SUPLEMENTARY INFORMATION

A Dissymmetric Molecular Capsule with Polar Interior and two Mechanically Locked Hemispheres.

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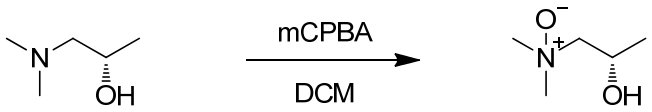
CONTENTS:

Synthesis and characterization of *N*-oxide *S*-7

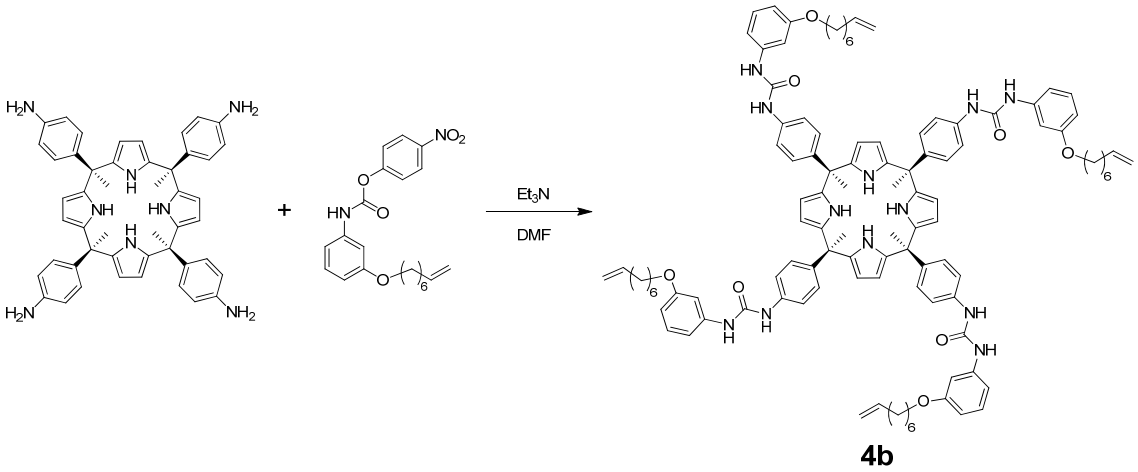


Scheme S1. Synthesis of the *N*-oxide *S*-**7**.

(S)-(+)-dimethylamino-2-propanol (167 mg, 1.62 mmol) was dissolved in dry dichloromethane (2 mL) and the resulting solution was placed in an ice bath. Then, m-chloroperoxybenzoic acid (336 mg, 1.95 mmol) was added and the reaction mixture was left stirring at room temperature for 3 hours. Then, 10 mL of dichloromethane and 6 mL of slightly acidic water were added. The two phases were separated and the aqueous layer was washed with 2 x 10 mL of dichloromethane. The aqueous layer was then evaporated to yield a colourless oil, that was passed through a short basic alumina column eluting with CH_2Cl_2 first and CH_2Cl_2/MeOH 3/1 later to obtain 180 mg of a colourless solid. Yield 93%; ^{1}H NMR (400 MHz, D_2O) δ 4.28 – 4.37 (m, 1H), 3.16 – 3.28 (m, 2H), 3.14 (s, 3H), 3.13 (s, 3H), 1.09 (d, 3H, J = 6.4 Hz); ^{13}C NMR (100 Hz, D_2O) δ 74.5 (CH_2), 62.9 (CH), 58.3 (CH_3), 58.2 (CH_3), 20.4 (CH_3).

Racemic **7** was obtained using the same procedure from dimethylamino-2-propanol. Spectroscopic data is the same.

Synthesis and characterization of tetraurea 4b



Scheme S2. Synthesis of the tetraurea **4b**.

Freshly prepared tetraaminocalix[4]pyrrole[1] (400 mg, 0.54 mmol) was dissolved in dry DMF (30 mL) and dry triethylamine (0.40 mL) was added. Then, the active carbamate[2] (1,043 g, 2.70 mmol) was added to the reaction mixture and the initially colourless solution immediately became deep yellow. The resulting solution was left stirring under Argon at room temperature for two days. Then, the reaction mixture was diluted with dichloromethane (200 mL) and washed with 1 M $K_2CO_{3(aq)}$ (150 mL) and then with 0.3 M $K_2CO_{3(aq)}$ (3 x 150 mL), until the yellowish colour of the organic layer vanishes. The resulting solution was then dried ($MgSO_4$) and evaporated, and the brownish residue chromatographed using CH_2Cl_2/MeOH 99/1 as eluent to obtain 822 mg of an off white solid. Yield 88%; ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.60 (br s, 4H), 8.56 (br s, 4H), 8.51 (br s, 4H), 7.32 (d, 8H, J = 8.6 Hz), 7.04 – 7.10 (m, 8H), 6.84 – 6.90 (m, 12 H), 6.49 (dd, 4H, J = 8.4, J = 1.9 Hz), 5.93 (br s, 8H), 5.72 – 5.84 (m, 4H), 4.89 – 5.02 (m, 8H), 3.87 (t, J = 6.5, 8H), 1.96 – 2.04 (m, 8H), 1.79 (s, 12H), 1.60 – 1.70 (m, 8H), 1.22 – 1.42 (m, 24H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 159.5 (C), 152.8 (C), 144.0 (C), 141.2 (C), 139.2 (CH), 138.5 (C), 137.7 (C), 129.9 (CH), 127.7 (CH), 118.4 (CH), 115.1 (CH_2), 110.9 (CH), 108.0 (CH), 105.2 (CH), 105.0 (CH), 67.7 (CH_2), 44.1 (C), 33.6 (CH_2), 31.6 (CH_3), 29.1 (CH_2), 28.7 (CH_2), 28.7 (CH_2), 25.8 (CH_2); exact MS (MALDI+/$[M]^+$) calcd. for $C_{108}H_{124}N_{12}O_8^+$: 1716.9660, found: 1716.9657.

[1] Ballester, P.; Gil-Ramirez, G., *Proc. Natl. Acad. Sci. U. S. A.* **2009,** 106, 10455-10459.
[2] Molokanova, O.; Bogdan, A.; Vysotsky, M. O.; Bolte, M.; Ikai, T.; Okamoto, Y.; Bohmer, V. *Chem. Eur. J.* **2007,** *13*, 6157.

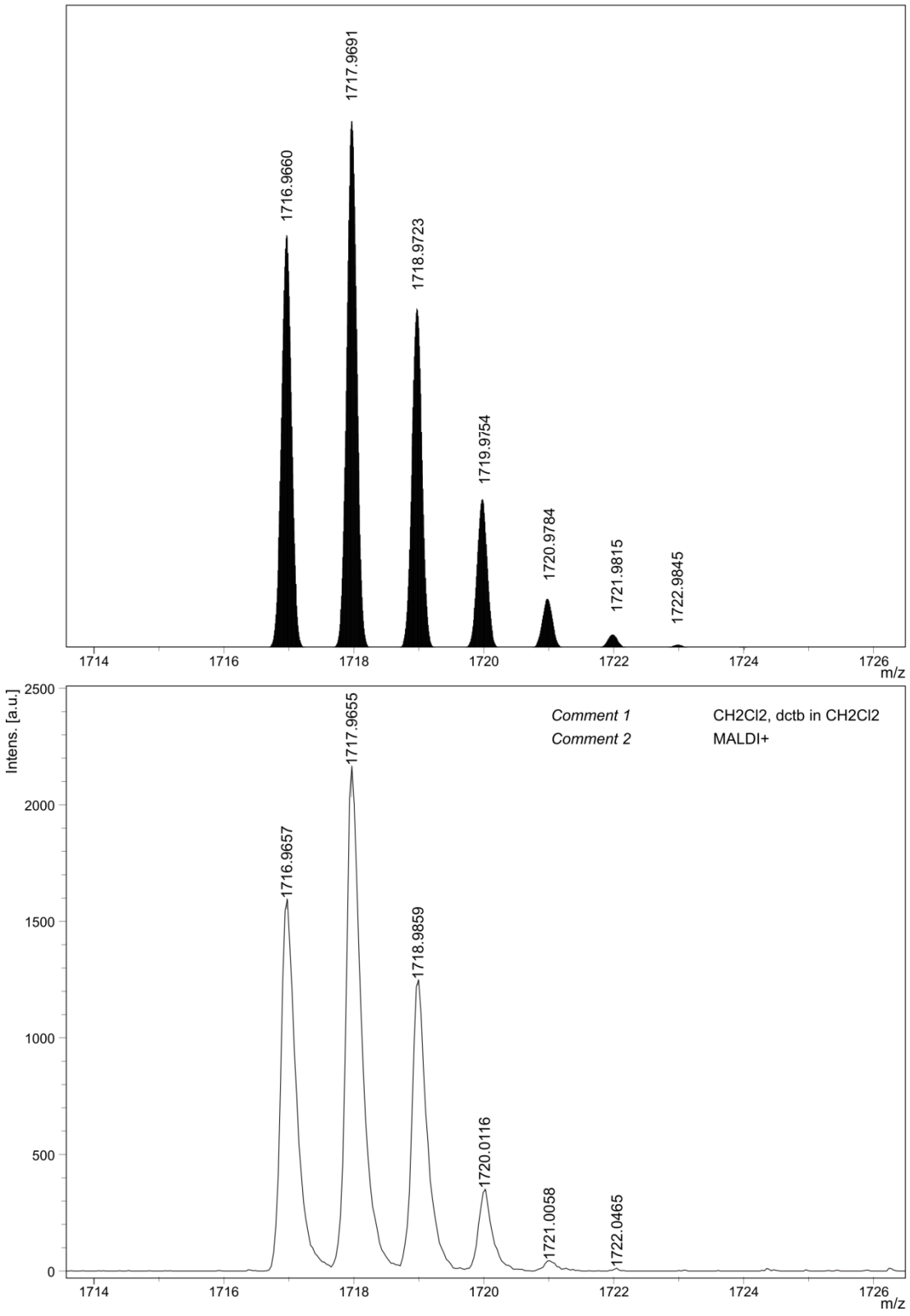
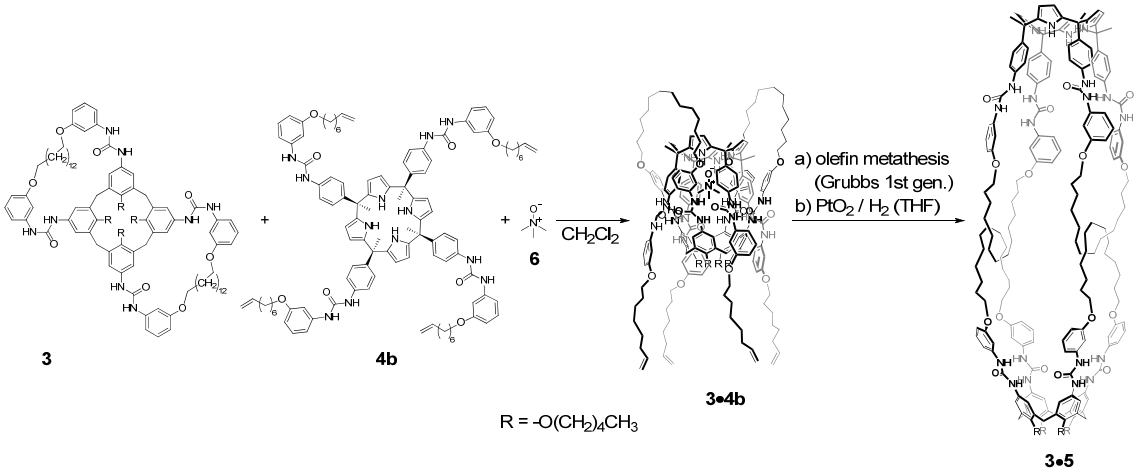


Figure S1. Exact MS (MALDI+) of calix[4]pyrrole **4b**; experimental (below) and theoretical calculated for $C_{108}H_{124}N_{12}O_8^+$ (above).

Synthesis and characterization of bis-[2]catenane 3•5



Scheme S2. Synthesis of bis-[2]catenane **3•5**.

Calix[4]pyrrole tetraurea **4b** (173 mg, 0.10 mmol), bis-loop calix[4]arene tetraurea **3**[2](171 mg, 0.10 mmol) and trimethylamine *N*-oxide **6** (7.56 mg, 0.10 mmol) were dissolved in dry CH_2Cl_2 (100 mL), and the resulting solution was purged with argon for 30 minutes and then a solution of the Grubbs catalyst (45 mg, 0.055 mmol) in CH_2Cl_2 was added via cannula. The resulting reaction mixture was left stirring at room temperature for two days. Then, triethylamine (0.5 mL) was added and the solvents evaporated. The dark solid residue was purified by column chromatography (CH_2Cl_2/CH_3CN 95/5) and the resulting white product was hydrogenated in dry THF (35 mL) with platinum dioxide (162 mg, 0.72 mmol) under hydrogen at atmospheric pressure. The reduction was followed by ^{1}H NMR (the signal at 5.4 ppm disappears upon reduction of the double bonds). The reaction mixture was then filtered through celite and evaporated to yield 222 mg of a white solid. Yield 65%. The ^{1}H NMR of this compound without the presence of an adequate guest affords not well defined proton signals specially in mesitylene-d_{12} solution (see ^{1}H NMR spectra in the following pages); MS (MALDI+/$[M]^+$): 3359.7.

The separation of the two enantiomers of the catenane was performed on a chiral Chiralpack IB 250x4.6mm, 5µm analytical column eluting with MeOH/CH_2Cl_2/EtOH with 1% diethylamine 45/10/45. (+)-**3•5**: $[\alpha]_{435}^{25}$ +5.5° (*c* 0.145 CH_2Cl_2). (-)-**3•5**: $[\alpha]_{435}^{25}$ -4.3° (*c* 0.145 CH_2Cl_2).

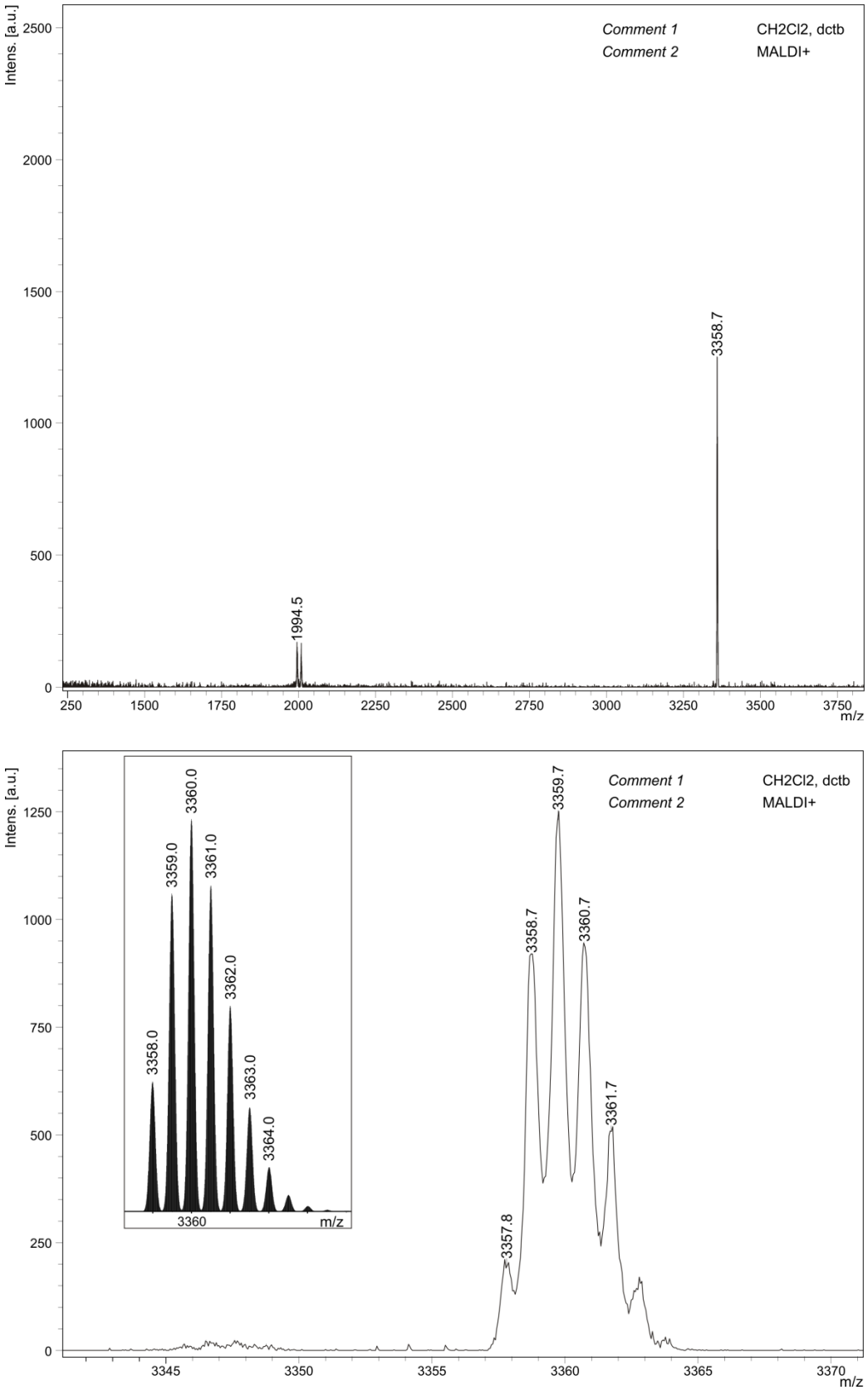


Figure S2. MS (MALDI+) of catenane **3•5**; full (above) and zoomed view of the molecular cation (below) with the theoretical peak calculated for $C_{208}H_{260}N_{20}O_{20}^{+}$.

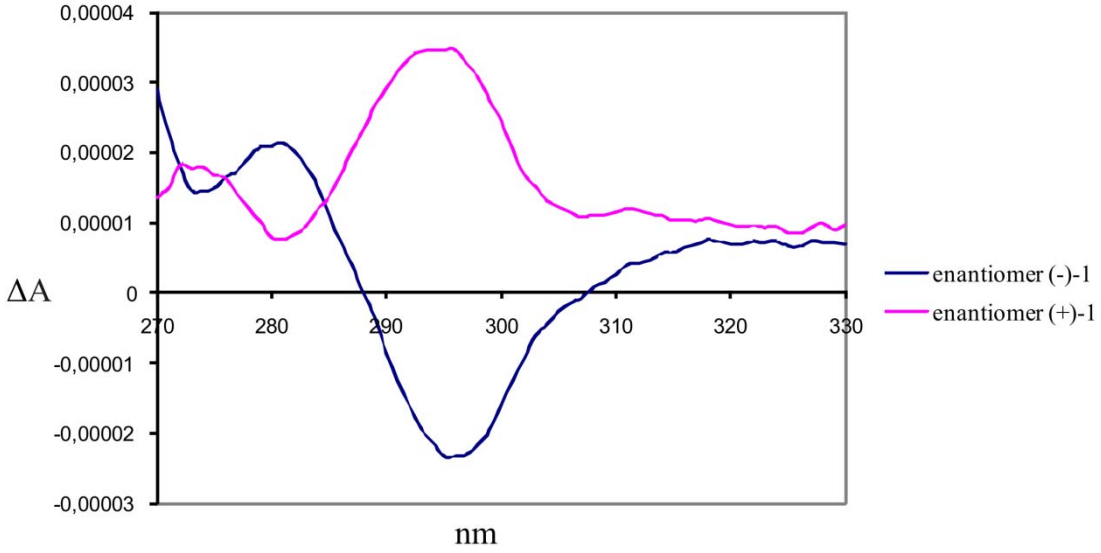


Figure S3. CD of catenaes (+)-**3•5** and (-)-**3•5**. Both solutions 20 μM in CH_2Cl_2.

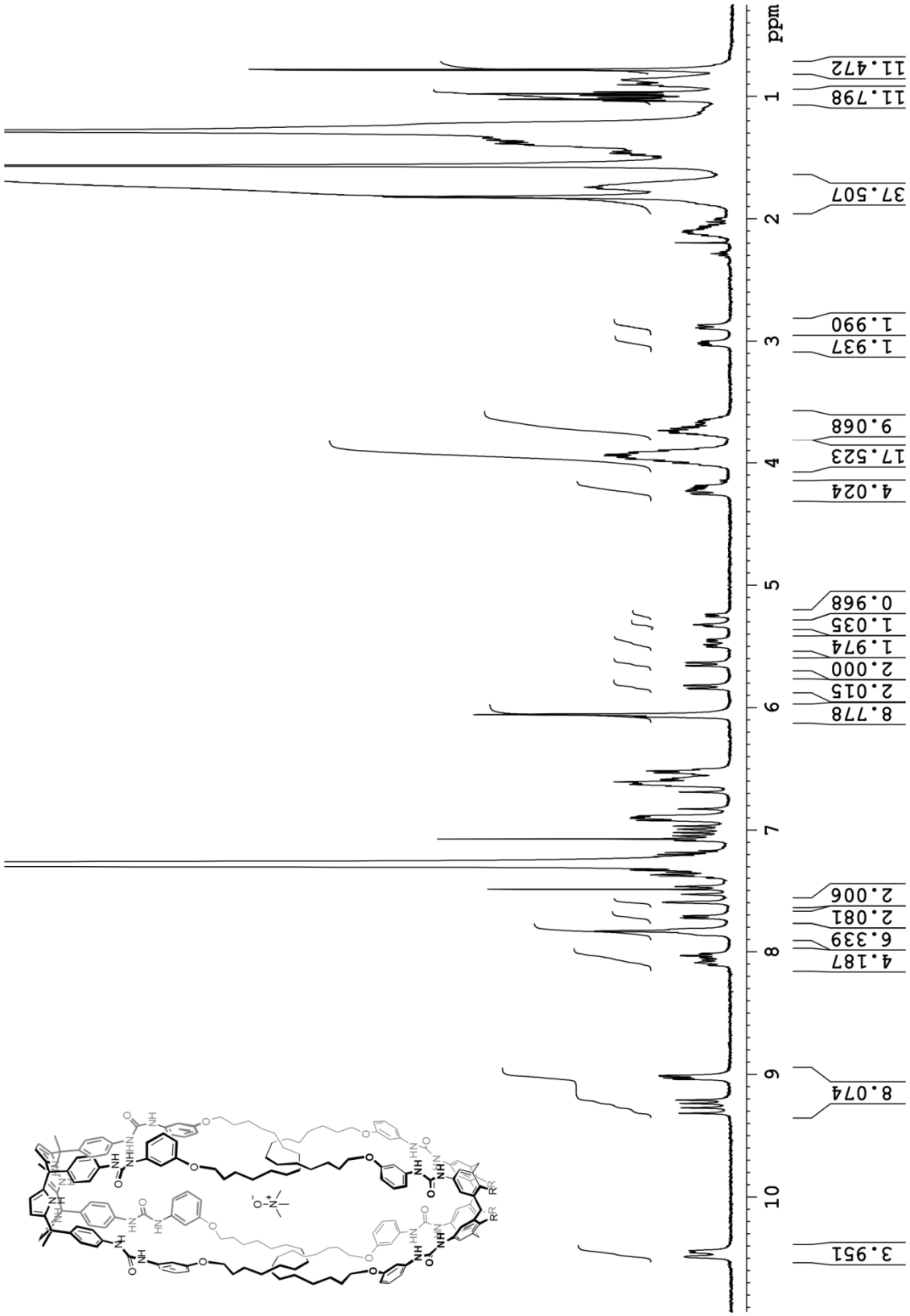


Figure S4. ^{1}H NMR ($CDCl_3$) of $CDCl_3$•**6**⊂ **3**•**5**.

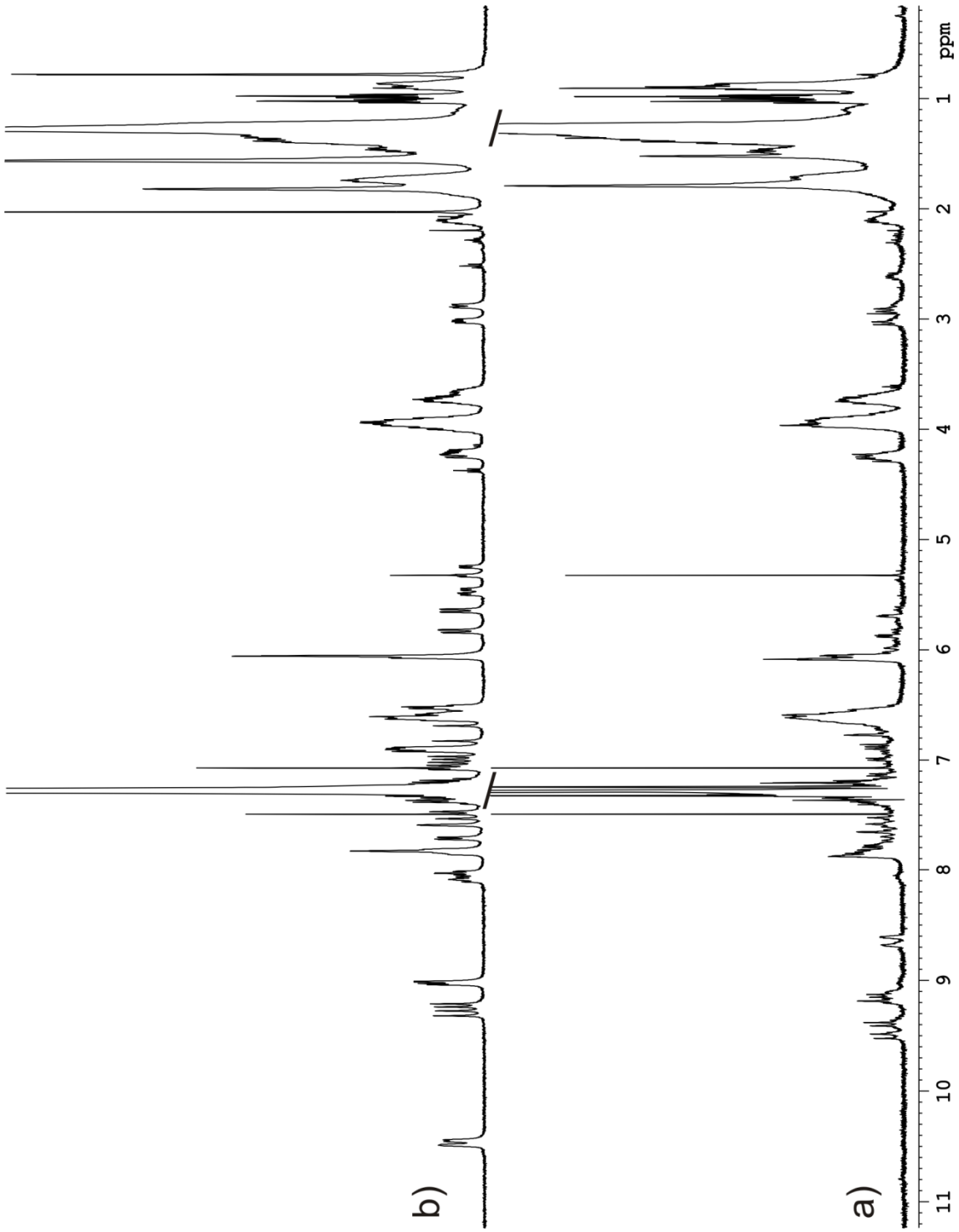


Figure S5. ^{1}H NMR ($CDCl_3$) of a) sample of racemic-**3•5** without any guest compared to b) capsular assembly $CDCl_3$•**6**⊂ **3•5**.

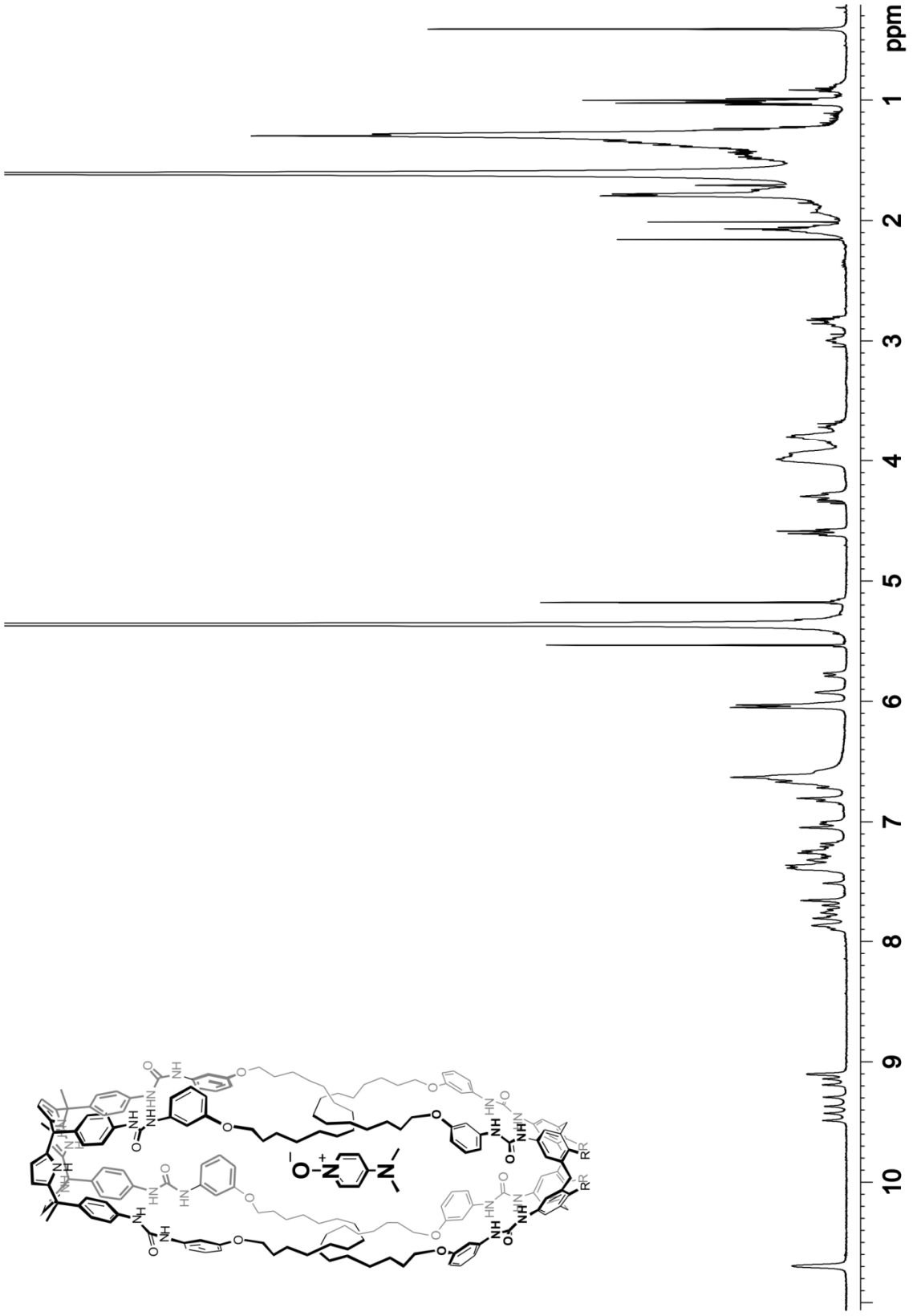


Figure S6. ^{1}H NMR ($CDCl_3$) of **8**⊂ **3•5**.

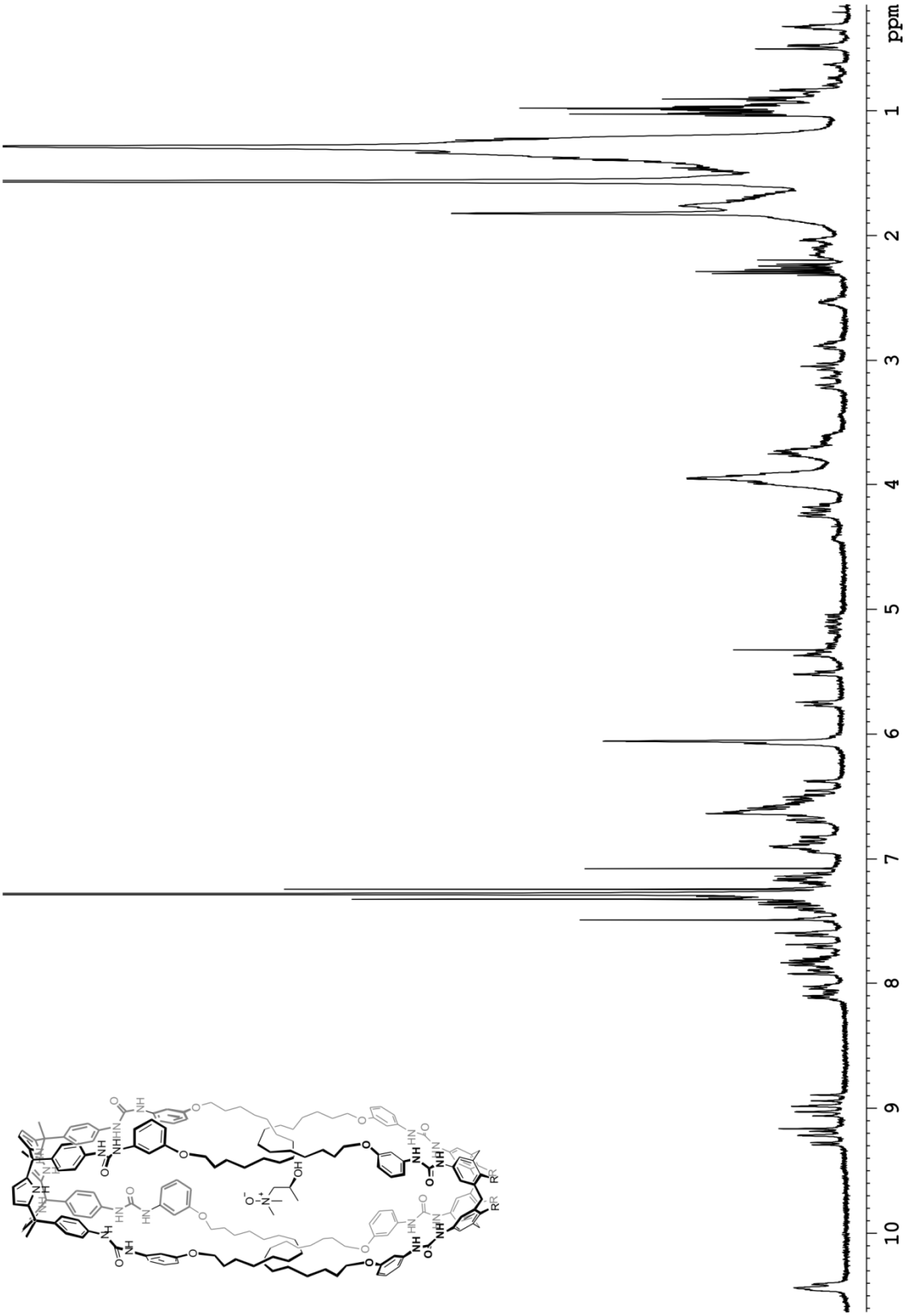


Figure S7. ^{1}H NMR ($CDCl_3$) of $CDCl_3$•*S*-**7**⊂ **3**•**5**.

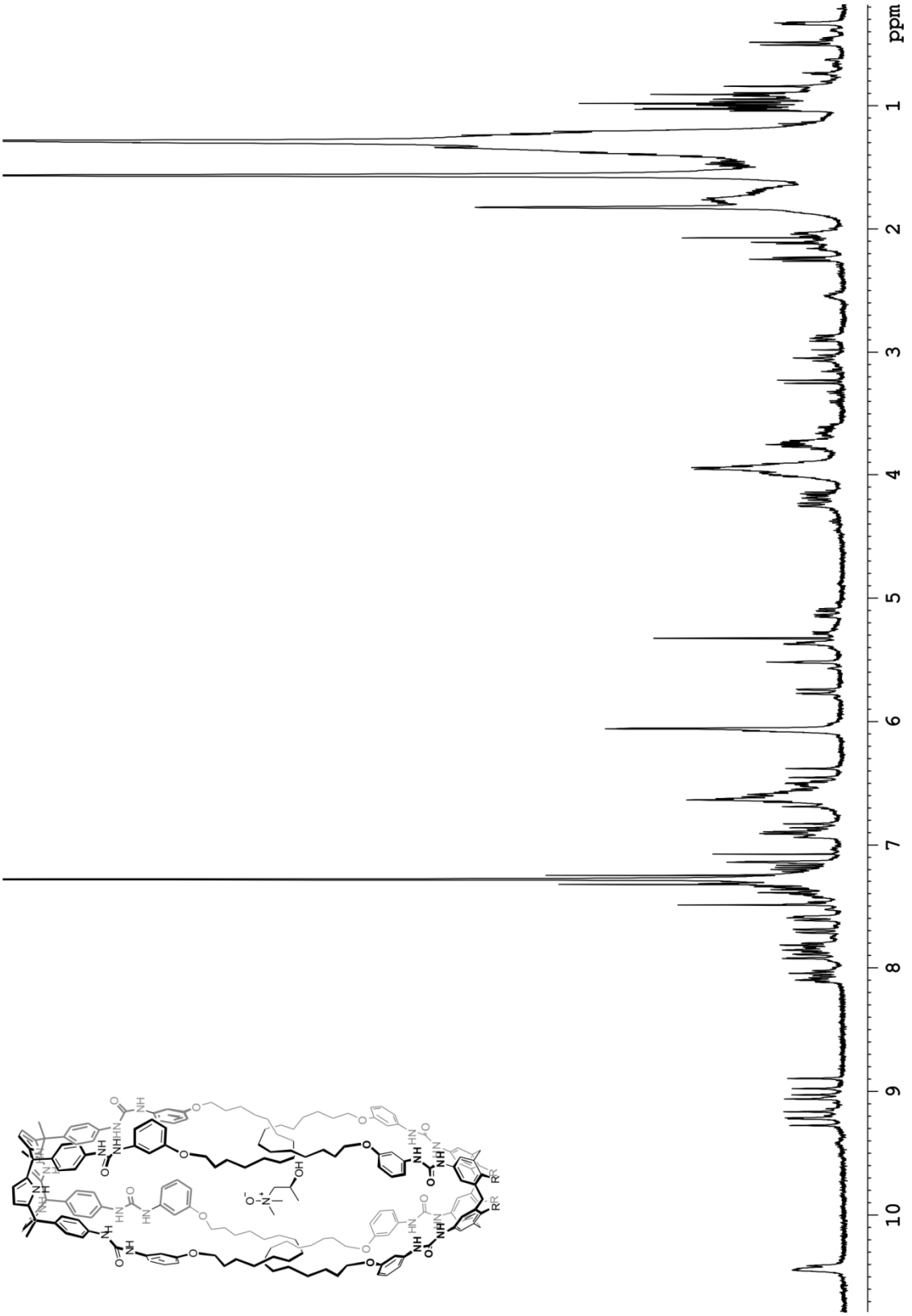


Figure S8. ^{1}H NMR ($CDCl_3$) of $CDCl_3$•*S*-**7**⊂ (+)-**3•5**.

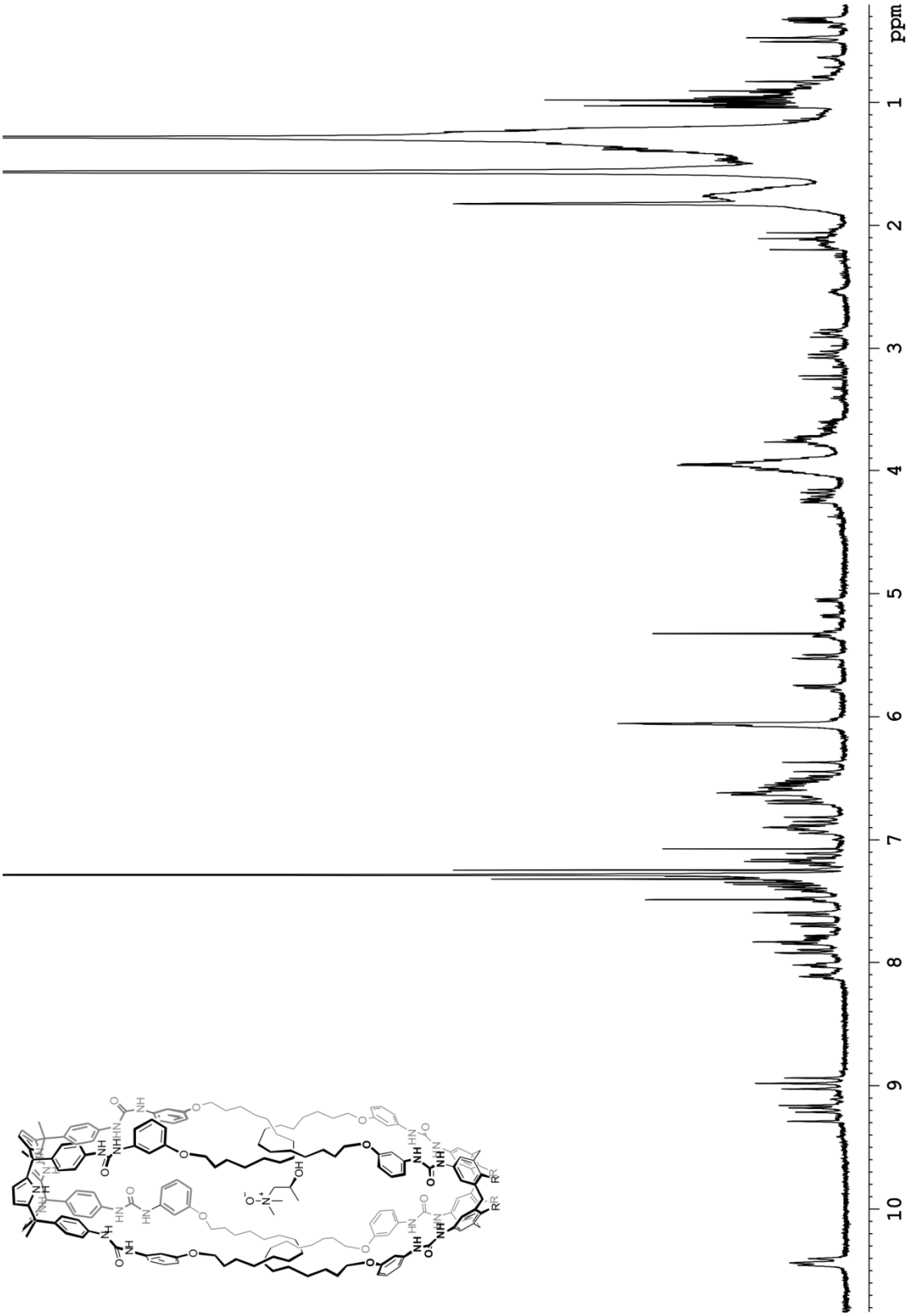


Figure S9. ^{1}H NMR ($CDCl_3$) of $CDCl_3$•*S*-**7**⊂ (-)-**3**•**5**.

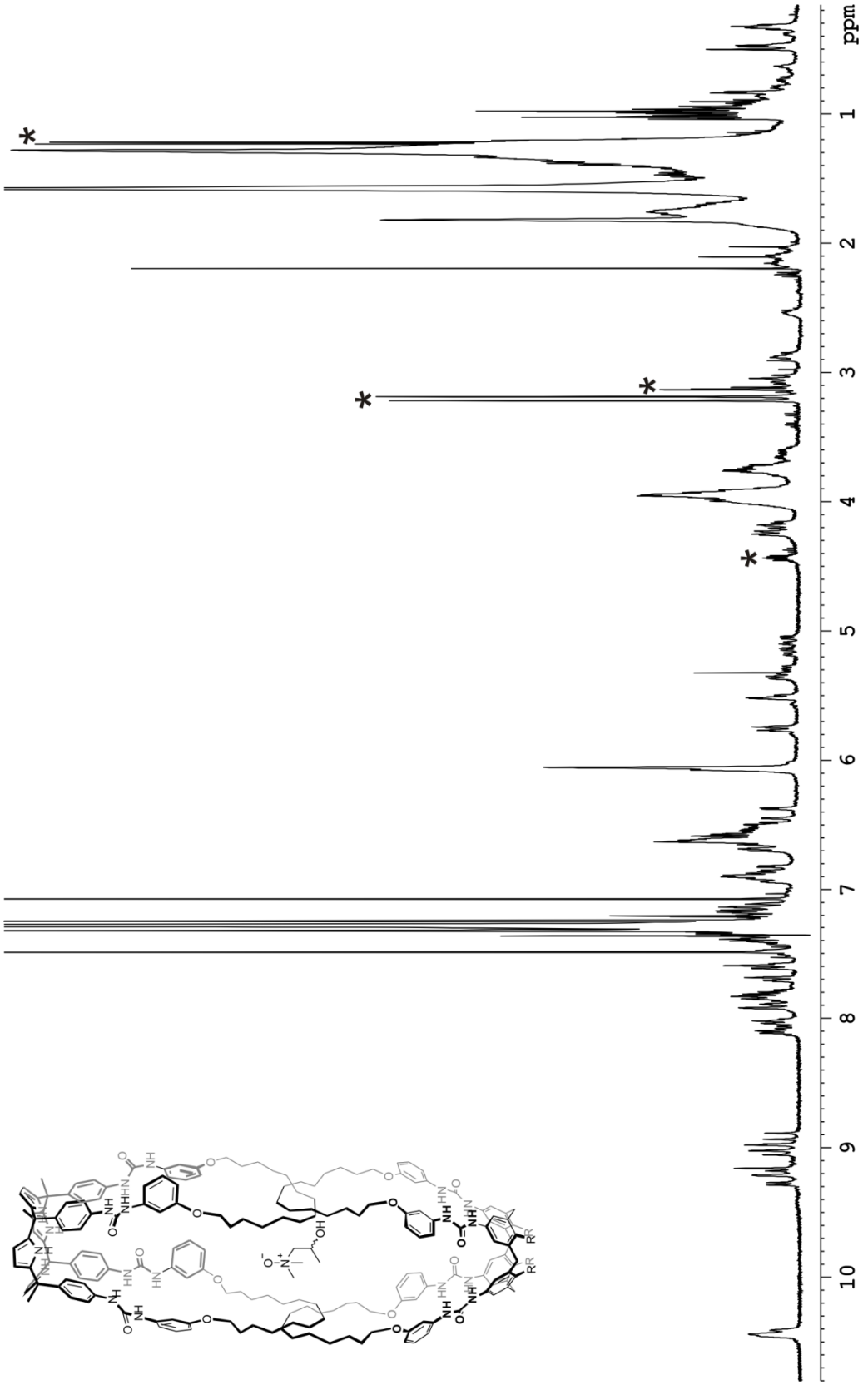


Figure S10. ^{1}H NMR ($CDCl_3$) of a solution containing 1 equivalent of (-)-**3•5** and 2 equivalents of racemic-**7**. The signals corresponding to the excess of guest **7** (free in solution) are marked with asterisks.

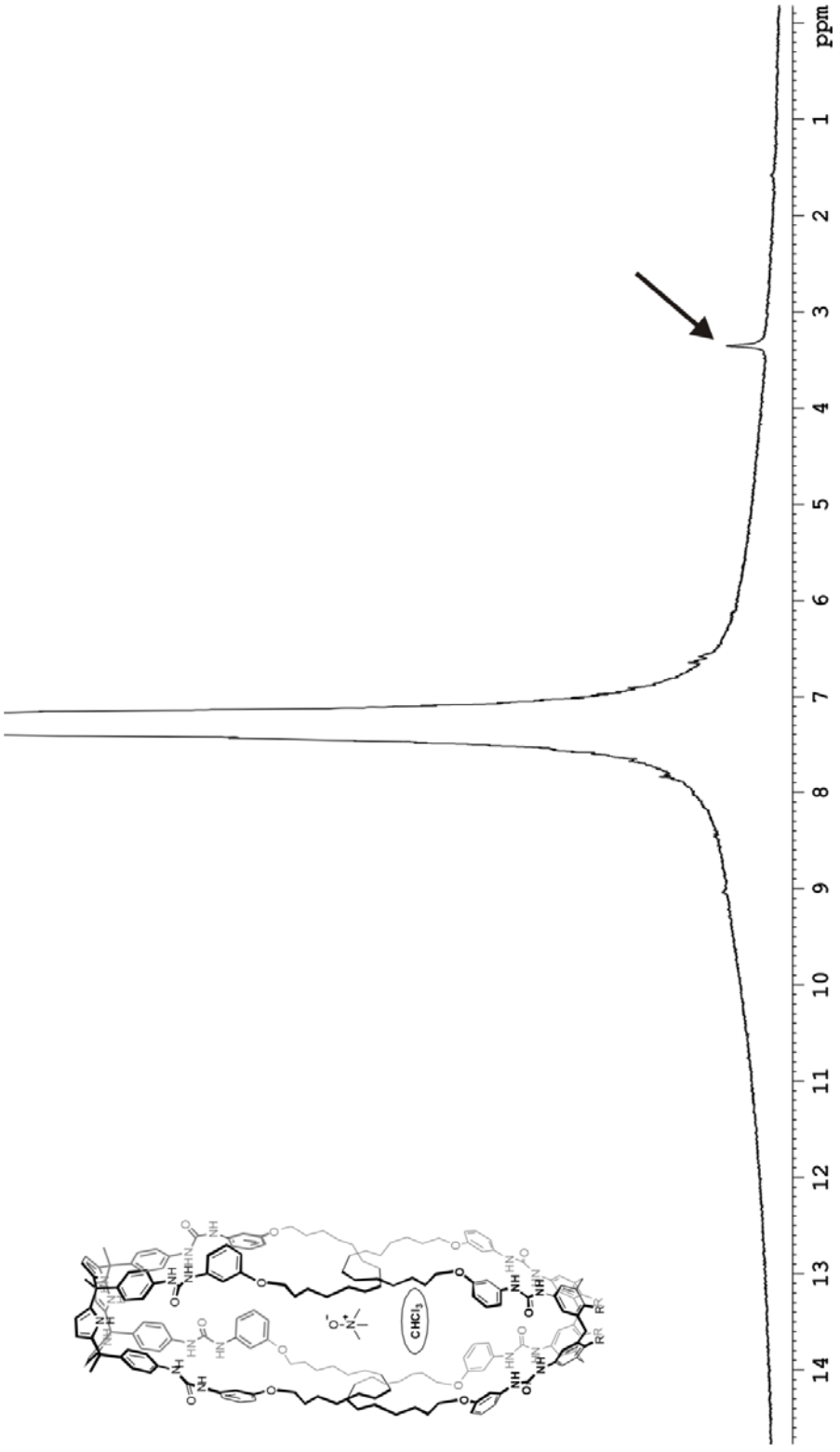


Figure S11 ^{1}H GOESY-NMR ($CHCl_3$) of assembly $CDCl_3$•**6**⊂ **3•5** with selective excitation at 7.30 ppm (signal of the bulk $CHCl_3$ solvent). The signal at 3.4 ppm (indicated with an arrow) is in chemical exchange with the solvent, suggesting the existence of a solvent molecule inside the capsule that is in slow chemical exchange with the bulk solvent.

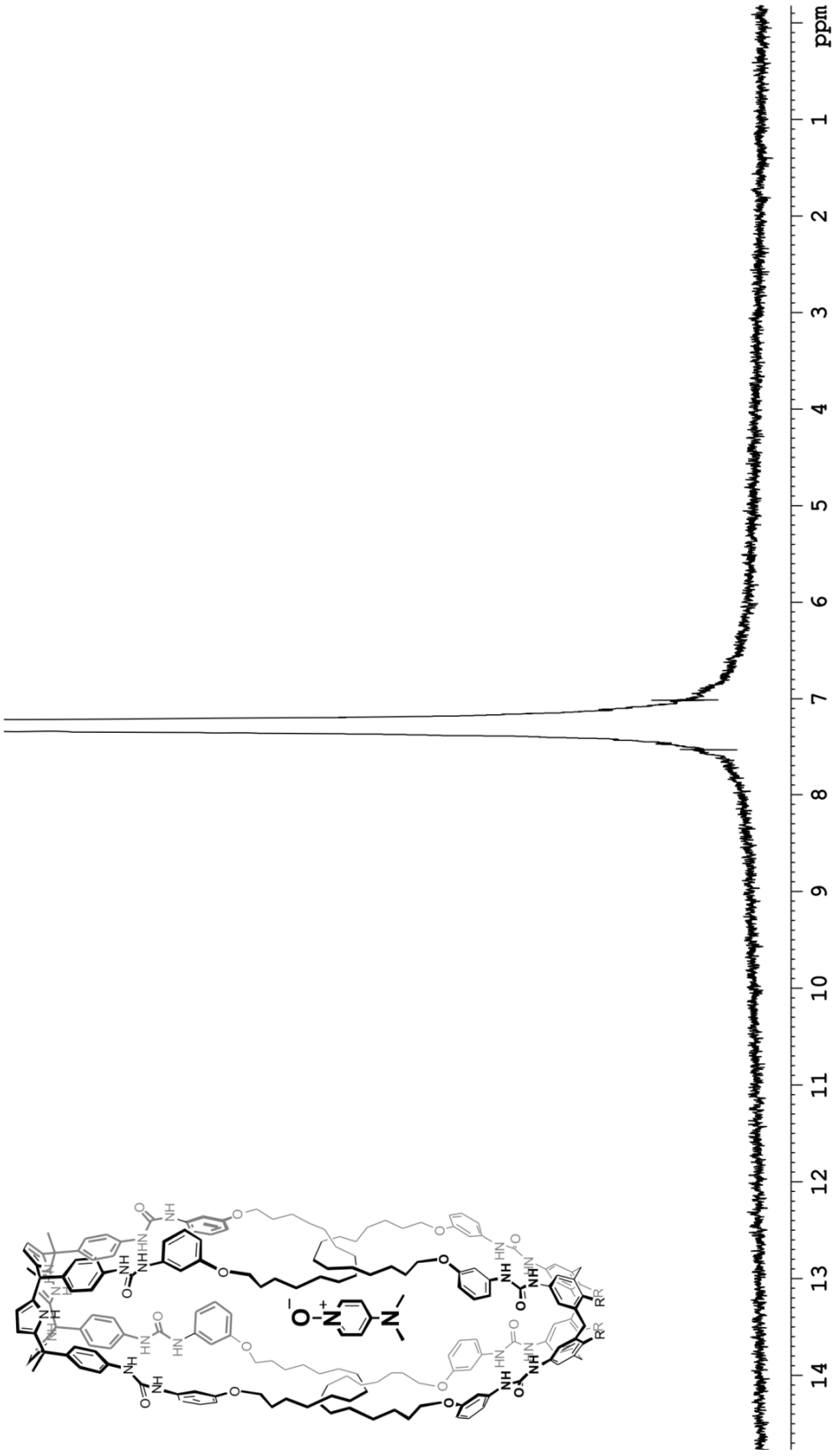


Figure S12. ^{1}H GOESY-NMR ($CHCl_3$) of assembly **8⊂ 3•5** with selective excitation at 7.30 ppm (signal of the bulk solvent), showing no other signals in chemical exchange in the upfield region.

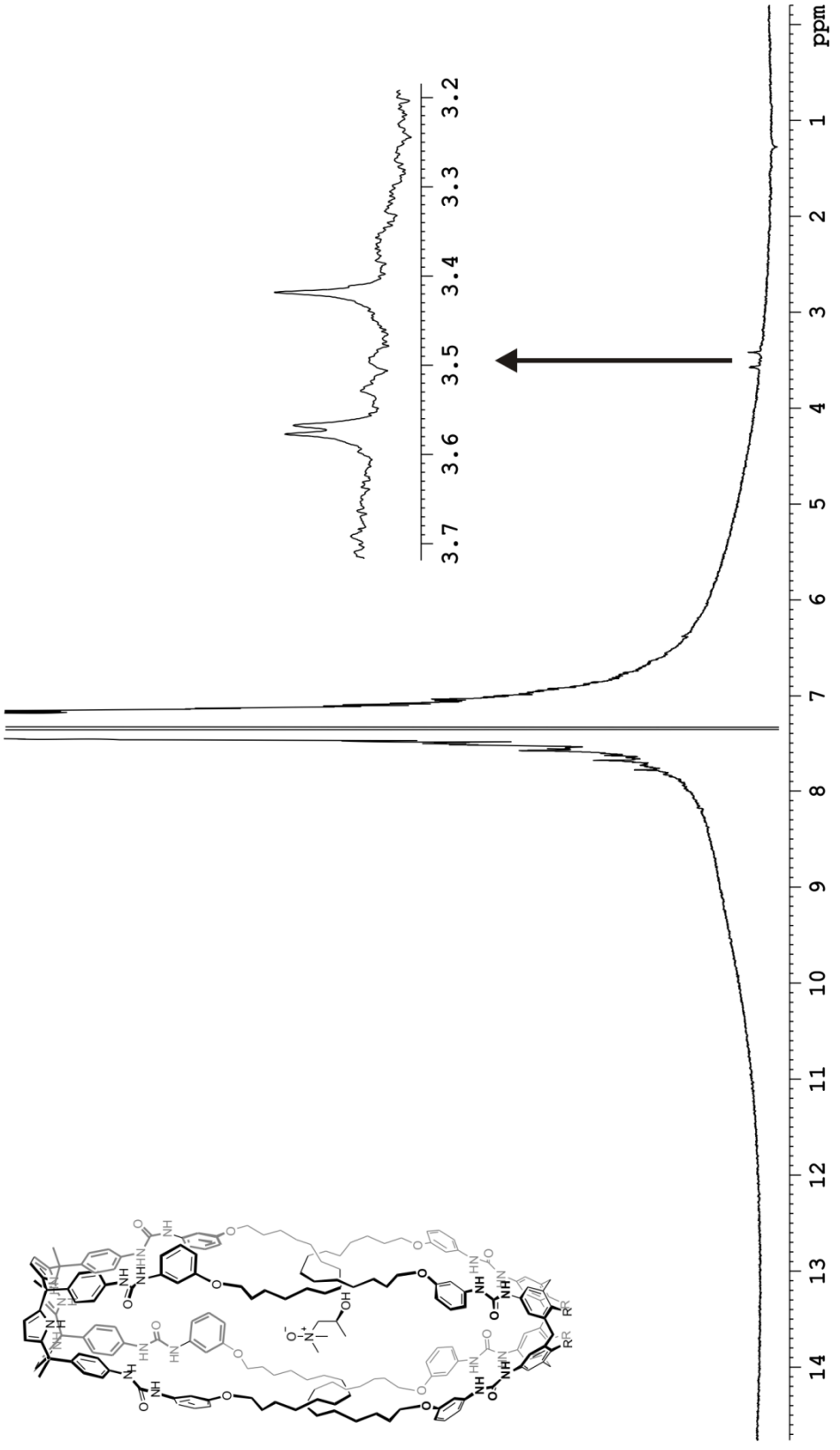


Figure S13. ^{1}H GOESY-NMR ($CHCl_3$) of $CDCl_3$•*S*-**7**⊂ rac-**3•5** with selective excitation at 7.30 ppm (signal of the bulk $CHCl_3$ solvent) showing four (1+1+2) signals for the chloroform molecules encapsulated in the four different cyclo-diastereoisomers that are in slow exchange (see magnified area).

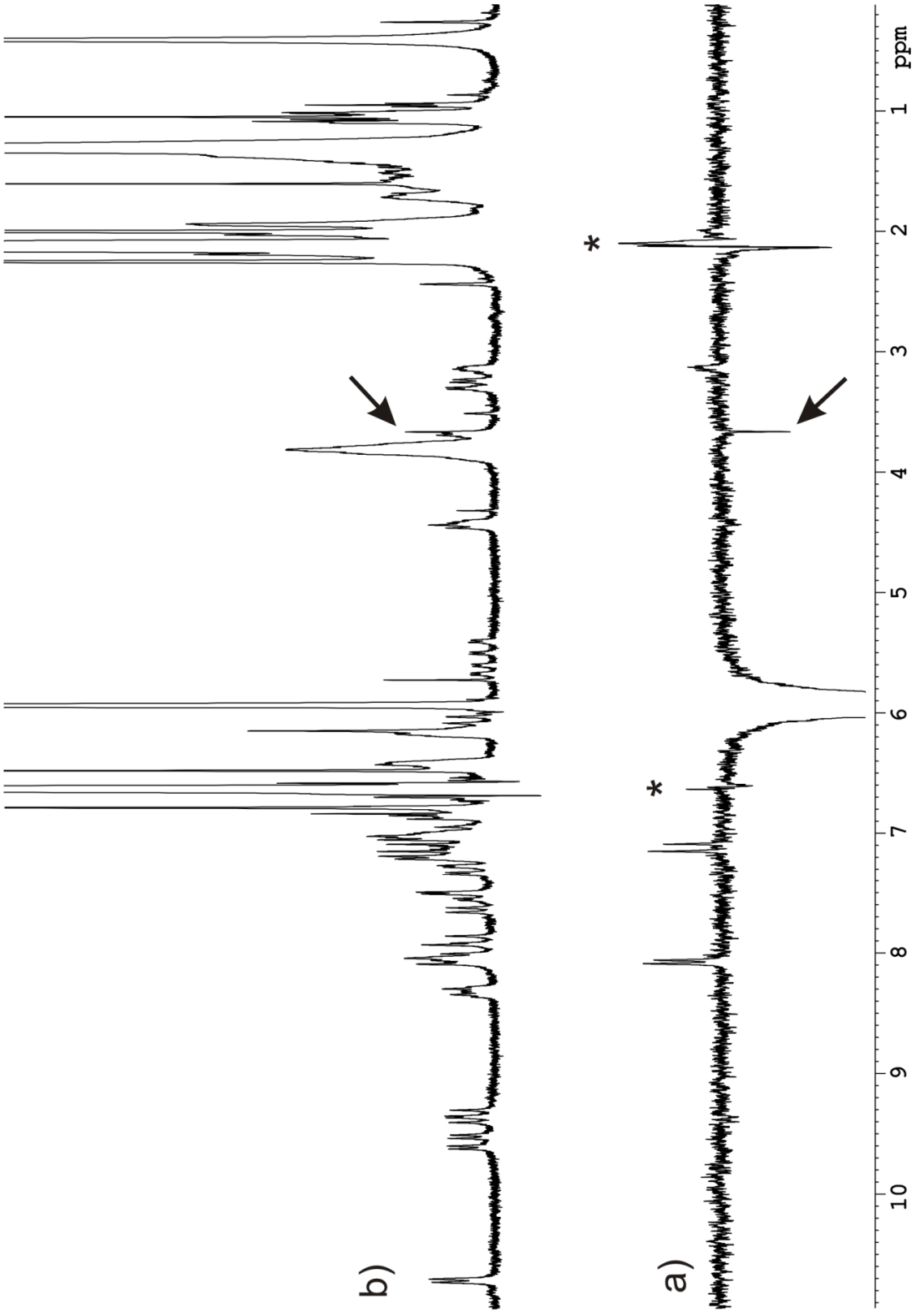


Figure S14. a) ^{1}H ROE experiment of $CDCl_3$•**6**⊂ **3**•**5** (mesitylene-d_{12}) with selective excitation to the signal for free chloroform at 5.94 ppm showing the existence of a slow chemical exchange with the signal at 3.7 ppm (indicated with an arrow) corresponding to the encapsulated $CHCl_3$ molecule. * indicates solvent signals' artifacts. b) ^{1}H-NMR spectrum with solvent suppression of the same sample.

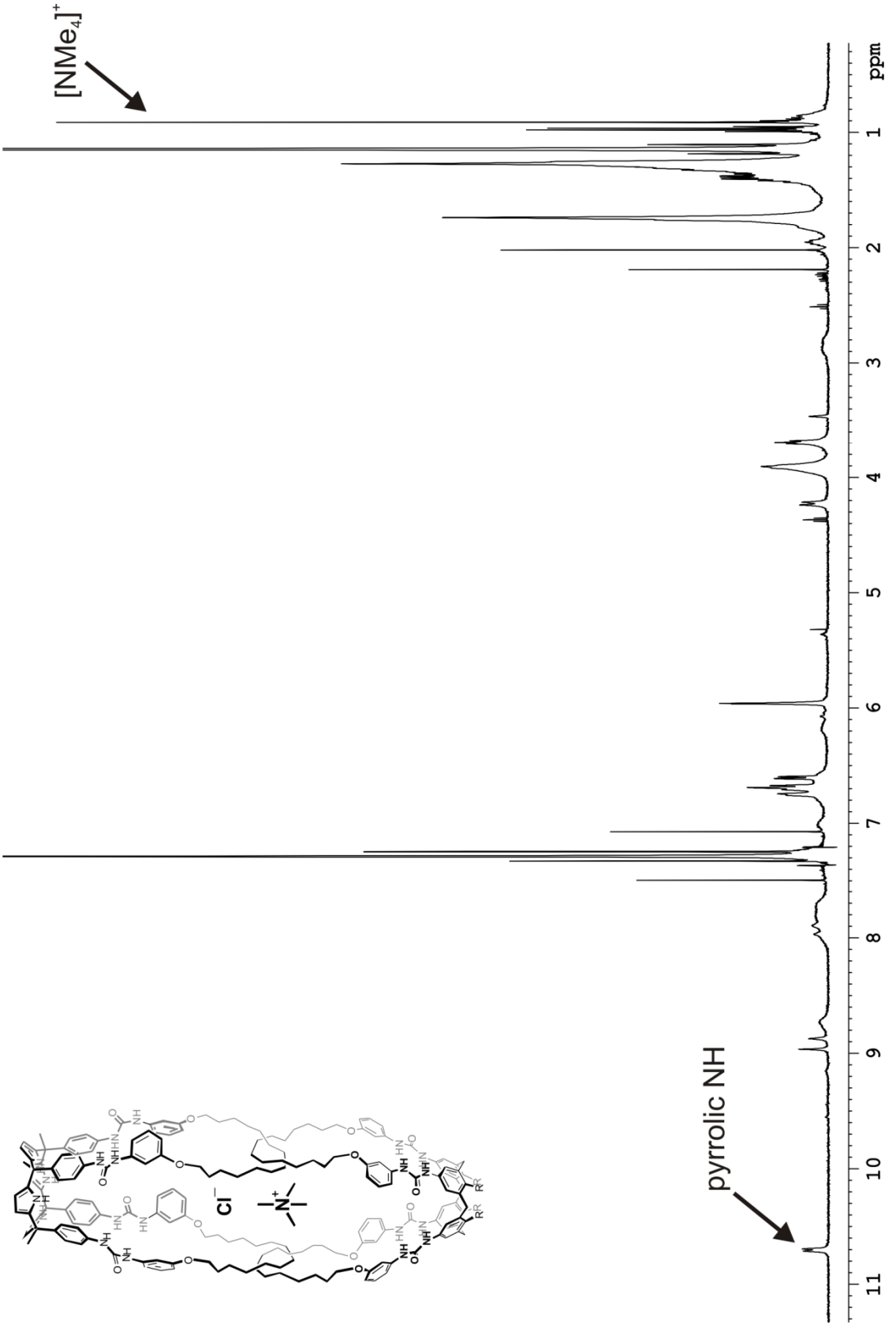


Figure S15. ^{1}H NMR ($CDCl_3$) of **9**•Cl⊂ **3**•**5**. The signals for the pyrrolic NHs at low field and the TMA^+ cation at high field are indicated.

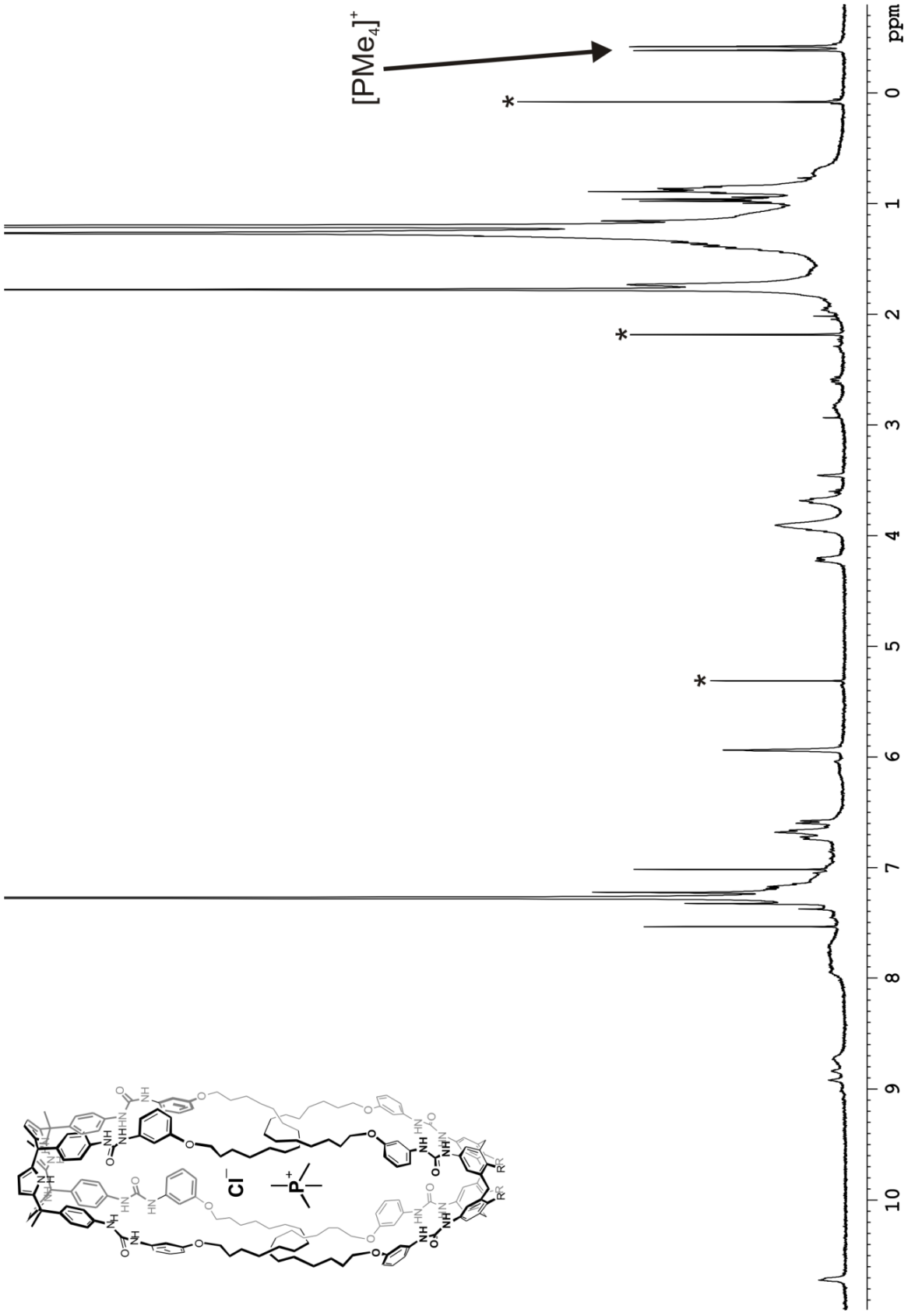


Figure S16. ^{1}H NMR ($CDCl_3$) of **10**•Cl⊂ **3**•**5**. The signal for the TMP^+ cation at high field is indicated with an arrow. * indicates solvent signals (DCM, acetone and silicone oil).

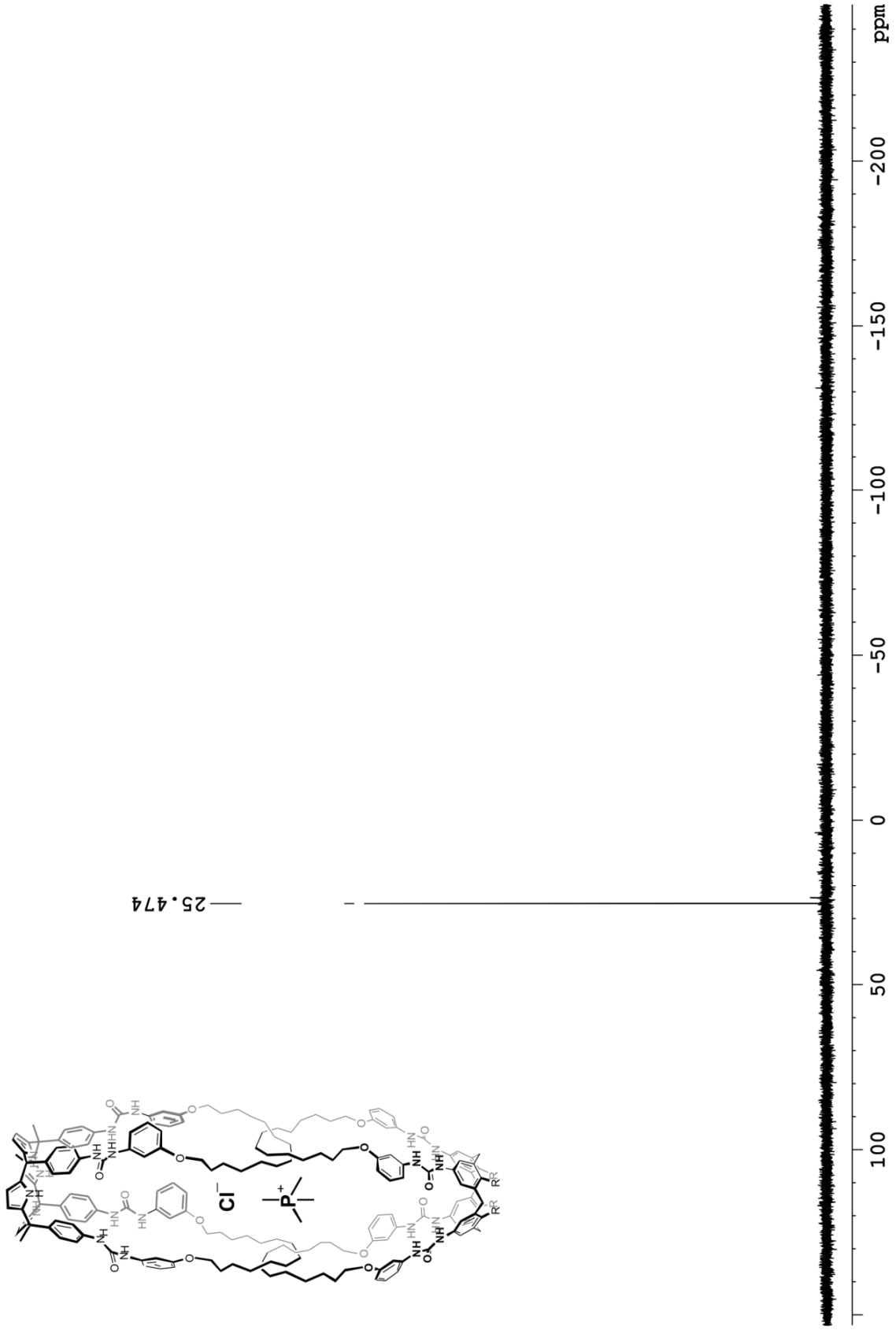


Figure S17. ^{31}P NMR ($CDCl_3$) of of **10**•Cl⊂ **3•5**. The chemical shift value for free **10**•Cl in the same solvent is δ = 26.8 ppm.

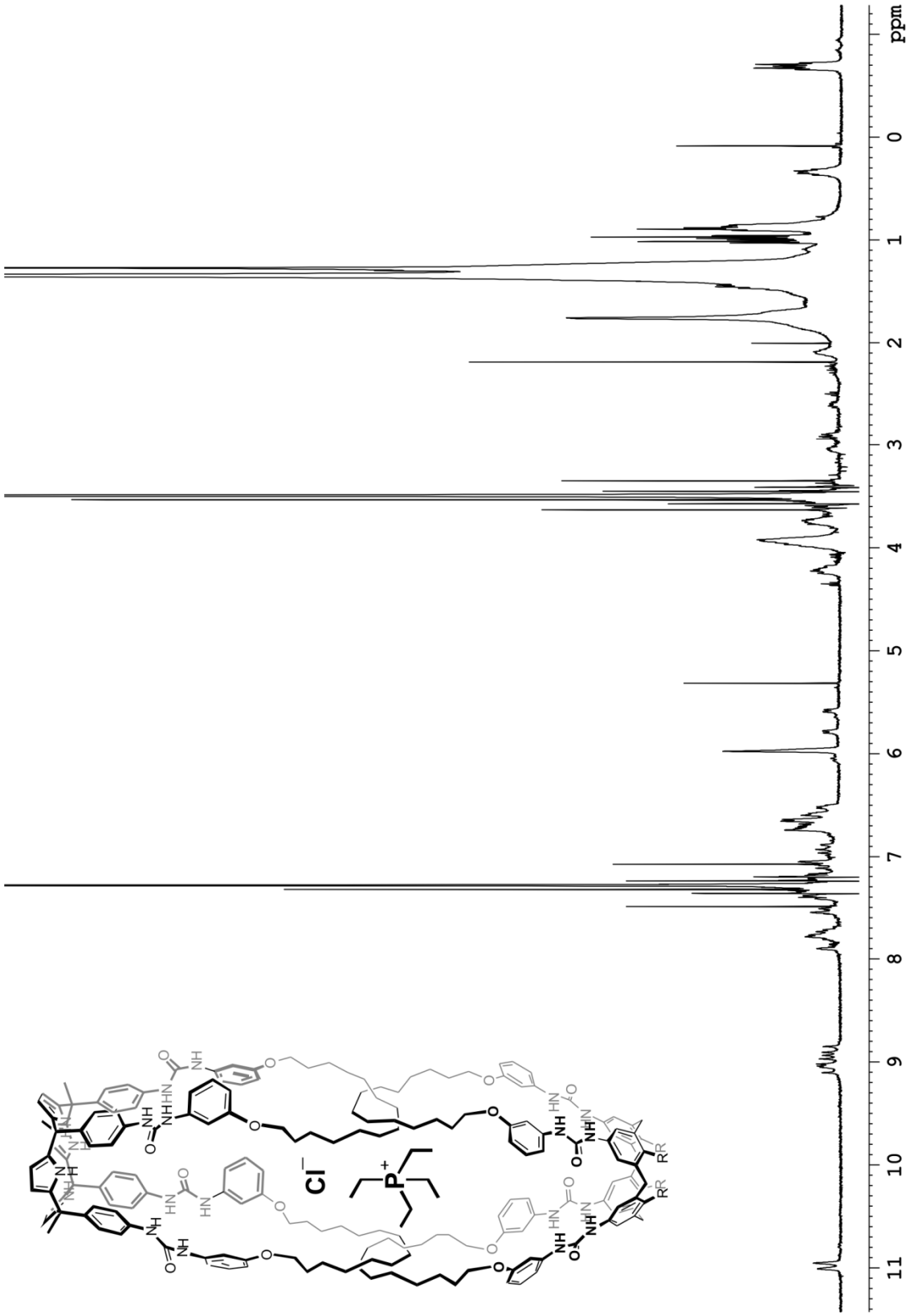


Figure S18. ^{1}H NMR ($CDCl_3$) of **11**•Cl⊂ **3•5**. The salt was added from a MeOH, solution.

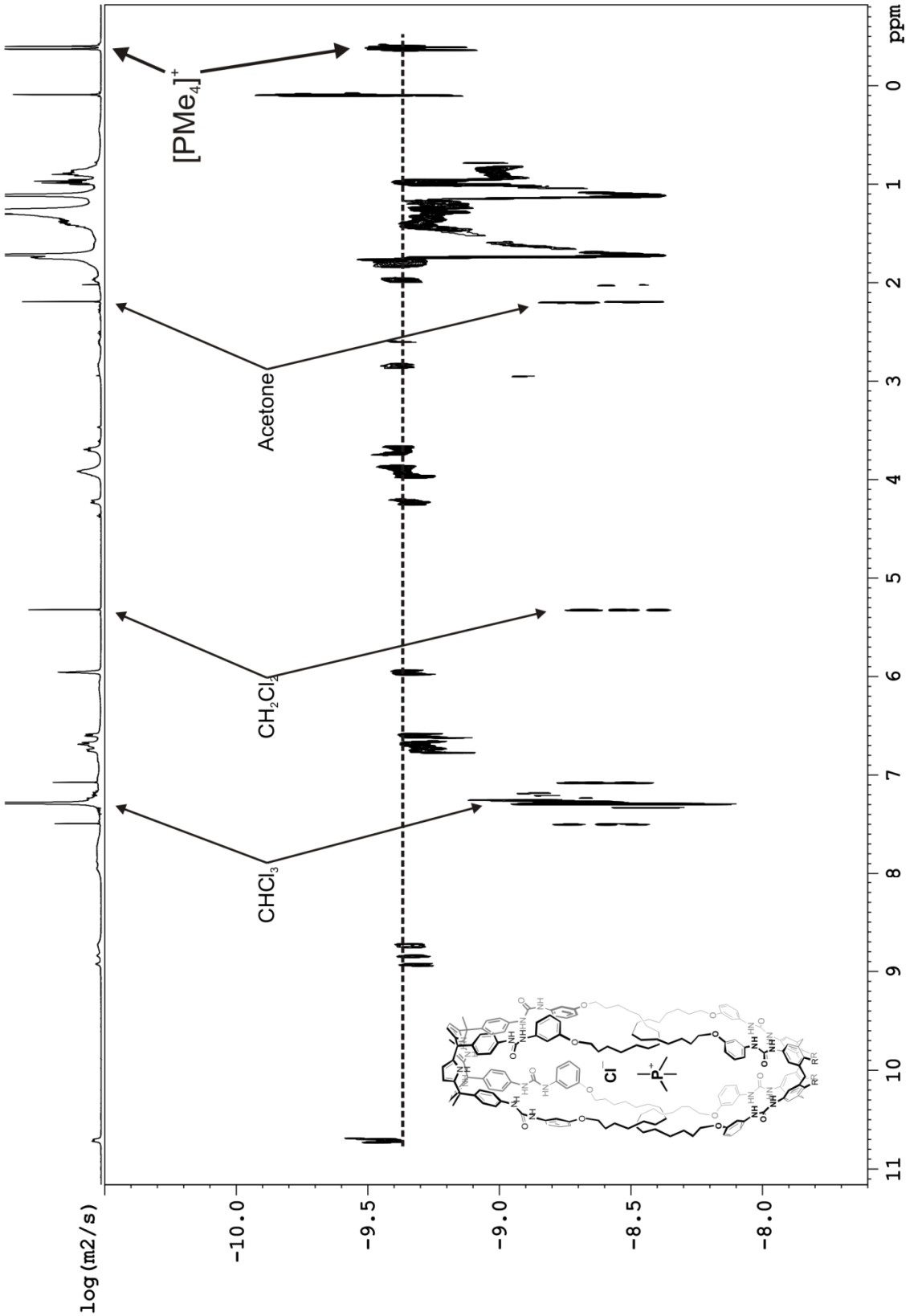


Figure S19. DOSY ^{1}H NMR ($CDCl_3$) of **10**•Cl⊂ **3•5**. The signal for the TMP^+ cation at high field is highlighted.

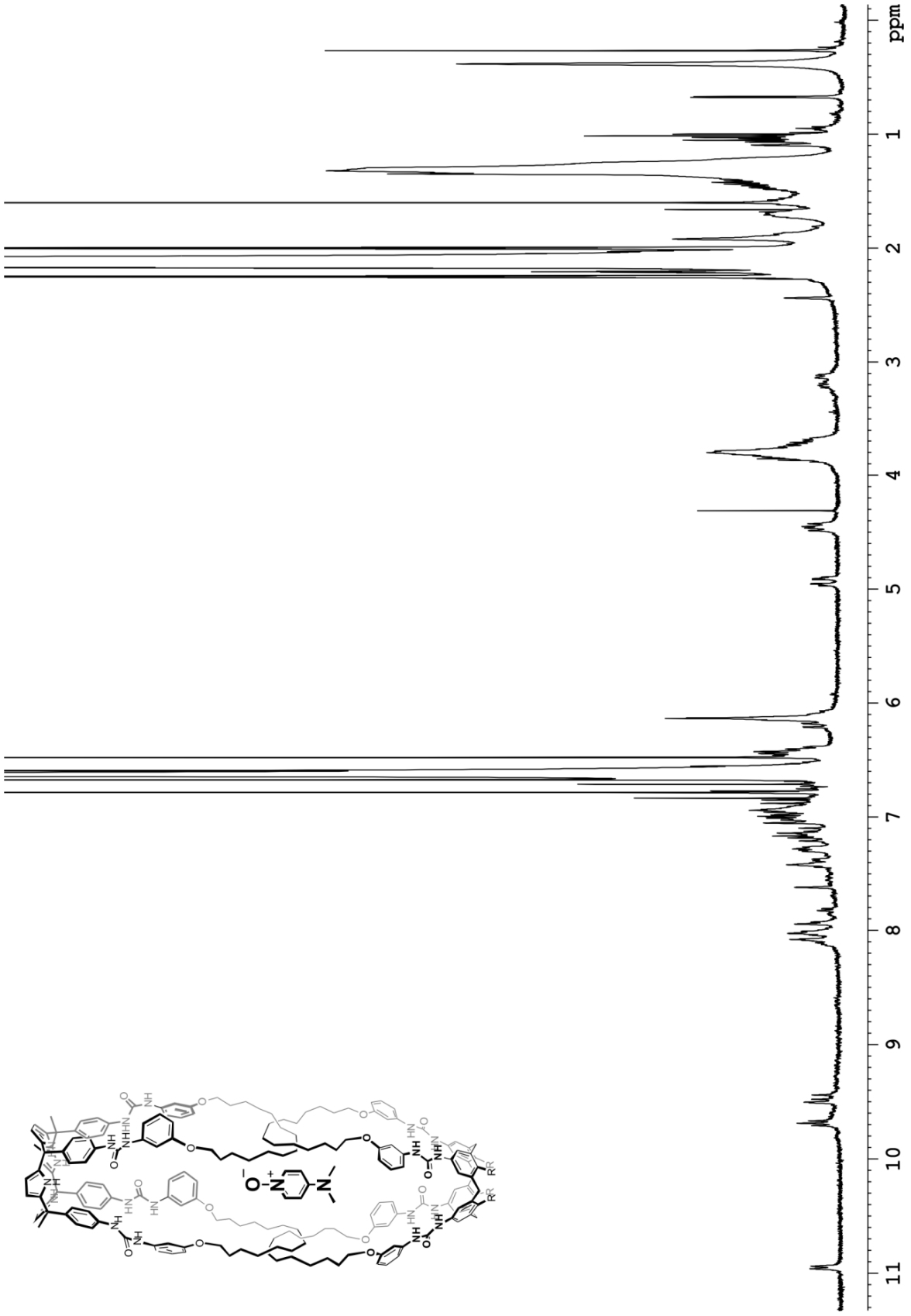


Figure S20. ^{1}H NMR of **8**⊂ **3•5** in mesitylene-d_{12} solution.

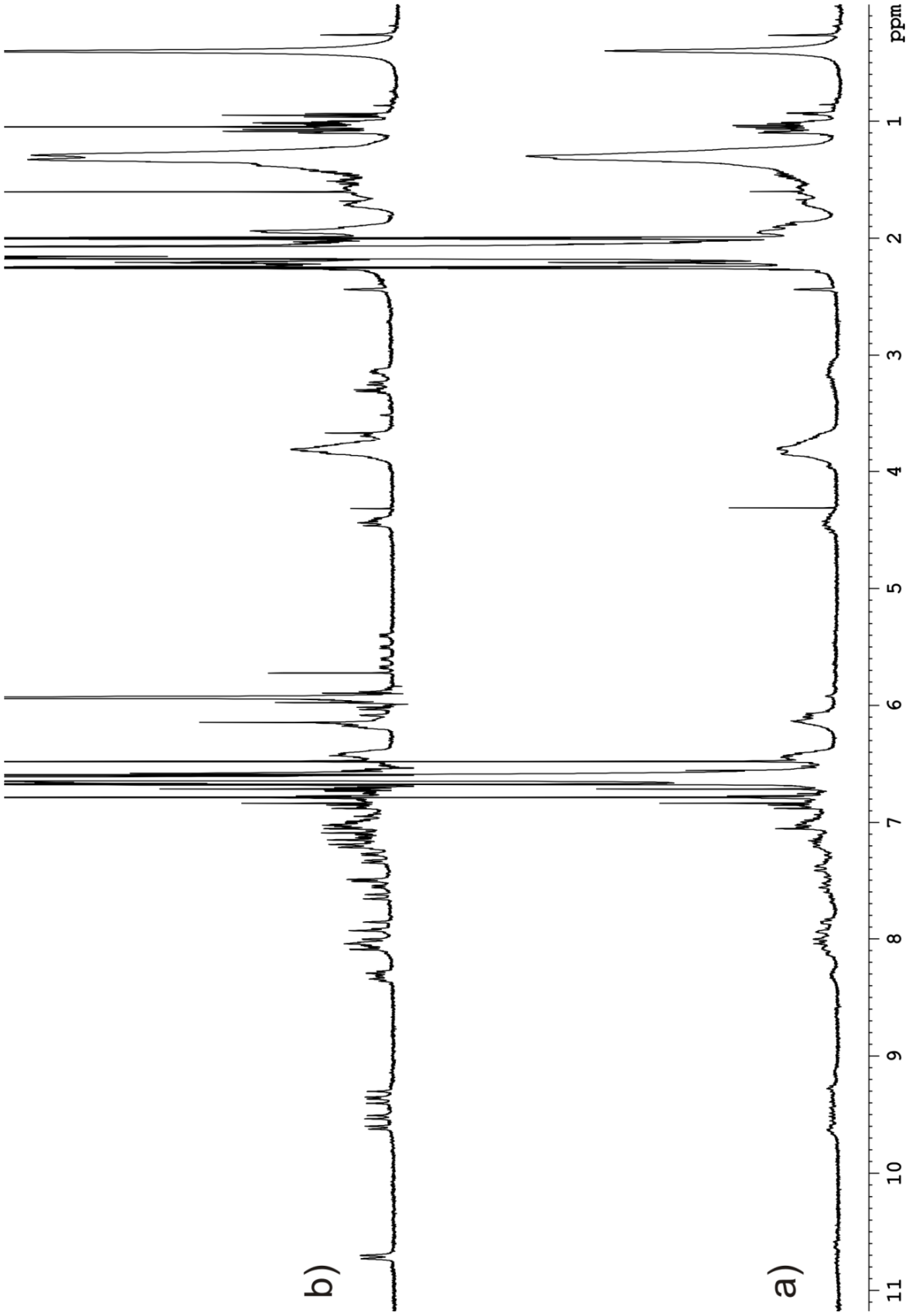


Figure S21. ^{1}H NMR of a) **6⊂ 3•5** in mesitylene-d_{12} with no $CHCl_3$ added and b) with a small amount of $CHCl_3$ in solution.

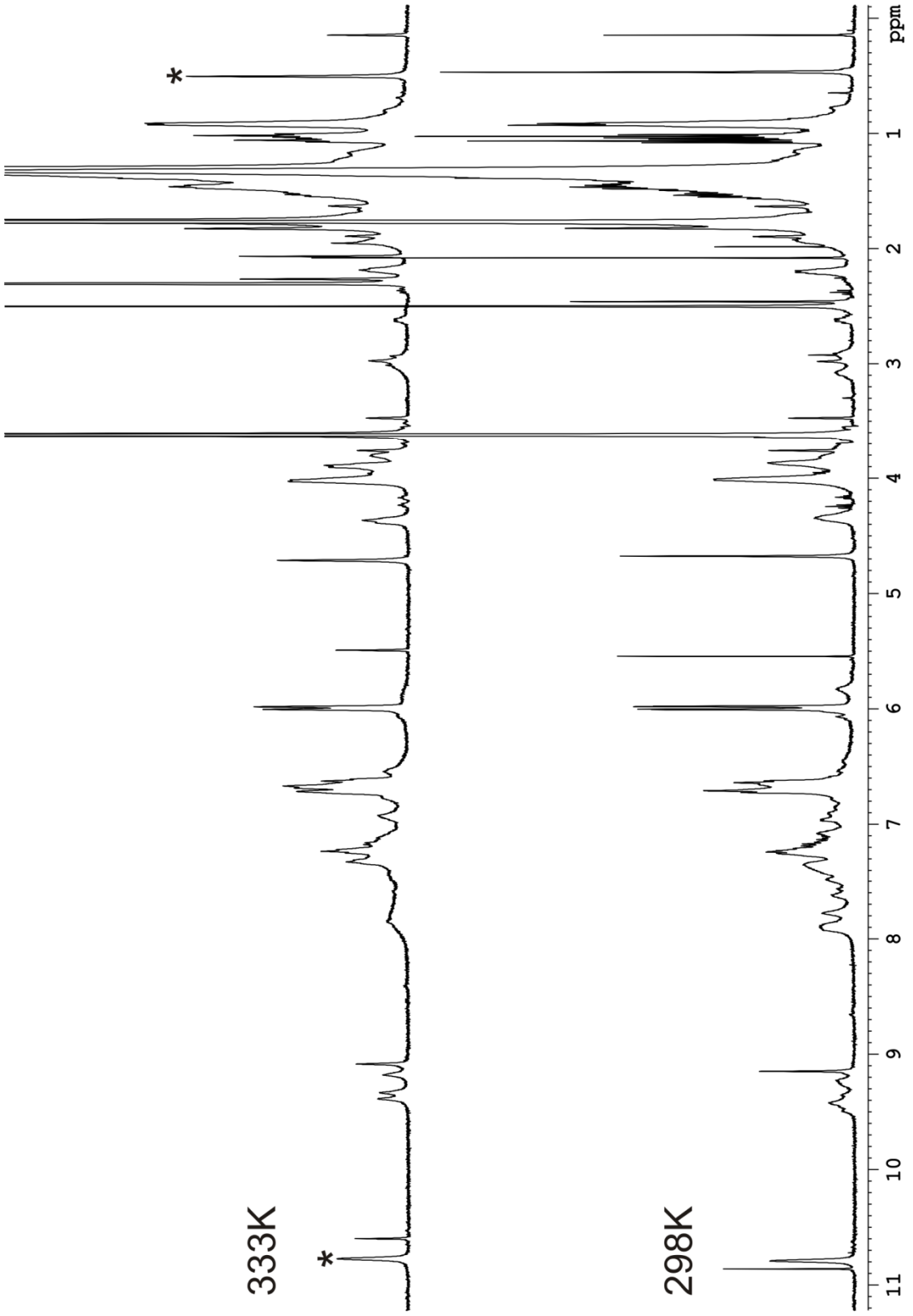


Figure S22. ^{1}H NMR of **8**⊂ **3•5** in THF-d_8 at 298K and 333K. Diagnostic signals of the capsular structure at 333K (pyrrolic NHs at low field and guest's methyl groups at high field) are indicated with an asterisk.