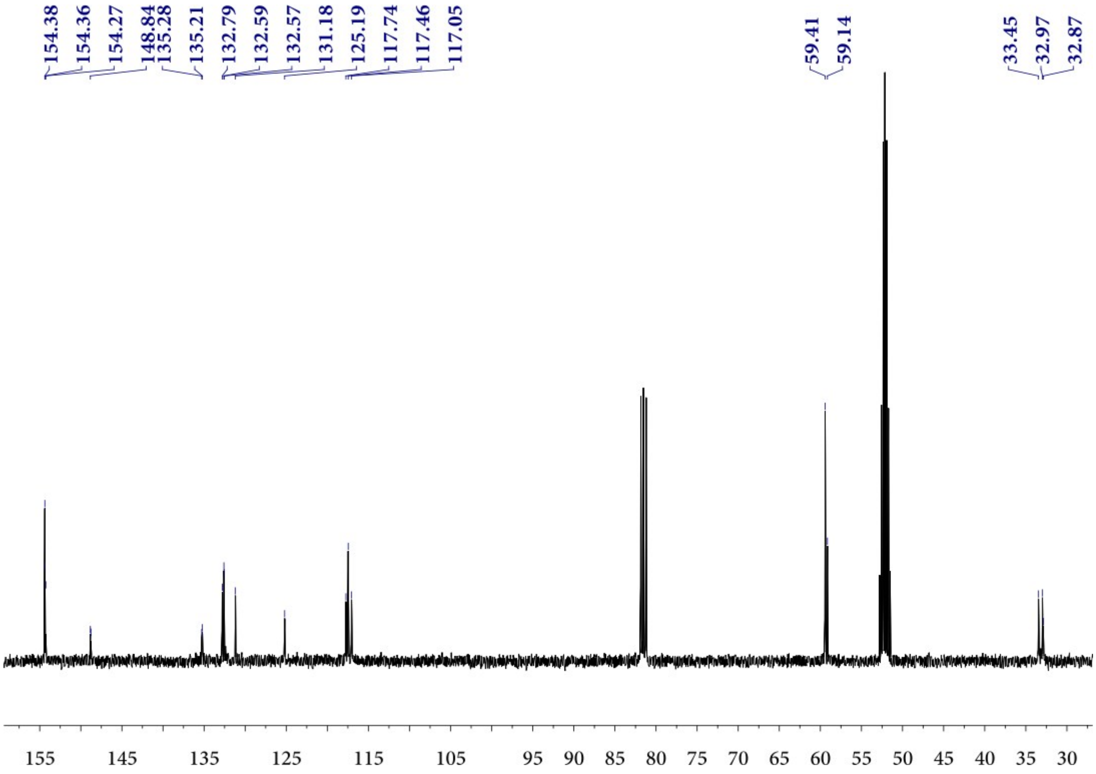


Figure S2. ^{13}C NMR spectrum (100 MHz, $CDCl_3/CD_3OD$ (1:1)) of **H1**

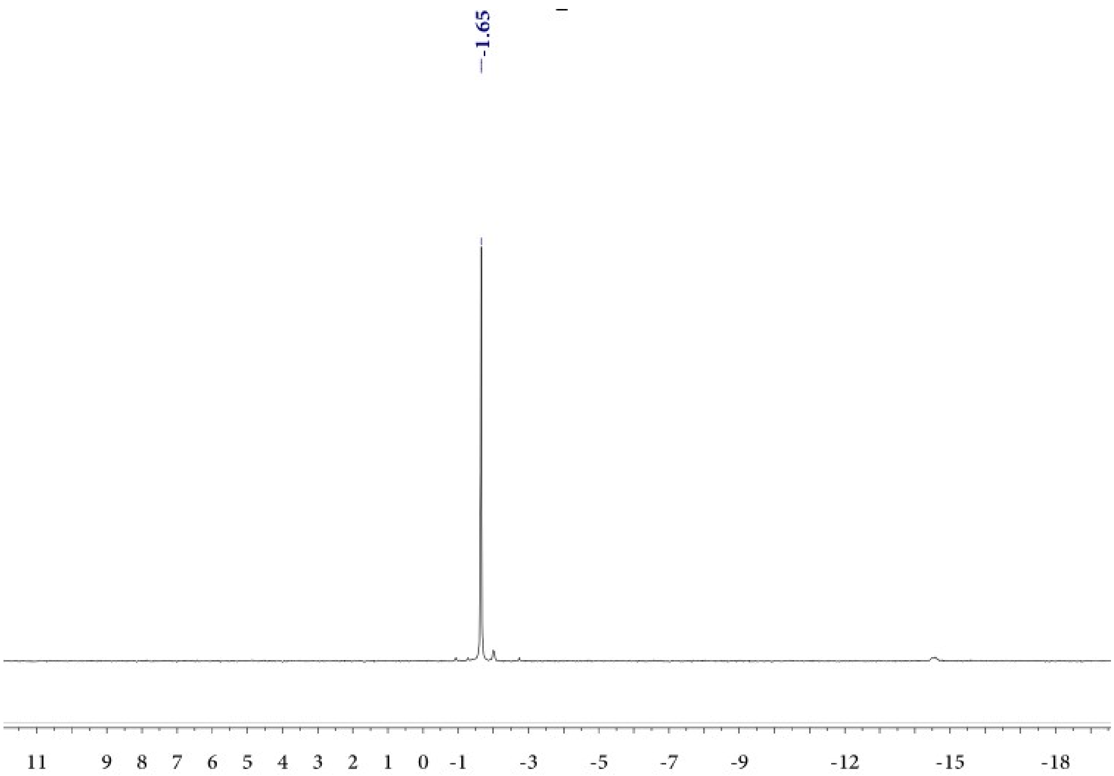


Figure S3. ^{31}P NMR spectrum (162 MHz, $CDCl_3$/CD_3OD (1:1)) of **H1**

Synthesis of H2: A solution of LiOH·H_2O (10.21 mg, 243.0 μmol) in 1.5 mL of CH_3OH was added to a stirred solution of phosphoric acid **H1** (50 mg, 61 μmol) in 5 mL of methanol at room temperature. After stirring the clear reaction solution for 30 min, methanol was evaporated in vacuo. The solid residue was dried to give the beige product in quantitative yield. M.p.182.2-183.0; The NMR spectra of **H2** were shown in Figures S4 – S6. ^{1}H NMR (400 MHz, D_2O, 298 K), δ (ppm): 6.94 (s, 2H), 6.89 (s, 2H), 6.70 (s, 2H), 6.63 (s, 2H), 6.48 (s, 2H), 4.09-3.25 (m, 34 H). ^{13}C NMR (100 MHz, D_2O, 298 K), δ (ppm): 151.15, 151.10, 151.02, 150.89, 146.68, 146.66, 146.61, 131.52 (2C), 131.49, 131.47, 130.89, 129.45, 128.81, 128.70, 122.78, 115.91, 115.82, 115.50, 115.45, 57.09, 56.85, 57.76, 56.66, 29.88, 29.81 (2C), 29.74, 29.71; ^{31}P NMR(162 MHz, D_2O, 298 K), δ (ppm): 0.61; MS (MALDI-TOF): m/z 907.2965 $[M+H]^+$, 901.2741 $[M-Li+2H]^+$, 895.2555 $[M-2Li+3H]^+$, 889.2004 $[M-3Li+4H]^+$.

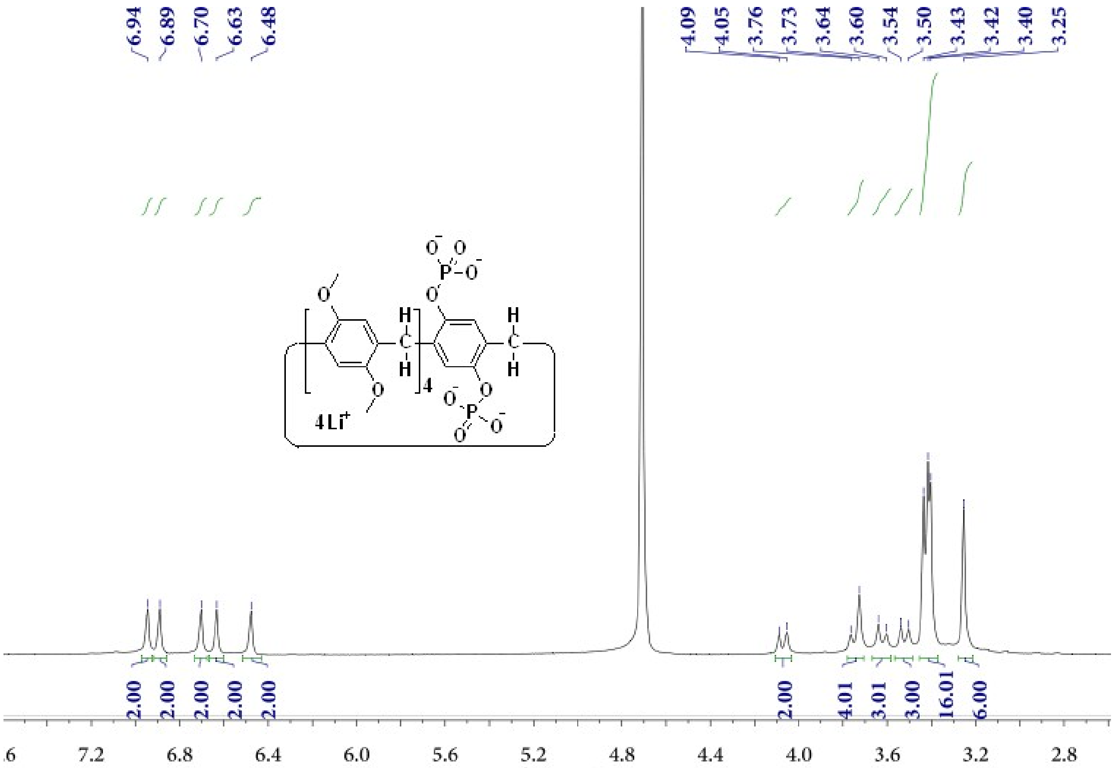


Figure S4. ^{1}H NMR spectrum (400 MHz, D_2O) of **H2**

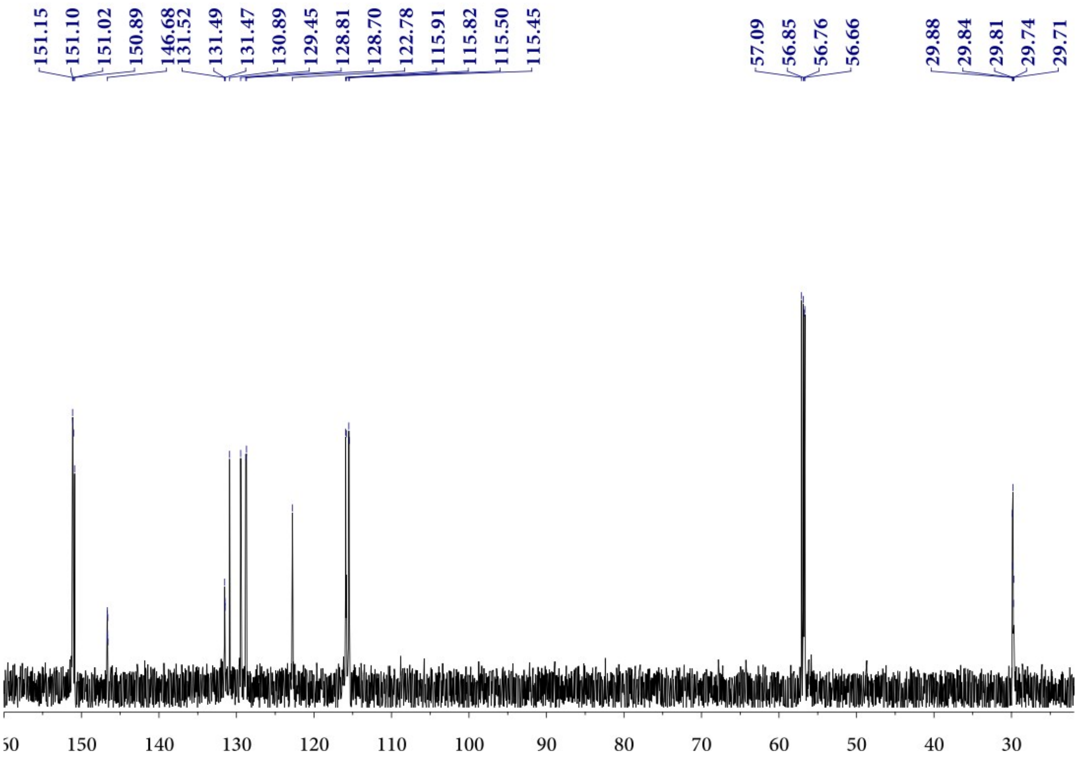


Figure S5. ^{13}C NMR spectrum (100 MHz, D_2O) of **H2**

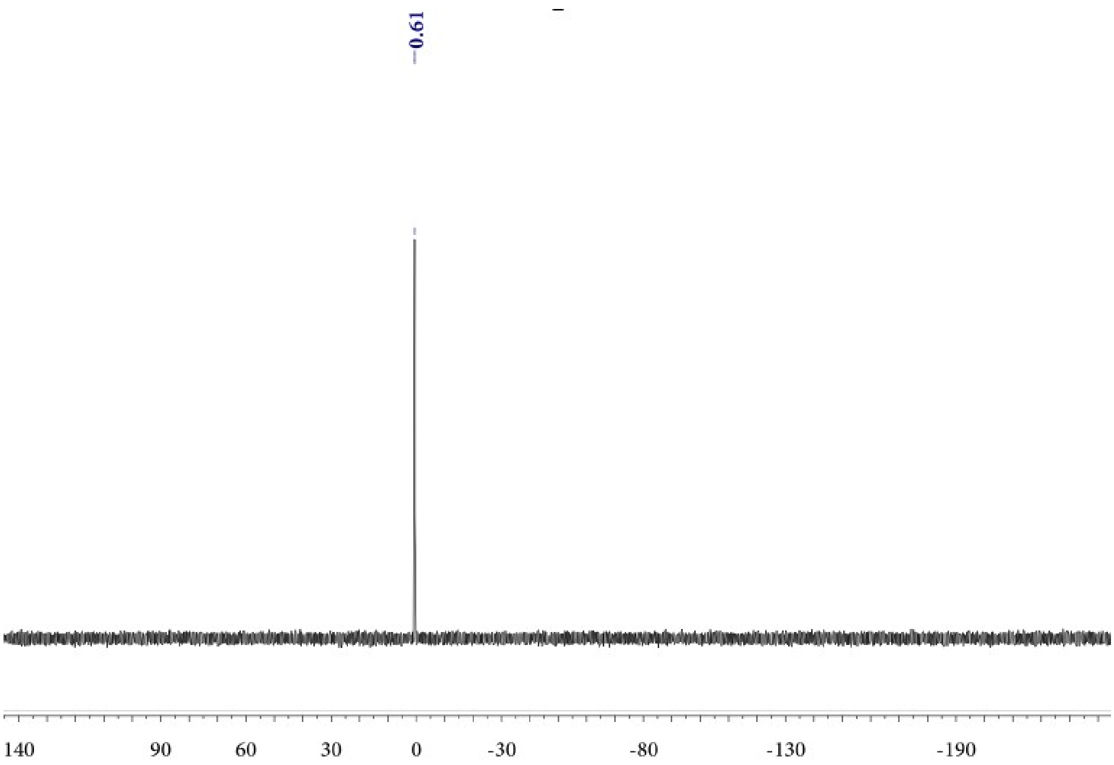


Figure S6. ^{31}P NMR spectrum (162 MHz, D_2O) of **H2**

3. *ESI-MS spectra of **H1** and **H2***

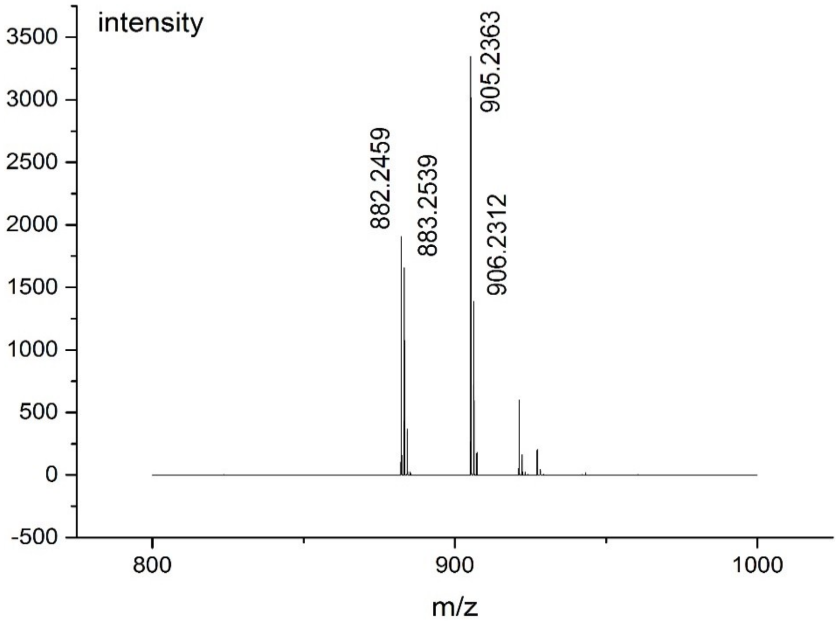


Figure S7. MS (MALDI-TOF) of **H1**

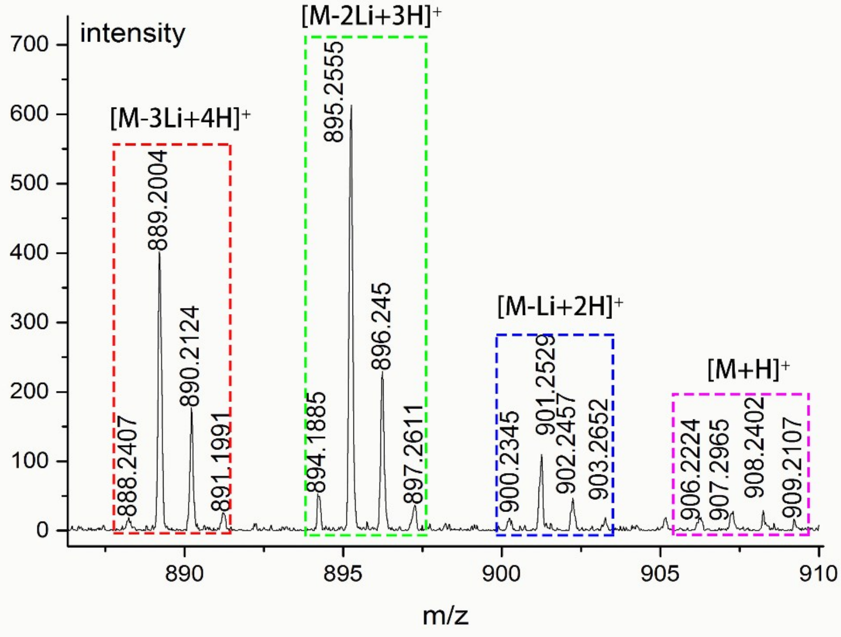


Figure S8. MS (MALDI-TOF) of **H2**

4. ^{1}*H NMR investigation of host⊂guest complexation between **H1** and the guests*

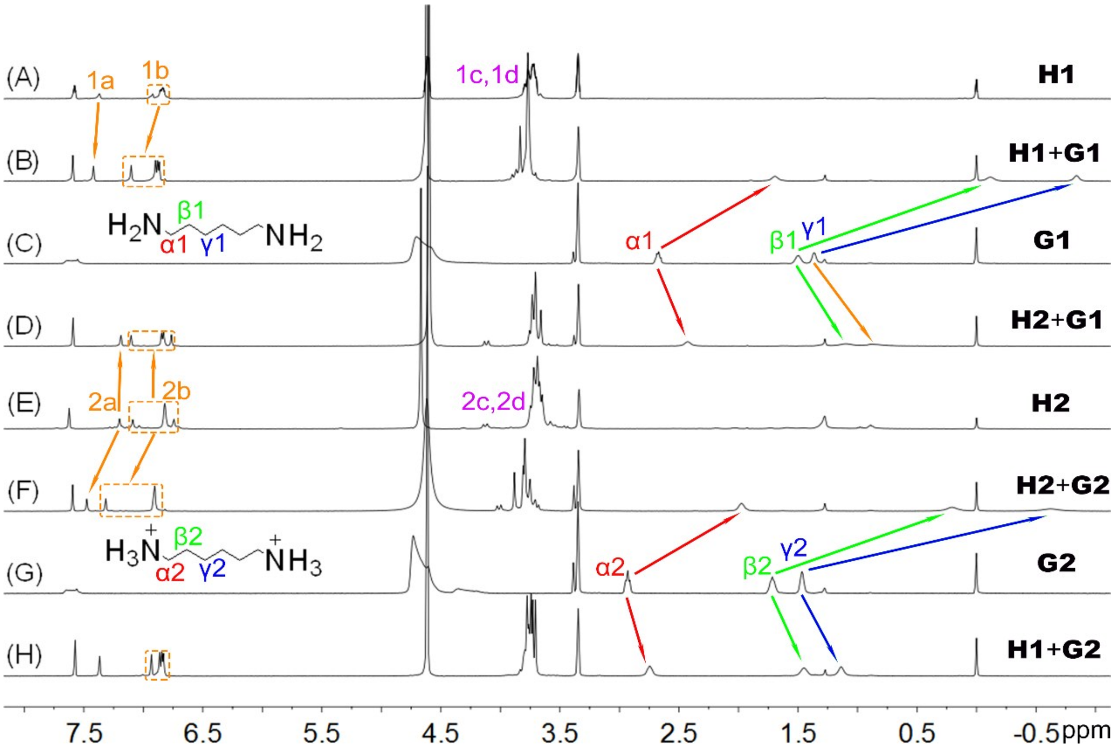


Figure S9. ^{1}H NMR spectra (400 MHz, 298K) of (A) **H1**; (B) **H1** + **G1**; (C) **G1**; (D) **H2** + **G1**; (E) **H2**; (F) **H2** + **G2**; (G) **G2**; (H) **H1** + **G2**; (I) **H1** in 1:1 $CDCl_3/CD_3OD$ solutions. The concentrations for all species are 5 mM.

5. *NMR titration for the complexation between the hosts and the alkyldiamines in a mixture of chloroform-d and methanol-d4 (1:1, v/v)*

^{1}H NMR titrations were conducted to determine the association constants between the hosts (**H1** and **H2**) and the guests (**G1** and **G2**) in a mixture of chloroform-*d* and methanol-*d4* (1:1, v/v). The concentration of the guest (5 mM) was kept constant while the concentrations of the host were varied. A nonlinear curve-fitting method was applied to calculate the association constant for complexation between the hosts and the guests, which was based on the equation as follows:

$$\Delta\delta = (\Delta\delta_\infty/[G]_0)\,(0.5[H]_0+0.5([G]_0+1/K)-(0.5(([H]_0)^2+(2[H]_0(1/K-[G]_0))+(1/K+[G]_0)^2)^{0.5})) \qquad \text{(Eq. S1)}$$

Where $\Delta\delta$, a dependent variable, is the chemical shift of $H^{\gamma 1}$ of **G1** or $H^{\gamma 2}$ of **G2** upon the addition of the host; $\Delta\delta_\infty$, a parameter, is the maximum chemical shift of $H^{\gamma 1}$ or $H^{\gamma 2}$ when the guest is completely complexed; $[G]_0$, a constant, is the fixed initial concentration of the guest, and $[H]_0$, an independent variable, is the total concentration of the host in the host-guest systems.

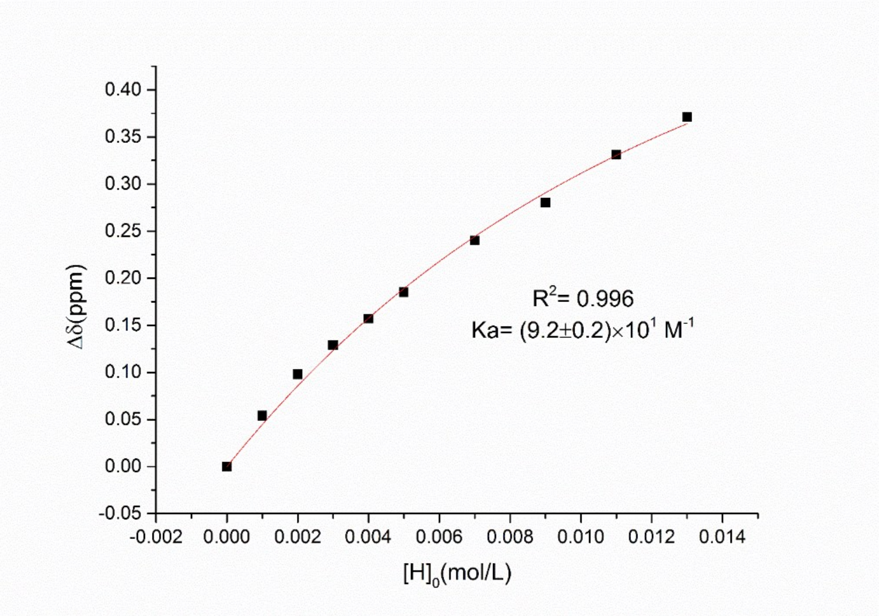


Figure S10. The chemical shift changes of $H^{\gamma 2}$ of **G2** (5.0 mM) upon the addition of **H1** (0 – 13 mM). The red solidline was obtained from the nonlinear curve-fitting.

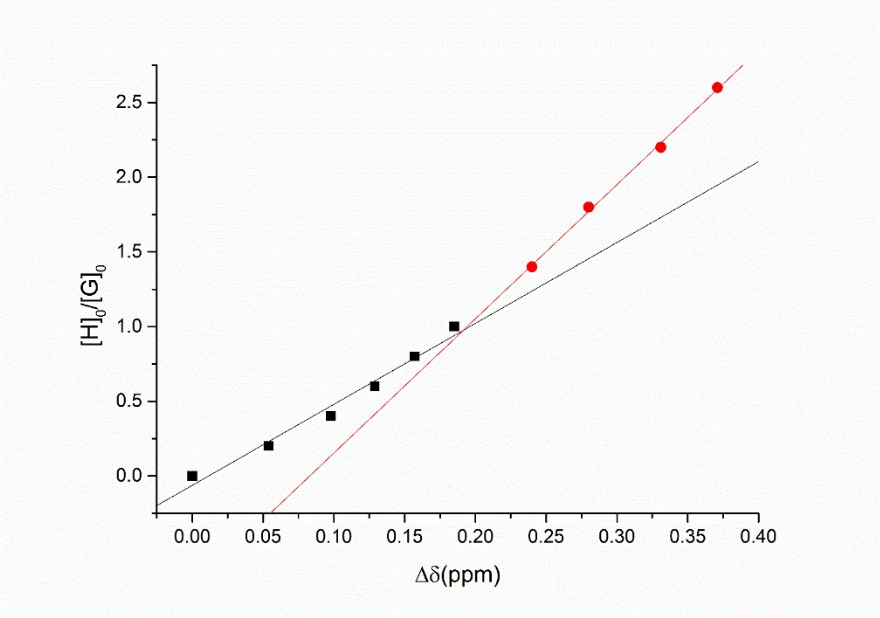


Figure S11. Mole ratio plot for the complexation between **H1** and **G2**, indicating a 1:1 stoichiometry.

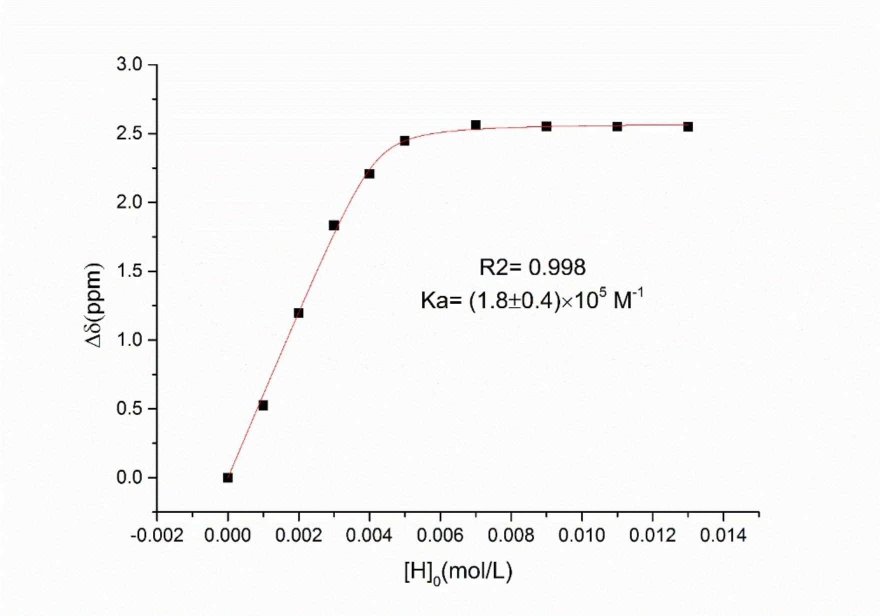


Figure S12. The chemical shift changes of $H^{\gamma 1}$ of **G1** (4.9 mM) upon the addition of **H1** (0 – 13 mM). The red solidline was obtained from the nonlinear curve-fitting.

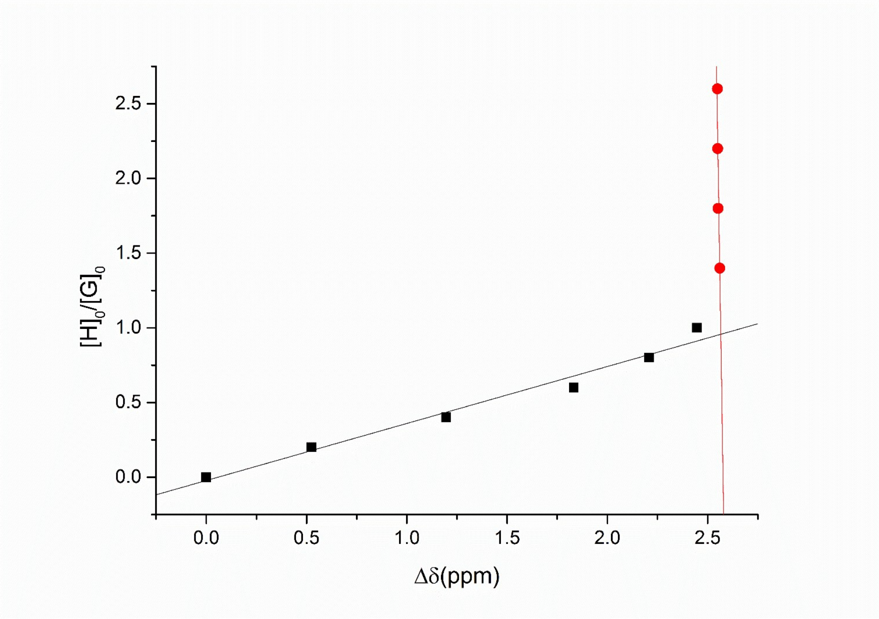


Figure S13. Mole ratio plot for the complexation between **H1** and **G1**, indicating a 1:1 stoichiometry.

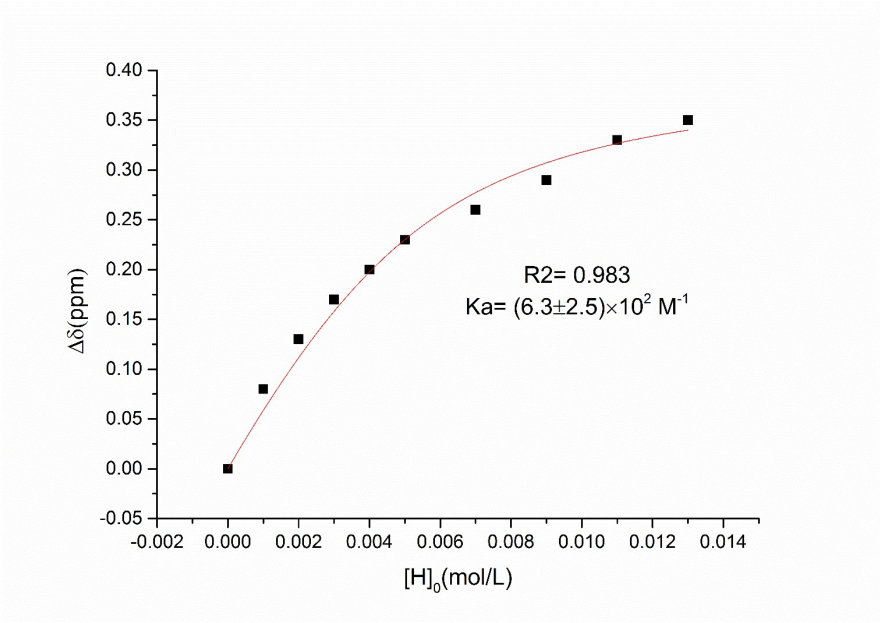


Figure S14. The chemical shift changes of $H^{\gamma 1}$ of **G1** (5.0 mM) upon the addition of **H2** (0 – 13 mM). The red solidline was obtained from the nonlinear curve-fitting.

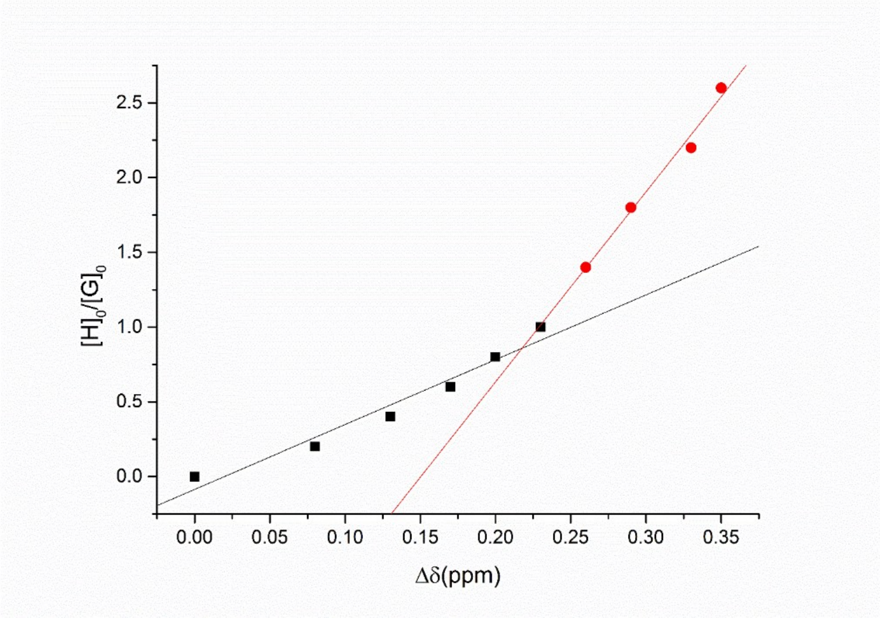


Figure S15. Mole ratio plot for the complexation between **H2** and **G1**, indicating a 1:1 stoichiometry.

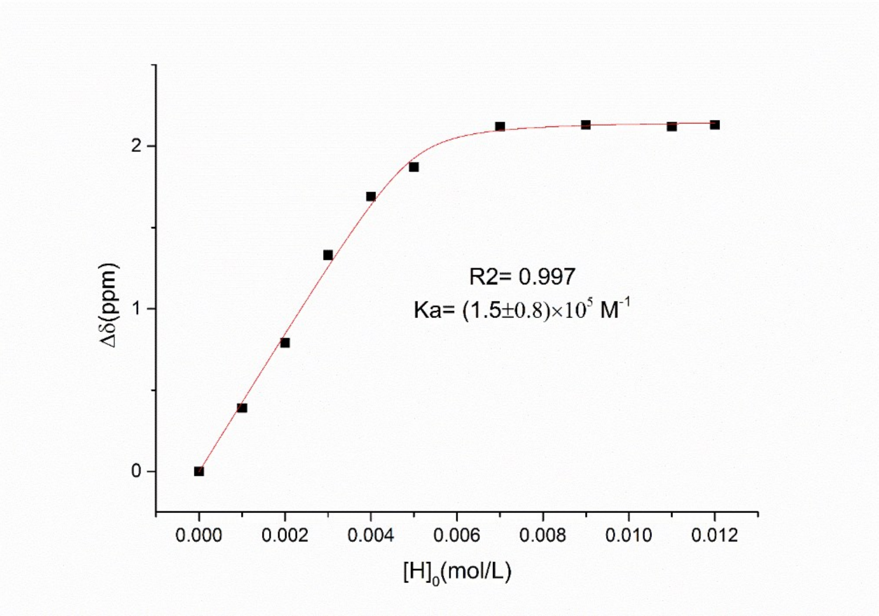


Figure S16. The chemical shift changes of H$^{\gamma 2}$ of **G2** (5.0 mM) upon the addition of **H2** (0 – 13 mM). The red solidline was obtained from the nonlinear curve-fitting.

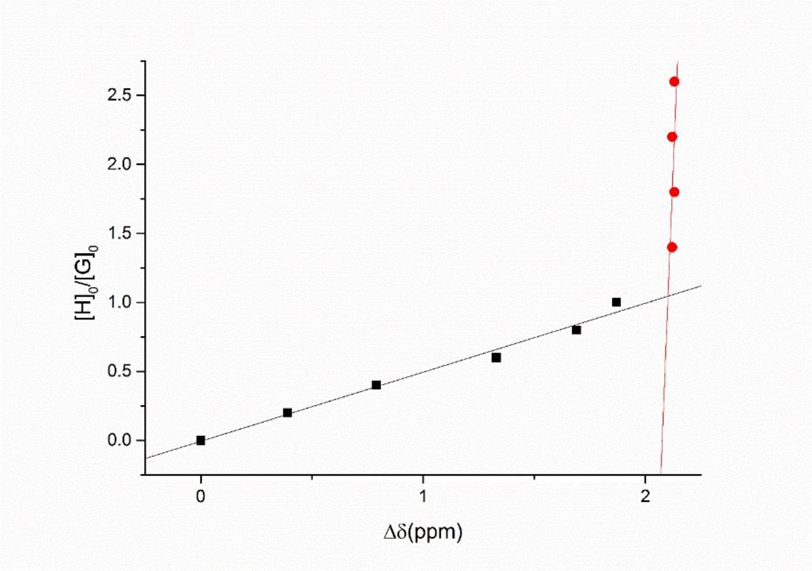


Figure S17. Mole ratio plot for the complexation between **H2** and **G2**, indicating a 1:1 stoichiometry.

6. *NMR titration for the complexation between **H2** and **G2** in D_2O*

^{1}H NMR titrations were conducted in the same manner as aforementioned in the section 5 except that the solvent was D_2O and $\Delta\delta$ represents the chemical shift of $H^{\alpha 2}$ or $H^{\beta 2}$ of **G2** for better peak identification. The *Ka* value for the **H2–G2** complex in D_2O was obtained as an average of the results determined for both $H^{\alpha 2}$ and $H^{\beta 2}$ of **G2**.

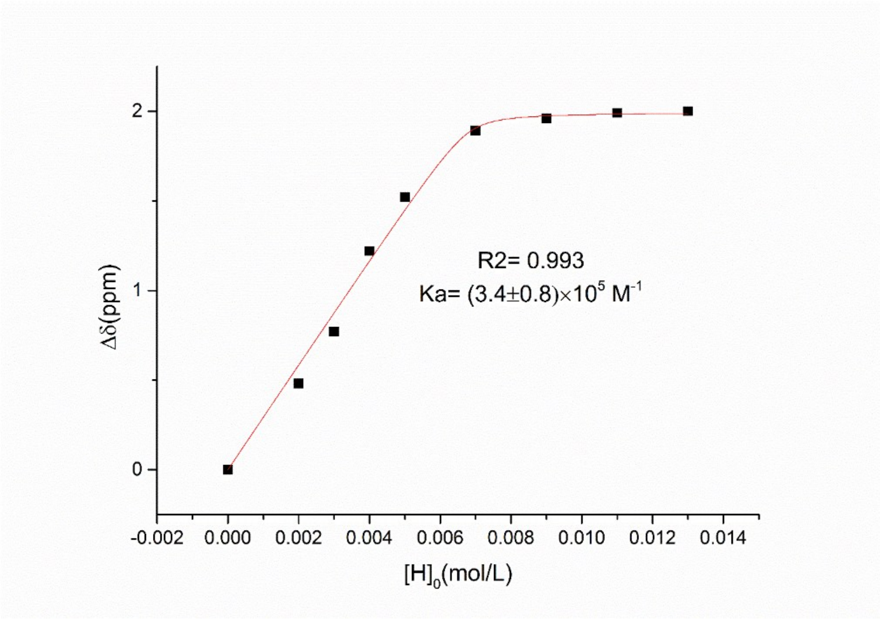


Figure S18. The chemical shift changes of $H^{\beta2}$ of **G2** (5.0 mM) upon the addition of **H2** (0 – 13 mM) in D_2O. The red solidline was obtained from the nonlinear curve-fitting.

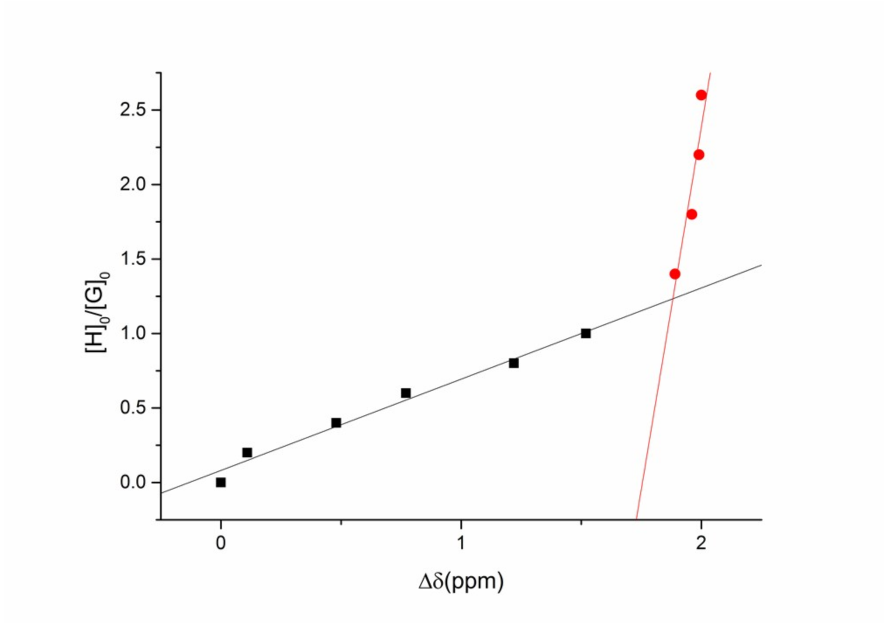


Figure S19. Mole ratio plot for the complexation between **H2** and **G2** in D_2O, indicating a 1:1 stoichiometry.

7. *ITC investigations of host⊂guest complexation between **H2** and the guests*

Isothermal titration calorimetry (ITC) is routinely used to study the binding interactions and the reactions since it can provide not only the association constant (*Ka*) but also the corresponding thermodynamic parameters such as enthalpy change ΔH° and entropy change ΔS°. It is a powerful tool in the host−guest study especially where the NMR titration cannot be employed due to no well-defined NMR signals or only the slow-exchange process observed for the host−guest system.

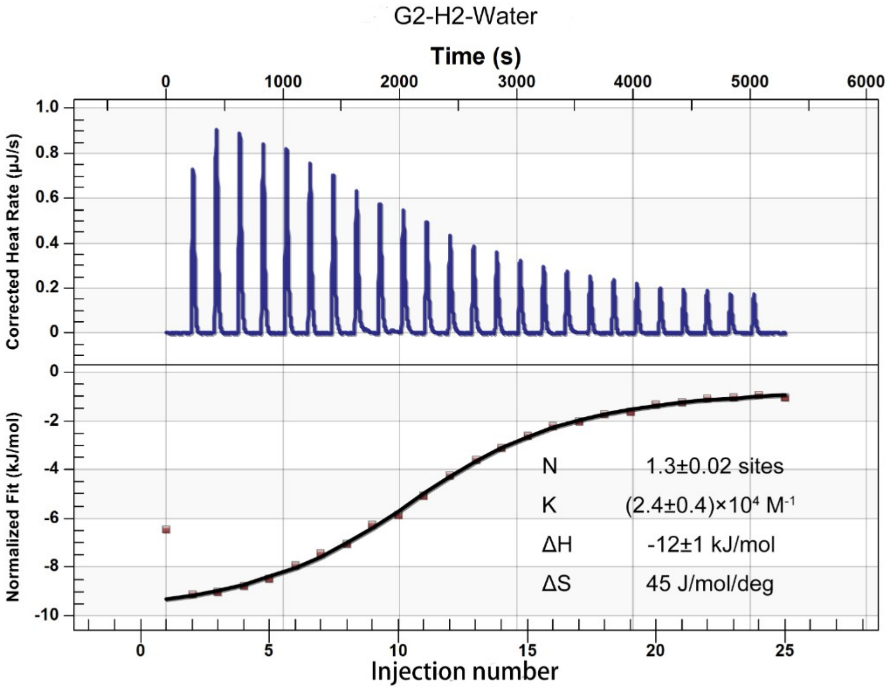


Figure S20. Microcalorimetric titration of **G2** (6.60 mM, 1.96 µL per injection) with **H2 (**1.00 mM in H_2O) at 298 K.

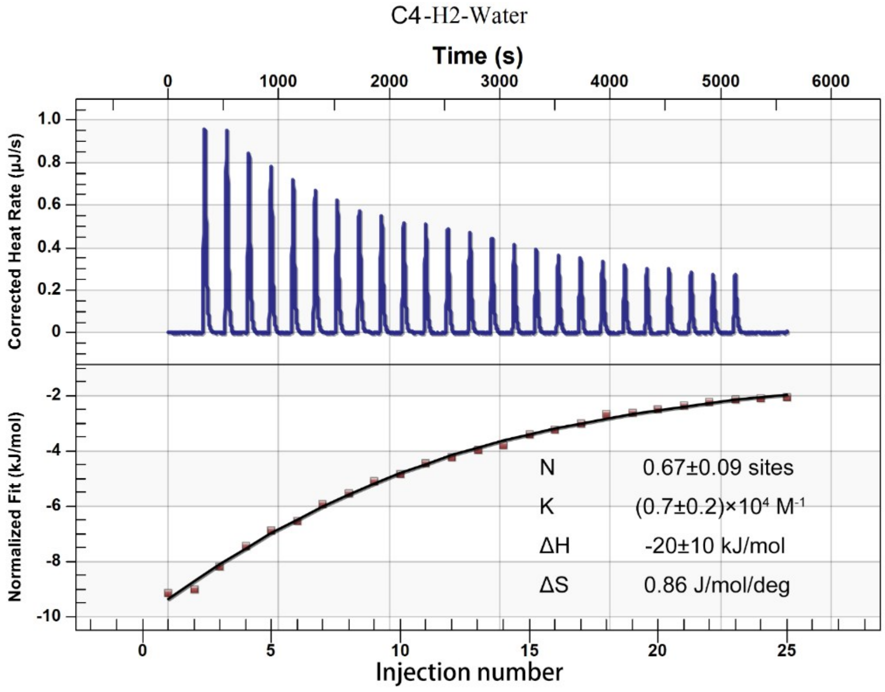


Figure S21. Microcalorimetric titration of **C4** (1.20 mM, 1.96 μL per injection) with **H2** (0.160 mM in H_2O) at 298 K.

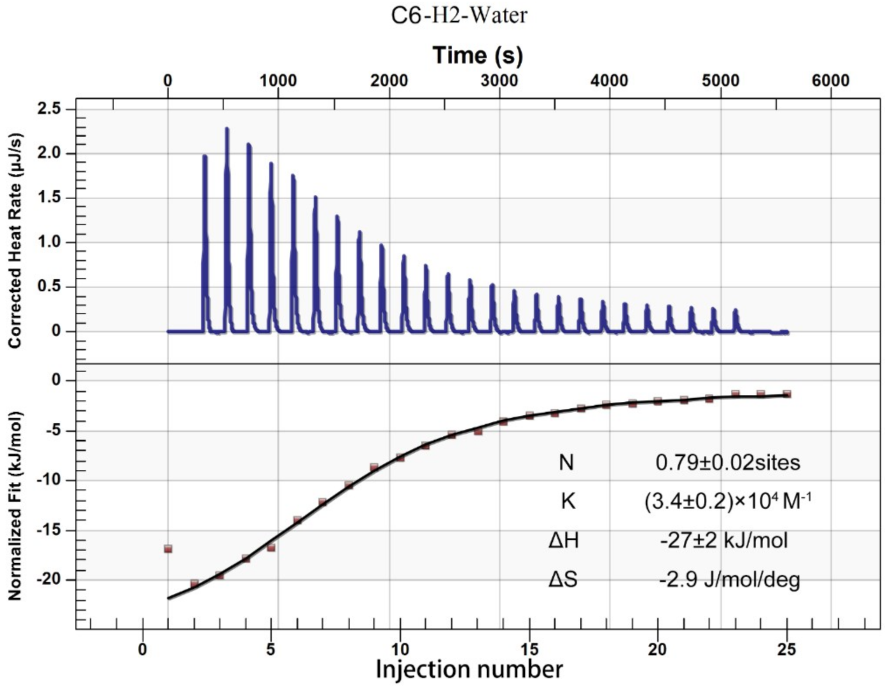


Figure S22. Microcalorimetric titration of **C6** (1.2 mM, 1.96 μL per injection) with **H2** (0.160 mM in H_2O) at 298 K.

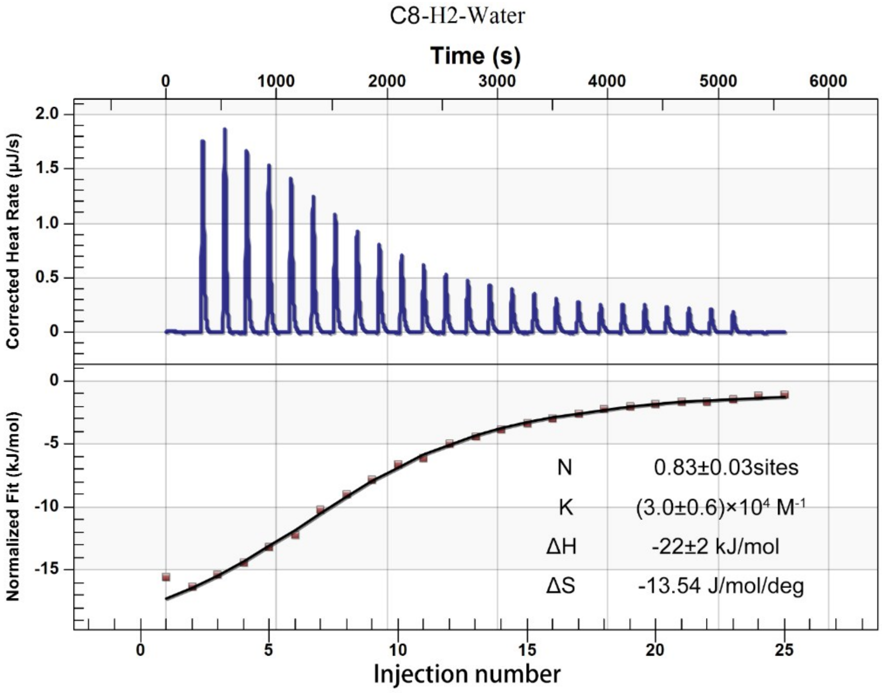


Figure S23. Microcalorimetric titration of **C8** (1.20 mM, 1.96 µL per injection) with **H2** (0.160 mM in H_2O) at 298 K.

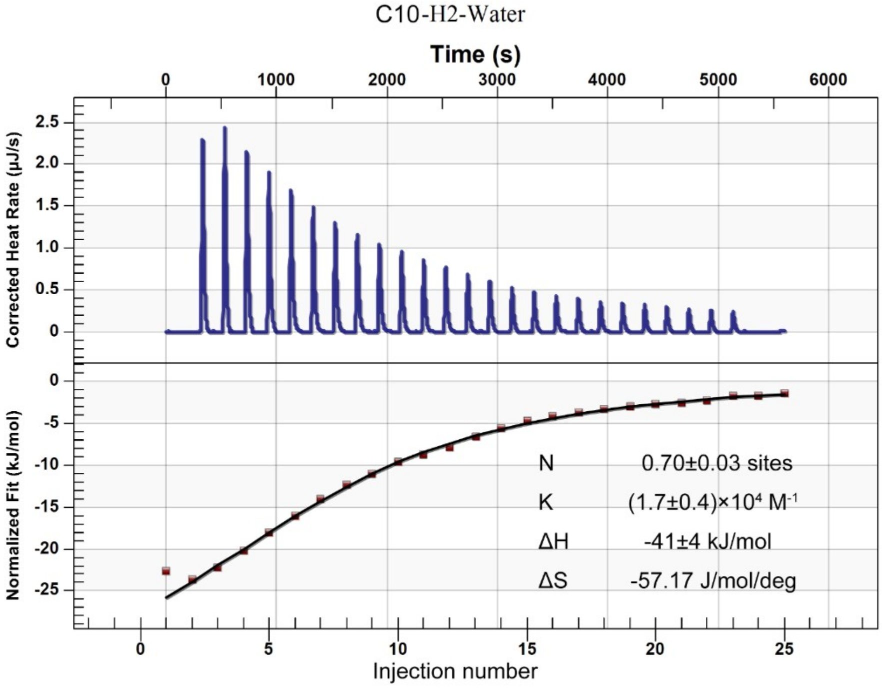


Figure S24. Microcalorimetric titration of **C10** (1.20 mM, 1.96 µL per injection) with **H2** (0.160 mM in H_2O) at 298 K.

8. *The concentration-dependent ^1H NMR studies of **C6** and **H2***

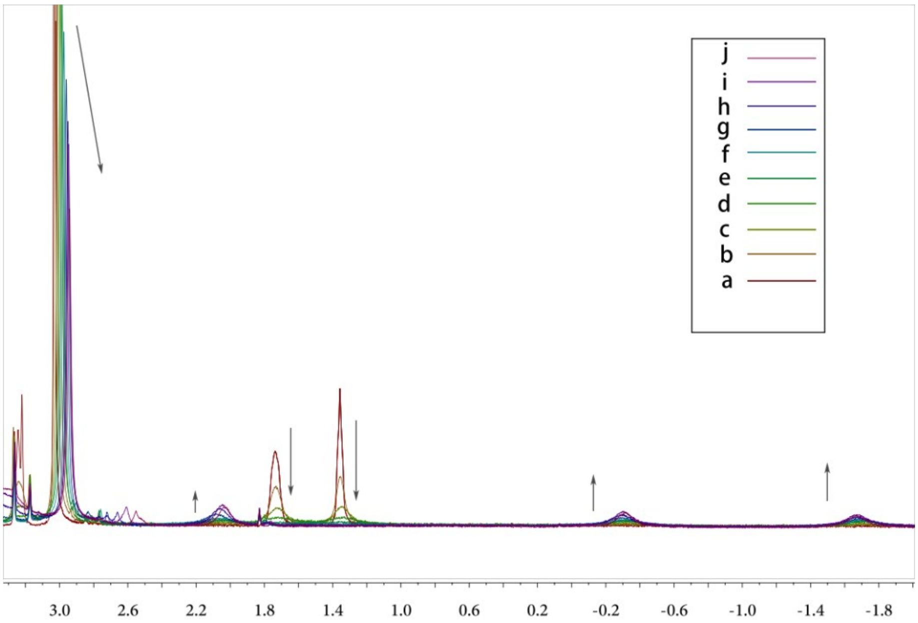


Figure S25. Partial ^{1}H NMR spectra (400 MHz, D_2O, 298 K) of **C6** at a concentration of 5 mM with different concentration (mM) of **H2** : (a) 0.00, (b) 0.99, (c) 1.98, (d)2.97, (e) 3.97, (f) 4.96, (g) 6.94, (h) 8.93, (i) 10.91, and (j) 12.90.

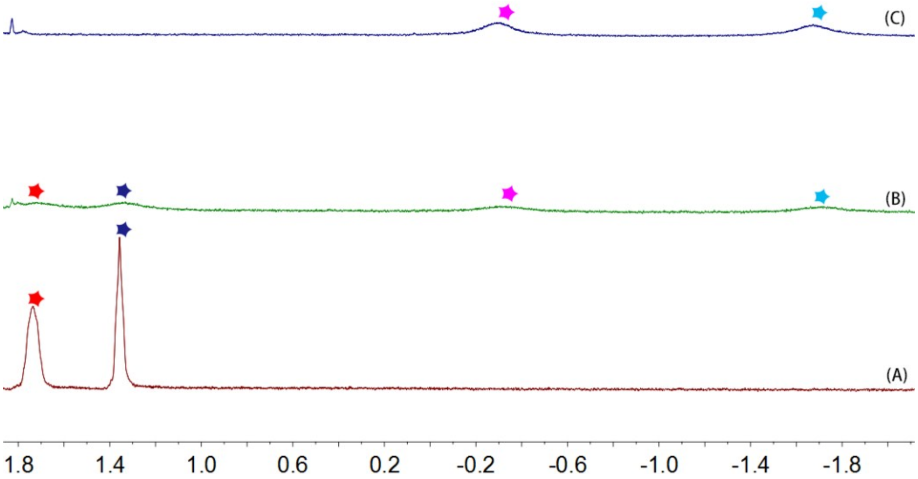


Figure S26. Partial ^{1}H NMR spectra (400 MHz, D_2O, 298 K) of **C6** at a concentration of 5 mM with different concentration (mM) of **H2** : (A) 0.00, (B) 2.97, (C) 8.93.

9. ^{1}*H NMR investigation of host⊂guest complexation between **H2** and bromoalkane*

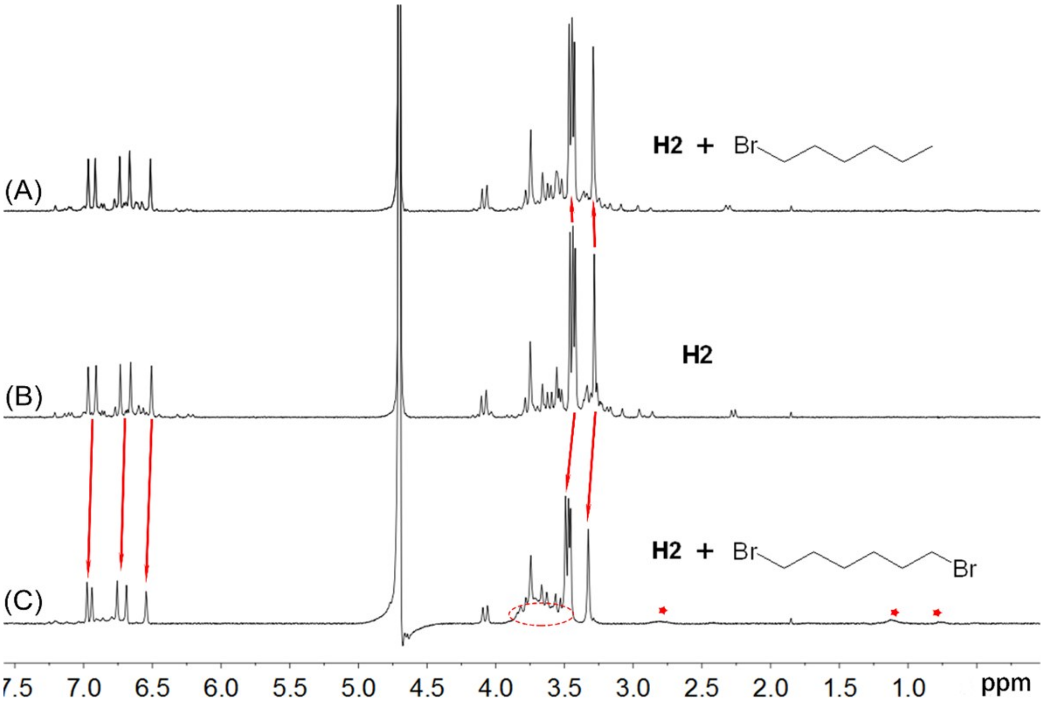


Figure S27. Partial ^{1}H NMR spectra (400 MHz, 298 K) of (A) **H2** + 1-bromohexane; (B) **H2**; (C) **H2** + 1,6-dibromohexane in D_2O solutions. The concentrations for all species are 5 mM.

10. *Precipitation test for the guests using **H2** aqueous solutions*

The guests, such as alkyl halides, 1,6-hexanediol and 1,6-hexanediamine, were injected into the **H2** solution (5 mM, deionized water) or the deionized water (i.e. the baseline solution) by a microsyringe such that the concentration of the guests was 5 mM. The mixtures were shaken and then allowed to settle for 20 min before observation. White solid precipitates were observed in the mixtures of **H2** and alkyl dihalides while faint opacities were observed in the mixtures of **H2** and alkyl monohalides. However, the baseline solutions with the guests, as well as the mixtures of **H2** and other guests such as 1,6-hexanediol or 1,6-hexanediamine, were kept clear and transparent.

Reference:

S1. (a) C. Han, Z. Zhang, G. Yu and F. Huang, *Chem. Comm.*, 2012, **48**, 9876-9878; (b) M. Pan and M. Xue, *Eur. J. Org. Chem.*, 2013, **2013**, 4787-4793.