Electronic Supplementary Information (ESI)

Homo and heteroassembly of amide-based [2]rotaxanes using *α,α'*-dimethyl-*p*-xylylenediamines

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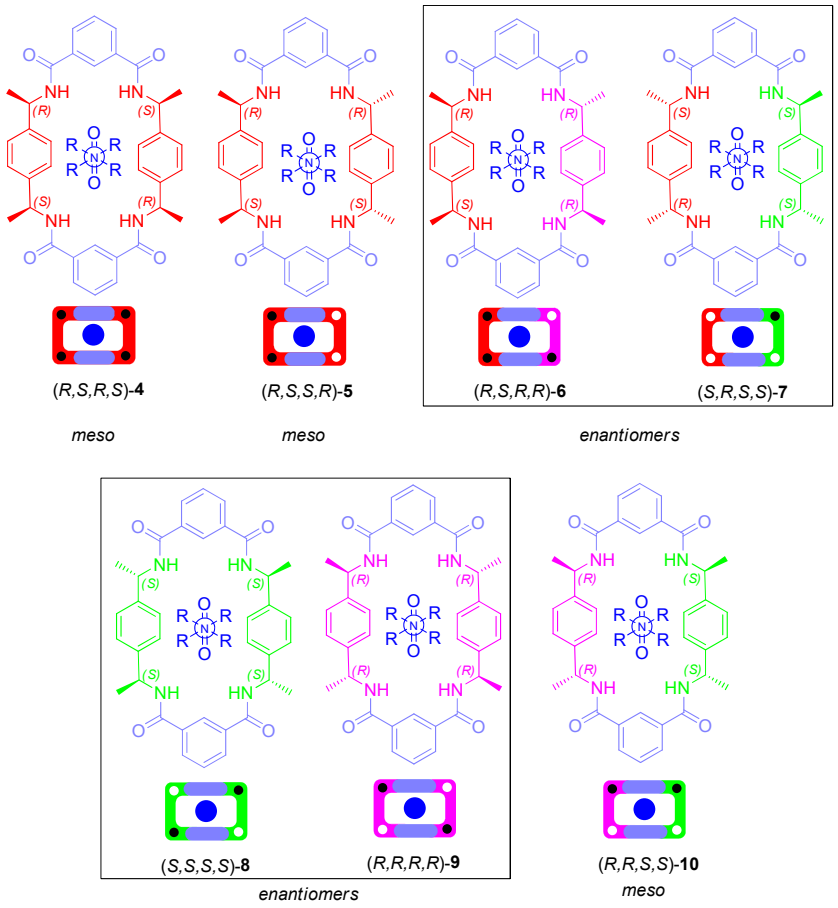
1. Structural interpretation of the schematic cartoons included in the figure 1.

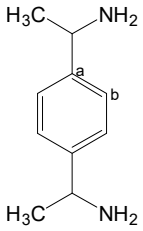


2. General experimental section.

Unless stated otherwise, all reagents were purchased from Aldrich Chemicals and used without further purification. HPLC grade solvents (Scharlab) were nitrogen saturated and were dried and deoxygenated using an Innovative Technology Inc. Pure-Solv 400 Solvent Purification System. Column chromatography was carried out using silica gel (60 Å, 70-200 μm, SDS) as stationary phase, and TLC was performed on precoated silica gel on aluminium cards (0.25 mm thick, with fluorescent indicator 254 nm, Fluka) and observed under UV light. All melting points were determined on a Kofler hot-plate melting point apparatus and are uncorrected. IR spectra were recorded on a PelkinElmer Spectrum 65 spectrometer using the ATR technique (attenuated total reflection) on bulk material, and data are quoted in wavenumbers (cm^{-1}). The intensities of the absorption bands are indicated as vs (very strong), s (strong), m (middle), w (weak) and vw (very weak). ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance 300, 400 and 600 MHz instruments. ^{1}H NMR chemical shifts are reported relative to Me_4Si and were referenced via residual proton resonances of the corresponding deuterated solvent whereas ^{13}C NMR spectra are reported relative to Me_4Si using the carbon signals of the deuterated solvent. Signals in the ^{1}H

and ^{13}C NMR spectra of the synthesized compounds were assigned with the aid of DEPT or two-dimensional NMR experiments (COSY, HSQC, HMBC and NOESY). Abbreviations of coupling patterns are as follows: br, broad; s, singlet; d, doublet; t, triplet; q, quadruplet; quint, quintet; m, multiplet. Coupling constants (*J*) are expressed in Hz. Microanalyses were performed on a Leco CHNS-932 Elemental Analyser. High-resolution mass spectra (HRMS) were obtained using a time-of-flight (TOF) instrument equipped with electrospray ionization (ESI).

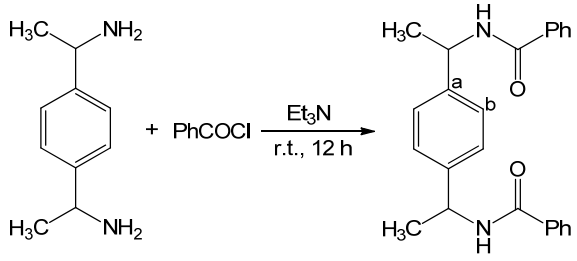
3. Synthesis of α,α'-dimethyl-*p*-xylylenediamine 1.



α,α'-Dimethyl-*p*-xylylenediamine **1** was prepared in 62% yield (2.04 g) from 1,4-diacetylbenzene (20 mmol, 3.25 g) and a mixture of formamide (80 mL) and formic acid (40 mL), following the previously reported procedure.[1] ^1H NMR (300 MHz, $CDCl_3$, 298 K): δ = 1.36 (d, *J*= 6.6 Hz, 6 H, CH_3), 1.45 (br s, 4 H, NH_2), 4.09 (q, *J*= 6.6 Hz, 2 H, CH), 7.29 (s, 4 H, H_b); ^{13}C NMR (75 MHz, $CDCl_3$, 298 K): δ = 25.61 (CH_3), 50.95 (CH), 125.71 (C_b), 146.31 (C_a).

To determine the stereisomeric composition of diamine **1**, derivatization with benzoyl chloride was required.[2]

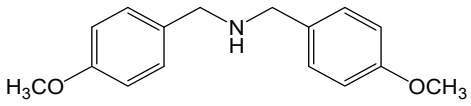
N,*N*'-Dibenzoyl derivatives of diamine 1 (S-1).



To a stirred solution of diamine **1** (0.5 g, 3 mmol) and Et_3N (0.77 g, 7.5 mmol) in anhydrous Et_2O (8 mL), benzoyl chloride (0.86 g, 6 mmol) in anhydrous Et_2O (2 mL) was added dropwise. After 24 h, the solvent was removed in vacuo and the residue was treated with NaOH 1M (10 mL) to give the title product as a white solid. While the NMR spectra of the diamine **1** does not differentiate between the *meso* and the racemic isomers, the spectra of the dibenzoyl derivative **S-1** clearly shows the mixture of both isomers (44/56 ratio for the *meso* and racemic forms). ^1H NMR (400

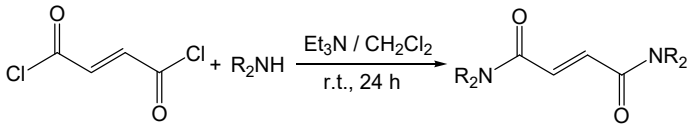
MHz, $CDCl_3$ + TFA, 298 K): δ = 1.609 (d, *J*= 6.8 Hz, 6 H, CH_3, *meso* or *rac*), 1.612 (d, *J*= 7.2 Hz, 6 H, CH_3, *meso* or *rac*), 5.23-5.34 (m, 4 H, CH, *meso* and *rac*), 6.86-6.96 (m, 4 H, NH, *meso* and *rac*), 7.34 (s, 4 H, H_b, rac), 7.35 (s, 4 H, H_b, *meso*), 7.41-7.48 (m, 8 H, H_m, *meso* and *rac*), 7.52-7.59 (m, 4 H, H_p, *meso* and *rac*), 7.67-7.74 (m, 8 H, H_o, *meso* and *rac*), 11.75 (s, CF_3COOH); ^{13}C NMR (100 MHz, $CDCl_3$, 298 K): δ = 21.21 (CH_3), 21.29 (CH_3), 50.14 (2 CH), 114.62 (q, *J*= 285,7 Hz, CF_3COOH), 126.69 (C_b), 126.71 (C_b), 127.07 (2 C_o), 128.96 (C_m), 128.97 (C_m), 132.39 (C_p), 132.80 (C_p), 141.29 (C_a), 141.32 (C_a), 159.26 (q, *J*= 41,8 Hz, CF_3COOH), 169.89 (CO), 169.92 (CO). The subsequent chiral HPLC of dibenzoyl derivatives **S-1** confirmed these findings (41/59 ratio for the *meso* and racemic forms) (See section S12).

4. Synthesis of bis(4-methoxybenzyl)amine.



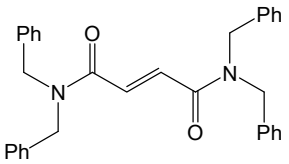
Bis(4-methoxybenzyl)amine was prepared in 96% yield from *p*-methoxybenzaldehyde and *p*-methoxybenzylamine, following the described procedure.[3]

5. General procedure for the synthesis of threads 3a-c.



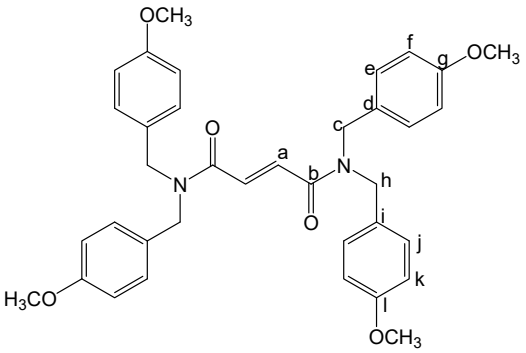
To a solution of the corresponding amine (2 equiv.) and Et_3N (2 equiv.) in anhydrous CH_2Cl_2 (50 mL), fumaryl dichloride (1 equiv.) in anhydrous CH_2Cl_2 (10 mL) was added dropwise at 0 ºC. The reaction mixture was stirred for 24 h at room temperature. After this time the solution was washed with HCl 1M (2 x 30 mL), NaOH 1M (2 x 30 mL) and brine (2 x 30 mL). The organic phase was dried over anhydrous $MgSO_4$ and concentrated under reduced pressure. The resulting residue was subjected to column chromatography on silica gel to give the corresponding thread **3**.

Thread 3a



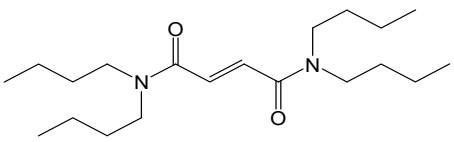
Thread **3a** (4.00 g, 65%) was prepared from dibenzylamine (5.10 g, 26 mmol) and fumaryl dichloride (2.00 g, 13 mmol). This compound showed identical spectroscopic data to those previously reported.[4]

Thread 3b



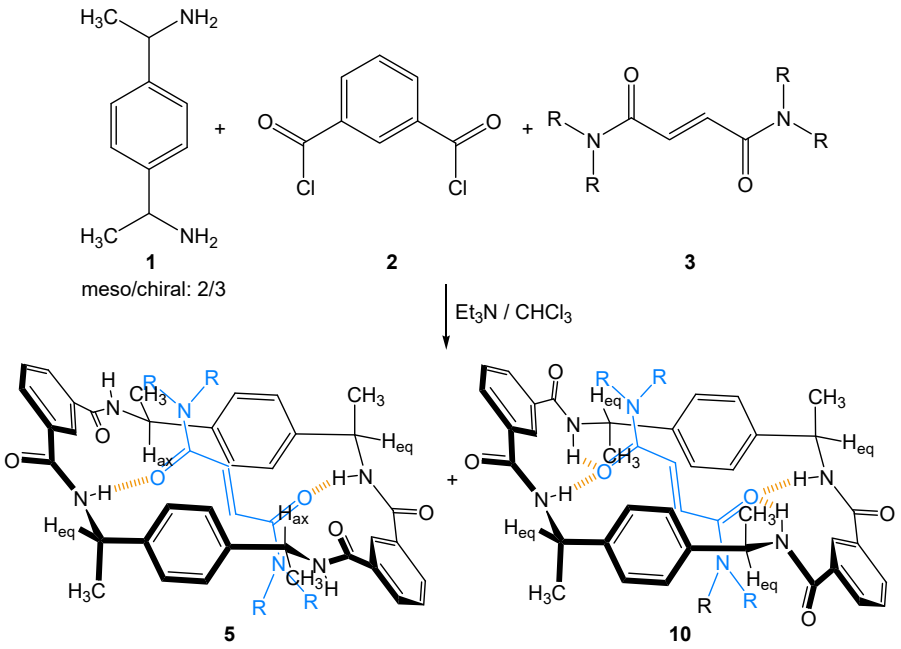
Thread **3b** was prepared from bis(4-methoxybenzyl)amine (6.7 g, 26 mmol) and fumaryl dichloride (2.00 g, 13 mmol). The resulting residue was subjected to column chromatography (silica gel) using a mixture of $CHCl_3$/$(CH_3)_2CO$ (9/1). The solvent was removed under reduced pressure to give the titled product as a white solid (7.24 g, 93%), R_f= 0.6; mp 192-194 ºC; IR (solid, ATR, cm^{-1}) ν = 1631 (m, CO), 1610 (m, CO); IR ($CHCl_3$, ATR, cm^{-1}) ν = 1631 (m, CO), 1610 (m, CO); ^{1}H NMR (400 MHz, $CDCl_3$, 298 K): δ = 3.79 (s, 6 H, OCH_3), 3.81 (s, 6 H, OCH_3), 4.48 (s, 4 H, H_h), 4.54 (s, 4 H, H_c), 6.84 (d, *J*= 8.7 Hz, 4 H, H_f), 6.88 (d, *J*= 8.7 Hz, 4 H, H_k), 7.07 (d, *J*= 8.7 Hz, 4 H, H_j), 7.16 (d, *J*= 8.7 Hz, 4 H, H_e), 7.56 (s, 2 H, H_a); ^{13}C NMR (100 MHz, $CDCl_3$, 298 K): δ = 47.60 (C_c), 49.27 (C_h), 55.23 (OCH_3), 55.26 (OCH_3), 113.99 (C_f), 114.31 (C_k), 127.93 (C_d or C_i), 128.02 (C_j), 128.84 (C_d or C_i), 129.74 (C_e), 132.32 (C_a), 159.05 (C_g or C_l), 159.22 (C_g or C_l), 165.60 (C_b); Elemental analysis ($C_{36}H_{38}N_2O_6$,%) calcd (found): C 72.71 (72.80), H 6.44 (6.42), N 4.71 (4.62); HRMS (ESI) calcd for $C_{36}H_{39}N_2O_6$ $[M + H]^+$ 595.2803, found 595.2792.

Thread 3c



Thread **3c** (3.10 g, 70%) was prepared from dibutylamine (3.38 g, 26 mmol) and fumaryl dichloride (2.00 g, 13 mmol). This compound showed identical spectroscopic data to those previously reported.[5]

6. General procedure for the preparation of the [2]rotaxanes 5 and 10.

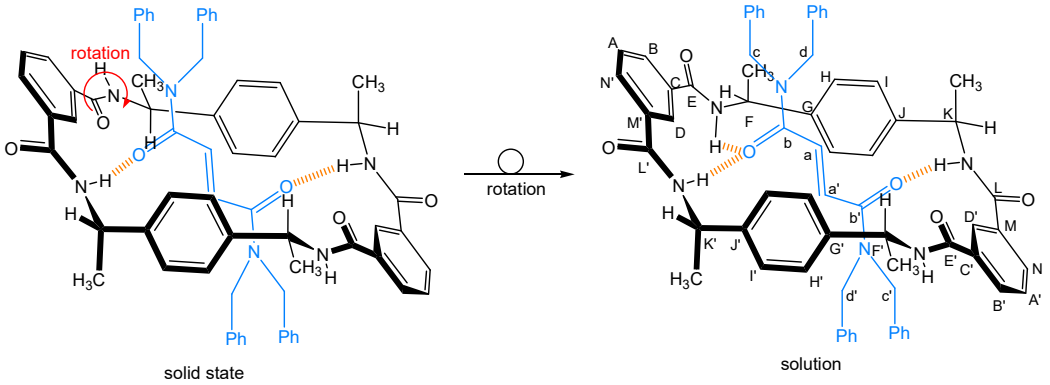


The thread **3** (1 equiv.) and Et_3N (12 equiv.) in anhydrous $CHCl_3$ (300 mL) were stirred vigorously whilst solutions of diamine **1** (8 equiv.) and Et_3N (12 equiv.) in anhydrous $CHCl_3$ (20 mL) and isophthaloyl dichloride **2** (8 equiv.) in anhydrous $CHCl_3$ (20 mL) were simultaneously added over a period of 4 h using motor-driven syringe pumps. After a further 4 h the resulting suspension was filtered through a Celite® pad, washed with water (3 x 50 mL), a solution of HCl 1M (3 x 50 mL), a saturated solution of $NaHCO_3$ (3 x 50 mL) and brine (3 x 50 mL). The organic phase was dried over anhydrous $MgSO_4$ and the solvent removed under reduced pressure. The resulting solid was subjected to column chromatography to yield unconsumed thread **3**, [2]rotaxanes **5** and **10** and a more polar fraction containing a mixture of macrocycles and catenanes.

Mixture of [2]Rotaxanes 5a and 10a (R= C_6H_5-CH_2)

The mixture of [2]rotaxanes **5a** and **10a** was obtained from the thread *N*,*N*,*N'*,*N'*-tetrabenzylfumaramide **3a** (0.5 g, 1.05 mmol). The solid crude was subjected to column chromatography on silica gel using a $CHCl_3$/$(CH_3)_2CO$ (9/1) mixture as eluent to give the unconsumed thread **3a** (0.27 g, 54% recovered, R_f= 0.8) and then a $CHCl_3$/$(CH_3)_2CO$ (7/3) mixture as eluent to give the titled mixture of [2]rotaxanes **5a** and **10a** in a ratio 1.9/1 as a white solid (0.087 g, 46% conversion, 17% combined yield based on recovered starting material) (R_f= 0.4, $CHCl_3$/$(CH_3)_2CO$ (9/1); R_f= 0.7, $CHCl_3$/$(CH_3)_2CO$ (7/3). Following successive crystallizations from $CHCl_3$ crystals of pure **5a** were obtained. Mother liquors contains a 1.35:1 ratio of a **10a**:**5a** mixture.

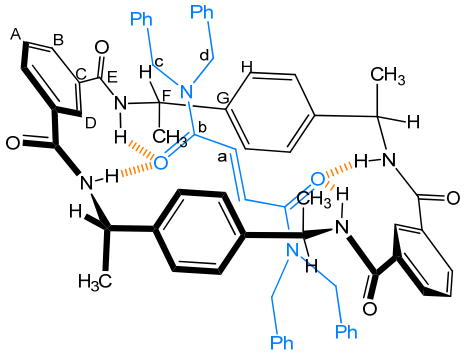
Rotaxane 5a



Colourless prisms; m.p. 245-247 °C; IR (solid, ATR, cm^{-1}) ν = 3318 (w, NH), 3259 (w, NH), 1648 (m, CO), 1618 (m, CO), 1605 (m, CO), 1523 (s, NH), 1495 (m, NH); IR ($CHCl_3$, ATR, cm^{-1}) ν = 3344 (w, NH), 1651 (vs, CO), 1600 (m, CO), 1515 (s, NH); mixture of rotamers in solution (5:1); NMR data for the major rotamer; ^{1}H NMR (600 MHz, $CDCl_3$, 298 K): δ = 1.42 (d, *J*= 6.6 Hz, 3 H, C_F-CH_3), 1.47 (d, *J*= 7.2 Hz, 3 H, $C_{K'}$-CH_3), 1.48 (d, (d, *J*= 6.6 Hz, 3 H, C_K-CH_3), 1.53 (d, *J*= 6.6 Hz, 3 H, $C_{F'}$-CH_3), 4.04 (d, *J*= 13.8 Hz, 1 H, $C_{c'}H_aH_b$), 4.16 (d, *J*= 16.8 Hz, 1 H, $C_{d'}H_aH_b$), 4.20 (d, *J*= 16.8 Hz, 1 H, $C_{d'}H_aH_b$), 4.39 (d, *J*= 16.8 Hz, 1 H, $C_dH_aH_b$), 4.50 (d, *J*= 16.8 Hz, 1 H, $C_dH_aH_b$), 4.61 (d, *J*= 13.8 Hz, 1 H, $C_cH_aH_b$), 4.66 (d, *J*= 13.8 Hz, 1 H, $C_{c'}H_aH_b$), 4.72 (d, *J*= 13.8 Hz, 1 H, $C_cH_aH_b$), 4.89 (quint, *J*= 6.6 Hz, 1 H, 1 $H_{F'}$), 5.40 (quint, *J*= 6.6 Hz, 1 H, 1 H_K), 5.44-5.50 (m, 2 H, H_F + $H_{K'}$), 5.72 (br s, 1H, 1 $C_{F'}$-NH), 6.24 (d, *J*= 14.4 Hz, 1 H, H_a), 6.31 (d, *J*= 14.4 Hz, 1 H, $H_{a'}$), 6.61 (d, *J*= 7.2 Hz, 2 H, H_o-Ph), 6.64 (d, *J*= 7.8 Hz, 2 H, $H_{H'}$), 6.66 (d, *J*= 6.0 Hz, 2 H, H_o-Ph), 6.87-7.02 (m, 11 H, 2 H_H + 2 H_I + 2 $H_{I'}$ + 4 H_o-Ph + 1 H_p-Ph), 7.09-7.13 (m, 4 H, 2 H_m-Ph + 1 H_p-Ph + 1 NH), 7.29-7.32 (m, 3 H, 2 H_m-Ph + 1 H_p-Ph), 7.37-7.43 (m, 6 H, 4 H_m-Ph + 1 H_p-Ph + 1 NH), 7.50 (t, *J*= 7.8 Hz, 1 H, H_A), 7.52 (t, *J*= 7.8 Hz, 1 H, $H_{A'}$), 7.92 (dt, *J*= 1.2, 7.8 Hz, 1H, $H_{B'}$), 8.18 (dt, *J*= 1.2, 7.8 Hz, 1H, $H_{N'}$), 8.20 (dt, *J*= 1.2, 7.8 Hz, 1H, 1 H_B), 8.25-8.33 (m, 4 H, H_N + H_D + $H_{D'}$ + 1 NH); ^{1}H NMR (400 MHz, $C_2D_2Cl_4$, 298 K): δ = 1.33 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.39 (d, *J*= 6.4 Hz, 3 H, CH_3), 1.40 (d, (d, *J*= 6.4 Hz, 3 H, CH_3), 1.44 (d, (d, *J*= 6.8 Hz, 3 H, CH_3), 3.87 (d, *J*= 14.0 Hz, 1 H, CH_aH_b), 4.01 (d, *J*= 17.2 Hz, 1 H, CH_aH_b), 4.08 (d, *J*= 17.2 Hz, 1 H, CH_aH_b), 4.28 (d, *J*= 17.2 Hz, 1 H, CH_aH_b), 4.38 (d, *J*= 17.2 Hz, 1 H, CH_aH_b), 4.54 (d, *J*= 14.0 Hz, 1 H, CH_aH_b), 4.61 (d, *J*= 14.0 Hz, 1 H, CH_aH_b), 4.65 (d, *J*= 14.0 Hz, 1 H, CH_aH_b), 4.80 (quint, *J*= 6.4 Hz, 1 H, 1 CH), 5.24-5.41 (m, 3 H, CH), 5.65 (br s, 1 H, NH), 6.12 (d, *J*= 14.4 Hz, 1 H, =CH), 6.19 (d, *J*= 14.4 Hz, 1 H, =CH), 6.48-6.60 (m, 6 H, H_{Ar}), 6.74-7.28 (m, 19 H, 17 H_{Ar} + 2 NH), 7.29-7.35 (m, 5 H, H_{Ar}), 7.42 (t, *J*= 7.6 Hz, 1 H, H_A), 7.45 (t, *J*= 7.8 Hz, 1 H, $H_{A'}$), 7.80 (d, *J*= 8.0 Hz, 1 H, $H_{B'}$), 8.05-8.10 (m, 3 H, H_B + H_N + $H_{N'}$), 8.17 (d, *J*= 8.0 Hz, 1H, NH), 8.25 (br s, 2 H, H_D + $H_{D'}$); ^{1}H NMR (400 MHz, DMSO-d_6, 298 K): δ = 1.34 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.39 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.41 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.46 (d, *J*= 7.2 Hz, 3 H, CH_3), 3.92 (br s, 2 H, CH_2), 4.01 (d, *J*= 16.6 Hz, 1 H, CH_AH_B), 4.06 (d, *J*= 16.6 Hz, 1 H, CH_AH_B), 4.21 (d, *J*= 14.8 Hz, 1 H, CH_AH_B), 4.33 (d, *J*= 14.8 Hz, 1 H, CH_AH_B), 4.43

(d, *J*= 14.6 Hz, 1 H, C*H*$_A$H$_B$), 4.47 (d, *J*= 14.6 Hz, 1 H, CH$_A$*H*$_B$), 4.91-4.99 (m, 1 H, CH), 5.04-5.23 (m, 3 H, CH), 6.02 (d, *J*= 14.8 Hz, 1 H, =CH), 6.08 (d, *J*= 14.8 Hz, 1 H, =CH), 6.72-6.85 (m, 6 H, H$_{Ar}$), 6.92 (d, *J*= 8.0 Hz, 2 H, H$_{Ar}$), 6.97-7.07 (m, 8 H, H$_{Ar}$), 7.09-7.31 (m, 12 H, H$_{Ar}$), 7.34 (t, *J*= 7.8 Hz, 1 H, H$_A$ or H$_{A'}$), 7.51 (t, *J*= 7.7 Hz, 1 H, H$_A$ or H$_{A'}$), 7.79 (d, *J*= 8.0 Hz, 1 H, H$_{B'}$), 7.89 (d, *J*= 7.6 Hz, 1 H, H$_{N'}$), 7.95-8.06 (m, 4 H, H$_B$, H$_N$ + 2 NH), 8.22 (br s, 1 H, H$_D$ or H$_{D'}$), 8.39 (br s, 1 H, H$_D$ or H$_{D'}$), 8.41 (d, *J*= 7.2 Hz, 1 H, NH), 8.77 (d, *J*= 8.0 Hz, 1 H, NH); ^{13}C NMR (125 MHz, $CDCl_3$, 298 K): δ = 19.05 (C$_F$-*C*H$_3$), 20.03 (C$_K$-*C*H$_3$), 20.24 (C$_{F'}$-*C*H$_3$), 21.37 (C$_{K'}$-*C*H$_3$), 47.09 (C$_F$), 47.73 (C$_{K'}$), 48.66 (C$_K$), 49.55 (C$_{F'}$), 50.04 (C$_{c'}$), 50.47 (C$_{d'}$), 51.70 (C$_c$ + C$_d$), 121.69 (C$_D$), 123.49 (C$_{D'}$), 125.18 (C$_o$-Ph), 126.14 (C$_o$-Ph), 126,95 (C$_{I'}$), 127.00 (C$_{H'}$), 127.28 (C$_H$), 127.64 (C$_I$), 127.89 (C$_p$-Ph), 127.98 (C$_p$-Ph), 128.25 (C$_p$-Ph), 128.77 (C$_m$-Ph), 128.83 (C$_m$-Ph), 129.11 (C$_A$ + C$_{A'}$ + C$_o$-Ph + C$_p$-Ph), 129.17 (2 C$_m$-Ph), 129.63 (C$_o$-Ph, C$_a$), 130.35 (C$_{a'}$), 130.57 (C$_{B'}$), 131.95 (C$_N$), 132.22 (C$_{N'}$), 132.31 (C$_B$), 133.12 (C$_C$), 133.20 (C$_{M'}$), 133.99 (C$_{d'}$-*C*$_i$-Ph), 134.27 (C$_M$), 134.95 (C$_{C'}$), 135.60 (C$_c$-*C*$_i$-Ph + C$_d$-*C*$_i$-Ph), 135.74 (C$_{c'}$-*C*$_i$-Ph), 141.19 (C$_J$), 141.28 (C$_G$), 141.39 (C$_{G'}$), 141.70 (C$_{J'}$), 164.68 (C$_E$), 164.79 (C$_{b'}$), 164.93 (C$_{L'}$), 165.85 (C$_L$), 166.63 (C$_b$), 167.13 (C$_{E'}$); Elemental analysis (C$_{68}$H$_{66}$N$_6$O$_6$,%) calcd (found): C 76.81 (76.77), H 6.26 (6.29), N 7.90 (7.83); HRMS (ESI) calcd for C$_{68}$H$_{67}$N$_6$O$_6$ [M + H]$^+$ 1063.5117, found 1063.5118.

Rotaxane 10a

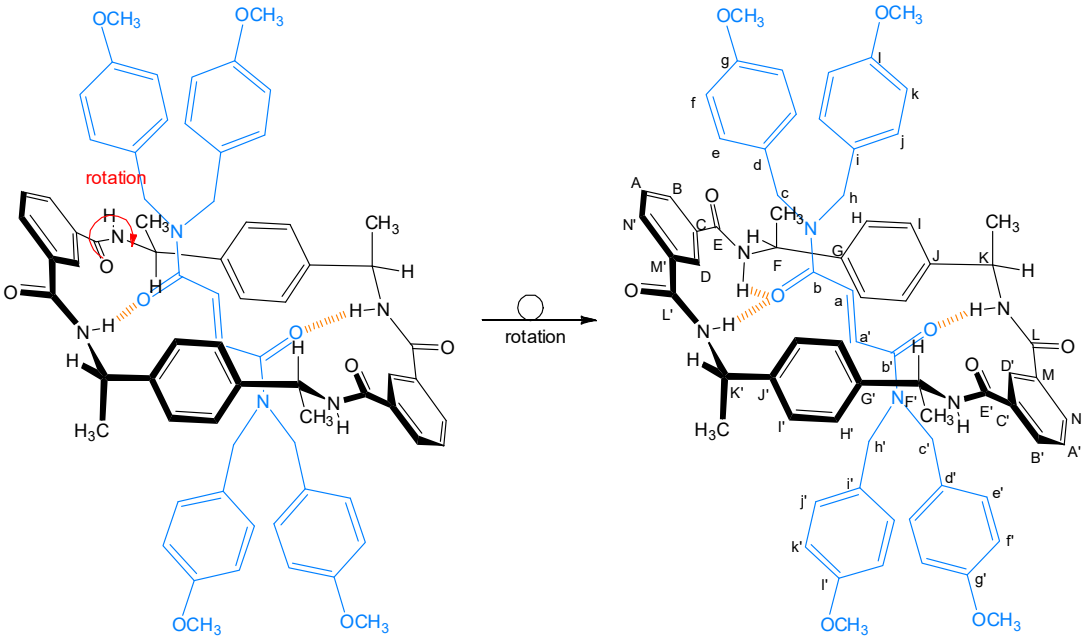


^{1}H NMR (600 MHz, $CDCl_3$, 600 MHz, 298 K): δ = 1.42 (d, *J*= 6.8 Hz, 12 H, CH$_3$), 4.42 (s, 4 H, H$_d$), 4.55 (s, 4 H, H$_c$), 5.43 (dq, *J*= 8.8, 6.9 Hz, 4 H, H$_F$), 6.25 (s, 2 H, H$_a$), 6.63 (d, *J*= 7.2 Hz, 4 H, H$_o$-Ph), 6.88 (s, 8 H, H$_H$), 6.89 (t, *J*= 7.2 Hz, 4 H, H$_m$-Ph), 7.02 (t, *J*= 7.2 Hz, 2 H, H$_p$-Ph), 7.22 (d, *J*= 8.8 Hz, 4 H, NH), 7.29-7.34 (m, 10 H, Ph), 7.54 (t, *J*= 7.8 Hz, 2 H, H$_A$), 8.23 (dd, *J*= 1.5, 7.8 Hz, 4 H, H$_B$), 8.34 (br s, 2 H, H$_D$). ^{13}C NMR (125 MHz, $CDCl_3$, 298 K): δ = 19.83 (CH$_3$), 47.59 (C$_F$), 51.01 (C$_c$), 51.39 (C$_d$), 121.88 (C$_D$), 125.49 (C$_o$-Ph), 127.20 (C$_H$), 128.14 (C$_p$-Ph), 128.63 (C$_p$-Ph), 128.90 (C$_m$-Ph), 128.99 (C$_m$-Ph), 129.09 (C$_a$),129.61 (C$_o$-Ph), 129.84 (C$_A$), 132.28 (C$_B$), 133.33 (C$_C$), 134.05 (C$_i$-Ph), 135.51 (C$_i$-Ph), 141.38 (C$_G$), 164.99 (C$_E$), 166.16 (C$_b$).

Mixture of [2]Rotaxanes 5b and 10b (R= 4-$H_3COC_6H_4$-CH_2)

The mixture of [2]rotaxanes **5b** and **10b** was obtained from the thread *N*,*N*,*N'*,*N'*-tetra(4-methoxybenzyl)fumaramide **3b** (0.5 g, 0.84 mmol). The solid crude was subjected to column chromatography on silica gel using a $CHCl_3$/$(CH_3)_2CO$ (9/1) mixture as eluent to give the unconsumed thread **3b** (0.34 g, 68% recovered, R_f= 0.6) and then a $CHCl_3$/$(CH_3)_2CO$ (7/3) mixture as eluent to give the titled mixture of [2]rotaxanes **5b** and **10b** in a ratio 1.5/1 as a white solid (0.10 g, 31% yield at 32% of conversion) (R_f= 0.2, $CHCl_3$/$(CH_3)_2CO$ (9/1); R_f= 0.7, $CHCl_3$/$(CH_3)_2CO$ (7/3). Following successive crystallizations from $CHCl_3$ crystals of pure **5b** were obtained. Mother liquors contains a 2.3:1 ratio of a **10b**:**5b** mixture.

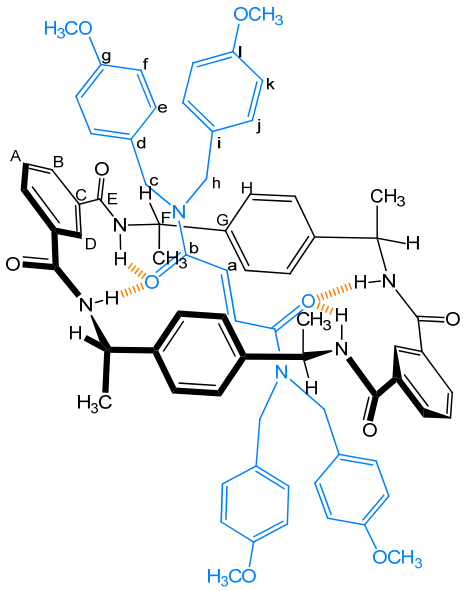
Rotaxane 5b



Colourless prisms; m.p. 218-220 °C; IR (solid, ATR, cm^{-1}) ν = 3390 (vw, NH), 3303 (w, NH), 1651 (m, CO), 1600 (m, CO), 1580 (w, CO), 1505 (vs, NH); IR ($CHCl_3$, ATR, cm^{-1}) ν = 3328 (w, NH), 1649 (m, CO), 1600 (m, CO), 1510 (s, NH); ^{1}H NMR (600 MHz, $CDCl_3$, 298 K): δ = 1.43 (d, *J*= 6.9 Hz, 3 H, C_F-CH_3), 1.47 (d, *J*= 6.9 Hz, 3 H, $C_{K'}$-CH_3), 1.498 (d, (d, *J*= 6.6 Hz, 3 H, C_K-CH_3), 1.50 (d, *J*= 6.6 Hz, 3 H, $C_{F'}$-CH_3), 3.61 (s, 3 H, C_{I}-OCH_3), 3.72 (s, 3 H, $C_{I'}$-OCH_3), 3.79 (s, 3 H, $C_{g'}$-OCH_3), 3.80 (s, 3 H, C_g-OCH_3), 3.85 (d, *J*= 13.8 Hz, 1 H, $C_{c'}H_aH_b$), 4.04 (d, *J*= 16.8 Hz, 1 H, $C_{h'}H_aH_b$), 4.08 (d, *J*= 16.8 Hz, 1 H, $C_{h'}H_aH_b$), 4.37 (d, *J*= 16.5 Hz, 1 H, $C_hH_aH_b$), 4.45 (d, *J*= 16.5 Hz, 1 H, $C_hH_aH_b$), 4.58 (d, *J*= 14.1 Hz, 1 H, $C_cH_aH_b$), 4.64 (d, *J*= 13.8 Hz, 1 H, $C_{c'}H_aH_b$), 4.72 (d, *J*= 14.1 Hz, 1 H, $C_cH_aH_b$), 4.81 (quint, *J*= 6.6 Hz, 1 H, $H_{F'}$), 5.38-5.51 (m, 3 H, H_F + H_K + $H_{K'}$), 5.85 (br s, 1 H, $C_{F'}$-NH), 6.21 (d, *J*= 14.5 Hz, 1 H, H_a), 6.25 (d, *J*= 14.5 Hz, 1 H, $H_{a'}$), 6.40 (d, *J*= 8.5 Hz, 2 H, H_k), 6.41 (d, *J*= 8.8 Hz, 2 H, $H_{k'}$), 6.51 (d, *J*= 8.8 Hz, 2 H, $H_{j'}$), 6.57 (d, *J*= 8.6 Hz, 2 H, $H_{H'}$), 6.62 (d, *J*= 8.5

Hz, 2 H, H_j), 6.82 (d, *J*= 8.6 Hz, 2 H, $H_{f'}$), 6.90 (d, *J*= 8.6 Hz, 2 H, $H_{l'}$), 6.91 (d, *J*= 8.5 Hz, 2 H, H_f), 6.99 (d, *J*= 8.4 Hz, 2 H, H_H), 7.00 (d, *J*= 8.6 Hz, 2 H, $H_{e'}$), 7.06 (d, *J*= 8.4 Hz, 2 H, H_l), 7.11 (d, *J*= 10.0 Hz, 1 H, C_F-NH), 7.35 (d, *J*= 8.5 Hz, 2 H, H_e), 7.48 (d, *J*= 9.0 Hz, 1 H, $C_{K'}$-NH), 7.50 (t, *J*= 7.8 Hz, 1 H, H_A), 7.58 (t, *J*= 7.7 Hz, 1 H, $H_{A'}$), 8.02 (dt, *J*= 1.4, 7.7 Hz, 1H, $H_{B'}$), 8.17 (dt, *J*= 1.4, 7.8 Hz, 1H, $H_{N'}$), 8.19 (dt, *J*= 1.4, 7.8 Hz, 1H, H_B), 8.29 (br s, 1 H, H_D), 8.32 (d, *J*= 7.7 Hz, 1 H, H_N), 8.39 (br s, 1 H, C_K-NH), 8.41 (br s, 1 H, $H_{D'}$); ^{13}C NMR (125 MHz, $CDCl_3$, 298 K): δ = 18.93 (C_F-*C*H_3), 20.19 (C_K-*C*H_3), 20.40 ($C_{F'}$-*C*H_3), 21.05 ($C_{K'}$-*C*H_3), 46.87 (C_F), 47.74 ($C_{K'}$), 48.87 (C_K), 49.19 ($C_{c'}$), 49.81 ($C_{h'}$), 49.95 ($C_{F'}$), 51.33 (C_h), 51.50 (C_c), 55.11 (C_l-O*C*H_3), 55.12 ($C_{l'}$-O*C*H_3), 55.33 (C_g-O*C*H_3 + $C_{g'}$-O*C*H_3), 114.16 ($C_{f'}$), 114.36 ($C_{k'}$), 114.44 (C_f), 114.45 (C_k), 121.75 (C_D), 123.55 ($C_{D'}$), 126.31 ($C_{j'}$), 126.98 ($C_{H'}$), 127.15 ($C_{l'}$), 127.28 (C_H), 127.47 (C_j), 127.65 (C_l), 129.03 (C_A), 129.12 ($C_{A'}$), 129.71 (C_a), 130.42 ($C_{a'}$), 130.55 ($C_{e'}$), 131.00 (C_e), 130.81 ($C_{B'}$), 132.12 ($C_{N'}$), 132.14 (C_B + C_N), 133.05 (C_C), 133.12 ($C_{M'}$), 134.32 (C_M), 134.98 ($C_{C'}$), 141.09 (C_J), 141.35 (C_G), 141.38 ($C_{G'}$), 141.58 ($C_{J'}$), 158.91 ($C_{I'}$), 159.09 (C_I), 159.42 ($C_{g'}$), 159.83 (C_g), 164.61 (C_E), 164.68 ($C_{b'}$), 164.87 ($C_{L'}$), 165.88 (C_L), 166.63 (C_b), 167.06 ($C_{E'}$); Elemental analysis ($C_{72}H_{74}N_6O_{10}$,%) calcd (found): C 73.08 (73.03), H 6.30 (6.35), N 7.10 (7.07); HRMS (ESI) calcd for $C_{72}H_{75}N_6O_{10}$ $[M + H]^+$ 1183.5539, found 1183.5552.

Rotaxane 10b



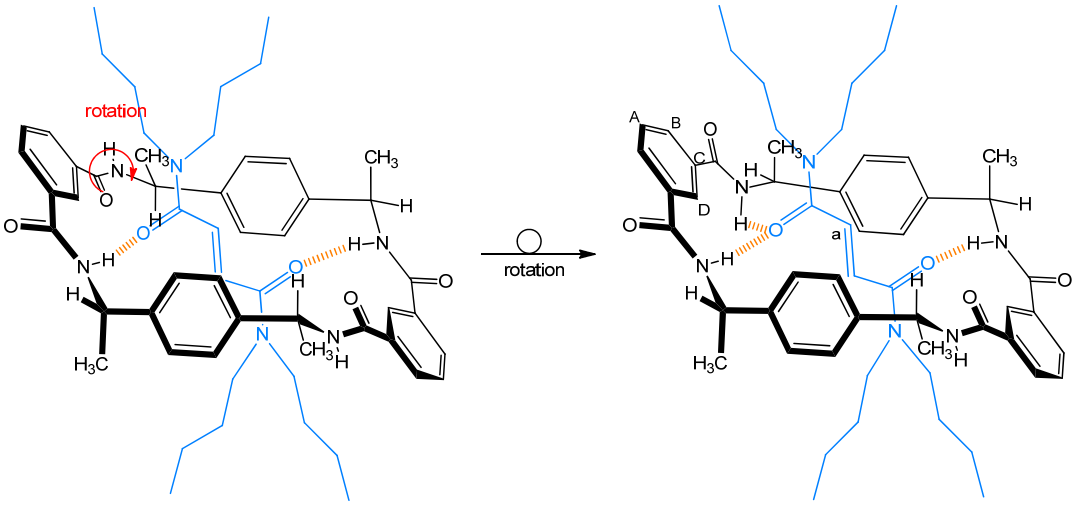
^{1}H NMR (600 MHz, $CDCl_3$, 298 K): δ = 1.42 (d, *J*= 6.8 Hz, 12 H, CH_3), 3.71 (s, 6 H, C_l-OCH_3), 3.76 (s, 6 H, C_g-OCH_3), 4.33 (s, 4 H, H_h), 4.47 (s, 4 H, H_c), 5.40-5.46 (m, 4 H, H_F), 6.24 (s, 2 H, H_a), 6.38 (d, *J*= 8.6 Hz, 4 H, H_k), 6.52 (d, *J*= 8.6 Hz, 4 H, H_j), 6.84 (d, *J*= 8.6 Hz, 4 H, H_f), 6.90 (s, 8 H, H_H), 7.25 (d, *J*= 8.6 Hz, 4 H, H_e), 7.28 (d, *J*= 8.8 Hz, 4 H, NH), 7.55 (t, *J*= 7.7 Hz, 2 H, H_A), 8.24 (dd, *J*= 1.4, 7.7 Hz, 4 H, H_B), 8.41 (br s, 2 H, H_D); ^{13}C NMR (125 MHz, $CDCl_3$, 298 K): δ = 19.77 (CH_3), 47.56 (C_F), 50.26 (C_c), 51.73 (C_h), 55.15 (C_l-OCH_3), 55.26 (C_g-OCH_3), 114.23 (C_f), 114.28

(C_k), 121.96 (C_D), 125.95 (C_d or C_i), 126.70 (C_j), 127.20 (C_H), 127.65 (C_d or C_i), 129.11 (C_a), 129.91 (C_A), 130.95 (C_e), 132.21 (C_B), 133.29 (C_C), 141.37 (C_G), 159.11 (C_l), 159.64 (C_g), 164.92 (C_E), 166.08 (C_b).

Mixture of [2]Rotaxanes 5c and 10c (R= $CH_3CH_2CH_2CH_2$)

The mixture of [2]rotaxanes **5c** and **10c** was obtained from the thread *N*,*N*,*N'*,*N'*-tetrabutylfumaramide **3c** (0.5 g, 1.48 mmol). The solid crude was subjected to column chromatography on silica gel using a $CHCl_3/(CH_3)_2CO$ (9/1) mixture as eluent to give the unconsumed thread **3c** (0.20 g, 40% recovered, Rf= 0.6) and then a $CHCl_3/(CH_3)_2CO$ (7/3) mixture as eluent to give the [2]rotaxane **10c** as a white solid (0.12 g, 15% yield at 60% of conversion) (Rf= 0.4, $CHCl_3/(CH_3)_2CO$ (9/1); Rf= 0.9, $CHCl_3/(CH_3)_2CO$ (7/3) and the rotaxane **5c** as a white solid (0.10 g, 12% yield at 60% of conversion) (Rf= 0.3, $CHCl_3/(CH_3)_2CO$ (9/1); Rf= 0.8, $CHCl_3/(CH_3)_2CO$ (7/3).

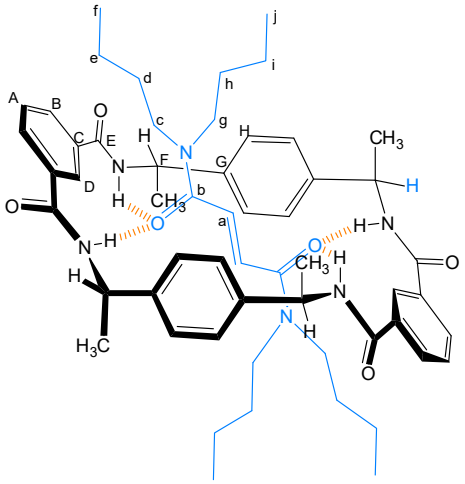
Rotaxane 5c



*Mixture of rotamers of **5c** and free thread **3c** in $CDCl_3$ at 298 K (major rotamer/minor rotamer/free thread: 60/18/22)*; ^{1}H NMR (400 MHz, $CDCl_3$, 298 K): δ = 0.43-1.89 [(m, 108 H, CH_3 (major rotamer and minor rotamer) + $CH_2CH_2CH_3$ (major rotamer, minor rotamer and free thread)], 2.43-3.69 [m, 24 H, CH_2 (major rotamer, minor rotamer and free thread)], 4.85-4.95 (m, 1 H, CH, major rotamer), 5.08-5.16 (m, 2 H, CH, minor rotamer), 5.18-5.27 (m, 2 H, CH, minor rotamer), 5.40-5.60 (m, 3 H, 3 CH, major rotamer), 5.96 (d, *J*= 14.4 Hz, 1 H, HC=, major rotamer), 5.99 (d, *J*= 14.4 Hz, 1 H, HC=, minor rotamer), 6.09 (d, *J*= 14.4 Hz, 1 H, HC=, major rotamer), 6.14 (d, *J*= 14.4 Hz, 1 H, HC=, minor rotamer), 7.01-7.15 [m, 19 H, H_{Ar} (major rotamer and minor rotamer) + 1 NH (major rotamer) + 2 NH (minor rotamer)], 7.36 (s, 2 H, HC=, free thread), 7.52 (d, *J*= 8.0 Hz, 1 H, NH,

major rotamer), 7.55-7.68 (m, 4 H, H_A, major rotamer and minor rotamer), 7.74 (d, *J*= 8.0 Hz, 1 H, NH, major rotamer), 7.79 (d, *J*= 8.0 Hz, 2 H, NH, minor rotamer), 8.04 (d, *J*= 8.0 Hz, 1 H, NH, major rotamer), 8.13-8.31 [m, 5 H, 2 H_B (major rotamer) + 2 H_B (minor rotamer) + H_D (minor rotamer)], 8.31-8.38 [m, 2 H_B (major rotamer) + 2 H_B (minor rotamer) + H_D (minor rotamer)], 8.52 (br s, 1 H, H_D, major rotamer), 8.88 (br s 1 H, H_D, major rotamer).

Rotaxane 10c



White prisms; m.p. 233-235 °C; IR (solid, ATR, cm^{-1}) ν = 3369 (w, NH), 1659 (vs, CO), 1592 (m, CO), 1523 (s, NH); IR ($CHCl_3$, ATR, cm^{-1}) ν = 3354 (w, NH), 1651 (m, CO), 1590 (m, CO), 1523 (m, NH); ^{1}H NMR (600 MHz, $CDCl_3$, 298 K): δ = 0.42-0.49 (m, 4 H, H_i), 0.52 (t, *J*= 7.1 Hz, 6 H, H_j), 0.96 (t, *J*= 7.4 Hz, 6 H, H_f), 1.10-1.18 (m, 4 H, H_h), 1.35-1.41 (m, 4 H, H_e), 1.46 (d, *J*= 6.9 Hz, 12 H, CH_3), 1.59-1.67 (m, 4 H, H_d), 2.88-2.93 (m, 4 H, H_g), 3.32-3.38 (m, 4 H, H_c), 5.55 (dq, *J*= 6.9, 9.2 Hz, 4 H, H_F), 5.95 (s, 2 H, H_a), 7.08 (s, 8 H, H_H), 7.60 (d, *J*= 9.2 Hz, 4 H, NH), 7.65 (t, *J*= 7.8 Hz, 2 H, H_A), 8.39 (dd, *J*= 7.8, 1.5 Hz, 4 H, H_B), 8.84 (s, 2 H, H_D); ^{13}C NMR (125 MHz, $CDCl_3$, 298 K): δ = 13.59 (C_i), 13.74 (C_f), 18.65 (CH_3), 19.60 (C_i), 20.36 (C_e), 30.35 (C_d), 32.22 (C_h), 46.46 (C_F), 47.78 (C_c), 48.89 (C_g), 122.04 (C_D), 127.06 (C_H), 128.42 (C_a), 129.46 (C_A), 132.37 (C_B), 133.27 (C_C), 141.34 (C_G), 164.46 (C_E), 165.03 (C_b); Elemental analysis ($C_{56}H_{74}N_6O_6$,%) calcd (found): C 72.54 (72.47), H 8.04 (8.30), N 9.06 (8.81); HRMS (ESI) calcd for $C_{56}H_{75}N_6O_6$ $[M + H]^+$ 927.5743, found 927.5734.

7. NMR conformational study for rotaxanes 5 and 10.

The ^{1}H NMR analysis of compound **5a** ($CDCl_3$, 298 K) clearly shows the presence of two conformers (ratio 5:1). The minor conformer shows a series of signals that indicates a high level of symmetry, similar to the conformation observed in the solid state. In contrast, the major

conformer shows an important level of asymmetry. In this section the elucidation of the asymmetric major conformer by NMR experiments is discussed. In the ^{1}H- and ^{13}C NMR spectra four different signals for each analogous nucleus are detected, clearly indicating the presence of four different fragments. Each fragment of the threaded macrocycle contains a sequence -CO-NH-CH(CH_3)- and part of its corresponding adjacent aromatic rings (figure S1).

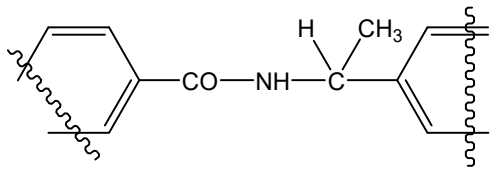


Figure S1. Fragment present on the macrocycle.

Three of the four macrocyclic fragments show very similar chemical shifts for analogous nuclei. In contrast, the signals of the fourth fragment appeared at different chemical shifts. The most significant variation on the chemical shift is that experienced by one NH proton of the macrocycle, appearing at δ 5.72 ppm (figure S2, highlighted in red), neatly differing from the other three, which are found in the aromatic region (δ 7.07-8.33 ppm). Other notorious differences are found for other signals in the ^{1}H or ^{13}C spectra (figures S3-S6). In the figures the atoms highlighted in red showed important displacements with respect to the other three analogues.

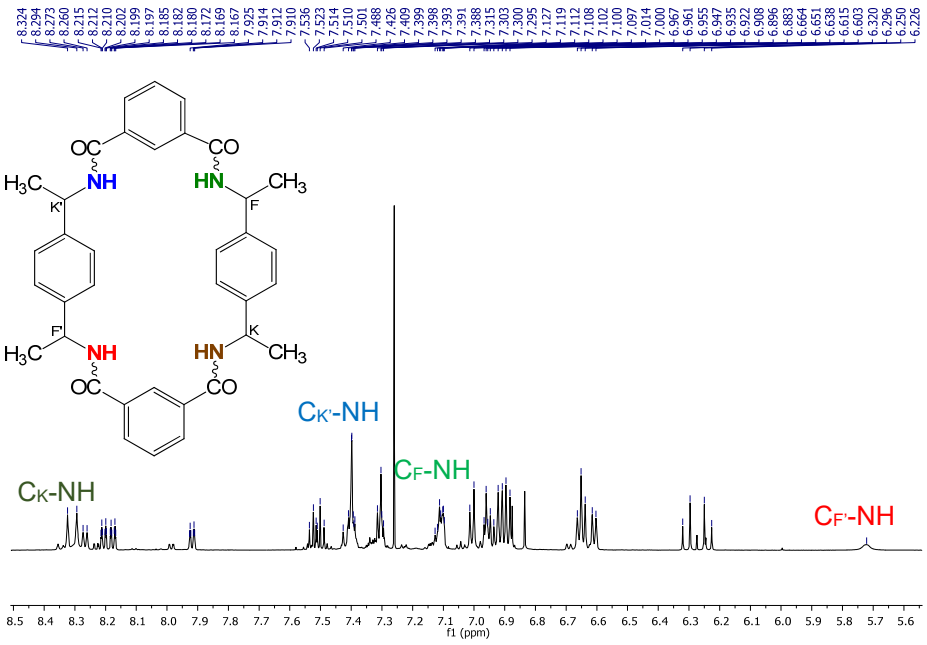


Figure S2. Selected region of ^{1}H NMR spectrum of rotaxane **5a** (600 MHz, $CDCl_3$, 298 K).

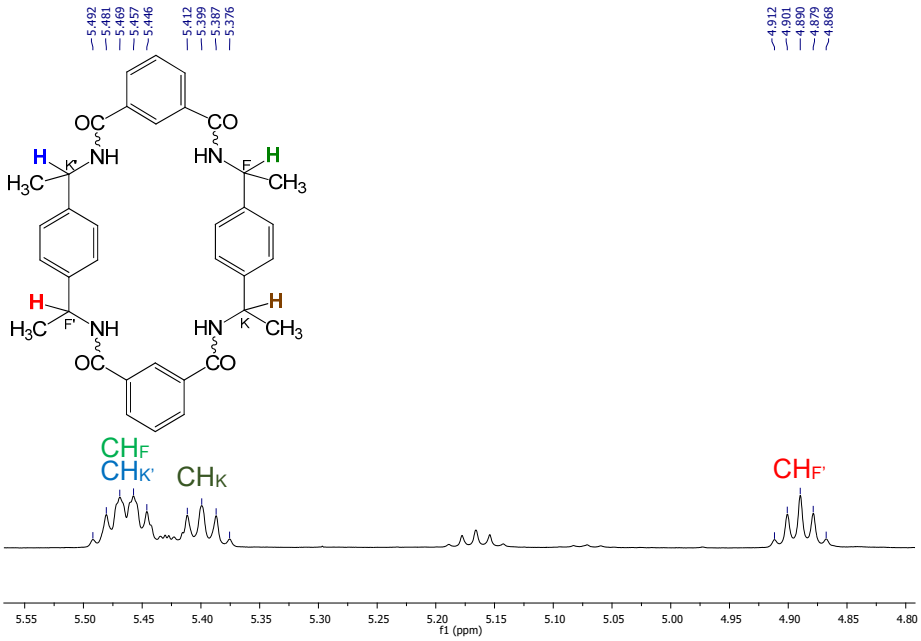


Figure S3. Selected region of ^{1}H NMR spectrum of rotaxane **5a** (600 MHz, $CDCl_3$, 298 K).

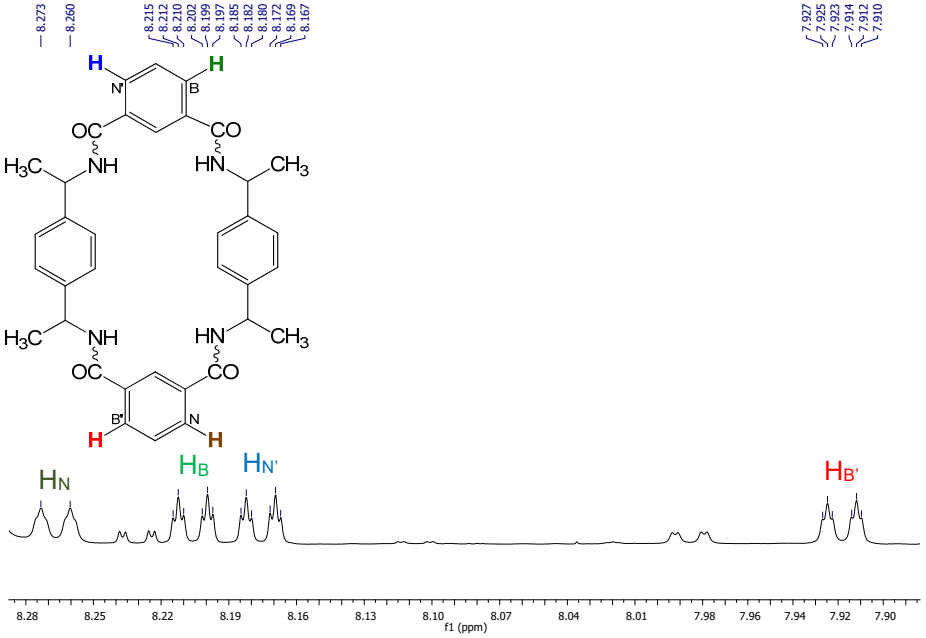


Figure S4. Selected region of ^{1}H NMR spectrum of rotaxane **5a** (600 MHz, $CDCl_3$, 298 K).

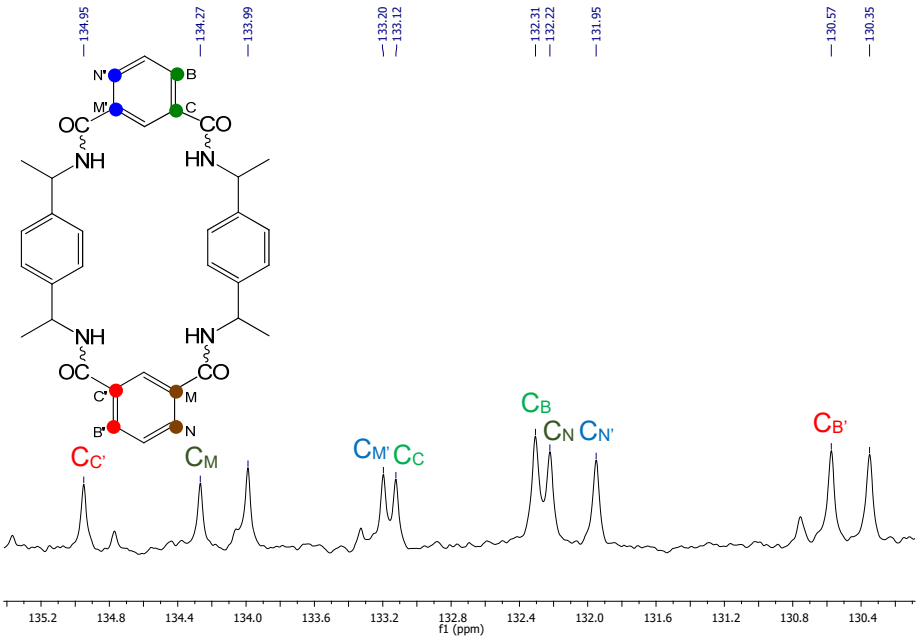


Figure S5. Selected region of ^{13}C NMR spectrum of rotaxane **5a** (150 MHz, $CDCl_3$, 298 K).

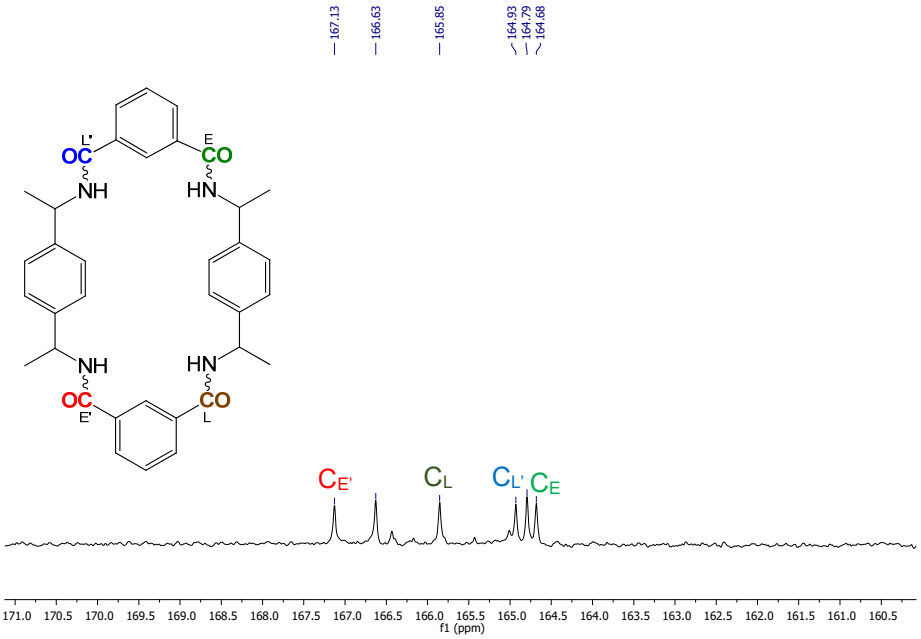


Figure S6. Selected region of ^{13}C NMR spectrum of rotaxane **5a** (150 MHz, $CDCl_3$, 298 K).

Rotaxane **5b** shows the same behaviour than **5a**, finding again one macrocyclic fragment appearing at different chemical shifts than the other three ones.

In Table 1 the chemical shifts of selected protons and carbons of both rotaxanes, **5a** and **5b**, which are next to the carbonyl groups, are listed. The average value of the chemical shifts of these nuclei

in the three similar fragments has been calculated, and compared with the corresponding one in the fourth different fragment.

Table 1

Comp.	fragment 1	fragment 2	fragment 3	$\overline{x}\delta_{1\text{-}3}$[a]	fragment 4	$\lvert\overline{x} - \delta_{fr4}\rvert$
5a	δ H_B: 8.20	δ $H_{N'}$: 8.18	δ H_N: 8.26	8.21	δ $H_{B'}$: 7.92	0.29
5b	δ H_B: 8.19	δ $H_{N'}$: 8.17	δ H_N: 8.32	8.23	δ $H_{B'}$: 8.02	0.21
5a	δ H_F: 5.47[b]	δ $H_{K'}$: 5.47 [b]	δ H_K: 5.40	5.45	δ $H_{F'}$: 4.89	0.56
5b	δ H_F: 5.45 [b]	δ H_K: 5.45 [b]	δ $H_{K'}$: 5.45 [b]	5.45	δ $H_{F'}$: 4.81	0.64
5a	δ H_{NH}: 7.11 [b]	δ H_{NH}: 7.40 [b]	δ H_{NH}: 8.29 [b]	7.60	δ H_{NH}: 5.72	1.88
5b	δ H_{NH}: 7.11	δ H_{NH}: 7.48	δ H_{NH}: 8.39	7.66	δ H_{NH}: 5.85	1.81
5a	δ C_F: 47.09	δ $C_{K'}$: 47.73	δ C_K: 48.66	47.83	δ $C_{F'}$: 49.55	1.72
5b	δ C_F: 46.87	δ $C_{K'}$: 47.74	δ C_K: 48.87	47.83	δ $C_{F'}$: 49.95	2.12
5a	δ C_B: 132.31	δ $C_{N'}$: 132.22	δ C_N: 131.95	132.16	δ $C_{B'}$: 130.57	1.59
5b	δ C_B: 132.14	δ $C_{N'}$: 132.12	δ C_N: 132.14	132.13	δ $C_{B'}$: 130.81	1.32
5a	δ C_C: 133.12	δ $C_{M'}$: 133.20	δ C_M: 134.27	133.53	δ $C_{C'}$: 134.95	1.42
5b	δ C_C: 133.05	δ $C_{M'}$: 133.12	δ C_M: 134.32	133.50	δ $C_{C'}$: 134.98	1.48
5a	δ C_E: 164.68	δ $C_{L'}$: 164.93	δ C_L: 165.85	165.15	δ $C_{E'}$: 167.13	1.98
5b	δ C_E: 164.61	δ $C_{L'}$: 164.87	δ C_L: 165.88	165.12	δ $C_{E'}$: 167.06	1.94

[a] $\overline{x}\delta_{1\text{-}3} = (\delta_{\text{fragment 1}} + \delta_{\text{fragment 2}} + \delta_{\text{fragment 3}}) / 3$.

[b] In the case in which the signal appeared as multiplet, the listed value is the chemical shift of the centrer of the interval.

All these data suggest that the carbonyl groups of the fragments 1, 2 and 3 are oriented in a similar disposition, which is different to the carbonyl group of the fragment 4. For clarifying the *in* or *out* orientation of the carbonyl groups of the macrocycle in rotaxanes **5a** and **5b** in solution, we compared all these data with the chemical shifts observed for rotaxanes **10**, in which the conformation in the solid state and solution is similar, having all the carbonyl groups in an *out* disposition.

In Table 2 the chemical shifts of rotaxanes **5a** and **5b** are compared with the ones observed for the rotaxanes **10a** and **10b**, respectively. The average value of the chemical shifts for the three "similar" fragments and the chemical shifts for the "different fragment" (fr 4) are compared with the corresponding shifts for compounds **10**.

Table 2

5			**10**	$\lvert\bar{x} - \delta_{10}\rvert$	$\lvert\delta_{fr\,4} - \delta_{10}\rvert$
fragment 1-3		fragment 4			
atoms	$\bar{x}\delta_{1-3}$[a]	δ_{atom}	δ_{atom}		
H_B, $H_{N'}$, H_N of **5a**	8.21	δ $H_{B'}$: 7.92	δ H_B of **10a**: 8.23	0.02	0.31
H_B, $H_{N'}$, H_N of **5b**	8.23	δ $H_{B'}$: 8.02	δ H_B of **10b**: 8.24	0.01	0.22
H_F, $H_{K'}$, H_K of **5a**	5.45	δ $H_{F'}$: 4.89	δ H_F of **10a**: 5.43	0.02	0.54
H_F, $H_{K'}$, H_K of **5b**	5.45	δ $H_{F'}$: 4.81	δ H_F of **10b**: 5.43	0.02	0.62
H_{NH} of **5a**	7.60	δ H_{NH}: 5.72	δ H_{NH} of **10a**: 7.22	0.38	1.50
H_{NH} of **5b**	7.66	δ H_{NH}: 5.85	δ H_{NH} of **10b**: 7.28	0.38	1.43
C_F, $C_{K'}$, C_K of **5a**	47.83	δ $C_{F'}$: 49.55	δ C_F of **10a**: 47.59	0.24	1.96
C_F, $C_{K'}$, C_K of **5b**	47.83	δ $C_{F'}$: 49.95	δ C_F of **10b**: 47.56	0.27	2.39
C_B, $C_{N'}$, C_N of **5a**	132.16	δ $C_{B'}$: 130.57	δ C_B of **10a**: 132.28	0.12	1.71
C_B, $C_{N'}$, C_N of **5b**	132.13	δ $C_{B'}$: 130.81	δ C_B of **10b**: 132.21	0.08	1.40
C_C, $C_{M'}$, C_M of **5a**	133.53	δ $C_{C'}$: 134.95	δ C_C of **10a**: 133.33	0.20	1.62
C_C, $C_{M'}$, C_M of **5b**	133.50	δ $C_{C'}$: 134.98	δ C_C of **10b**: 133.29	0.21	1.66
C_E, $C_{L'}$, C_L of **5a**	165.15	δ $C_{E'}$: 167.13	δ C_E of **10a**: 164.99	0.16	2.14
C_E, $C_{L'}$, C_L of **5b**	165.12	δ $C_{E'}$: 167.06	δ C_E of **10b**: 164.92	0.20	2.14

[a] $\bar{x}\delta_{1-3} = (\delta_{fragment\ 1} + \delta_{fragment\ 2} + \delta_{fragment\ 3}) / 3$.

As it can be observed, the chemical shifts for rotaxanes **10** are very similar with those of the three analogous fragments in rotaxanes **5**. In contrast there is an important difference between the data for compounds **10** and the fragment 4 in rotaxanes **5**. All these data suggest that the CO groups of the three “similar” fragments in compounds **5** adopt an *out* disposition such as that observed in **10**.

Another experimental information that supports this assignment is the observed cross-peak between the protons $C_{F'}$-NH and $H_{B'}$ in the NOESY spectrum of **5a** (figure S7).

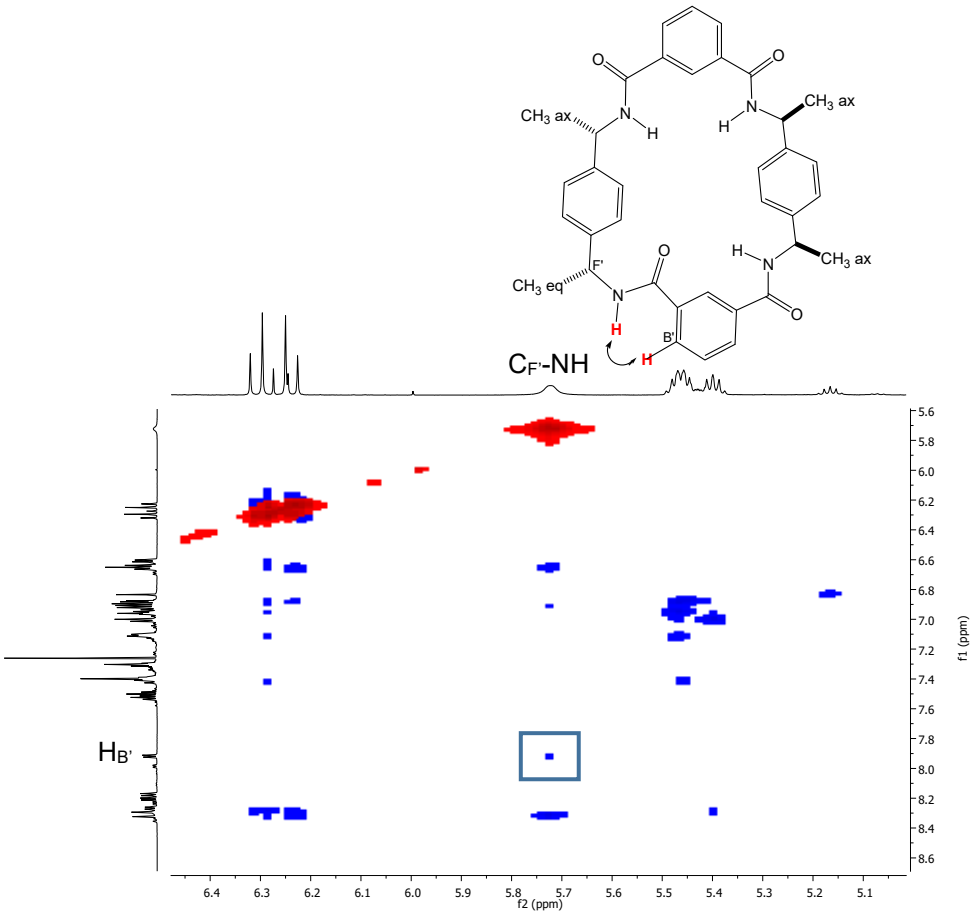


Figure S7. Partial ^{1}H,^{1}H-NOESY spectrum crosspeaks for rotaxane **5a**.

Additionally, the methyl groups in the three "similar" fragments of the macrocyclic counterpart adopt a *pseudoaxial* disposition, and that of the different fourth fragment a *pseudoequatorial* one. The ^{1}H NMR spectrum shows three signals (around δ 5.45 ppm) in the *pseudoequatorial* region[6] and one (centered at δ 4.89 ppm for **5a** and δ 4.81 ppm for **5b**) in the *pseudoaxial* region (and showed in figure S3).

With all these data in hand, we concluded that the macrocycle in rotaxanes **5** adopts a chair-like conformation in solution, having three fragments in the following disposition: CO *out*, NH *in*, CH_3 *pseudoaxial* (figure S8, in blue, green and orange). In contrast, the dissimilar fourth fragment has a disposition: CO *in*, NH *out*, CH_3 *pseudoequatorial* (figure S8, in red).

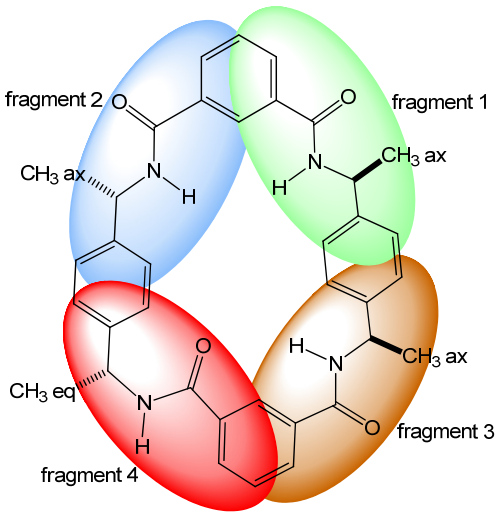


Figure S8. Fragments 1-4 of the macrocycle in rotaxane **5** in solution. The thread has been deleted for clarity.

In line with previous reports,[7] the ^{1}H NMR of **5a** recorded at different times in $CDCl_3$ in the presence of D_2O revealed the different H/D exchange rate between the *in* and *out* amide protons of the molecule (figure S9). One of the NH protons slowly exchange (2.5 days) while the other three do not. The amide signals that do not exchange are due to protons that are buried inside the molecule and are involved in intramolecular hydrogen bonds. In contrast, the signal at δ 5.72 ppm is due to proton (CF'-NH) that is exposed to solvent and so exchange with deuterium.

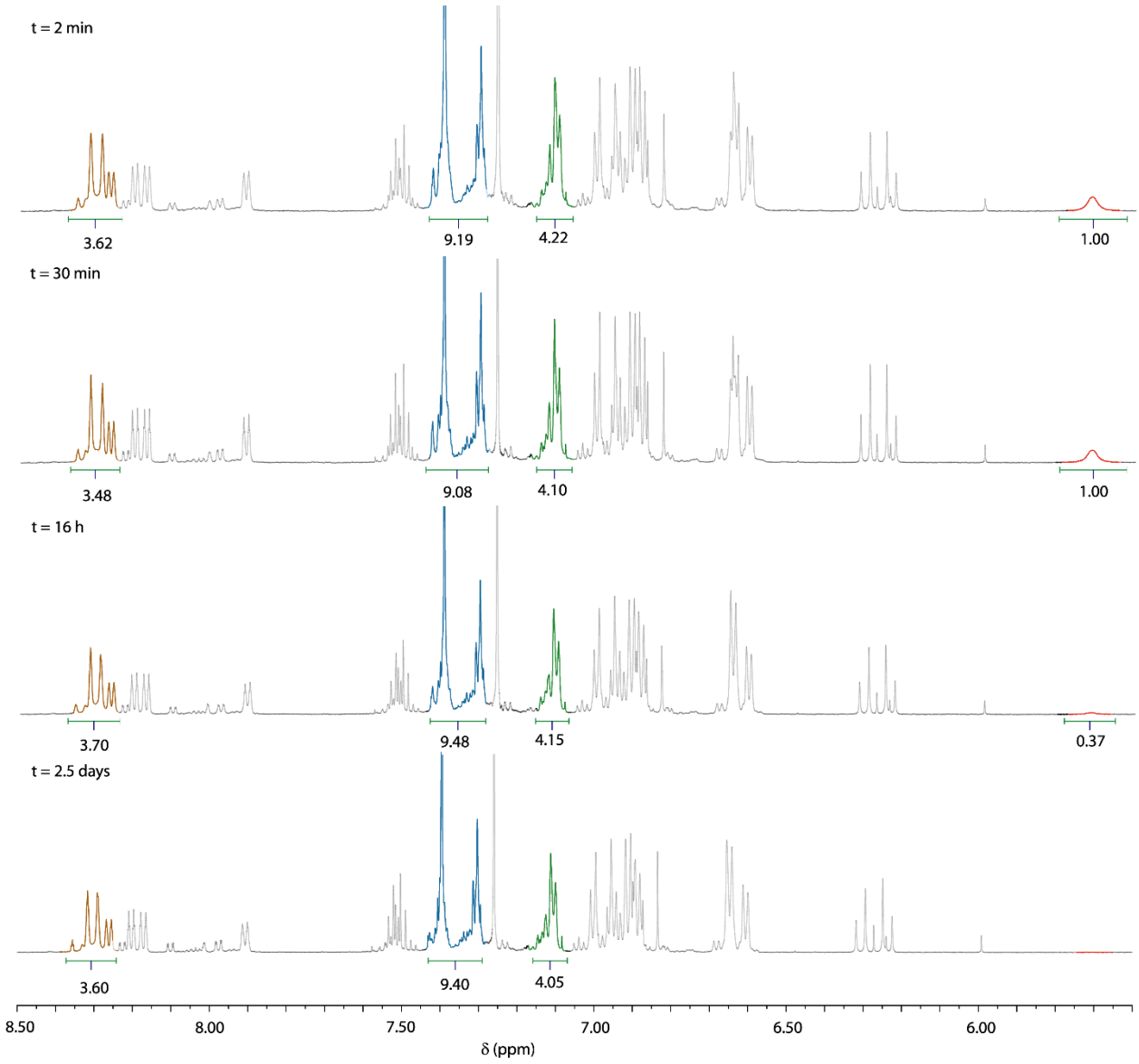


Figure S9. Selected region of ^{1}H NMR spectrum of rotaxane **5a** (600 MHz, $CDCl_3$ + D_2O, 298 K). The region of the NH *out* is highlighted in red and the corresponding to NH *in* are in blue, green and brown.

A similar experiment carried out with a **5b** + **10b** mixture, showed only the exchange of the δ 5.85 ppm, signal due to the proton outside the cavity ($C_{F'}$-NH de **5b**) and not those at δ 7.11, 7.48, 8.39 ppm (C_F-NH, $C_{K'}$-NH, C_K-NH of **5b**) and 7.28 ppm (NH of **10b**), all of them due to protons inside the cavity (figure S10).

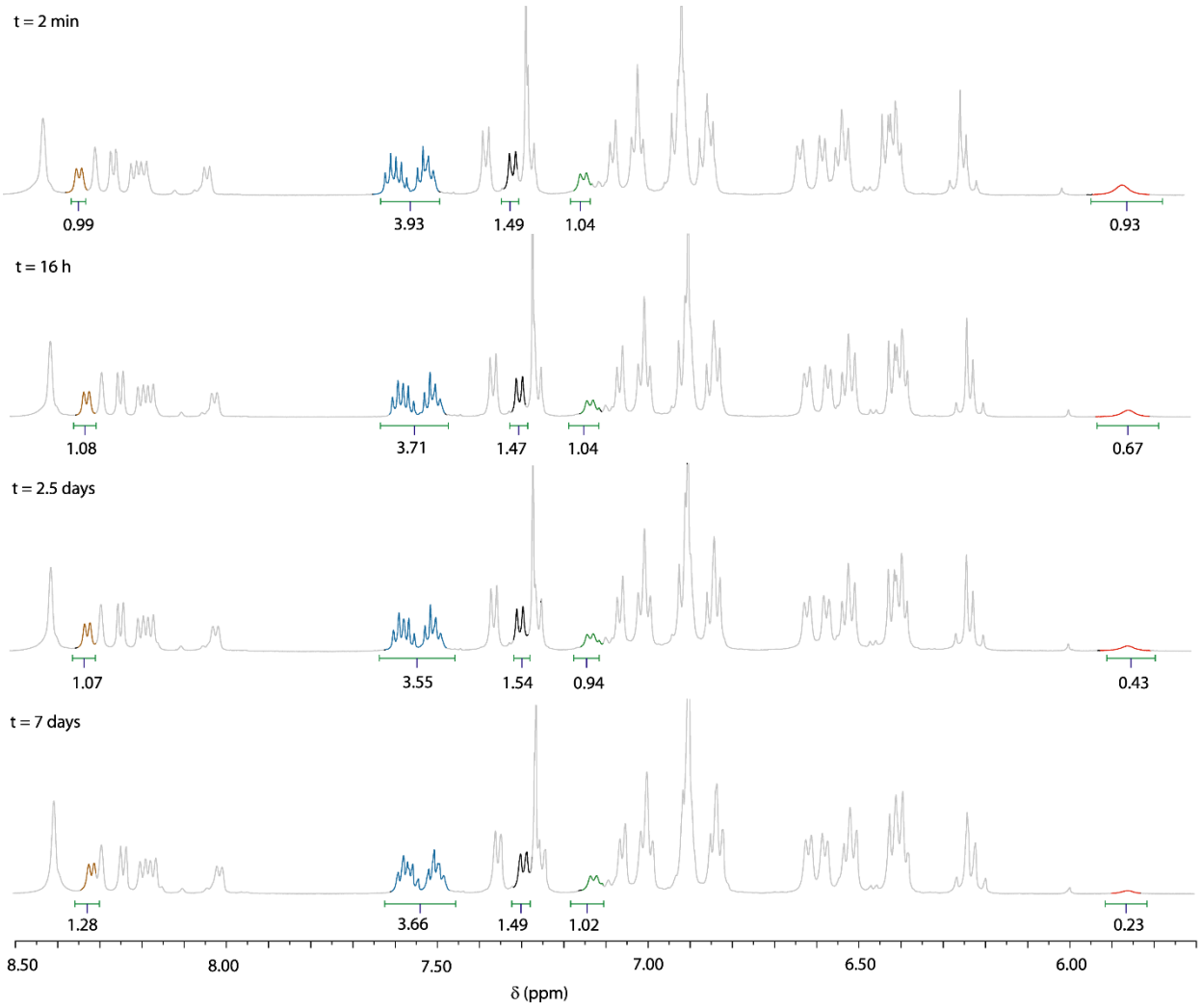


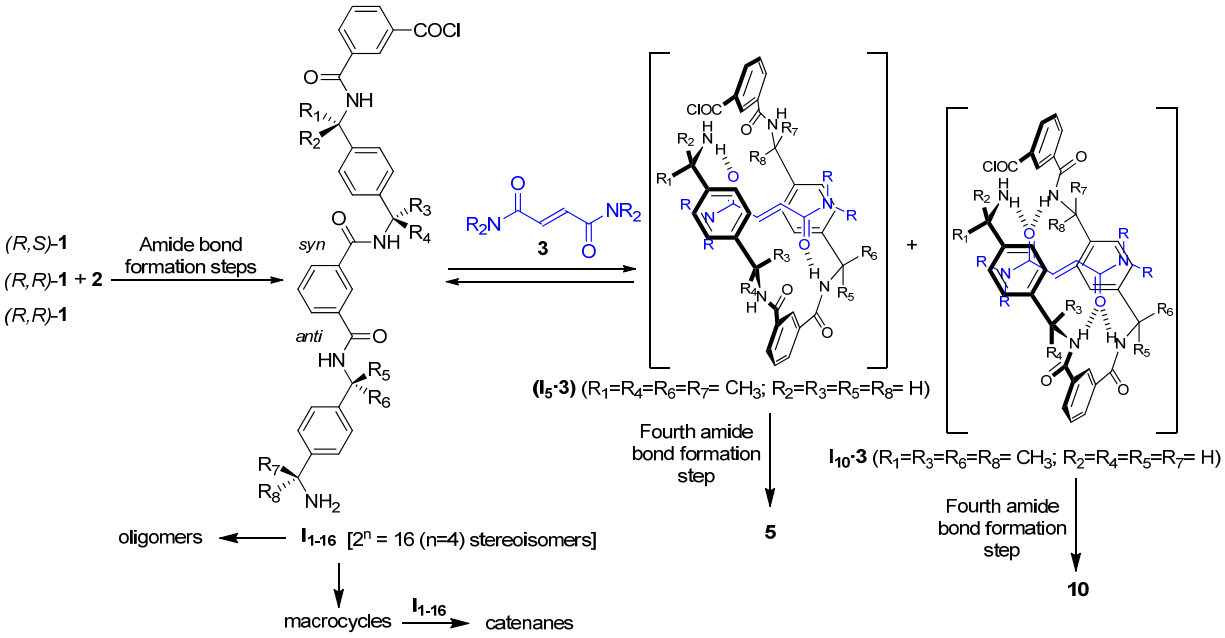
Figure S10. Selected region of ^{1}H NMR spectrum of a mixture of rotaxanes **5b** and **10b** (3/1) (600 MHz, $CDCl_3$ + D_2O, 298 K). The region of the NH *out* of **5b** is highlighted in red and the corresponding to NH *in* are in blue, green and brown. The signal of NH *in* of **10b** is marked in black.

8. Comments on the level of the stereoselection in the rotaxane formation.

In order to have an idea about the selection degree of this reaction it is convenient consider the key steps of the five component clipping reaction to form this amide-based rotaxane reported by Prof. Leigh.[8] In our particular case, the reaction of the diamines *(R,S)*-**1**, *(R,R)*-**1** and (*S,S*)-**1** and isophthaloyl dichloride **2** would lead to a set of 16 (2^4) of stereoisomeric open chain intermediates $\mathbf{I_{1\text{-}16}}$. The reversible association of these non-isolated intermediates with the fumaramide **3** leading to the rotaxanes is the most important step in which the selection occurs. In this step, the preorganization of linear intermediates[9] around the thread must be configurationally and conformationally directed to avoid other competing reaction pathways leading to oligomers,

macrocycles and catenanes. Finally, the last amide bond formation kinetically traps the supramolecular complexes $\mathbf{I_n \cdot 3}$ affording up to seven possible rotaxanes.

Taking into account that the comparable clipping reaction using *p*-xylylenediamine, isophthaloyl chloride and tetrabenzylfumaramide provides the unsubstituted rotaxane in 36% yield,[10] the formation of only two out of seven tetramethyl rotaxanes in 17-31% combined yields based on recovered starting material seems to point out a high degree of stereoselectivity.



9. Kinetic measurements for the calculation of the deslipping rate constant of the thermal dethreading of rotaxane 10c.

The rate constant *k* of the deslipping reaction of rotaxane **10c** has been calculated at 373 K, following the disappearing of the rotaxane **10c** and formation of the free thread **3c** with the time by ^{1}H-NMR experiments. Measurements were carried out inside the NMR instrument by heating the sample with the high temperature unit. For the evaluation of the data, the integration of as many signals as possible was averaged in order to reduce experimental error. The rate constant, half-life time and the free energy $\Delta G^{\ddagger}$ were determined by using the Eyring equation.

Variation of % conversion was measured over time using ^{1}H NMR spectroscopy (400 MHz, $C_2D_2Cl_4$) at 373K. The sample was prepared by dissolving 5 mg of rotaxane **10c** in 0.5 mL of solvent. From the corresponding data, reaction constant *k*, half-life time $t_{1/2}$ and free energy $\Delta G^{\ddagger}$ were obtained.

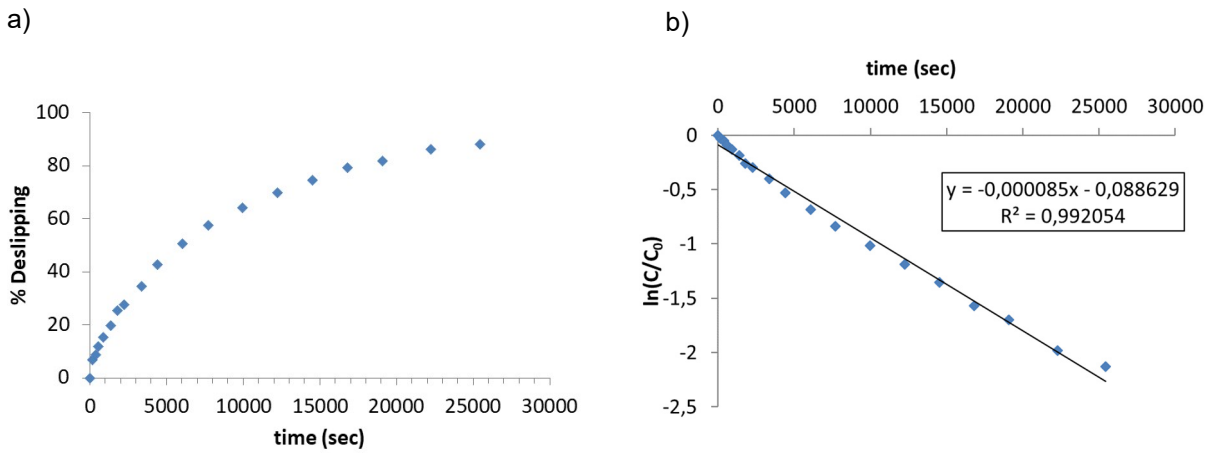


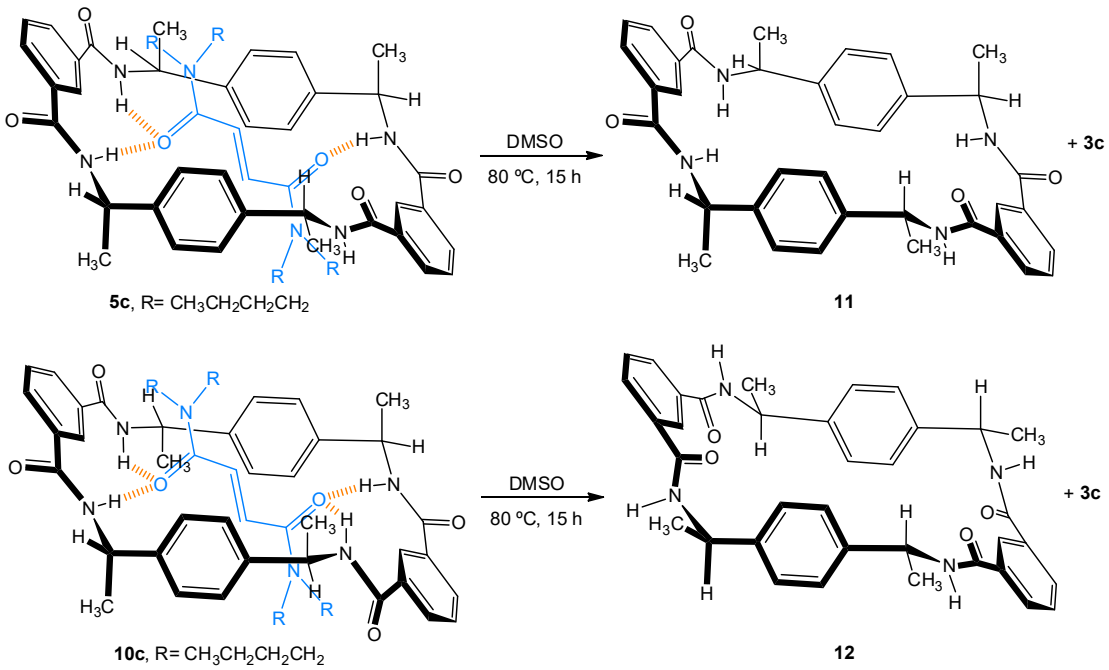
Figure S11. a) Plot of % deslipping of the rotaxane **10c** *versus* time; b) Plot of $\ln(C/C_0)$ *versus* time.

$$t_{1/2} = 8155 \text{ sec}$$

$$k_{deslipping} = 8.5 \times 10^{-5} \text{ s}^{-1}$$

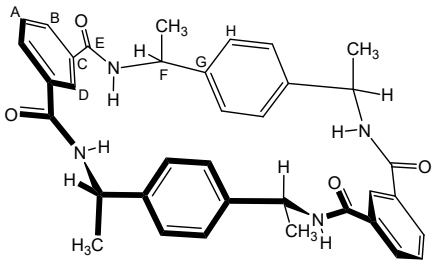
$$\Delta G^{\ddagger} = 121.1 \text{ KJ·mol}^{-1}$$

10. Preparation of the macrocycles 11 and 12.



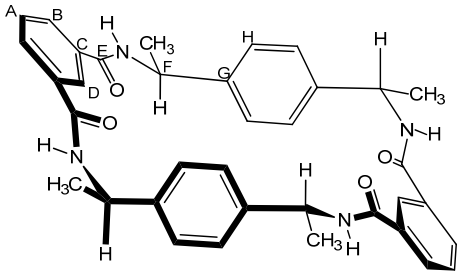
A solution of the corresponding rotaxane in DMSO (3 mL) was heated for 15 h at 80 ºC. After cooling, water (3 mL) was added and the resulting solid was filtered, washed with water (3 mL), $CHCl_3$ (3 mL), Et_2O (3 mL) and pentane (3 mL) and dried, to yield the title macrocycle.

Macrocycle 11



Macrocycle **11** was obtained from rotaxane **5c** (0.1 g, 0.108 mmol) by using the described method in 98% yield (62.5 mg). White solid; p. f. > 320 ºC; IR (solid, ATR, cm^{-1}) ν = 3290 (w, NH), 1641 (vs, CO), 1606 (w, CO), 1531 (s, NH); ^{1}H NMR (400 MHz, $CDCl_3$ + TFA, 298 K): δ = 1.61 (d, *J*= 7.2 Hz, 3 H, CH_3), 1.62 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.65 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.66 (d, *J*= 6.8 Hz, 3 H, CH_3), 5.10-5.34 (m, 4 H, H_F), 7.09 (br s, 2 H, NH), 7.27-7.35 (m, 8 H, H_H), 7.38 (d, *J*= 8.4 Hz, 1 H, NH), 7.48 (d, *J*= 8.0 Hz, 1 H, NH), 7.56 (t, *J*= 7.6 Hz, 1 H, H_A), 7.57 (t, *J*= 7.6 Hz, 1 H, H_A), 7.86-8.00 (m, 5 H, 4 H_B + H_D), 8.06 (br s, 1 H, H_D), 10.66 (s, CF_3COOH); ^{1}H NMR (400 MHz, DMSO-d_6, 298 K): δ = 1.46 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.47 (d, *J*= 6.8 Hz, 3 H, CH_3), 1.48 (d, (d, *J*= 6.8 Hz, 3 H, CH_3), 1.51 (d, (d, *J*= 6.8 Hz, 3 H, CH_3), 4.99-5.14 (m, 3 H, H_F), 5.14-5.24 (m, 1 H, H_F), 7.23-7.37 (m, 8 H, H_H), 7.55 (t, *J*= 7.6 Hz, 1 H, H_A), 7.56 (t, *J*= 7.6 Hz, 1 H, H_A), 7.88-8.02 (m, 5 H, 4 H_B + H_D), 8.13 (br s, 1H, 1 H_D), 8.60-8.74 (m, 2 H, NH), 8.83-8.97 (m, 2 H, NH); ^{1}H NMR (400 MHz, DMSO-d_6, 323 K): δ = 1.49 (d, *J*= 7.2 Hz, 6 H, CH_3), 1.51 (d, *J*= 7.2 Hz, 3 H, CH_3), 1.53 (d, (d, *J*= 6.8 Hz, 3 H, CH_3), 5.04-5.24 (m, 4 H, H_F), 7.27-7.39 (m, 8 H, H_H), 7.539 (t, *J*= 8.0 Hz, 1 H, H_A), 7.542 (t, *J*= 7.8 Hz, 1 H, H_A), 7.90-8.01 (m, 5 H, 4 H_B + H_D), 8.12 (br s, 1H, H_D), 8.50 (d, *J*= 7.6 Hz, 1 H, NH), 8.51 (d, *J*= 7.6 Hz, 1 H, NH), 8.72 (d, *J*= 8.0 Hz, 1 H, NH) 8.77 (d, *J*= 8.0 Hz, 1 H, NH); ^{13}C NMR (100 MHz, $CDCl_3$ + TFA, 298 K): δ = 19.81 (CH_3), 20.12 (CH_3), 20.87 (CH_3), 21.23 (CH_3), 50.14 (C_F), 50.23 (C_F), 50.41 (C_F), 51.03 (C_F), 114.48 (q, $^1J_{CF}$= 283.0 Hz, *C*F_3COOH), 125.15 (C_D), 126.75 (C_H), 126.78 (C_H), 126.90 (C_D + C_H), 127.15 (C_H), 129.59 (C_A), 129.81 (C_A), 130.68 (C_B), 131.08 (C_B), 131.38 (C_B), 131.54 (C_B), 133.46 (C_C), 133.49 (C_C), 133.54 (C_C), 133.67 (C_C), 140.55 (C_G), 140,63 (C_G), 141.43 (C_G), 141.96 (C_G), 159.76 (q, $^2J_{CF}$= 41.7 Hz, CF_3*C*OOH), 168.59 (C_E), 168.73 (C_E), 168.76 (C_E), 169.03 (C_E); ^{13}C NMR (100 MHz, DMSO-d_6, 313 K): 20.67 (CH_3), 20.94 (CH_3), 21.51 (CH_3), 21.71 (CH_3), 47.80 (C_F), 48.20 (C_F), 48.45 (C_F), 48.64 (C_F), 126-126.38 (C_H + C_D), 128.06 (C_A), 129.56 (2 C_B), 129.74 (C_B), 129.88 (C_B), 134.75 (C_C), 134.81 (C_C), 135.04 (C_C), 135.15 (C_C), 142.58 (C_G), 142,69 (C_G), 142.81 (C_G), 143.28 (C_G), 165.17 (C_E), 165.45 (C_E), 165.49 (C_E), 165.67 (C_E); Elemental analysis ($C_{36}H_{36}N_4O_4 \cdot$ 1.2 DMSO,%) calcd (found): C 67.58 (67.38), H 6.38 (6.17), N 8.21 (8.30); HRMS (ESI) calcd for $C_{36}H_{37}N_4O_4$ $[M + H]^+$ 589.2809, found 589.2816.

Macrocycle 12



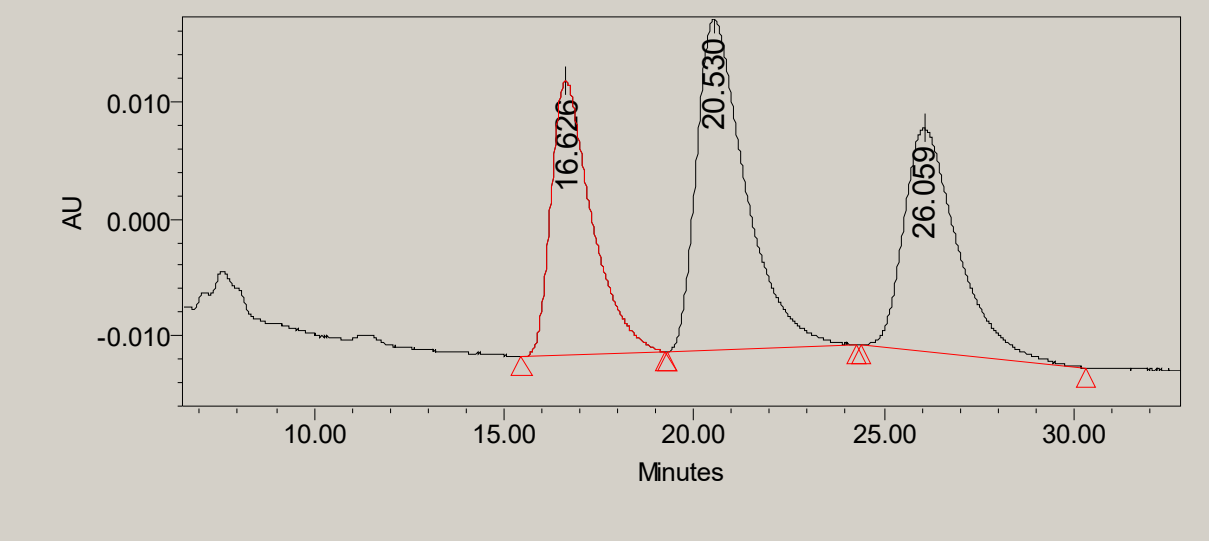
Macrocycle **12** was obtained from rotaxane **10c** (0.1 g, 0.108 mmol) by using the described method in 97% yield (61.5 mg). White solid; p. f. > 320 ºC; IR (solid, ATR, cm^{-1}) ν = 3288 (m, NH), 1639 (vs, CO), 1531 (m, NH); ^{1}H NMR (400 MHz, $CDCl_3$ + TFA, 298 K): δ = 1.62 (d, *J*= 6.9 Hz, 12 H, CH_3), 5.10-5.33 (m, 4 H, H_F), 7.04 (d, *J*= 7.4 Hz, 4 H, NH), 7.27 (s, 8 H, H_H), 7.64 (t, *J*= 7.8 Hz, 2 H, H_A), 7.90 (s, 2 H, H_D), 8.00 (dd, *J*= 7.8, 1.1 Hz, 4 H, H_B), 10.59 (s, CF_3COOH); ^{1}H NMR (400 MHz, DMSO-d_6, 298 K): δ = 1.48 (d, *J*= 7.2 Hz, 12 H, CH_3), 5.00-5.10 (m, 4 H, H_F), 7.33 (s, 8 H, H_H), 7.56 (t, *J*= 7.7 Hz, 2 H, H_A), 7.83 (s, 2 H, H_D), 7.91 (dd, *J*= 7.7, 1.6 Hz, 4 H, H_B), 8.76 (d, *J*= 8.2 Hz, 4 H, NH); ^{13}C NMR (100 MHz, $CDCl_3$ + TFA, 298 K): δ = 19.78 (CH_3), 50.37 (C_F), 114.29 (q, $^1J_{CF}$= 282.7 Hz, *C*F_3COOH), 125.66 (C_D), 126.96 (C_H), 129.95 (C_A), 131.36 (C_B), 133.37 (C_C), 140.63 (C_G), 160.94 (q, $^2J_{CF}$= 42.7 Hz, CF_3*C*OOH),168.84 (C_E); ^{13}C NMR (100 MHz, DMSO-d_6, 298 K): δ = 20.87 (CH_3), 48.07 (C_F), 125.88 (C_D), 126.04 (C_H), 127.98 (C_A), 129.41 (C_B), 134.93 (C_C), 142.56 (C_G), 165.59 (C_E); Elemental analysis ($C_{36}H_{36}N_4O_4$ · 1.23 DMSO,%) calcd (found): C 67.46 (67.31), H 6.38 (6.22), N 8.18 (8.24); HRMS (ESI) calcd for $C_{36}H_{37}N_4O_4$ $[M + H]^+$ 589.2809, found 589.2816.

11. References

1. (a) J. Dalmolen, T. D. Tiemersma-Wegman, J. W. Nieuwenhuijzen, M. van der Sluis, E. van Echten, T. R. Vries, B. Kaptein, Q. B. Broxterman, R. M. Kellogg, *Chem. Eur. J.*, **2005**, *11*, 5619-5624. (b) M. A. J, Veld, K. Hult, A. R. A. Palmans, E. W. Meijer, *Eur. J. Org. Chem.*, **2007**, 5416-5421.
2. (a) N. Moyano, J. Frydman, G. Buldain, O. Ruiz, R. B. Frydmam, *J. Med. Chem.*, 1990, **33**, 1969-1974. (b) A. F. Kotthaus, F. Ballaschk, V. Stakaj, F. Mohr, S. F. Kirsch, *Synthesis*, 2017, **49**, 3107-3111.
3. L. L. R. Lorentz-Petersen, P. Jensen, R. Madsen, *Synthesis*, 2009, 4110-4112.
4. A. Martinez-Cuezva, C. Lopez-Leonardo, D. Bautista, M. Alajarin, J. Berna, *J. Am. Chem. Soc.*, 2016, **138**, 8726-8729.
5. A. Kinnell, T. Harman, M. Bingham, A. Berry, A. Nelson, *Tetrahedron*, 2012, **68**, 7719-7722.

6. V. Bermudez, N. Capron, T. Gase, F. G. Gatti, F. Kajzar, D. A. Leigh, F. Zerbetto, S. W. Zhang, *Nature*, 2000, **406**, 608-611.
7. C. A. Hunter, *J. Am. Chem. Soc.*, 1992, **114**, 5303-5311.
8. F. G. Gatti, D. A Leigh, S. A Nepogodiev, A M. Slawin, S. J. Teat, J. K. Wong, *J. Am. Chem. Soc.*, 2001, **123**, 5983-9.
9. These intermediates adopt a linear conformation due to the preference isophthalamide moiety for adopting a *syn-anti* conformation. (a) F. J. Carver, C. A. Hunter, R. J. Shannon, *J. Chem. Soc., Chem. Commun.* 1994, **0**, 1277-1280. (b) S. G. Geib, C. Vincent, E. Fan, A. D. Hamilton, *Angew. Chem., Int. Ed. Engl.* 1993, **32**, 119-121. (c) A. G. Johnston, D. A. Leigh, L. Nezhat, J. P. Smart, M. D. Deegan, *Angew. Chem., Int. Ed. Engl.* 1995, **34**, 1212-1216.
10. A. Martinez-Cuezva, C. Lopez-Leonardo, M. Alajarin, and J. Berna, *Synlett*, 2019, **30**, 893-902.

12. Chiral HPLC of dibenzamides S-1.



	Name	Retention Time (min)	Area	% Area	Height
1	Dibenzamide1	16.626	1759867	28.51	23461
2	Dibenzamide 2	20.530	2541661	41.17	28301
3	Dibenzamide 3	26.059	1871761	30.32	19065

Figure S12. Chiral HPLC for dibenzamides **S-1** using Chiralpak IA, hexane-i-PrOH 2.5:7.5, 1 mL/min.

13. X-Ray Structure Determinations.

Intensities were registered at low temperature on a Bruker D8QUEST diffractometer using monochromated Mo *K*α radiation (λ = 0.71073Å) for **5a**, **10a** and **12** compounds. Absorption corrections were based on multi-scans (program SADABS for **5a** and **10a** and TWINABS version 2012/1 for **12**). Structures were refined anisotropically using SHELXL-2018. Hydrogen atoms were included using rigid methyl groups or a riding model. The NH hydrogens were located in a difference synthesis and refined freely in **12** and freely with SADI in **5a** and **10a**.

Special features and exceptions:

10a: There is a poorly-resolved region of residual electron density; this could not be adequately modelled and so was "removed" using the program SQUEEZE, which is part of the PLATON system. The void volume per cell was 462 eÅ^3, with a void electron count per cell of 168. This additional solvent was not taken account of when calculating derived parameters such as the formula weight, because the nature of the solvent was uncertain.

Table S3. Crystal data and structure refinement for **5a**.

	5a (CCDC 1906991)	
Empirical formula	$C_{72}H_{70}Cl_{12}N_6O_6$	
Formula weight	1540.74	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	Pbca	
Unit cell dimensions	a = 20.6179(9) Å	α= 90°.
	b = 16.6222(7) Å	β= 90°.
	c = 21.6049(9) Å	γ = 90°.
Volume	7404.3(5) $Å^3$	
Z	4	
Density (calculated)	1.382 Mg/m^3	
Absorption coefficient	0.504 mm^{-1}	
F(000)	3184	
Crystal size	0.310 x 0.160 x 0.100 mm^3	
Theta range for data collection	1.834 to 28.283°.	
Index ranges	-27<=h<=27, -22<=k<=22, -28<=l<=28	
Reflections collected	386561	
Independent reflections	9188 [R(int) = 0.0647]	
Completeness to theta = 25.242°	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7210 and 0.7210	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	9188 / 1 / 442	
Goodness-of-fit on F^2	1.031	
Final R indexes [I>2sigma(I)]	R1 = 0.0422, wR2 = 0.0952	
R indexes (all data)	R1 = 0.0546, wR2 = 0.1019	
Largest diff. peak and hole	0.671 and -0.745 $e.Å^{-3}$	

Table S4. Hydrogen bonds for rotaxane **5a** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1)-H(01)...O(3)	0.834(18)	2.135(19)	2.9291(18)	159(2)
N(2)-H(02)...O(1)#2	0.838(18)	2.161(18)	2.9775(19)	164.5(19)
C(92)-H(92)...O(2)	1.00	2.14	3.045(2)	149.1

Symmetry transformations used to generate equivalent atoms:
#1 -x+1,-y+1,-z+1 #2 -x+3/2,y-1/2,z

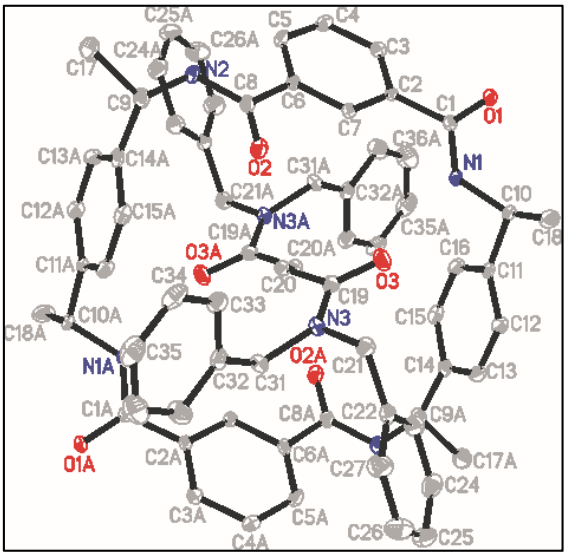


Figure S13. Molecular structure of the rotaxane **5a** with thermal ellipsoids drawn at 50% probability.

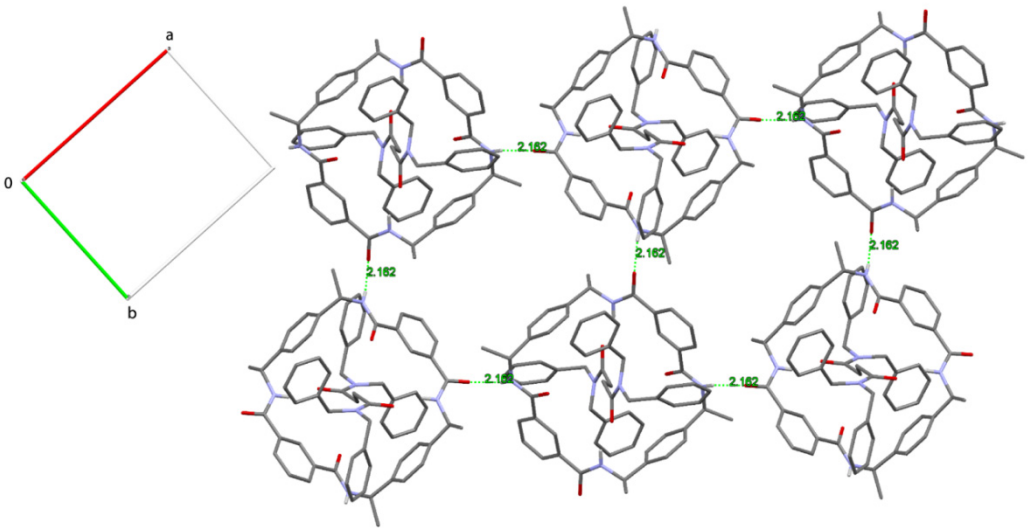


Figure S14. Perspective view of crystal packing of rotaxane **5a** along c axis.

Table S5. Crystal data and structure refinement for **10a**.

	10a (CCDC: 1906992)	
Empirical formula	$C_{69}H_{68}Cl_2N_6O_6$	
Formula weight	1148.19	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	C2/c	
Unit cell dimensions	a = 50.7230(19) Å	α= 90°.
	b = 11.0306(4) Å	β= 105.156(2)°.
	c = 22.3781(9) Å	γ = 90°.
Volume	12085.2(8) $Å^3$	
Z	8	
Density (calculated)	1.262 Mg/m^3	
Absorption coefficient	0.166 mm^{-1}	
F(000)	4848	
Crystal size	0.120 x 0.060 x 0.040 mm^3	
Theta range for data collection	2.065 to 27.103°.	
Index ranges	-64<=h<=64, -14<=k<=14, -28<=l<=28	
Reflections collected	227877	
Independent reflections	13316 [R(int) = 0.1111]	
Completeness to theta = 25.242°	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7437 and 0.7219	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	13316 / 6 / 769	
Goodness-of-fit on F^2	1.049	
Final R indexes [I>2sigma(I)]	R1 = 0.0558, wR2 = 0.1032	
R indexes (all data)	R1 = 0.0938, wR2 = 0.1171	
Largest diff. peak and hole	0.609 and -0.790 $e.Å^{-3}$	

Table S6. Hydrogen bonds for **10a** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1)-H(01)...O(5)	0.864(16)	2.242(17)	3.095(2)	169(2)
N(2)-H(02)...O(5)	0.861(16)	2.466(17)	3.296(2)	162(2)
N(3)-H(03)...O(6)	0.864(16)	2.309(17)	3.167(2)	172(2)
N(4)-H(04)...O(6)	0.861(16)	2.317(17)	3.171(2)	171(2)
C(41)-H(41B)...O(2)#1	0.99	2.44	3.377(3)	158.6
C(51)-H(51A)...O(2)#1	0.99	2.59	3.461(3)	146.7
C(61)-H(61B)...O(4)#2	0.99	2.55	3.497(2)	161.1
C(98)-H(98A)...O(1)	0.99	2.13	3.105(3)	167.4

Symmetry transformations used to generate equivalent atoms:
#1 x,y+1,z #2 x,y-1,z

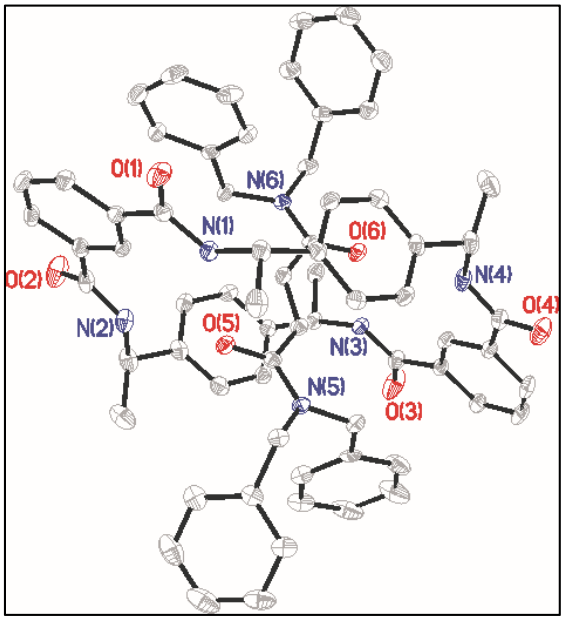


Figure S15. Molecular structure of the rotaxane **10a** with thermal ellipsoids drawn at 50% probability.

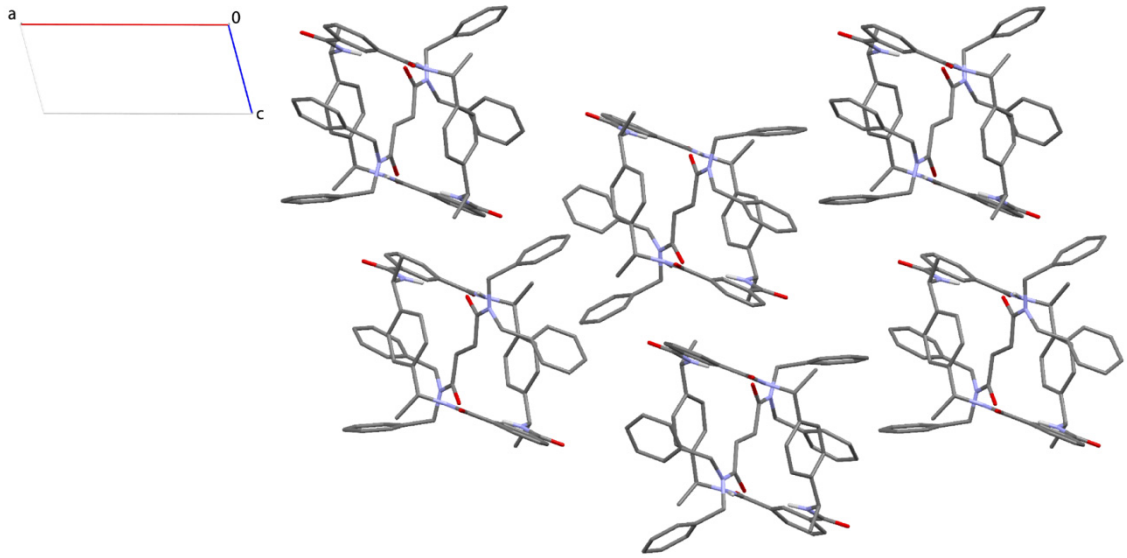


Figure S16. Perspective view of crystal packing of rotaxane **10a** along b axis.

Table S7. Crystal data and structure refinement for **12**.

	12 (CCDC: 1906993)	
Empirical formula	$C_{44}H_{60}N_4O_8S_4$	
Formula weight	901.20	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	$P2_1/c$	
Unit cell dimensions	a = 8.9332(6) Å	α= 90°.
	b = 17.8759(13) Å	β= 104.251(3)°.
	c = 15.1341(10) Å	γ = 90°.
Volume	2342.4(3) $Å^3$	
Z	2	
Density (calculated)	1.278 Mg/m^3	
Absorption coefficient	0.257 mm^{-1}	
F(000)	960	
Crystal size	0.320 x 0.080 x 0.080 mm^3	
Theta range for data collection	1.796 to 27.076°.	
Index ranges	-11<=h<=11, 0<=k<=22, 0<=l<=19	
Reflections collected	5488	
Independent reflections	5488	

Table S7. Crystal data and structure refinement for **12** (continued).

	12 (CCDC: 1906993)
Completeness to theta = 25.242°	99.9 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7455 and 0.6659
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	5488 / 2 / 286
Goodness-of-fit on F^2	1.129
Final R indexes [I>2sigma(I)]	R1 = 0.0518, wR2 = 0.0958
R indexes (all data)	R1 = 0.0660, wR2 = 0.1009
Largest diff. peak and hole	0.364 and -0.331 e.Å^{-3}

Table S8. Hydrogen bonds for **12** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1)-H(01)...O(91)#2	0.816(17)	2.120(18)	2.931(3)	172(3)
N(2)-H(02)...O(92)	0.837(17)	2.021(18)	2.848(3)	170(3)
C(91)-H(91B)...O(92)#3	0.98	2.44	3.399(5)	166.2
C(91)-H(91C)...O(2)#4	0.98	2.53	3.358(5)	141.5
C(92)-H(92A)...O(2)#4	0.98	2.24	3.144(4)	152.2
C(94)-H(94A)...O(1)#5	0.98	2.51	3.417(3)	154.5

Symmetry transformations used to generate equivalent atoms:

#1 -x,-y+1,-z+1 #2 -x+1,-y+1,-z+1 #3 x,-y+1/2,z+1/2
#4 x+1,-y+1/2,z+1/2 #5 x+1,y,z

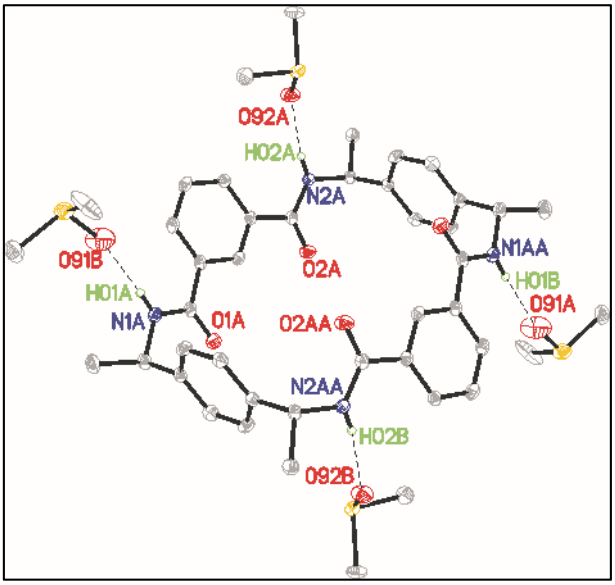
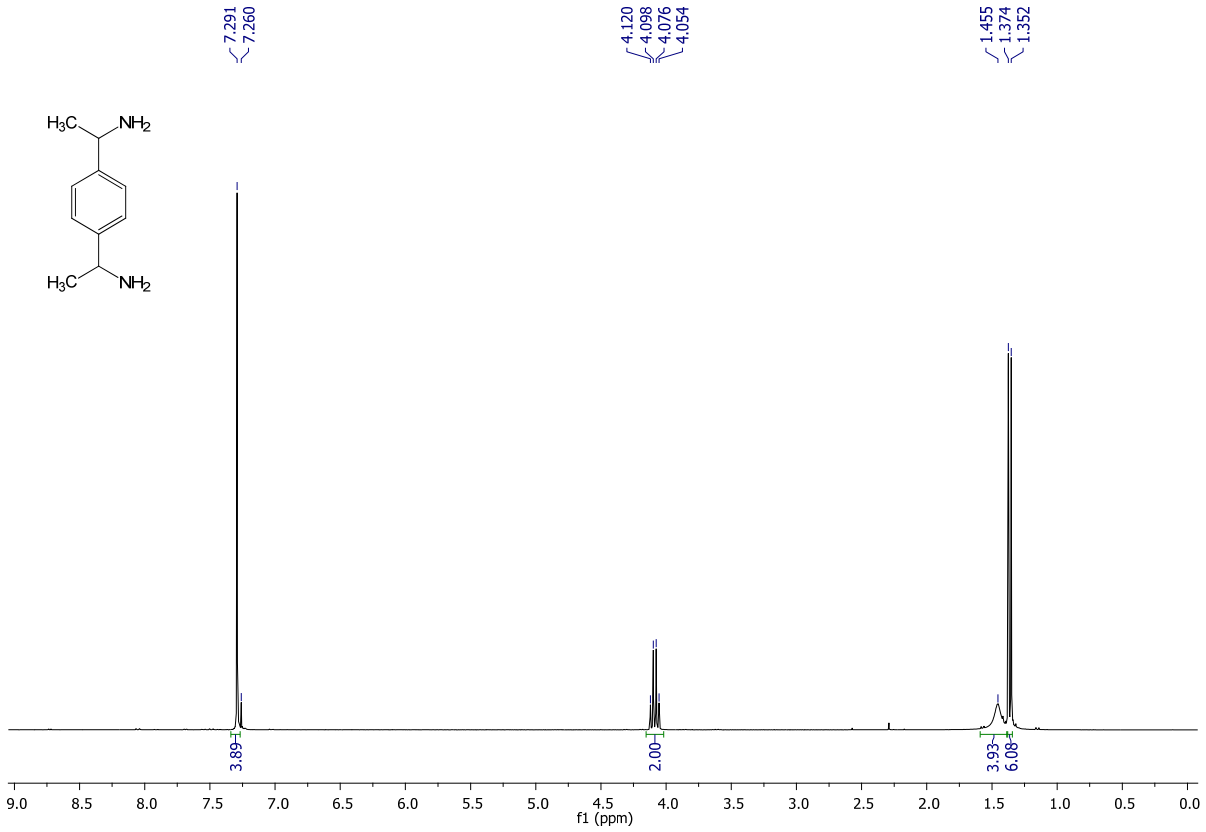


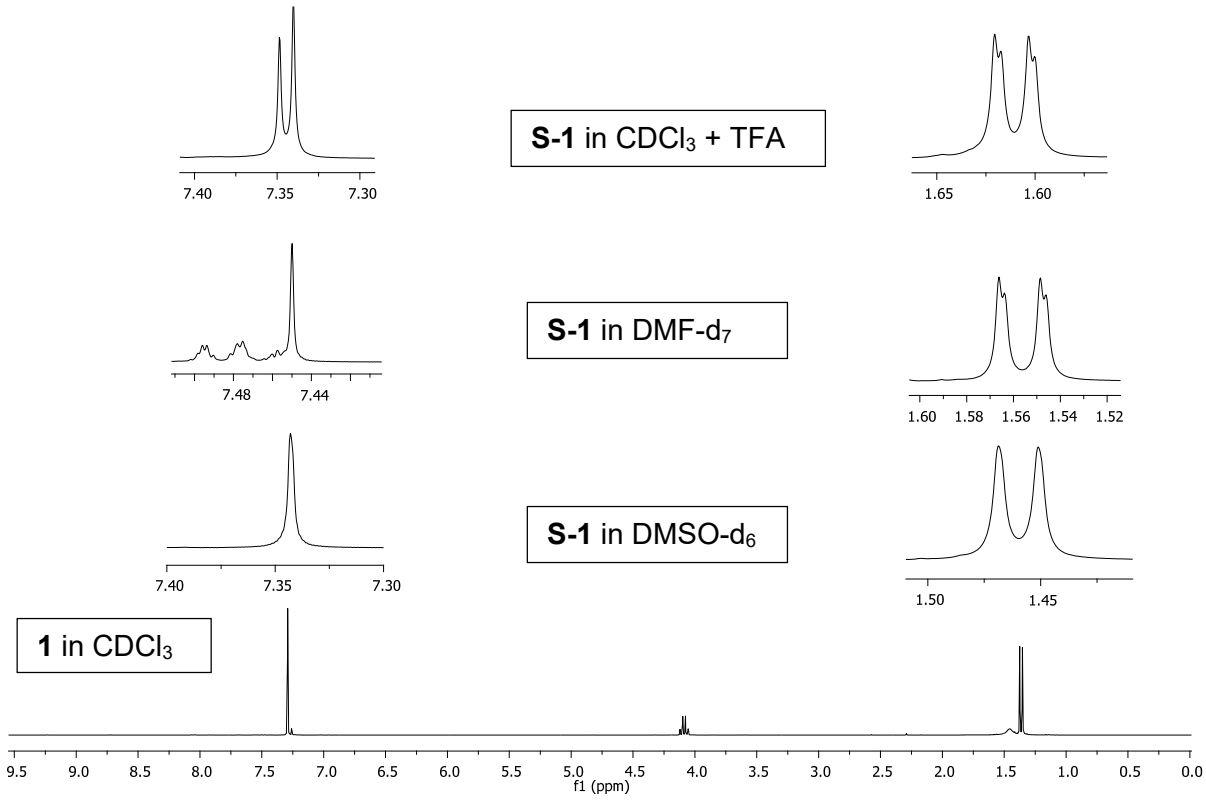
Figure S17. Molecular structure of the macrocycle **12** with thermal ellipsoids drawn at 50% probability.

14. NMR Spectra of the synthesized compounds

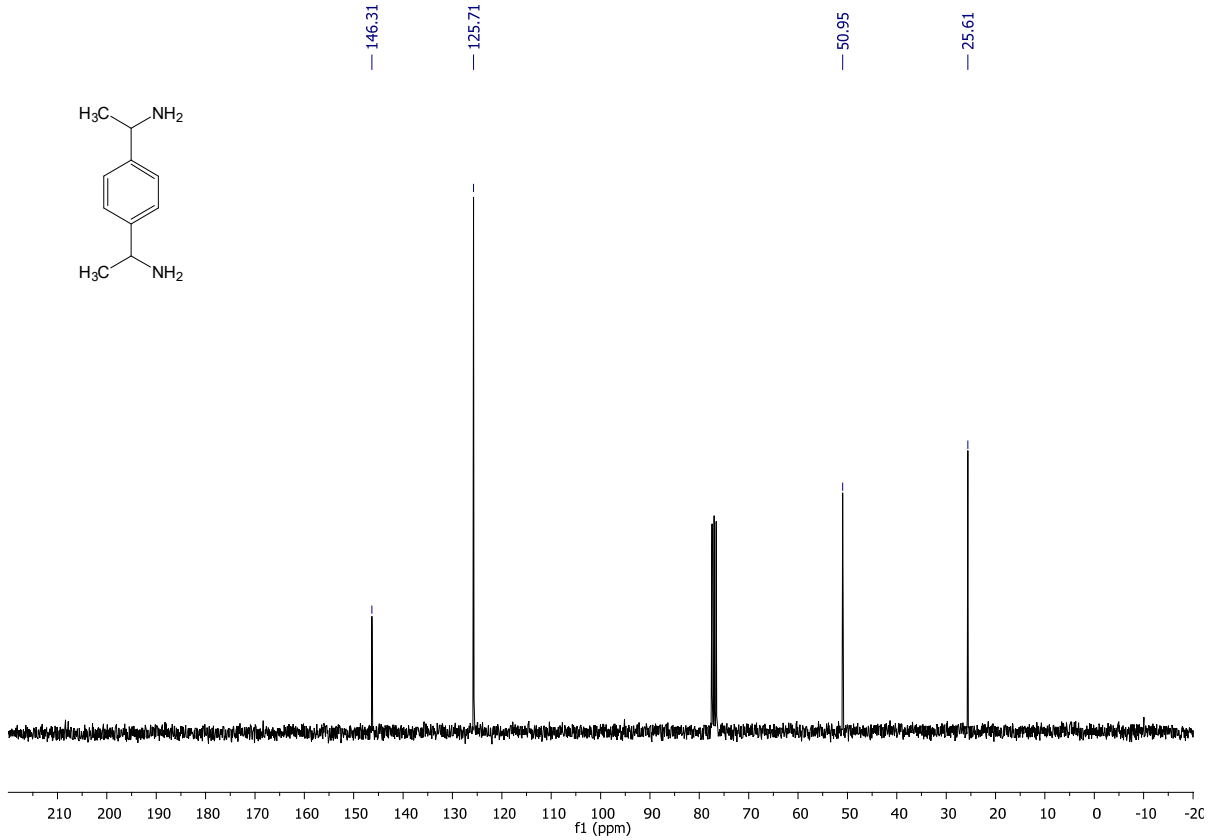
1 (^{1}H NMR, 300 MHz, $CDCl_3$, 298 K)



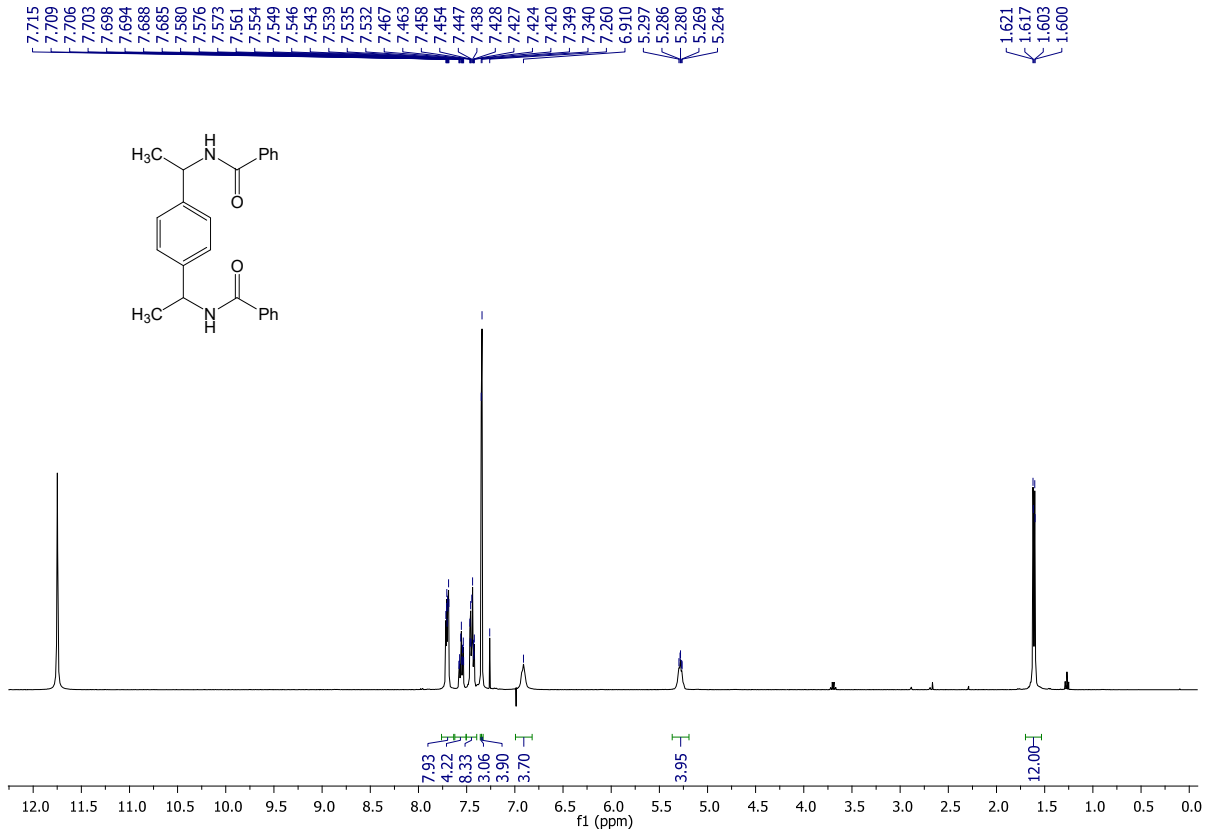
1 (^{1}H NMR, 300 MHz, $CDCl_3$, 298 K) and amplifications of signals of **S-1** in different solvents



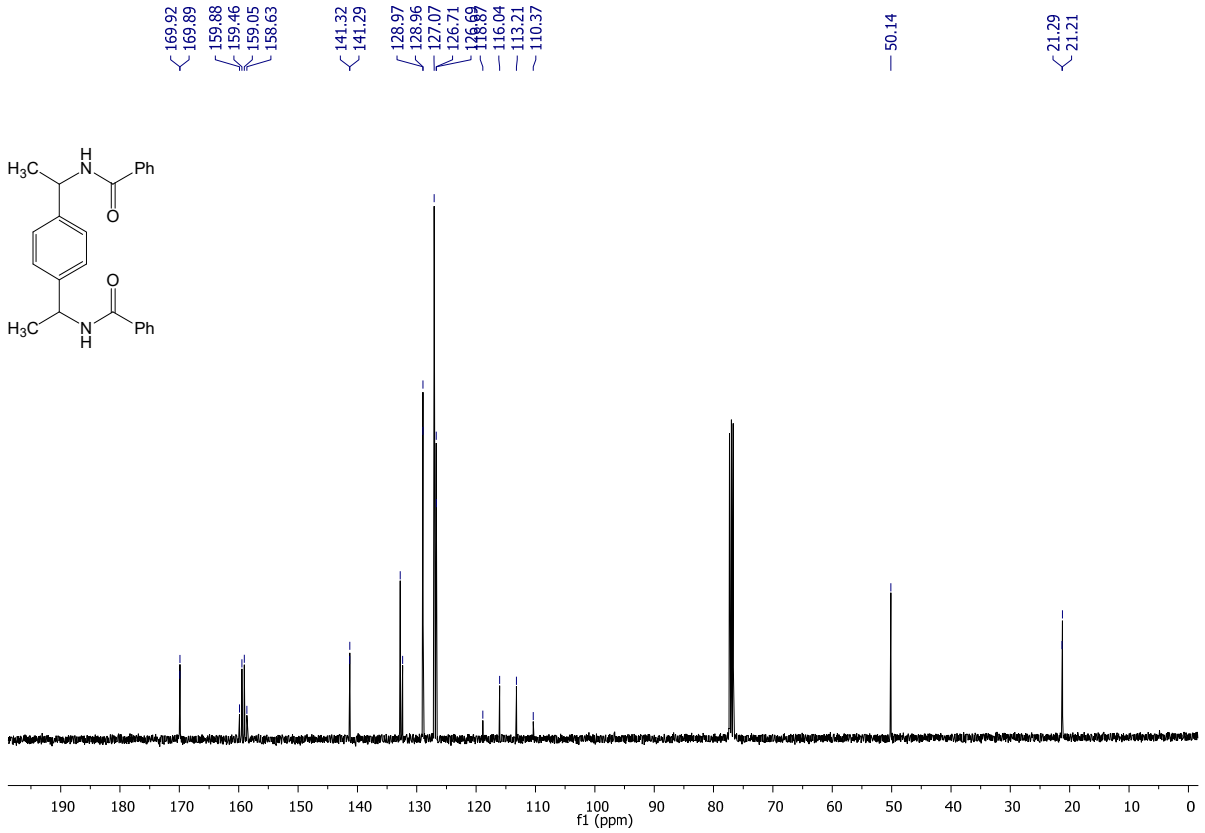
1 (^{13}C NMR, 75 MHz, $CDCl_3$, 298 K)



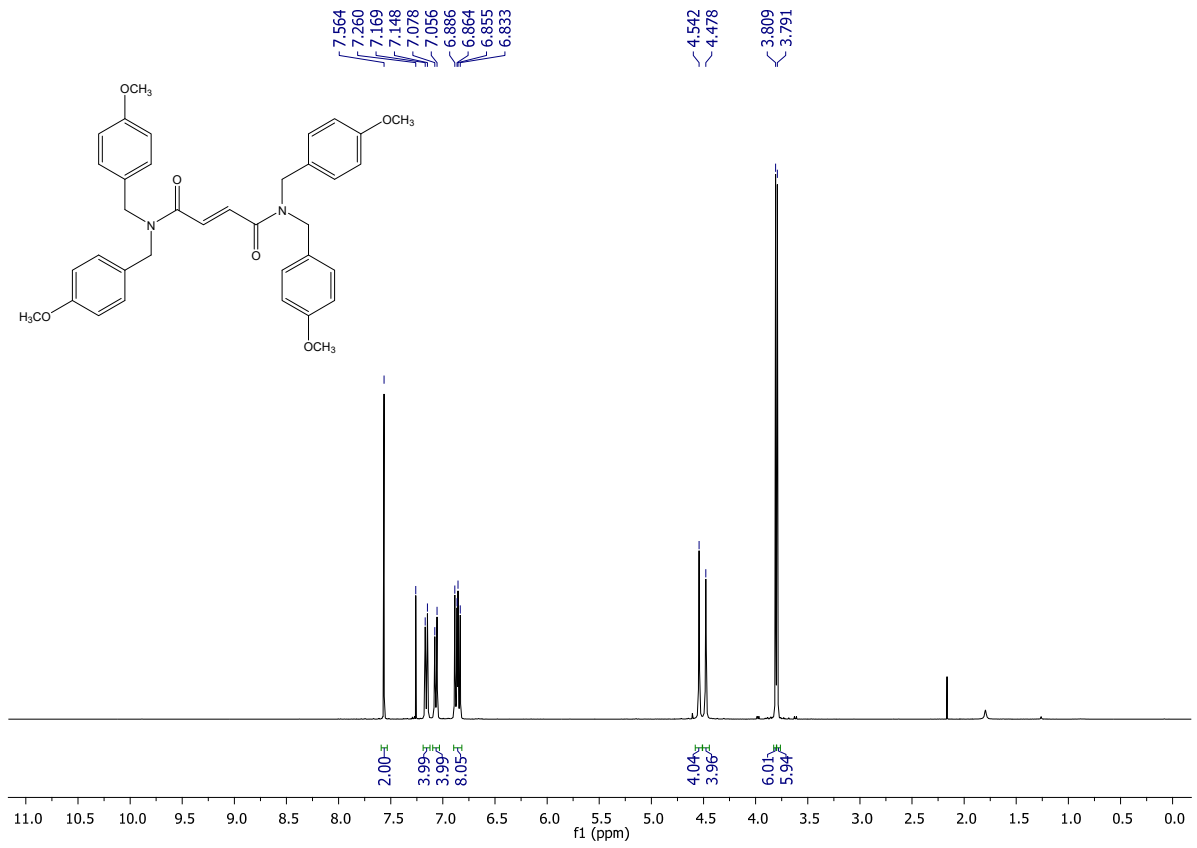
S-1 (^{1}H NMR, 400 MHz, $CDCl_3$ + TFA, 298 K)



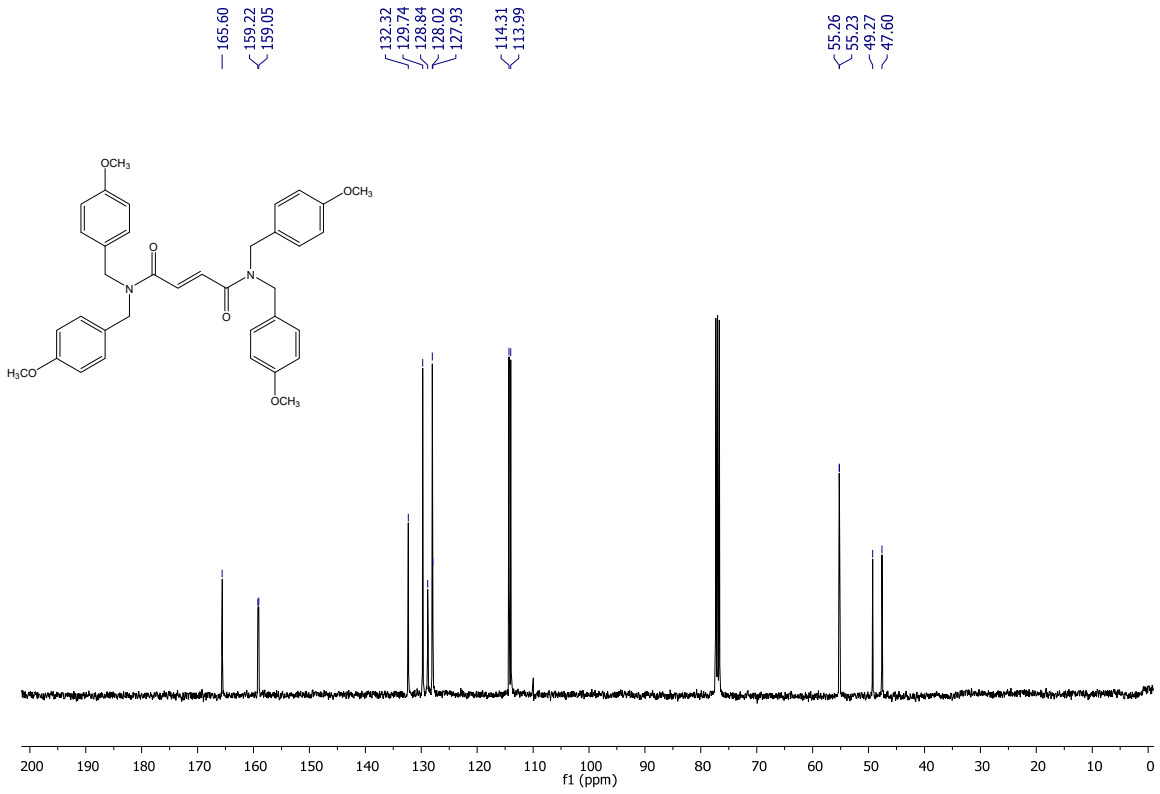
S-1 (^{13}C NMR, 125 MHz, $CDCl_3$ + TFA, 298 K)



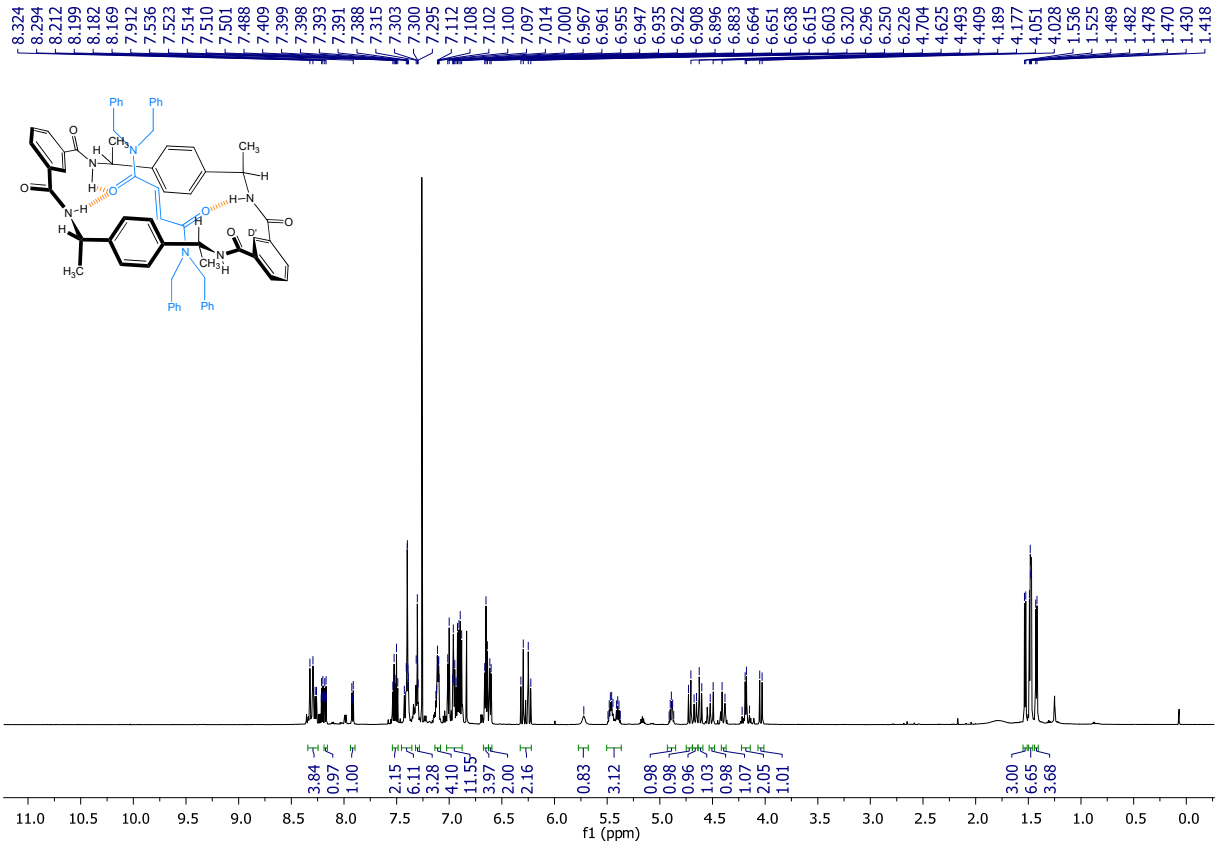
3b (^{1}H NMR, 400 MHz, $CDCl_3$, 298 K)



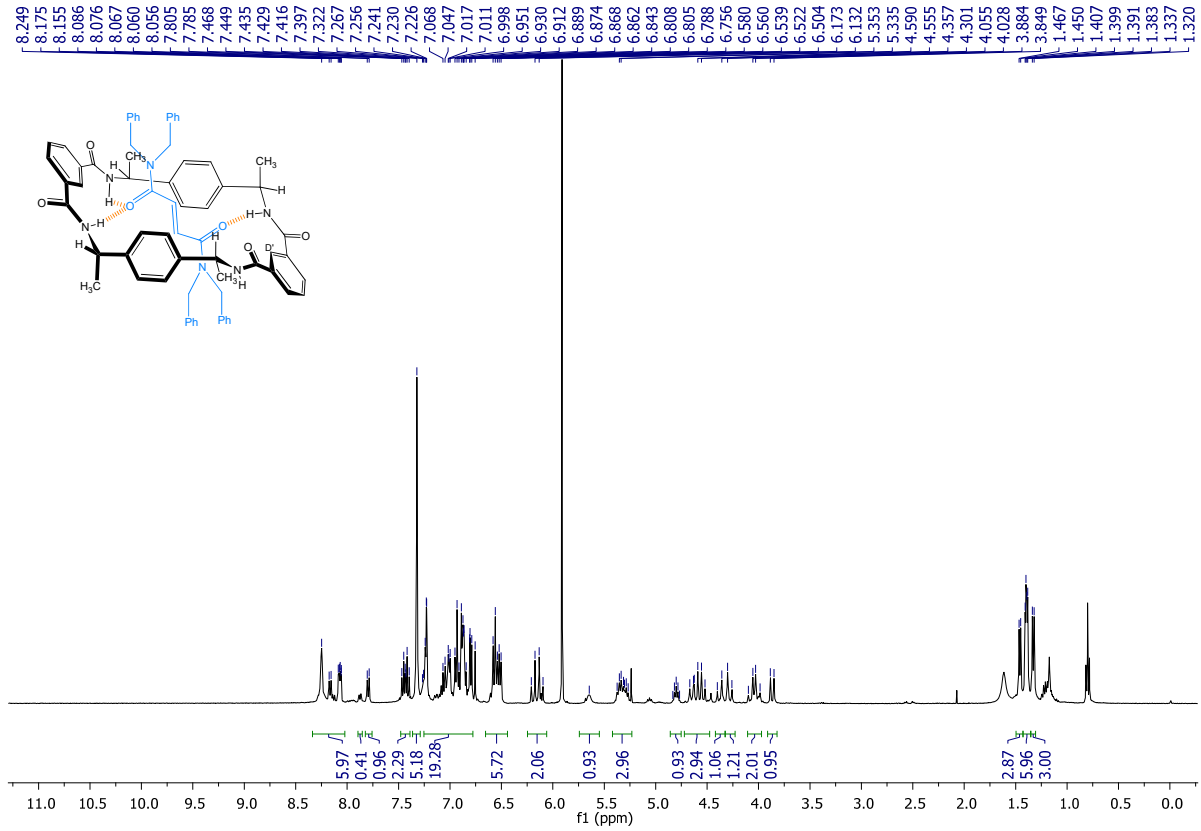
3b (^{13}C NMR, 100 MHz, $CDCl_3$, 298 K)



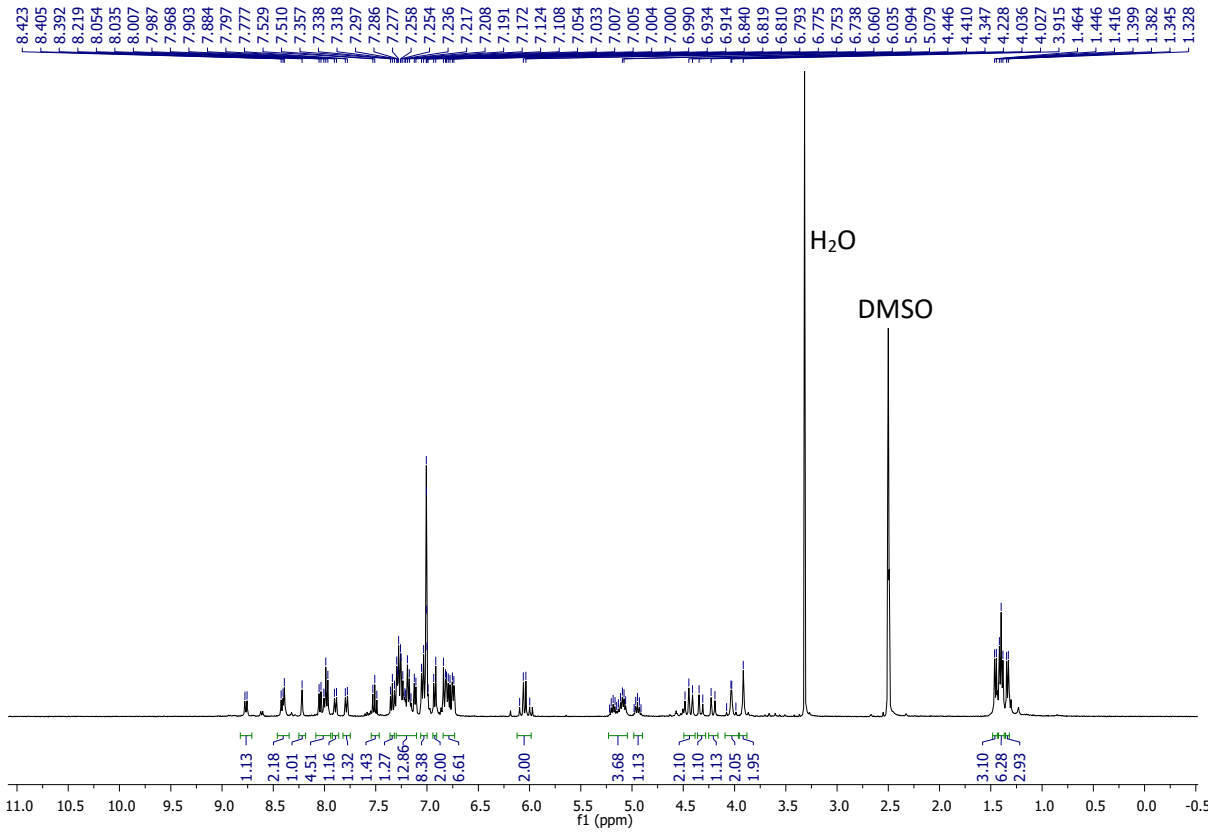
Rotaxane **5a** (^{1}H NMR, 600 MHz, $CDCl_3$, 298 K)



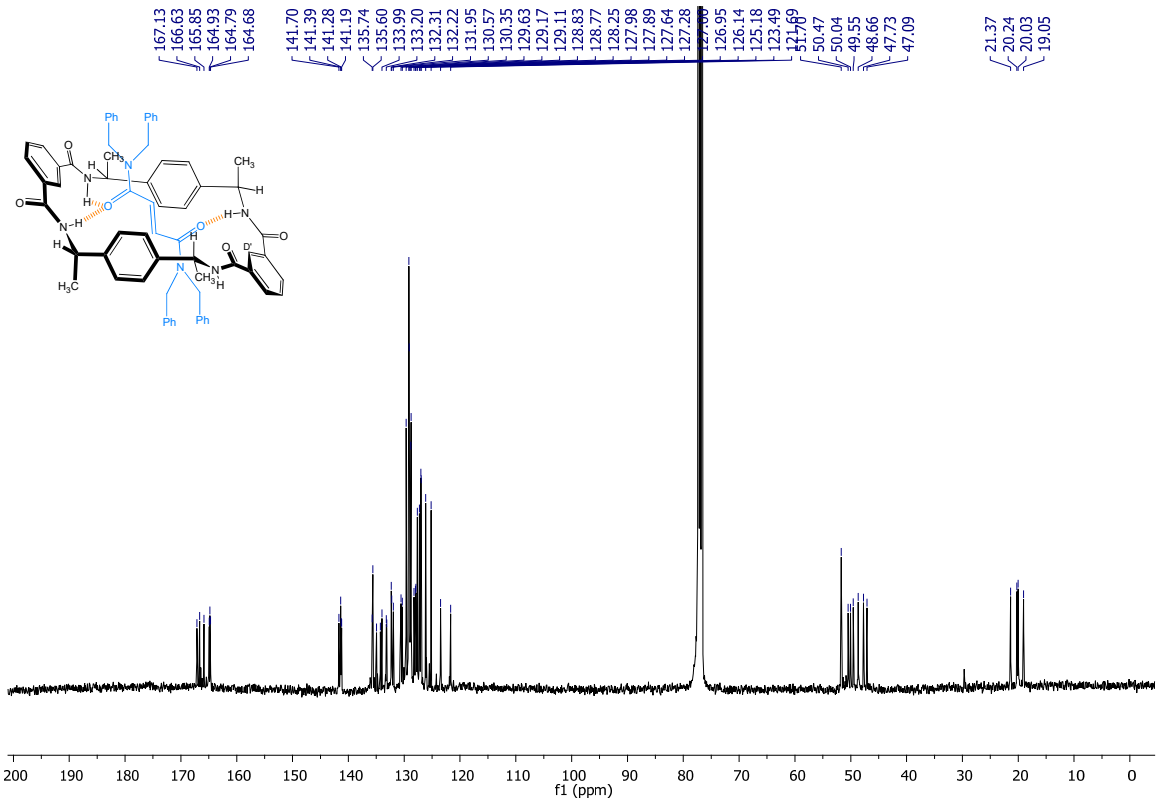
Rotaxane **5a** (^{1}H NMR, 400 MHz, $C_2D_2Cl_4$, 298 K)



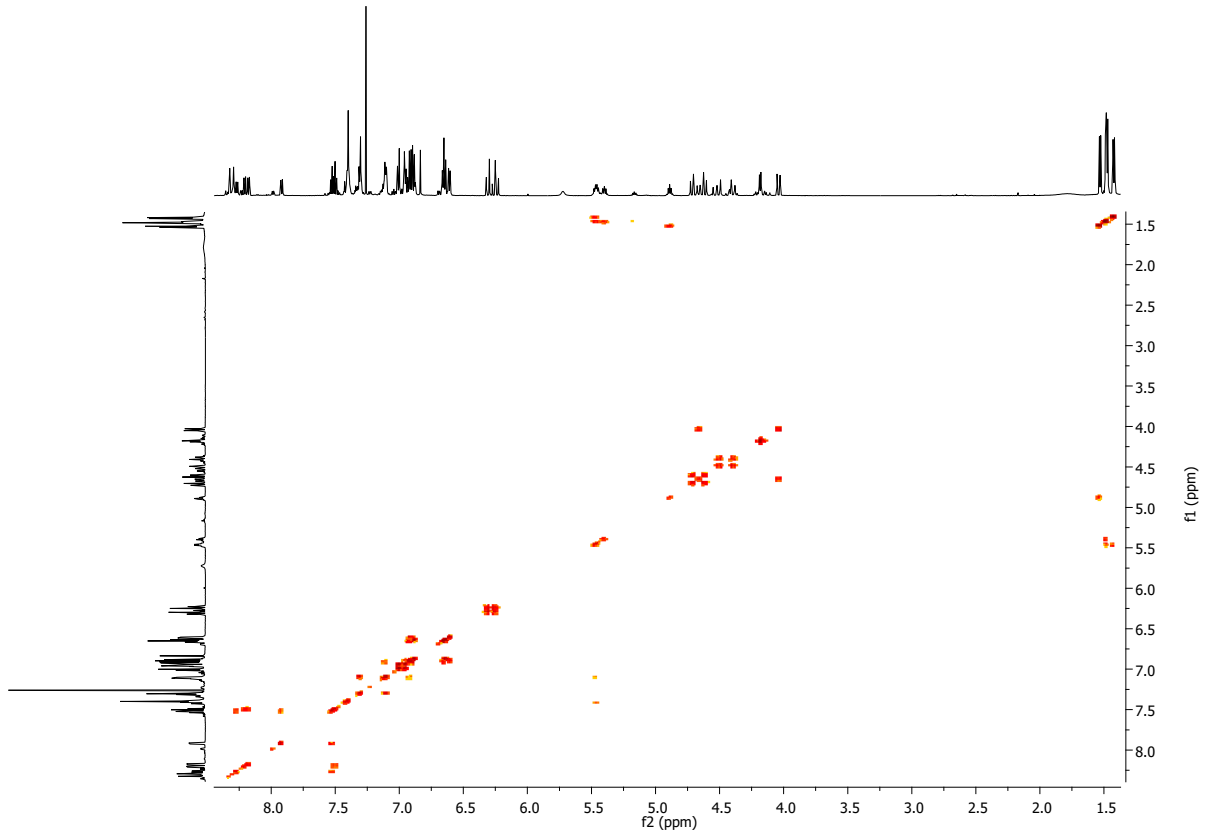
Rotaxane **5a** (^{1}H NMR, 400 MHz, DMSO-d_6, 298 K)



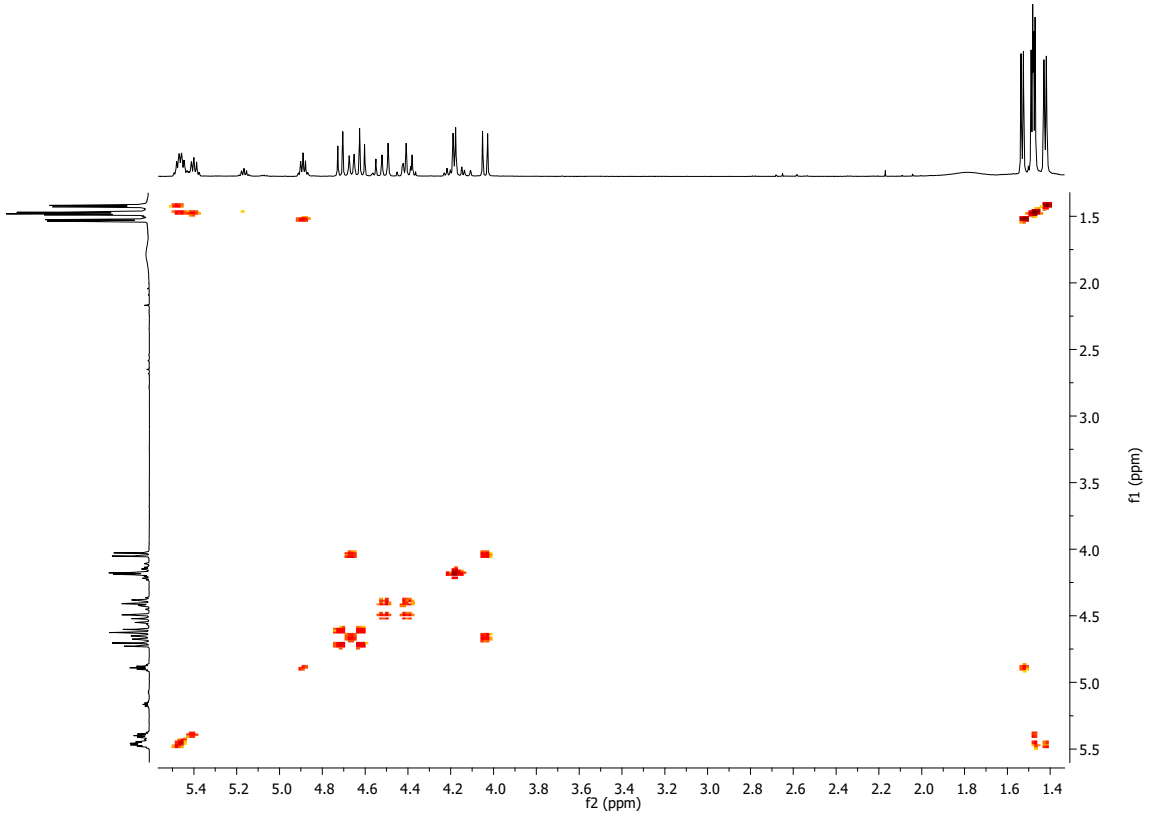
Rotaxane **5a** (^{13}C NMR, 125 MHz, $CDCl_3$, 298 K)



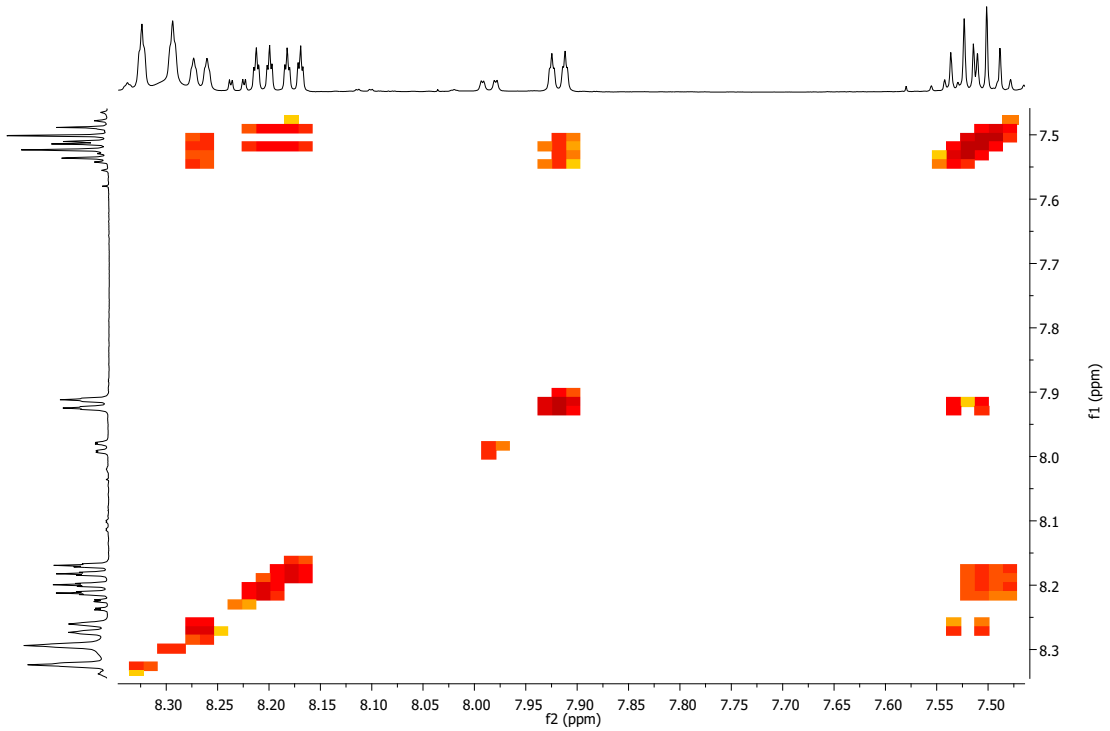
Rotaxane **5a** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



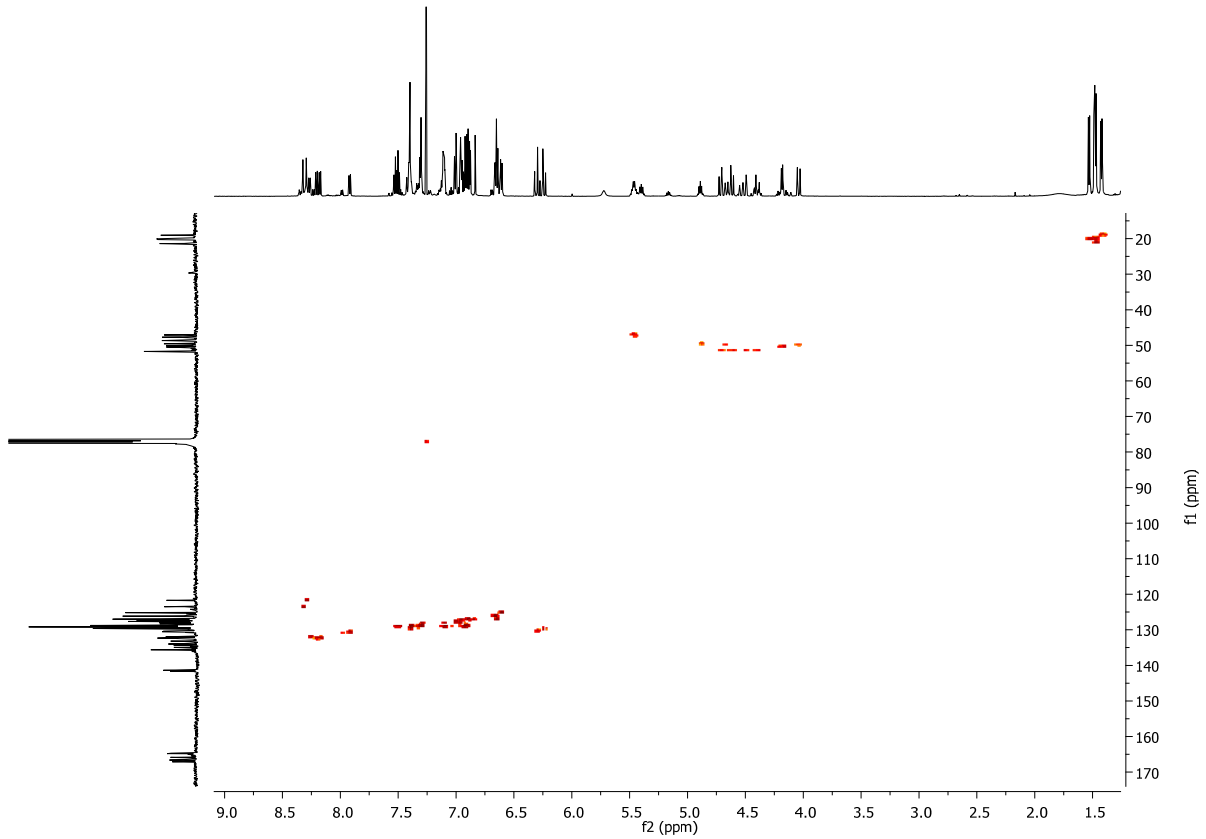
Rotaxane **5a** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



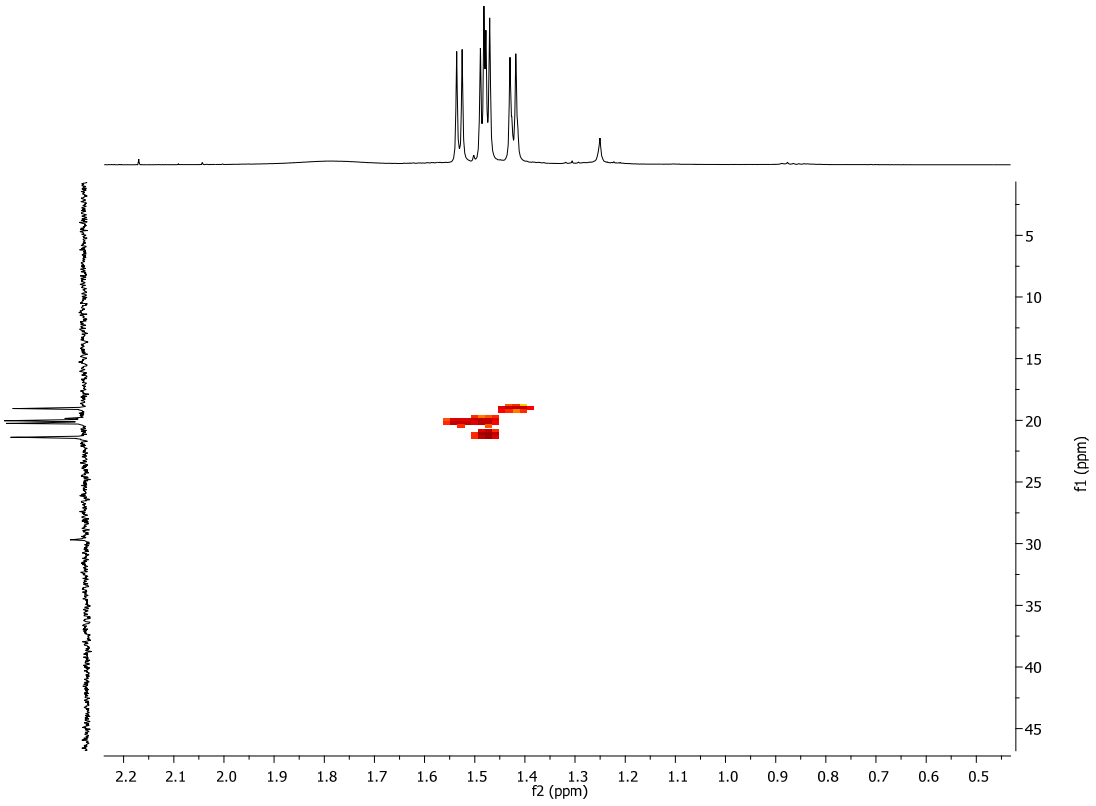
Rotaxane **5a** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



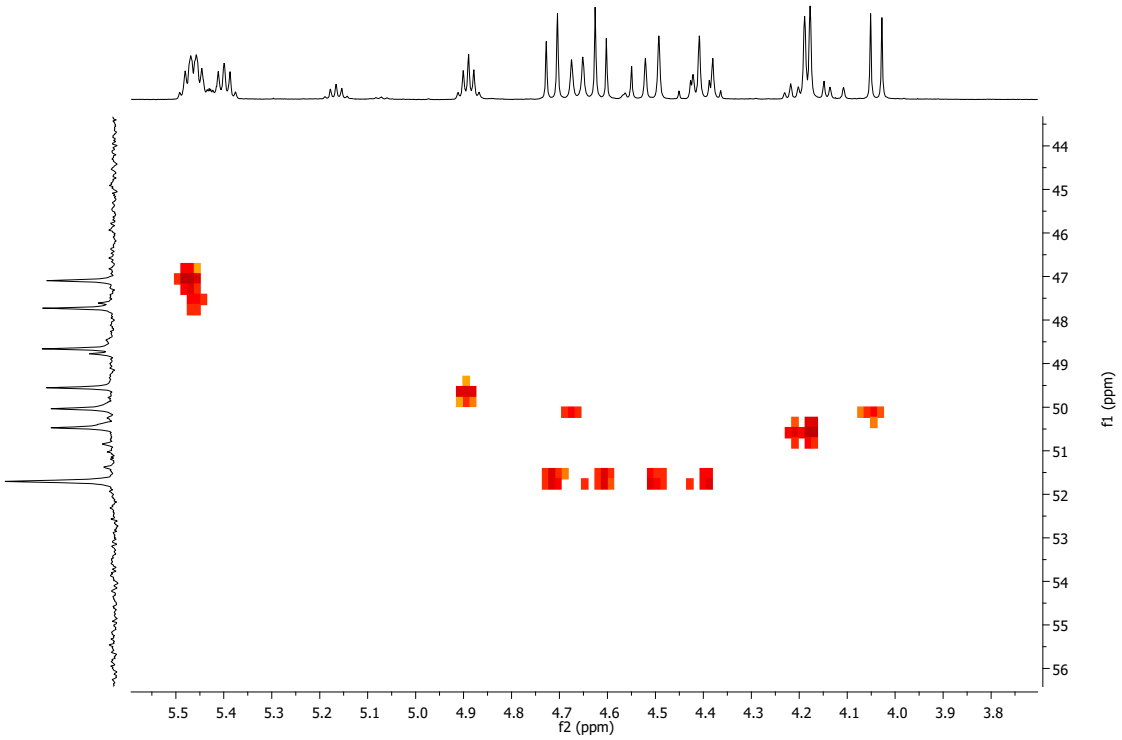
Rotaxane **5a** (HSQC, 600 MHz, $CDCl_3$, 298 K)



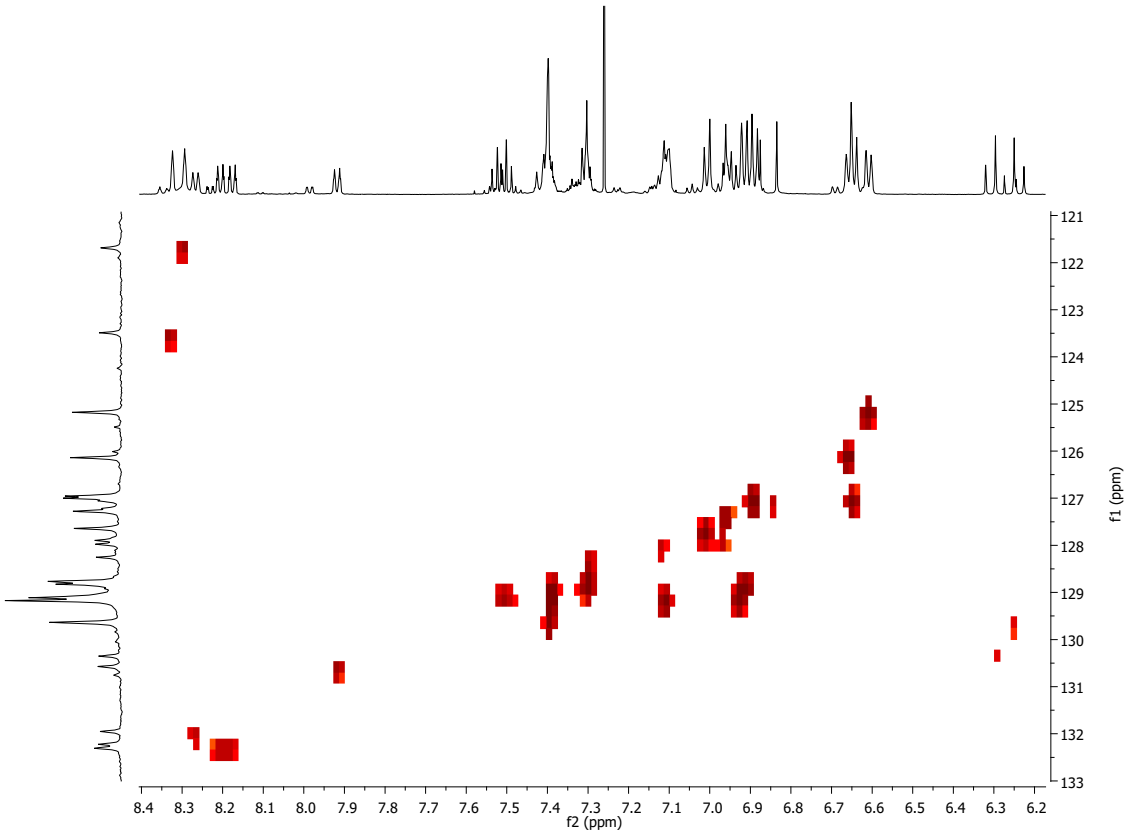
Rotaxane **5a** (HSQC, 600 MHz, $CDCl_3$, 298 K)



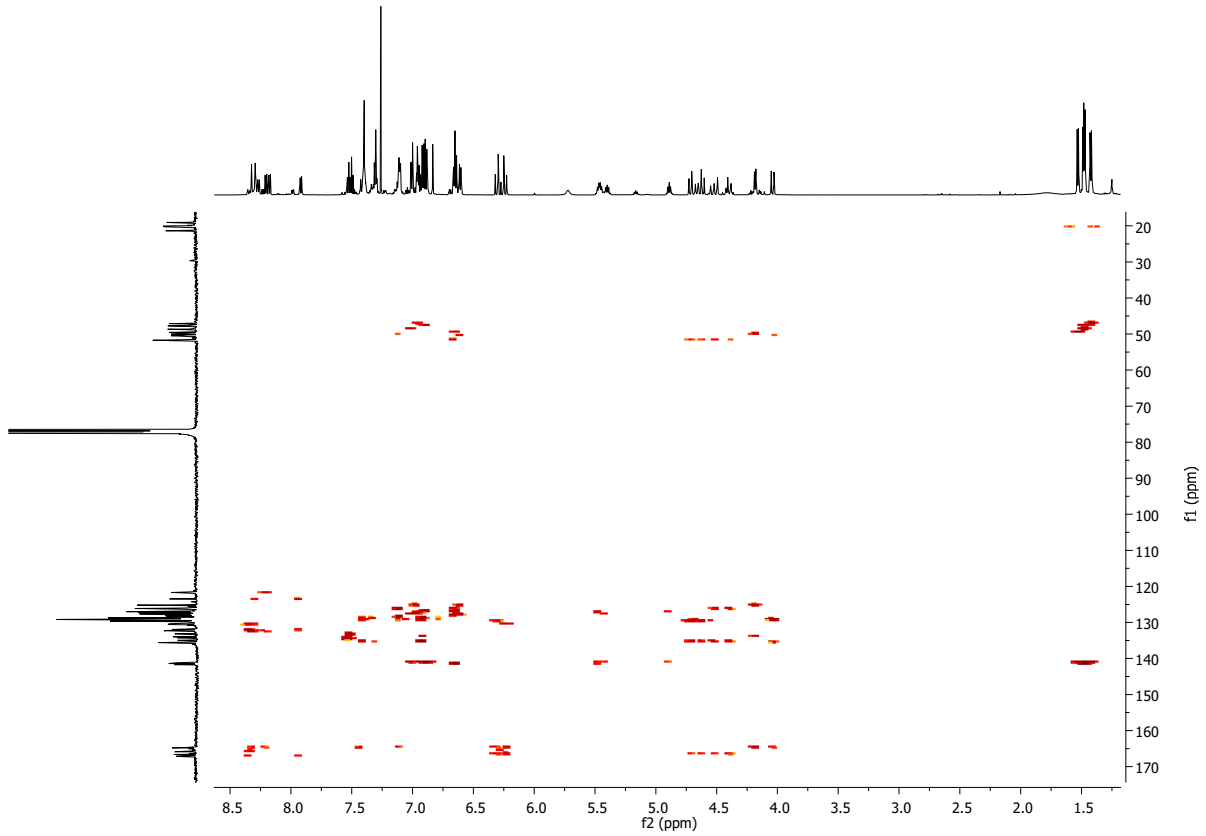
Rotaxane **5a** (HSQC, 600 MHz, $CDCl_3$, 298 K)



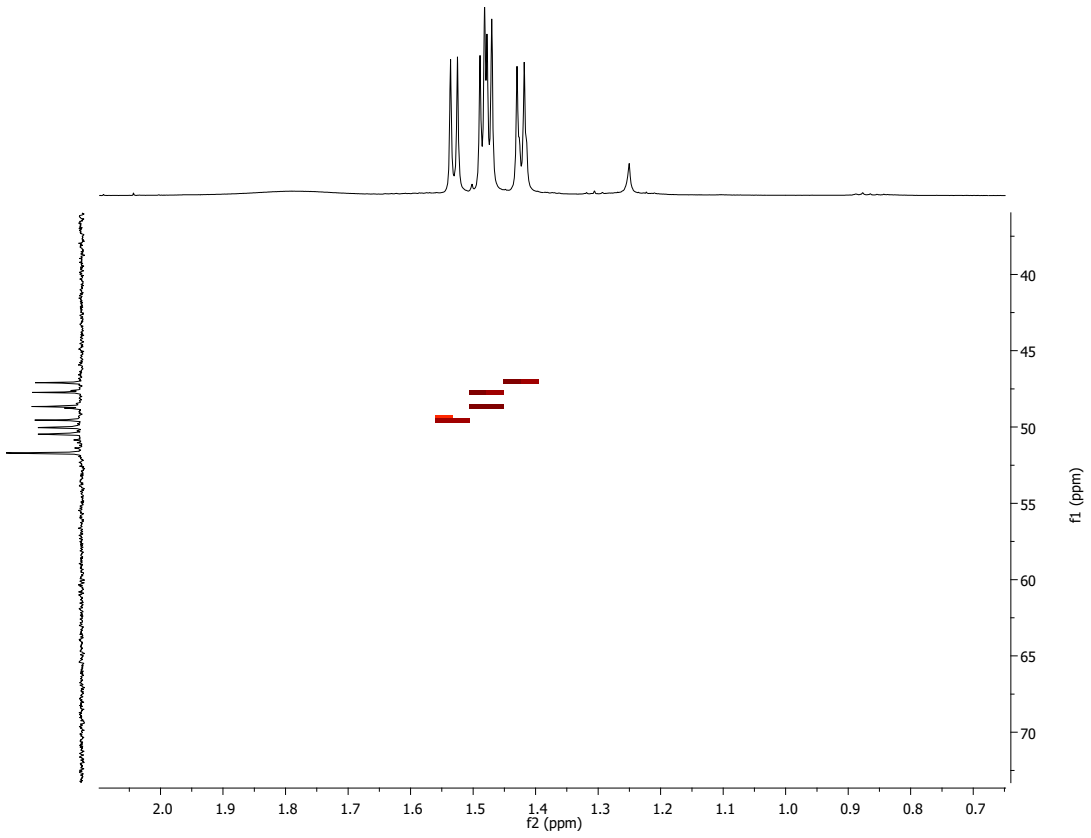
Rotaxane **5a** (HSQC, 600 MHz, $CDCl_3$, 298 K)



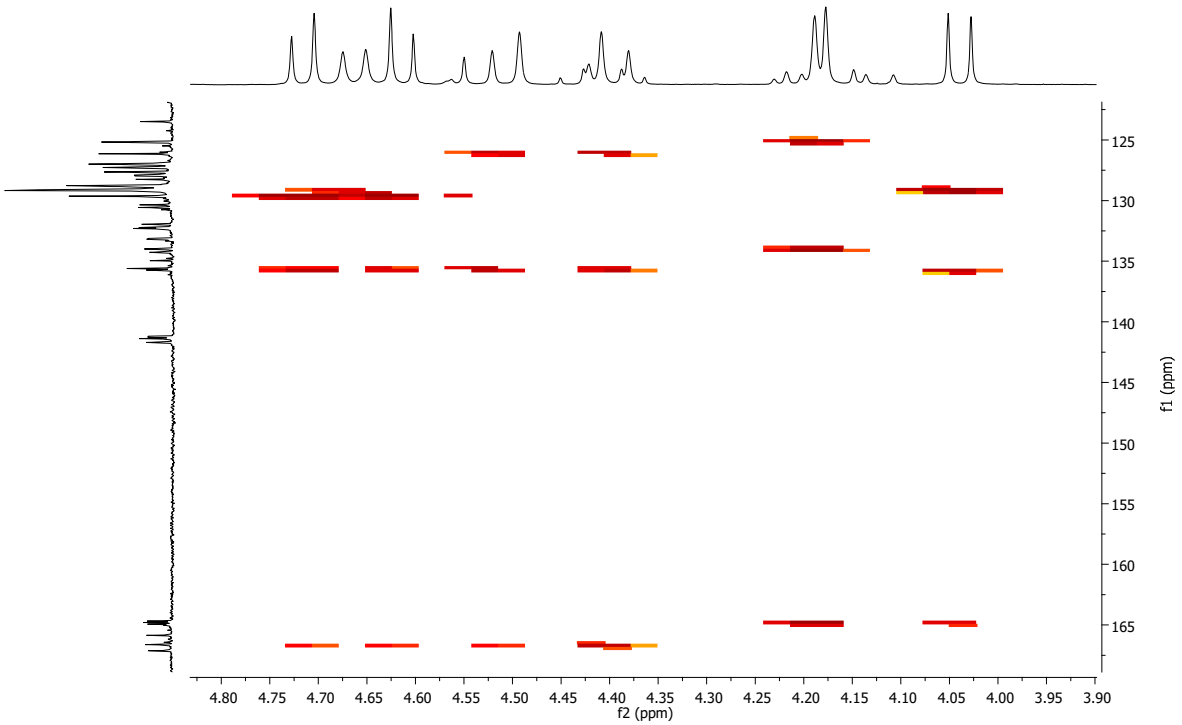
Rotaxane **5a** (HMBC, 600 MHz, $CDCl_3$, 298 K)



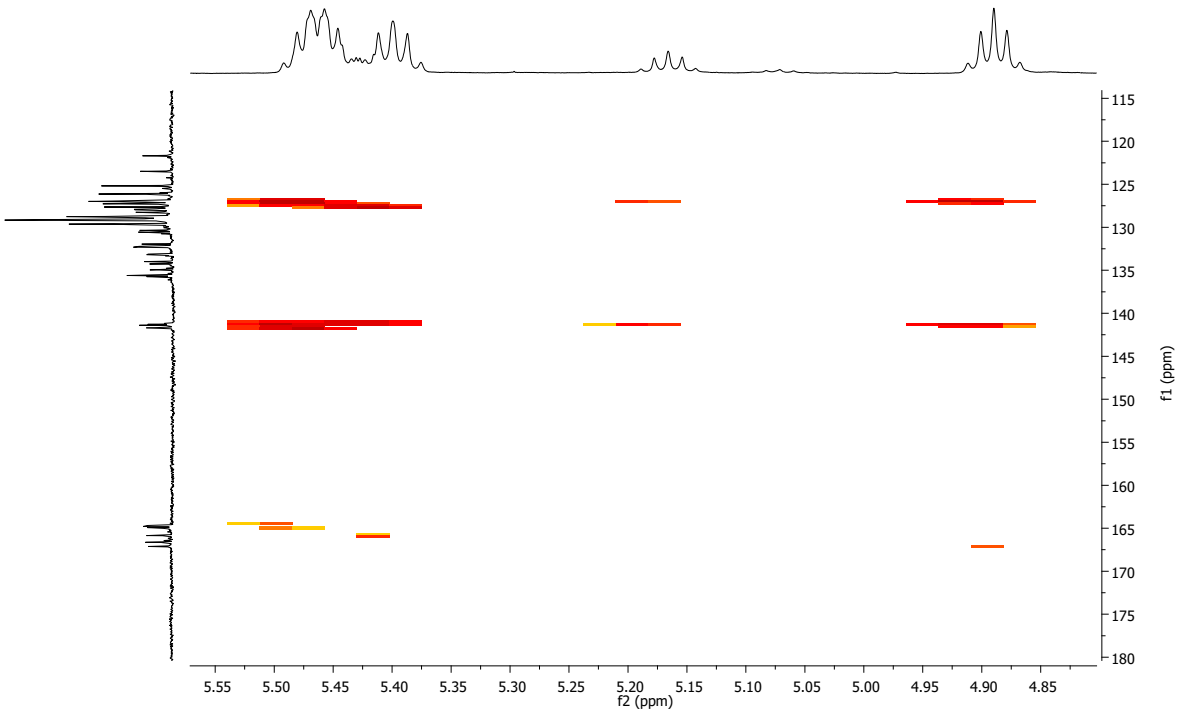
Rotaxane **5a** (HMBC, 600 MHz, $CDCl_3$, 298 K)



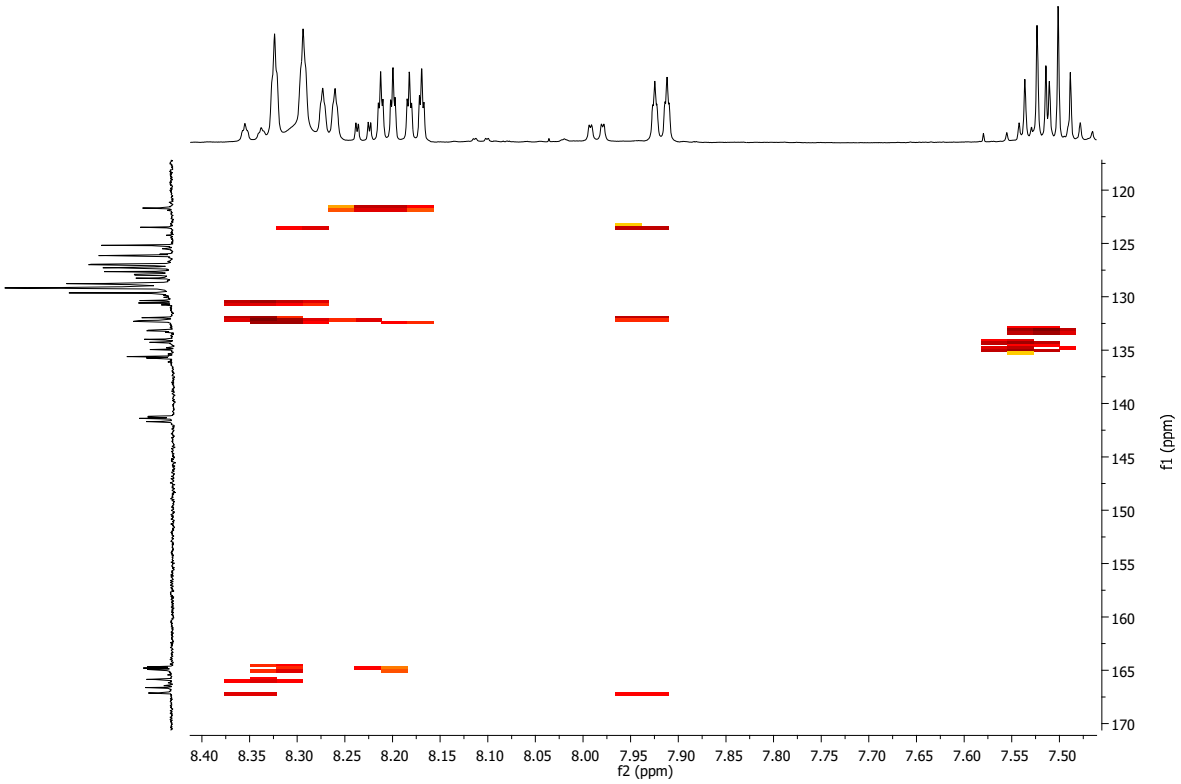
Rotaxane **5a** (HMBC, 600 MHz, $CDCl_3$, 298 K)



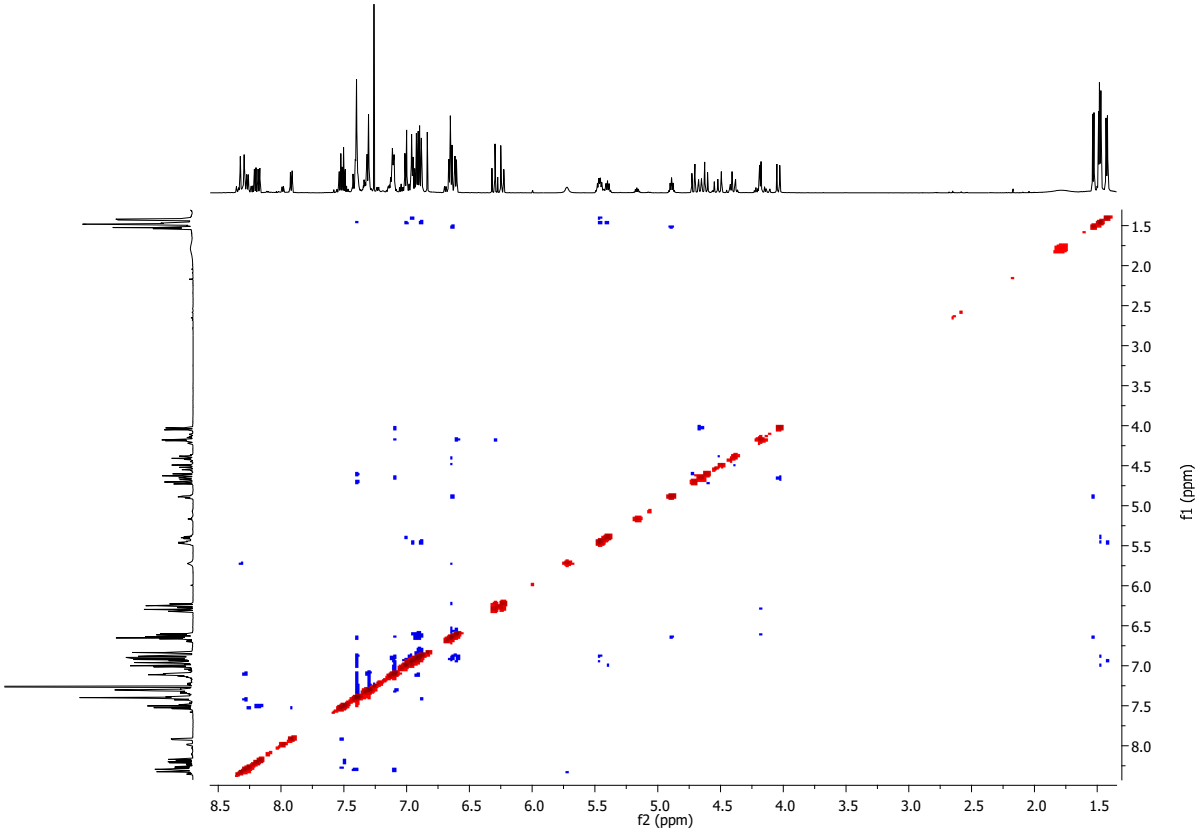
Rotaxane **5a** (HMBC, 600 MHz, $CDCl_3$, 298 K)



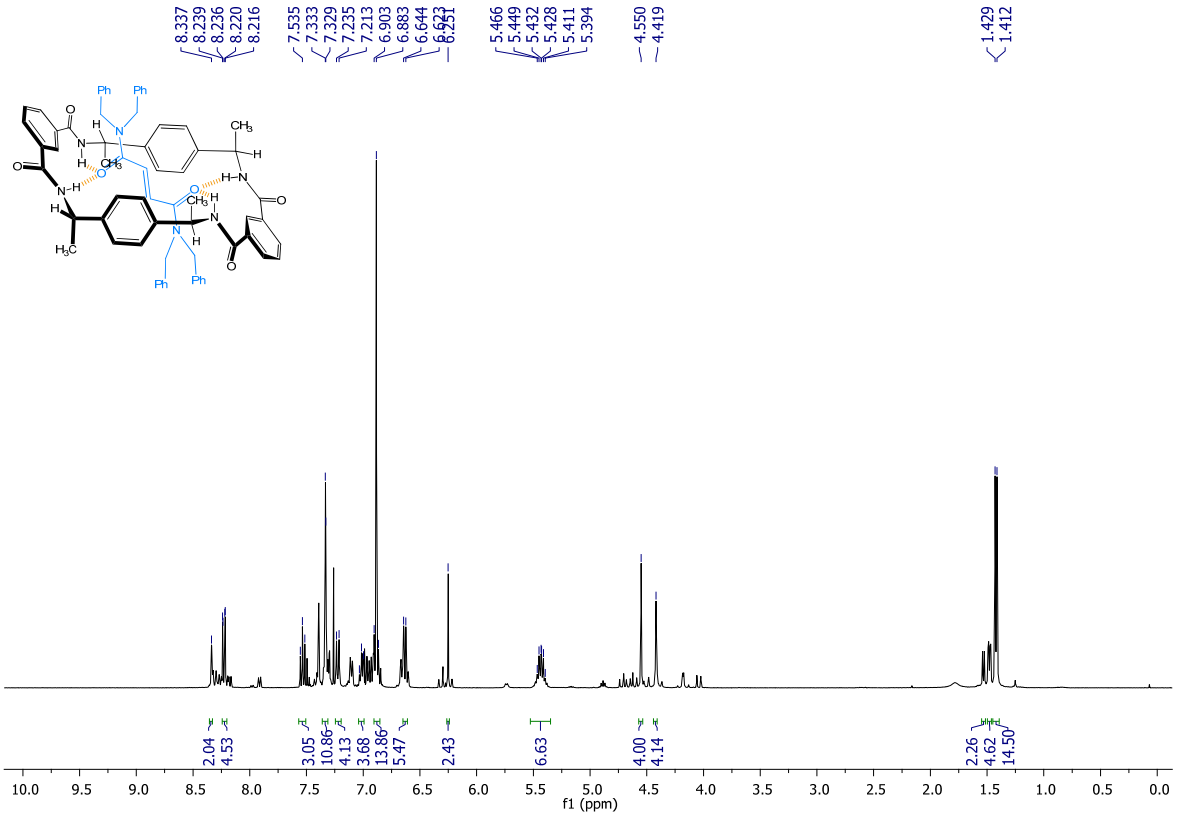
Rotaxane **5a** (HMBC, 600 MHz, $CDCl_3$, 298 K)



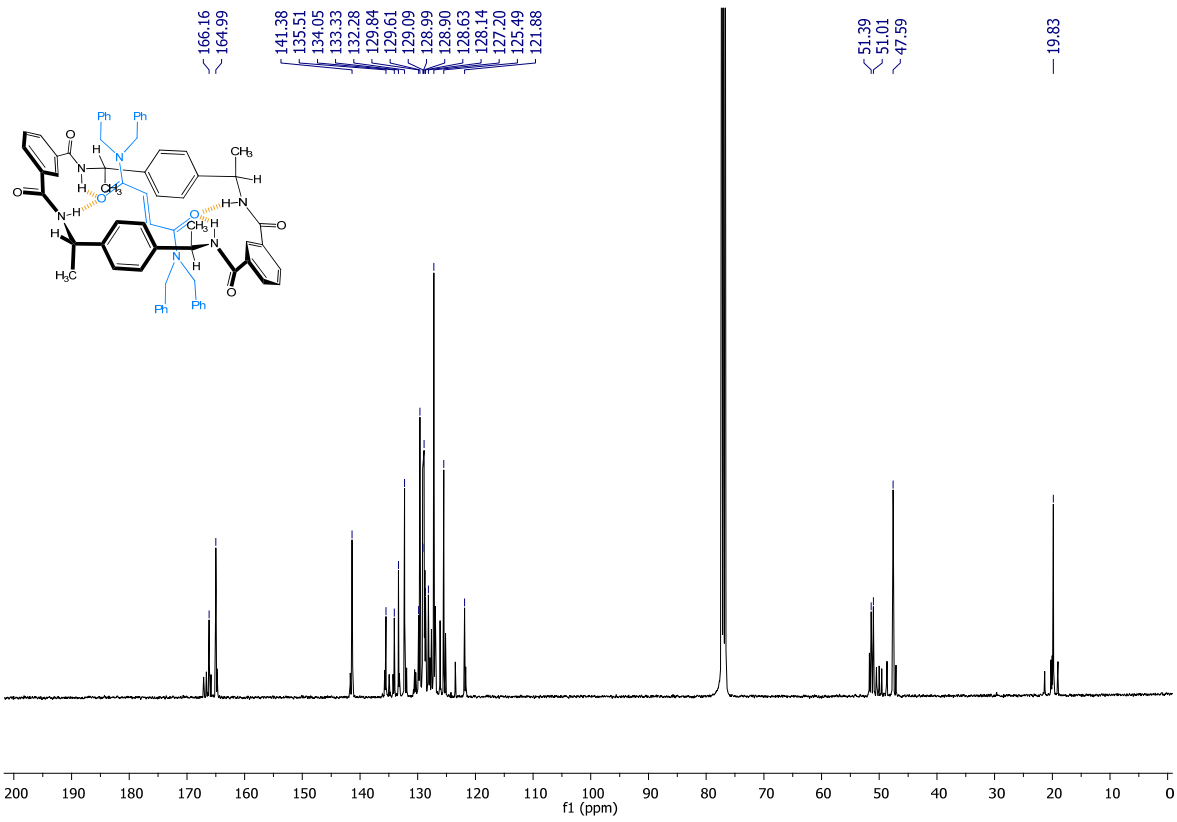
Rotaxane **5a** (1H,1H-NOESY, 600 MHz, $CDCl_3$, 298 K)



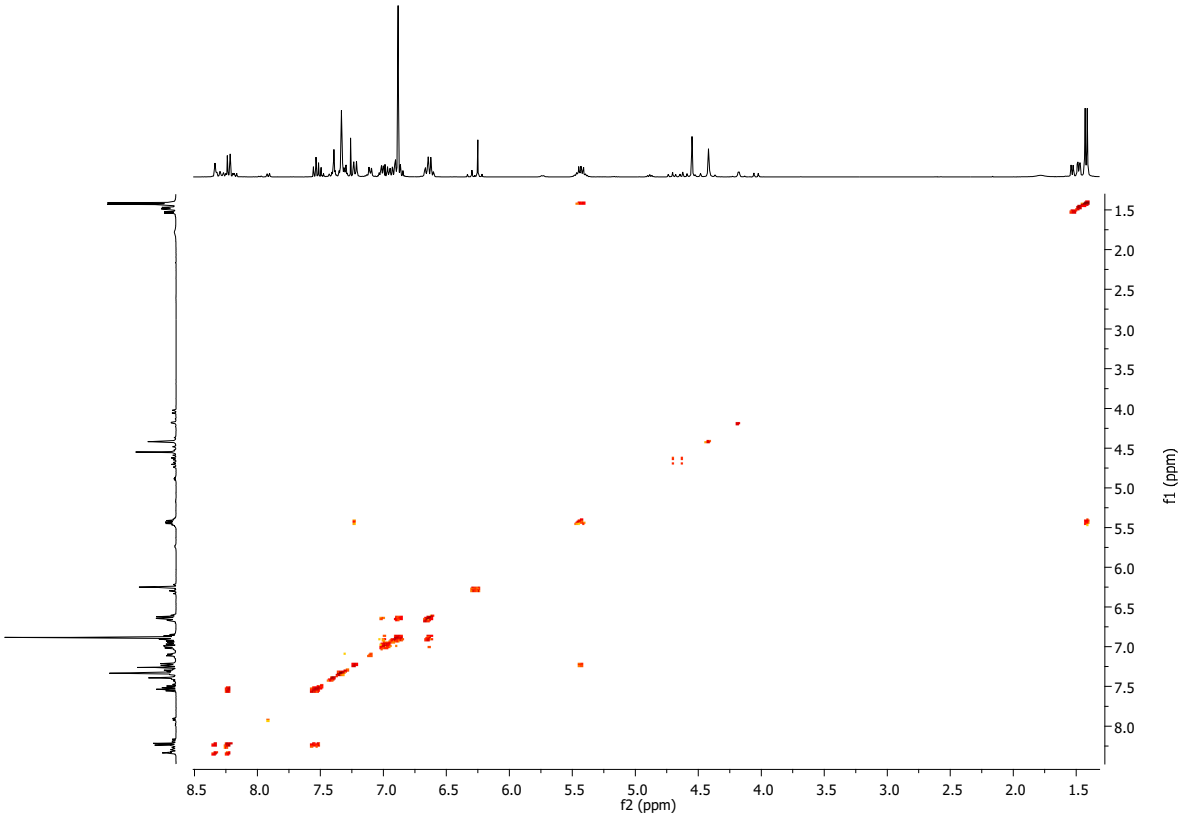
Mixture of rotaxanes **5a/10a** in 1/1.35 ratio (^{1}H NMR, 400 MHz, $CDCl_3$, 298 K). Only **10a** signals are marked



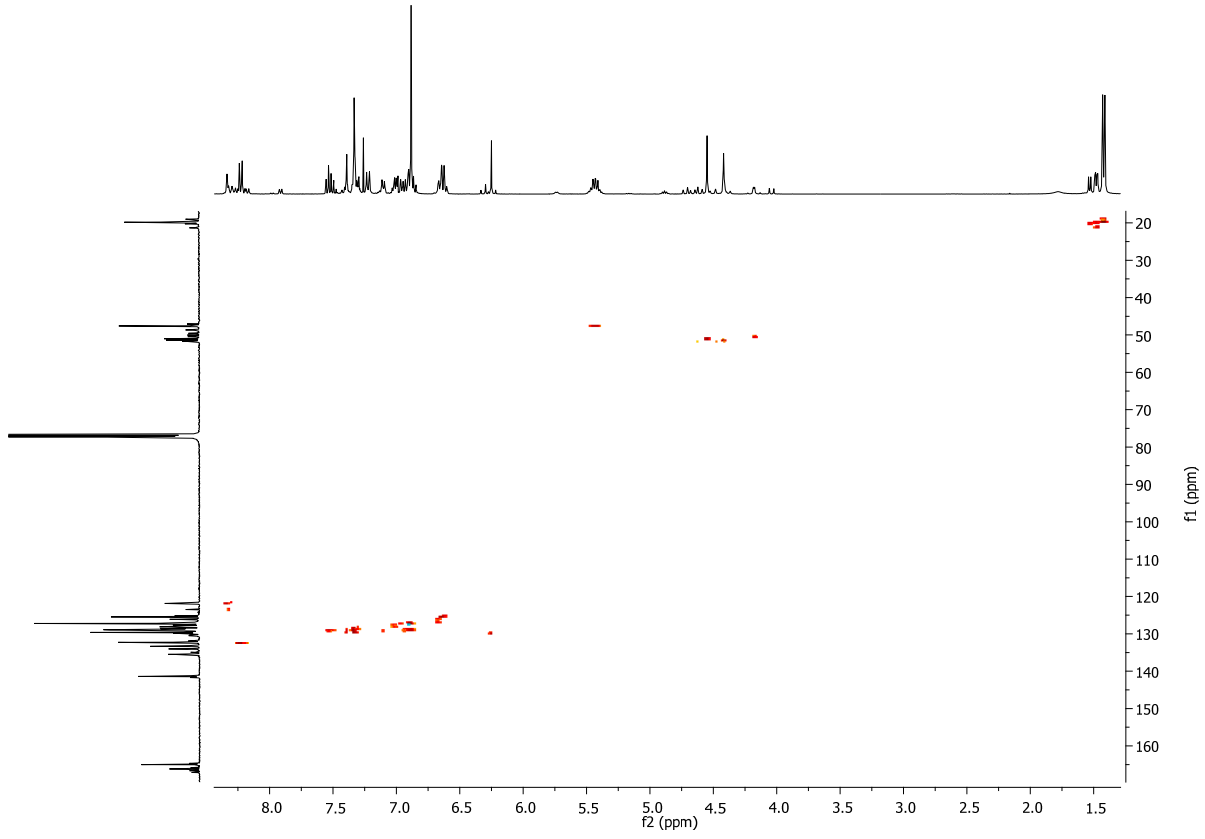
Mixture of rotaxanes **5a/10a** in 1/1.35 ratio (^{13}C NMR, 100 MHz, $CDCl_3$, 298 K). Only **10a** signals are marked



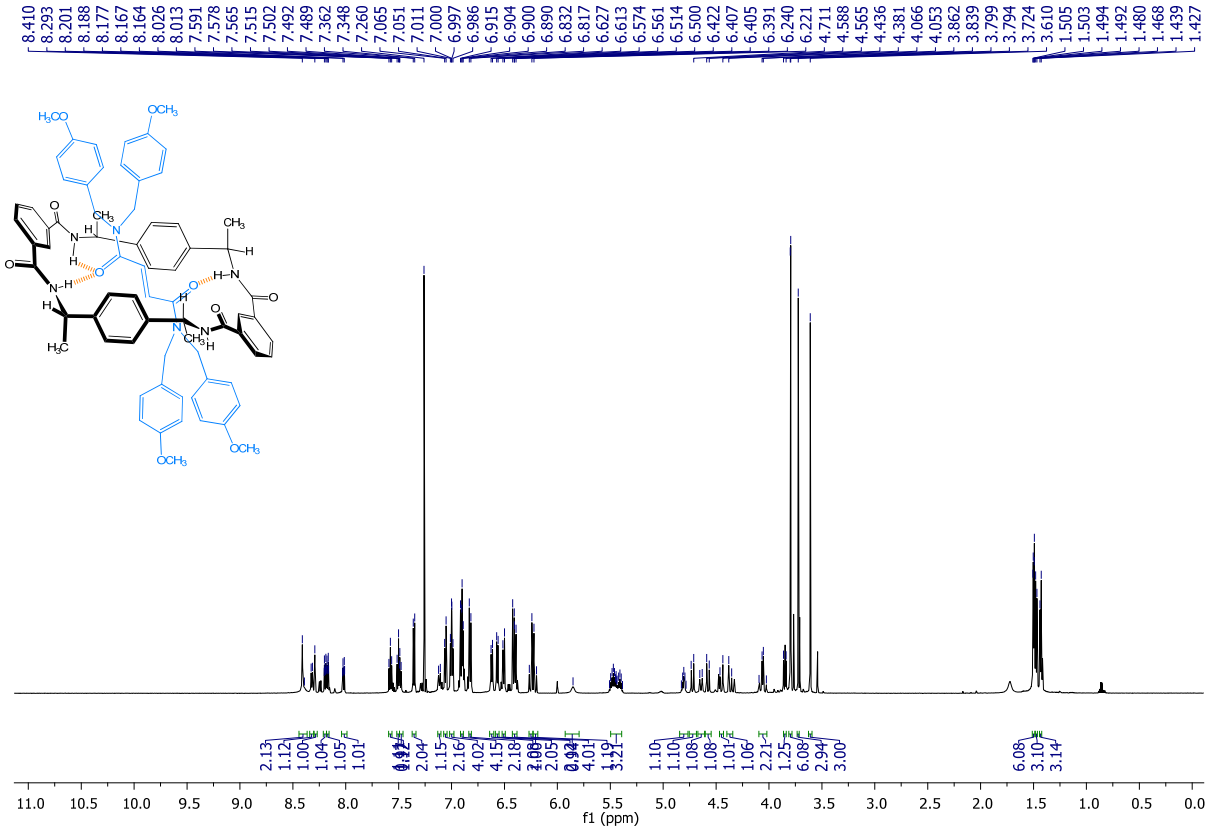
Mixture of rotaxanes **5a/10a** in 1/1.35 ratio (^{1}H,^{1}H-COSY, 400 MHz, $CDCl_3$, 298 K)



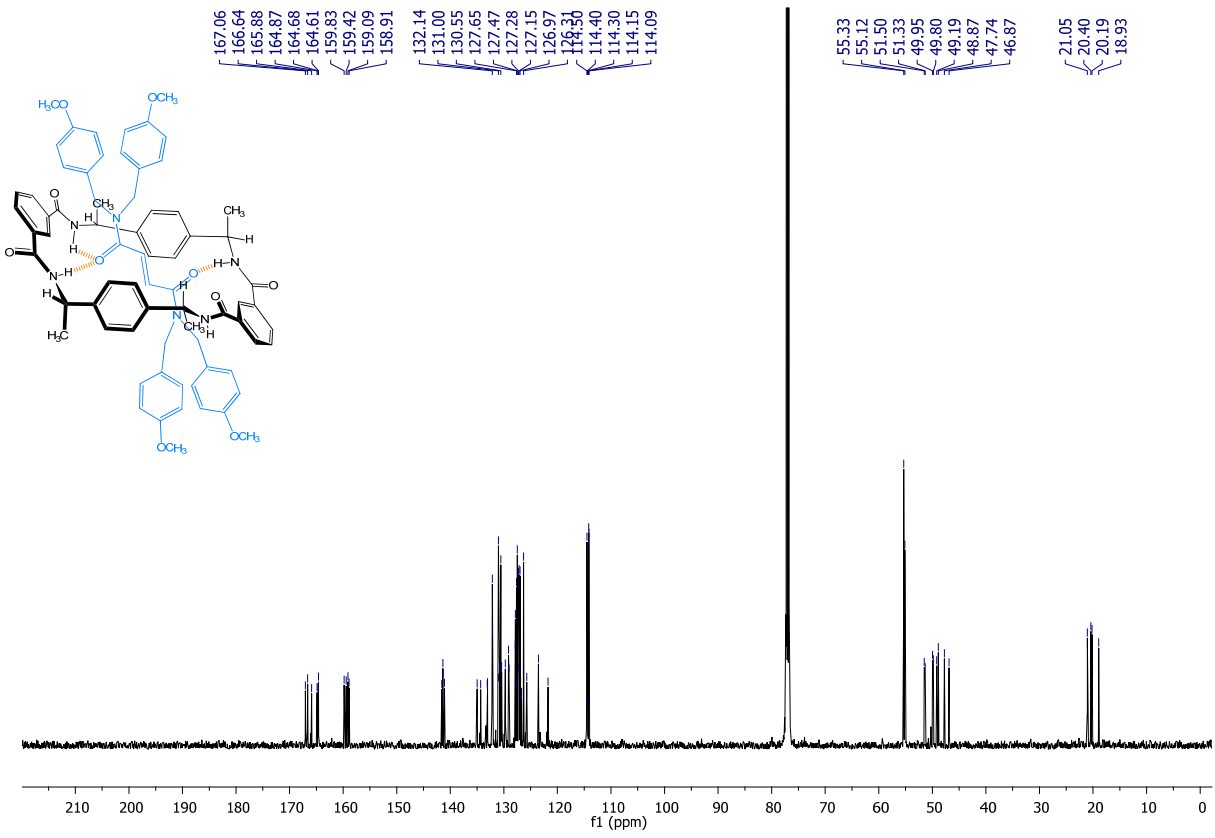
Mixture of rotaxanes **5a/10a** in 1/1.35 ratio (HSQC, 400 MHz, $CDCl_3$, 298 K)



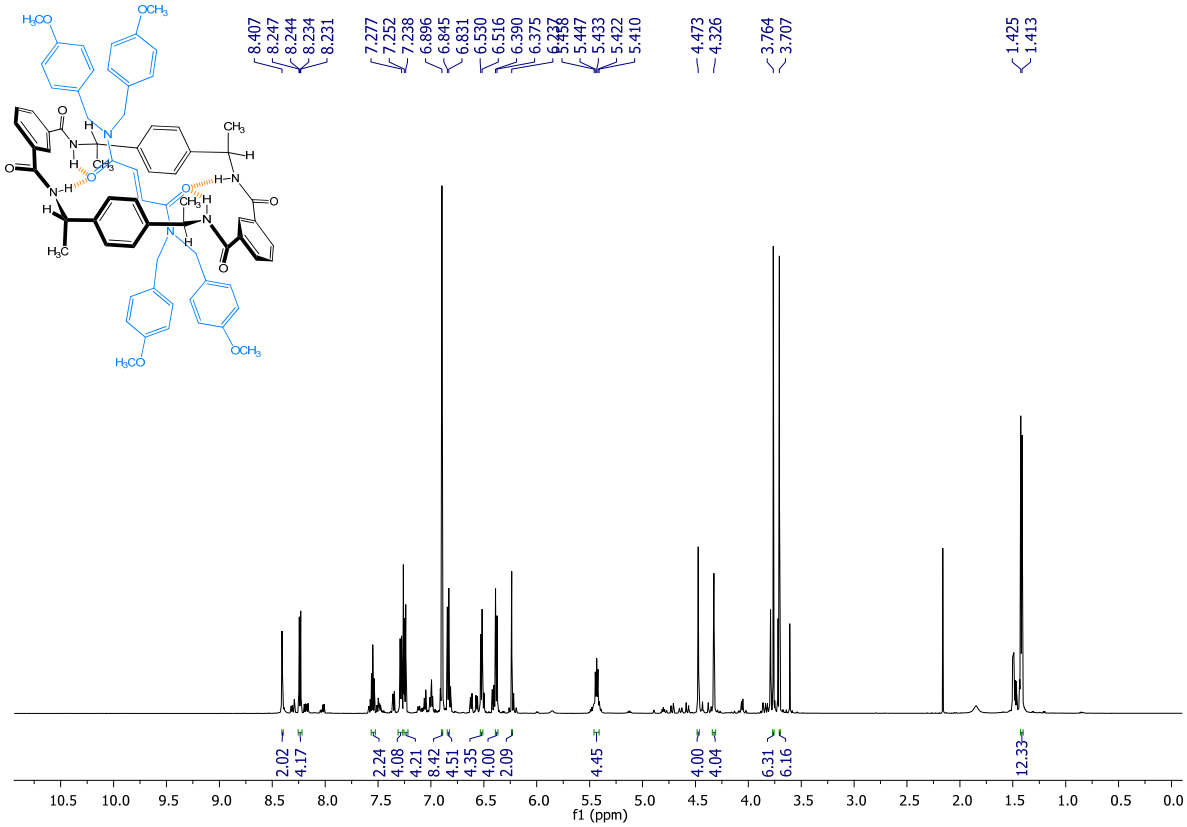
Rotaxane **5b** (^{1}H NMR, 600 MHz, $CDCl_3$, 298 K)



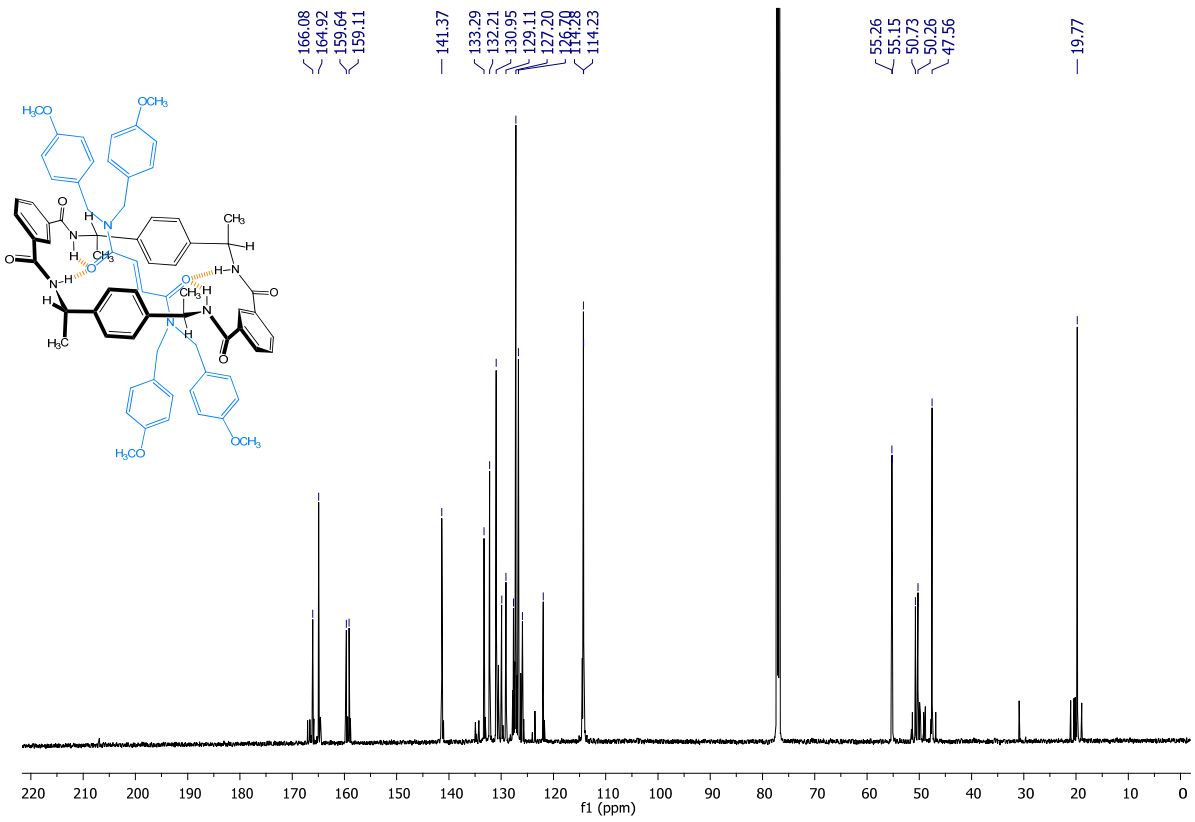
Rotaxane **5b** (^{13}C NMR, 125 MHz, $CDCl_3$, 298 K)



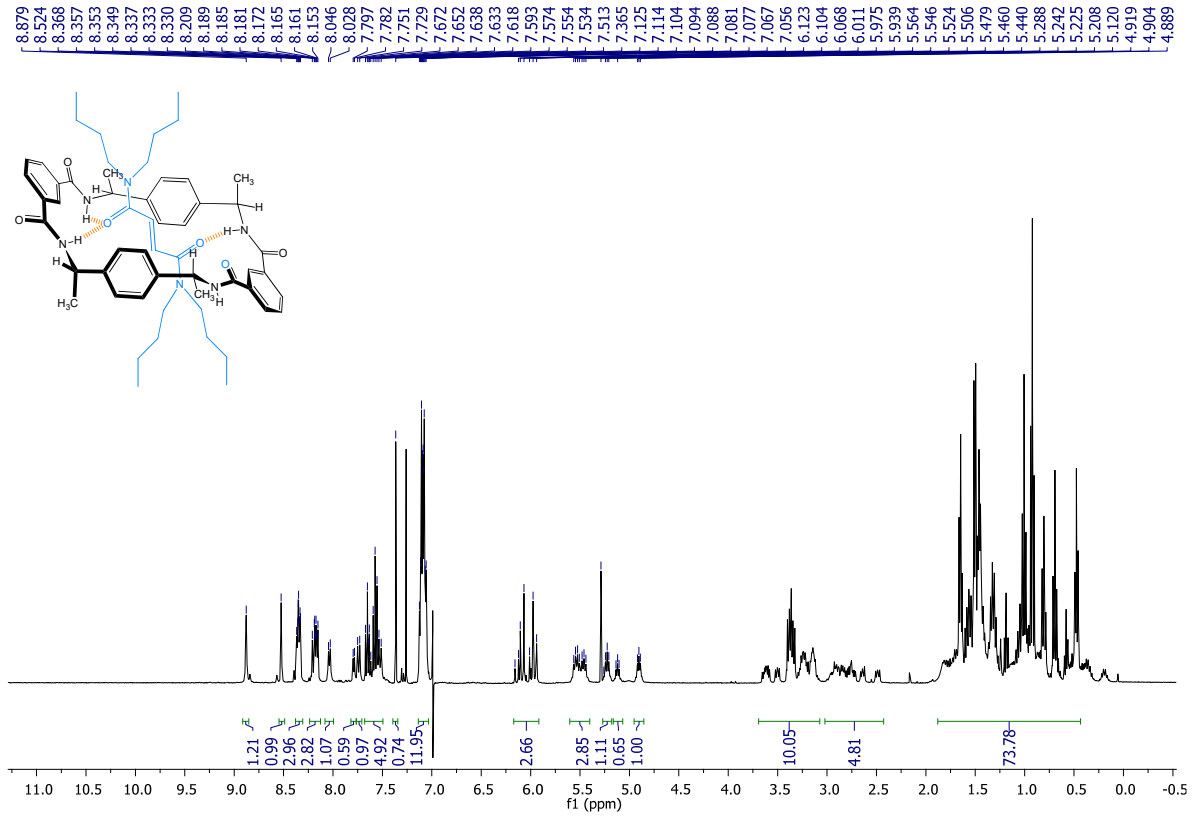
Mixture of rotaxanes **5b/10b** in 1/2.3 ratio (^{1}H NMR, 400 MHz, $CDCl_3$, 298 K). Only **10b** signals are marked



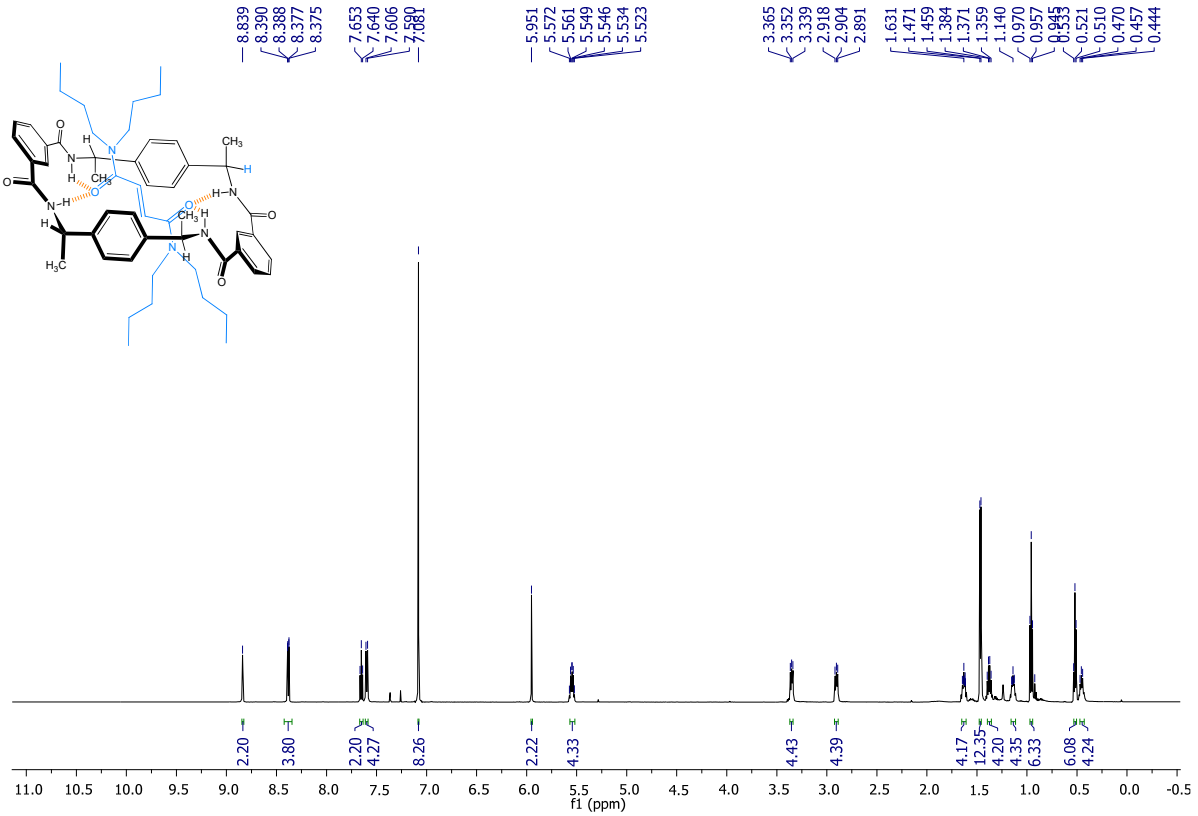
Mixture of rotaxanes **5b/10b** in in 1/2.3 ratio (^{13}C NMR, 100 MHz, $CDCl_3$, 298 K). Only **10b** signals are marked



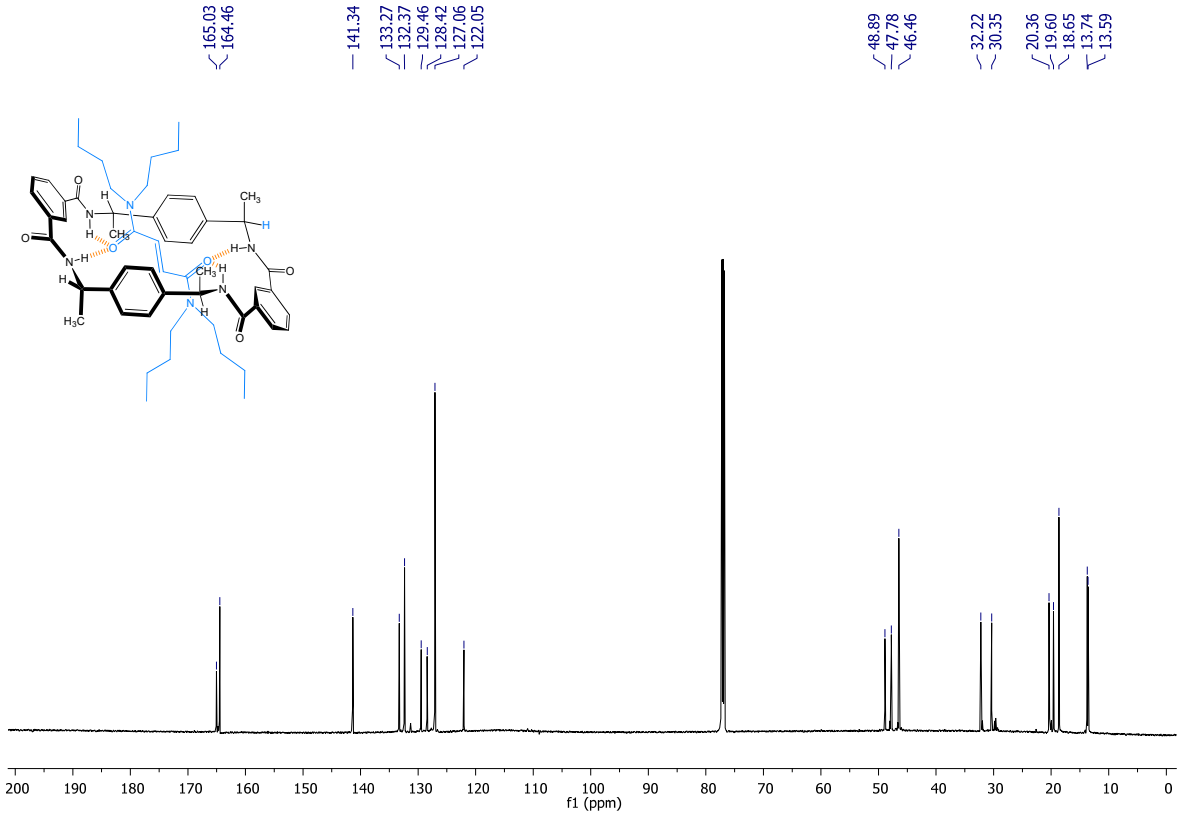
Mixture of conformers of the rotaxane **5c** (60%/18%) and the thread **3c** (22%) (^{1}H NMR, 400 MHz, $CDCl_3$, 298 K).



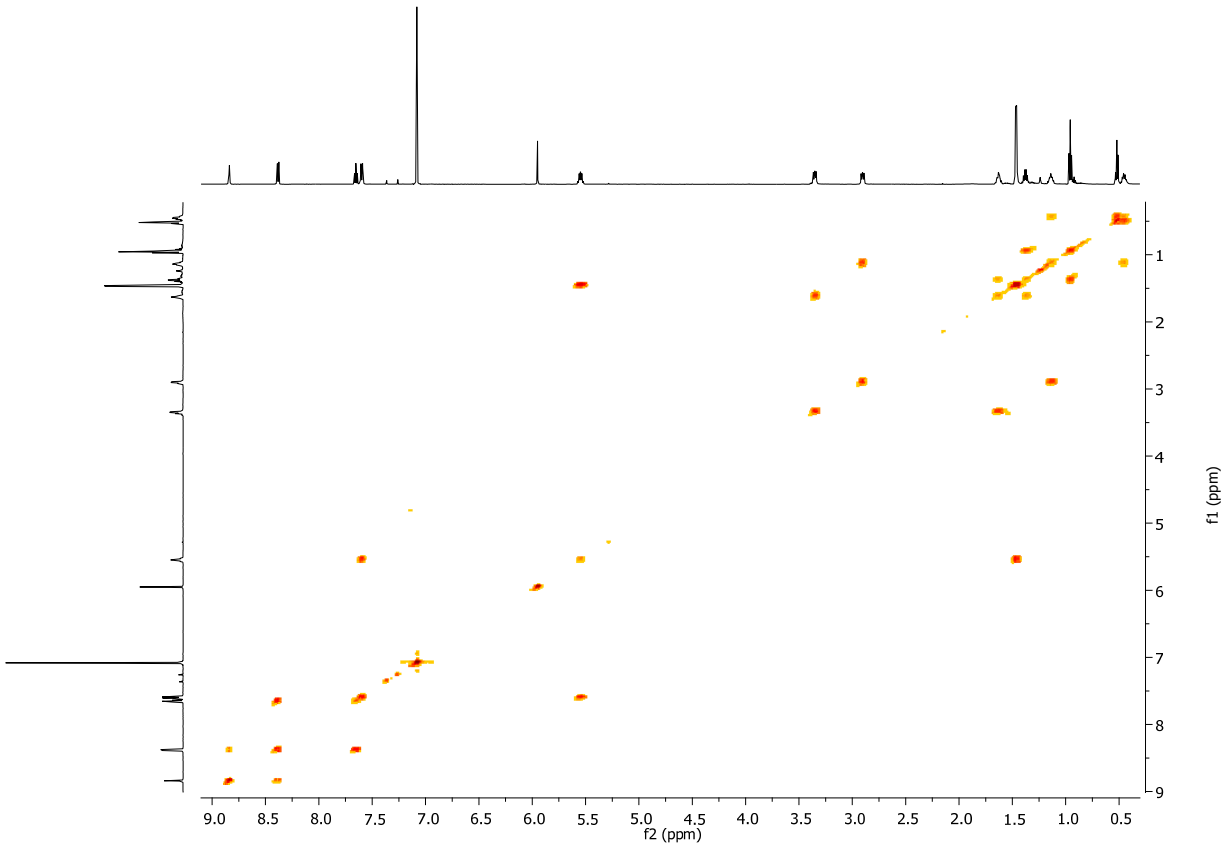
Rotaxane **10c** (^{1}H NMR, 600 MHz, $CDCl_3$, 298 K)



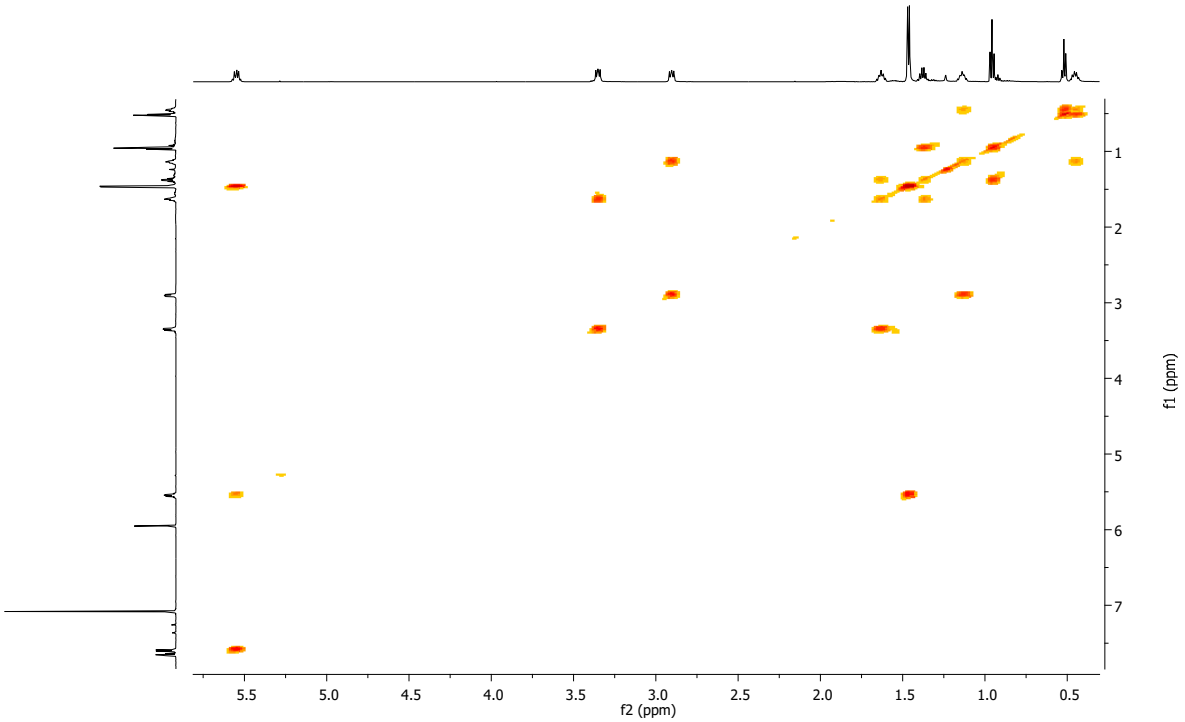
Rotaxane **10c** (^{13}C NMR, 125 MHz, $CDCl_3$, 298 K)



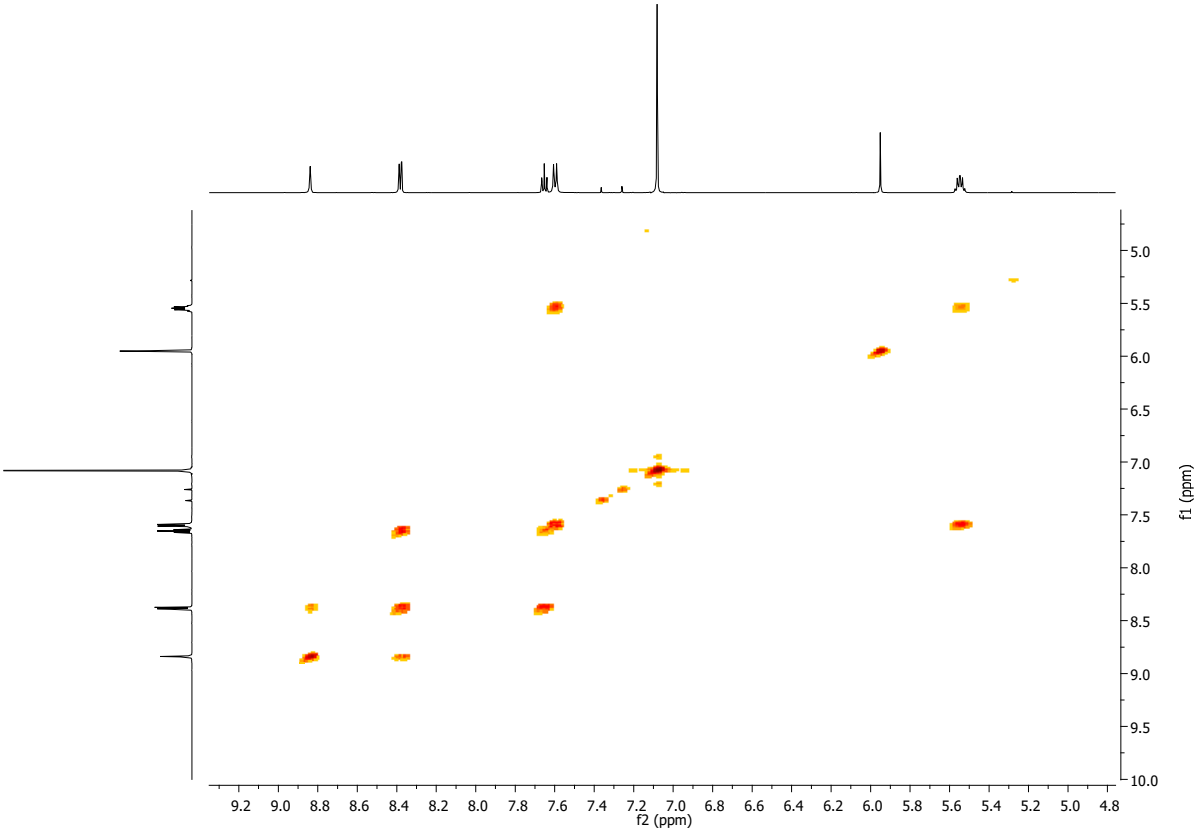
Rotaxane **10c** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



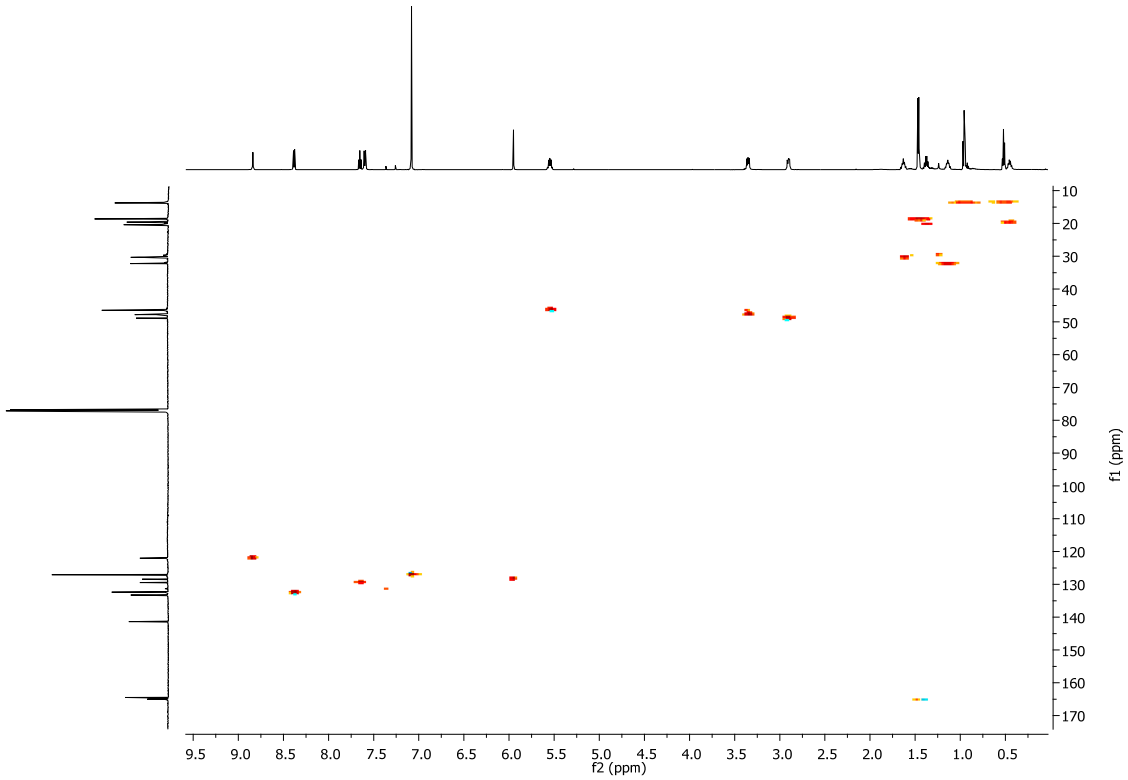
Rotaxane **10c** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



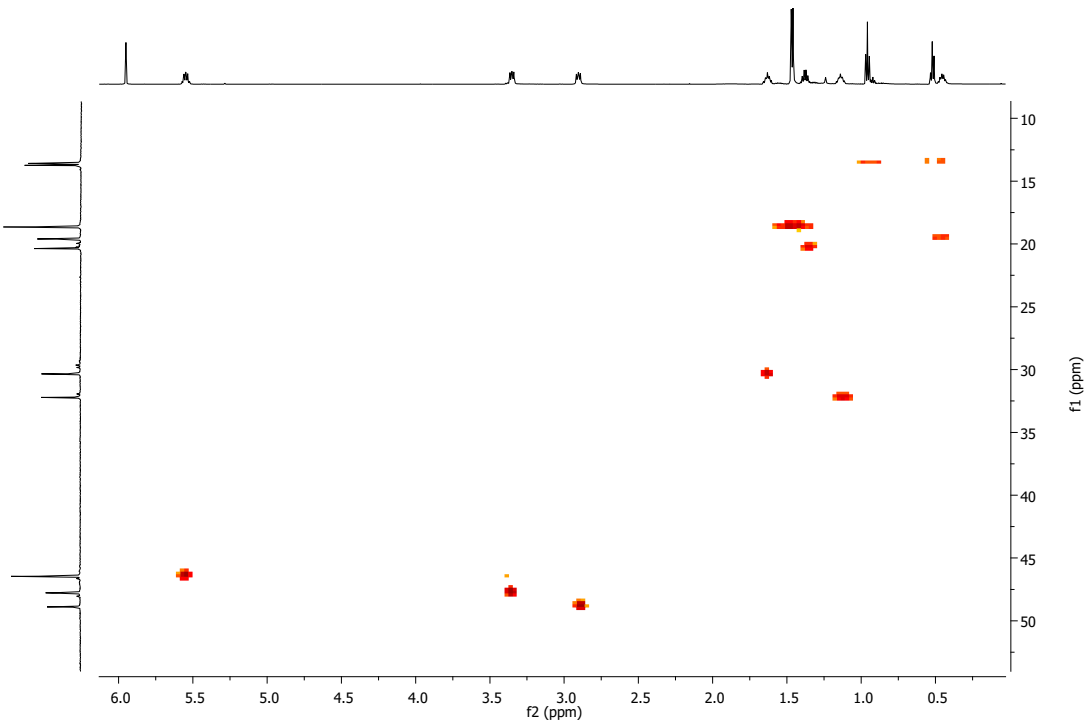
Rotaxane **10c** (^{1}H,^{1}H-COSY, 600 MHz, $CDCl_3$, 298 K)



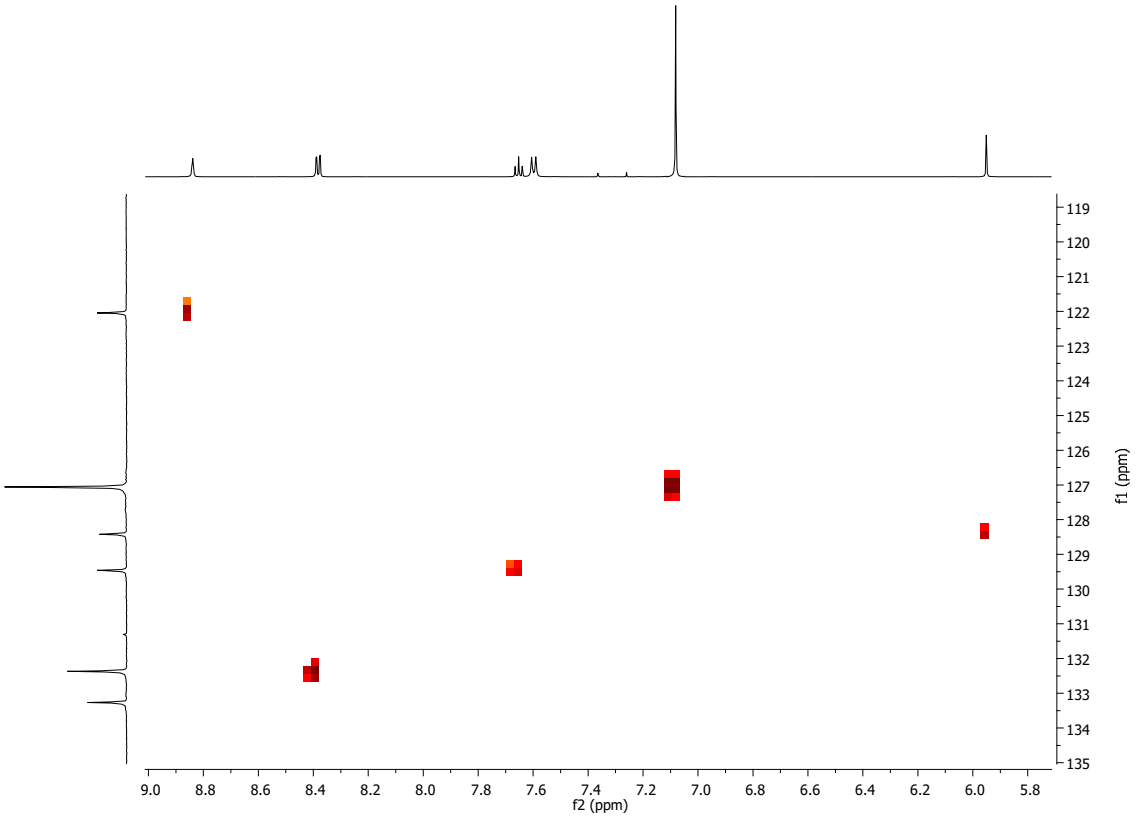
Rotaxane **10c** (HSQC, 600 MHz, $CDCl_3$, 298 K)



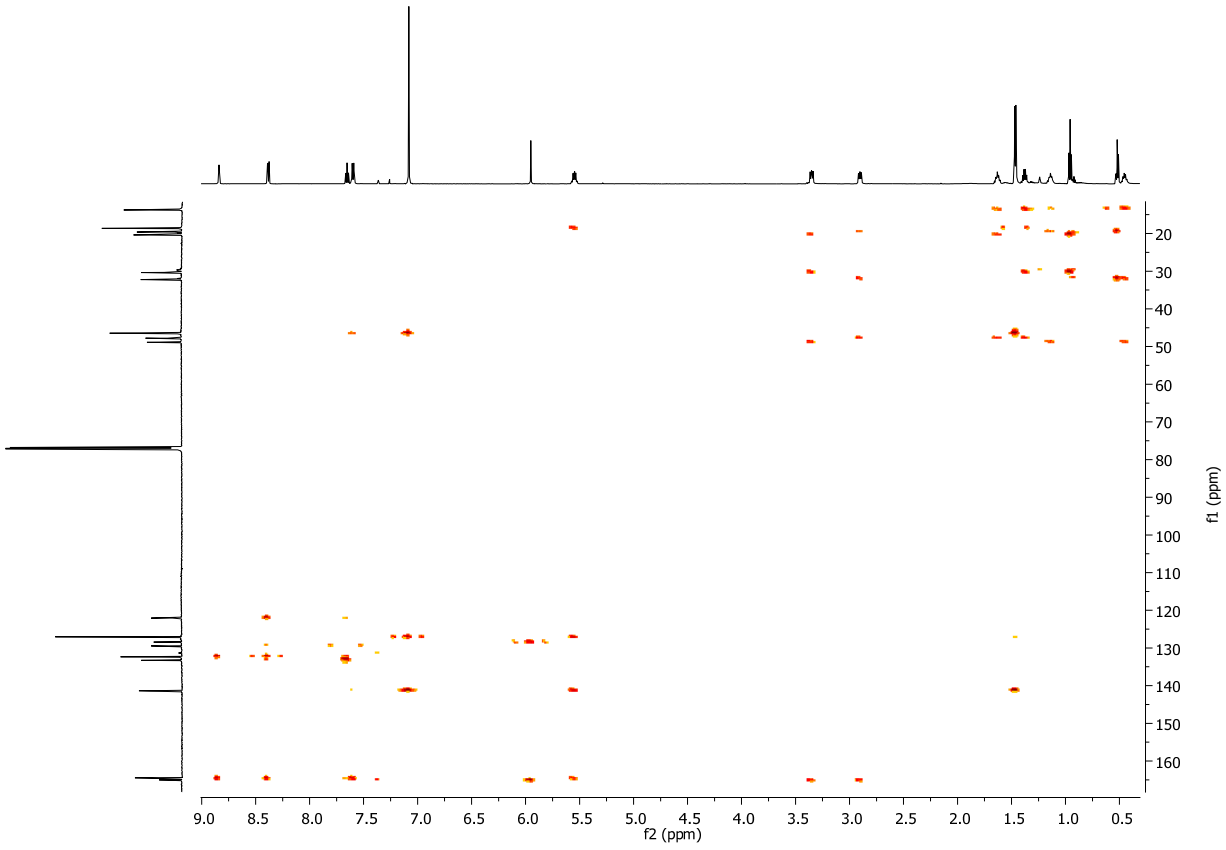
Rotaxane **10c** (HSQC, 600 MHz, $CDCl_3$, 298 K)



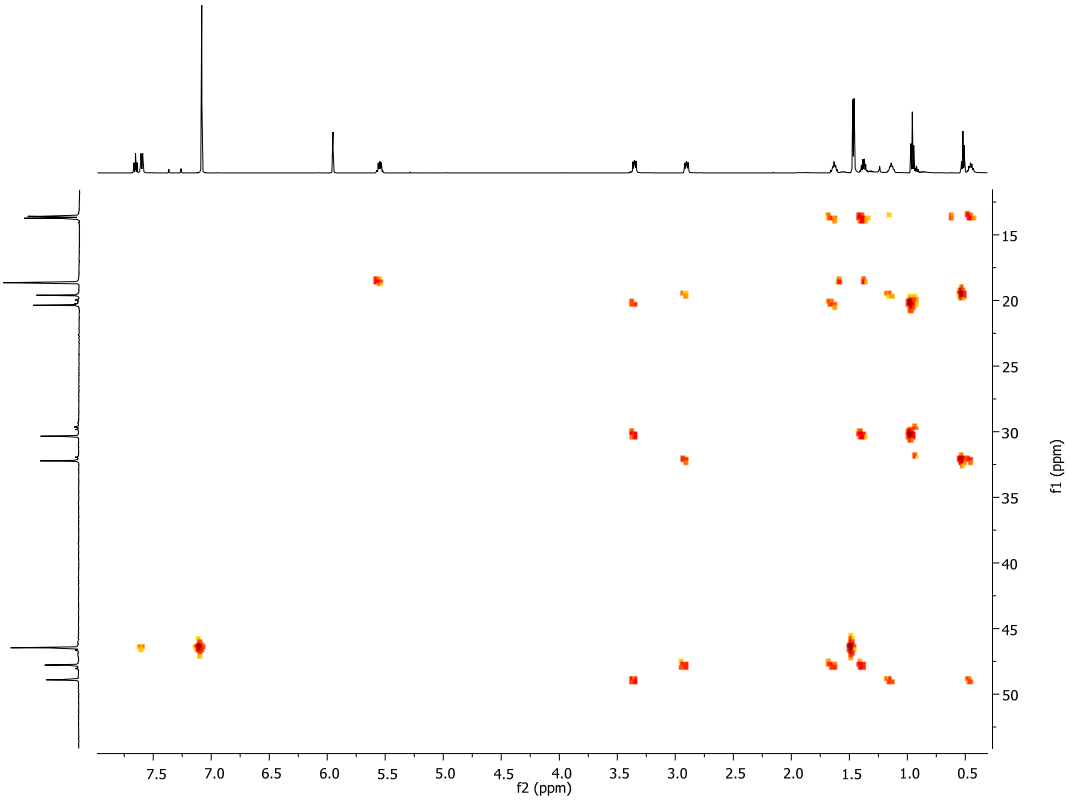
Rotaxane **10c** (HSQC, 600 MHz, $CDCl_3$, 298 K)



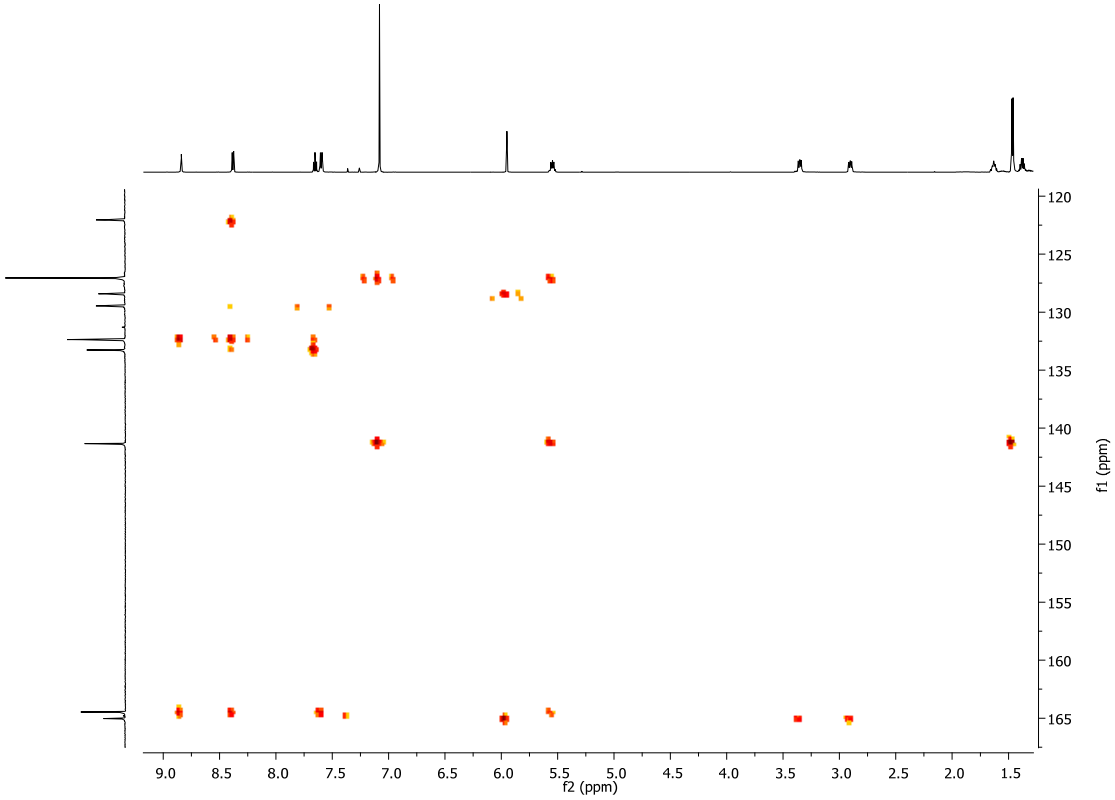
Rotaxane **10c** (HMBC, 600 MHz, $CDCl_3$, 298 K)



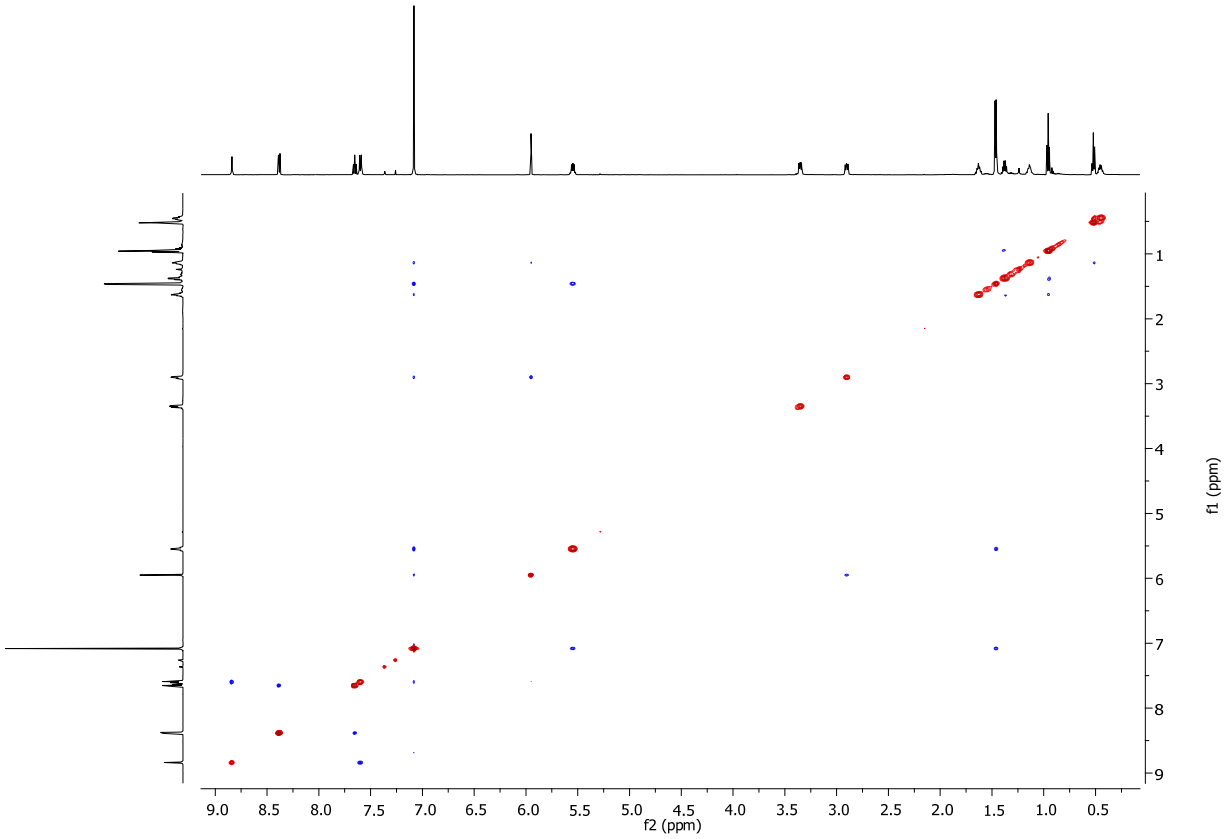
Rotaxane **10c** (HMBC, 600 MHz, $CDCl_3$, 298 K)



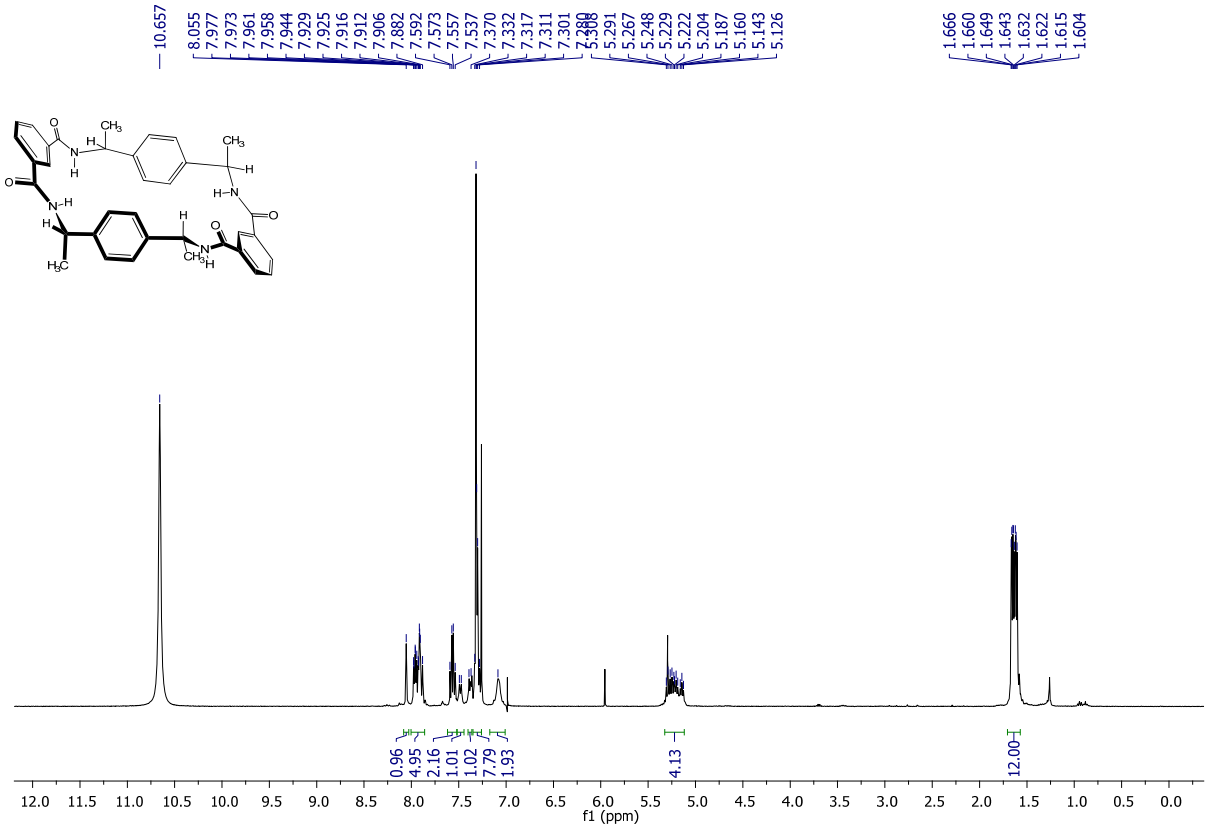
Rotaxane **10c** (HMBC, 600 MHz, $CDCl_3$, 298 K)



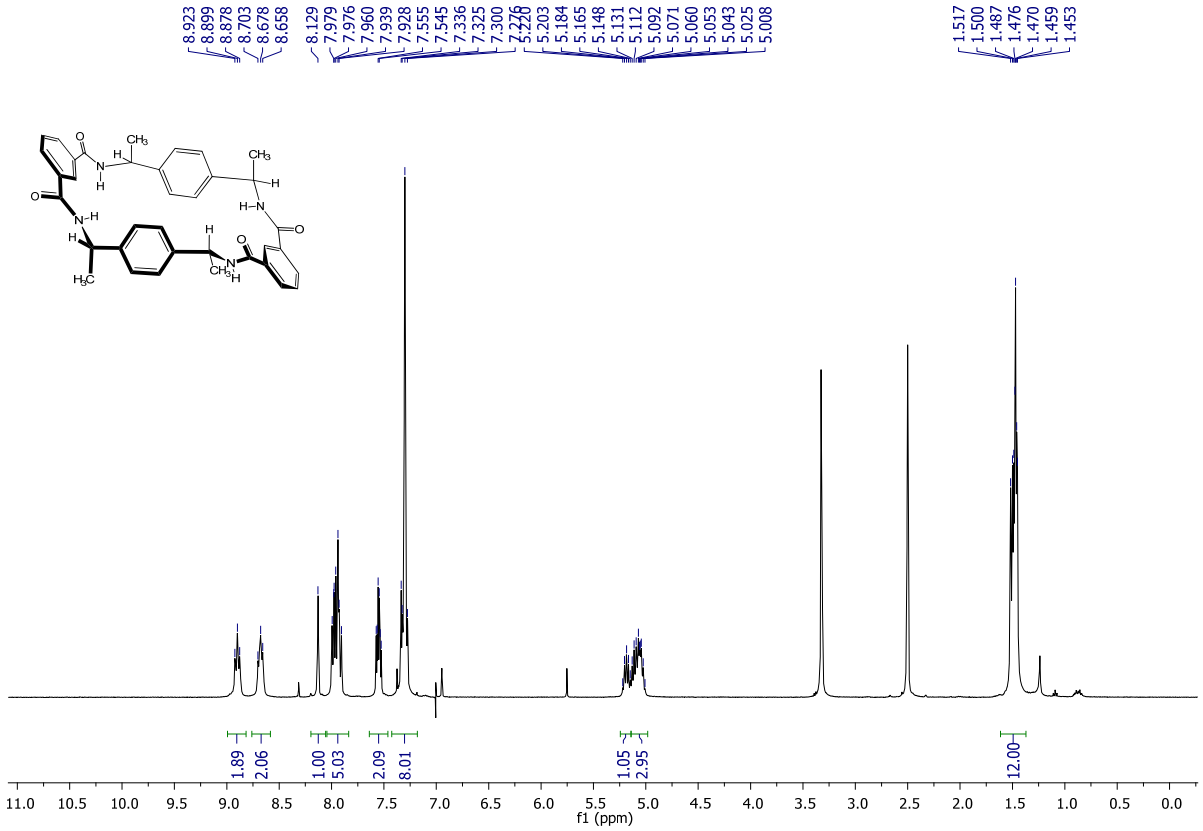
Rotaxane **10c** (^{1}H,^{1}H-NOESY, 600 MHz, $CDCl_3$, 298 K)



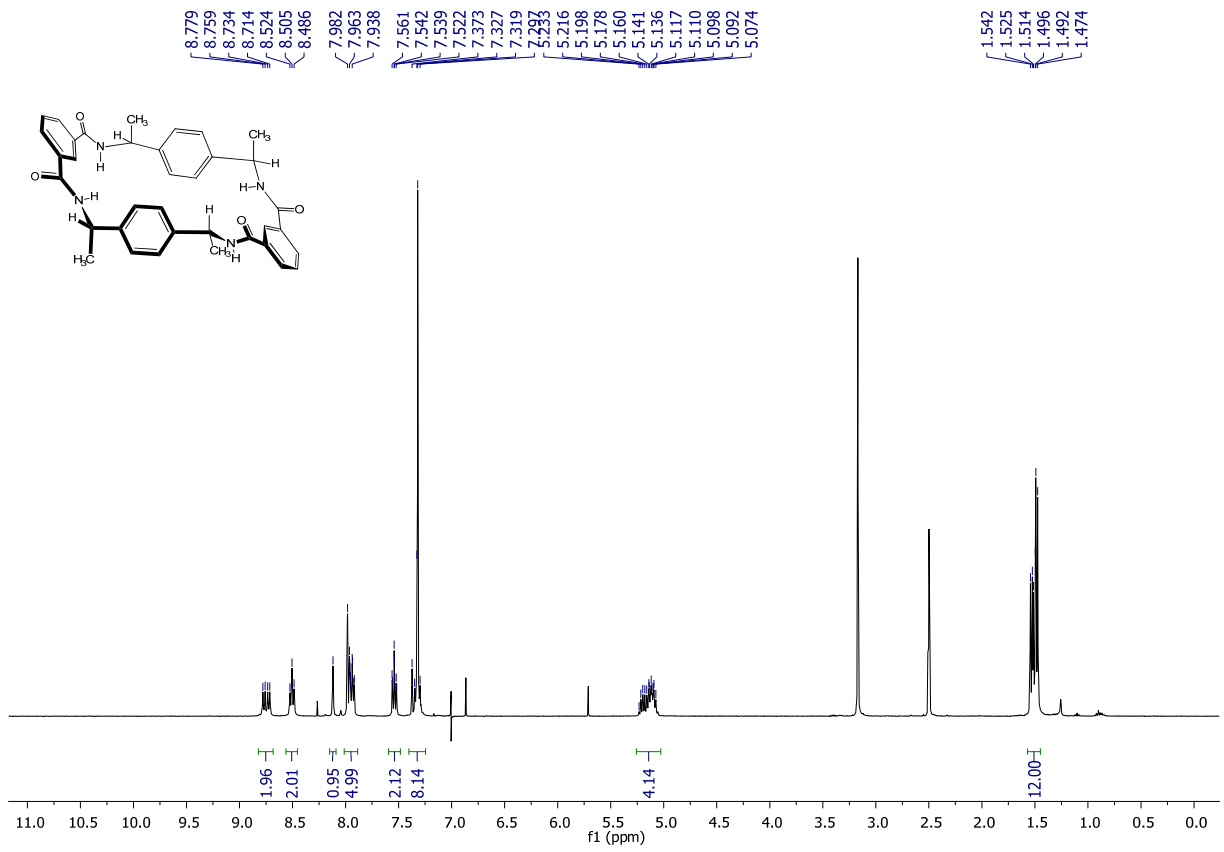
Macrocycle **11** (^{1}H NMR, 400 MHz, $CDCl_3$ + TFA, 298 K)



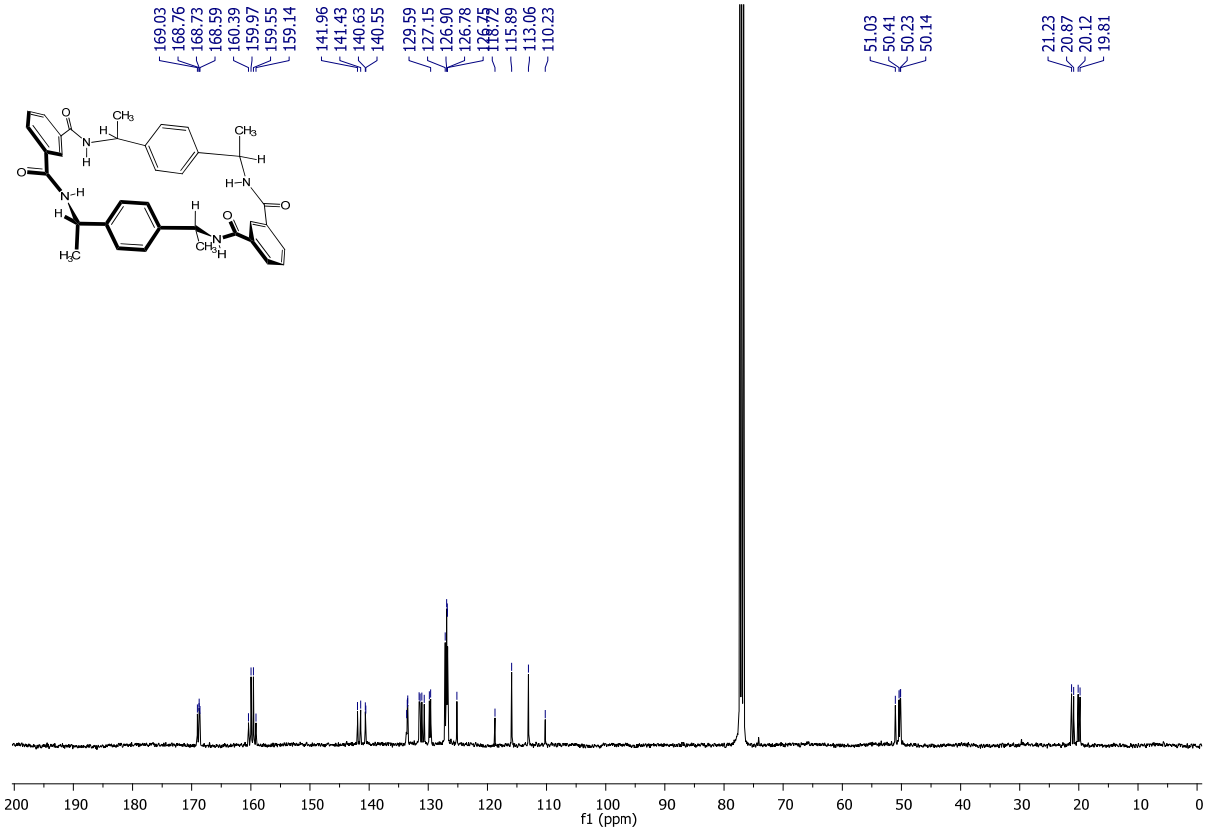
Macrocycle **11** (^{1}H NMR, 400 MHz, DMSO-d_6, 298 K)



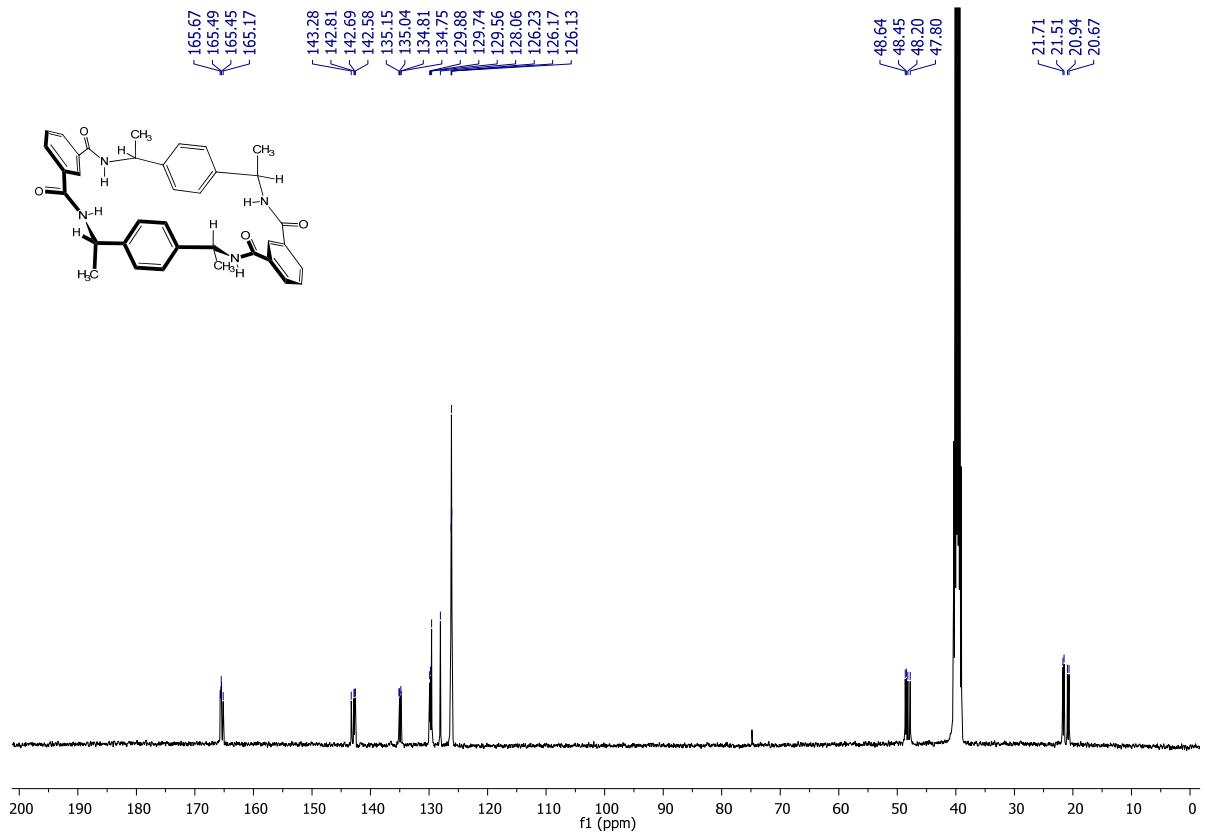
Macrocycle **11** (^{1}H NMR, 400 MHz, DMSO-d_6, 323 K)



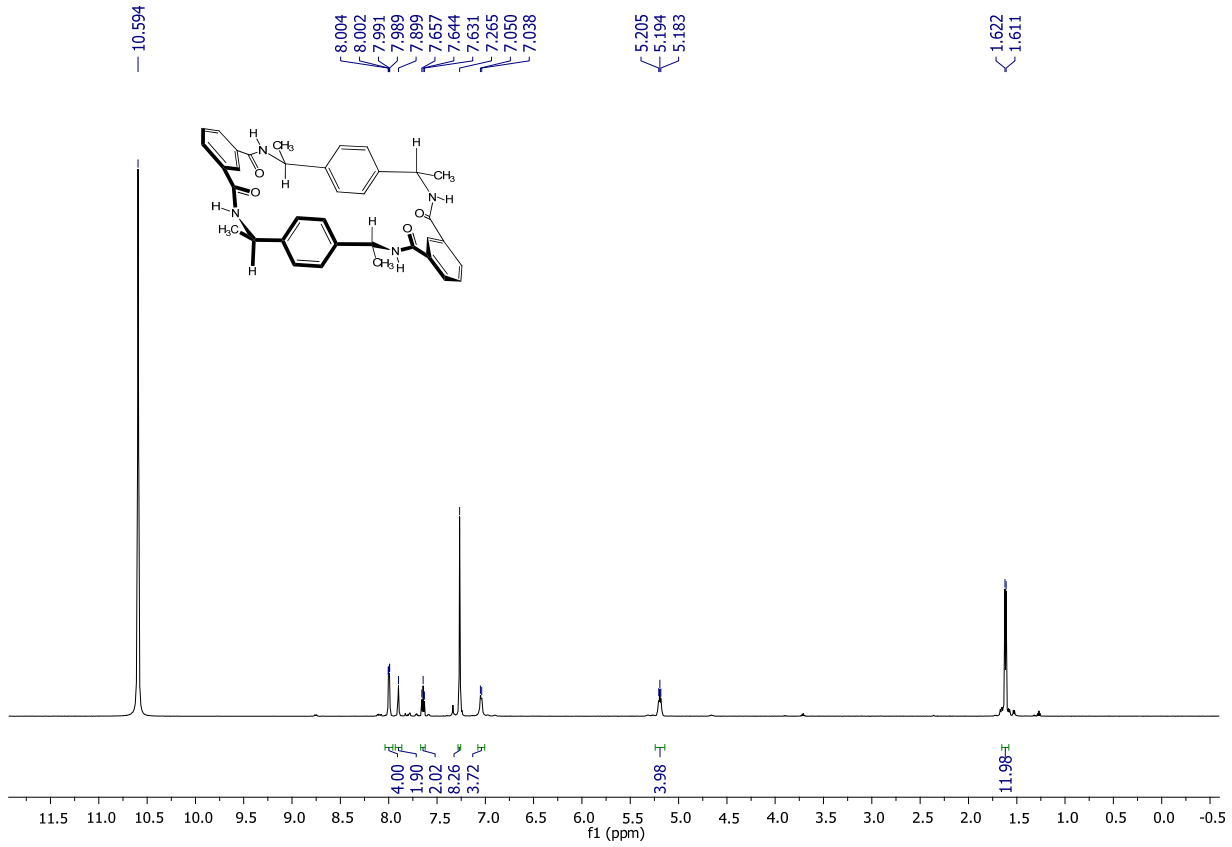
Macrocycle **11** (^{13}C NMR, 100 MHz, $CDCl_3$ + TFA, 298 K)



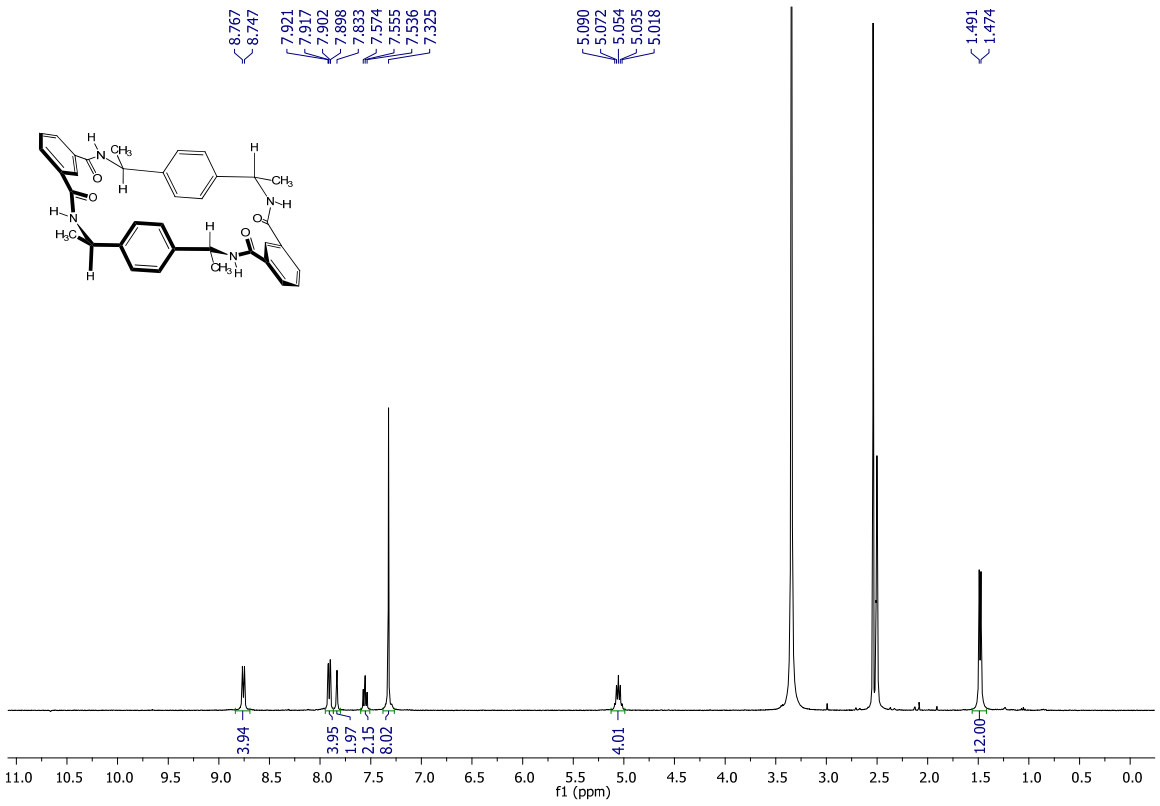
Macrocycle **11** (^{13}C NMR, 100 MHz, DMSO-d_6, 323 K)



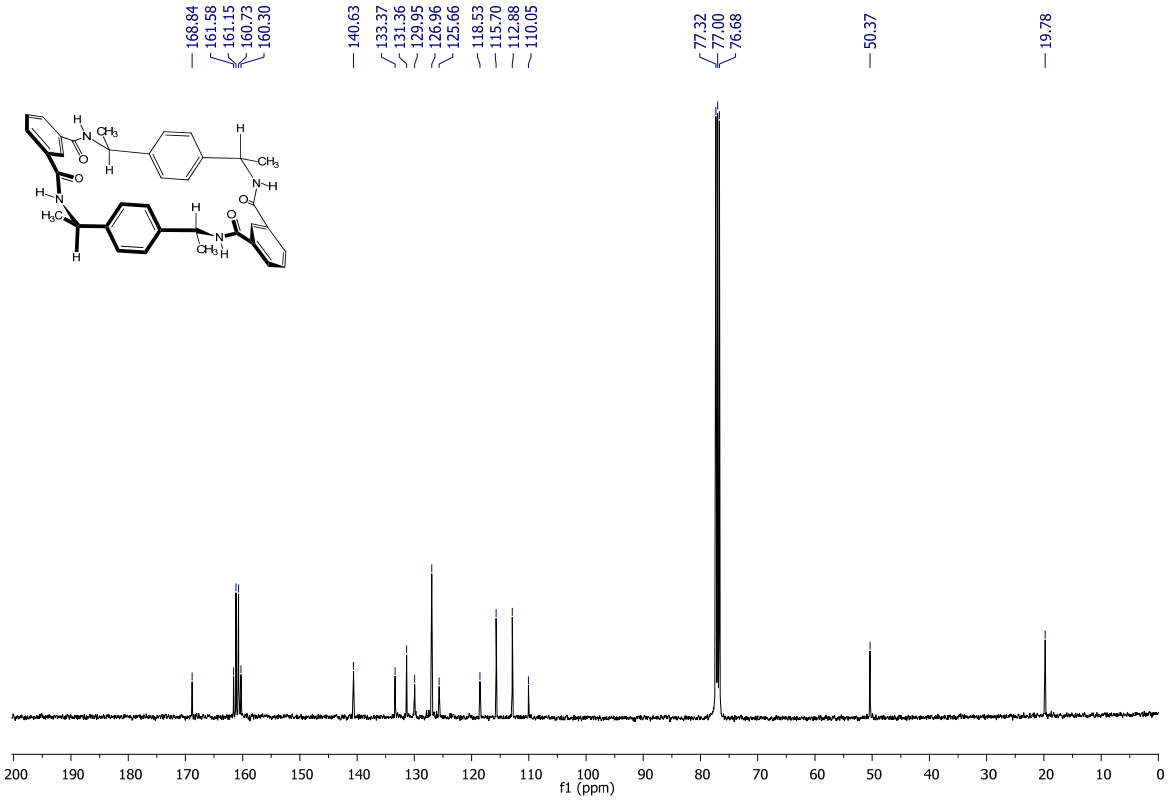
Macrocycle **12** (^{1}H NMR, 600 MHz, $CDCl_3$ + TFA, 298 K)



Macrocycle **12** (^{1}H NMR, 400 MHz, DMSO-d_6, 298 K)



Macrocycle **12** (^{13}C NMR, 100 MHz, $CDCl_3$ + TFA, 298 K)



Macrocycle **12** (^{13}C NMR, 100 MHz, DMSO-d_6, 298 K)