

Electronic Supplementary Information:

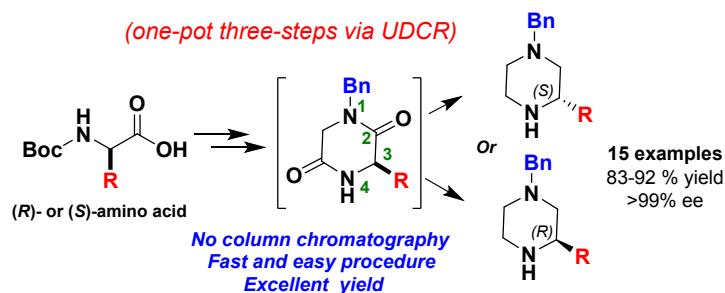
Efficient one-pot synthesis of enantiomerically pure *N*-protected- α -substituted piperazines from readily available α -amino acids

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1. General information

^1H and ^{13}C NMR spectra (25°C) were recorded at 250 MHz and 63 MHz on a Bruker Avance DRX 250 spectrometer. Chemical shifts are in parts per million (ppm). HRMS data was recorded with a Micromass QTOF-micro system. Mass spectra were recorded with a LCMS-MS triple-quadrupole system. (I) Analytical HPLC was performed on an Agilent 1100 Series system with a Supelco Discovery BIO Wide Pore RP column (25 cm $\times$ 4.6 mm, 5 μm). Flow rates of 1 ml/min were used and detection was done at 215 nm. The solvent system consisted of 0.1% TFA in water (A) and 0.1% TFA in acetonitrile (B). The gradient consisted of a 20 min. run from 3% B to 97% B. (II) Analytical RP-HPLC were carried out on a Chromaster system (VWR Hitachi) using a Chromolith HighResolution RP-18e column from Merck (150 Å, 1.1 μm , 50 $\times$ 4.6 mm) or on an Agilent 1100 Series system (Waldbronn, Germany) with a SUPELCO Discovery BIO Wide Pore® (Bellefonte, PA, USA) RP C-18 column (15 cm $\times$ 2.1 mm, 3 μm) using UV detection at 215 nm. The mobile phase was a mixture of water (A) and acetonitrile (B) both containing 0.1% TFA (v/v). The standard gradients are from 1 to 100% B/A over 4 min at 3 mL/min for the VWR Hitachi system or from 3 to 97% B/A over 20 min at 0.3 mL/min for the Agilent system. Glass plates with silica gel 60 F254 (Merck) were used for thin layer chromatography. Visualization of the products on TLC plates was realized using UV light (254 nm), KMnO_4 spray. Melting points were determined on a Büchi B-540 apparatus and are uncorrected. Reactions were performed using a Biotage® Initiator⁺ Microwave Synthesizer. All commercial reagents and solvents were used without further purification. Specific rotations were measured on a polarimeter polartronic M Schmidt-Haensch using a 5 cm cell in standard conditions (20°C / 589.3 nm^{air} / 589.44 nm^{vac}).

2. General procedure for one-pot tandem Ugi-4CR/boc-deprotection/lactamization/reduction sequence (2a-n).

In a 5 mL microwave-vessel containing a stirring bar, the *N*-Boc protected (*L/D*)-amino acids (0.5 mmol), the aldehyde (0.5 mmol) and the amine (0.5 mmol) were dissolved and mixed in methanol (3 mL). The solution was stirred at room temperature for 30 min. Isocyanide (0.5 mmol) was then added, and the resulting mixture was stirred at room temperature. After 6 hours, total conversion was determined from LC-MS analysis and the solvent was removed in vacuo. The crude Ugi-4CR product was dissolved in glacial acetic acid (3 mL each) and the reaction vessels were capped and heated at 160 °C for 2 hours. After completion the tandem *N*-Boc deprotection and lactamization steps (monitored by HPLC and LC-MS), the solvent was evaporated in vacuo. Next, the crude deprotected Ugi product was dissolved in THF (2 mL) and were slowly added at 0 °C to a suspension of LiAlH₄ (2 mmol) in THF (2 mL). The resulting mixture was stirred at 0 °C for one hour and at room temperature for an additional hour. The reaction mixture was then quenched with saturated MgSO₄ solution (2 mL) and with diethyl ether (8 mL). After filtration through celite, the solution was extracted with H₂O (3 X 3 mL), sat. NaHCO₃ (3 X 3 mL), sat. NaCl (3 X 3 mL), dried over MgSO₄ and the solvent was removed under reduced pressure. The resulting piperazine products (**2a-n**) were isolated in excellent purity and yields without further purification. Purity (%) was determined by reversed phase HPLC, using UV detection (215 nM).

3. Synthesis of *N,N*-diprotected 2-substituted piperazine (3)

Boc₂O (66 mg, 0.3 mmol, 1 equiv) was added to a stirred solution of the (*S*)-1,3-Dibenzylpiperazine **2g** (80 mg, 0.3 mmol, 1 equiv) and Et₃N (45 µL, 0.3 mmol, 1 equiv) in CH₂Cl₂ (2 mL) at room temperature. The reaction was allowed to stir for 18 h. The solution was successively washed with 1 N HCl (3 mL), H₂O (3 mL) and brine (3 mL). The organic layer phase was dried over MgSO₄ and concentrated to dryness under vacuum to give compound **3** (107 mg, 96 %) as a colourless oil.

4. Synthesis of *N*-boc-2-substituted piperazine (4)

10 % Pd on charcoal (32 mg) was added to a solution of **5** (74 mg, 0.2 mmol) in MeOH (2 mL). The reaction was stirred under a H₂-atmosphere at room temperature for 12 h. Filtration over celite and concentration to dryness under vacuum gave **4** (55 mg, 99 %) quantitatively as a colourless oil.

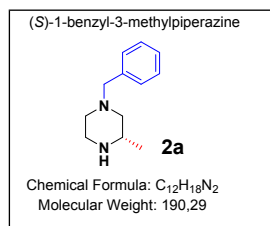
5. Synthesis of *N*-benzyl-3-phenyl diketopiperazine (7)

In a 5 mL microwave-vessel containing a stirring bar, the *N*-Boc-(*L*)-phenylglycine (0.5 mmol), the paraformaldehyde (0.5 mmol) and the methylamine chlorhydrate (0.5 mmol) were dissolved and mixed in methanol (3 mL). The solution was stirred at room temperature for 30 min. Isocyanide (0.5 mmol) was then added, and the resulting mixture was stirred at room temperature. After 6 hours, total conversion was determined from LC-MS analysis and the solvent was removed in vacuo. The crude Ugi-4CR product was dissolved in glacial acetic acid (3 mL each) and the reaction vessel was capped and heated at 160 °C for 2 hours. After completion the tandem *N*-Boc deprotection and lactamization steps, the mixture was poured into water (3 mL), and the resulting thick precipitates were collected by filtration. The resulting diketopiperazine **7** was isolated in excellent purity and yield (130 mg, 88 %).

Purity (%) was determined by reversed phase HPLC, using UV detection (215 nM).

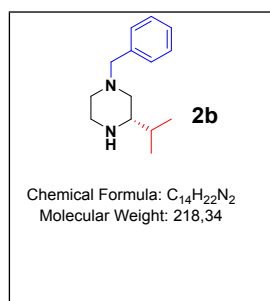
6. Characterization of compounds (2a-n).

(S)-1-benzyl-3-methylpiperazine (2a):



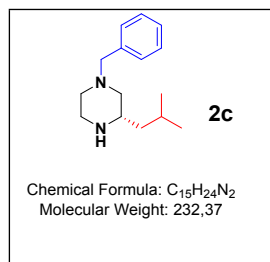
Yield (80 mg, 84 %). Colourless oil. $[\alpha]_D = -25.5^\circ$ ($c = 0.4$, $CHCl_3$). 1H NMR ($CDCl_3$, 250 MHz): δ 0.90 (d, $J = 6.5$ Hz, 3H); 1.57 (t, $J = 10.3$ Hz, 1H); 1.79-1.97 (m, 2H); 2.60-2.85 (m, 5H); 3.38 (s, 2H); 7.11-7.24 (m, 5H). ^{13}C NMR ($CDCl_3$, 63 MHz): δ 19.9; 45.8; 50.5; 53.6; 61.2; 63.4; 127.0; 128.2; 129.2; 138.1. rt(HPLC) = 5.94 min (26 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{19}N_2$ 191.1543; found 191.1554.

(S)-1-benzyl-3-isopropylpiperazine (2b):



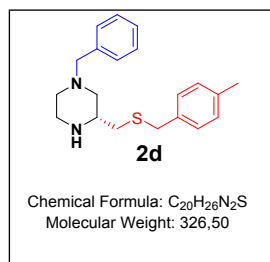
Yield (99 mg, 87 %). Colourless oil. $[\alpha]_D = +32.2^\circ$ ($c = 0.5$, $CHCl_3$). 1H NMR ($CDCl_3$, 250 MHz): δ 0.78 (d, $J = 6.8$ Hz, 3H); 0.82 (d, $J = 6.8$ Hz, 3H); 1.14-1.28 (m, 1H); 1.33-1.52 (m, 1H); 1.67 (t, $J = 11.2$ Hz, 1H); 1.81-1.93 (m, 1H); 2.31-2.44 (m, 1H); 2.55-2.89 (m, 4H); 3.33 (d, $J = 13.2$ Hz, 1H); 3.45 (d, $J = 13.2$ Hz, 1H); 7.08-7.25 (m, 5H). ^{13}C NMR ($CDCl_3$, 63 MHz): δ 19.0; 19.2; 31.4; 45.9; 53.7; 57.7; 60.8; 63.6; 126.9; 128.1; 129.1; 138.1. rt(HPLC) = 7.79 min (26 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for $C_{14}H_{23}N_2$ 219.1856; found 219.1835.

(S)-1-benzyl-3-isobutylpiperazine (2c):



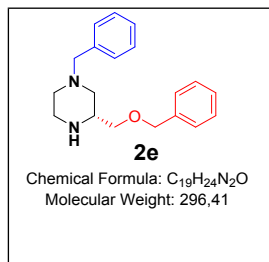
Yield (102 mg, 88 %). Colourless oil. $[\alpha]_D = +28.8^\circ$ ($c = 0.5$, $CHCl_3$). 1H NMR ($CDCl_3$, 250 MHz): δ 0.80 (d, $J = 3.5$ Hz, 3H); 0.83 (d, $J = 3.5$ Hz, 3H); 1.01-1.27 (m, 2H); 1.51-1.70 (m, 2H); 1.88-2.02 (m, 3H); 2.64-2.95 (m, 4H); 3.38 (d, $J = 13.3$ Hz, 1H); 3.47 (d, $J = 13.3$ Hz, 1H); 7.17-7.27 (m, 5H). ^{13}C NMR ($CDCl_3$, 63 MHz): δ 22.4; 23.2; 29.7; 43.5; 45.7; 52.9; 53.7; 60.3; 63.5; 127.0; 128.2; 129.2; 138.0. rt(HPLC) = 1.56 min (4 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for $C_{15}H_{25}N_2$ 233.2012; found 233.1988.

(R)-1-benzyl-3-(((4-methylbenzyl)thio)methyl)piperazine (2d):



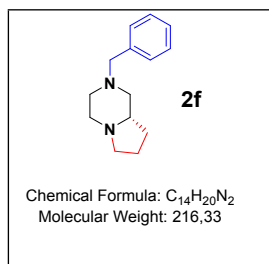
Yield (138 mg, 85 %). Yellow oil. $[\alpha]_D = +42.1^\circ$ ($c = 0.7$, $CHCl_3$). 1H NMR ($CDCl_3$, 250 MHz): δ 1.68 (t, $J = 10.0$ Hz, 1H); 1.93-2.03 (m, 1H); 2.22 (s, 3H); 2.23-2.39 (m, 3H); 2.57-2.89 (m, 5H); 3.39 (s, 2H); 3.55 (s, 2H); 6.98-7.22 (m, 9H). ^{13}C NMR ($CDCl_3$, 63 MHz): δ 21.2; 35.6; 36.1; 45.5; 53.4; 58.9; 63.3; 127.1; 128.3; 128.8; 129.2; 129.3; 135.0; 136.7; 138.0. rt(HPLC) = 2.12 min (4 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for $C_{20}H_{27}N_2S$ 327.1889; found 327.1868.

((R)-1-benzyl-3-((benzyloxy)methyl)piperazine (2e):



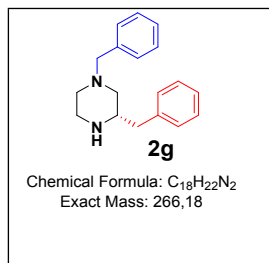
Yield (164 mg, 83 %). Colourless oil. $[\alpha]_D^{25} = +19.8^\circ$ ($c = 0.5$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 1.77 (t, $J = 10.5$ Hz, 1H); 1.97-2.07 (m, 1H); 2.55-2.70 (m, 3H); 2.89-3.03 (m, 3H); 3.24-3.39 (m, 2H); 3.40 (s, 2H); 4.39 (s, 2H); 7.10-7.29 (m, 10H). ¹³C NMR (CDCl₃, 63 MHz): δ 45.2; 53.7; 54.7; 55.8; 63.4; 72.6; 73.4; 127.1; 127.7; 127.8; 128.2; 128.4; 129.2; 138.0; 138.1. rt(HPLC) = 1.79 min (4 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₉H₂₅N₂O 297.1961; found 297.1940.

(S)-2-benzyl-3-benzylpyrrolidine (2f):



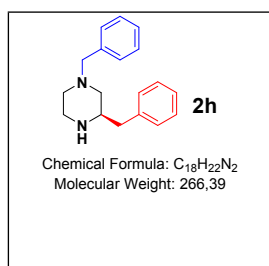
Yield (97 mg, 90 %). Colourless oil. $[\alpha]_D^{25} = +44.3^\circ$ ($c = 0.35$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 1.30-1.46 (m, 1H); 1.64-1.91 (m, 4H); 2.00-2.20 (m, 2H); 2.22-2.35 (m, 2H); 2.75-2.84 (m, 1H); 2.91-3.10 (m, 3H); 3.52 (d, $J = 12.8$ Hz, 1H); 3.59 (d, $J = 12.8$ Hz, 1H); 7.23-7.34 (m, 5H). ¹³C NMR (CDCl₃, 63 MHz): δ 21.4; 27.5; 51.6; 52.6; 53.3; 57.8; 62.7; 62.9; 127.0; 128.2; 128.8; 129.2; 138.3. rt(HPLC) = 1.16 min (4 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₄H₂₁N₂ 217.1699; found 217.1773.

(S)-1,3-dibenzylpiperazine (2g):



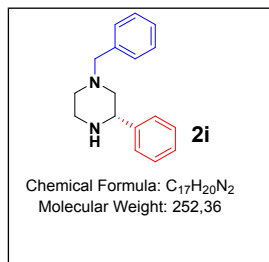
Yield (115 mg, 87 %). Colourless oil. $[\alpha]_D^{25} = +34.7^\circ$ ($c = 0.6$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 1.92 (t, $J = 10.5$ Hz, 1H); 1.96-2.02 (m, 2H); 2.39-2.42 (m, 1H); 2.44-2.80 (m, 5H); 2.83-2.94 (m, 1H); 3.34 (d, $J = 13.0$ Hz, 1H); 3.43 (d, $J = 13.0$ Hz, 1H); 7.06-7.21 (m, 10H). ¹³C NMR (CDCl₃, 63 MHz): δ 40.9; 45.8; 53.4; 56.3; 59.7; 63.4; 126.4; 127.1; 128.3; 128.6; 129.2; 129.3; 138.2; 138.6. rt(HPLC) = 9.85 min (26 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₈H₂₃N₂ 267.1856; found 267.1832.

(R)-1,3-dibenzylpiperazine (2h):



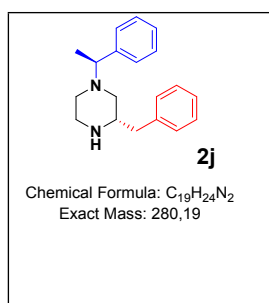
Yield (110 mg, 83 %). Colourless oil. $[\alpha]_D^{25} = -35.3^\circ$ ($c = 0.55$, CHCl₃). ¹H NMR (CDCl₃, 300 MHz): δ 1.90 (t, $J = 10.5$ Hz, 1H); 1.99-2.09 (m, 2H); 2.43-2.57 (m, 1H); 2.60-2.85 (m, 5H); 2.90-3.02 (m, 1H); 3.41 (d, $J = 13.0$ Hz, 1H); 3.49 (d, $J = 13.0$ Hz, 1H); 7.047-7.33 (m, 10H). ¹³C NMR (CDCl₃, 63 MHz): δ 40.9; 45.8; 53.4; 56.3; 59.7; 63.4; 126.4; 127.1; 128.3; 128.6; 129.2; 129.3; 138.2; 138.6. rt(HPLC) = 1.68 min (4 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₈H₂₃N₂ 267.1856; found 267.1827..

(S)-1-benzyl-3-phenylpiperazine (2i):



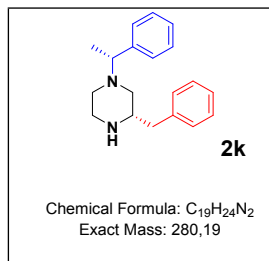
Yield (116 mg, 92 %). Colourless oil (100%). $[\alpha]_D = -27.5^\circ$ ($c = 0.45$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 1.75 (br s, 1H); 1.93 (t, $J = 10.5$ Hz, 1H); 2.02-2.14 (m, 1H); 2.69-2.85 (m, 2H); 2.92-2.99 (m, 2H); 3.44 (s, 2H); 3.76-3.81 (m, 1H); 7.10-7.30 (m, 10H). ¹³C NMR (CDCl₃, 63 MHz): δ 46.3; 53.3; 60.4; 61.3; 63.4; 127.2; 127.5; 128.3; 128.4; 129.3; 138.0; 142.7. rt(HPLC) = 1.61 min (4 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for C₁₇H₂₁N₂ 253.1699; found 253.1666.

(S)-3-benzyl-1-((S)-1-phenylethyl)piperazine (2j):



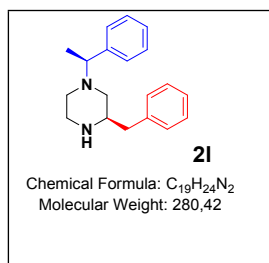
Yield (121mg, 87 %). Pale yellow oil. $[\alpha]_D = +25.6^\circ$ (c 0.6, CHCl₃). ¹H NMR (250 MHz, CDCl₃) δ 1.38 (d, $J = 7.0$ Hz, 3H); 1.83 (brs, 1H); 1.93 (t, $J = 10.5$ Hz, 1H); 2.14 (t, $J = 8.5$ Hz, 1H); 2.10-2.18 (m, 1H); 2.63 (dd, $J = 13.8, 4.3$ Hz, 1H); 2.72-2.96 (m, 5H); 3.42 (q, $J = 7.0$ Hz, 1H), 7.15-7.37 (m, 10H). ¹³C NMR (63 MHz, CDCl₃) δ 19.3; 40.9; 46.0; 50.4; 56.5; 57.3; 64.9; 126.3; 126.9; 127.7; 128.3; 128.5; 129.2; 138.7; 143.9. rt(HPLC) = 10.21 min (26 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for C₁₉H₂₅N₂ 281.2012; found 281.1991.

(S)-3-benzyl-1-((R)-1-phenylethyl)piperazine (2k):



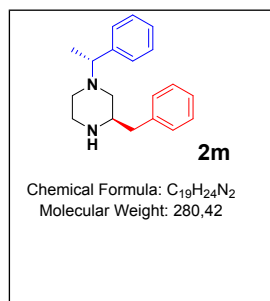
Yield (127 mg, 91 %); Pale yellow oil; $[\alpha]_D = +33.7^\circ$ (c 0.5, CHCl₃); ¹H NMR (250 MHz, CDCl₃) δ 1.36 (d, $J = 7.0$ Hz, 3H); 1.85 (brs, 1H); 1.94 (t, $J = 10.0$ Hz, 1H); 1.97-2.03 (m, 1H); 2.51-2.87 (m, 5H); 2.95-3.06 (m, 2H); 3.37 (q, $J = 7.0$ Hz, 1H), 7.17-7.34 (m, 10H). ¹³C NMR (63 MHz, CDCl₃) δ 19.6; 41.1; 46.0; 51.0; 56.6; 56.8; 65.1; 126.4; 126.9; 127.7; 128.2; 128.5; 129.2; 138.7; 143.8. rt(HPLC) = 1.78 min (4 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for C₁₉H₂₅N₂ 281.2012; found 281.1476.

(R)-3-benzyl-1-((S)-1-phenylethyl)piperazine (2l):



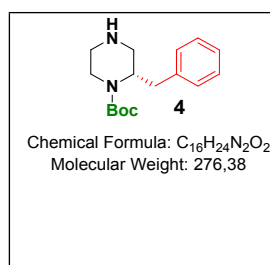
Yield (120 mg, 87 %); Pale yellow oil; $[\alpha]_D = -28.6^\circ$ (c 0.55, CHCl₃); ¹H NMR (250 MHz, CDCl₃) δ 1.35 (d, $J = 7.0$ Hz, 3H); 1.70 (brs, 1H); 1.82-2.03 (m, 2H); 2.50-2.84 (m, 5H); 2.92-3.06 (m, 2H); 3.36 (q, $J = 7.0$ Hz, 1H), 7.16-7.32 (m, 10H). ¹³C NMR (63 MHz, CDCl₃) δ 19.6; 41.0; 46.0; 51.0; 56.6; 56.8; 65.1; 126.4; 126.9; 127.8; 128.3; 128.6; 129.3; 138.7; 143.7. rt(HPLC) = 1.73 min (4 min); HRMS-ESI (m/z): $[M+H]^+$ calcd for C₁₉H₂₅N₂ 281.2012; found 281.1913.

(R)-3-benzyl-1-((R)-1-phenylethyl)piperazine (2m):



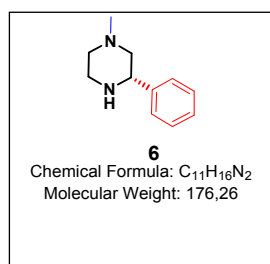
Yield (118 mg, 85 %). Colourless oil. $[\alpha]_D = -22.9^\circ$ ($c = 0.6$, CHCl₃). ¹H NMR (250 MHz, CDCl₃) δ 1.35 (d, $J = 6.8$ Hz, 3H); 1.57 (brs, 1H); 1.79 (t, $J = 10.5$ Hz, 1H); 2.11 (dt, $J = 18.0, 4.3$ Hz, 1H); 2.42 (dd, $J = 13.3, 9.5$ Hz, 1H); 2.72-2.95 (m, 6H); 3.39 (q, $J = 6.8$ Hz, 1H), 7.15-7.37 (m, 10H). ¹³C NMR (63 MHz, CDCl₃) δ 19.2; 40.8; 46.1; 50.4; 56.5; 57.3; 64.9; 126.3; 126.9; 127.7; 128.2; 128.5; 129.2; 138.7; 143.9. rt(HPLC) = 1.73 min (4 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₉H₂₅N₂ 281.2012; found 281.1868.

tert-butyl (S)-2-benzylpiperazine-1-carboxylate (4)



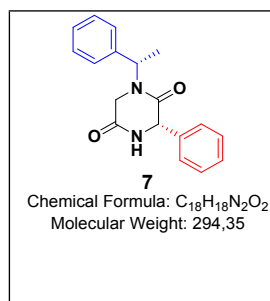
Yield (55 mg, 95 % over two steps). Colourless oil. $[\alpha]_D = +34.6^\circ$ ($c = 0.55$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 1.27 (s, 9H); 2.56-2.74 (m, 2H); 2.80-3.19 (m, 5H); 3.85-3.91 (m, 1H); 4.17 (brs, 1H); 4.82 (br s, 1H); 7.04-7.24 (m, 5H). ¹³C NMR (CDCl₃, 63 MHz): δ 28.2; 35.1; 38.7; 45.2; 46.3; 52.2; 79.8; 126.3; 128.4; 129.3; 138.5; 154.4. rt(HPLC) = 12.28 min (26 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₆H₂₅N₂O₂ 277.1910; found 277.1880.

(S)-1-methyl-3-phenylpiperazine (6)



Yield (76 mg, 86 %). Colourless oil. $[\alpha]_D = +45.6^\circ$ ($c = 0.65$, CHCl₃). ¹H NMR (CDCl₃, 250 MHz): δ 2.02 (t, $J = 10.5$ Hz, 1H); 2.16 (dt, $J = 10.5, 3.3$ Hz, 1H); 2.32 (s, 3H); 2.55 (brs, 1H); 2.80-2.90 (m, 2H); 2.99-3.15 (m, 2H); 3.88 (dd, $J = 10.5, 3.0$ Hz, 1H); 7.20-7.42 (m, 5H). ¹³C NMR (CDCl₃, 63 MHz): δ 46.1; 46.2; 55.1; 60.3; 63.1; 127.0; 127.5; 128.4; 142.2. rt(HPLC) = 0.67 min (4 min); HRMS-ESI (m/z): [M+H]⁺ calcd for C₁₁H₁₇N₂ 177.1386; found 177.1363.

(S)-3-phenyl-1-((S)-1-phenylethyl)piperazine-2,5-dione (7)



Yield (129 mg, 88 %). White solid. $[\alpha]_D = +5.8^\circ$ ($c = 0.5$, CHCl₃). mp= 220–222 °C. ¹H NMR (DMSO-d₆, 250 MHz): δ 1.40 (d, $J = 8.0$ Hz, 3H); 3.33 (d, $J = 17.5$ Hz, 1H); 4.03 (d, $J = 17.5$ Hz, 1H); 5.10 (d, $J = 3.0$ Hz, 1H); 5.74 (q, $J = 8.0$ Hz, 1H); 7.23-7.52 (m, 10H); 8.85 (brs, 1H). ¹³C NMR (DMSO-d₆, 63 MHz): δ 15.2; 44.0; 50.0; 58.7; 126.6; 127.0; 127.6; 128.0; 128.6; 128.7; 138.5; 139.2; 164.6; 165.5. rt(HPLC) = 2.23 min (4 min); [(M+H)] = 294.8828

5. NMR Spectra

(2a): ^1H NMR (250 MHz, CDCl_3)

7.239
7.113

3.383

2.849

2.600

1.970

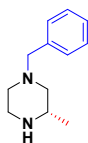
1.789

1.610

1.569

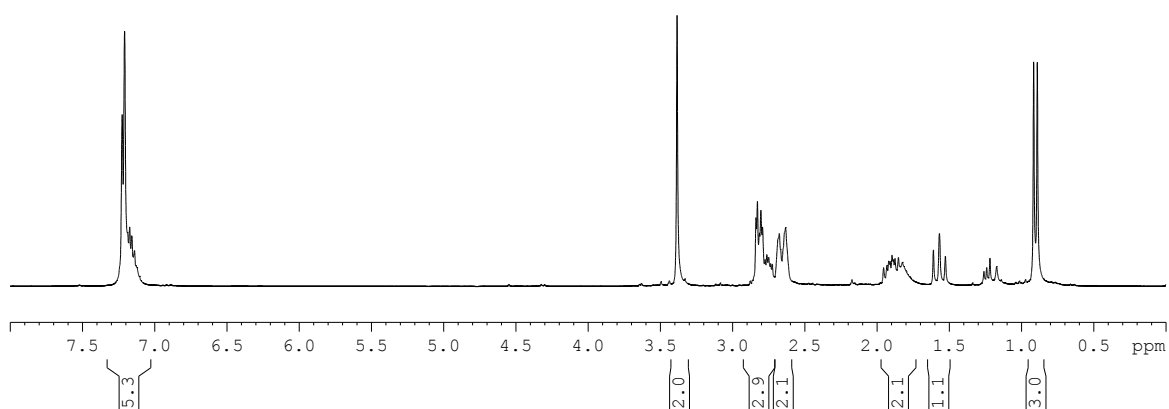
1.525

0.916
0.890



2a

Chemical Formula: $\text{C}_{12}\text{H}_{18}\text{N}_2$



(2a): ^{13}C NMR (63 MHz, CDCl_3)

138.08

129.16

128.16

126.97

77.77

77.26

76.75

63.37

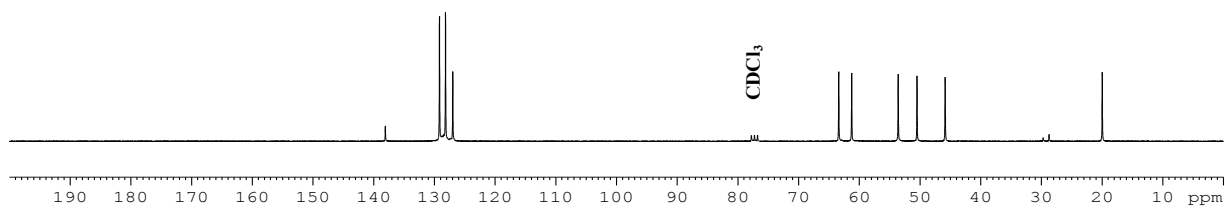
61.24

53.57

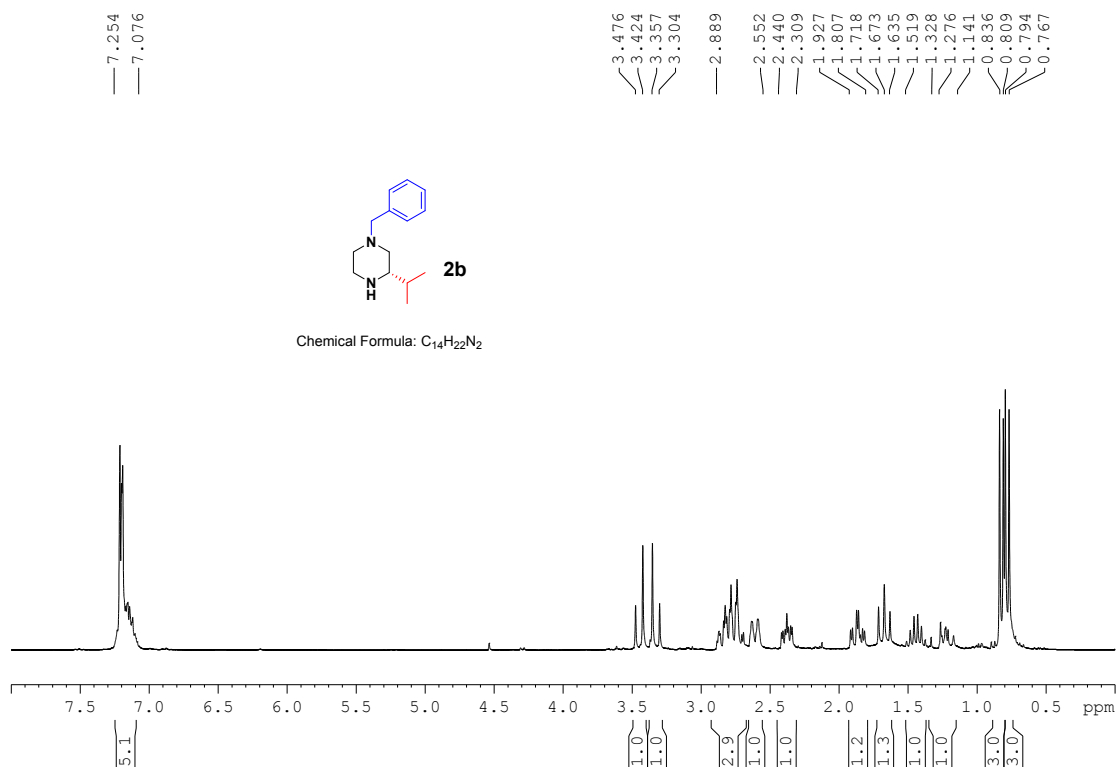
50.48

45.84

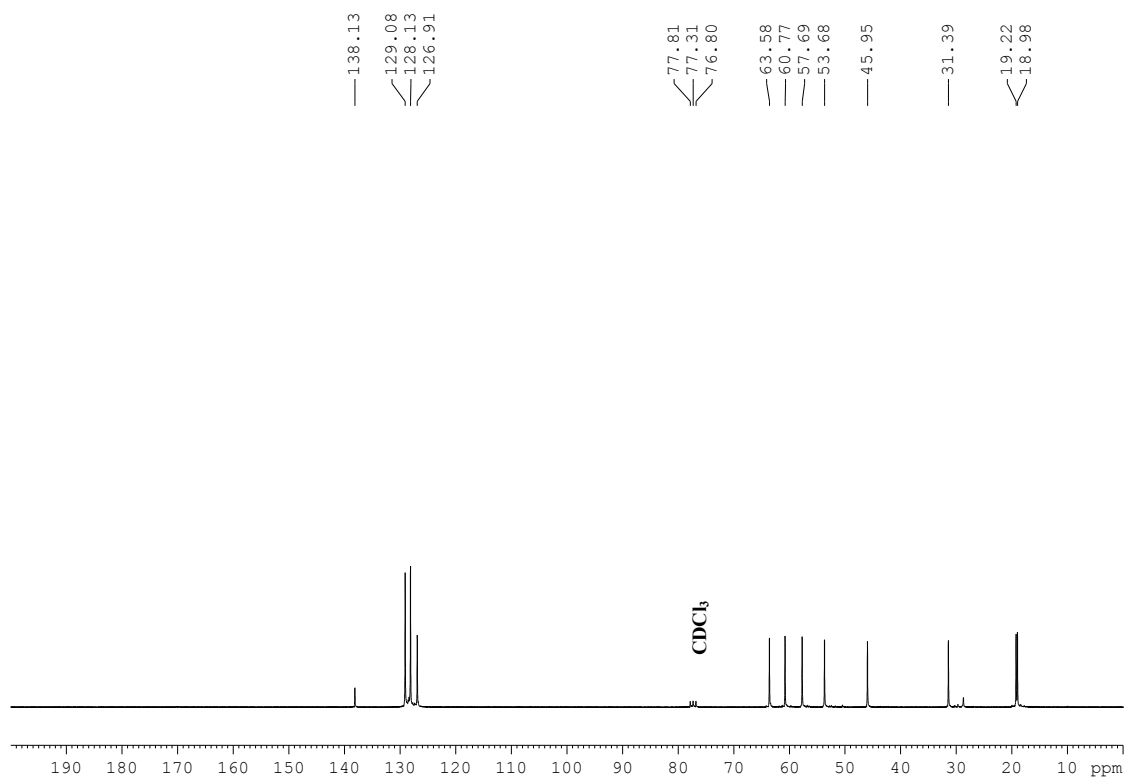
19.95



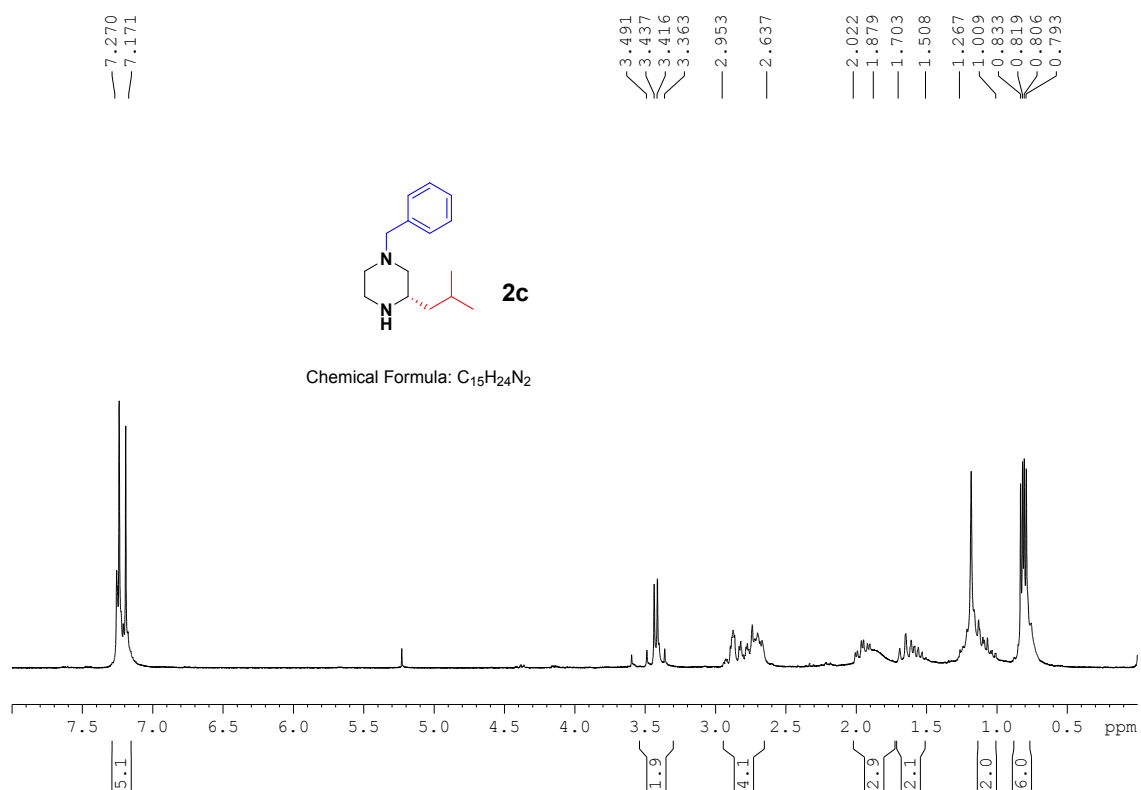
(2b): ^1H NMR (250 MHz, CDCl_3)



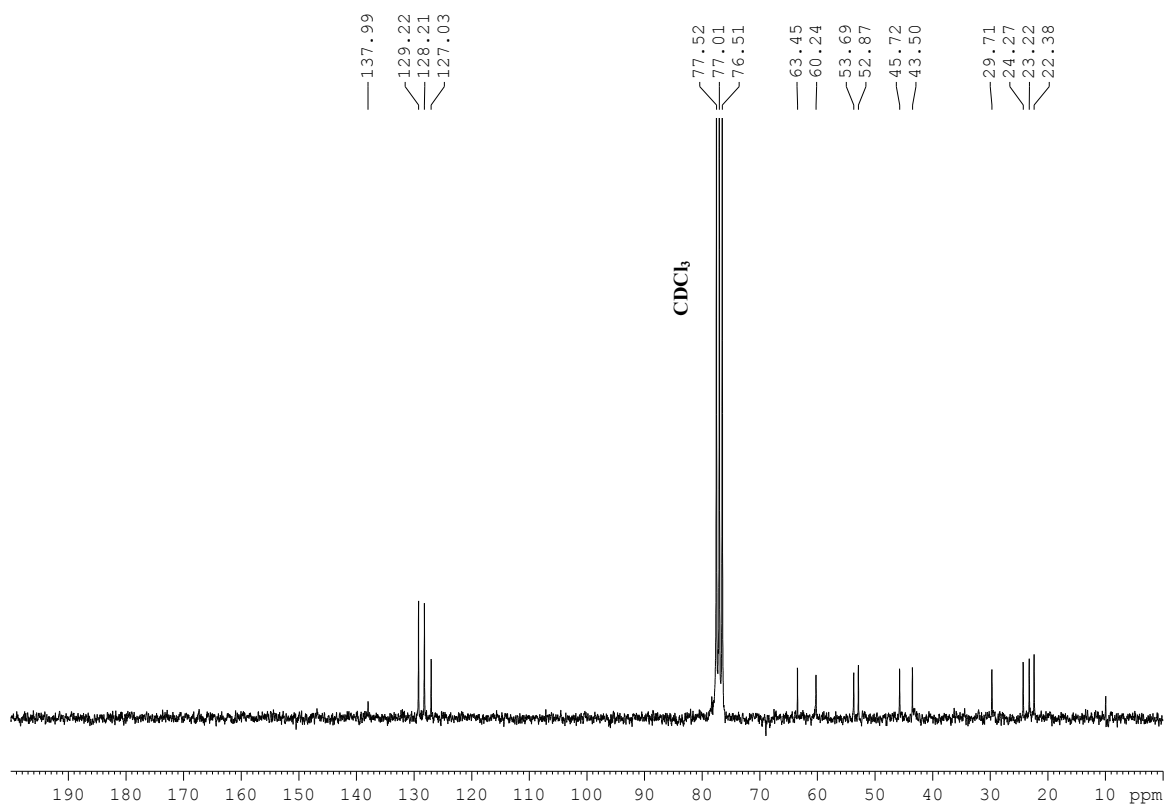
(2b): ^{13}C NMR (63 MHz, CDCl_3)



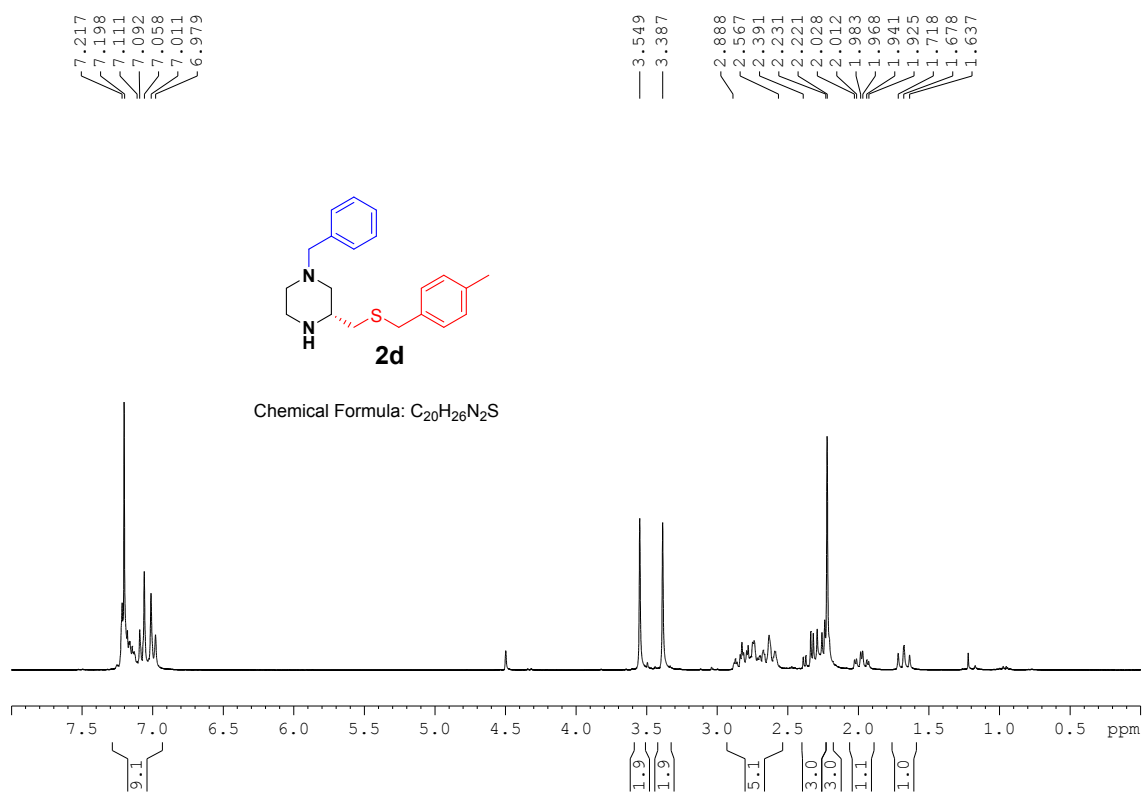
(2c): ^1H NMR (250 MHz, CDCl_3)



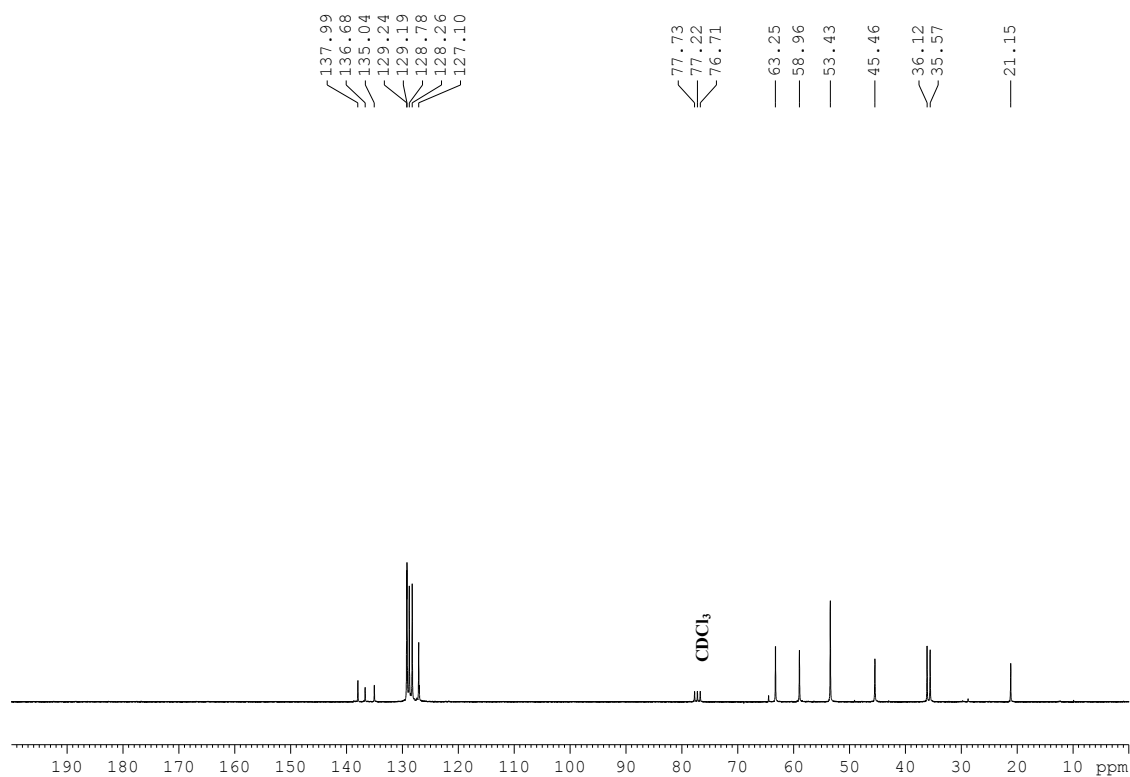
(2c): ^{13}C NMR (63 MHz, CDCl_3)



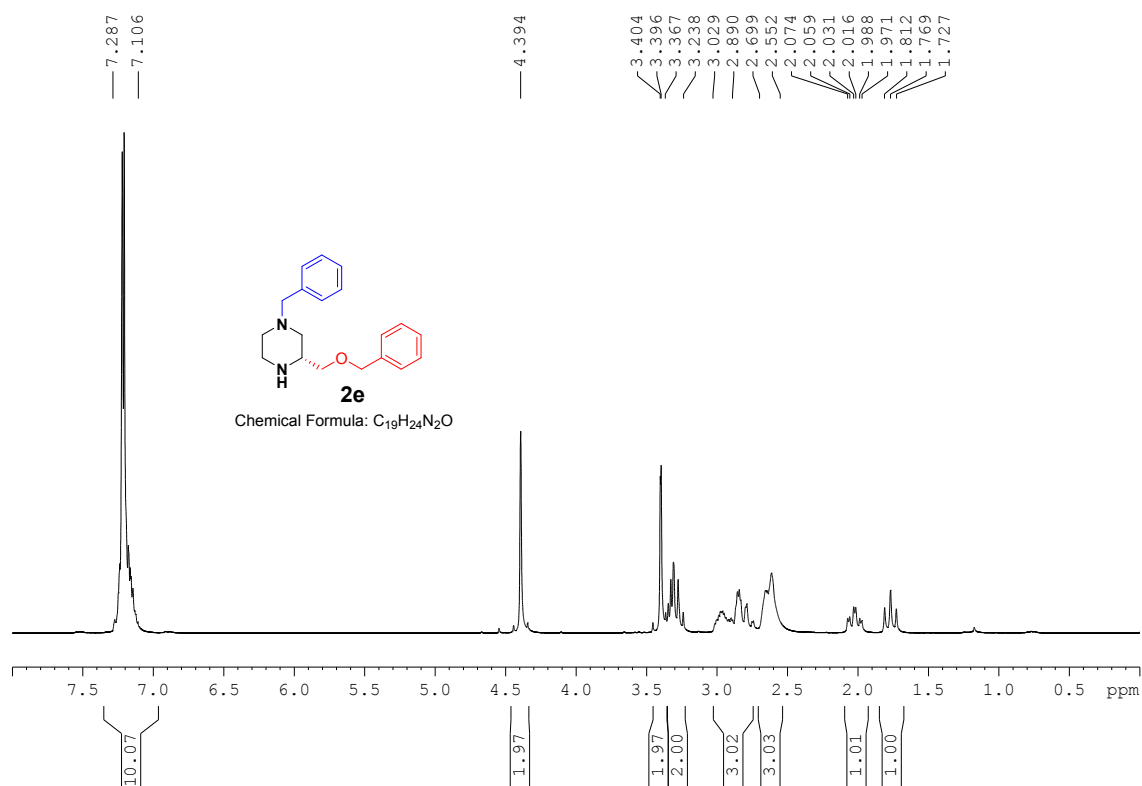
(2d): ^1H NMR (250 MHz, CDCl_3)



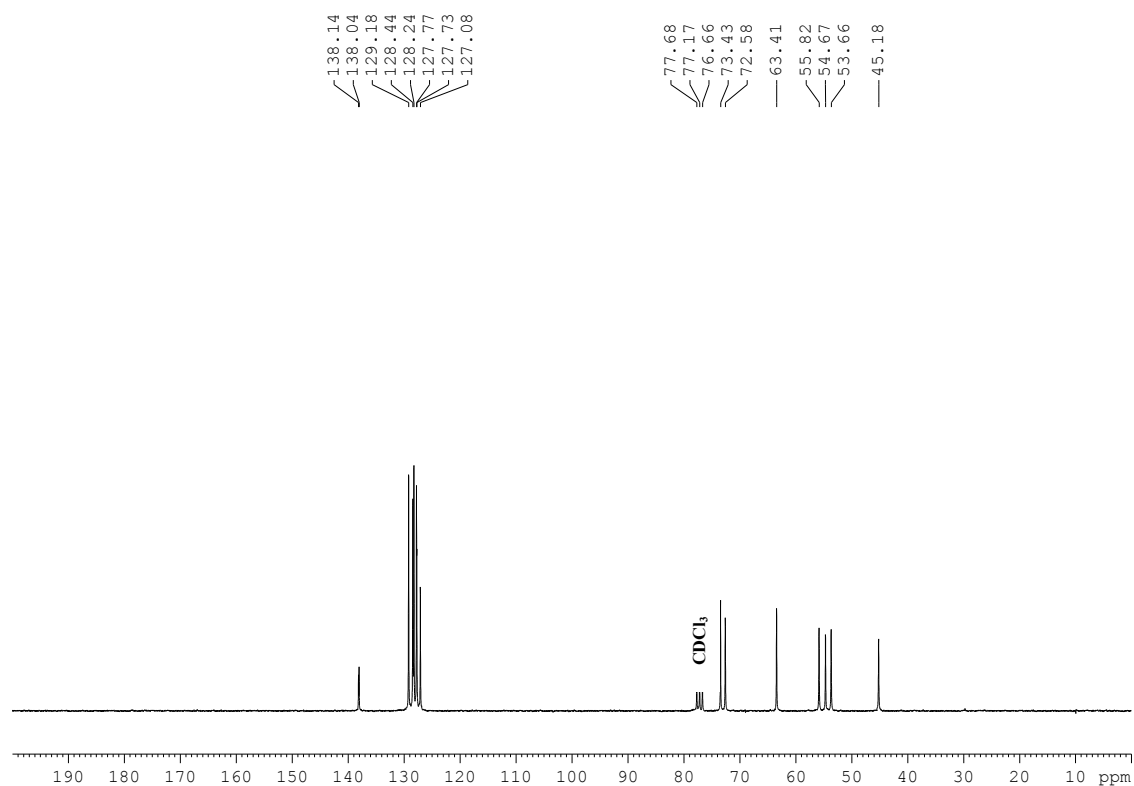
(2d): ^{13}C NMR (63 MHz, CDCl_3)



(2e): ^1H NMR (250 MHz, CDCl_3)



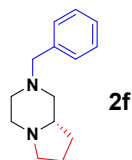
(2e): ^{13}C NMR (63 MHz, CDCl_3)



(2f): ^1H NMR (250 MHz, CDCl_3)

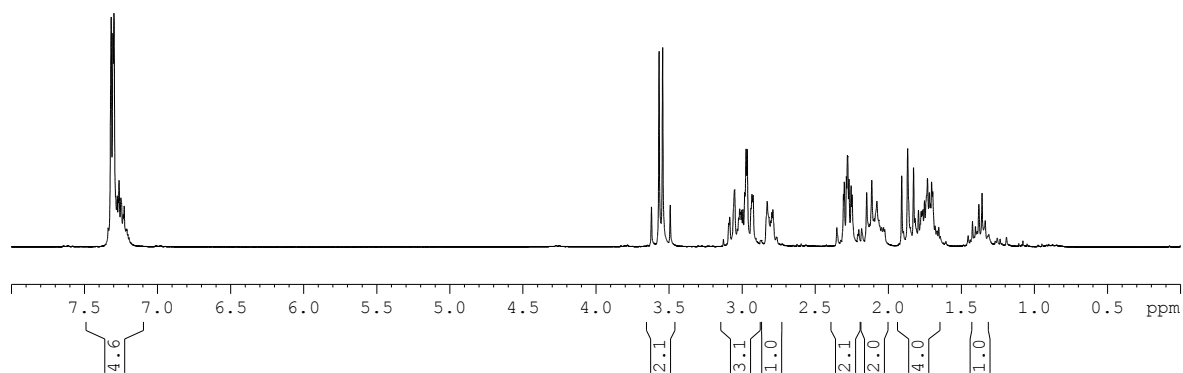
7.340
7.227

3.619
3.568
3.542
3.491
3.098
2.914
2.843
2.756
2.352
2.221
2.203
2.004
1.909
1.642
1.463
1.297



2f

Chemical Formula: $\text{C}_{14}\text{H}_{20}\text{N}_2$

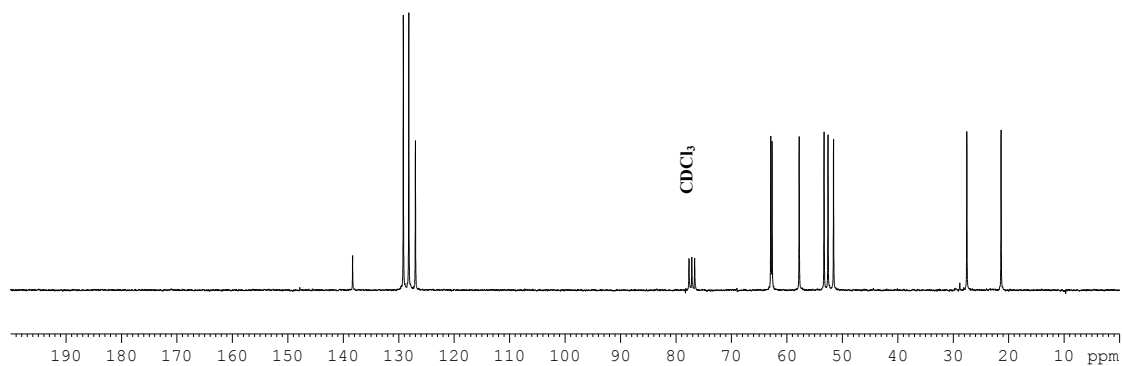


(2f): ^{13}C NMR (63 MHz, CDCl_3)

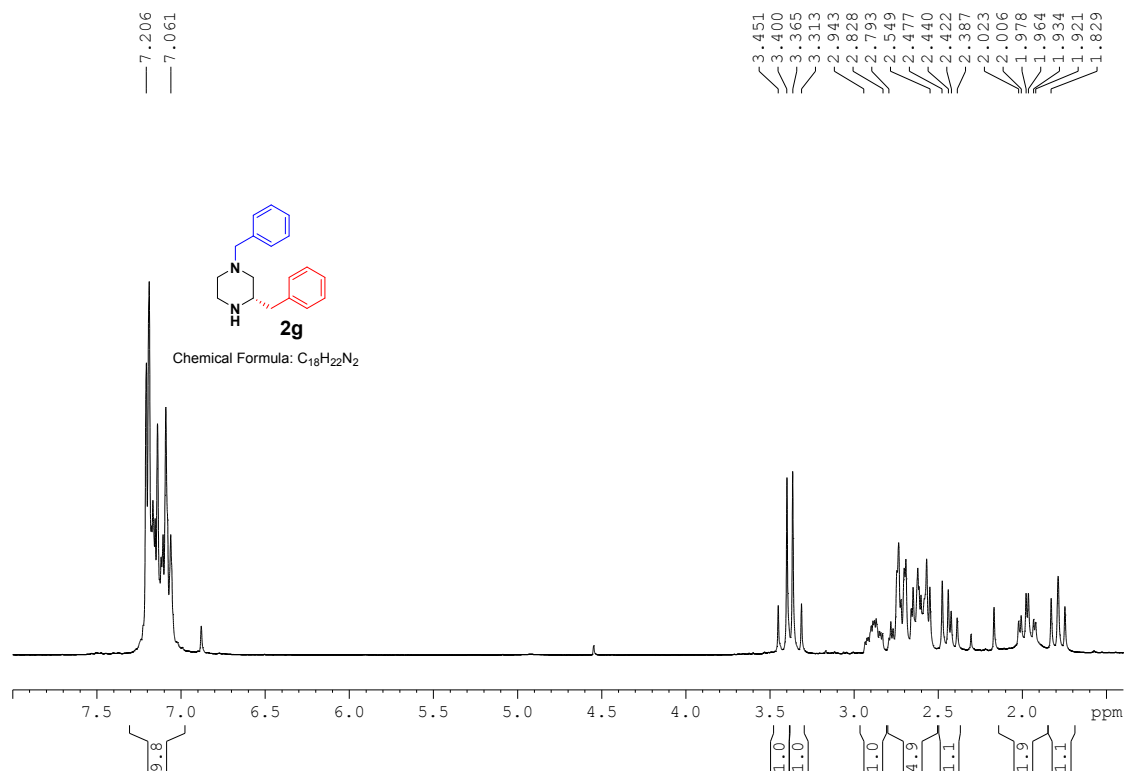
138.31
129.16
128.18
126.98

77.64
77.13
76.62
62.89
62.66
57.77
53.28
52.57
51.56

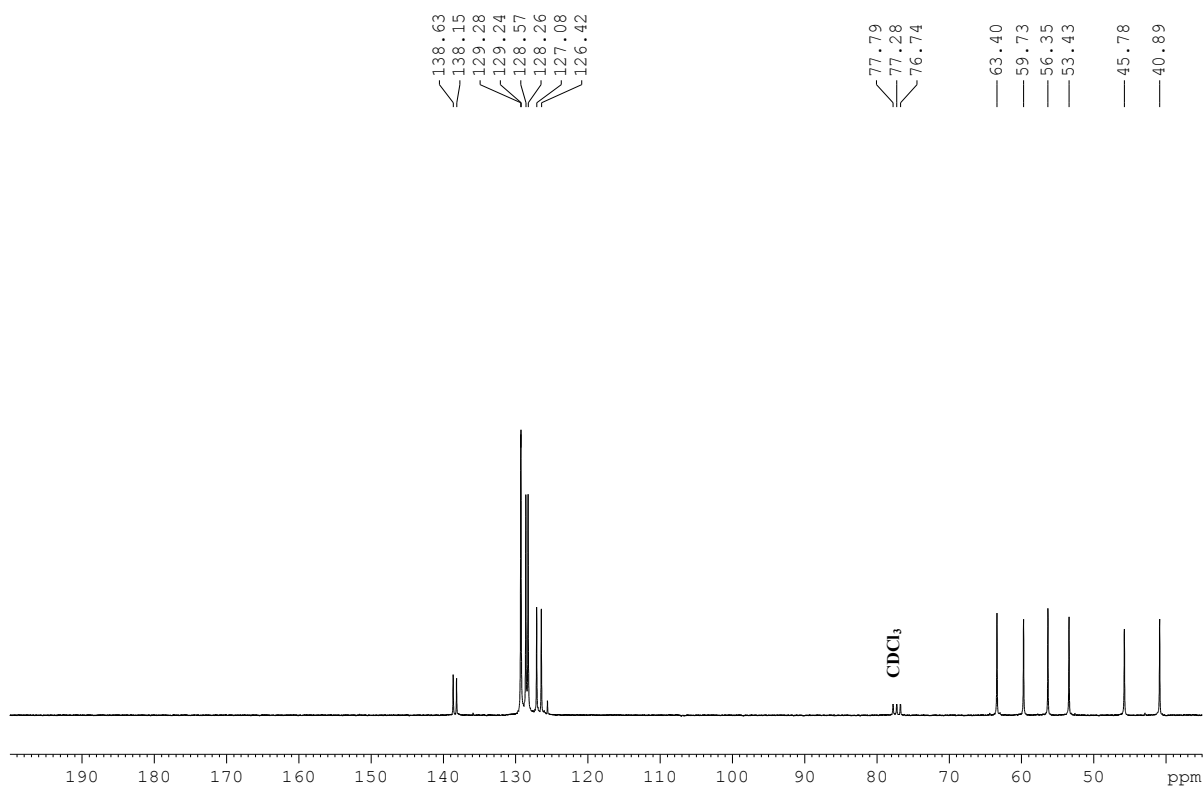
27.54
21.36



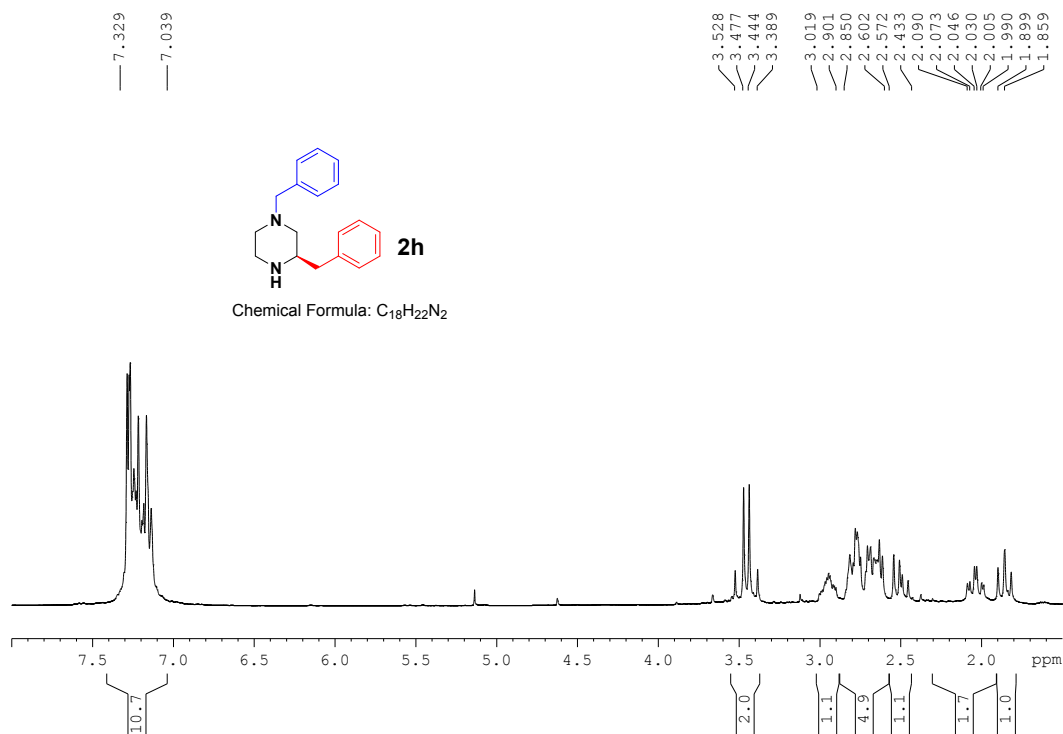
(2g): ^1H NMR (250 MHz, CDCl_3)



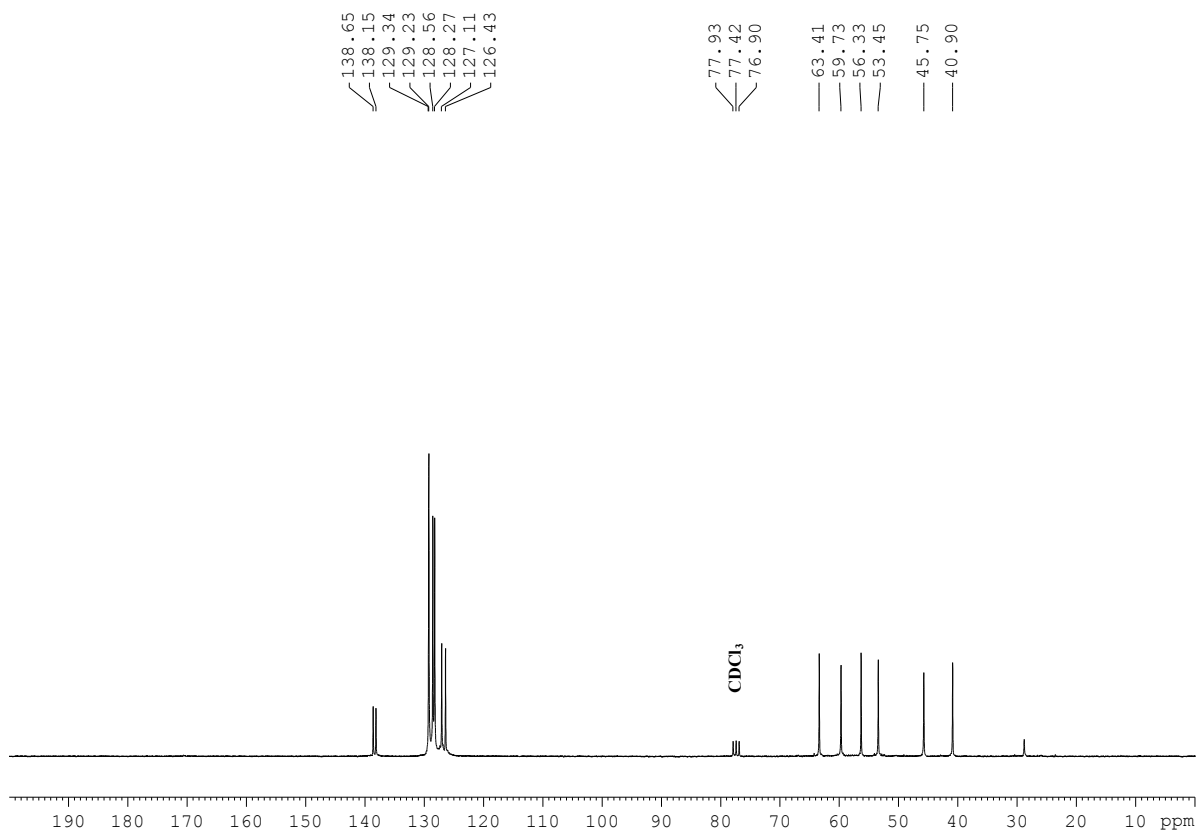
(2g): ^{13}C NMR (63 MHz, CDCl_3)



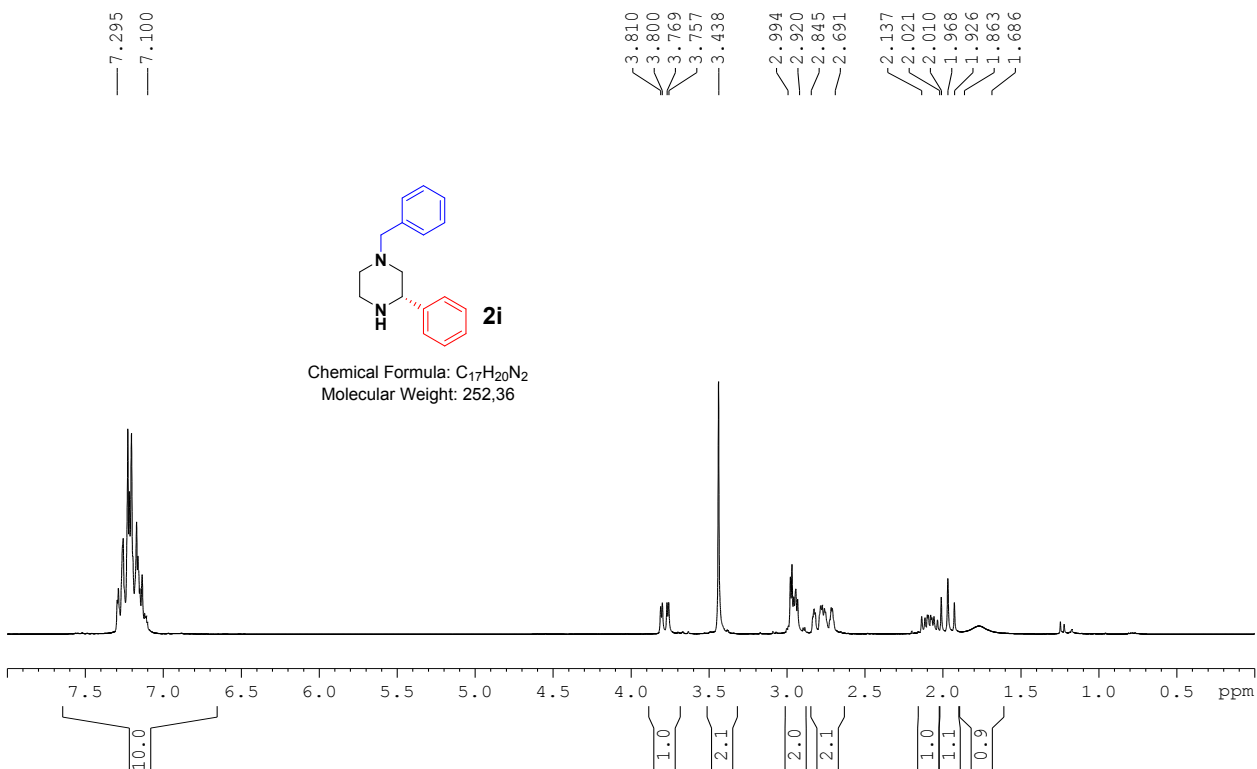
(2h): ^1H NMR (250 MHz, CDCl_3)



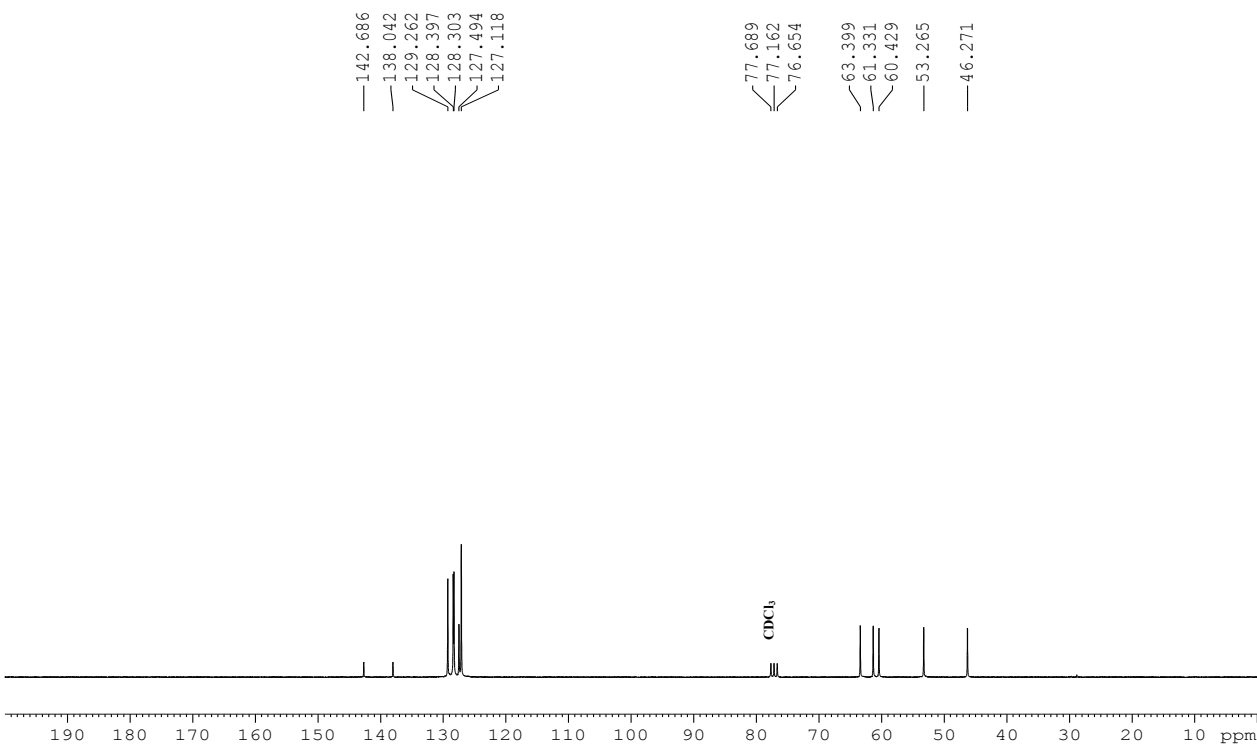
(2h): ^{13}C NMR (63 MHz, CDCl_3)



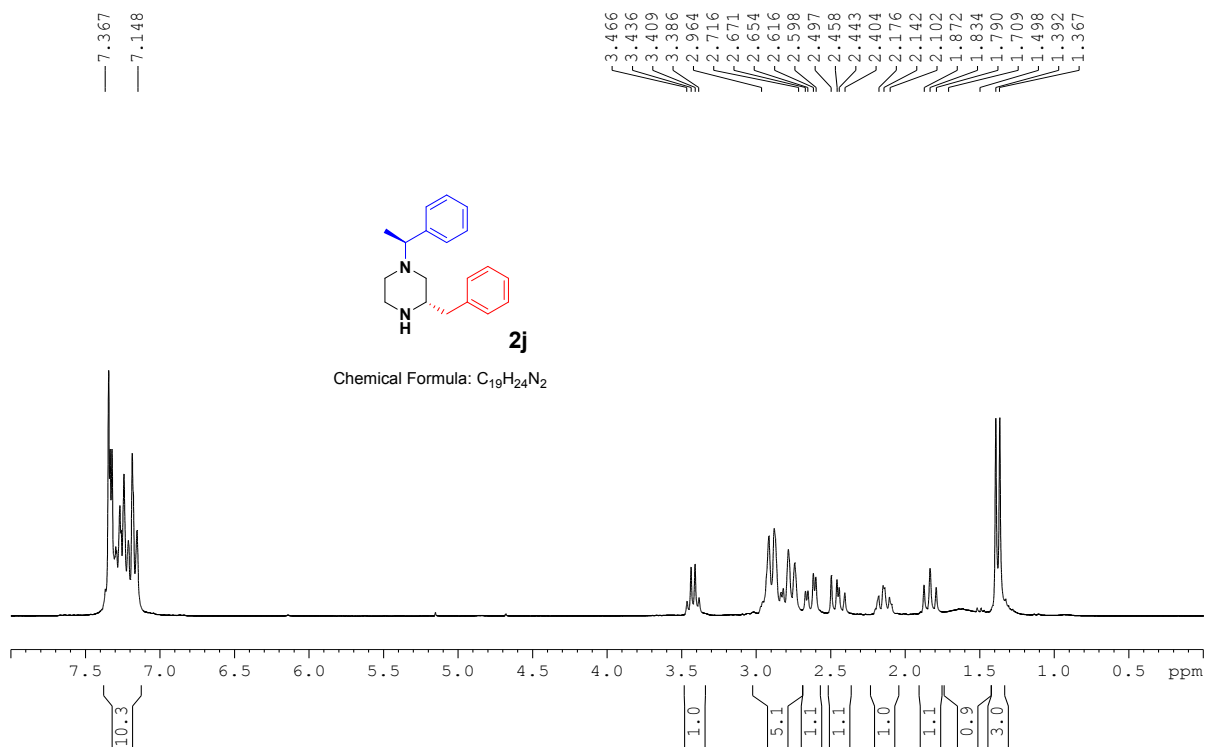
(2i): ^1H NMR (250 MHz, CDCl_3)



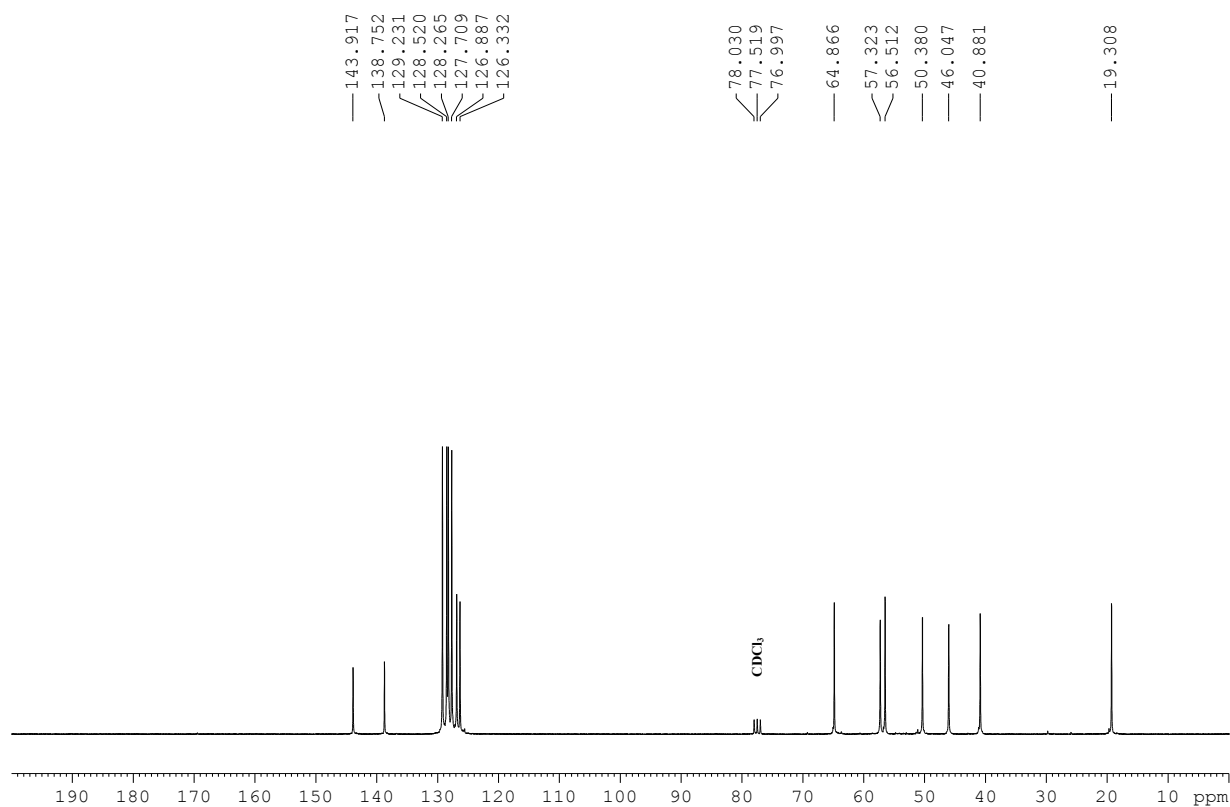
(2i): ^{13}C NMR (63 MHz, CDCl_3)



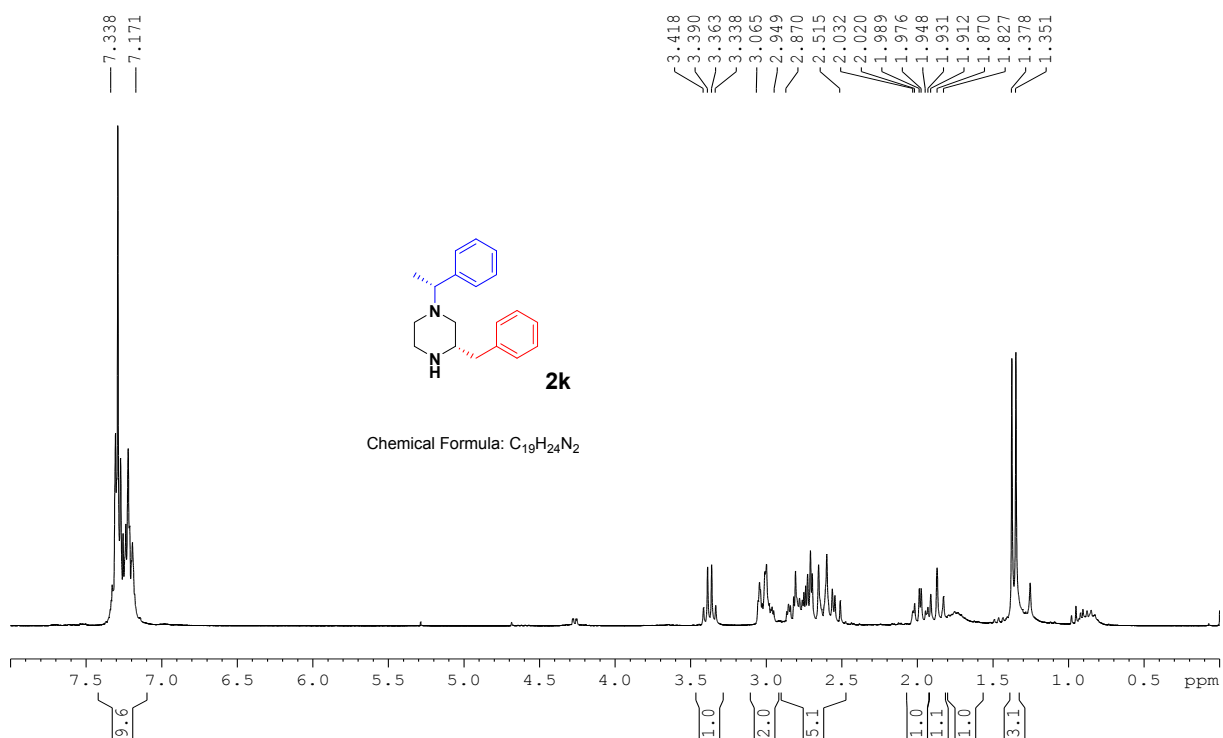
(2j): ^1H NMR (250 MHz, CDCl_3)



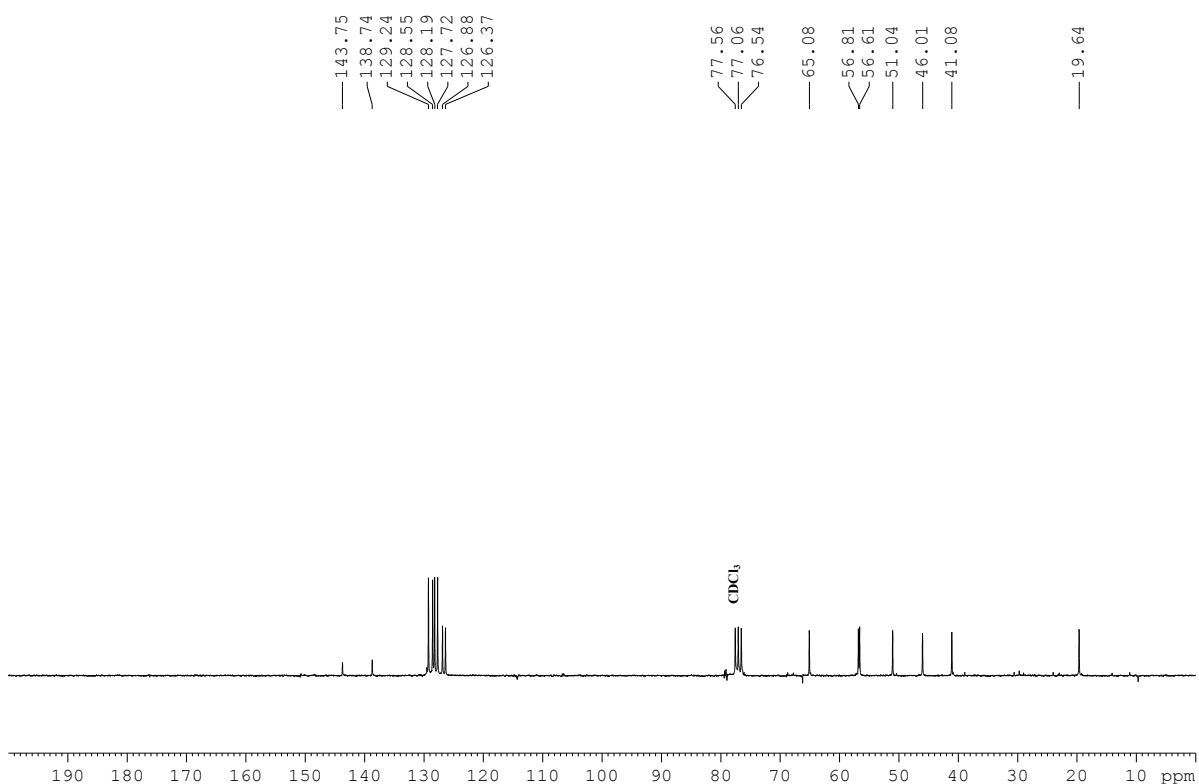
(2j): ^{13}C NMR (63 MHz, CDCl_3)



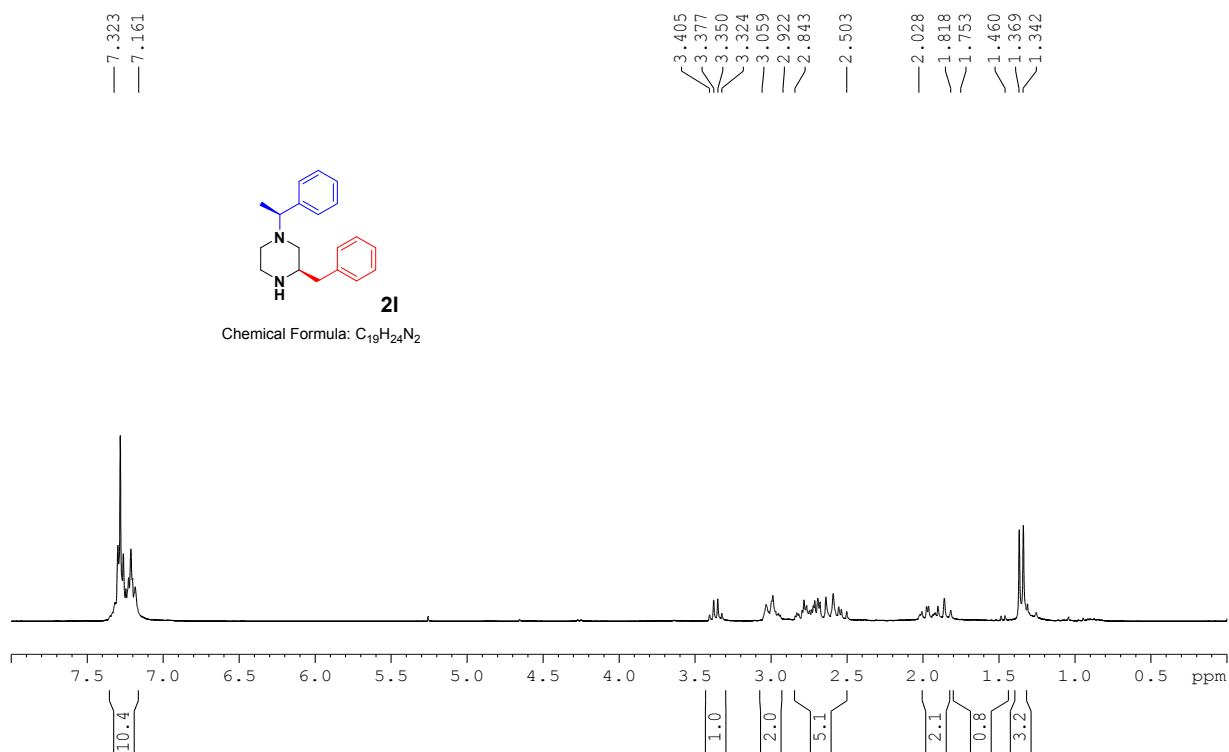
(2k): ^1H NMR (250 MHz, CDCl_3)



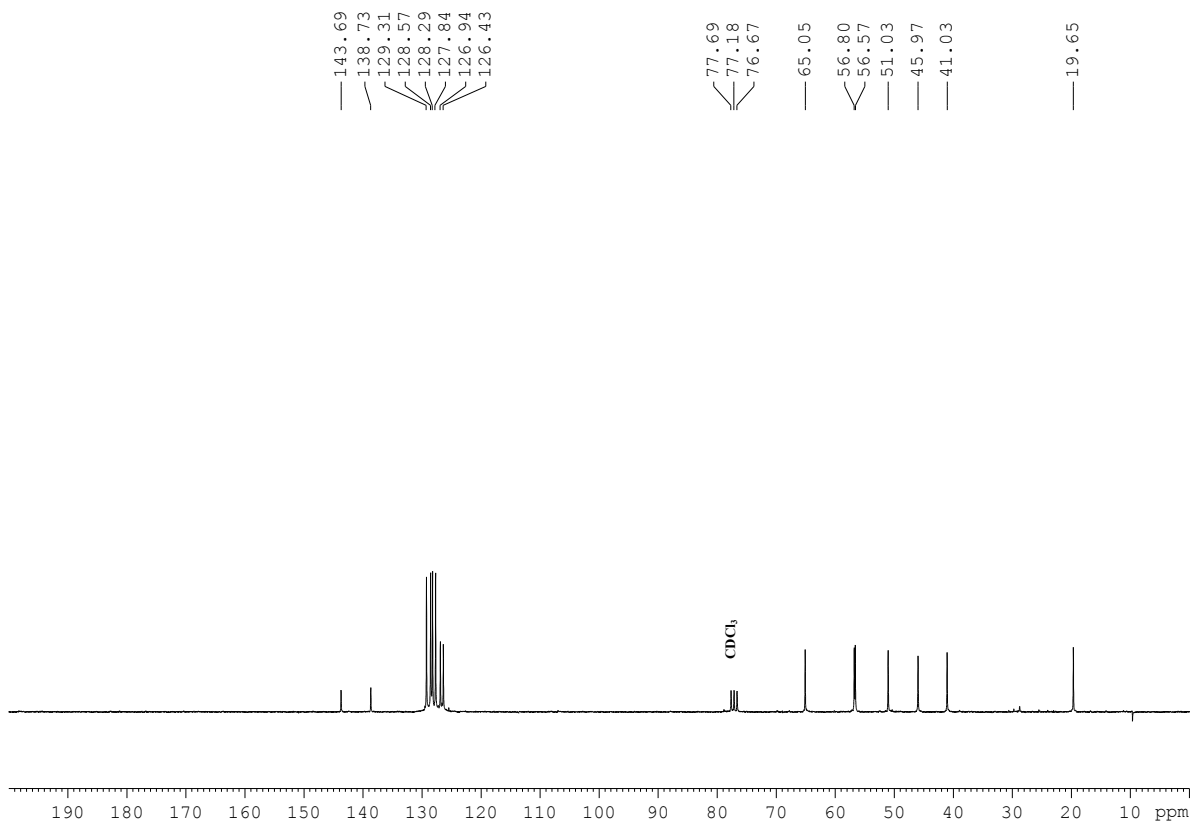
(2k): ^{13}C NMR (63 MHz, CDCl_3)



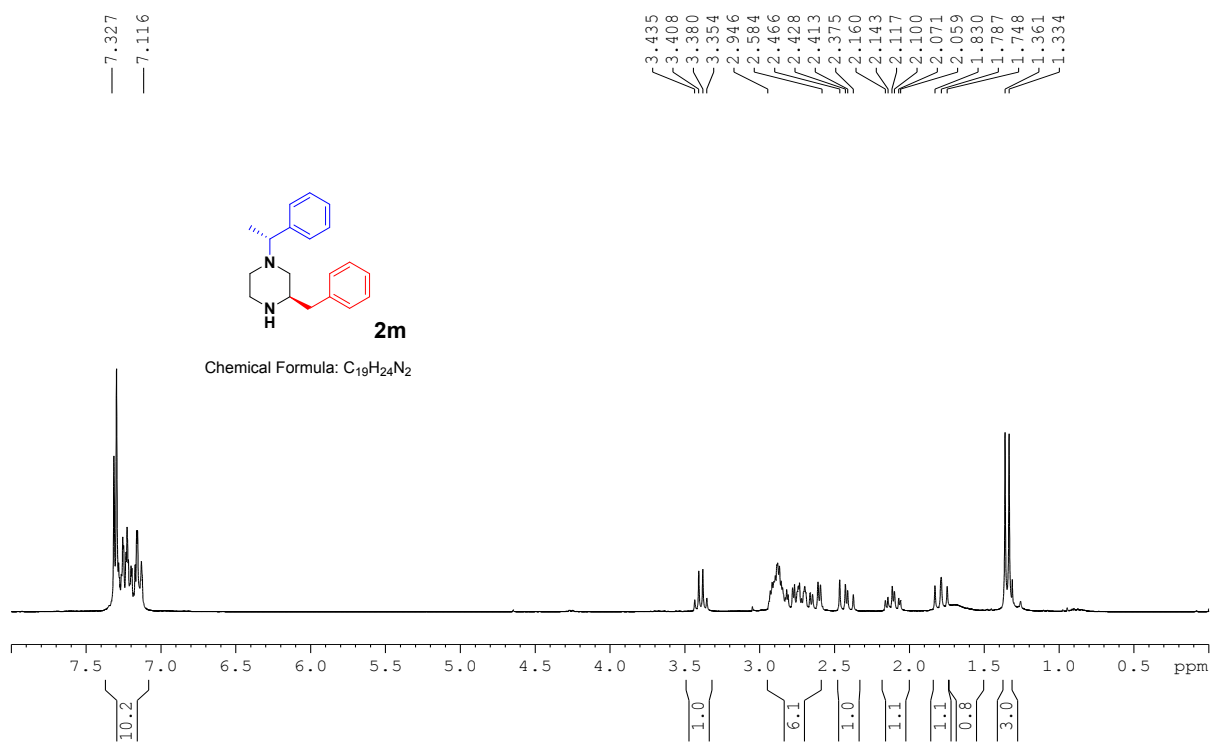
(2I): ^1H NMR (250 MHz, CDCl_3)



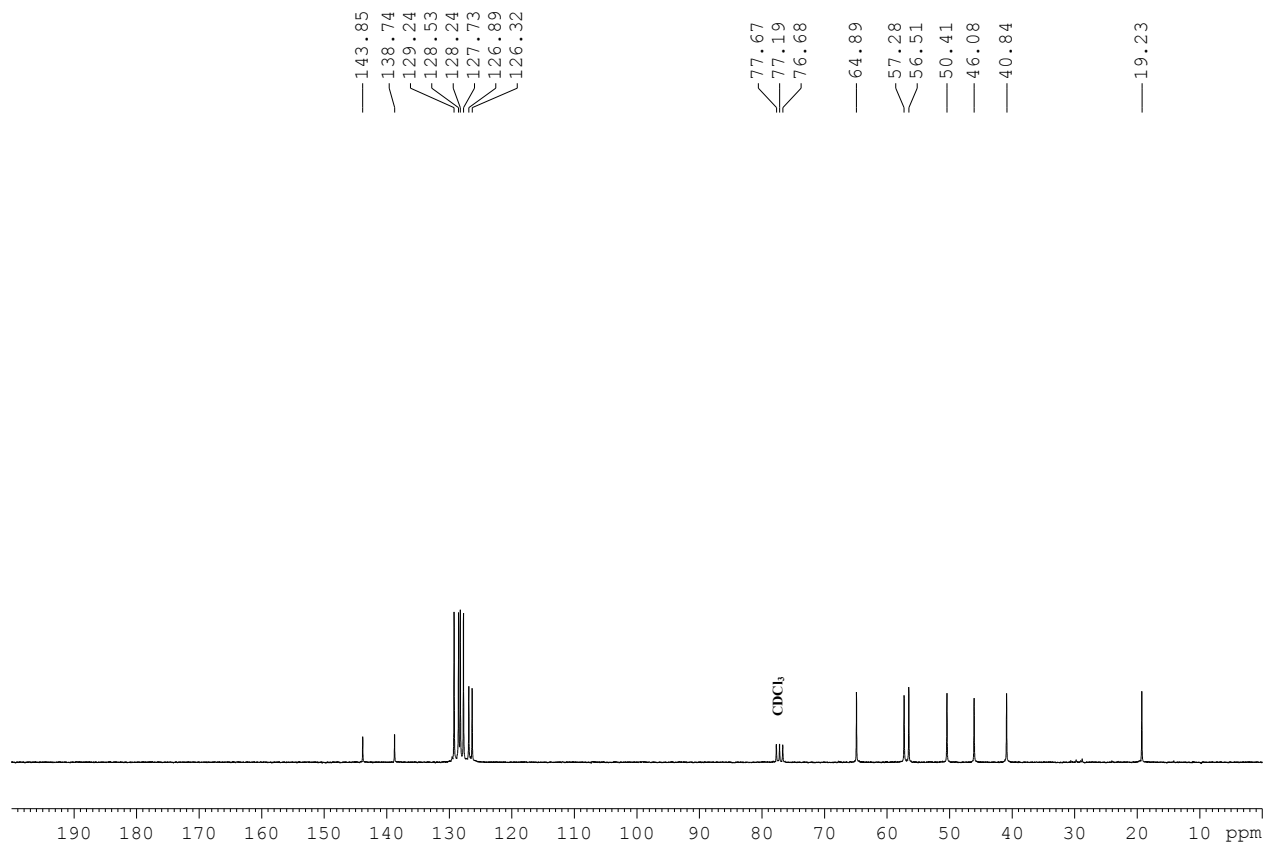
(2I): ^{13}C NMR (63 MHz, CDCl_3)



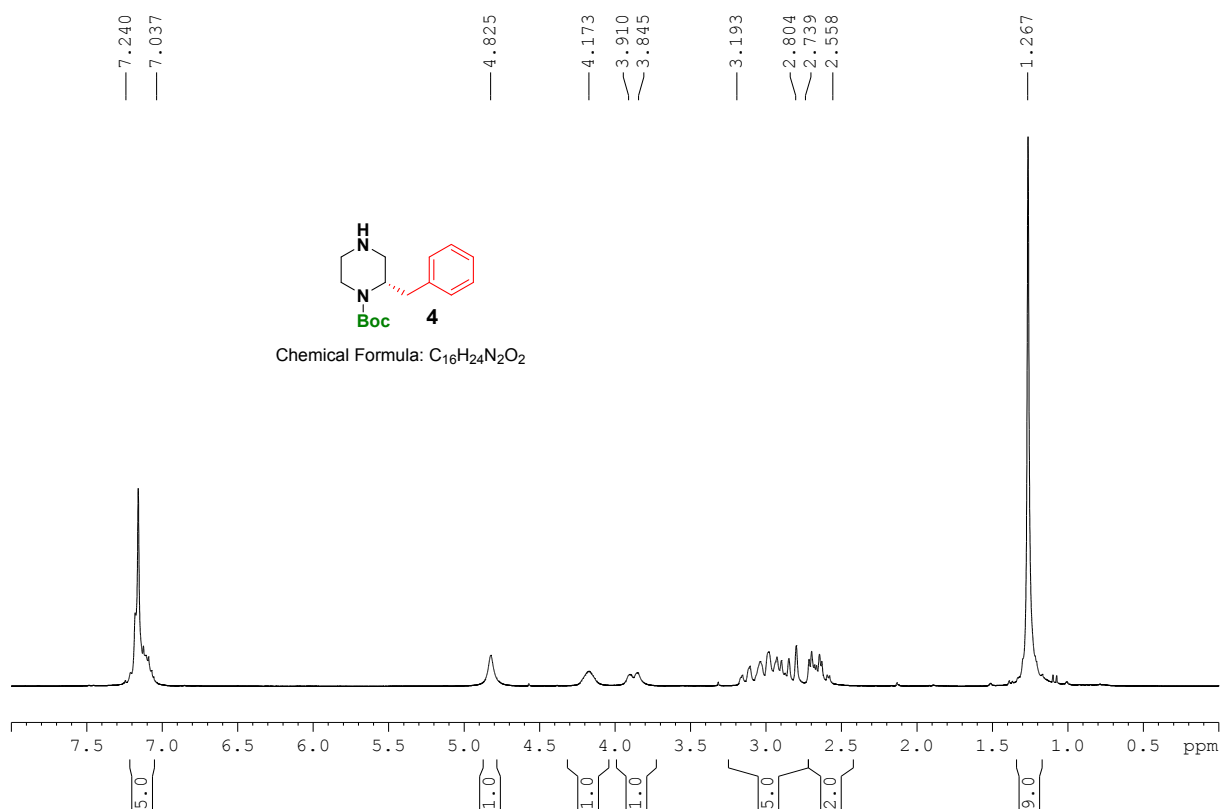
(2m): ^1H NMR (250 MHz, CDCl_3)



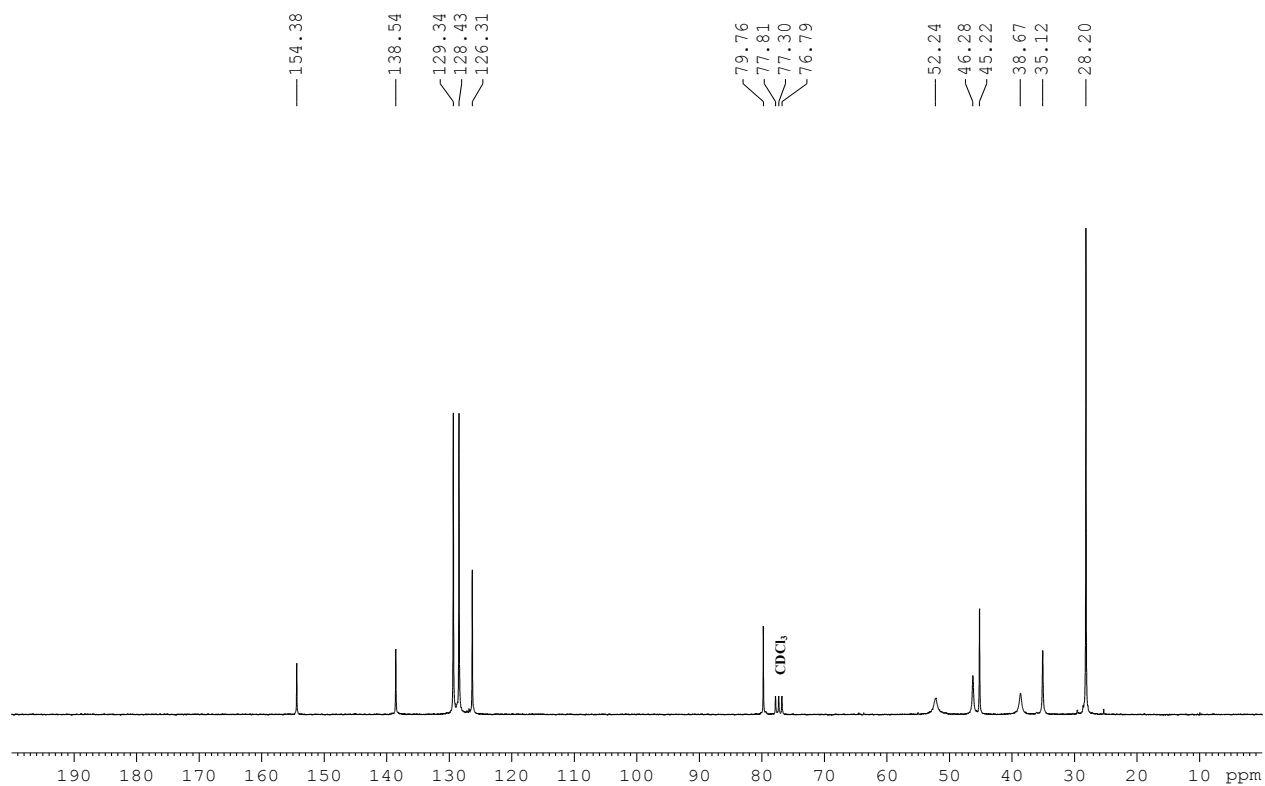
(2m): ^{13}C NMR (63 MHz, CDCl_3)



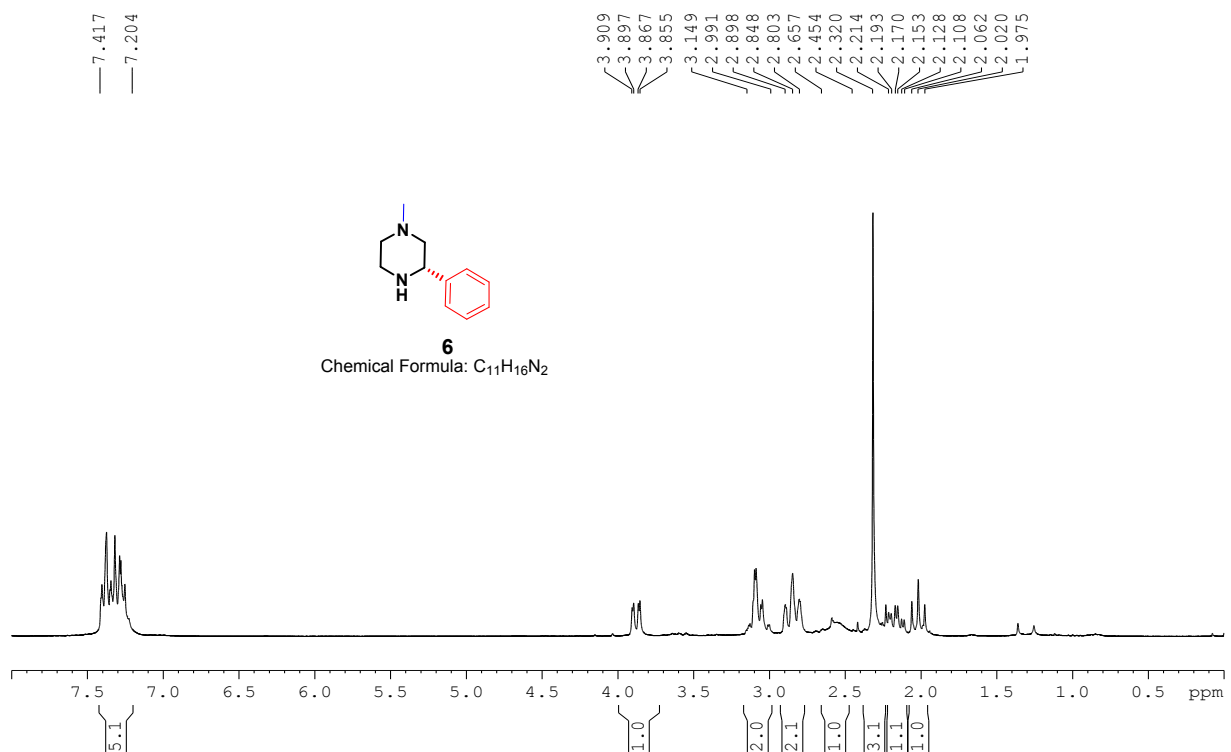
(4): ¹H NMR (250 MHz, CDCl₃)



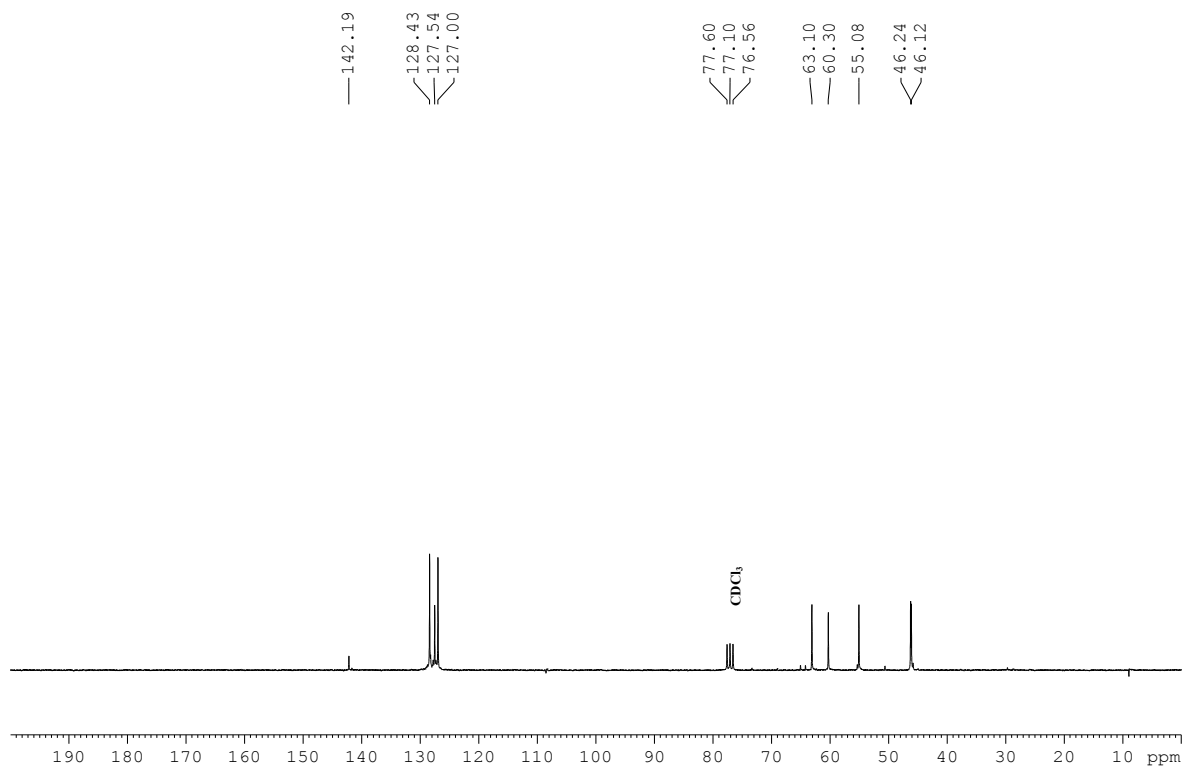
(4): ¹³C NMR (63 MHz, CDCl₃)



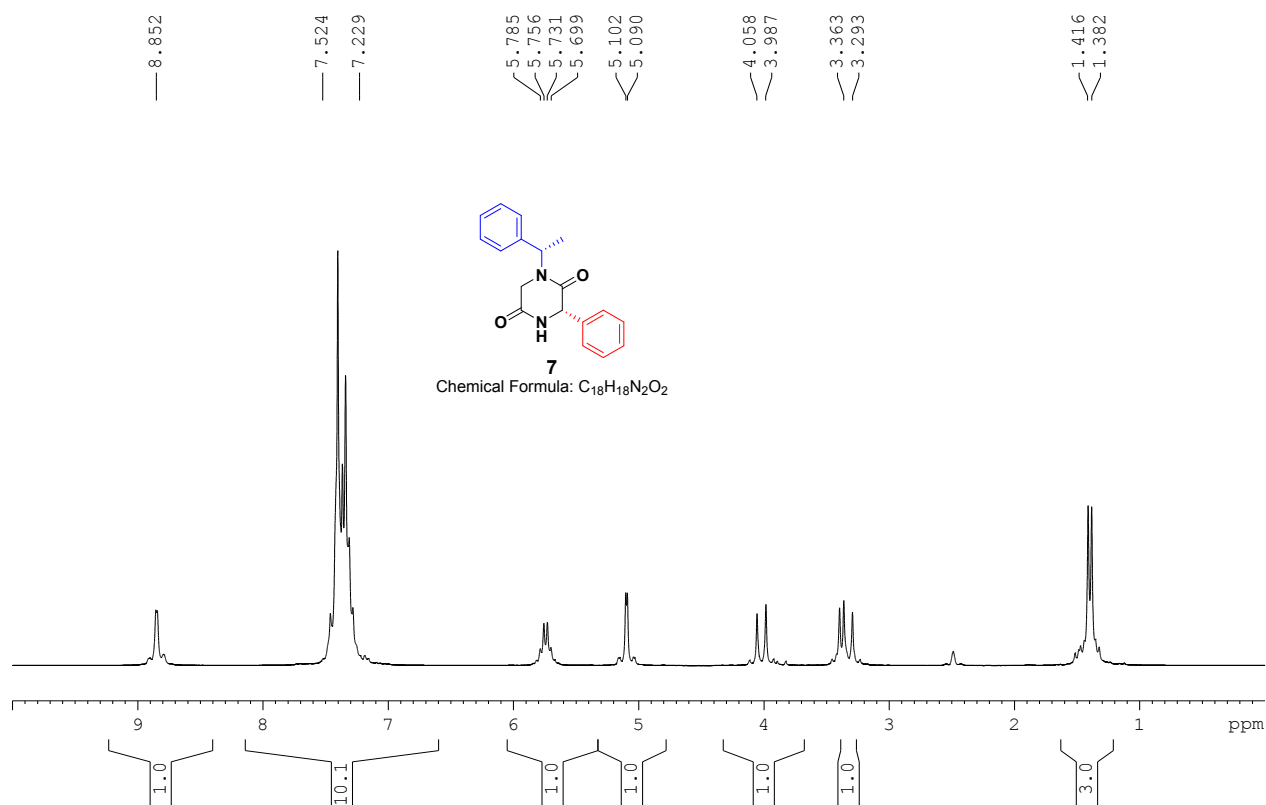
(6): ^1H NMR (250 MHz, CDCl_3)



(6): ^{13}C NMR (63 MHz, CDCl_3)



(7): ^1H NMR (250 MHz, DMSO-d_6)



(7): ^{13}C NMR (63 MHz, DMSO-d_6)

