

Supporting Information

2,12-Diaza[6]helicene: a non-conventional stereogenic scaffold for designing efficient enantioselective sensing layers.

Francesca Fontana*, Benedetta Bertolotti, Patrizia Romana Mussini, Serena Arnaboldi, Sara Grecchi, Roberto Cirilli, Laura Micheli, Matteo Tommasini and Simona Rizzo*

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SI.1 Synthesis of 2,12-diaza[6]helicene (4)

The procedure for obtaining 11-bromobenzo[k]phenanthridine was the same as the one described in ref. [6].

To a solution of 11-bromobenzo[k]phenanthridine (150 mg, 0.45 mmol) in DMA (11 mL) under nitrogen NaOAc 3H₂O (200 mg, 1.47 mmol), 4-vinylpyridine (2 mL) and dichlorobis(triphenylphosphine)palladium(II) (3.4 mg, 0.0049 mmol) were subsequently added. The reaction was refluxed for 2 days, then cooled, diluted with water, extracted with several portions of ethyl acetate. The organic phase was dried on Na₂SO₄, evaporated and purified by column chromatography on alumina, eluting with pure ethyl acetate to afford 106 mg (0.32 mmol, 65% yield) of the stilbene precursor (6).

(6) was characterized by MS spectroscopy (m/z 332, M⁺) and by UV-Vis spectrum.

UV spectrum (CH₃OH, 10⁻⁵ M): nm (log ε) 395 (3.08), 354, (4.14), 340 (4.18), 310 (4.33), 266 (4.23), 203 (4.42).

(6) (100 mg, 0.3 mmol) was then dissolved in ethyl acetate (200 mL) and photolyzed in quartz vessels during 4.5 h with 366 nm UV light, in the presence of catalytic I₂ (approx. 10⁻⁵ M) to obtain crude product **4**. The crude product was purified by column chromatography on alumina with ethyl acetate as the eluent, obtaining **4** in a yield of 32 mg (30%).

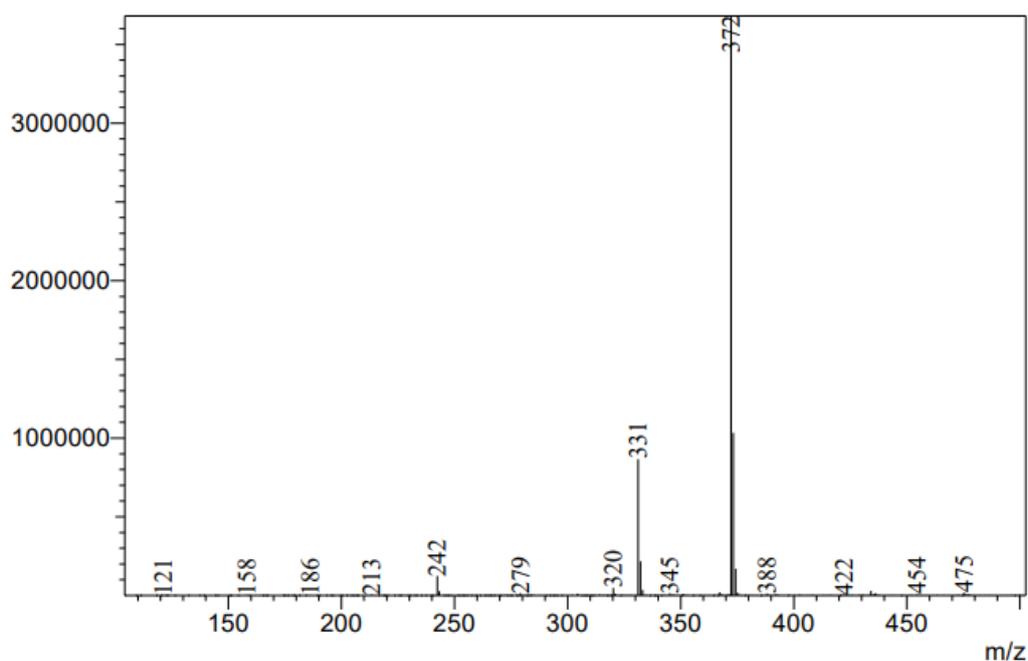


Figure S1 – ESI mass spectrum of compound **4**

ACN/H₂O solvent carrier on a Shimadzu LCMS2020 ESI/DUIS mass detector. MS: m/z 331 (M+1), 372 (M+1+CH₃CN).

UV spectrum (CH₃OH, 3 × 10⁻⁶ M): nm (log ε) 407 (3.88), 383 (3.88), 347 (4.12), 322 (4.34), 308 (4.37), 261 (4.51), 225 (4.74), 203 (4.86).

SI.2 NMR characterization of compound **4**.

The ¹H-NMR spectrum of (±)-**4** shows at low fields the two singlets and the doublet of the CH groups adjacent to the nitrogen atoms corresponding to the position 11, 1 and 3 respectively (Figure SI2). The COSY experiment revealed the cross peaks between the proton in position 3 and the one in position 4 at 7.68 ppm (Figure SI4). The two triplets at 7.46 and 6.81 ppm related to the protons in position 14 and 15 exhibit the cross peak with the hydrogen in position 13 (8.20 ppm) and the one in position 16 (7.45 ppm) respectively. All the other signals were assigned by comparison with COSY and NOESY experiments (Figures SI4 and SI5).

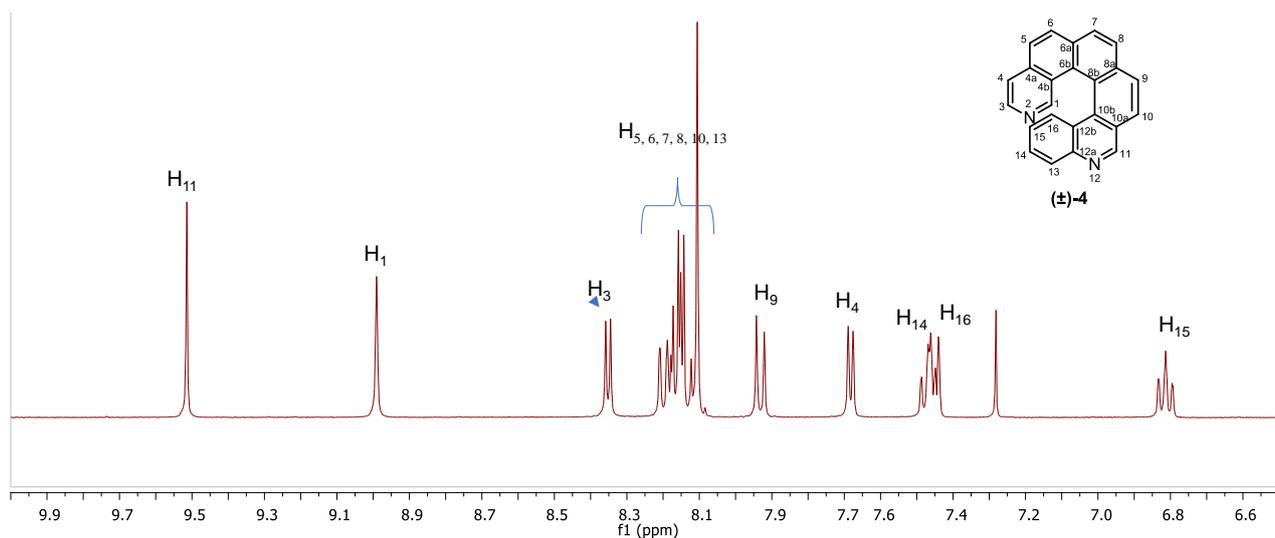


Figure S2 – ^1H NMR of **4** (400.13 MHz, CDCl_3)

δ 9.51 (s, 1H, H in 11), 8.99 (s, 1H, H in 1), 8.35 (d, $^3J = 5.6$ Hz, 1H, H in 3), 8.25-8.07 (m, 6H, H in 13, 5, 6, 7, 8, 10), 7.93 (d, $^3J = 8.4$ Hz, 1H, H in 9), 7.68 (d, $^3J = 5.2$ Hz, 1H, H in 4), 7.51-7.42 (m, 2H, H in 14 and 16), 6.81 (t, $^3J = 7.6$ Hz, 1H, H in 15).

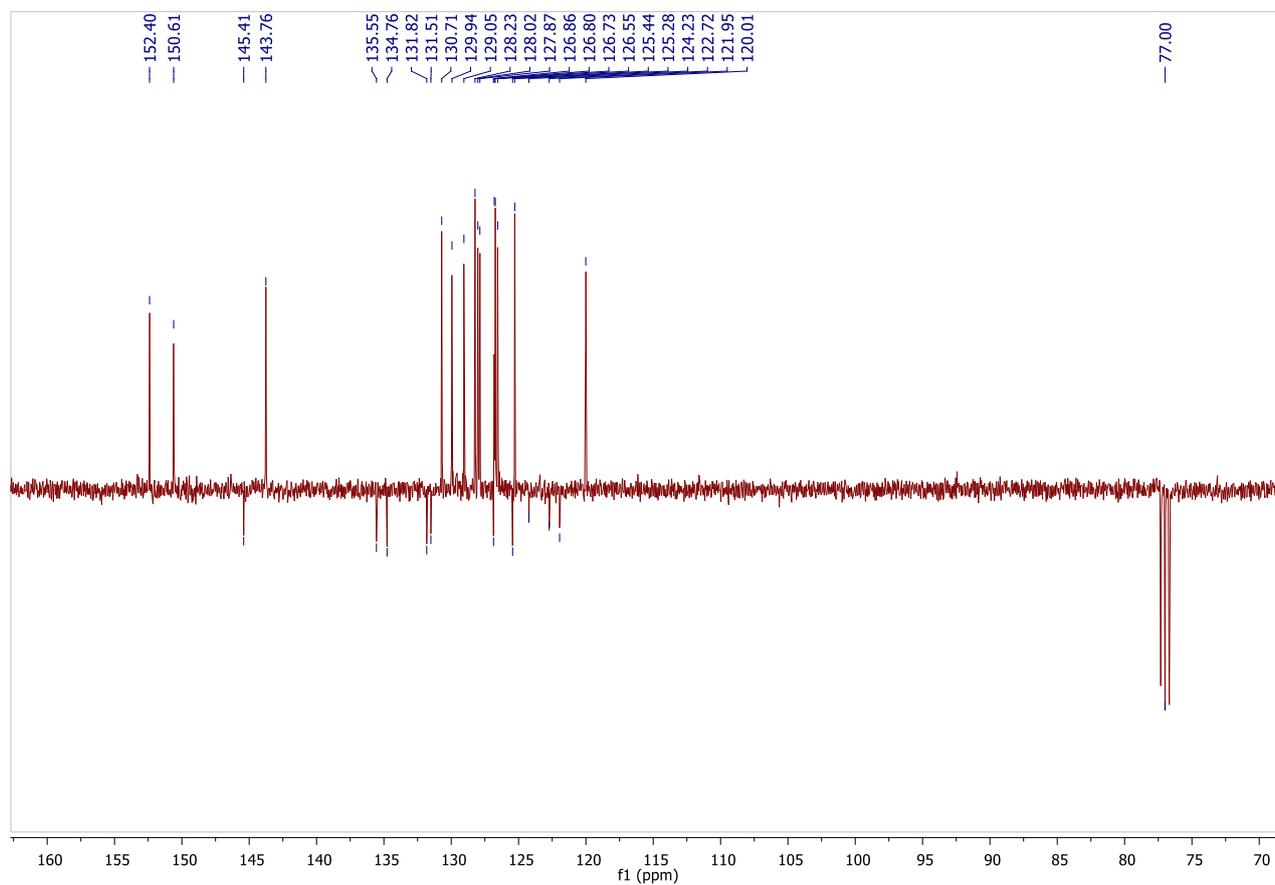


Figure S3 - APT NMR of **4** (75.47 MHz, CDCl_3)

δ 152.40 (s, CH in 11), 150.61 (s, CH in 1), 145.41 (s, C in 12a), 143.76 (s, CH in 3), 135.55 (s, C), 134.76 (s, C), 131.82 (s, C), 131.51 (s, C), 130.71 (s, CH), 129.94 (s, CH), 129.05 (s, CH), 128.23 (s, CH), 128.02 (s, CH), 127.87 (s, CH), 126.86 (s, C), 126.80 (s, CH), 126.73 (s, CH), 126.55 (s, CH), 125.44 (s, C), 125.28 (s, CH in 15), 124.23 (s, C), 122.72 (s, C in 12b), 121.95 (s, C), 120.01 (s, CH in 4).

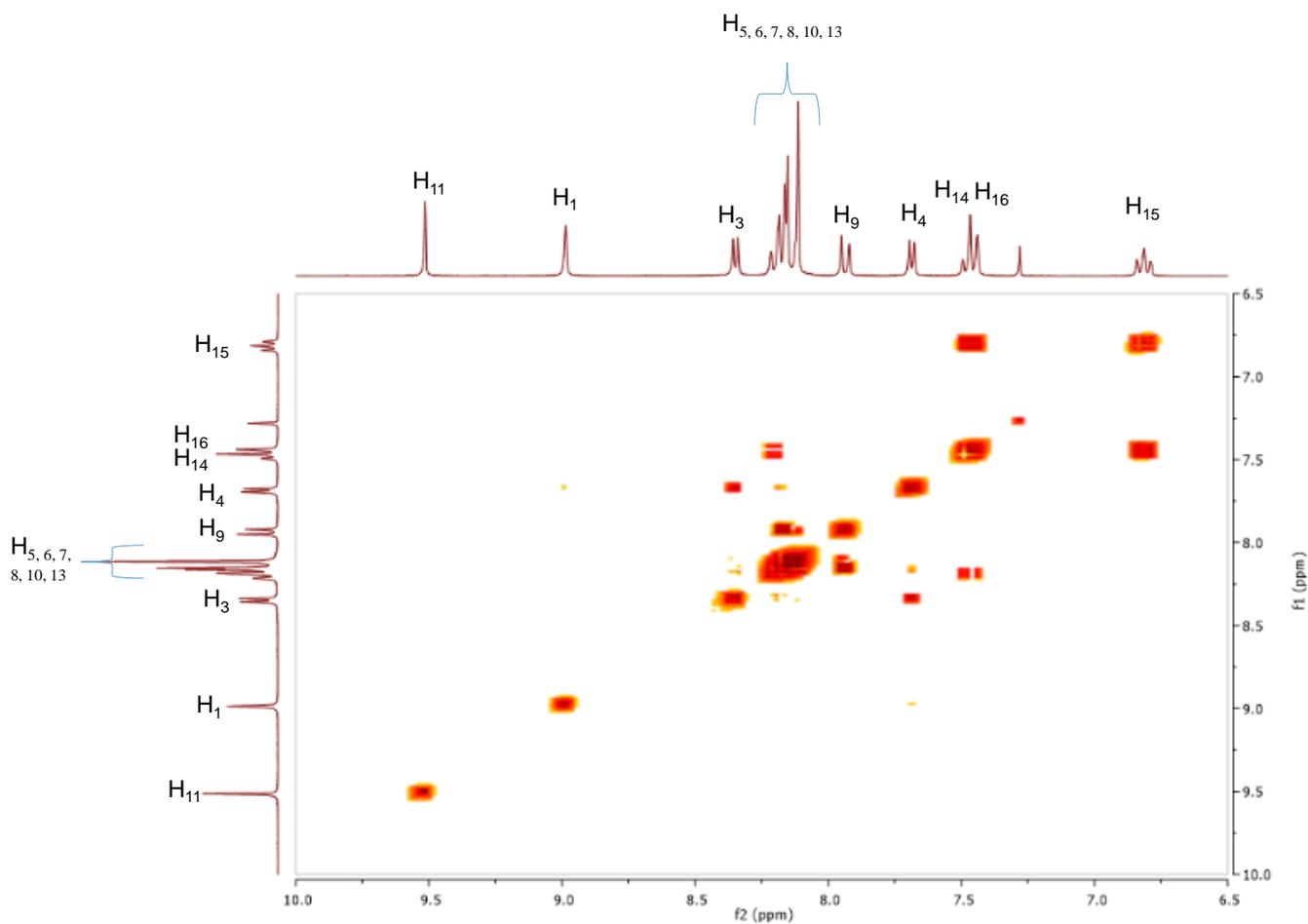


Figure S4 – COSY plot of 4 in CDCl₃ (300.14 MHz).

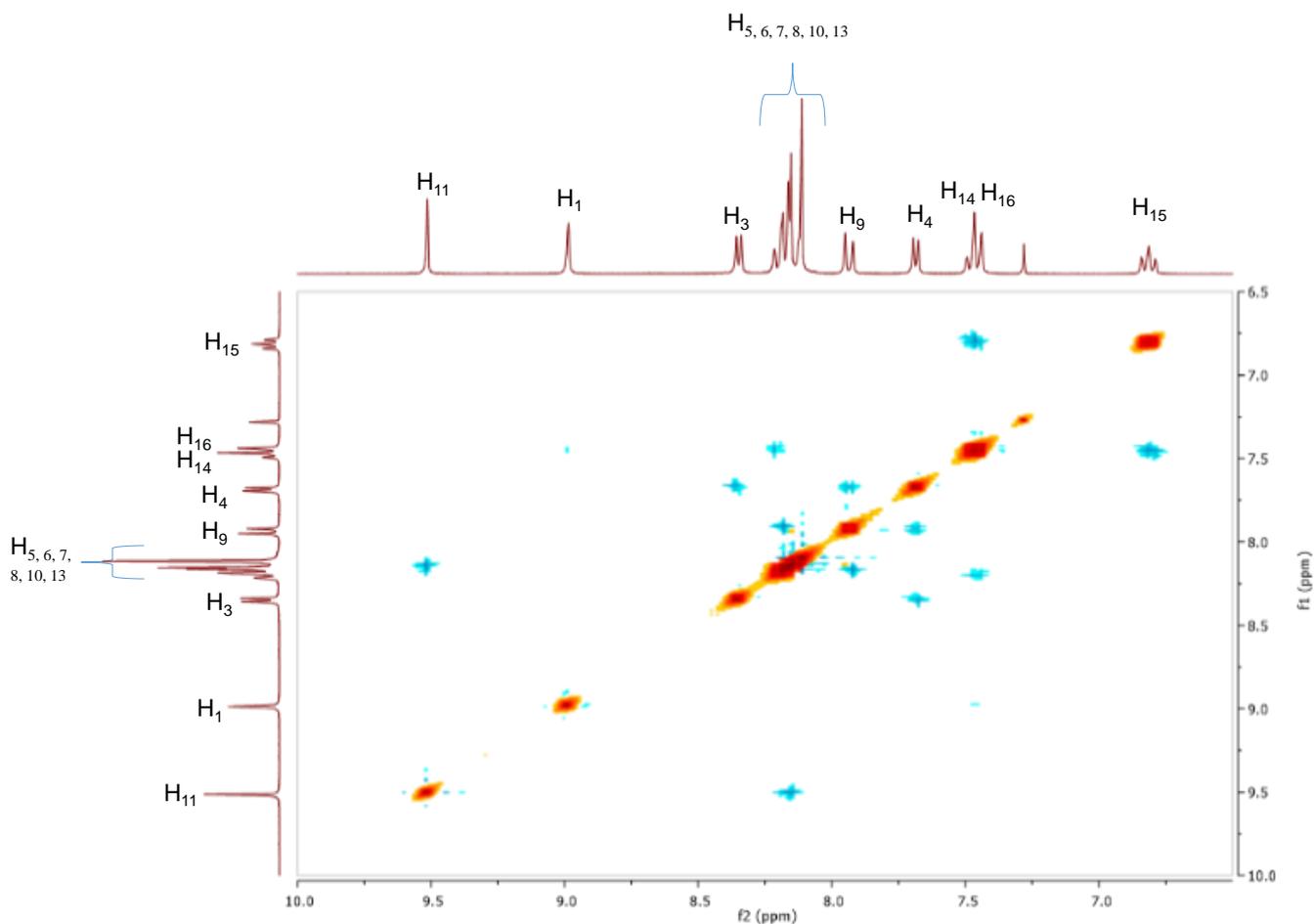


Figure S5 – NOESY plot of **4** in CDCl₃ (300.14 MHz).

It was possible to assign the pertinent signals to the CH carbons in position 11, 1, 3, 4 e 15 (Figure SI4) by HSQC experiments (Figure SI7), while signals to the quaternary carbons C 12a (showing a cross peak with CH in position 11) and C 12b (showing a cross peak with CH in position 15) were assigned on the basis of the HMBC experiments (Figure SI8).

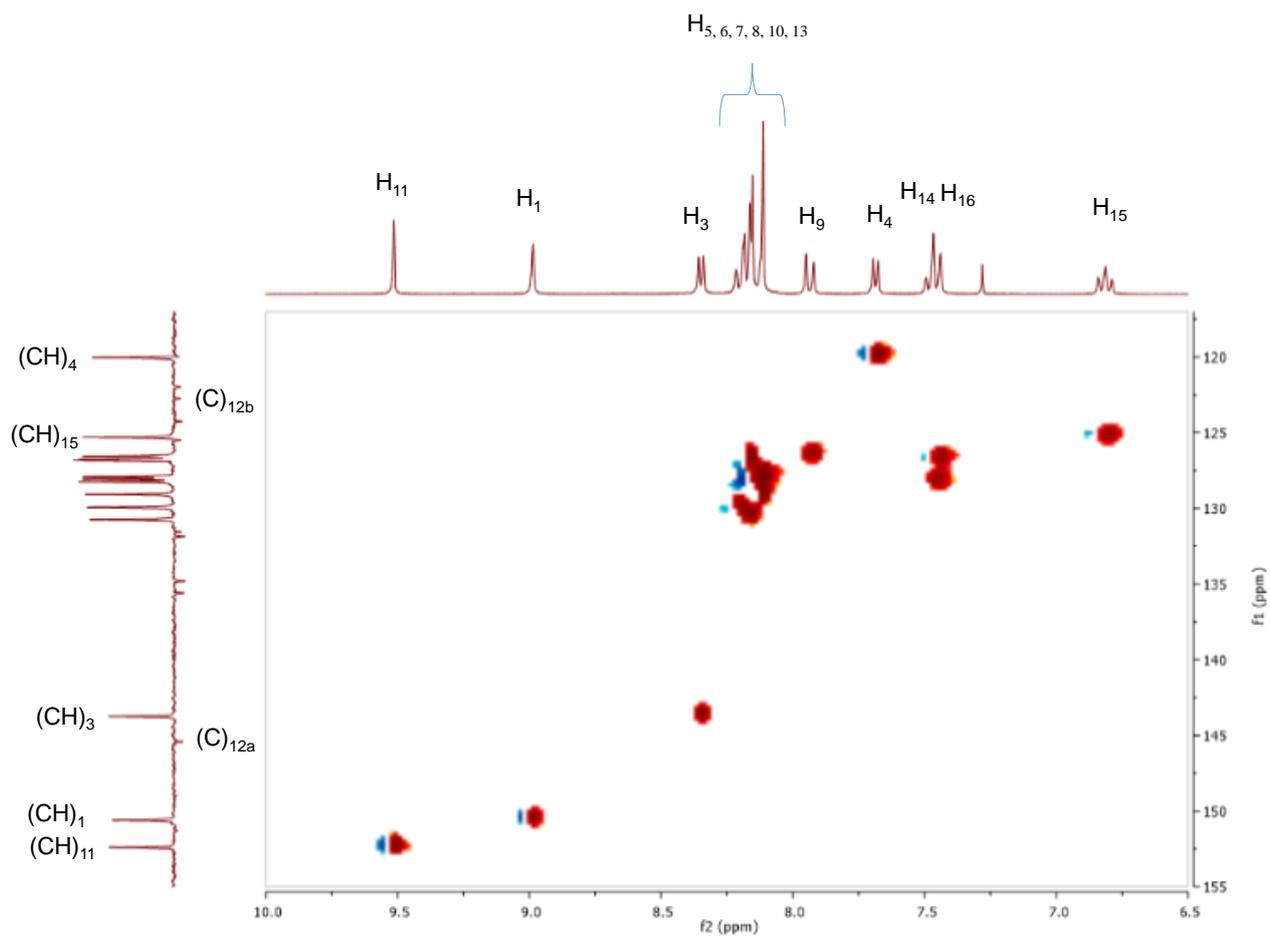


Figure S6 – HSQC of **4** in CDCl₃ (300.14 MHz).

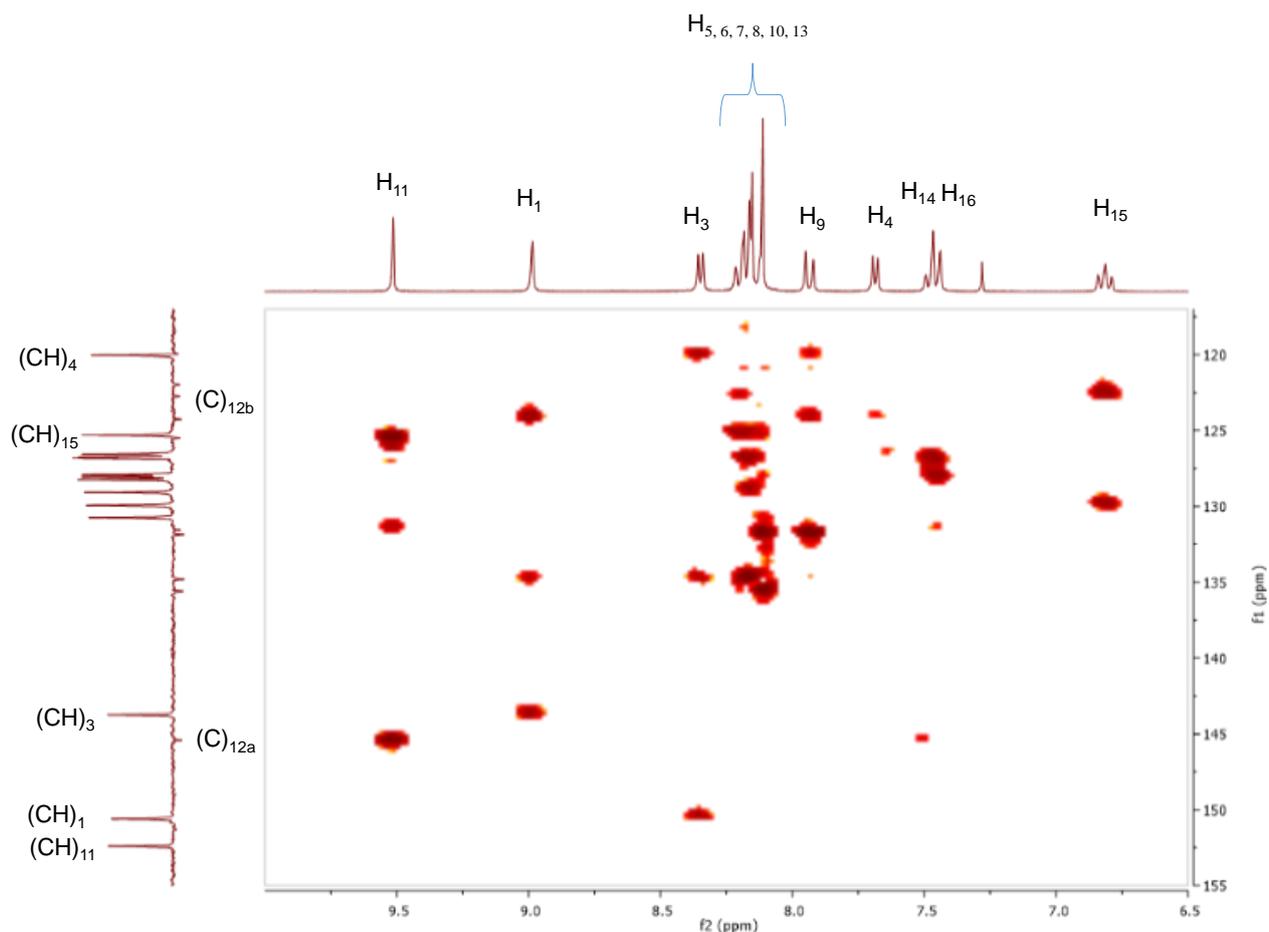


Figure S7 – HMBC of (\pm)-4 in CDCl_3 (300.14 MHz).

SI.3 Synthesis of 2-ethyl-2,12-diaza[6]helicenium iodide

The iodoethane (0.6 mL) was added to (\pm)-, (*P*)-, (*M*)-2,12-diaza[6]helicene (11.3 mg, 3.4×10^{-2} mmol). The reaction mixture was stirred at RT for 2.5 days. The iodoethane was evaporated and the product obtained was the mono alkylated (\pm)-, (*P*)-, (*M*)-*N*-ethyl-2,12-aza[6]helicenium iodide (15.2 mg, 92%). This assignment is based on spectroscopic experiments (^1H -NMR, APT NMR, COSY, NOESY, HSQC).

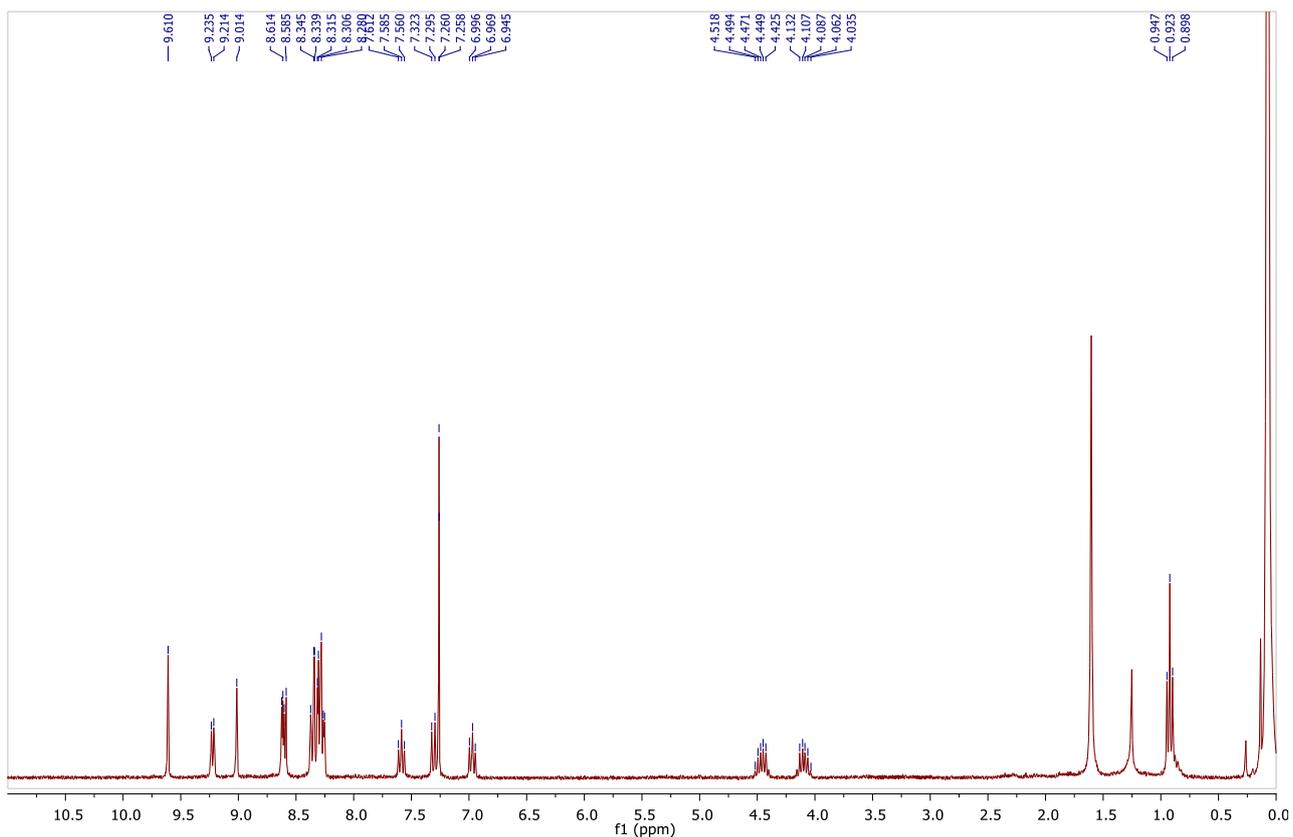


Figure S8 - ¹H NMR of 7 (300.14 MHz, CDCl₃)

δ 9.63 (s, 1H, H in 11), 9.24 (d, ³J = 6.3 Hz, 1H, H in 3), 9.03 (s, 1H, H in 1), 8.67-8.59 (m, 2H, H in 4 and another one), 8.42-8.25 (m, 6H), 7.60 (t, ³J = 9.0 Hz, 1H, H in 14), 7.33 (d, ³J = 9.0 Hz, 1H, H in 16), 6.99 (t, ³J = 9.0 Hz, 1H, H in 15), 4.55-4.40 (m, 1H, Ha of CH₂), 4.19-4.04 (m, 1H, Hb of CH₂), 0.94 (t, ³J = 7.50 Hz, 3H, CH₃).

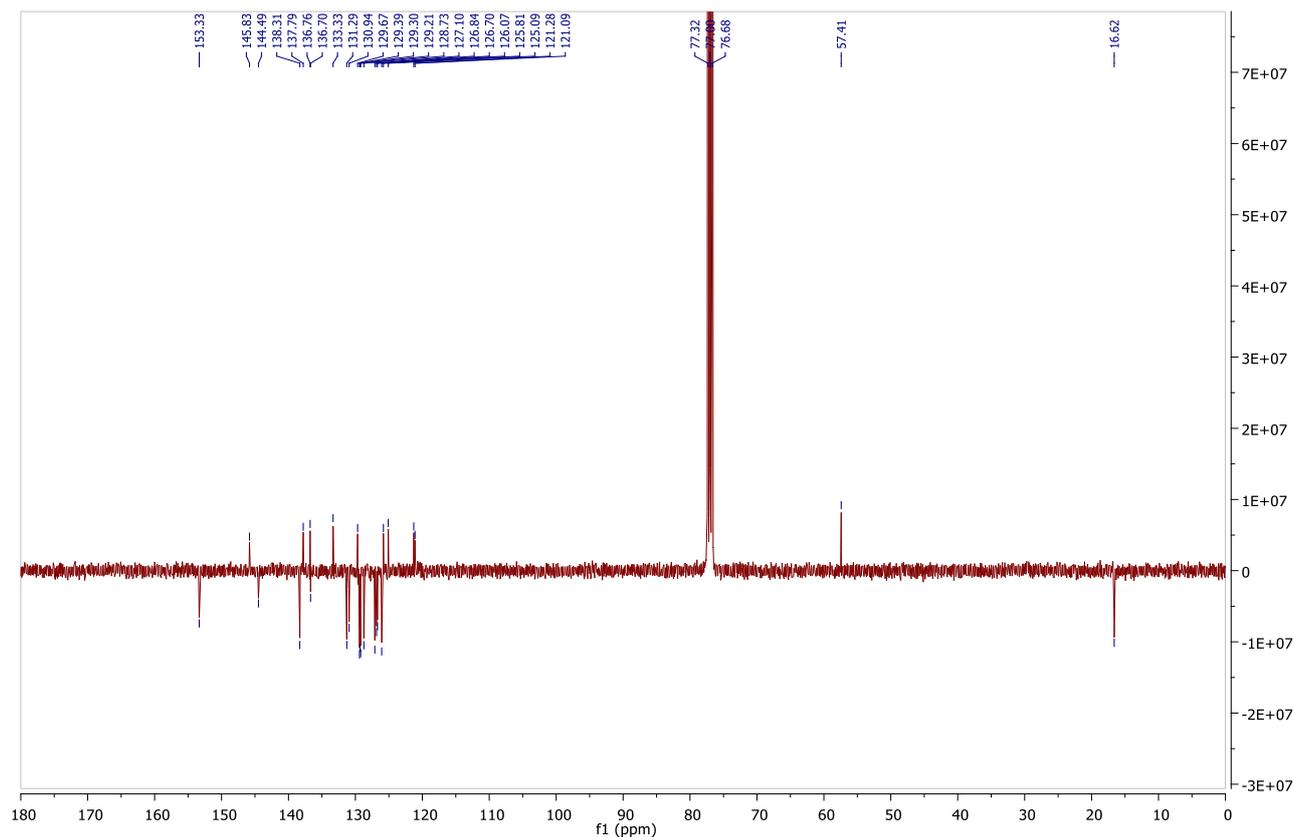


Figure S9 - APT NMR of 7 (100.63 MHz, CDCl₃)

δ 153.33 (s, CH, CH in 11), 145.83 (s, C), 144.49 (s, CH, CH in 1), 138.31 (s, CH), 137.79 (s, C), 136.76 (s, C), 136.70 (s, CH, CH in 3), 133.33 (s, C), 131.29 (s, CH), 130.94 (s, CH), 129.67 (s, C), 129.39 (s, CH), 129.30 (s, CH), 129.21 (s, CH), 128.73 (s, CH), 127.10 (s, CH), 126.84 (s, CH), 126.70 (s, CH), 126.07 (s, CH), 125.81 (s, C), 125.09 (s, C), 121.28 (s, C), 121.09 (s, C), 57.41 (s, CH₂), 16.62 (s, CH₃).

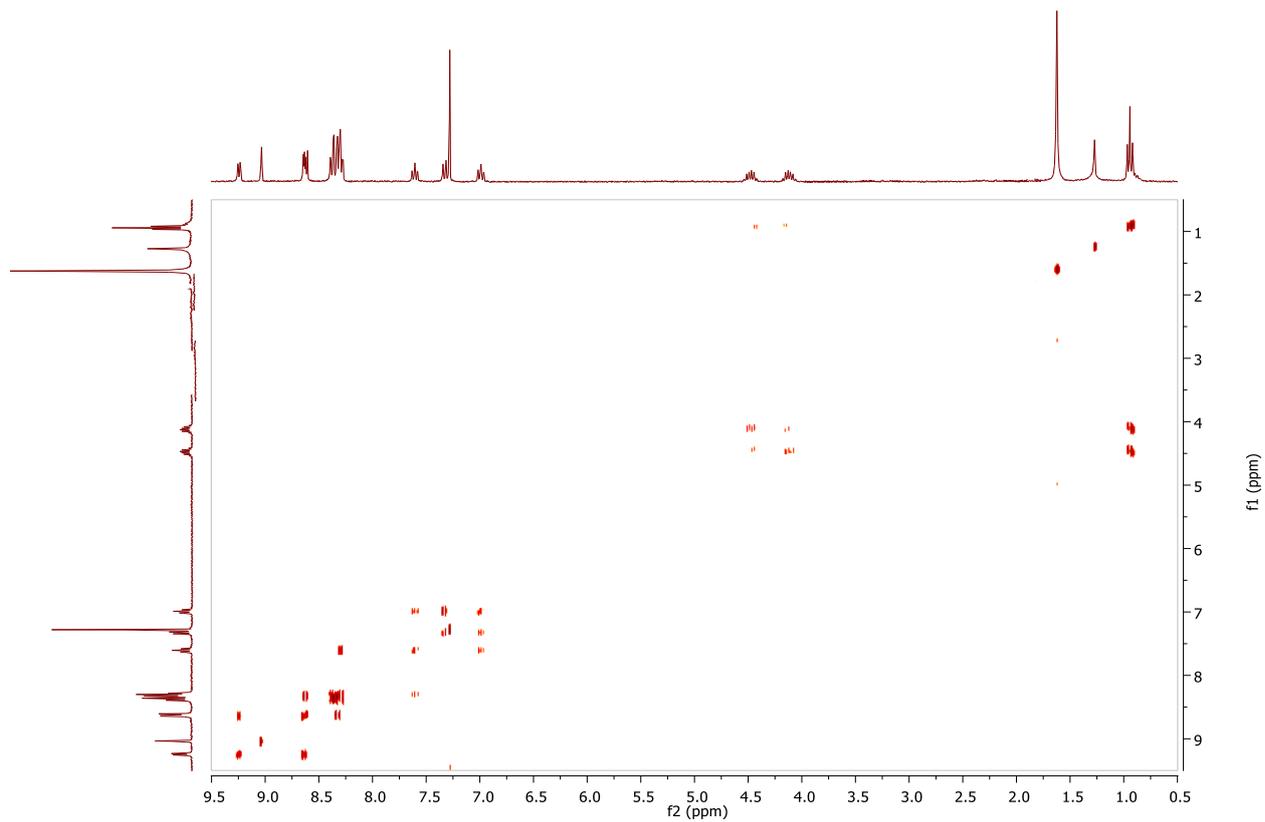


Figure S10 – COSY of 7 in CDCl₃ (300.14 MHz).

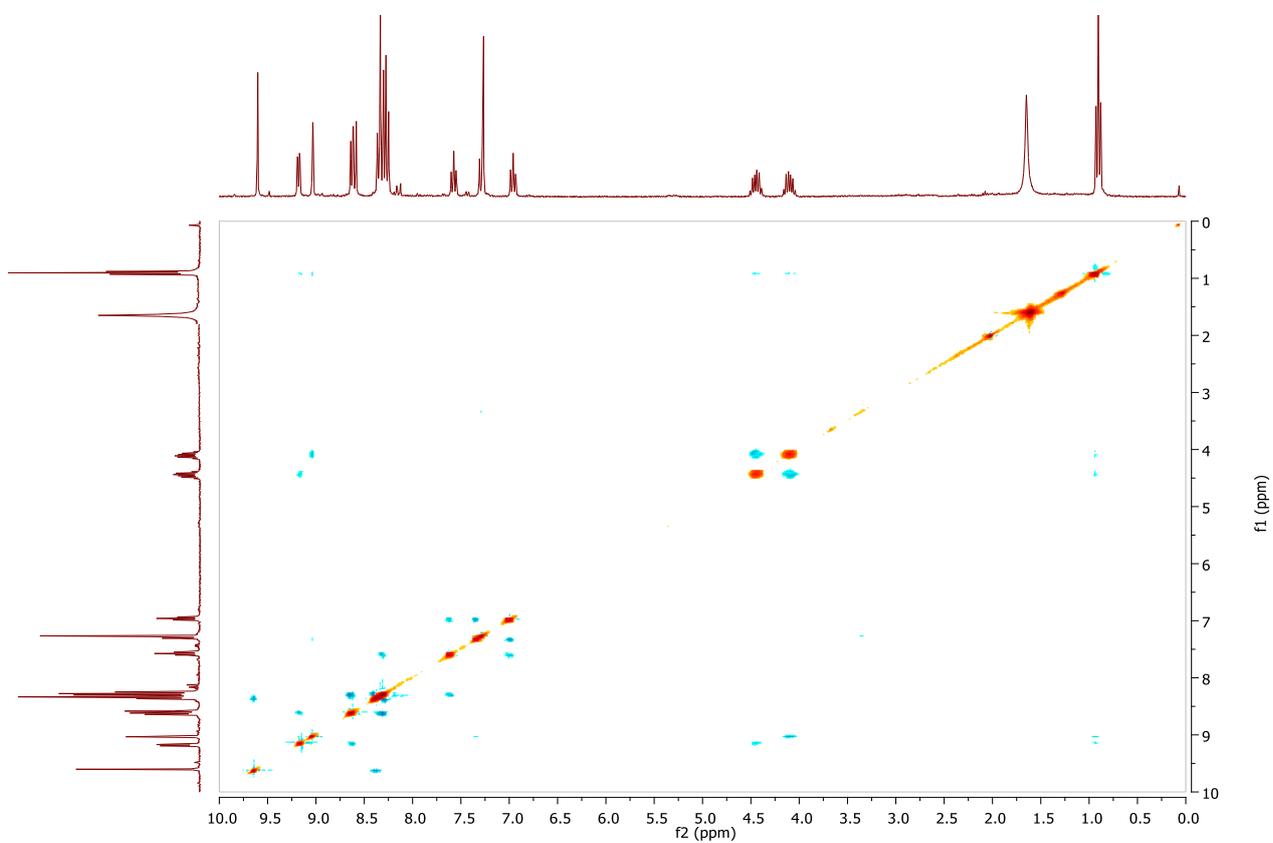


Figure S11 – NOESY of 7 in CDCl₃ (300.14 MHz).

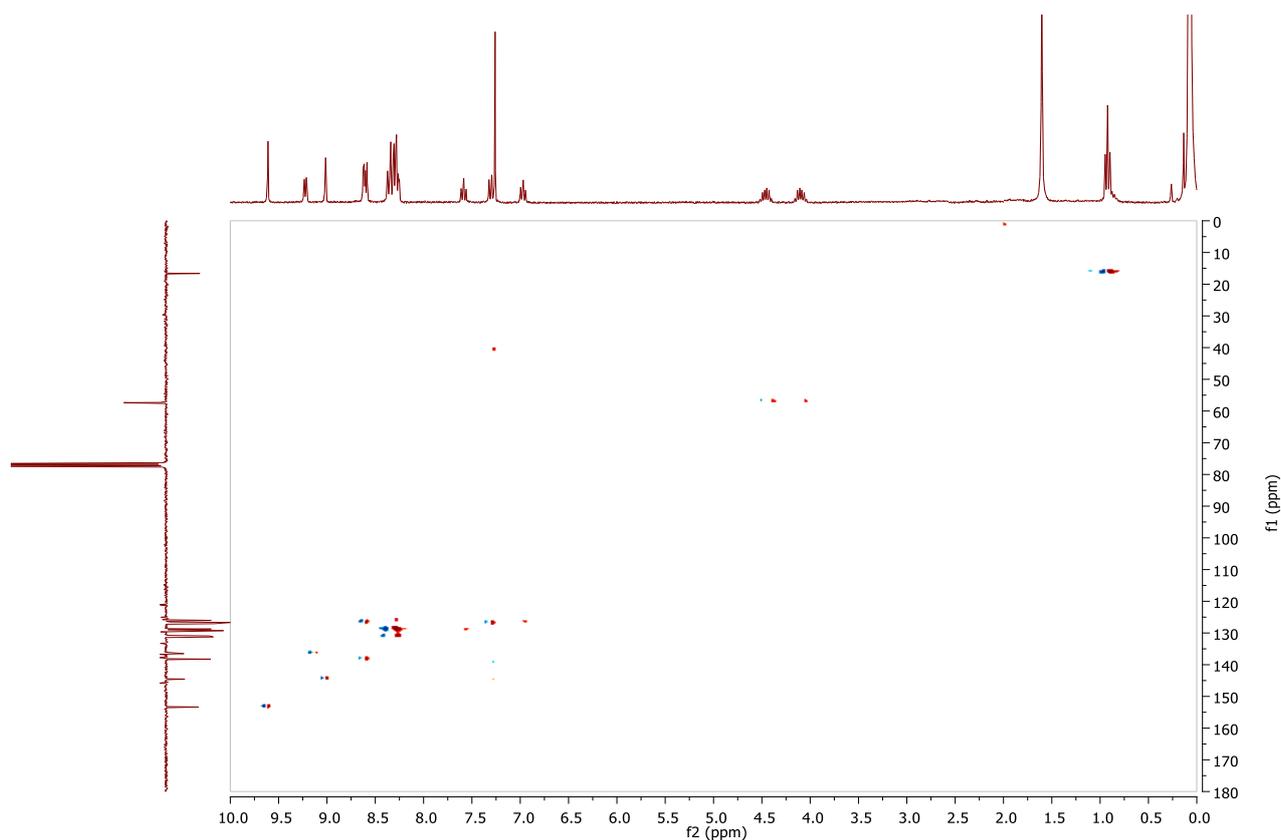


Figure S12 – HSQC of **7** in CDCl_3 (300.14 MHz).

SI.4 Synthesis of *N,N'*-diethyl-2,12-diaza[6]helicenium diiodide

The iodoethane (0.4 mL) was added to (\pm)-, (*P*)-, (*M*)-*N*-ethyl-2,12-diaza[6]helicene (8.1 mg, $17 \cdot 10^{-3}$ mmol). The reaction mixture was stirred at 50°C for 11 days (after 72 h a second portion of iodoethane was added) then for 2.5 days after acetonitrile addition (2 mL) and a new portion of iodoethane (0.6 mL). The iodoethane and the solvent were evaporated and the product obtained was the (\pm)-, (*P*)-, (*M*)-*N,N'*-diethyl-2,12-diaza[6]helicene-2,12-dium diiodide (red coloured, 10,8 mg, 99%). This assignment is based on spectroscopic experiments $^1\text{H-NMR}$ (Figure SI13), $^{13}\text{C NMR}$ (Figure SI14), COSY (Figure SI15), HSQC (Figure SI16).

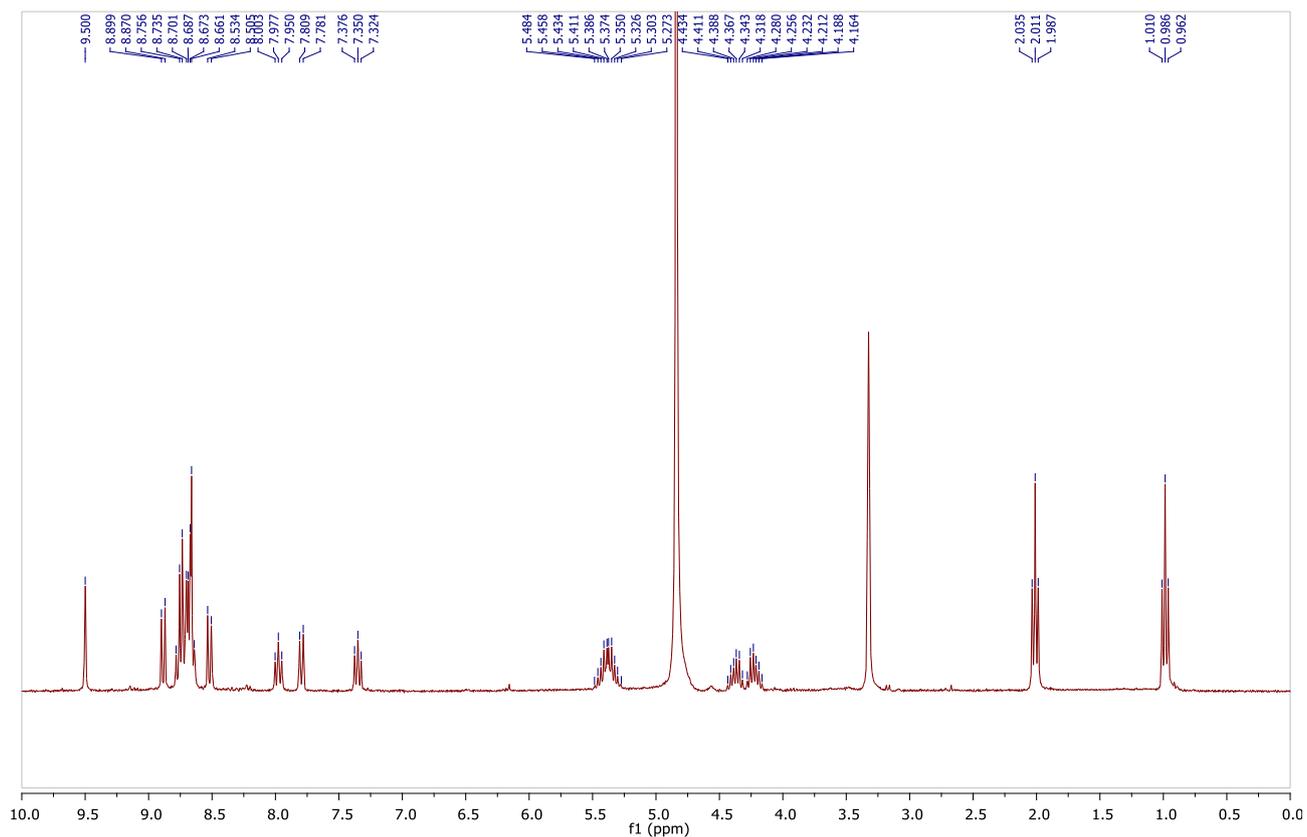


Figure S13 – ^1H NMR of **8** (300.14 MHz, CD_3OD)

δ 10.52 (s, 1H, H in 11), 9.50 (s, 1H, H in 1), 8.88 (d, $^3J = 8.7$ Hz, 1H, H in 3), 8.80-8.60 (m, 7H), 8.52 (d, $^3J = 8.7$ Hz, 1H, H in 4), 7.98 (t, $^3J = 7.8$ Hz, 1H, H in 14), 7.80 (d, $^3J = 8.4$ Hz, 1H, H in 16), 7.35 (t, $^3J = 7.8$ Hz, 1H, H in 15), 5.50-5.25 (m, 2H, CH_2 Et in 12), 4.47-4.15 (m, 2H, CH_2 Et in 2), 2.01 (t, $^3J = 7.2$ Hz, 3H, CH_3 Et in 12), 0.99 (t, $^3J = 7.2$ Hz, 3H, CH_3 Et in 2).

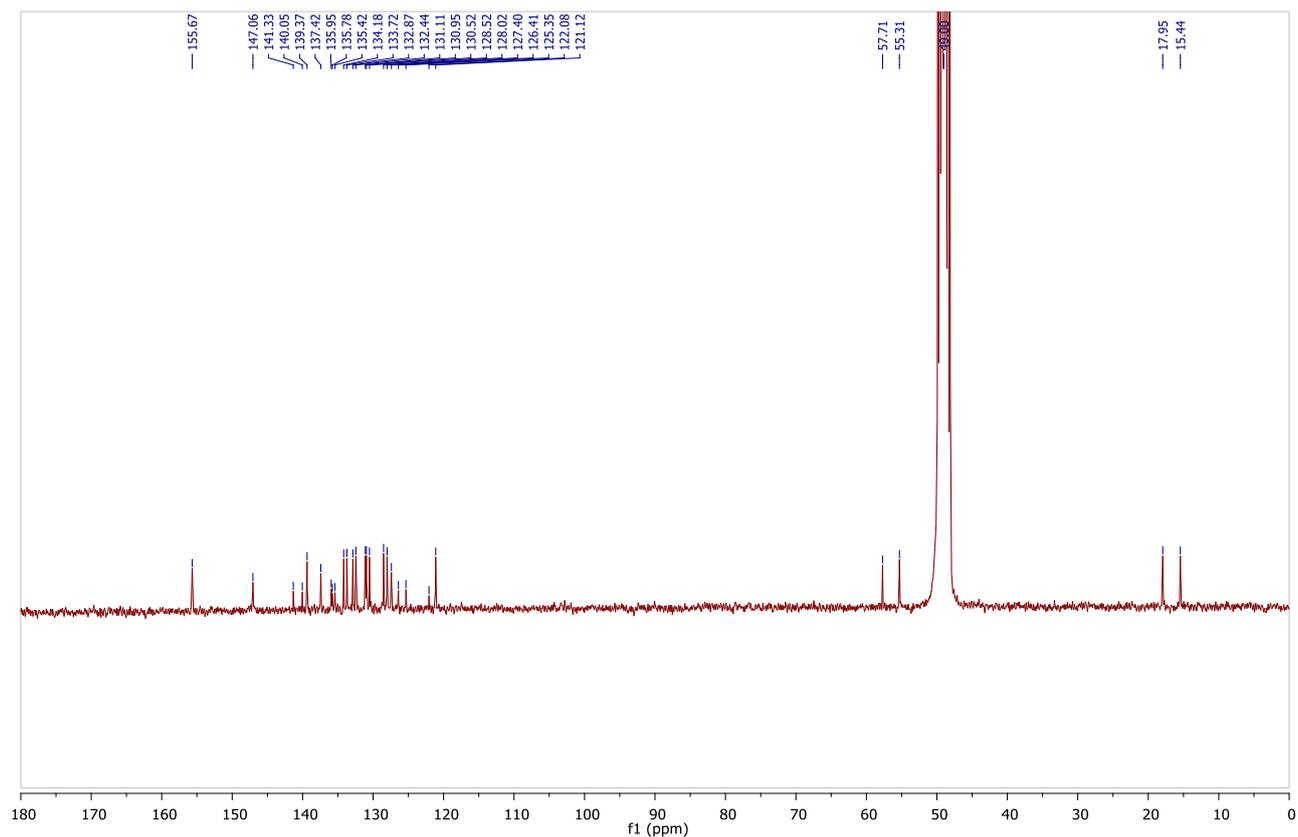


Figure S14 - ^{13}C NMR of **8** (75.48 MHz, CD_3OD)

δ 155.67 (s, 1CH, CH in 11), 147.06 (s, 1CH, CH in 1), 141.33 (s, C), 140.05 (s, C), 139.37 (s, CH), 137.42 (s, CH), 135.95 (s, C), 135.78 (s, C), 135.42 (s, C), 134.18 (s, CH), 133.72 (s, CH), 132.87 (s, CH), 132.44 (s, CH), 131.11 (s, CH), 130.95 (s, CH), 130.52 (s, CH), 128.52 (s, CH), 128.02 (s, CH), 127.40 (s, 2C), 126.41 (s, C), 125.35 (s, C), 122.08 (s, C), 121.12 (s, CH), 57.71 (s, 1CH₂, CH₂ Et in 2), 55.31 (s, 1CH₂, CH₂ Et in 12), 17.95 (s, 1CH₃, CH₃ Et in 2), 15.44 (s, 1CH₃, CH₃ Et in 12).

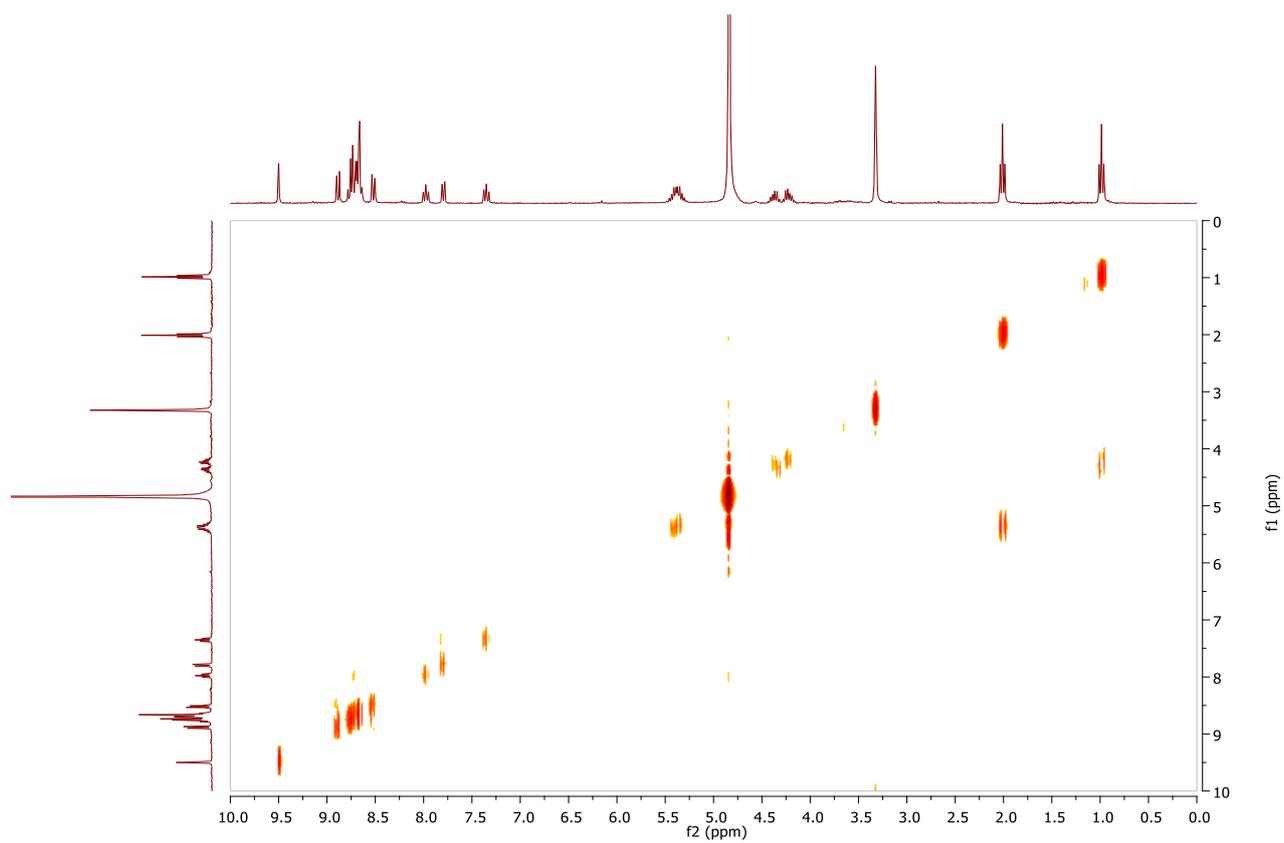


Figure S15 – COSY of 8 in CD₃OD (300.14 MHz, CD₃OD).

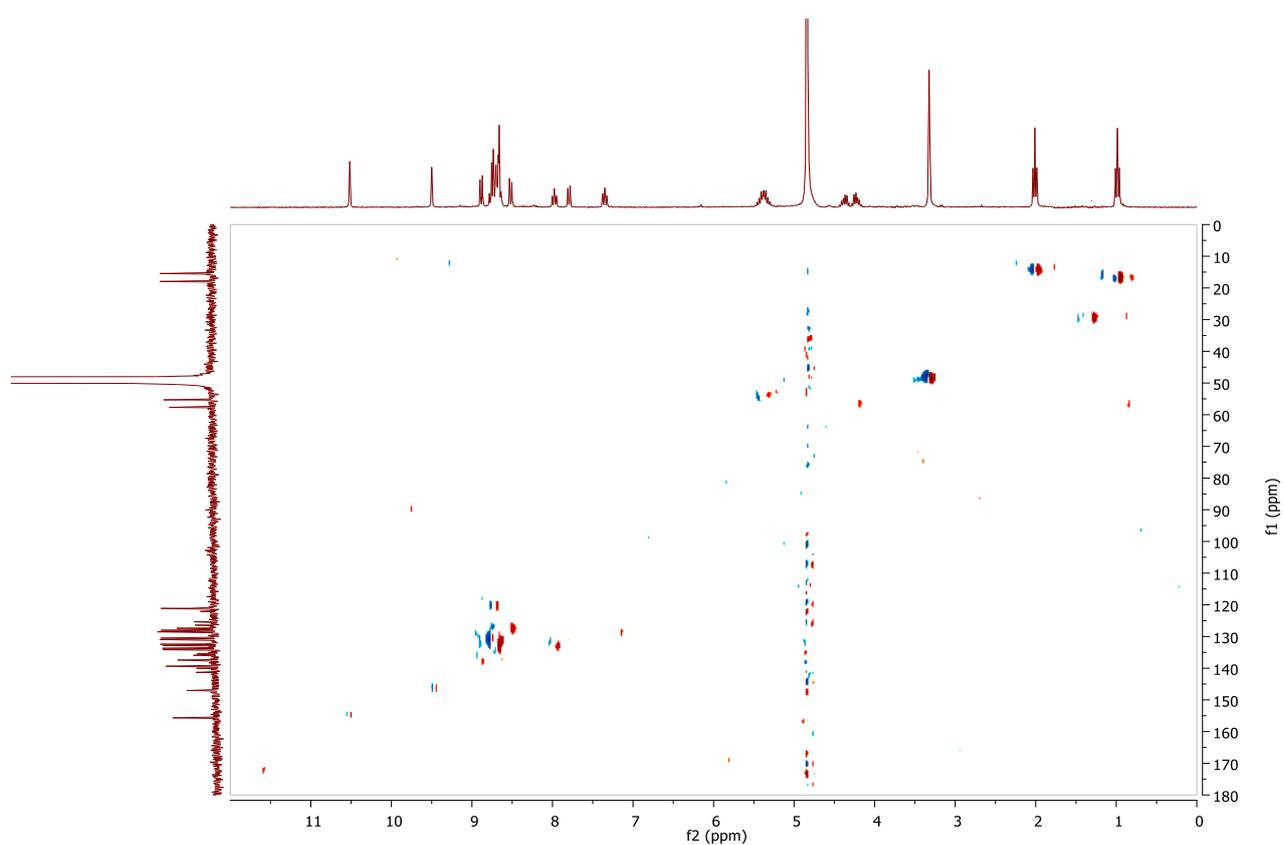


Figure S16 – HSQC of 8 in CD₃OD (300.14 MHz, CD₃OD).

SI.5 Synthesis of (\pm)-, (*P*)-, (*M*)-2-N-ethyl-2,12-diaza[6]helicenium bis(trifluoromethanesulfonyl) imidate.

A solution of silver bis(trifluoromethanesulfonyl)imide (3.5 mg, 9×10^{-3} mmol) in EtOH (0.2 ml) was dropped into a stirred solution of (\pm)-, (*P*)-, (*M*)-*N*-ethyl-2,12-diaza[6]helicenium iodide (4.4 mg, 9×10^{-3} mmol) in EtOH (0.2 mL). Stirring was continued for 72 h at room temperature to complete the reaction. During this time the precipitate was formed and this was removed by filtration and finally the filtrate was evaporated under reduced pressure and the corresponding product was obtained as a yellow waxy solid (5.8 mg, 100%). This assignment is based by spectroscopic experiments (^1H -NMR, ^{19}F NMR, ^{13}C NMR, COSY, NOESY, HSQC, HMBC).

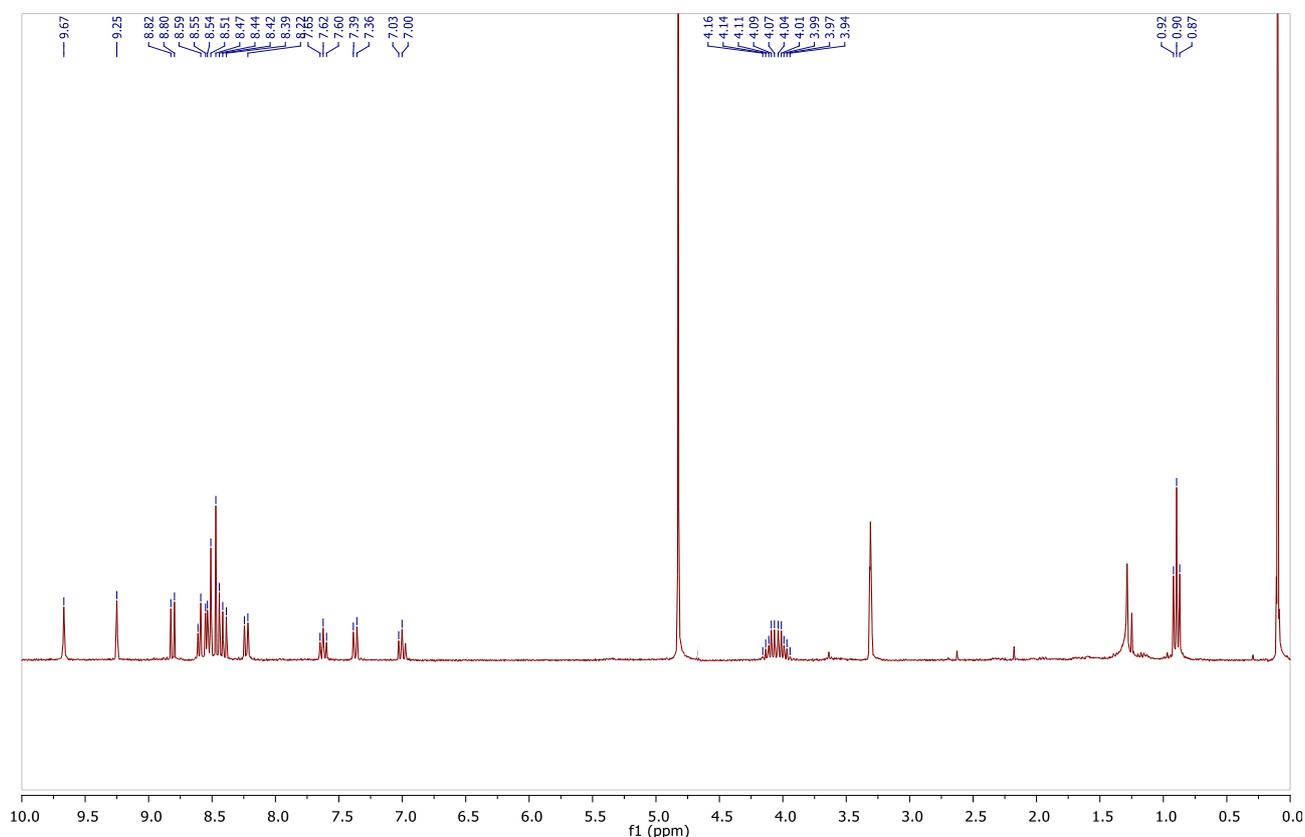


Figure S17 - ^1H -NMR of compound **9** (300.14 MHz, CD_3OD)

δ 9.67 (s, 1H, H in 11), 9.25 (s, 1H, H in 1), 8.81 (d, $^3J = 8.7$ Hz, 1H, H in 3), 8.63-8.37 (m, 7H), 8.23 (d, $^3J = 8.1$ Hz, 1H, H in 13), 7.62 (t, $^3J = 7.8$ Hz, 1H, H in 14), 7.37 (d, $^3J = 8.4$ Hz, 1H, H in 16), 7.00 (t, $^3J = 7.8$ Hz, 1H, H in 15), 4.20-3.93 (m, 2H, CH_2), 0.90 (t, $^3J = 7.4$ Hz, 1H, CH_3).

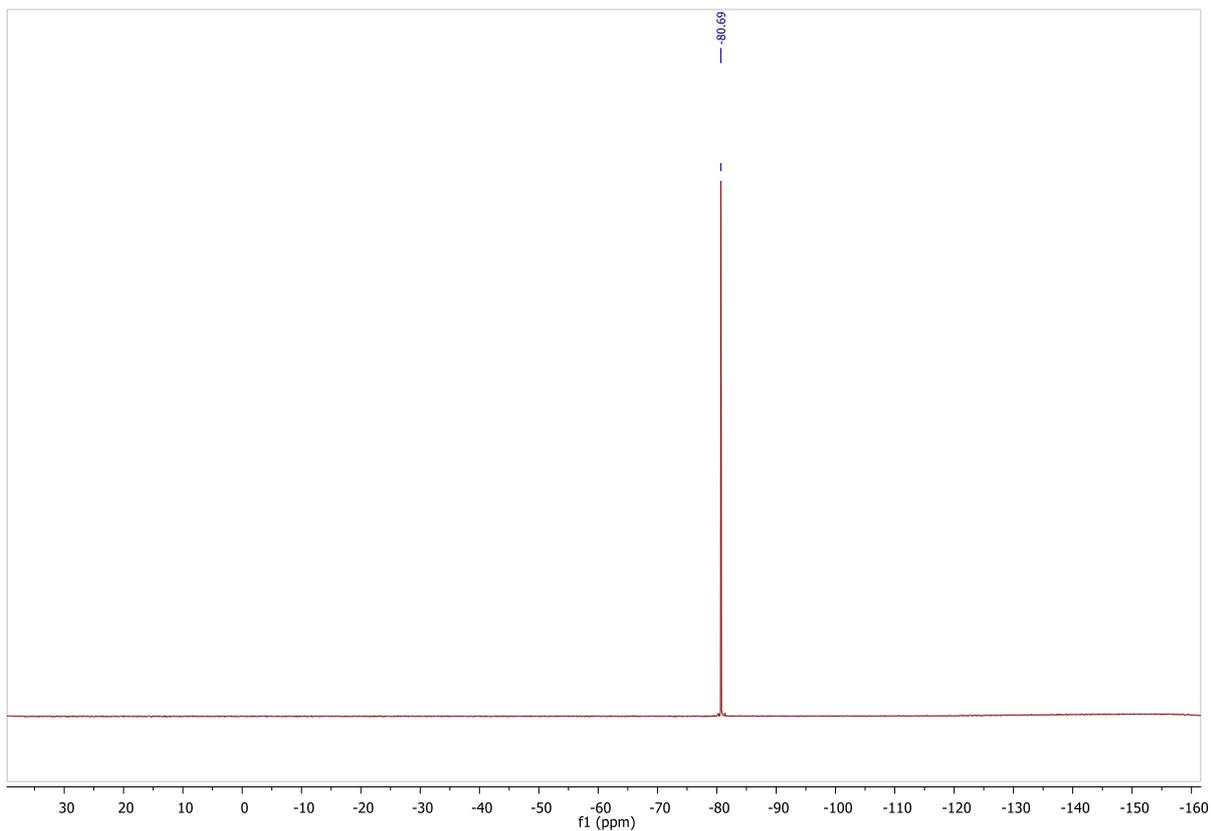


Figure S18 – ¹⁹F NMR (300.14 MHz, HZpPT(Hz)= 0.87, CD₃OD) δ -80.69 (s).

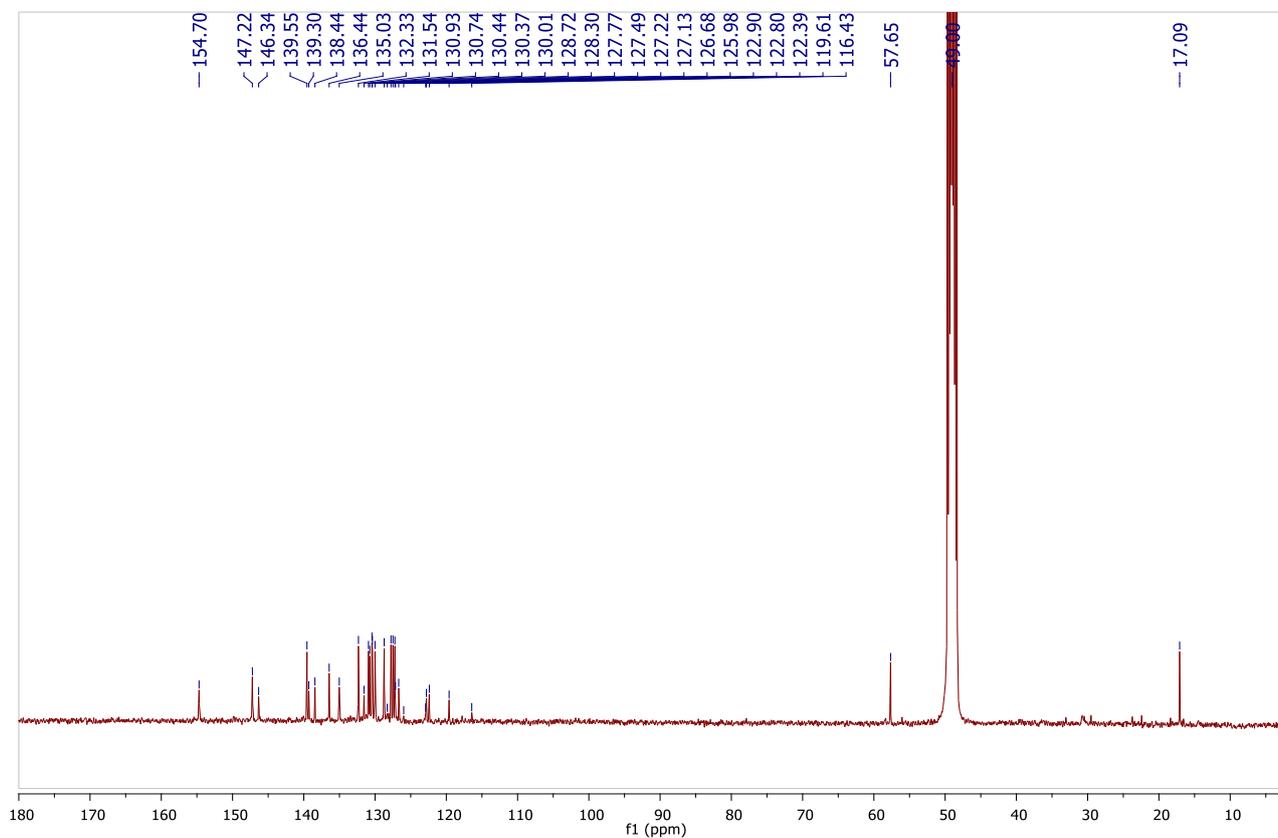


Figure S19 - APT NMR (100.62 MHz, CD₃OD)

δ 154.70 (s, CH, CH in 11), 147.22 (s, CH, CH in 1), 146.34 (s, C, C in 12a), 139.55 (s, CH), 139.30 (s, C), 138.44 (s, C), 136.44 (s, CH), 135.03 (s, C), 132.33 (s, CH), 131.54 (s, C), 130.93 (s, CH), 130.74 (s,

CH), 130.44 (s, CH), 130.37 (s, CH), 130.01 (s, CH), 128.72 (s, CH), 128.30 (br s, C), 127.77 (s, CH), 127.49 (s, CH), 127.22 (s, CH), 127.13 (s, C), 126.68 (s, C), 122.90 (br s, C, C in 12b), 122.39 (s, C), 121.20 (q, $^1J(\text{C},\text{F}) = 320.0$ Hz, CF_3), 57.65 (s, CH_2), 17.09 (s, CH_3).

SI.6 Synthesis of 2,12-*N,N'*-diethyl-2,12-diaza[6]helicene-2,12-dium bis(trifluoromethane sulfonyl) imidate .

A solution of (\pm)-, (*P*)-, (*M*)-*N,N'*-diethyl-2,12-diaza[6]helicenium diiodide (27.7 mg, $4.3 \cdot 10^{-2}$ mmol) in CH_3CN (4 mL) was dropped into a stirred solution of silver bis(trifluoromethanesulfonyl)imide (33.5 mg, $8.6 \cdot 10^{-2}$ mmol) in EtOH (1.5 ml). Stirring was continued for 4 days at room temperature to complete the reaction. During this time a precipitate was formed and was removed by filtration and finally the filtrate was evaporated under reduced pressure and the corresponding product was obtained as a yellow waxy solid (35.0 mg, 85%). $^1\text{H-NMR}$ (300,14 MHz, CD_3OD) δ 10.45 (s, 1H), 9.22 (s, 1H), 8.87 (d, $^3J = 9.0$ Hz, 1H), 8.74-8.62 (m, 7H), 8.50 (d, $^3J = 9.0$ Hz, 1H), 7.97 (t, $^3J = 9.0$ Hz, 1H), 7.80 (d, $^3J = 9.0$ Hz, 1H), 7.33 (t, $^3J = 9.0$ Hz, 1H), 5.48-5.23 (m, 2H), 4.24-4.03 (m, 2H), 1.95 (t, $^3J = 6.0$ Hz, 1H), 0.97 (t, $^3J = 6.0$ Hz, 1H); $^{19}\text{F NMR}$ (300,14 MHz, CD_3OD) δ -80.71 (s); APT NMR (75,48 MHz, CD_3CN); δ 153.60 (s), 145.80 (s), 140.25 (s), 139.12 (s), 138.34 (s), 136.38 (s), 134.89 (s), 134.85 (s), 134.31 (s), 133.51 (s), 133.06 (s), 132.76 (s), 132.22 (s), 131.55 (s), 130.85 (s), 130.16 (s), 129.92 (s), 129.78 (s), 127.83 (s), 127.23 (s), 126.70 (s), 126.47 (s), 125.75 (s), 125.41 (s), 122.15 (q, $^2J(\text{C},\text{F}) = 311.0$ Hz), 113.96 (s), 57.03 (s), 54.50 (s), 16.81 (s), 14.65 (s).

SI.7 Resolution of the enantiomers

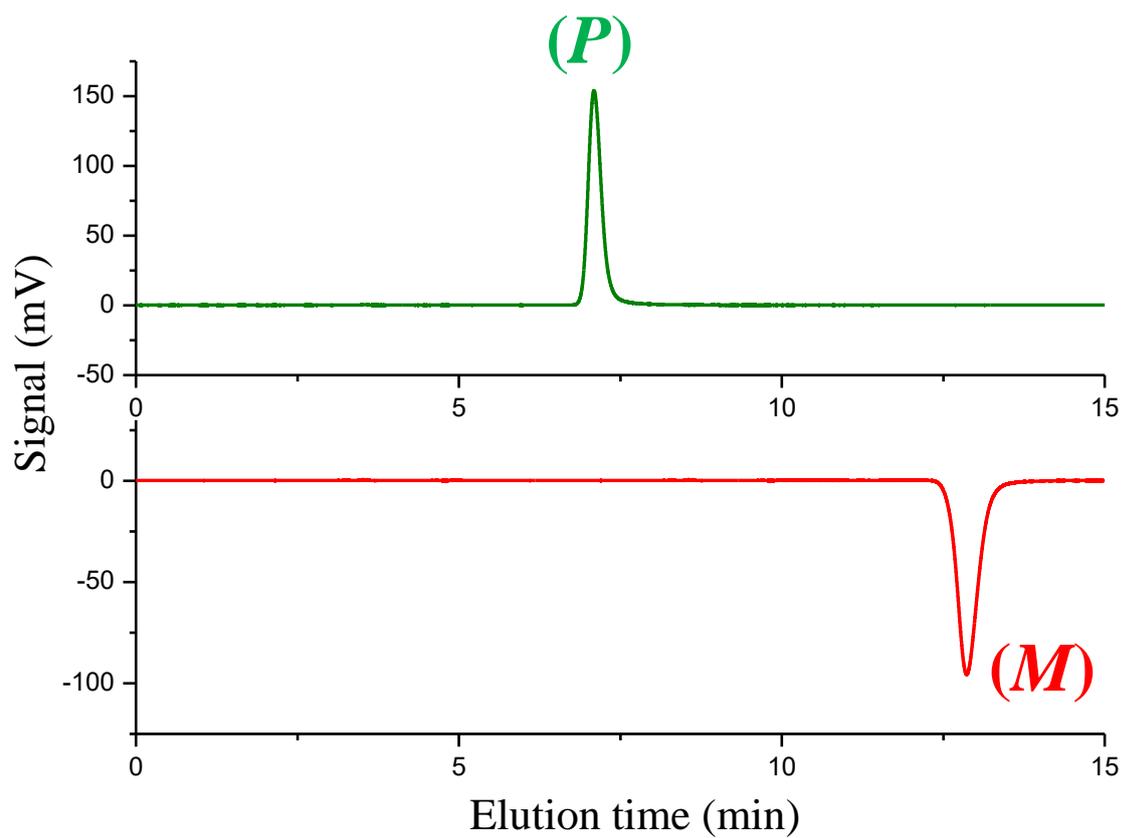


Figure S20. Enantioselective HPLC analysis of the enantiomers of 2,12-diaza[6]helicene isolated on a semipreparative scale. Chromatographic conditions: columns, Chiralpak IA (250 mm x 4.6 mm); mobile phase, n-hexane-acetone-2-propanol-diethylamine 50:50:0.2:0.2 (*v/v/v/v*); flow rate: 1.0 mL/min; temperature, 5 °C; detector, CD at 330 nm.

SI.8 Reproducibility Tests for (R)-Fc and (S)-Fc

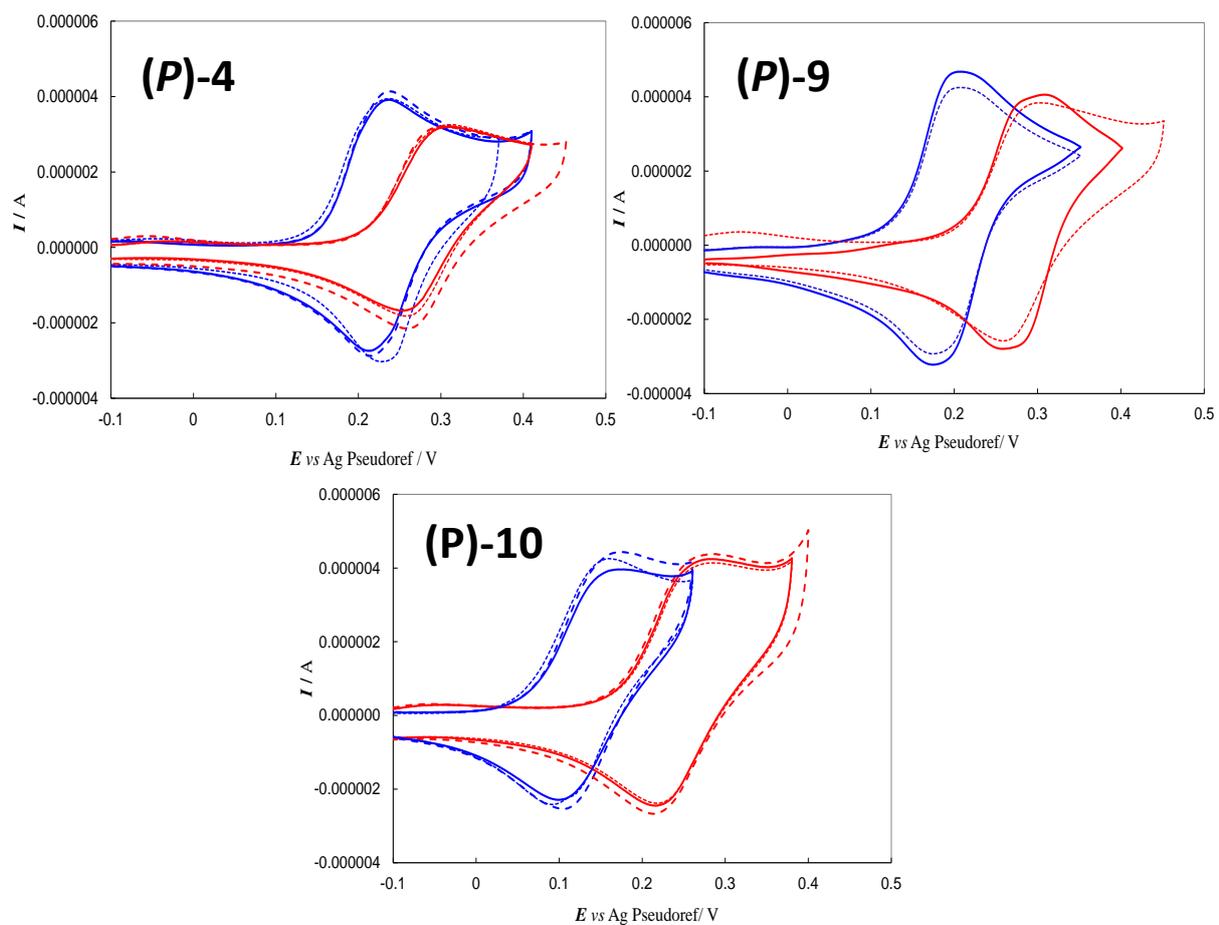


Figure S21. A synopsis of CV reproducibility checks for (R)-Fc (blue line) and (S)-Fc (red line) solutions on graphite SPE in BMIMTf₂N with (P)-4, (P)-9 and (P)-10 as low concentration chiral additives (0.02 M).