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Supporting Information

Concise Approach to Pyrrolizino[1,2-*b*]indoles from Indole-Derived Donor-Acceptor Cyclopropanes

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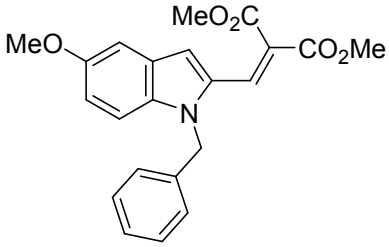
General Information

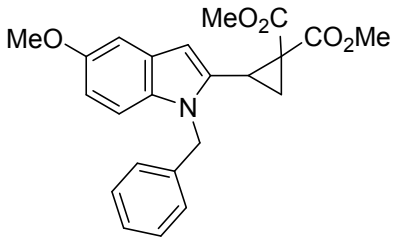
NMR spectra were acquired on Bruker Avance 600 spectrometer at room temperature; the chemical shifts δ were measured in ppm with respect to solvent (^{1}H: $CDCl_3$, δ = 7.27 ppm; ^{13}C: $CDCl_3$, δ = 77.00 ppm). Splitting patterns are designated as s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; dd, double doublet. Coupling constants (*J*) are in Hertz. The structures of synthesized compounds were elucidated with the aid of 1D NMR (^{1}H, ^{13}C) and 2D NMR (COSY ^{1}H-^{1}H, HSQC and HMBC ^{1}H-^{13}C, NOESY ^{1}H-^{1}H) spectroscopy. Infrared spectra were recorded on Thermo Nicolet IR200 FT-IR and Agilent FTIR Cary 630 spectrometers with ATR (Attenuated Total Reflectance) module. MALDI-TOF (Matrix Assisted Laser Desorption Ionization / Time of Flight) mass spectra were recorded on Bruker Daltonics Ultraflex II spectrometer in positive mode; anthracene or 1,8,9-trihydroxyanthracene were used as a matrix. High resolution and accurate mass measurements were carried out using a Bruker micrOTOF-Q^{TM} ESI-TOF (Electro Spray Ionization / Time of Flight) and Thermo Scientific* LTQ Orbitrap mass spectrometers. Elemental analyses were performed with Fisons EA-1108 CHNS elemental analyser instrument. Melting points (mp) are uncorrected and were measured on Electrothermal 9100 capillary melting point apparatus. Analytical thin layer chromatography (TLC) was carried out with silica gel plates (silica gel 60, F_{254}, supported on aluminium); the revelation was done by UV lamp (365 nm). Column chromatography was performed on silica gel 60 (230-400 mesh, Merck). The preparation of 2-(2-indolyl)cyclopropane-1,1-diesters **1a-d, f** was described earlier.[S1] 2-(2-Indolyl)cyclopropane-1,1-diesters **1e,g** were prepared similarly to the published procedures.[S1-S3] All the reactions were carried out using freshly distilled and dry solvents. Quantum chemical calculations were performed using Gaussian 98 package.[S4]

Dimethyl 2-[(1-benzyl-5-methoxy-1*H*-indol-2-yl)methylene]malonate (S1). To a solution of 1-



benzyl-5-methoxy-1*H*-indole-2-carbaldehyde (0.75 g, 2.8 mmol) and dimethyl malonate (0.37 g, 2.8 mmol) in toluene (2 mL) glacial acetic acid (0.032 mL, 0.56 mmol) and piperidine (0.028 mL, 0.28 mmol) were added. The mixture was refluxed with the Dean-Stark trap until water separation was finished (4 h). Upon cooling, water (2 mL) was added to the mixture and the organic layer was separated. The aqueous phase was extracted with ether (3×3 mL). The combined organic fractions were washed with water (3×3 mL), dried with Na_2SO_4, concentrated *in vacuo*. The purification by column chromatography (SiO_2) afforded **S1** (0.86 g, 80%) as yellow solid; mp 191–192 °C; R_f = 0.43 (SiO_2, petroleum ether : ethyl acetate, 2:1). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 3.82 (s, 3H, CH_3O), 3.84 (s, 3H, CH_3O), 3.95 (s, 3H, CH_3O), 5.40 (s, 2H, CH_2Ph), 6.93 (br. s, 1H, CH, Ind), 6.94 (dd, ^3J = 8.9 Hz, ^4J = 2.4 Hz, 1H, CH, Ind), 7.02–7.03 (m, 2H, Ph), 7.07 (br. d, ^4J = 2.4 Hz, 1H, CH, Ind), 7.17 (br. d, ^3J = 8.9 Hz, 1H, CH, Ind), 7.24–7.29 (m, 3H, Ph), 7.78 (s, 1H, CH=); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 46.9 (*C*H_2Ph), 52.6 (CH_3O), 52.9 (CH_3O), 55.7 (CH_3O), 102.1 (CH, Ar), 106.4 (CH, Ar), 111.1 (CH, Ar), 116.3 (CH, Ar), 123.8 (C, Ar), 126.0 (2×CH, Ph), 127.7 (CH, Ar), 128.2 (C, Ar), 128.9 (2×CH, Ph), 130.0 (CH=), 132.0 (C, Ar), 134.2 (C, Ar), 137.1 (C, Ar), 155.0 (C), 164.4 (*C*O_2Me), 167.2 (*C*O_2Me); IR (Nujol, cm^{-1}): 2975, 1730, 1630, 1535, 1470, 1390, 1340, 1300, 1250 (br), 1185, 1170, 1080, 1045, 990, 960; MS MALDI–TOF: *m/z* = 379 $[M]^+$ (379 calcd for $C_{22}H_{21}NO_5$); Anal. calcd for $C_{22}H_{21}NO_5$: C, 69.64; H, 5.58, N, 3.69. Found: C, 69.72; H, 5.72, N, 3.67.

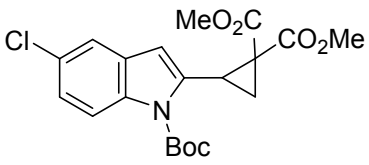
Dimethyl 2-(1-benzyl-5-methoxy-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate (1e). Dimethyl



2-[(1-benzyl-5-methoxy-1*H*-indol-2-yl)methylene]malonate (381 mg, 1 mmol), NaH (29 mg, 1.2 mmol) and trimethylsulfoxonium iodide (224 mg, 1.2 mmol) in DMSO (3 mL) after 15 min gave **1e** (224 mg, yield 60%) as brown oil. R_f = 0.57 (SiO_2, petroleum ether : ethyl acetate, 2:1). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 1.78 (dd, ^2J = 5.0 Hz, ^3J = 9.3 Hz, 1H, CH_2),

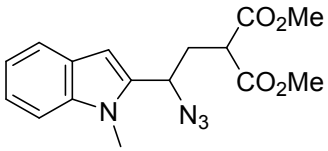
2.22 (dd, ^2J = 5.0 Hz, ^3J = 7.8 Hz, 1H, CH_2), 3.01 (dd, ^3J = 9.3 Hz, ^3J = 7.8 Hz, 1H, CH), 3.38 (s, 3H, CH_3O), 3.79 (s, 3H, CH_3O), 3.84 (s, 3H, CH_3O), 5.34 (d, ^2J = 17.0 Hz, 1H, CH_2Ph), 5.39 (d, ^2J = 17.0 Hz, 1H, CH_2Ph), 6.22 (s, 1H, CH, Ind), 6.81 (dd, ^3J = 8.9 Hz, ^4J = 2.5 Hz, 1H, Ind), 7.03 (d, ^4J = 2.5 Hz, 1H, CH, Ind), 7.04–7.16 (m, 2H, CH, Ph), 7.11 (d, ^3J = 8.9 Hz, 1H, CH, Ind), 7.23–7.26 (m, 1H, CH, Ph), 7.27–7.30 (m, 2H, CH, Ph); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 18.8 (CH_2), 24.6 (CH), 37.2 (C), 47.1 (CH_2), 52.5 (OCH_3), 52.9 (OCH_3), 55.8 (OCH_3), 100.7 (CH, Ar), 102.4 (CH, Ar), 110.1 (CH, Ar), 112.0 (CH, Ar), 126.3 (2×CH, Ph), 127.4 (CH, Ar), 127.6 (C, Ar), 128.8 (2×CH, Ph), 133.2 (C, Ar), 134.8 (C, Ar), 137.7 (C, Ar), 154.2 (C, Ar), 166.6 (*C*O_2Me), 169.7 (*C*O_2Me); IR (Nujol, cm^{-1}): 2950, 1730, 1620, 1580, 1520, 1480, 1445, 1415, 1330, 1280, 1220, 1175, 1130, 1030, 995, 970; MS MALDI–TOF: *m/z* = 393 $[M]^+$ (393 calcd for $C_{23}H_{23}NO_5$); HRMS MALDI–TOF: *m/z* = 394.1646 $[M+H]^+$ (394.1649 calcd for $C_{23}H_{24}NO_5$).

Dimethyl 2-[1-(*tert*-butoxycarbonyl)-5-chloro-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate



(1g). Dimethyl 2-[(1-(*tert*-butoxycarbonyl)-5-chloro-1*H*-indol-2-yl)methylene]malonate (260 mg, 0.64 mmol), NaH (17 mg, 0.7 mmol) and trimethylsulfoxonium iodide (154 mg, 0.7 mmol) in DMSO (3 mL) after 30 min gave **1g** (182 mg, yield 70%) as brown oil. R_f = 0.62 (SiO_2, petroleum ether : ethyl acetate, 2:1). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 1.66 (s, 9H, 3×CH_3), 1.90 (dd, ^2J = 5.1 Hz, ^3J = 8.8 Hz, 1H, CH_2), 2.10 (dd, ^2J = 5.1 Hz, ^3J = 7.8 Hz, 1H, CH_2), 3.35 (s, 3H, CH_3O), 3.56 (dd, ^3J = 8.8 Hz, ^3J = 7.8 Hz, ^4J = 1.2 Hz, 1H, CH), 3.80 (s, 3H, CH_3O), 6.31 (br. s, 1H, CH, Ind), 7.21 (dd, ^3J = 8.9 Hz, ^4J = 2.0 Hz, 1H, Ind), 7.41 (br. d, ^4J = 2.0 Hz, 1H, CH, Ind), 8.02 (br. d, ^3J = 8.9 Hz, 1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 20.0 (CH_2), 27.4 (CH), 28.0 (3×CH_3), 36.5 (C), 52.4 (OCH_3), 52.7 (OCH_3), 84.6 (C), 108.3 (CH, Ind), 116.4 (CH, Ind), 119.9 (CH, Ind), 124.4 (CH, Ind), 128.2 (C, Ind), 129.2 (C, Ind), 135.6 (C, Ind), 136.7 (C, Ind), 149.9 (C, Ind), 166.8 (*C*O_2Me), 169.9 (*C*O_2Me); IR (Nujol, cm^{-1}): 2985, 1730, 1585, 1450, 1390, 1370, 1355, 1335, 1285, 1220, 1175, 1740, 1095, 1080, 1035, 965, 890, 865, 820, 780; HRMS MALDI–TOF: *m/z* =408.1210 $[M+H]^+$ (408.1208 calcd for $C_{20}H_{23}ClNO_6$).

Dimethyl 2-[2-azido-2-(1-methyl-1*H*-indol-2-yl)ethyl]malonate (2a′). To 0.5 M solution of



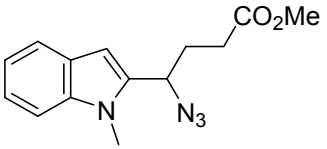
cyclopropane **1a** (480 mg, 1.67 mmol) in dry DMF triethylamine hydrochloride (2 equiv.) and sodium azide (2 equiv.) were added in a single portion under argon atmosphere. The resulting mixture was stirred for 4 h at 75–80 °C, poured into H_2O (10 mL) and extracted with ethyl acetate (3×15 mL). The combined organic fractions were washed with water (5×10 mL) and dried with Na_2SO_4. Solvent was evaporated. Product was purified by column chromatography on silica gel. Azide **2a′** (391 mg, yield 71%) was obtained as brown oil. R_f = 0.35 (diethyl ether : petroleum ether; 1:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.63 (ddd, ^2J = 14.2 Hz, ^3J = 7.4 Hz, ^3J = 6.5 Hz, 1H, CH_2), 2.64 (ddd, ^2J = 14.2 Hz, ^3J = 8.3 Hz, ^3J = 6.9 Hz, 1H, CH_2), 3.72 (dd, ^3J = 7.4 Hz, ^3J = 6.9 Hz, 1H, CH), 3.77 (s, 3H, CH_3), 3.78 (s, 3H, CH_3), 3.80 (s, 3H, CH_3), 4.70 (dd, ^3J = 8.3 Hz, ^3J = 6.5 Hz, 1H, CHN_3), 6.61 (br. s, 1H, CH, Ind), 7.17 (ddd, ^3J = 7.9 Hz, ^3J = 7.0 Hz, ^4J = 0.9 Hz, 1H, CH, Ind), 7.30 (ddd, ^3J = 8.3 Hz, ^3J = 7.0 Hz, ^4J = 1.1 Hz, 1H, CH, Ind), 7.37 (br. dd, ^3J = 8.3 Hz, ^4J = 0.9 Hz, 1H, CH, Ind), 7.65 (ddd, ^3J = 7.9 Hz, ^4J = 1.1 Hz, ^4J = 0.9 Hz, 1H, CH, Ind); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 30.0 ($^1J_{CH}$ = 139 Hz, CH_3N), 32.5 ($^1J_{CH}$ = 134 Hz, CH_2), 48.8 ($^1J_{CH}$ = 133 Hz, CH), 52.9 ($^1J_{CH}$ = 148 Hz, 2×CH_3O), 56.1 ($^1J_{CH}$ = 145 Hz, CHN_3), 101.3 (CH, Ind), 109.4 (CH, Ind), 120.0 (CH, Ind), 121.1 (CH, Ind), 122.5 (CH, Ind), 126.9 (C, Ind), 136.3 (C, Ind), 138.2 (C, Ind), 169.1 (*C*O_2Me), 169.2 (*C*O_2Me); IR (film, cm^{-1}): 2954, 2104, 1735, 1613, 1541, 1469, 1437, 1316, 1267, 1238, 1157, 1055, 876, 791, 703; HRMS MALDI–TOF: *m/z* = 353.1217 $[M+Na]^+$(353.1220 calcd for $C_{16}H_{18}N_4NaO_4$).

General procedure for synthesis of azides 2a–e

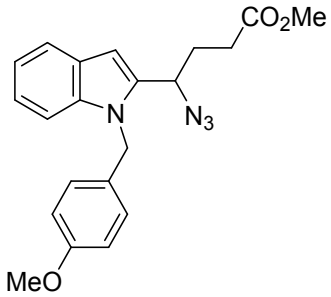
To 0.5 M solution of cyclopropane **1** in dry DMF triethylamine hydrochloride (2 equiv.) and sodium azide (2 equiv.) were added in a single portion under argon atmosphere. The mixture was stirred under the condition specified. Then water (6 equiv.) and LiCl (6 equiv.) were added. The resulting mixture was heated at 110 °C for the specified time, poured into cold H_2O (10 mL). Product was extracted with ethyl acetate (5×10 mL). The combined organic fractions were washed

with water (5×20 mL) and dried with Na_2SO_4. Solvent was evaporated. Product was purified by column chromatography.

Methyl 4-azido-4-(1-methyl-1*H*-indol-2-yl)butanoate (2a). Azide **2a** was obtained by General procedure as brown oil (280 mg, yield 59%) from cyclopropane **1a** (500 mg, 1.74 mmol) under heating at 75 °C for 4 h, addition of H_2O and LiCl and heating at 110 °C for 25 h in DMF or at 110 °C for 18.5 h in pyridine. Alternatively, **2a** was obtained (180 mg, 62%) from **2a′** (350 mg, 1.06 mmol) by heating with LiCl (6 equiv.) and water (6 equiv,) in DMF at 115 °C for 6 h under microwave irradiation. R_f = 0.80 (ethyl acetate:petroleum ether; 1:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.37–2.41 (m, 2H, CH_2), 2.55–2.64 (m, 2H, CH_2), 3.74 (s, 3H, CH_3), 3.82 (s, 3H, CH_3), 4.65–4.67 (m, 1H, CHN_3), 6.61 (dd, ^4J = 1.3 Hz, ^5J = 0.8 Hz, 1H, CH, Ind), 7.19 (ddd, ^3J = 8.0 Hz, ^3J = 7.0 Hz, ^4J = 0.7 Hz, 1H, CH, Ind), 7.31 (ddd, ^3J = 8.2 Hz, ^3J = 7.0 Hz, ^4J = 1.1 Hz, 1H, CH, Ind), 7.38 (ddd, ^3J = 8.2 Hz, ^4J = 1.3 Hz, ^4J = 0.7 Hz, 1H, CH, Ind), 7.67 (ddd, ^3J = 8.0 Hz, ^4J = 1.1 Hz, ^5J = 0.8 Hz, 1H, CH, Ind); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 28.4 ($^1J_{CH}$ = 130 Hz, CH_2), 30.0 ($^1J_{CH}$ = 138 Hz, CH_3N), 30.7 ($^1J_{CH}$ = 129 Hz, CH_2), 51.8 ($^1J_{CH}$ = 147 Hz, CH_3O), 57.2 ($^1J_{CH}$ = 143 Hz, CHN_3), 101.1 (CH, Ind), 109.3 (CH, Ind), 119.9 (CH, Ind), 121.0 (CH, Ind), 122.4 (CH, Ind), 127.0 (C, Ind), 136.0 (C, Ind), 138.1 (C, Ind), 173.1 (CO_2Me); IR (film, cm^{-1}): 2952, 2097, 1733, 1613, 1540, 1468, 1437, 1417, 1361, 1316, 1233, 1201, 1170, 1136, 1065, 1010, 917, 871, 786, 736, 703; HRMS MALDI–TOF: *m/z* = 273.1352 $[M+H]^+$ (273.1346 calcd for $C_{14}H_{17}N_4O_2$).

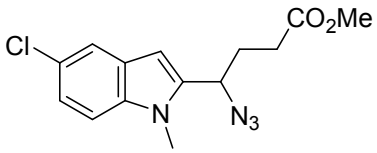


Methyl 4-azido-4-[1-(4-methoxybenzyl)-1*H*-indol-2-yl]butanoate (2b) was obtained as brown oil (306 mg, yield 61%) using the General procedure from cyclopropane **1b** (450 mg, 1.15 mmol) after 4 h at 90 °C (1st step) and 16 h at 110 °C (2nd step) in DMF. R_f = 0.80 (ethyl acetate : petroleum ether; 1:1). ^{1}HNMR (600 MHz, $CDCl_3$): δ = 2.28–2.36 (m, 2H, CH_2), 2.41–2.51 (m, 2H, CH_2), 3.66 (s, 3H, CH_3O), 3.77 (s, 3H, CH_3O), 4.47–4.50 (m, 1H, CHN_3), 5.38 (d, ^2J = 17.0 Hz, 1H, NCH_2), 5.44 (d, ^2J = 17.0 Hz, 1H, NCH_2), 6.67 (s, 1H, Ind), 6.82



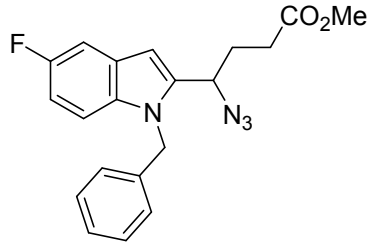
(br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 6.91 (br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 7.15–7.18 (m, 1H, CH, Ind), 7.21–7.24 (m, 1H, CH, Ind), 7.29–7.30 (m, 1H, CH, Ind), 7.66–7.69 (m, 1H, CH, Ind); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 28.6 (CH_2), 30.7 (CH_2), 46.3 (CH_2), 51.7 (CH_3O), 55.3 (CH_3O), 56.9 (CHN_3), 101.6 (CH, Ar), 109.9 (CH, Ar), 114.3 (2×CH, Ar), 120.2 (CH, Ar), 121.1 (CH, Ar), 122.7 (CH, Ar), 127.0 (2×CH, Ar), 127.2 (C, Ar), 129.5 (C, Ar), 136.0 (C, Ar), 137.9 (C, Ar), 159.0 (C, Ar), 172.9 (CO_2Me); IR (film, cm^{-1}): 2970, 2125, 1745, 1620, 1590, 1525, 1470, 1430, 1360, 1325, 1300, 1260, 1215, 1190, 1120, 1045, 925, 885, 830, 805, 755; MS MALDI-TOF: *m/z* = 378 $[M]^+$ (378 calcd for $C_{21}H_{22}N_4O_3$); Anal. calcd for $C_{21}H_{22}N_4O_3$: C, 66.65; H, 5.86; N, 14.81. Found: C, 66.59; H, 5.81; N, 14.82.

Methyl 4-azido-4-(5-chloro-1-methyl-1*H*-indol-2-yl)butanoate (2c) was obtained as yellow oil



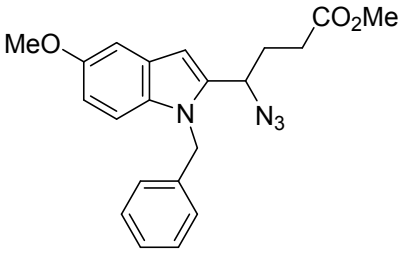
(170 mg, yield 63%) using the General procedure from cyclopropane **1c** (287 mg, 1.74 mmol) after 4 h at 80 °C (1st step) and 22 h at 110 °C (2nd step) in DMF. R_f = 0.43 (Al_2O_3, diethyl ether : petroleum ether; 1:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.30–2.38 (m, 2H, CH_2), 2.52–2.61 (m, 2H, CH_2), 3.71 (s, 3H, CH_3), 3.77 (s, 3H, CH_3), 4.62 (dd, ^3J = 7.9 Hz, ^3J = 6.8 Hz, 1H, CHN_3), 6.50 (s, 1H, CH, Ind), 7.21 (dd, ^3J = 8.7 Hz, ^4J = 1.9 Hz, 1H, CH, Ind), 7.25 (d, ^3J = 8.7 Hz, 1H, CH, Ind), 7.58 (d,^4J = 1.9 Hz, 1H, CH, Ind); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 28.3 (CH_2), 30.2 (CH_3N), 30.5 (CH_2), 51.9 (CH_3O), 57.0 (CHN_3), 100.6 (CH, Ind), 100.4 (CH, Ind), 120.3 (CH, Ind), 122.6 (CH, Ind), 125.6 (C, Ind), 127.9 (C, Ind), 136.5 (C, Ind), 137.4 (C, Ind), 173.0 (CO_2Me); IR (film, cm^{-1}): 2970, 2130, 1740, 1615, 1580, 1540, 1480, 1445, 1415, 1375, 1345, 1325, 1270, 1220, 1185, 1120, 1075 1025, 920, 890, 815, 770, 750; MS MALDI-TOF: *m/z* = 307 $[M+H]^+$ (307 calcd for $C_{14}H_{16}ClN_4O_2$); Anal. calcd for $C_{14}H_{15}ClN_4O_2$: C, 54.82; H, 4.93, N, 18.27; Found: C, 54.73; H, 4.88, N, 18.21.

Methyl 4-azido-4-(1-benzyl-5-fluoro-1*H*-indol-2-yl)butanoate (2d) was obtained as brown oil



(683 mg, yield 72%) using the General procedure from cyclopropane **1d** (1 g, 2.6 mmol) after 5 h at 85 °C (1st step) and 20 h at 110 °C (2nd step) in DMF. R_f = 0.70 (Al_2O_3, diethyl ether : petroleum ether; 2:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.35–2.36 (m, 2H, CH_2), 2.44–2.56 (m, 2H, CH_2), 3.67 (s, 3H, CH_3O), 4.50–4.52 (m, 1H, CHN_3), 5.45 (d, ^2J = 17.4 Hz, 1H, CH_2N), 5.49 (d, ^2J = 17.4 Hz, 1H, CH_2N), 6.67 (s, 1H, CH, Ind), 6.96–7.00 (m, 3H, Ar), 7.18 (dd, ^3J = 9.0 Hz, $^4J_{HF}$ = 4.5 Hz, 1H, CH, Ind), 7.27–7.31 (m, 3H, Ph), 7.35 (dd, $^3J_{HF}$ = 9.4 Hz, ^4J = 2.3 Hz, 1H, CH, Ind); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 28.5 (CH_2), 30.6 (CH_2), 47.0 (CH_2), 51.8 (CH_3O), 56.9 (CHN_3), 101.6 (d, $^4J_{CF}$ = 5 Hz, CH, Ind), 105.9 (d, $^2J_{CF}$ = 23 Hz, CH, Ind), 110.7 (d, $^3J_{CF}$ = 10 Hz, CH, Ind), 111.2 (d, $^2J_{CF}$ = 26 Hz, CH, Ind), 125.7 (2×CH, Ph), 127.5 (d, $^3J_{CF}$ = 10 Hz, C, Ind), 127.6 (CH, Ph), 129.0 (2×CH, Ph), 134.5 (C), 137.3 (C), 137.8 (C), 158.1 (d, $^1J_{CF}$ = 235 Hz, C, Ind), 172.8 (*C*O_2Me); IR (film, cm^{-1}): 2975, 2140, 1750, 1615, 1585, 1515, 1470, 1435, 1355, 1315, 1305, 1255, 1185, 1110, 1050, 930, 880, 815; HRMS MALDI–TOF: *m/z* = 324.1394 $[M–N_3]^+$(324.1394 calcd for $C_{20}H_{19}FNO_2$).

Methyl 4-azido-4-(1-benzyl-5-methoxy-1*H*-indol-2-yl)butanoate (2e) was obtained as brown oil



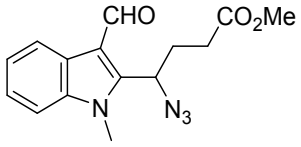
(108 mg, yield 70%) using the General procedure from cyclopropane **1e** (160 g, 0.41 mmol) after 4 h at 85 °C (1st step) and 29 h at 110 °C (2nd step) in DMF. R_f = 0.61 (Al_2O_3, diethyl ether : petroleum ether; 2:1). ^{1}HNMR (600 MHz, $CDCl_3$): δ = 2.25–2.31 (m, 2H, CH_2), 2.38–2.49 (m, 2H, CH_2), 3.63 (s, 3H, OCH_3), 3.86 (s, 3H, OCH_3), 4.41–4.43 (m, 1H, CHN_3), 5.39 (d, ^2J = 17.3 Hz, 1H, CH_2N), 5.44 (d, ^2J = 17.3 Hz, 1H, CH_2N), 6.58 (s, 1H, Ind), 6.87 (dd, ^3J = 8.9 Hz, ^4J = 2.5 Hz, 1H, Ind), 6.93–6.94 (m, 2H, Ph), 7.12 (d, ^4J = 2.5 Hz, 1H, CH, Ind), 7.14 (d, ^3J = 8.9 Hz, 1H, CH, Ind), 7.23–7.25 (m, 2H, Ph), 7.26–7.27 (m, 1H, Ph); ^{13}CNMR (150 MHz, $CDCl_3$): δ = 26.5 (CH_2), 30.7 (CH_2), 46.9 (CH_2), 51.7 (CH_3O), 55.8 (CH_3O), 56.9 (CHN_3), 101.3 (CH, Ar), 102.6 (CH, Ar), 110.7 (CH, Ar), 113.1 (CH, Ar), 125.7 (2×CH, Ph),

127.4 (CH, Ar), 127.5 (C, Ar), 128.8 (2×CH, Ph), 133.1 (C, Ar), 136.4 (C, Ar), 137.6 (C, Ar), 154.5 (C, Ar), 172.9 (*C*O_2Me); IR (film, cm^{-1}): 2980, 2125, 1755, 1600, 1580, 1510, 1480, 1460, 1430, 1370, 1310, 1300, 1250, 1190, 1165, 1010, 1100, 920, 875, 810; HRMS MALDI–TOF: *m/z*= 379.1763 $[M+H]^+$(379.1765 calcd for $C_{21}H_{23}N_4O_3$).

General procedure for synthesis of formylazides 3a–e

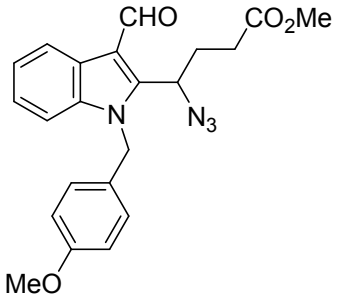
To cold DMF (4.4 equiv.) $POCl_3$ (1.1 equiv.) was added dropwise. The mixture was stirred for 40 min and was allowed to be warmed up to room temperature. Then, DMF solution (6 M) of azide **2** (1 equiv.) was added in a single portion. The resulting mixture was heated at 50 °C for the specified time. Then NaOH (20% aq.) (4-5 equiv.) was added and the mixture was stirred for 30 min. Product was extracted with ethyl acetate (5×10 mL). The combined organic fractions were washed with water (5×20 mL) and dried with Na_2SO_4. Solvent was evaporated. Product was purified by column chromatography.

Methyl 4-azido-4-(3-formyl-1-methyl-1*H*-indol-2-yl)butanoate (3a) was obtained as brown oil



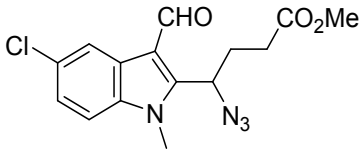
(189 mg, yield 74%) from azide **2a** (230 mg, 0.85 mmol) after heating at 50 °C for 3 h. R_f = 0.55 (Al_2O_3, ethyl acetate : petroleum ether; 1:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.21–2.27 (m, 1H, CH_2), 2.31–2.37 (m, 1H, CH_2), 2.47–2.55 (m, 2H, CH_2), 3.63 (s, 3H, CH_3), 3.98 (s, 3H, CH_3), 5.83–5.86 (m, 1H, CHN_3), 7.37 (dd, ^3J = 8.3 Hz, ^3J = 7.9 Hz, 1H, CH, Ind), 7.40–7.43 (m, 2H, CH, Ind), 8.27 (br. d, ^3J = 7.9 Hz, 1H, CH, Ind), 10.38 (s, 1H, CHO); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 29.9 (CH_2), 30.3 (CH_2), 31.7 (CH_3N), 51.9 (CH_3O), 56.8 (CHN_3), 109.9 (CH, Ind), 115.1 (C, Ind), 120.6 (CH, Ind), 123.3 (CH, Ind), 124.3 (CH, Ind), 125.8 (C, Ind), 137.7 (C, Ind), 143.5 (C, Ind), 172.7 (*C*O_2Me), 184.4 (CHO); IR (film, cm^{-1}): 2953, 2101, 1732, 1648, 1611, 1580, 1523, 1470, 1437, 1395, 1371, 1325, 1240, 1201, 1170, 1128, 1044, 1015, 898, 867, 805, 745; HRMS MALDI–TOF: *m/z* = 323.1119 $[M+Na]^+$ (323.1115 calcd for $C_{15}H_{16}N_4NaO_3$).

Methyl 4-azido-4-(3-formyl-1-(4-methoxybenzyl)-1*H*-indol-2-yl)butanoate (3b) was obtained as



brown oil (163 mg, yield 76%) from azide **2b** (200 g, 0.53 mmol) after heating at 50 °C for 3 h. R_f = 0.50 (Al_2O_3, ethyl acetate : petroleum ether; 1:2). ^{1}H NMR (600 MHz, $CDCl_3$): δ= 2.07 (dddd, ^2J = 14.3 Hz, ^3J = 7.8 Hz, ^3J = 6.7 Hz, ^3J = 6.3 Hz, 1H, CH_2), 2.18 (dddd, ^2J = 14.3 Hz, ^3J = 9.0 Hz, ^3J = 6.6 Hz, ^3J = 6.2 Hz, 1H, CH_2), 2.38–2.47 (m, 2H, CH_2), 3.65 (s, 3H, CH_3O), 3.77 (s, 3H, CH_3O), 5.57 (AB-system, ^2J = 17.0 Hz, 2H, CH_2N), 5.65 (dd, ^3J = 9.0 Hz, ^3J = 6.7 Hz, 1H, CHN_3), 6.84 (br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 6.93 (br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 7.26 (br. d, ^3J = 8.3 Hz, 1H, CH, Ind), 7.30 (ddd, ^3J = 8.0 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1H, CH, Ind), 7.34 (ddd, ^3J = 8.3 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1H, CH, Ind), 8.34 (br. d, ^3J = 8.0 Hz, 1H, CH, Ind), 10.44 (1H, CHO); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 30.1 (CH_2), 30.9 (CH_2), 47.7 (CH_2), 51.8 (CH_3O), 55.3 (CH_3O), 57.0 (CHN_3), 110.7 (CH, Ar), 114.5 (2×CH, Ar), 115.5 (C, Ar), 121.3 (CH, Ar), 123.4 (CH, Ar), 124.5 (CH, Ar), 125.9 (C, Ar), 127.0 (2×CH, Ar), 127.8 (C, Ar), 137.3 (C, Ar), 144.6 (C, Ar), 159.3 (C, Ar), 172.7 (CO$_2$Me), 184.8 (CHO); IR (film, cm^{-1}): 2975, 2130, 1735, 1660, 1615, 1585, 1525, 1470, 1440, 1410, 1370, 1340, 1300, 1260, 1185, 1050, 920, 840, 765; MS MALDI-TOF: *m/z* = 445 $[M+K]^+$ (445 calcd for $C_{22}H_{22}N_4KO_4$); Anal. calcd for $C_{22}H_{22}N_4O_4$: C, 65.01; H, 5.46; N, 13.78. Found: C, 65.40; H, 5.65; N, 13.13.

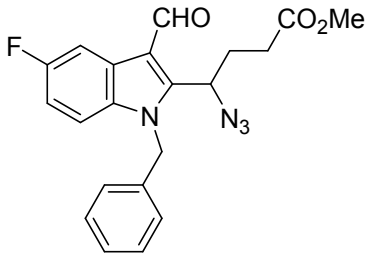
Methyl 4-azido-4-(5-chloro-3-formyl-1-methyl-1*H*-indol-2-yl)butanoate (3c) was obtained as



brown oil (78 mg, yield 71%) from azide **2c** (100 mg, 0.33 mmol) after heating at 50 °C for 3 h. R_f = 0.57 (Al_2O_3, ethyl acetate: petroleum ether; 1:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.18–2.24 (m, 1H, CH_2), 2.26–2.32 (m, 1H, CH_2), 2.45–2.53 (m, 2H, CH_2), 3.61 (s, 3H, CH_3), 3.93 (s, 3H, CH_3), 5.73 (dd, ^3J = 8.3 Hz, ^3J = 7.2 Hz, 1H, CHN_3), 7.29 (dd, ^3J = 8.7 Hz, ^5J = 0.7 Hz, 1H, CH, Ind), 7.31 (dd, ^3J = 8.7 Hz, ^4J = 1.8 Hz, 1H, CH, Ind), 8.25 (dd, ^4J = 1.8 Hz, ^5J = 0.7 Hz, 1H, CH, Ind), 10.29 (s, 1H, CHO); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 30.0 (CH_2), 30.1 (CH_2), 31.9 (CH_3N), 51.9 (CH_3O), 56.7 (CHN_3), 110.9 (CH, Ind), 114.6 (C, Ind), 120.5 (CH, Ind), 124.7 (CH, Ind), 126.6 (C,

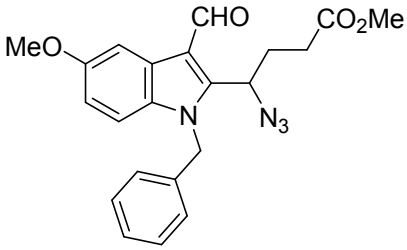
Ind), 129.3 (C, Ind), 136.0 (C, Ind), 144.8 (C, Ind), 172.6 (CO$_2$Me), 184.0 (CHO); IR (film, cm^{-1}): 2970, 2870, 2130, 1735, 1660, 1615, 1580, 1530, 1465, 1405, 1370, 1270, 1250, 1215, 1180, 1085, 1050, 970, 940, 900, 880, 850, 810, 750, 720; MS MALDI-TOF: *m/z* = 335 $[M+H]^+$ (334 calcd for $C_{15}H_{15}ClN_4O_3$); Anal. calcd for $C_{15}H_{15}ClN_4O_3$: C, 53.82; H, 4.52, N, 16.74; Found: C, 53.80; H, 4.51, N, 16.78.

Methyl 4-azido-4-(1-benzyl-5-fluoro-3-formyl-1*H*-indol-2-yl)butanoate (3d) was obtained as



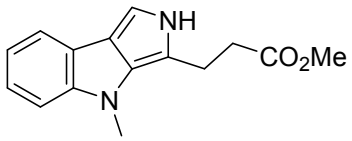
brown oil (200 mg, yield 77%) from azide **2d** (300 g, 0.82 mmol) after heating at 50 °C for 4 h. R_f = 0.60 (Al_2O_3, ethyl acetate: petroleum ether; 1:2). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.09 (dddd, ^2J = 14.3 Hz, ^3J = 8.2 Hz, ^3J = 6.8 Hz, ^3J = 6.2 Hz, 1H, CH_2), 2.16 (dddd, ^2J = 14.3 Hz, ^3J = 9.3 Hz, ^3J = 6.2 Hz, ^3J = 6.1 Hz, 1H, CH_2), 2.42 (ddd, 1H, ^2J = 17.1 Hz, ^3J = 6.2 Hz, ^3J = 6.2 Hz, 1H, CH_2), 2.47 (ddd, ^2J = 17.1 Hz, ^3J = 8.2 Hz, ^3J = 6.1 Hz, 1H, CH_2), 3.65 (s, 3H, CH_3O), 5.58 (dd, ^3J = 9.1 Hz, ^3J =6.8 Hz, 1H, CHN_3), 5.60 (d, ^2J = 17.7 Hz, 1H, CH_2N), 5.63 (d, ^2J = 17.7 Hz, 1H, CH_2N), 6.97–6.99 (m, 2H, Ph), 7.03 (ddd, $^3J_{HF}$ = 11.5 Hz, ^3J = 8.9 Hz, ^4J = 2.4 Hz, 1H, CH, Ind), 7.16 (dd, ^3J = 8.9 Hz, $^4J_{HF}$ = 4.1 Hz, 1H, CH, Ind), 7.28–7.34 (m, 3H, Ph), 8.03 (dd, $^3J_{HF}$ = 9.1 Hz, ^4J = 2.4 Hz, 1H, CH, Ind), 10.39 (s, 1H, CHO); ^{13}C NMR (150 MHz, $CDCl_3$) δ = 30.0 (CH_2), 31.0 (CH_2), 48.4 (CH_2), 51.9 (CH_3O), 59.9 (CHN_3), 107.0 (d, $^2J_{CF}$ = 25 Hz, CH, Ind), 111.6 (d, $^3J_{CF}$ = 9 Hz, CH, Ind), 113.0 (d, $^2J_{CF}$ = 26 Hz, CH, Ind), 115.5 (d, $^4J_{CF}$ = 5 Hz, C, Ind), 125.6 (2×CH, Ph), 126.4 (d, $^3J_{CF}$ = 11 Hz, C, Ind), 128.1 (CH, Ph), 129.2 (2×CH, Ph), 133.7 (C), 135.6 (C), 146.0 (C), 160.0 (d, $^1J_{CF}$ = 240 Hz, C, Ind), 172.7 (CO$_2$Me), 184.5 (CHO); IR (film, cm^{-1}): 2950, 2100, 1730, 1650, 1620, 1515, 1480, 1450, 1435, 1400, 1365, 1330, 1250, 1200, 1170, 1140, 1025, 910, 870, 805, 735; HRMS MALDI–TOF: *m/z* = 395.1511 $[M+H]^+$ (395.1514 calcd for $C_{21}H_{20}FN_4O_3$).

Methyl 4-azido-4-(1-benzyl-3-formyl-5-methoxy-1*H*-indol-2-yl)butanoate (3e) was obtained as



brown oil (74 mg, yield 70%) from azide **2e** (100 mg, 0.26 mmol) after heating at 50 °C for 4 h. R_f = 0.47 (Al_2O_3, ethyl acetate: petroleum ether; 1:2). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.05–2.11 (m, 1H, CH_2), 2.13–2.19 (m, 1H, CH_2), 2.38–2.47 (m, 2H, CH_2), 3.65 (s, 3H, CH_3O), 3.91 (s, 3H, CH_3O), 5.69 (dd, ^3J = 7.9 Hz, ^3J = 5.6 Hz, 1H, CHN_3), 5.58 (s, 2H, CH_2N), 6.92 (dd, ^3J = 8.9 Hz, ^4J = 2.5 Hz, 1H, CH, Ind), 6.99 (dd, ^3J = 8.2 Hz, ^4J = 1.5 Hz, 2H, CH, Ph), 7.12 (d, ^3J = 8.9 Hz, 1H, CH, Ind), 7.28–7.33 (m, 3H, Ph), 7.86 (d, ^4J = 2.5 Hz, 1H, CH, Ind), 10.40 (s, 1H, CHO); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 30.1 (CH_2), 31.1 (CH_2), 48.2 (CH_2), 51.8 (CH_3O), 55.8 (CH_3O), 57.0 (CHN_3), 102.8 (CH, Ind), 111.5 (CH, Ind), 115.0 (CH, Ind), 115.5 (C, Ind), 125.6 (2×CH, Ph), 126.5 (C, Ind), 127.9 (CH, Ph) 129.1 (2×CH, Ph), 132.1 (C), 135.9 (C), 144.8 (C), 157.1 (C, Ind), 172.7 (CO$_2$Me), 184.7 (CHO); IR (film, cm^{-1}) 2980, 2105, 1750, 1680, 1610, 1520, 1475, 1435, 1390, 1365, 1315, 1245, 1190, 1165, 1140, 1020, 890, 860, 735; HRMS MALDI–TOF: *m/z* = 407.1715 $[M+H]^+$ (407.1714 calcd for $C_{22}H_{23}FN_4O_4$).

Methyl 3-(4-methyl-2,4-dihydropyrrolo[3,4-*b*]indol-3-yl)propanoate (4a). Triphenylphosphine

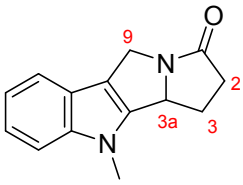


(134 mg, 0.51 mmol) was added to a solution of azide **3a** (153 mg, 0.51 mmol) in CH_2Cl_2 (8 mL). The resulting mixture was stirred at room temperature for 12 h. The solvent evaporation afforded crude product which cannot be purified by column chromatography due to instability. This product was characterized by NMR data. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.71 (t, ^3J = 6.9 Hz, 2H, CH_2), 3.22 (t, ^3J = 6.9 Hz, 2H, CH_2), 3.68 (s, 3H, CH_3), 3.74 (s, 3H, CH_3), 6.85 (d, ^3J = 2.7 Hz, 1H, CH), 6.97 (ddd, ^3J = 8.3 Hz, ^3J = 7.4 Hz, ^4J = 0.9 Hz 1H, CH), 7.08 (br. d, ^3J = 8.2 Hz, 1H, CH), 7.22 (ddd, ^3J = 8.2 Hz, ^3J = 7.4 Hz, ^4J = 1.1 Hz, 1H, CH), 7.28 (br. d, ^3J = 8.3 Hz, 1H, CH), 9.08 (br. s, 1H, NH); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 21.0 (CH_2), 31.1 (CH_3N), 35.7 (CH_2), 51.7 (CH_3O), 102.9 (CH, Ar), 104.2 (C, Ar), 107.5 (CH, Ar), 109.0 (C, Ar), 117.4 (CH, Ar), 120.3 (CH, Ar), 122.5 (C, Ar), 122.9 (C, Ar), 123.4 (CH, Ar), 147.3 (C, Ar), 174.1 (CO$_2$Me).

General procedure for the synthesis of pyrrolizino[1,2-*b*]indolones 5.

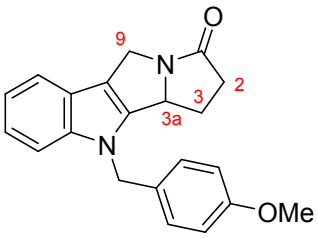
Triphenylphosphine (134 mg, 0.51 mmol) was added to a solution of azide **3a** (153 mg, 0.51 mmol) in CH_2Cl_2 (8 mL). The resulting mixture was stirred at room temperature for 12 h. The solvent was evaporated. The residue was diluted with methanol (2.5 mL), then $NaBH_4$ (29 mg, 0.77 mmol) was added under argon atmosphere. The reaction mixture was stirred for 4 h and poured into saturated NH_4Cl solution (10 mL). Product was extracted with ethyl acetate. The combined organic fractions were dried with Na_2SO_4. After solvent evaporation, product was purified by column chromatography on silica gel.

4-Methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5a) was obtained as brown



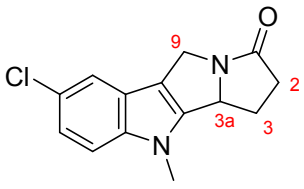
crystals from azide **3a** in 62% yield (71 mg). Mp 180 – 183 °C (dec.). R_f = 0.10 (ethyl acetate). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 2.22 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$ = 10.0 Hz, $^3J_{3,2}$ = 8.6 Hz, $^3J_{3,3a}$ = 7.4 Hz, 1H, C(3)H_2), 2.49 (ddd, ^2J = 17.2 Hz, $^3J_{2,3}$ = 9.7 Hz, $^3J_{2,3}$ = 8.6 Hz, 1H, C(2)H_2), 2.53 (ddd, ^2J = 17.2 Hz, $^3J_{2,3}$ = 10.0 Hz, $^3J_{2,3}$ = 4.3 Hz, 1H, C(2)H_2), 2.59 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$ = 9.7 Hz, $^3J_{3,3a}$ = 8.1 Hz, $^3J_{3,2}$ = 4.3 Hz, 1H, C(3)H_2), 3.71 (s, 3H, CH_3N), 4.87 (d, ^2J = 12.2 Hz, 1H, C(9)H_2), 4.90 (d, ^2J = 12.2 Hz, 1H, C(9)H_2), 5.18 (dd, $^3J_{3a,3}$ = 8.1 Hz, $^3J_{3a,3}$ = 7.4 Hz, 1H, C(3a)H), 7.14–7.16 (m, 1H, CH, Ind), 7.23–7.26 (m, 1H, CH, Ind), 7.27–7.28 (m, 1H, CH, Ind), 7.65–7.66 (m, 1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 28.1 ($^1J_{CH}$ = 135 Hz, CH_2), 30.2 ($^1J_{CH}$ = 132 Hz, CH_2; $^1J_{CH}$ = 138 Hz, CH_3N), 50.8 ($^1J_{CH}$ = 142 Hz, CHN), 53.9 ($^1J_{CH}$ = 142 Hz, CH_2), 108.9 (CH, Ind), 112.3 (C, Ind), 118.6 (CH, Ind), 119.8 (CH, Ind), 122.2 (CH, Ind), 127.2 (C, Ind), 136.0 (C, Ind), 137.0 (C, Ind), 178.5 (CO); IR (film, cm^{-1}): 2950, 2890, 1680, 1475, 1415, 1390, 1335, 1265, 1165, 1100, 1050, 990, 760; MS MALDI-TOF: *m/z* = 227 $[M+H]^+$ (227 calcd for $C_{14}H_{15}N_2O$); HRMS ESI-TOF: *m/z* = 227.1183 $[M + H]^+$ (227.1179 calcd for $C_{14}H_{15}N_2O$).

4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b) was obtained as brown oil from azide **3b** (130 mg, 0.32 mmol) in 69% yield (73 mg).



R_f = 0.14 (SiO_2, ethyl acetate). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 1.86 (dddd, ^2J = 13.2 Hz, $^3J_{3,2}$ = 9.9Hz, $^3J_{3,2}$ = 9.1 Hz, $^3J_{3,3a}$= 7.5 Hz, 1H, C(3)H_2), 2.07 (dddd, ^2J = 13.2 Hz, $^3J_{3,2}$= 9.9 Hz, $^3J_{3,3a}$= 7.9 Hz, $^3J_{3,2}$ = 4.0 Hz, 1H, C(3)H_2), 2.23 (ddd, ^2J = 17.3 Hz, $^3J_{2,3}$ = 9.9 Hz, $^3J_{2,3}$ = 9.1 Hz, 1H, C(2)H_2), 2.31 (ddd, ^2J = 17.3 Hz, $^3J_{2,3}$ = 9.9 Hz, $^3J_{2,3}$ = 4.0 Hz, 1H, C(2)H_2), 3.73 (s, 3H, CH_3O), 4.82 (d, ^2J = 12.3 Hz, 1H, C(9)H_2), 4.85 (d, ^2J = 12.3 Hz, 1H, C(9)H_2), 4.94 (dd, ^3J = 7.9 Hz, ^3J = 7.5 Hz, 1H, C(3a)H), 5.13 (d, ^2J = 17.1 Hz, 1H, CH_2, PMB), 5.27 (d, ^2J = 17.1 Hz, 1H, CH_2, PMB), 6.76 (br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 6.83 (br. d, ^3J = 8.8 Hz, 2H, CH, Ar), 7.14 (ddd, ^3J = 8.2 Hz, ^3J = 7.8 Hz, ^4J = 1.8 Hz, 1H, CH, Ind), 7.18 (ddd, ^3J = 8.2 Hz, ^3J = 7.8 Hz, ^4J = 1.2 Hz, 1H, Ind), 7.20 (dd, ^3J = 7.8 Hz, ^4J = 1.8 Hz, 1H, CH, Ind), 7.70 (br. d, ^3J = 7.8 Hz, 1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 28.5 (C(3)H_2), 29.8 (C(2)H_2), 45.8 (CH_2, PMB), 50.6 (C(3a)H), 53.7 (C(9)H_2), 54.7 (CH_3O), 109.0 (CH, Ind), 112.4 (C, Ind), 113.8 (2×CH, Ar), 118.2 (CH, Ind), 119.6 (CH, Ind), 122.0 (CH, Ind), 126.5 (2×CH, Ar), 127.1 (C, Ind), 128.9 (C, Ar), 135.9 (C, Ind), 136.4 (C, Ind), 158.5 (C, Ar), 177.8 (CO); IR (film, cm^{-1}): 2970, 2890, 1700, 1475, 1450, 1390, 1320, 1295, 1260, 1180, 1050, 990, 890, 805, 735; HRMS ESI-TOF: *m/z* = 333.1594 $[M + H]^+$ (333.1598 calcd for $C_{21}H_{21}N_2O_2$).

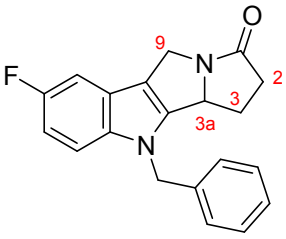
7-Chloro-4-methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5c) was obtained as brown solid from azide **3c** (64 mg, 0.20 mmol) in 75% yield (39 mg). Mp 199 – 201 °C (dec.).



R_f = 0.12 (ethyl acetate). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 2.10 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$ = 10.0 Hz, $^3J_{3,2}$ = 7.8 Hz, $^3J_{3,3a}$ = 7.0 Hz, 1H, C(3)H_2), 2.43 (ddd, ^2J = 17.2 Hz, $^3J_{2,3}$ = 9.9 Hz, $^3J_{2,3}$ = 7.8 Hz, 1H, C(2)H_2), 2.45 (ddd, ^2J = 17.2 Hz, $^3J_{2,3}$ = 10.0 Hz, $^3J_{2,3}$= 4.3 Hz, 1H, C(3)H_2), 2.48 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$= 9.9 Hz, $^3J_{3,3a}$ = 7.9 Hz, $^3J_{3,2}$= 4.3 Hz, 1H, C(2)H_2), 3.63 (s, 3H, CH_3N), 4.73 (d, ^2J = 12.3 Hz, 1H, C(9)H_2), 4.77 (d, ^2J = 12.3 Hz, 1H, C(9)H_2), 5.05 (dd, $^3J_{3a,3}$ = 7.9 Hz, $^3J_{3a,3}$ = 7.0 Hz, 1H, C(3a)H), 7.14 (dd, ^3J = 8.7 Hz, ^5J = 0.6 Hz, 1H, Ind), 7.17 (dd, ^3J = 8.7 Hz, ^4J = 1.8 Hz, 1H, Ind), 7.61 (dd, ^4J = 1.8

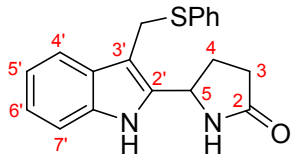
Hz, ^5J = 0.6 Hz, 1H, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 28.4 ($^1J_{CH}$ = 134 Hz, CH_2), 30.2 ($^1J_{CH}$ = 129 Hz, CH_2), 30.5 ($^1J_{CH}$ = 138 Hz, CH_3N), 51.0 ($^1J_{CH}$ = 141 Hz, CHN), 54.0 ($^1J_{CH}$ = 142 Hz, CH_2), 110.0 (CH, Ind), 112.0 (C, Ind), 118.0 (CH, Ind), 122.5 (CH, Ind), 125.7 (C, Ind), 128.2 (C, Ind), 135.4 (C, Ind), 137.5 (C, Ind), 178.3 (CO); IR (film, cm^{-1}): 2970, 2890, 1700, 1470, 1385, 1300, 1270, 1190, 1085, 985, 880, 810, 740; HRMS ESI-TOF: *m/z* = 261.0796 $[M + H]^+$ (261.0789 calcd for $C_{14}H_{14}ClN_2O$).

4-Benzyl-7-fluoro-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5d) was obtained as



brown oil from azide **3d** (100 mg, 0.25 mmol) in 77% yield (62 mg). R_f = 0.10 (ethyl acetate). ^{1}H NMR ($CDCl_3$, 600 MHz): δ =1.92 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$ = 9.8 Hz, $^3J_{3,2}$ = 9.2 Hz, $^3J_{3,3a}$= 7.6 Hz, 1H, C(3)H_2), 2.14 (dddd, ^2J = 12.7 Hz, $^3J_{3,2}$ = 9.4 Hz, $^3J_{3,3a}$ = 8.2 Hz, $^3J_{3,2}$= 4.2 Hz, 1H, C(2)H_2), 2.28 (ddd, ^2J = 17.4 Hz, $^3J_{2,3}$ = 9.8 Hz, $^3J_{2,3}$ = 4.2 Hz, 1H, C(2)H_2), 2.35 (ddd, ^2J = 17.4 Hz, $^3J_{2,3}$ = 9.4 Hz, $^3J_{2,3}$= 9.2 Hz, 1H, C(2)H_2), 4.79 (d, ^2J = 12.5 Hz, 1H, C(9)H_2), 4.84 (d, ^2J = 12.5 Hz, 1H, C(9)H_2), 5.00 (dd, $^3J_{3a,3}$ = 8.2 Hz, $^3J_{3a,3}$ = 7.6 Hz, 1H, C(3a)H), 5.28 (d, ^2J = 17.8 Hz, 1H, CH_2Ph), 5.36 (d, 1H, ^2J = 17.8 Hz, 1H, CH_2Ph), 6.89–6.91 (m, 2H, CH, Ph), 6.92 (ddd, $^3J_{HF}$ = 11.7 Hz, ^3J = 8.9 Hz, ^4J = 2.6 Hz, 1H, CH, Ind), 7.09 (dd, ^3J = 8.9 Hz, $^4J_{HF}$ = 4.2 Hz, 1H, CH, Ind), 7.24–7.28 (m, 3H, Ph), 7.35 (dd, $^3J_{HF}$ = 9.2 Hz, ^4J = 2.6 Hz, 1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 29.0 (CH_2), 30.1 (CH_2), 47.3 (*C*H_2Ph), 51.1 (CH), 62.3 (CH_2), 103.9 (d, $^2J_{CF}$ = 24 Hz, CH, Ind), 110.1 (d, $^4J_{CF}$ = 5 Hz, C, Ind), 110.4 (d, $^3J_{CF}$ = 9 Hz, CH, Ind), 110.9 (d, $^2J_{CF}$ = 26 Hz, CH, Ind), 125.7 (2×CH, Ph), 127.7 (CH, Ph), 128.6 (d, $^3J_{CF}$ = 9 Hz, C, Ind), 129.0 (2×CH, Ph), 133.5 (C), 137.0 (C), 139.2 (C), 158.4 (d, $^1J_{CF}$ = 235 Hz, C, Ind), 178.0 (CO); IR (film, cm^{-1}): 2970, 2890, 1690, 1530, 1470, 1390, 1300, 1255, 1185, 1080, 1045, 990, 965, 870, 810, 770, 745, 710; HRMS MALDI–TOF: *m/z* = 321.1298 $[M+H]^+$ (321.1298 calcd for $C_{20}H_{18}FN_2O$).

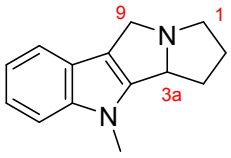
5-{3-[(Phenylsulfanyl)methyl]-1*H*-indol-2-yl}pyrrolidin-2-one (6). Compound **5b** (145 mg, 0.44



mmol) was added at 0 °C to the mixture of thiophenol (14 mL, 50 equiv.) and TFA (1.76 mL, 50 equiv.). The solution was stirred for 2 h, poured

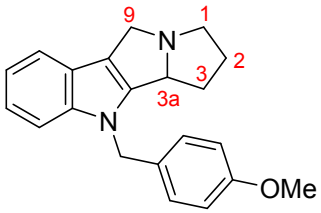
into cold saturated solution of $NaHCO_3$ and extracted with CH_2Cl_2 (3×15 mL). The combined organic fractions were dried with Na_2SO_4. Solvent was evaporated. Product was purified by column chromatography on silica gel. Compound **6** (113 mg, 79 %) was obtained as white solid. Mp 191–193 °C (dec.). R_f = 0.10 (SiO_2, ethyl acetate). ^{1}H NMR ($CDCl_3$, 600 MHz): δ =1.96–2.03 (m, 1H, C(4)H_2), 2.27–2.32 (m, 1H, C(4)H_2), 2.35 (ddd, ^2J = 14.4 Hz, ^3J = 9.2 Hz, ^3J = 5.2 Hz, 1H, C(3)H_2), 2.41 (ddd, ^2J = 14.4 Hz, ^3J = 10.6 Hz, ^3J = 4.9 Hz, 1H, C(3)H_2), 4.18 (AB-system, ^2J = 12.8 Hz, 2H, CH_2S), 4.74 (dd, ^3J = 7.6 Hz, ^3J = 7.1 Hz, 1H, C(5)H), 6.35 (br. s, 1H, NH), 7.13–7.16 (m, 1H, C(5′)H, Ind), 7.15–7.18 (m, 1H, *para*-CH, Ph), 7.21 (ddd, ^3J = 7.9 Hz, ^3J = 7.0 Hz, ^4J = 1.1 Hz, 1H, C(6′)H, Ind), 7.23–7.26 (m, 2H, *meta*-CH, Ph), 7.29 (br. dd, ^3J = 7.2 Hz, ^4J = 1.1 Hz, 2H, *ortho*-CH, Ph), 7.38 (br. d, ^3J = 7.9 Hz, 1H, C(7′)H, Ind), 7.63 (br. d, ^3J = 7.9 Hz, 1H, C(4′)H, Ind), 9.92 (s, 1H, NH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 29.0 (C(4)H_2, *C*H_2SPh), 30.3 (C(3)H_2), 50.3 (CH), 107.7 (C(3′), Ind), 111.3 (C(7′)H, Ind), 118.9 (C(4′)H, Ind), 119.8 (C(5′)H, Ind), 122.5 (C(6′)H, Ind), 126.7 (*para*-CH, Ph), 127.5 (C(3a′), Ind), 128.8 (2×*meta*-CH, Ph), 131.0 (2×*ortho*-CH, Ph), 136.00 (C(2′ or 7a′), 136.04 (C(2′ or 7a′), 136.7 (C, Ph), 177.8 (CO); IR(film, cm-1): 3270, 3055, 2925, 1690, 1580, 1510, 1480, 1455, 1440, 1335, 1300, 1250, 1085, 1025, 1010, 735, 690; HRMS ESI-TOF: *m/z* = 345.1031 $[M + Na]^+$ (345.1032 calcd for $C_{19}H_{18}N_2NaOS$); Anal. calcd for $C_{19}H_{18}N_2OS$: C, 70.78; H, 5.63, N, 8.69. Found: C, 70.40; H, 5.82, N, 8.38.

4-Methyl-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7a). A solution of **5a** (300 mg, 1.33 mmol) in dry THF (17 mL) was cooled to 0 °C and $LiAlH_4$ (504 mg, 13 mmol) was added portionwise. The reaction mixture was heated under reflux for 3 h, cooled to 0 °C and quenched by dropwise addition of H_2O (532 μL). NaOH (1.064 g) and H_2O (4.25 mL) was added; the mixture was stirred for 30 min and filtered, the solid was washed with DCM. The combined organic fractions were washed with brine, dried with Na_2SO_4. Solvent was evaporated. The residue was purified by column chromatography on silica gel (benzene/DCM). Product **7a** was obtained in 39 % yield (110 mg) as brown oil. R_f = 0.15 (DCM). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 1.90–1.96 (m, 1H, CH_2), 1.99–2.07 (m, 2H, CH_2), 2.18–2.26 (m,



1H, CH_2), 3.09 (ddd, ^2J = 10.8 Hz, ^3J = 8.5 Hz, ^3J = 5.6 Hz, 1H, CH_2), 3.20 (ddd, ^2J = 10.8 Hz, ^3J = 7.2 Hz, ^3J = 6.8 Hz, 1H, CH_2), 3.68 (s, 3H, CH_3N), 4.66 (dd, ^3J = 8.4 Hz, ^3J = 8.0 Hz, 1H, C(3a)H), 4.79 (d, ^2J = 13.2 Hz, 1H, C(9)H_2), 4.91 (d, ^2J = 13.2 Hz, 1H, C(9)H_2), 7.09 (ddd, ^3J = 7.9 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1H, CH, Ind), 7.20 (ddd, ^3J = 7.9 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1H, CH, Ind), 7.22 (br. d, ^3J = 7.9 Hz, 1H, CH, Ind), 7.51 (br. d, ^3J = 7.9 Hz, 1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 25.2 (CH_2), 30.1 (CH_3N), 31.6 (CH_2), 45.5 (CH_2), 54.6 (CHN), 55.0 (CH_2), 109.2 (CH, Ind), 113.0 (C, Ind), 118.3 (CH, Ind), 119.7 (CH, Ind), 122.0 (CH, Ind), 126.6 (C, Ind), 136.0 (C, Ind), 136.2 (C, Ind); IR (film, cm^{-1}): 2965, 2885, 1550, 1465, 1370, 1335, 1290, 1265, 1185, 1090, 1045, 1015, 985, 880, 805, 745; HRMS MALDI–TOF: *m/z* = 213.1386 $[M+H]^+$ (213.1389 calcd for $C_{14}H_{17}N_2$).

4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b) was obtained as brown oil from **5b** (65 mg, 0.20 mmol) in 41 % yield (24 mg) by procedure analogous to that for **7a** synthesis. R_f = 0.10 (DCM). ^{1}H NMR ($CDCl_3$, 600 MHz): δ = 1.61 (dddd, ^2J = 12.6 Hz, ^3J = 9.7 Hz, ^3J = 7.2 Hz, ^3J = 2.4 Hz, 1H, C(3)H_2), 1.71–1.79 (m, 1H, C(2)H_2), 1.94–1.99 (m, 1H, C(2)H_2), 2.04 (dddd, ^2J = 12.6 Hz, ^3J = 10.7 Hz, ^3J = 9.7 Hz, ^3J = 8.1 Hz, 1H, C(3)H_2), 3.04 (ddd, ^2J = 11.6 Hz, ^3J = 8.9 Hz, ^3J = 4.9 Hz, 1H, C(1)H_2), 3.19 (ddd, ^2J = 11.6 Hz, ^3J = 8.2 Hz, ^3J = 7.6 Hz, 1H, C(1)H_2), 3.75 (s, 3H, CH_3O), 4.69 (dd, ^3J = 10.7 Hz, ^3J = 7.2 Hz, 1H, C(3a)H), 4.80 (d, ^2J = 13.2 Hz, 1H, C(9)H_2), 5.08 (d, ^2J = 13.2 Hz, 1H, C(9)H_2), 5.36 (d, ^2J = 17.0 Hz, 1H, CH_2, PMB), 5.50 (d, ^2J = 17.0 Hz, 1H, CH_2, PMB), 6.77 (d, ^3J = 8.7 Hz, 2H, CH, Ar), 6.89 (d, ^3J = 8.7 Hz, 2H, CH, Ar), 7.11 (br. d, ^3J = 8.2 Hz, ^3J = 7.0 Hz, 1H, CH, Ind), 7.19 (br. d, ^3J = 8.0 Hz, ^3J = 7.0 Hz, ^4J = 1.0 Hz, 1H, CH, Ind), 7.24 (br. d, ^3J = 8.2 Hz, 1H, CH, Ind), 7.56 (br. d, ^3J = 8.0 Hz,1H, CH, Ind); ^{13}C NMR ($CDCl_3$, 150 MHz): δ = 24.7 (C(2)H_2), 30.0 (C(3)H_2), 44.7 (C(1)H_2), 46.3 (CH_2, PMB), 54.9 (C(9)H_2), 55.0 (C(3a)H), 55.3 (CH_3O), 109.7 (CH, Ind), 114.2 (2×CH, Ar), 114.6 (C, Ind), 118.7 (CH, Ind), 120.2 (CH, Ind), 123.0 (CH, Ind), 126.5 (C, Ind), 127.2 (2×CH, Ar), 129.7 (C, Ar), 131.6 (C, Ind), 136.2 (C, Ind), 159.0 (C, Ar); IR (film, cm^{-1}): 2965, 2890, 1525, 1465, 1440, 1385, 1345, 1295, 1260,



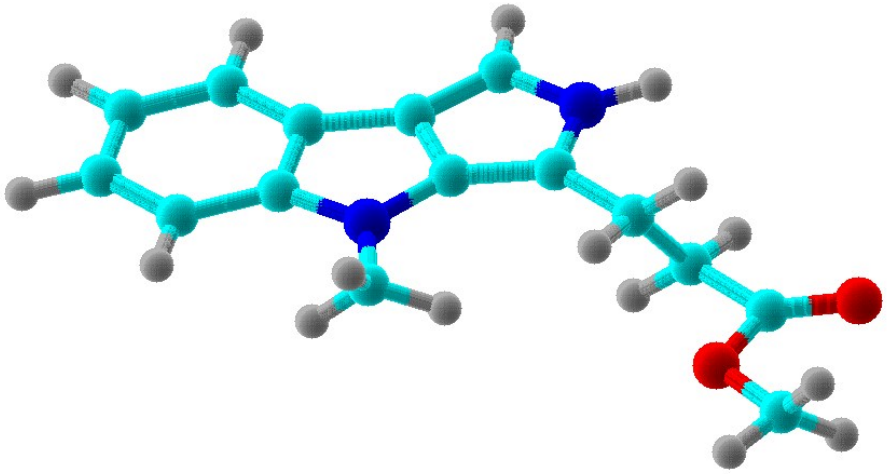
1210, 1180, 1160, 1085, 1045, 990, 950, 910, 880, 845, 830, 815, 775; HRMS MALDI–TOF: *m/z* = 319.1805 $[M+H]^+$ (319.1805 calcd for $C_{21}H_{23}N_2O$).

Cell assays

The cytotoxicity of tested substances was assessed using the MTT (3-(4,5-dimethylthiazol-2-yl)2,5-diphenyl tetrazolium bromide) assay[S5] with some modifications. 4000 cells per well for VA-13 cell line and 3000 cells per well for MCF7, HEK293T and A549 cell lines were plated out in 135 mcl of DMEM-F12 media in 96-well plate and incubated in the 5% CO_2 incubator for first 18 h without treating. Then we add 15 mcl of media-DMSO solutions of tested substances to the cells (final DMSO concentrations in the media were 1% or less) and treated cells 72 h with 50 nM -100 mcM (eight dilutions) of our substances (triplicate each) and doxorubicin like control substance. At the end we added MTT up to 0,5 mg/ml in the media, incubated cells 2 h followed by removing media and addition of 100 mcl of DMSO and measure the amount of MTT reduced by cells to its blue formazan derivative spectrophotometrically at 565 nm using a plate reader. Data was normalised by cells, treated with media-DMSO solutions without substances and IC50 was calculated with "GraphPad Prism 6" software (GraphPad Software, Inc., San Diego, CA). Doxorubicin, etoposide and amircumacin were used as standards.

Results of quantum chemical calculations at B3LYP/6-311G level**

Compound **4a**

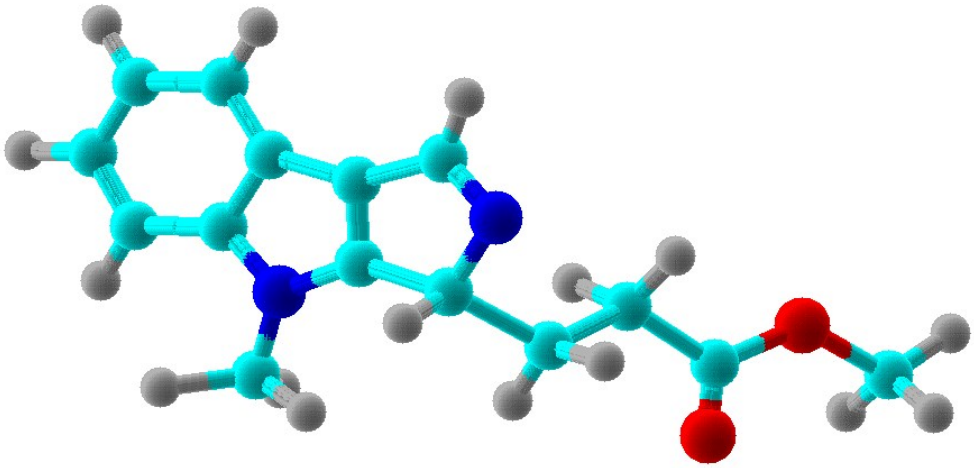


E = -841.395556 a.u. (E_{rel} = 0)

Standard orientation:

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	6	0	-4.282869	0.818608	-0.303452
2	6	0	-5.202146	-0.224878	-0.393058
3	6	0	-4.782979	-1.553407	-0.265441
4	6	0	-3.443031	-1.873466	-0.050902
5	6	0	-2.520695	-0.830687	0.027258
6	6	0	-2.936279	0.529866	-0.088131
7	7	0	-1.138737	-0.898163	0.212360
8	6	0	-1.737948	1.323029	0.069949
9	6	0	-0.658676	0.407722	0.272905
10	6	0	-0.397101	-2.100035	0.519400
11	6	0	-1.201116	2.596473	0.107585
12	6	0	0.519258	1.109888	0.445111
13	7	0	0.146869	2.448456	0.325124
14	6	0	1.943805	0.703716	0.633119
15	6	0	2.736349	0.563402	-0.696583
16	6	0	4.157230	0.120639	-0.438276
17	8	0	5.121941	0.841903	-0.388747
18	8	0	4.214157	-1.213918	-0.213292
19	6	0	5.517480	-1.738069	0.100765
20	1	0	-4.612353	1.847757	-0.396145
21	1	0	-6.250840	-0.006713	-0.558670
22	1	0	-5.512512	-2.353058	-0.330074
23	1	0	-3.137853	-2.907807	0.054848
24	1	0	-0.810664	-2.942854	-0.037666
25	1	0	-0.420249	-2.344878	1.589337
26	1	0	0.643234	-1.980817	0.212654
27	1	0	-1.646759	3.572530	0.013579
28	1	0	0.787650	3.215590	0.445258
29	1	0	2.459504	1.430955	1.271195
30	1	0	1.983892	-0.248962	1.166225
31	1	0	2.772800	1.522158	-1.214768
32	1	0	2.235552	-0.164092	-1.338147
33	1	0	5.376315	-2.807525	0.240450
34	1	0	5.905642	-1.279280	1.011533
35	1	0	6.213234	-1.545745	-0.717177

Compound **4a′**



E = -841.387188 a.u. (E_{rel} = 22.0 kJ mol^{-1})

Standard orientation:

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2	6	0	-4.460631	-0.559947	-1.518125
3	6	0	-4.370051	-1.625528	-0.607388
4	6	0	-3.343920	-1.686858	0.328588
5	6	0	-2.407964	-0.653009	0.332808
6	6	0	-2.481411	0.438866	-0.585570
7	7	0	-1.295237	-0.475528	1.160846
8	6	0	-1.358432	1.275246	-0.266657
9	6	0	-0.683711	0.685769	0.775796
10	6	0	-0.902576	-1.371926	2.233205
11	6	0	-0.619544	2.494438	-0.557658
12	6	0	0.487966	1.548873	1.159515
13	7	0	0.410417	2.679875	0.201770
14	6	0	1.881511	0.898896	1.135981
15	6	0	2.278603	0.351211	-0.234772
16	6	0	3.562646	-0.446382	-0.186483
17	8	0	4.066328	-0.911688	0.806840
18	8	0	4.081480	-0.601820	-1.422832
19	6	0	5.286327	-1.384409	-1.501586
20	1	0	-3.609850	1.285554	-2.224146
21	1	0	-5.273751	-0.543658	-2.234851
22	1	0	-5.112494	-2.414748	-0.634329
23	1	0	-3.279021	-2.513535	1.026521
24	1	0	-1.729297	-1.515446	2.934180
25	1	0	-0.062113	-0.938200	2.771968
26	1	0	-0.599761	-2.347331	1.841418
27	1	0	-0.864809	3.216294	-1.331684
28	1	0	0.331718	1.975303	2.158850
29	1	0	1.931278	0.096664	1.876603
30	1	0	2.605520	1.655636	1.447979
31	1	0	1.503581	-0.316676	-0.630074
32	1	0	2.382954	1.154978	-0.965267
33	1	0	5.554471	-1.400107	-2.555583
34	1	0	6.079955	-0.925691	-0.909887
35	1	0	5.111119	-2.397171	-1.134833

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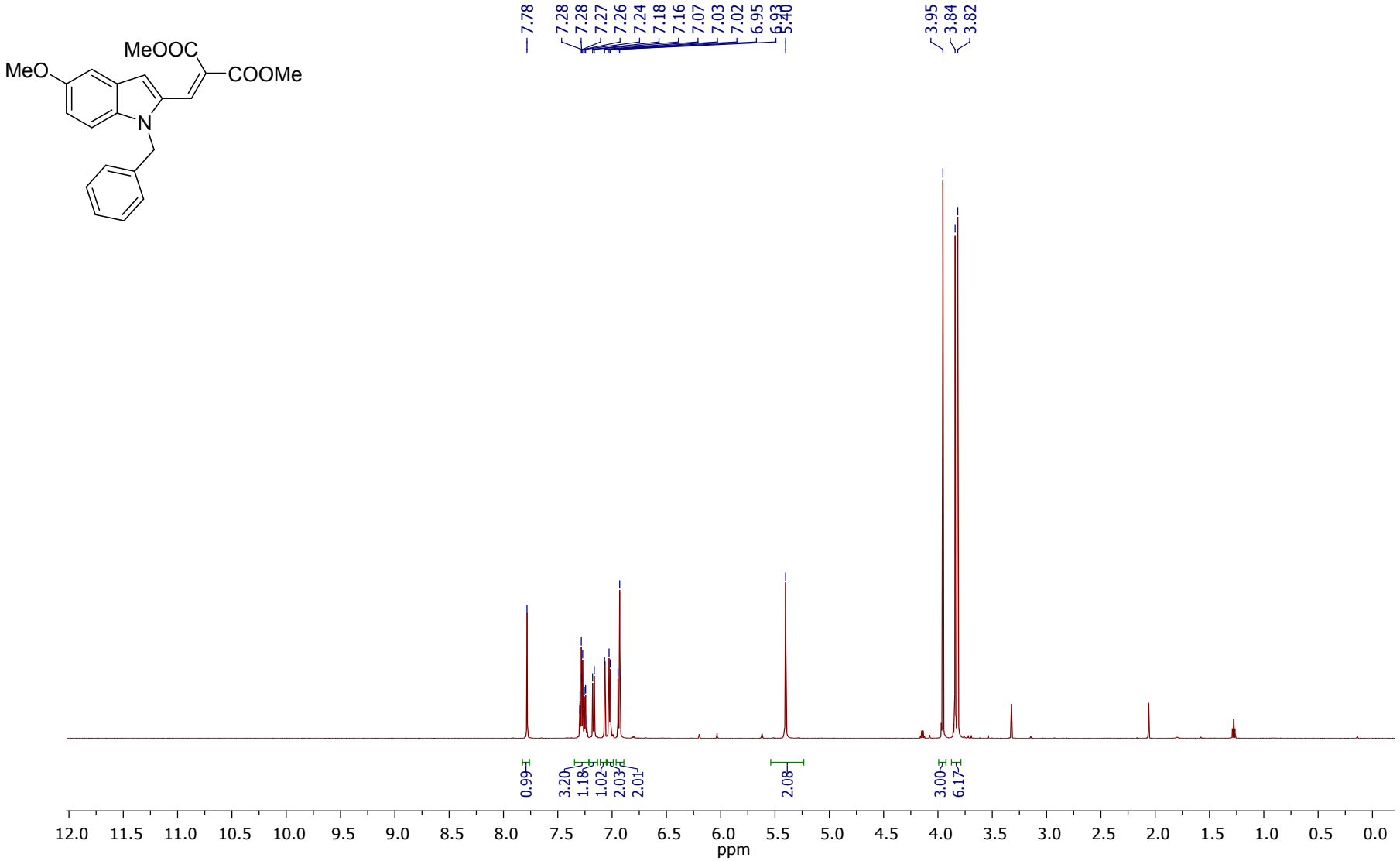
Dimethyl 2-[(1-benzyl-5-methoxy-1*H*-indol-2-yl)methylene]malonate (S1)

^{1}H NMR ($CDCl_3$, 600 MHz)



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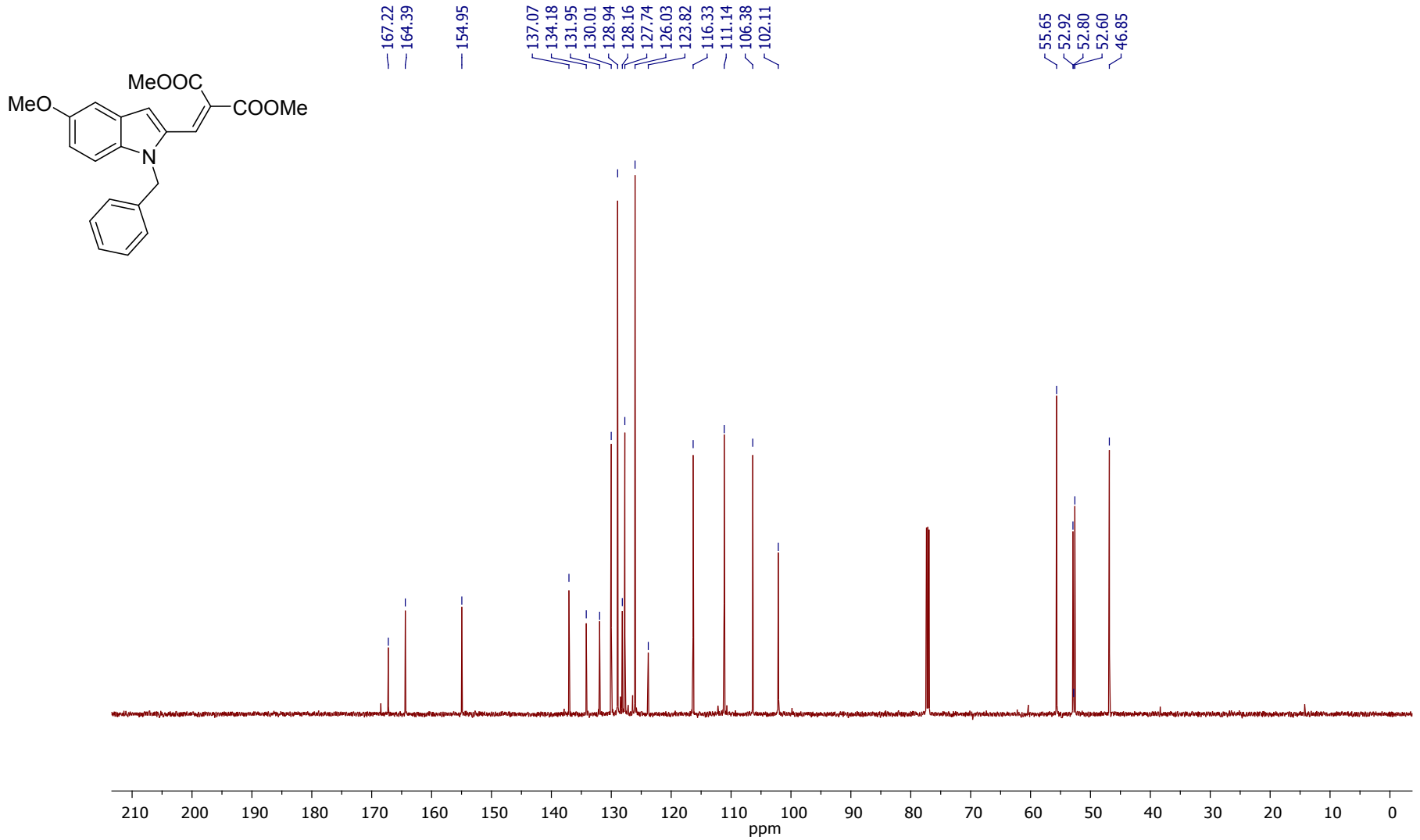
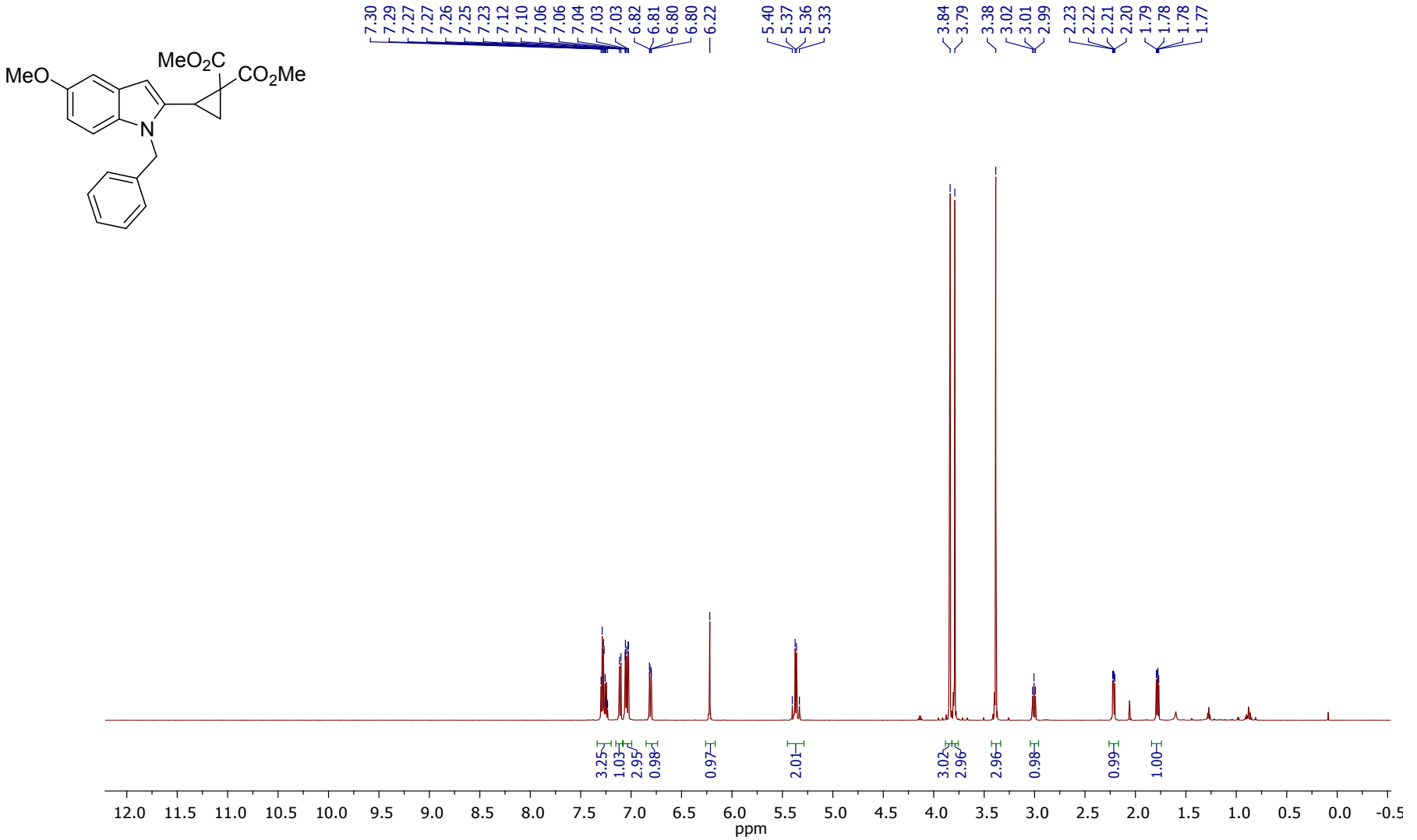
^{13}C NMR ($CDCl_3$, 100 MHz)



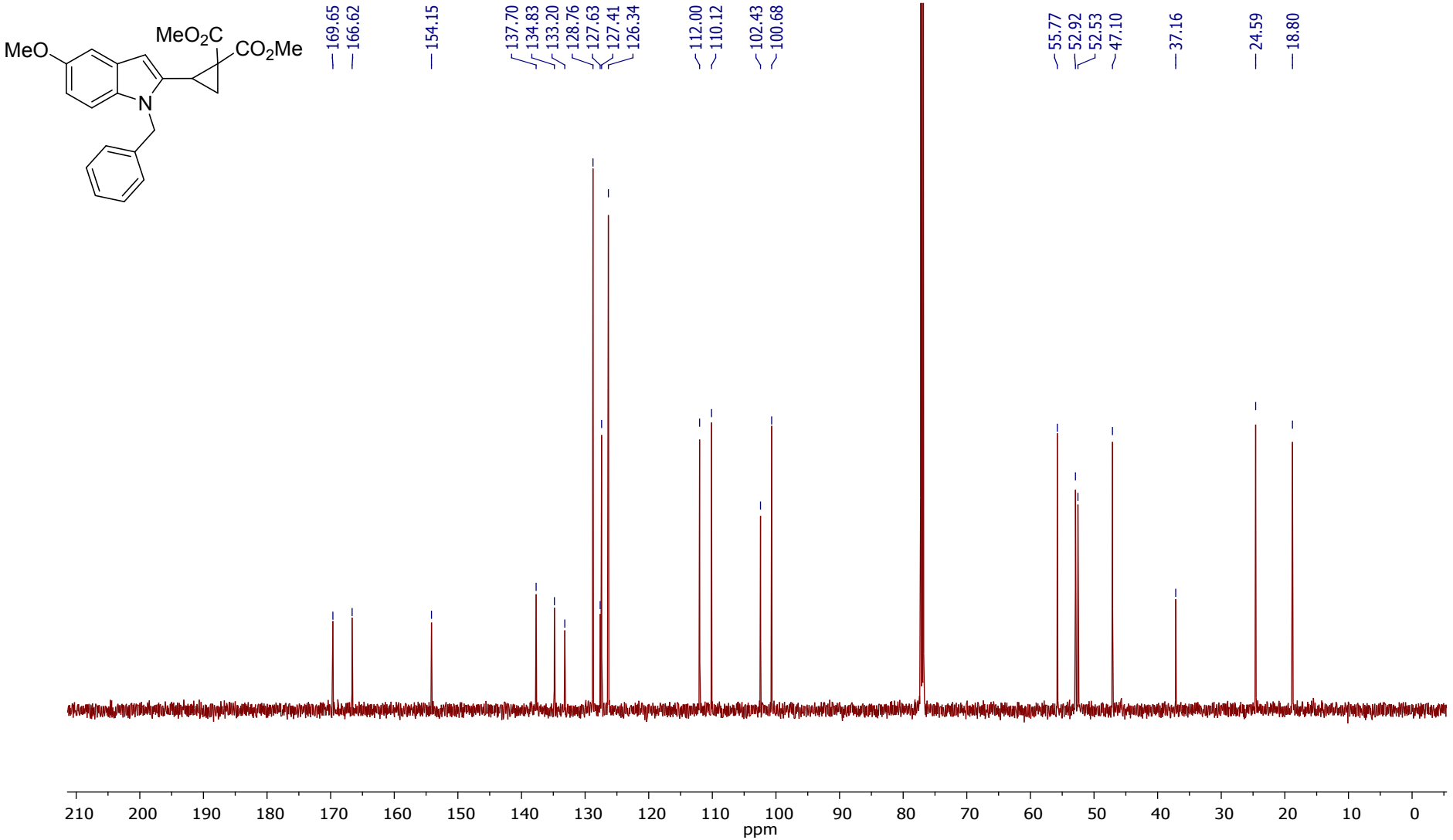
Dimethyl 2-(1-benzyl-5-methoxy-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate (1e)

^{1}H NMR ($CDCl_3$, 600 MHz)



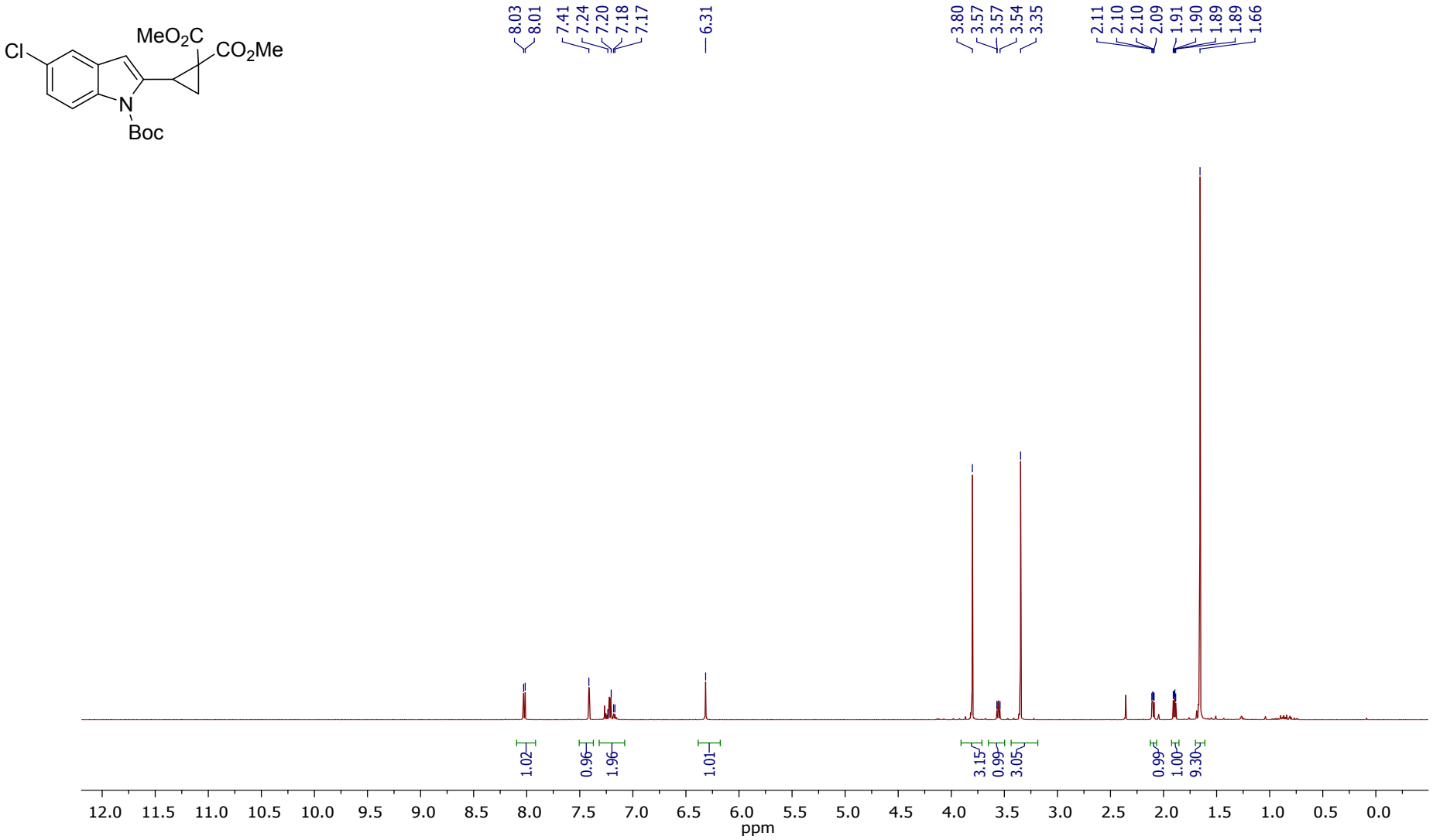
Dimethyl 2-(1-benzyl-5-methoxy-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate (1e)

^{13}C NMR ($CDCl_3$, 100 MHz)



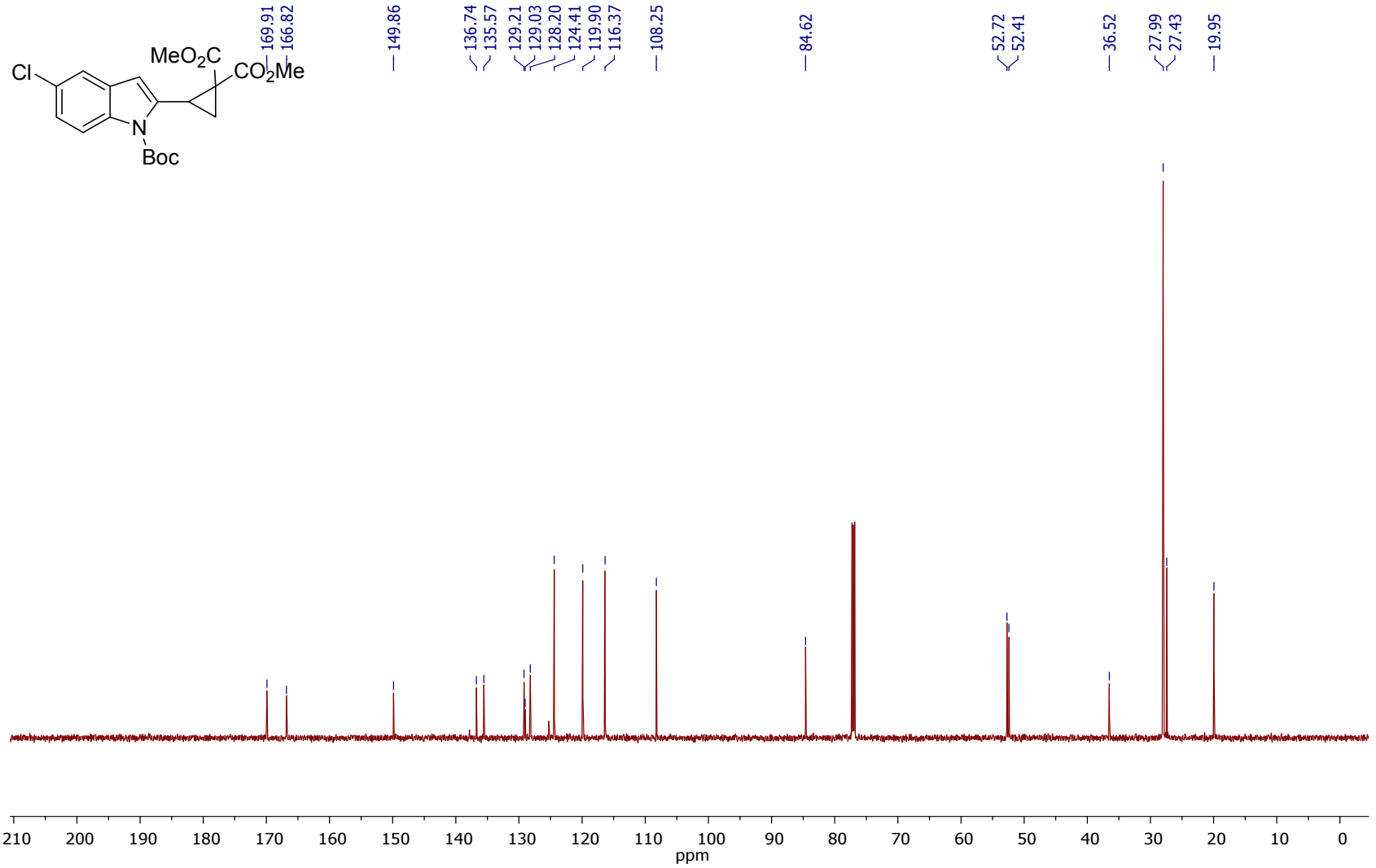
Dimethyl 2-[1-(*tert*-butoxycarbonyl)-5-chloro-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate

^{1}H NMR ($CDCl_3$, 600 MHz)



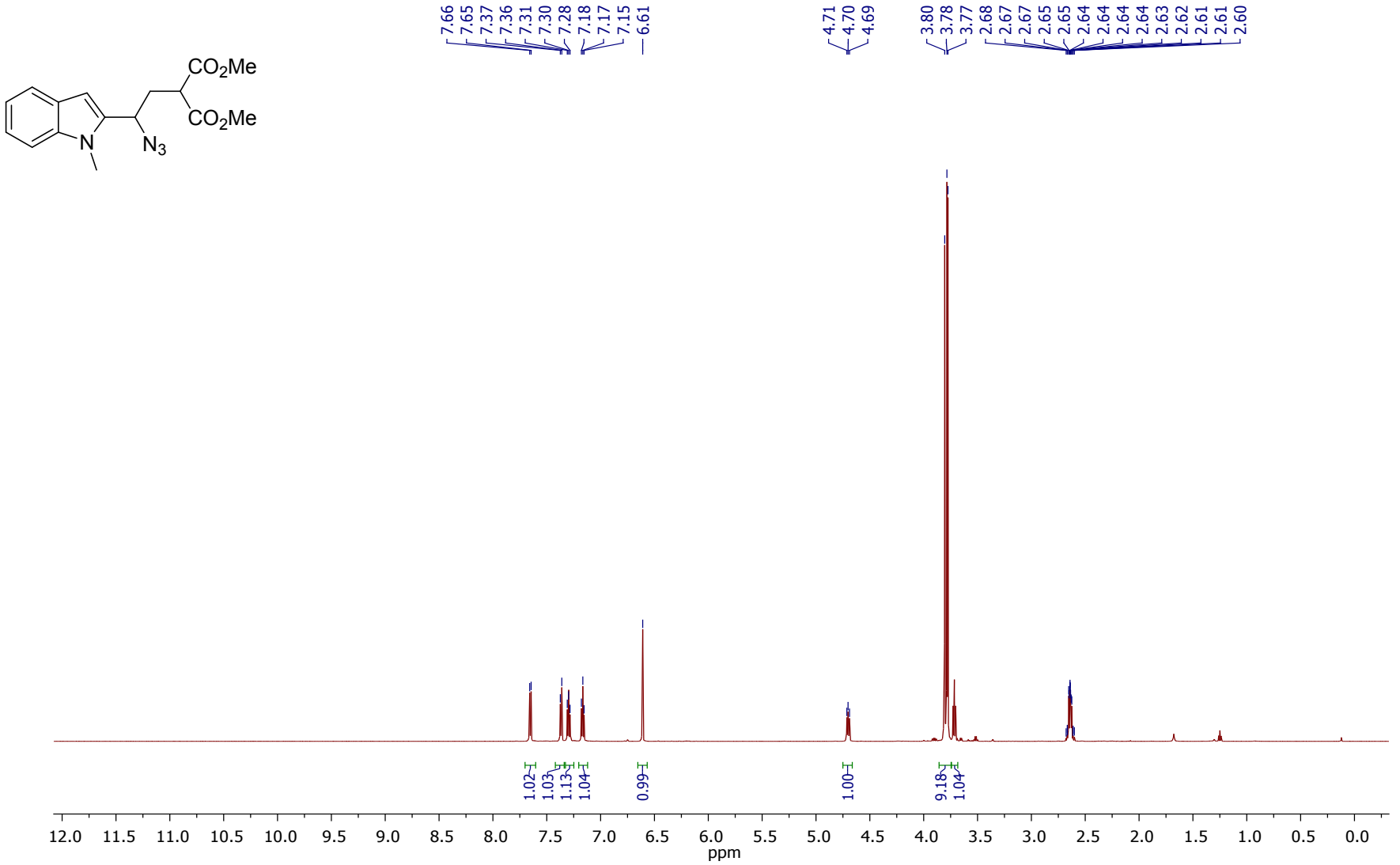
Dimethyl 2-[1-(*tert*-butoxycarbonyl)-5-chloro-1*H*-indol-2-yl)cyclopropane-1,1-dicarboxylate

^{13}C NMR ($CDCl_3$, 100 MHz)



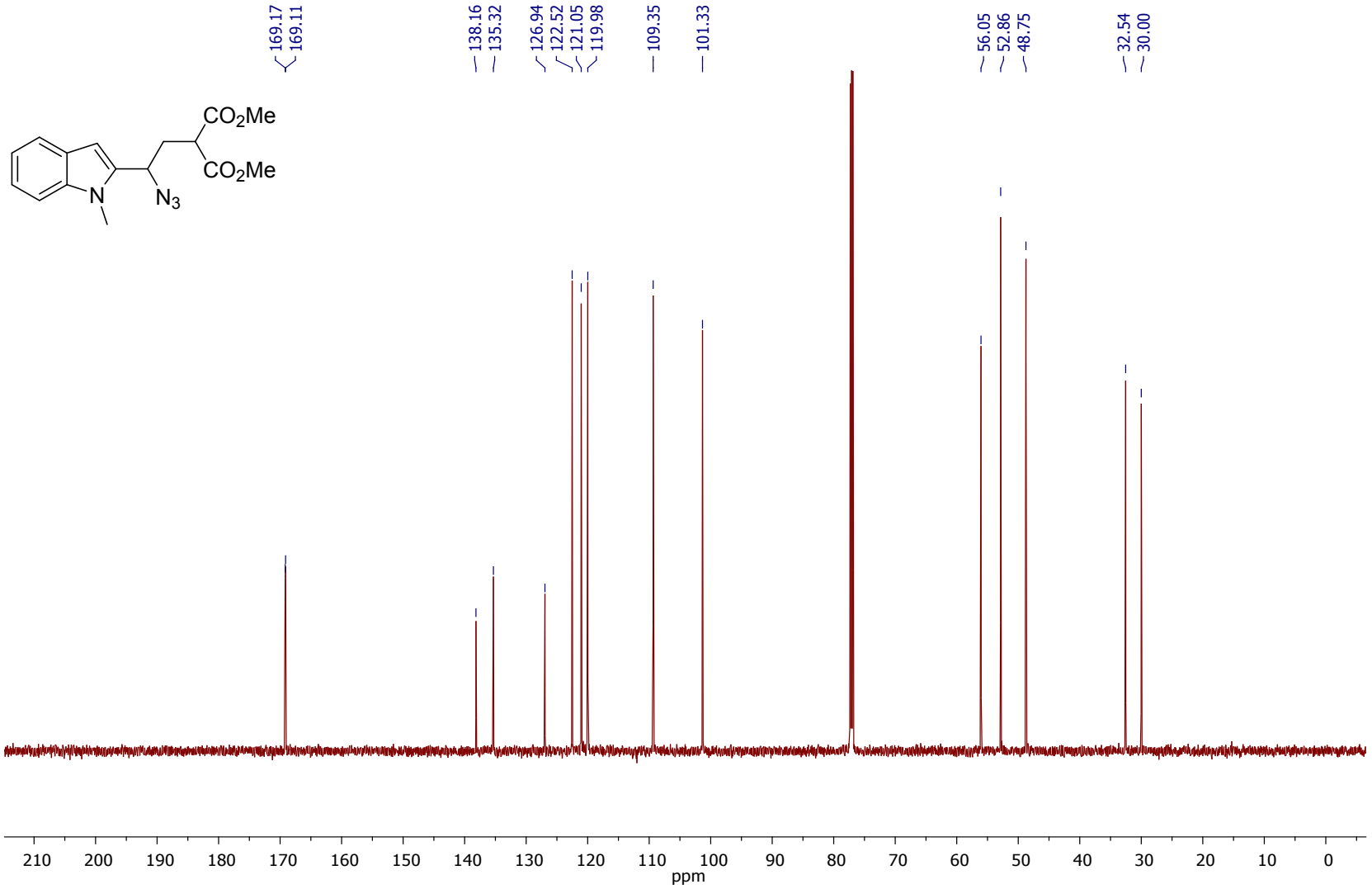
Dimethyl 2-[2-azido-2-(1-methyl-1*H*-indol-2-yl)ethyl]malonate (2a′)

^{1}H NMR ($CDCl_3$, 600 MHz)



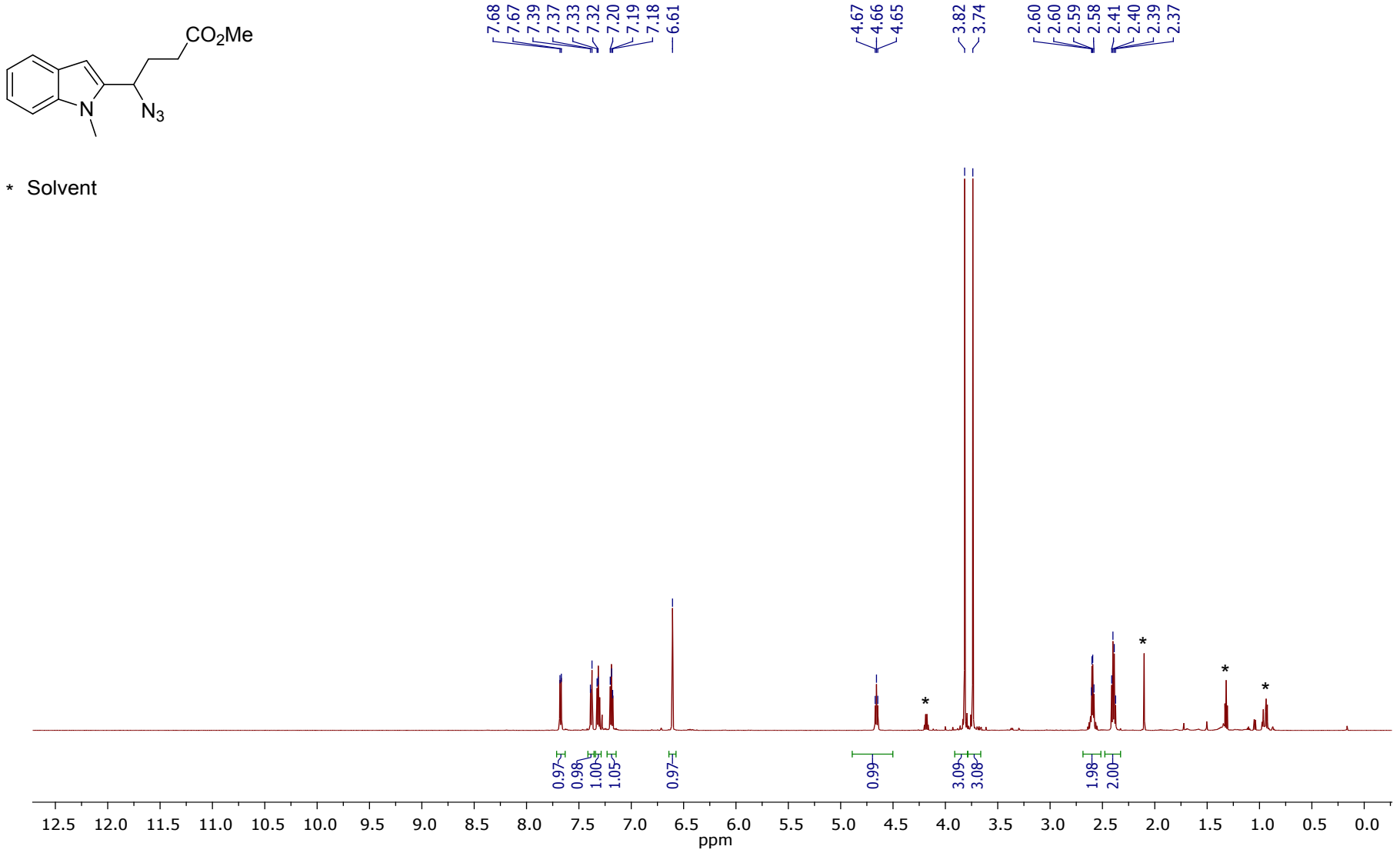
Dimethyl 2-[2-azido-2-(1-methyl-1*H*-indol-2-yl)ethyl]malonate (2a′)

^{13}C NMR ($CDCl_3$, 100 MHz)



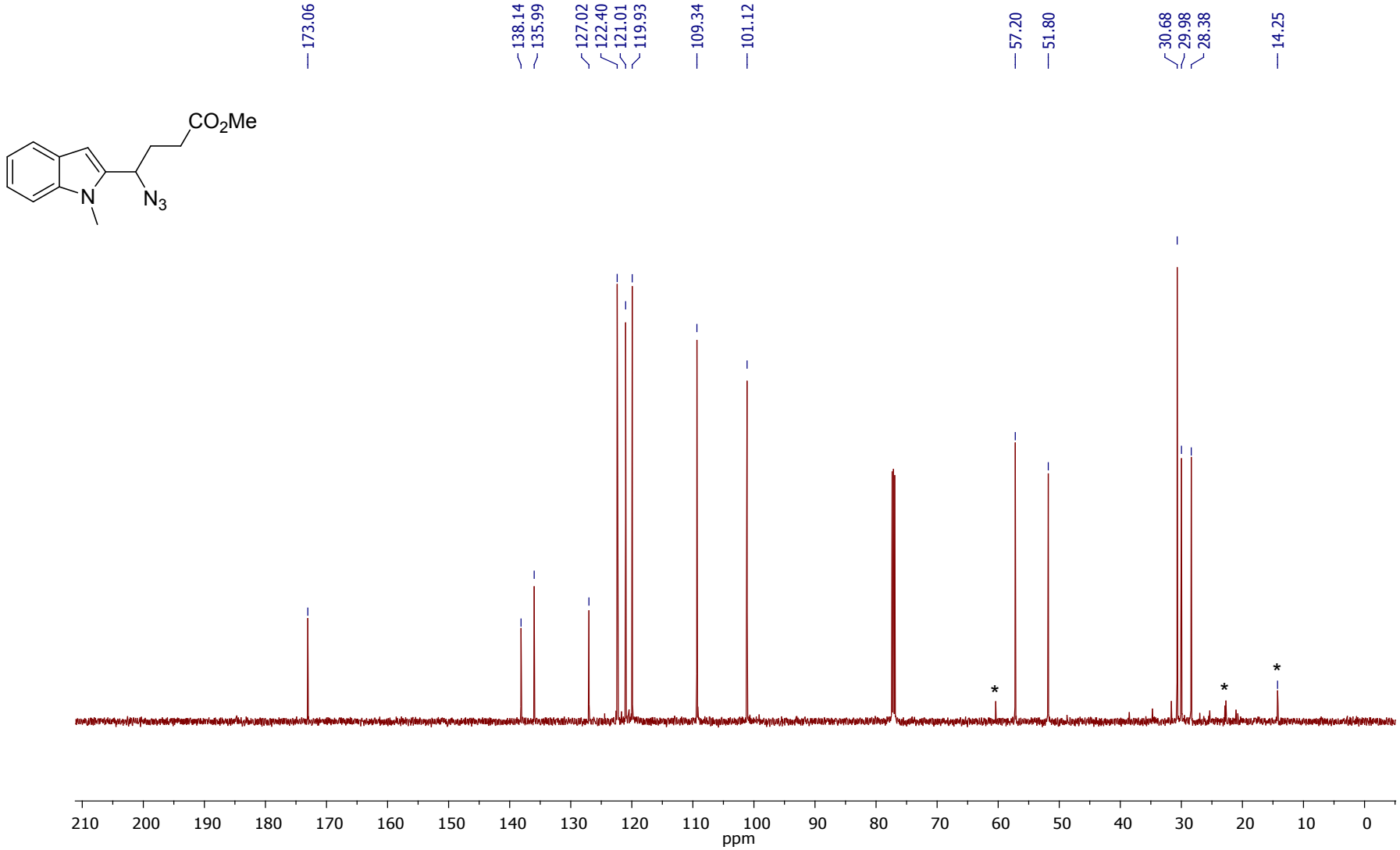
Methyl 4-azido-4-(1-methyl-1*H*-indol-2-yl)butanoate (2a)

^{1}H NMR ($CDCl_3$, 600 MHz)



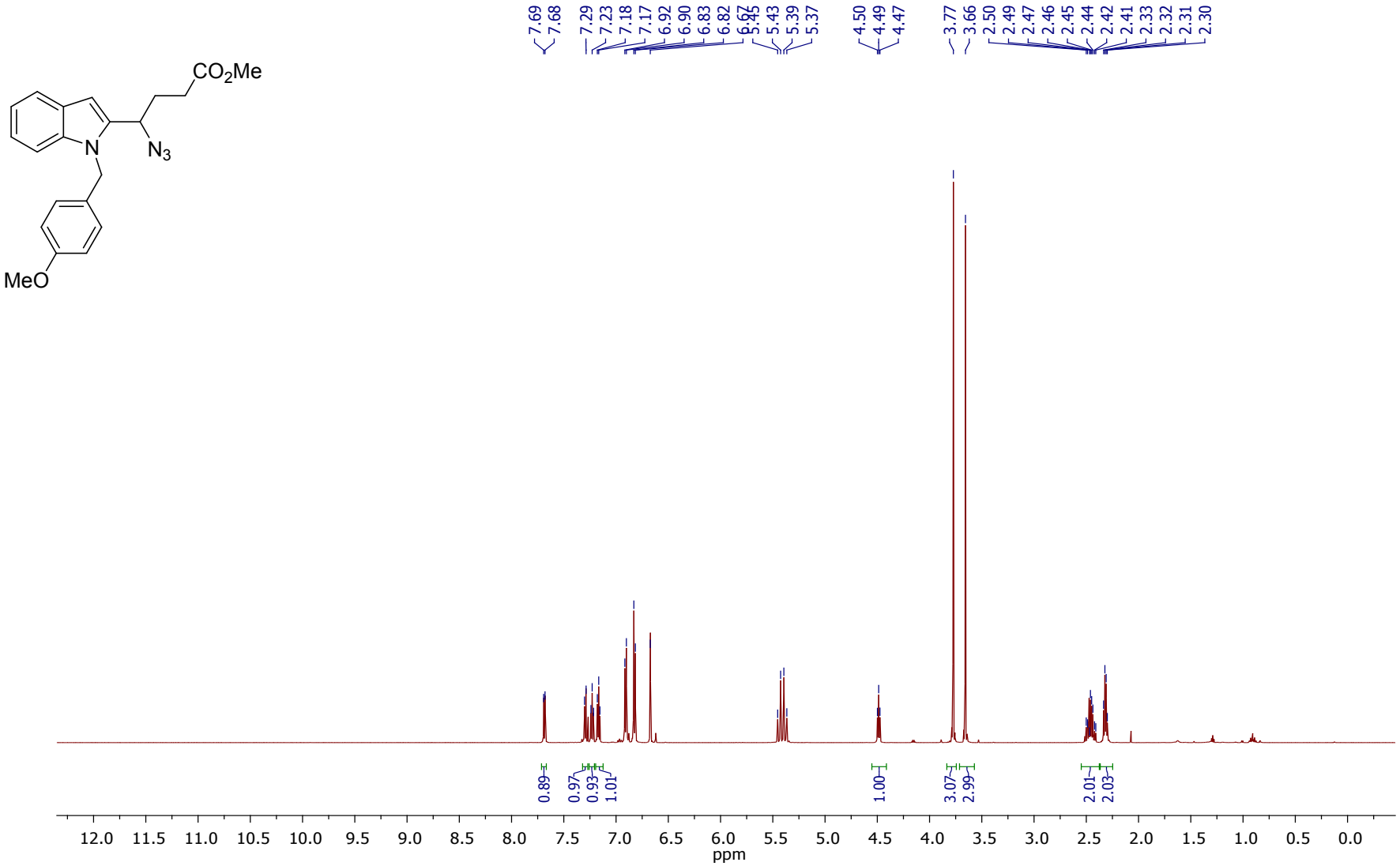
Methyl 4-azido-4-(1-methyl-1*H*-indol-2-yl)butanoate (2a)

^{13}C NMR ($CDCl_3$, 100 MHz)



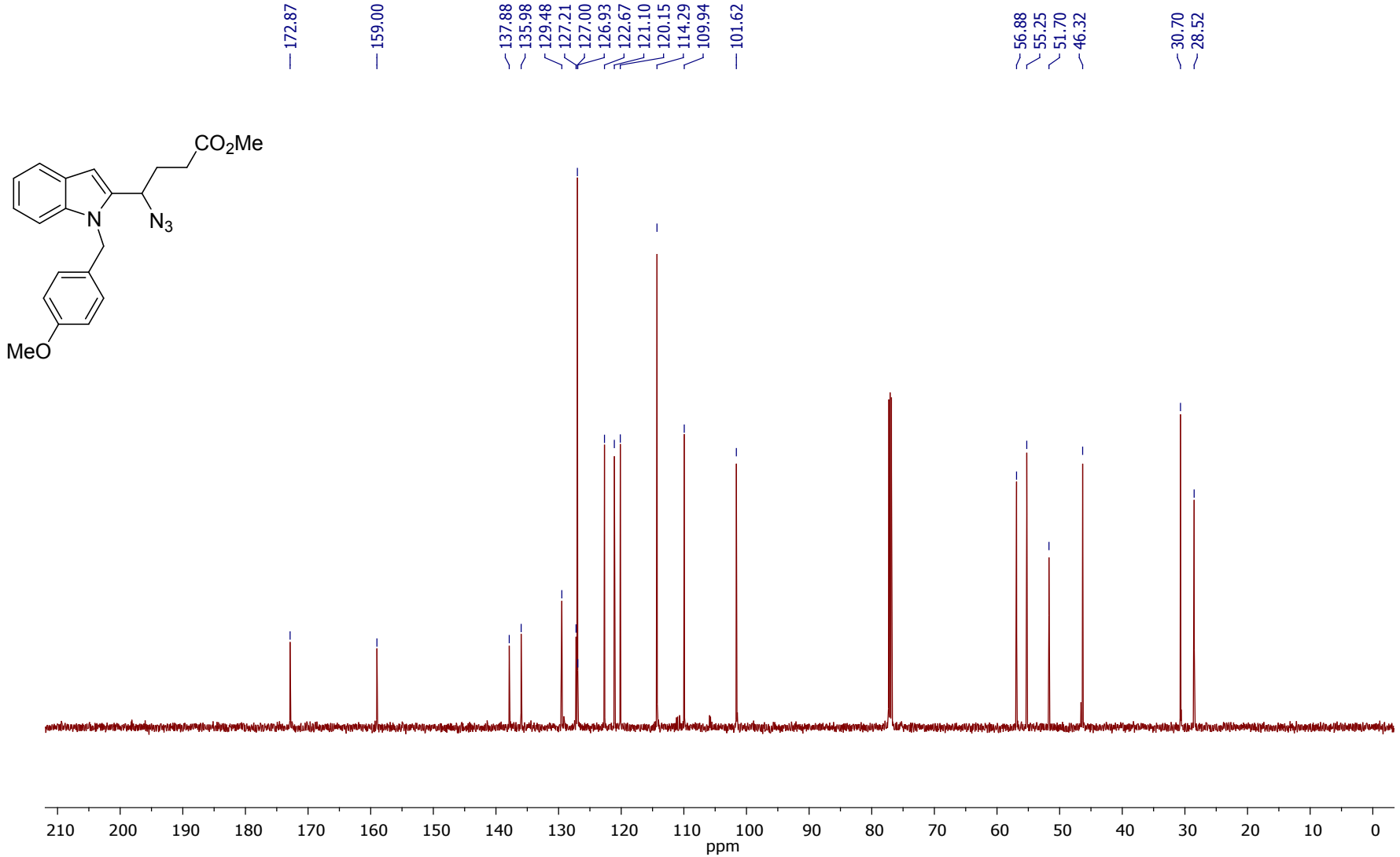
Methyl 4-azido-4-[1-(4-methoxybenzyl)-1*H*-indol-2-yl]butanoate (2b)

^{1}H NMR ($CDCl_3$, 600 MHz)



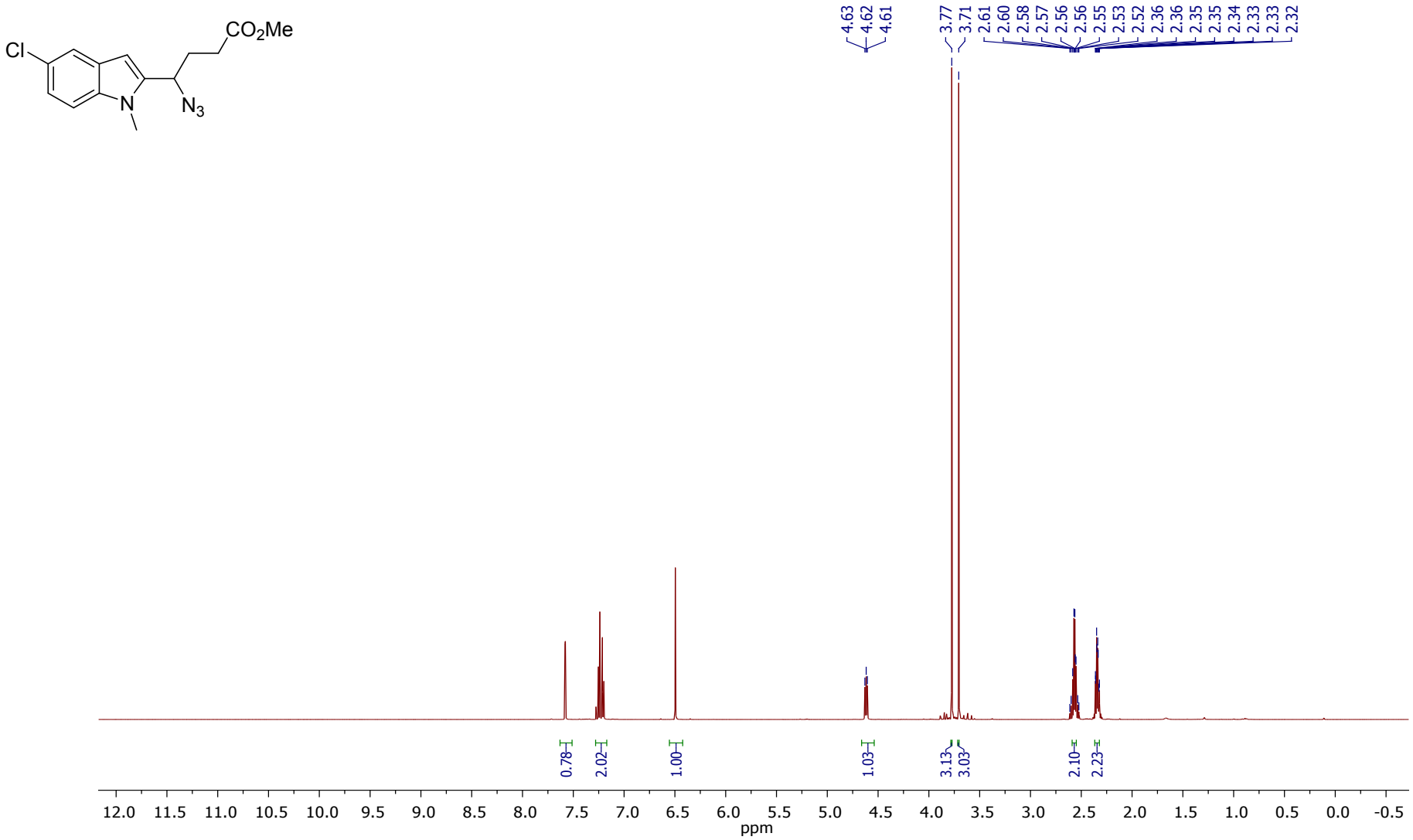
Methyl 4-azido-4-[1-(4-methoxybenzyl)-1*H*-indol-2-yl]butanoate (2b)

^{13}C NMR ($CDCl_3$, 100 MHz)



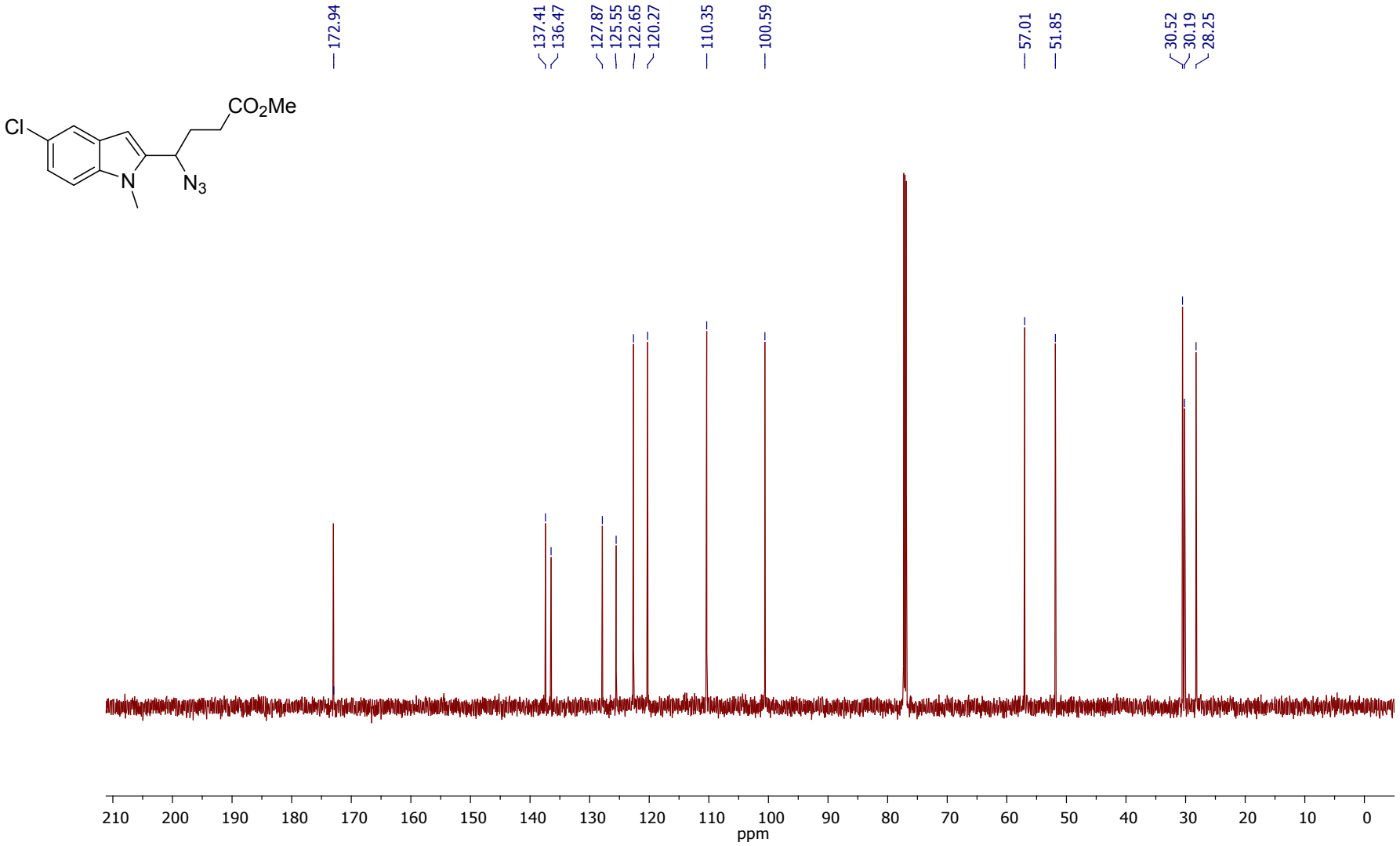
Methyl 4-azido-4-(5-chloro-1-methyl-1H-indol-2-yl)butanoate (2c)

^{1}H NMR ($CDCl_3$, 600 MHz)



Methyl 4-azido-4-(5-chloro-1-methyl-1H-indol-2-yl)butanoate (2c)

^{13}C NMR ($CDCl_3$, 100 MHz)



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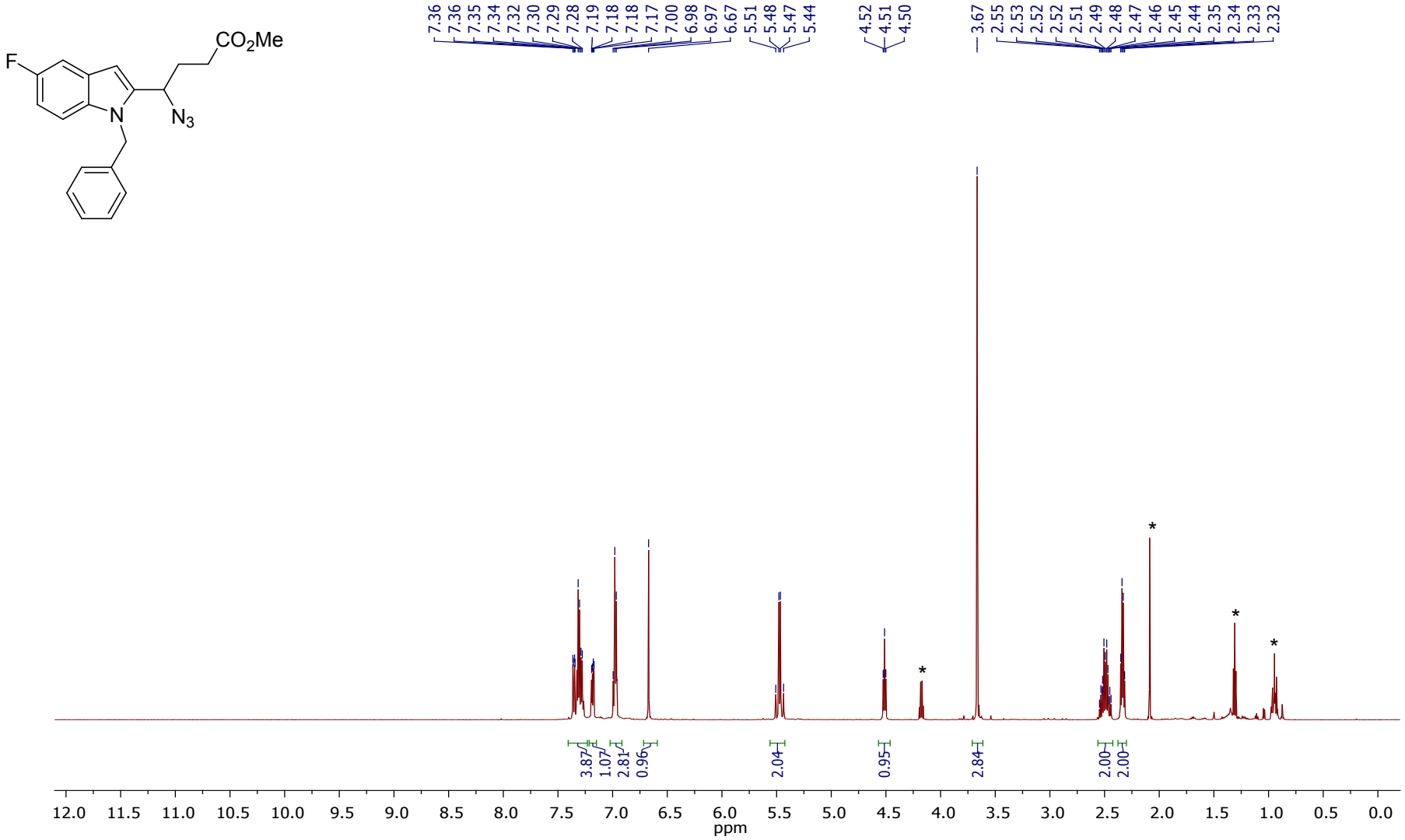
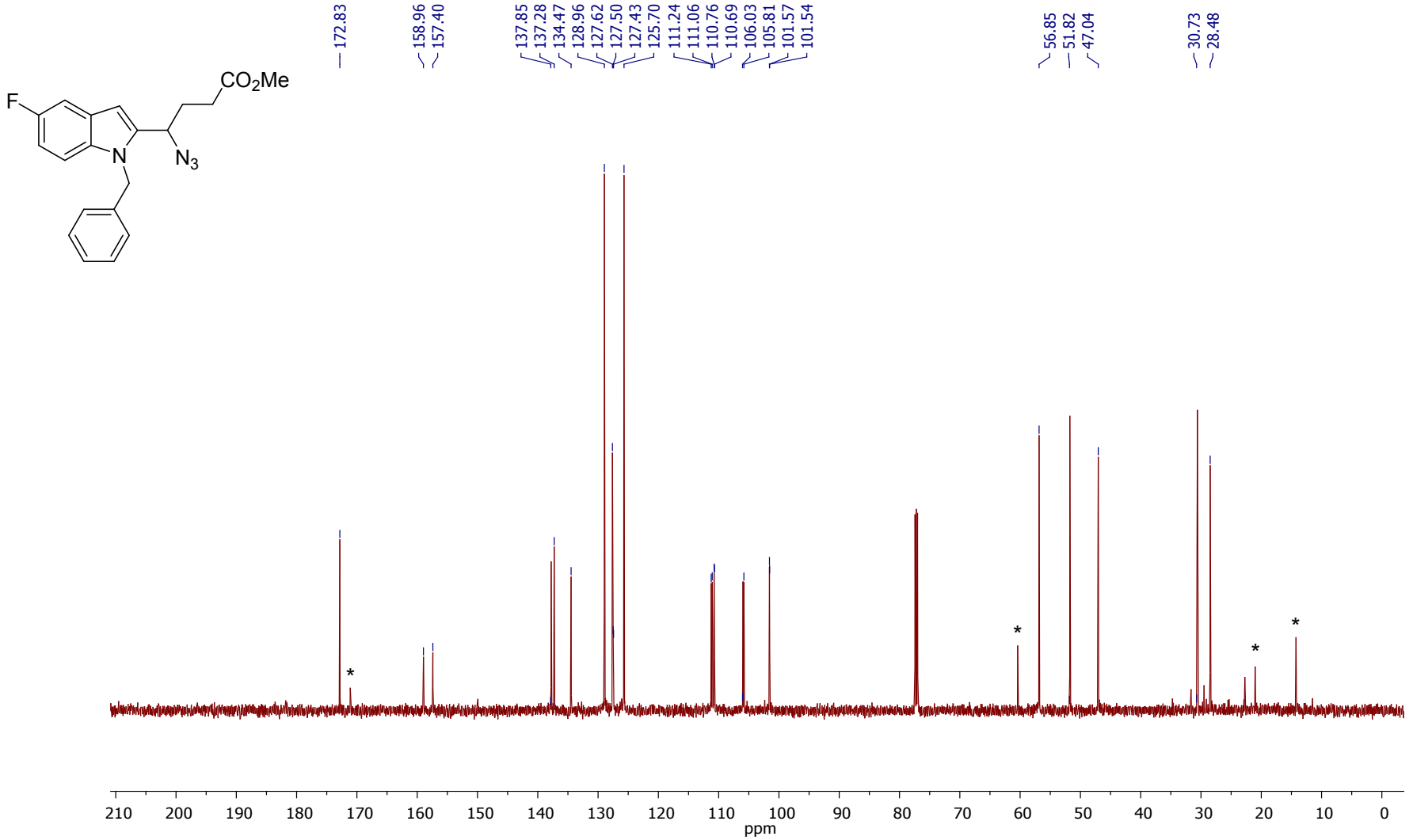
^{1}H NMR ($CDCl_3$, 600 MHz)



Methyl 4-azido-4-(1-benzyl-5-fluoro-1H-indol-2-yl)butanoate (2d)

^{13}C NMR ($CDCl_3$, 100 MHz))



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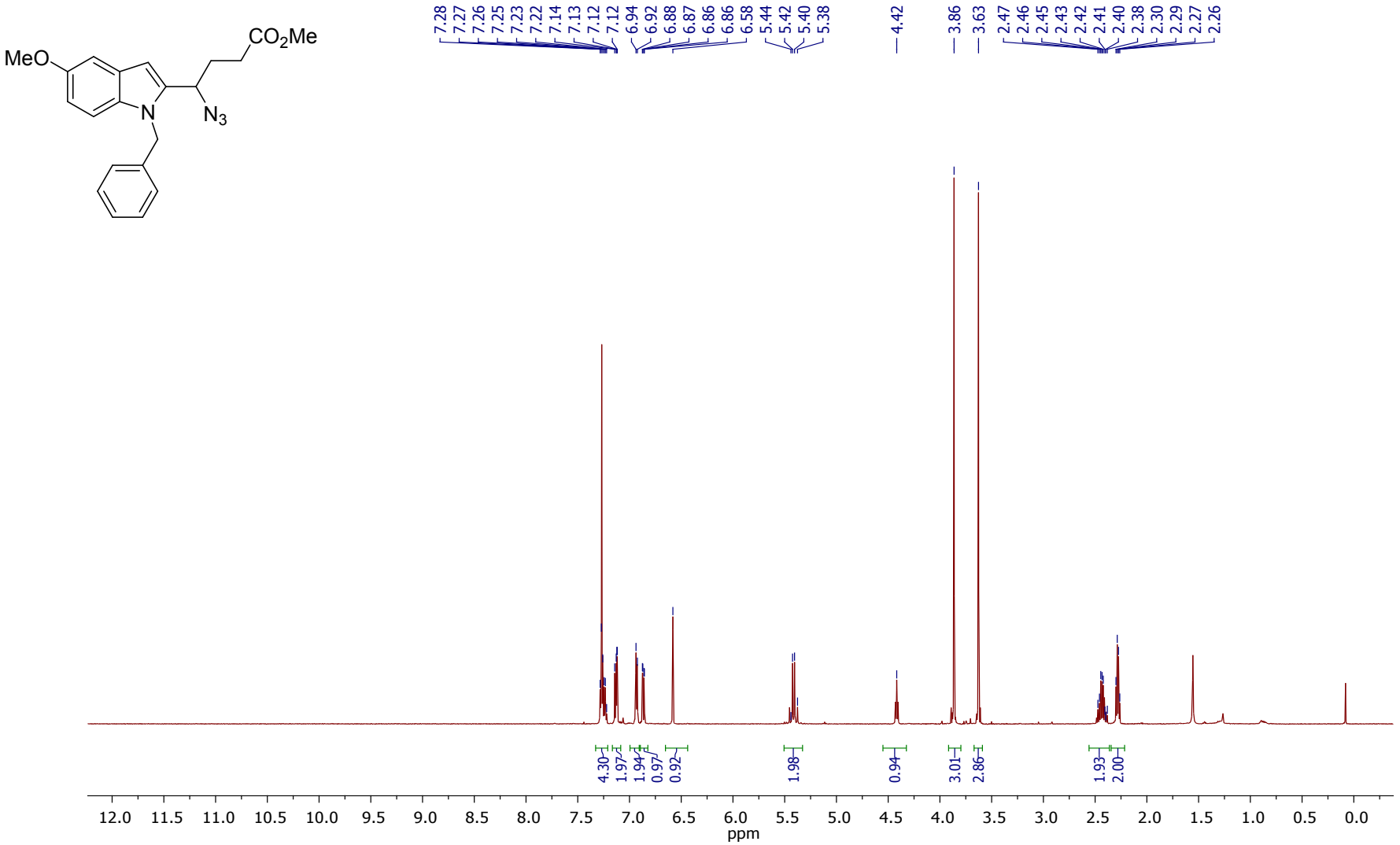
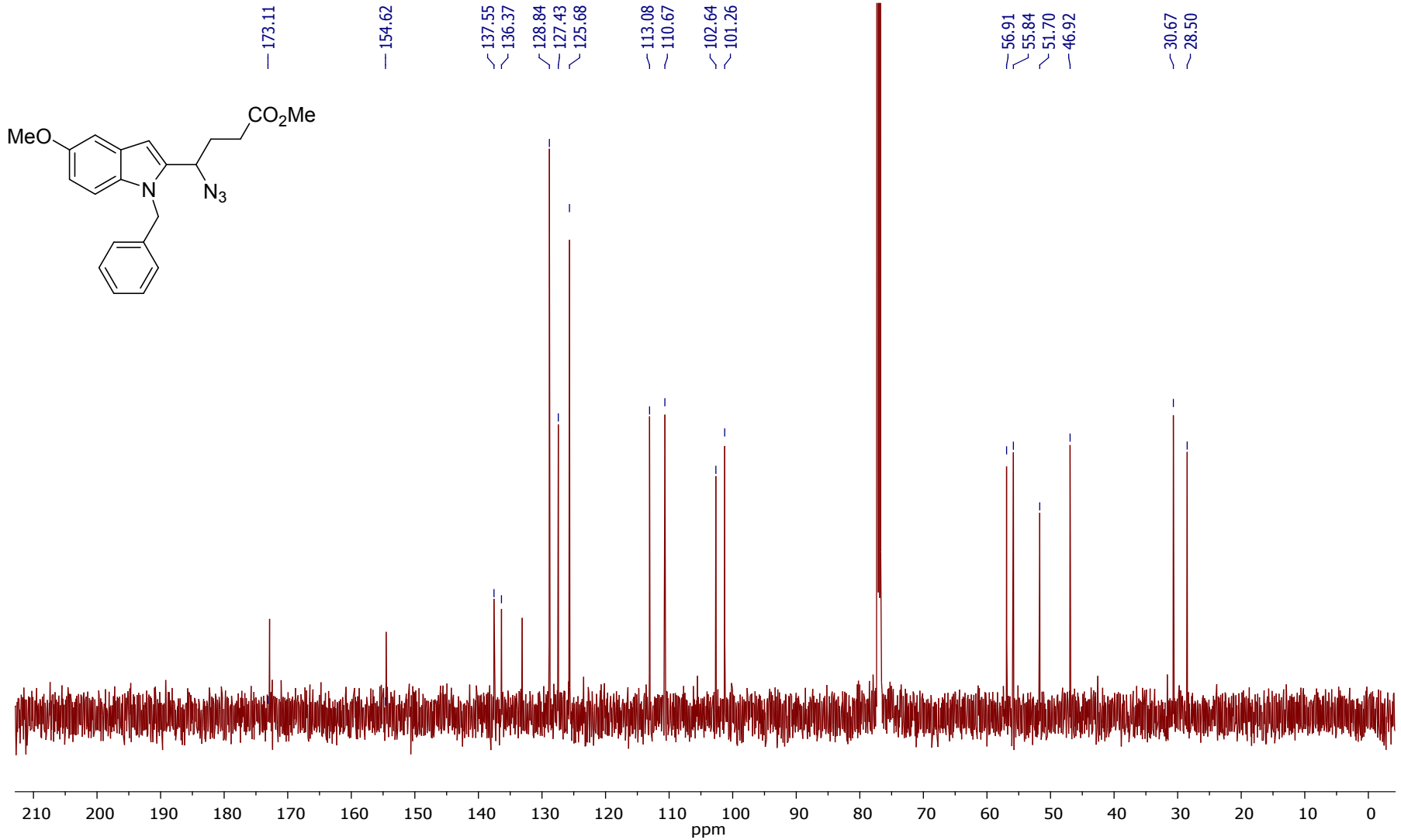
^{1}H NMR ($CDCl_3$, 600 MHz)



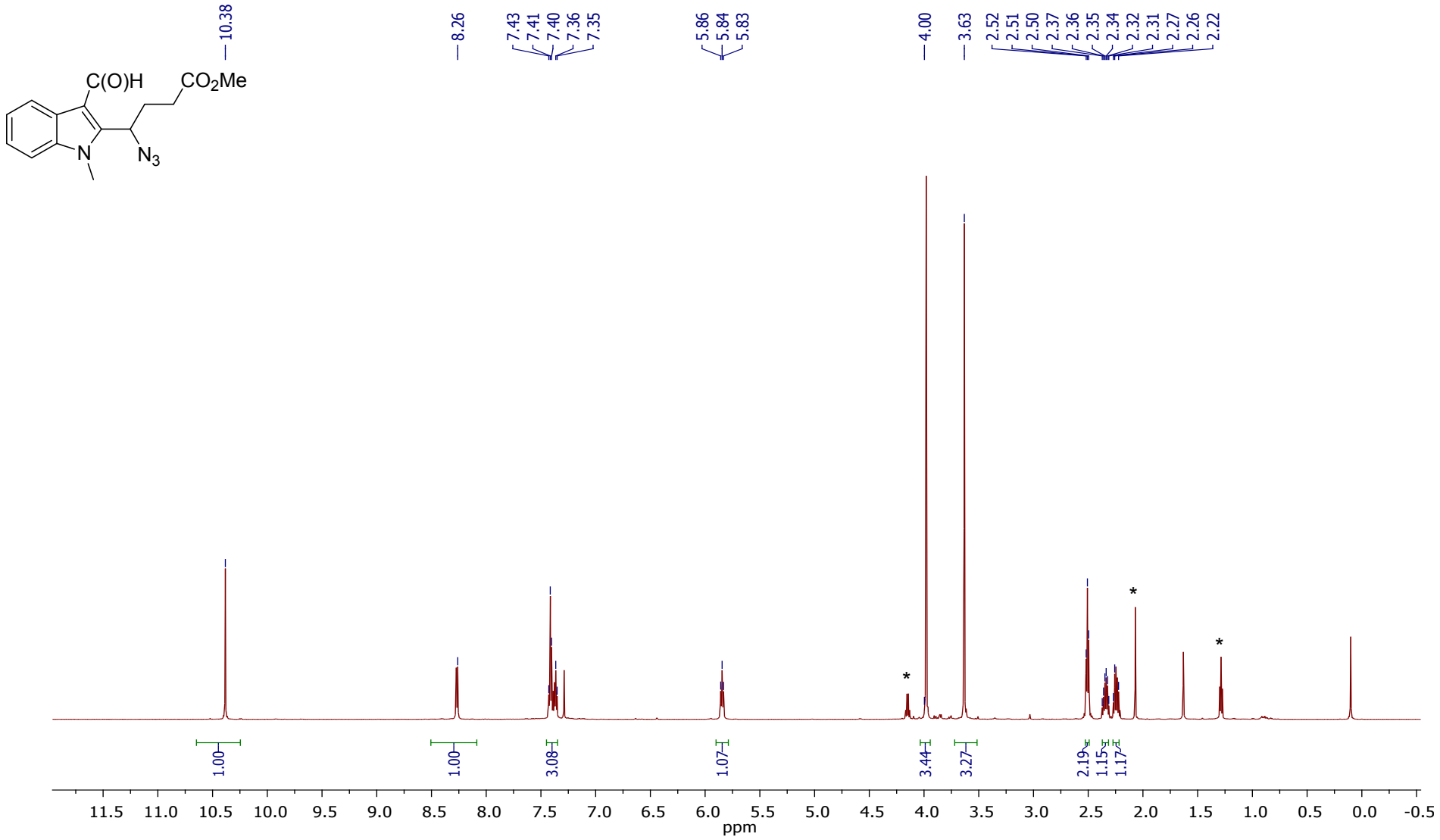
Methyl 4-azido-4-(1-benzyl-5-methoxy-1*H*-indol-2-yl)butanoate (2e)

^{13}C NMR ($CDCl_3$, 100 MHz)



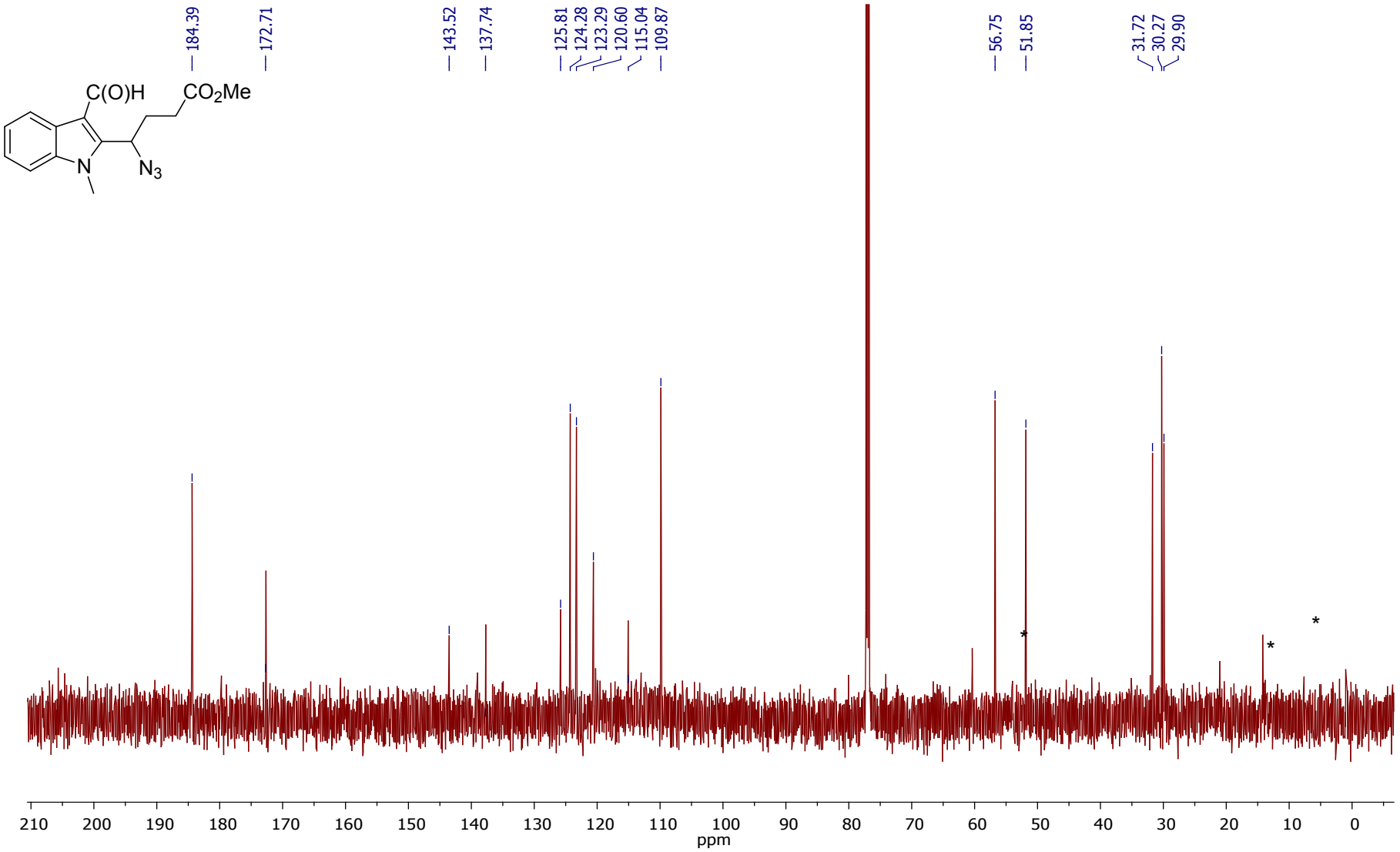
Methyl 4-azido-4-(3-formyl-1-methyl-1*H*-indol-2-yl)butanoate (3a)

^{1}H NMR ($CDCl_3$, 600 MHz)



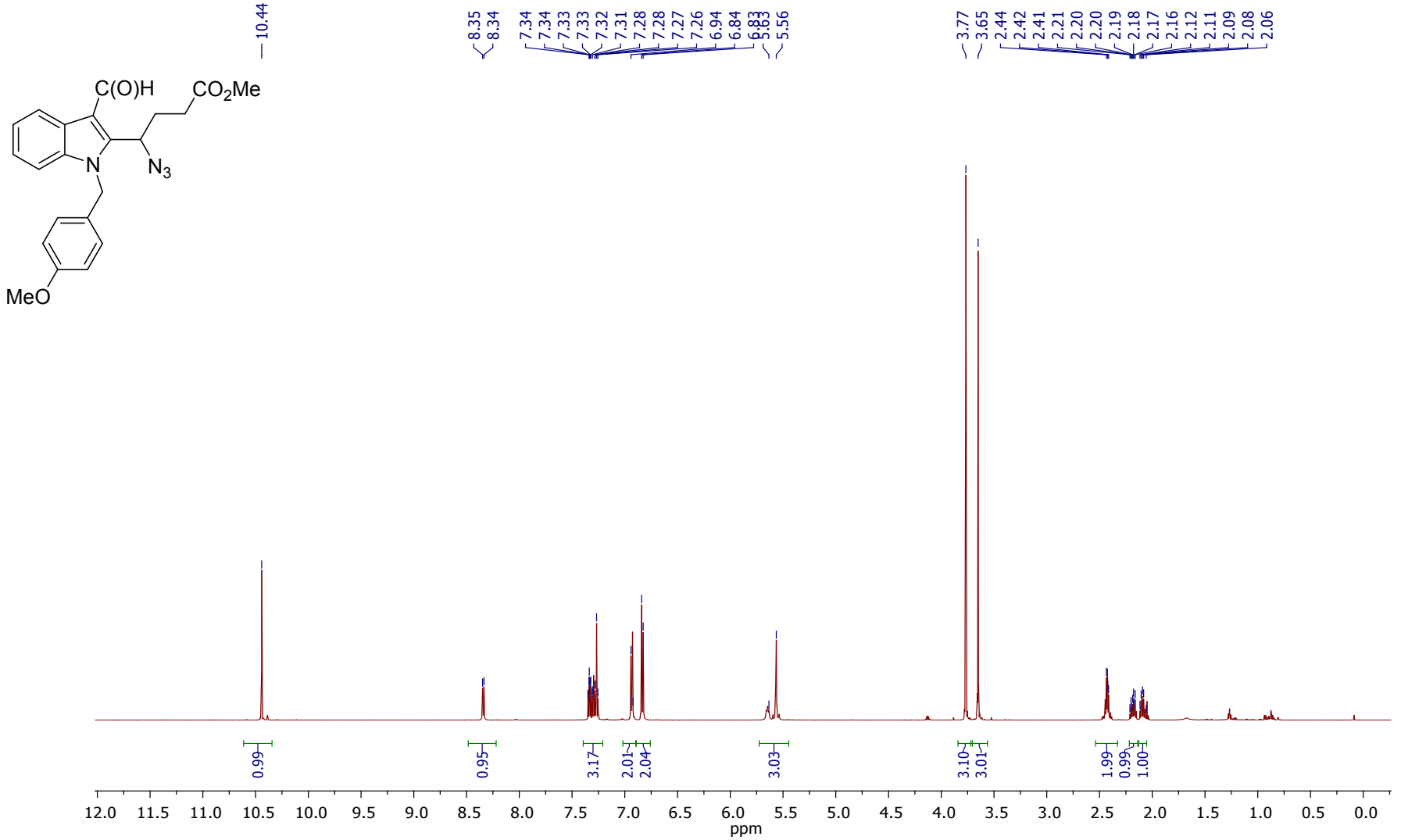
Methyl 4-azido-4-(3-formyl-1-methyl-1*H*-indol-2-yl)butanoate (3a)

^{13}C NMR ($CDCl_3$, 100 MHz)



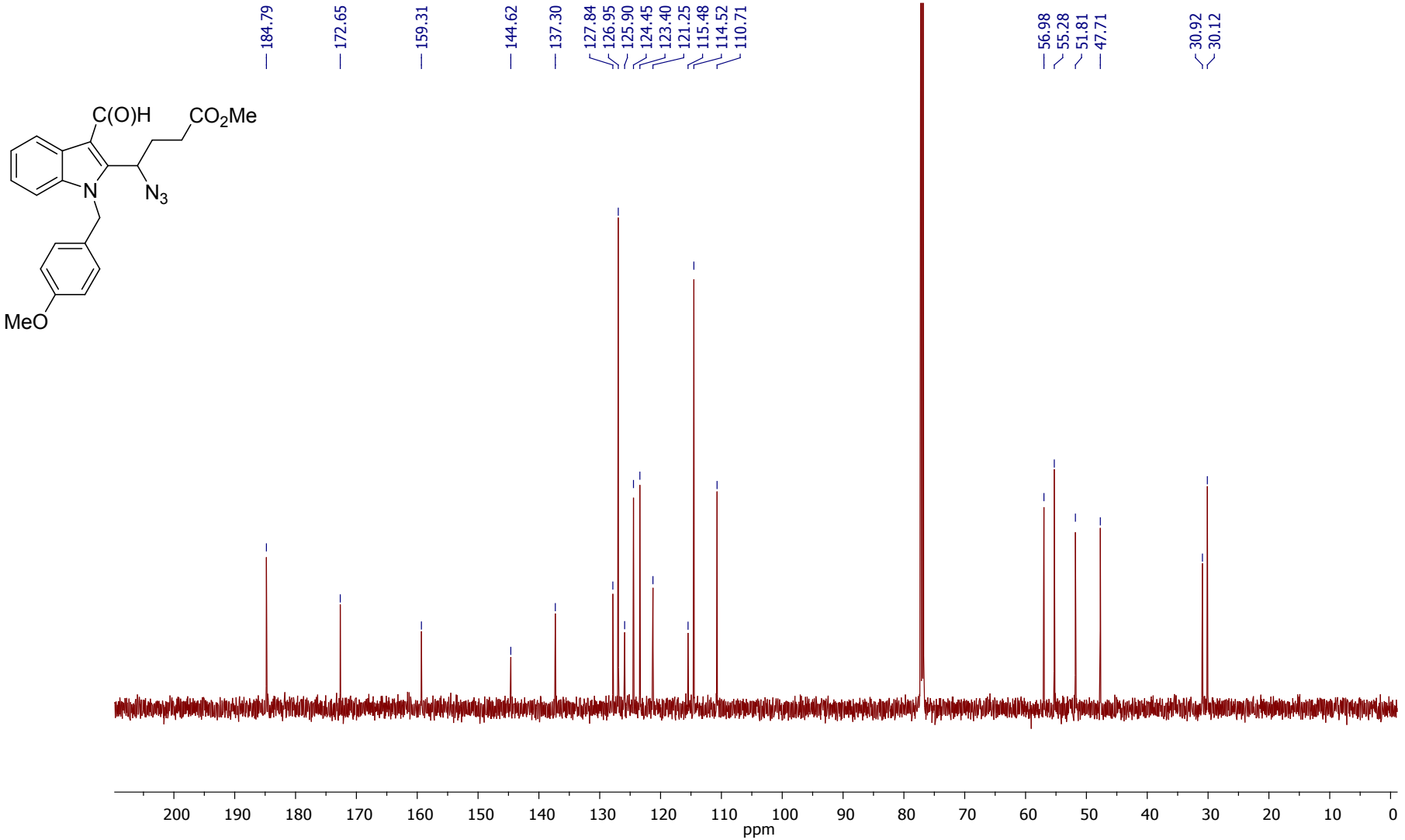
Methyl 4-azido-4-(3-formyl-1-(4-methoxybenzyl)-1H-indol-2-yl)butanoate (3b)

^{1}H NMR ($CDCl_3$, 600 MHz)



Methyl 4-azido-4-(3-formyl-1-(4-methoxybenzyl)-1H-indol-2-yl)butanoate (3b)

^{13}C NMR ($CDCl_3$, 100 MHz)



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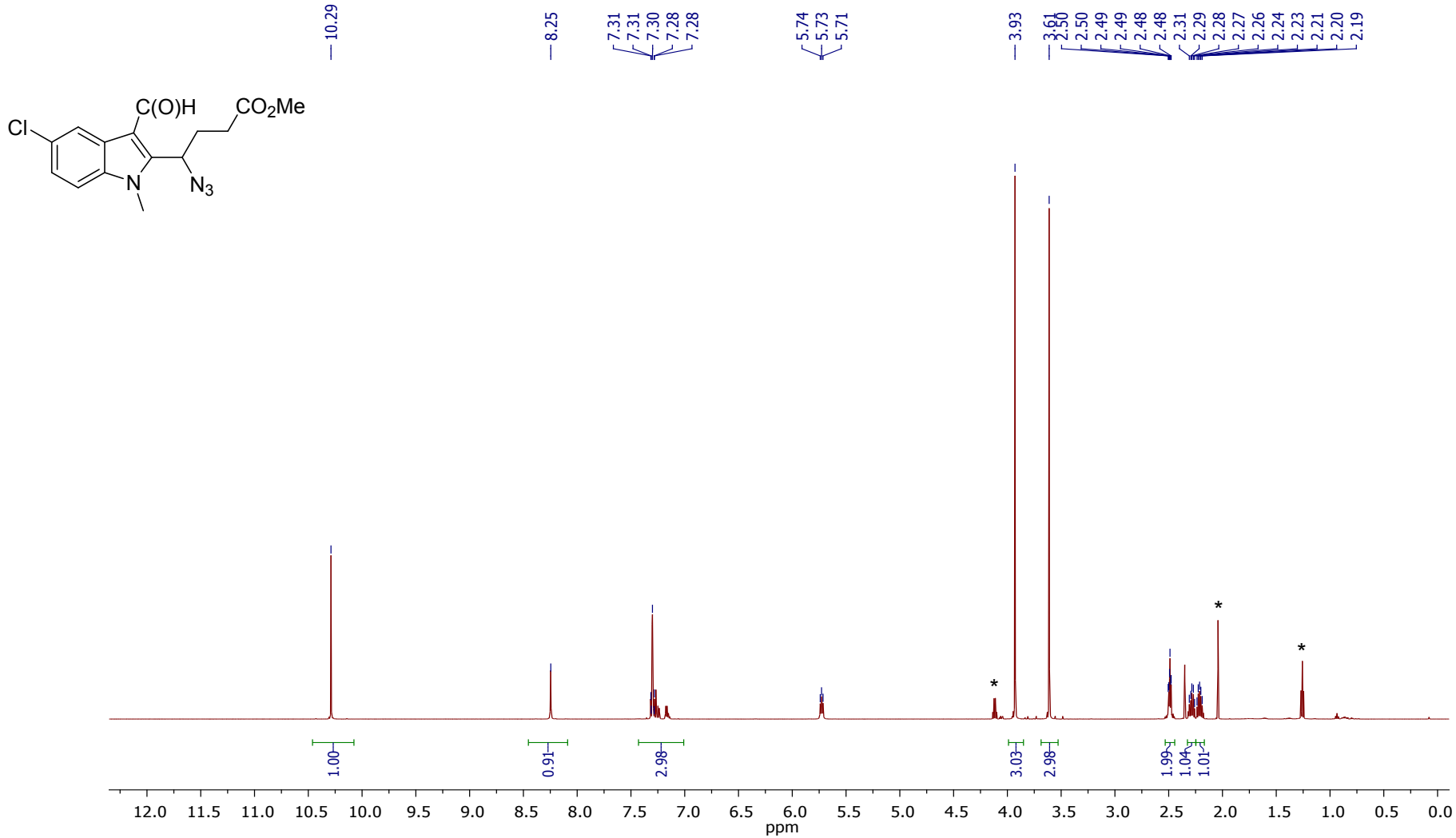
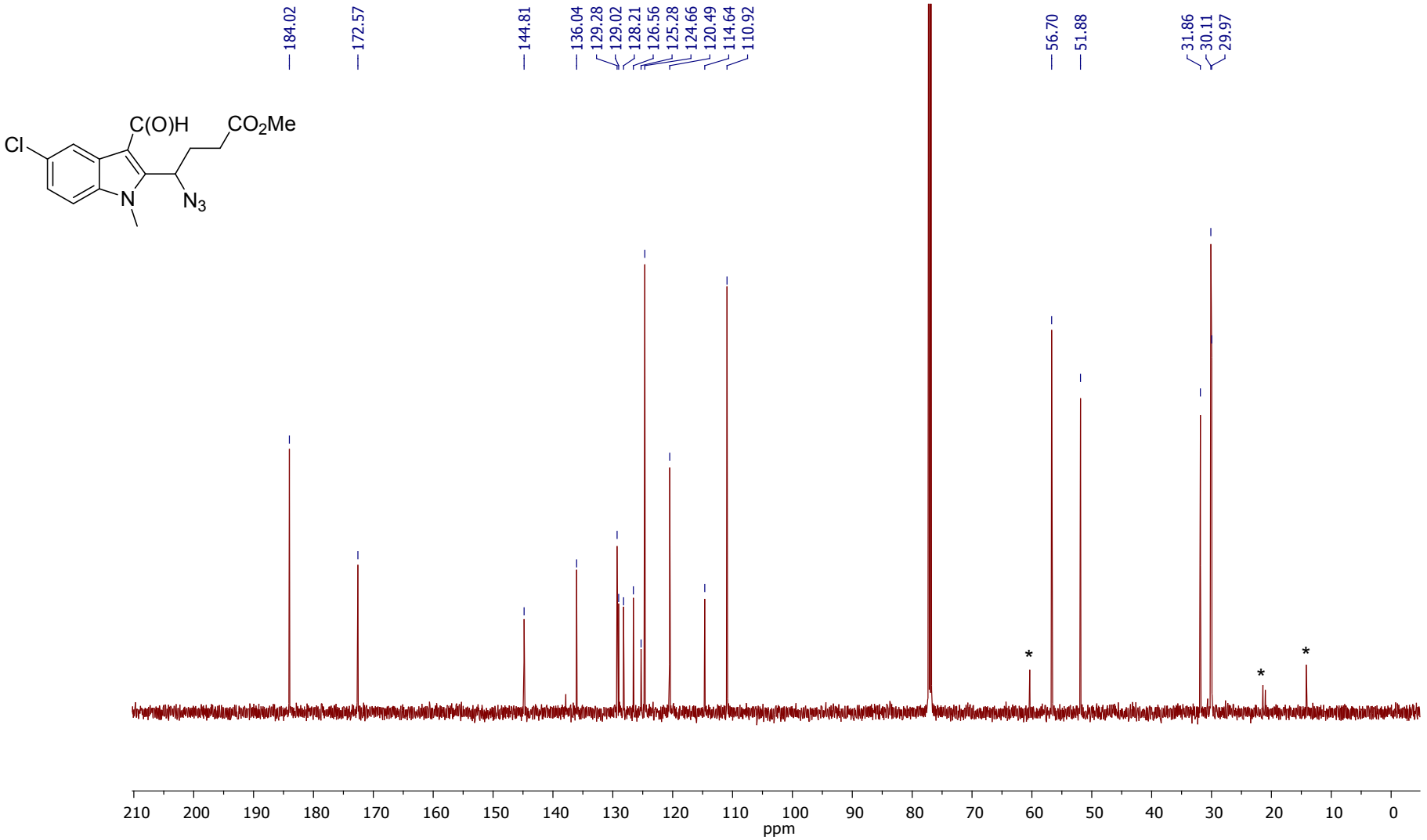
^{1}H NMR ($CDCl_3$, 600 MHz)



Methyl 4-azido-4-(5-chloro-3-formyl-1-methyl-1H-indol-2-yl)butanoate (3c)

^{13}C NMR ($CDCl_3$, 100 MHz)



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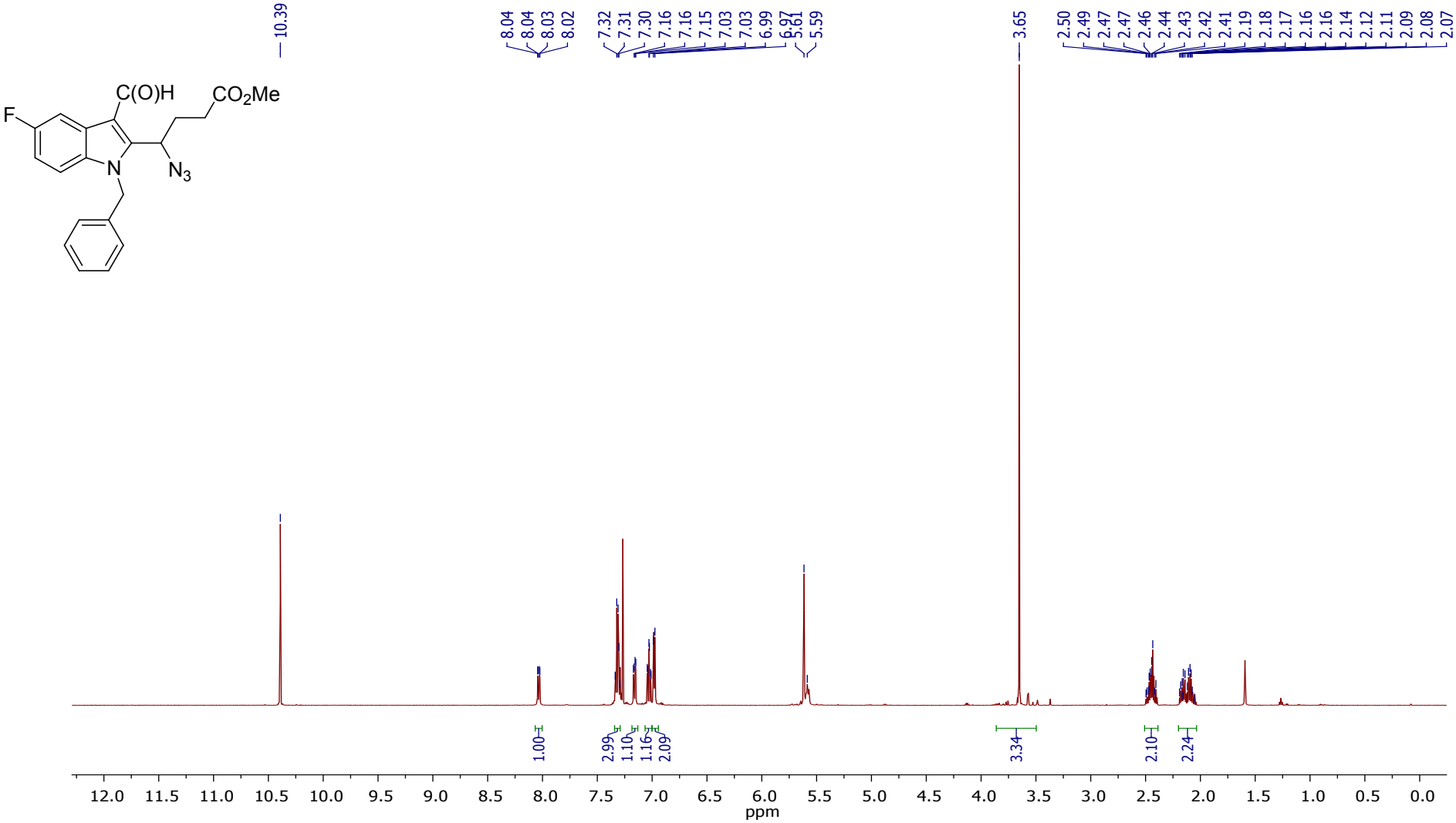
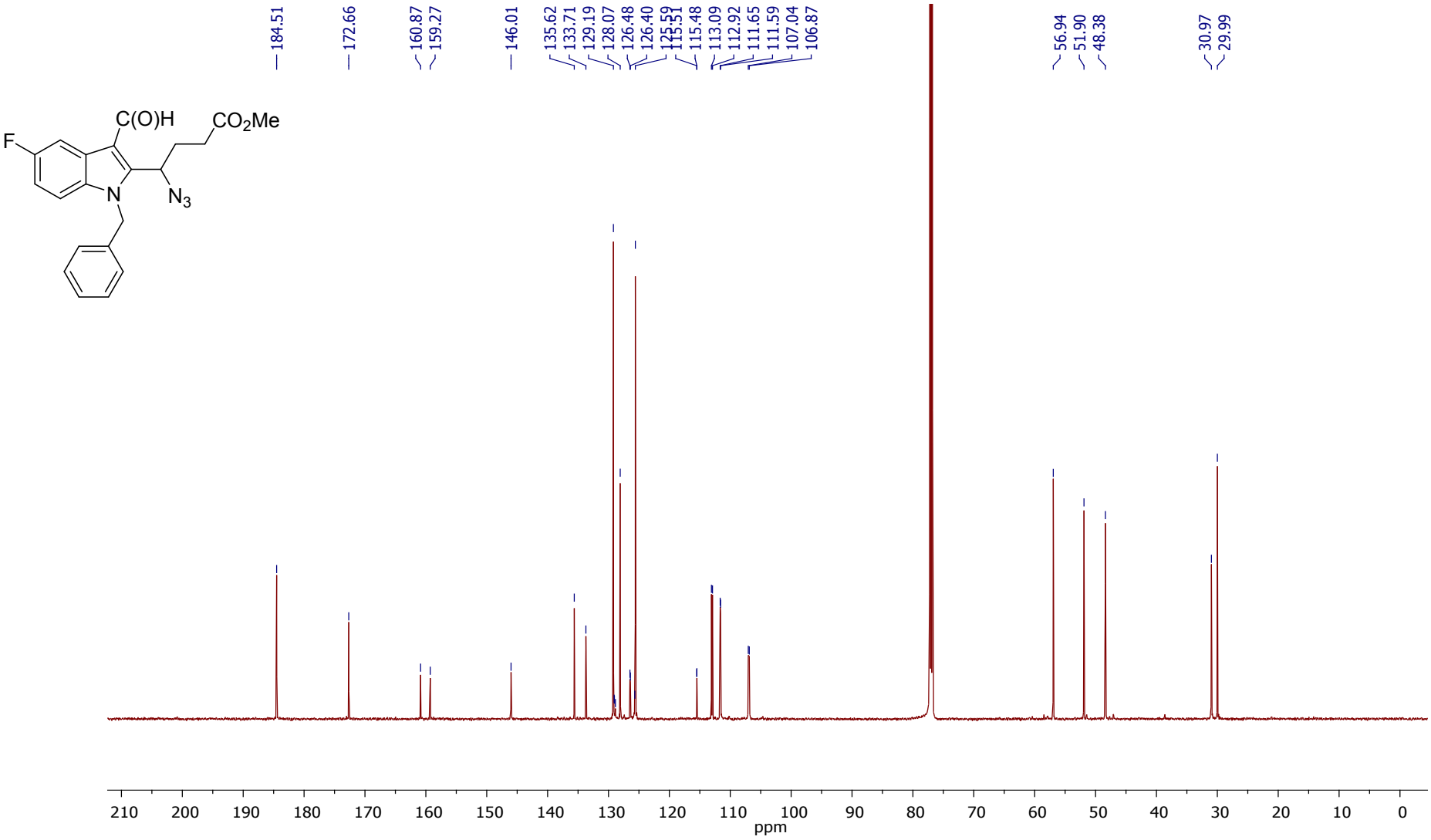
^{1}H NMR ($CDCl_3$, 600 MHz)



Methyl 4-azido-4-(1-benzyl-5-fluoro-3-formyl-1H-indol-2-yl)butanoate (3d)

^{13}C NMR ($CDCl_3$, 100 MHz)



Methyl 4-azido-4-(3-formyl-5-methoxy-1-methyl-1H-indol-2-yl)butanoate (3e)

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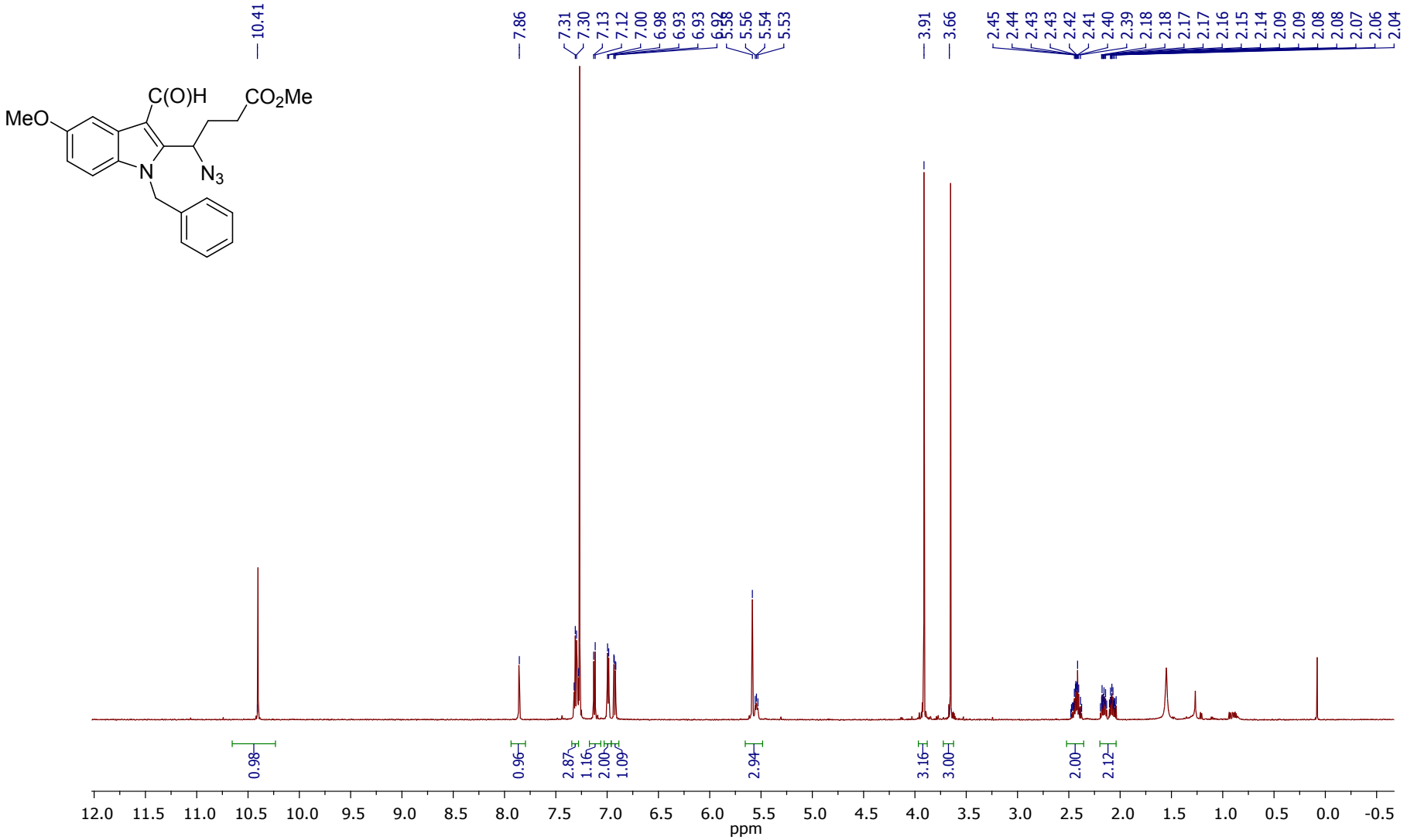
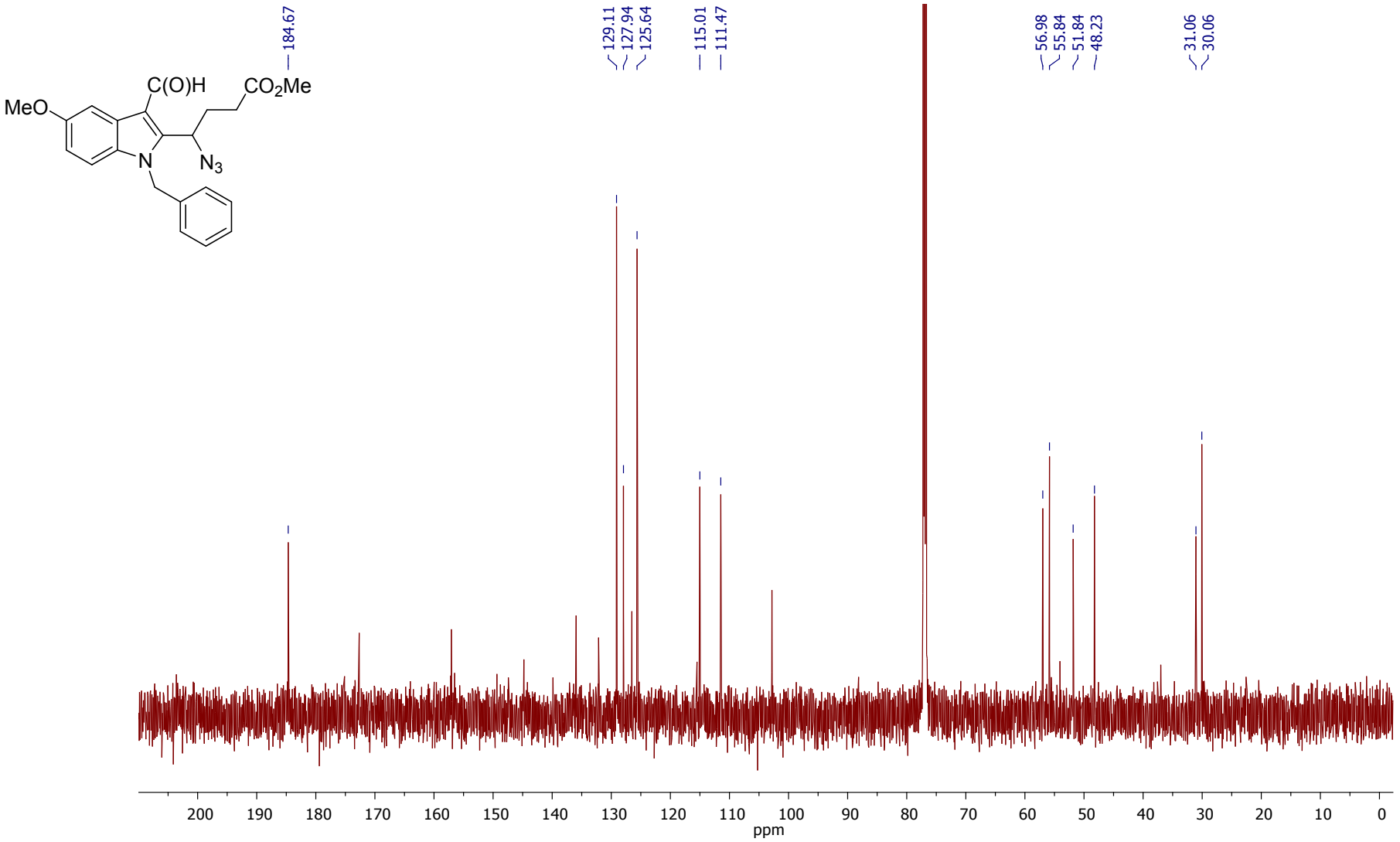


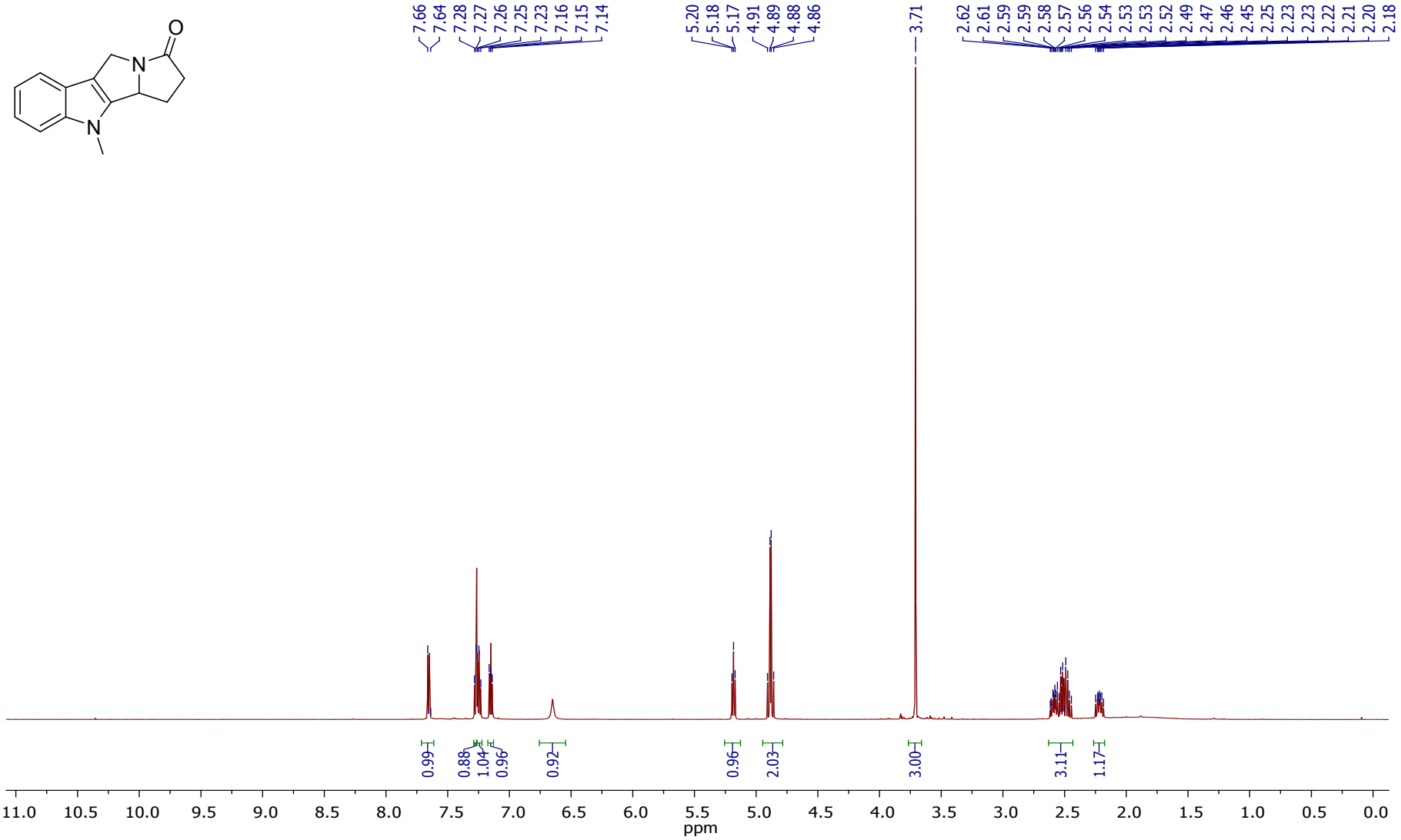
Methyl 4-azido-4-(3-formyl-5-methoxy-1-methyl-1H-indol-2-yl)butanoate (3e)

^{13}C NMR ($CDCl_3$, 100 MHz)



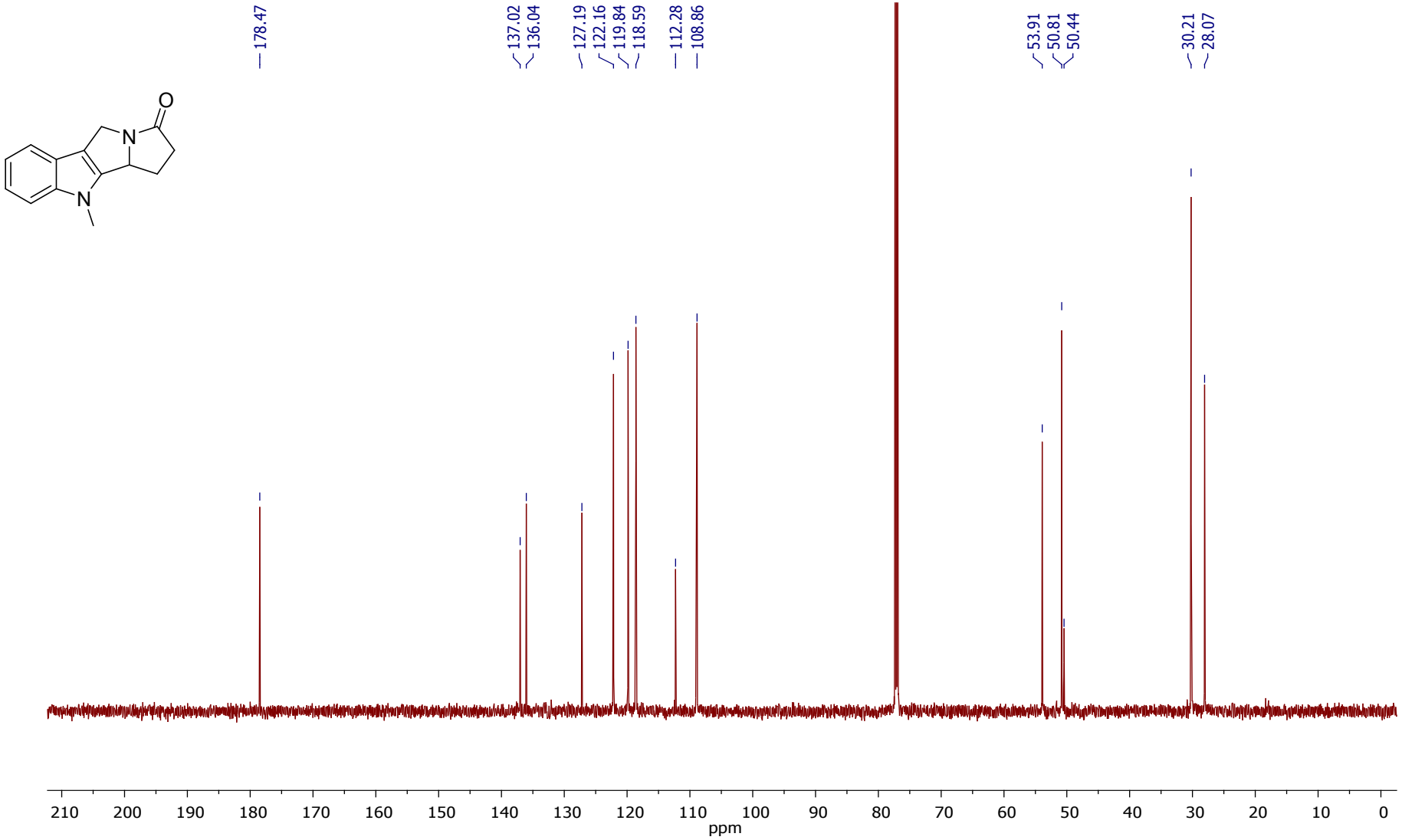
4-Methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5a)

^{1}H NMR ($CDCl_3$, 600 MHz)



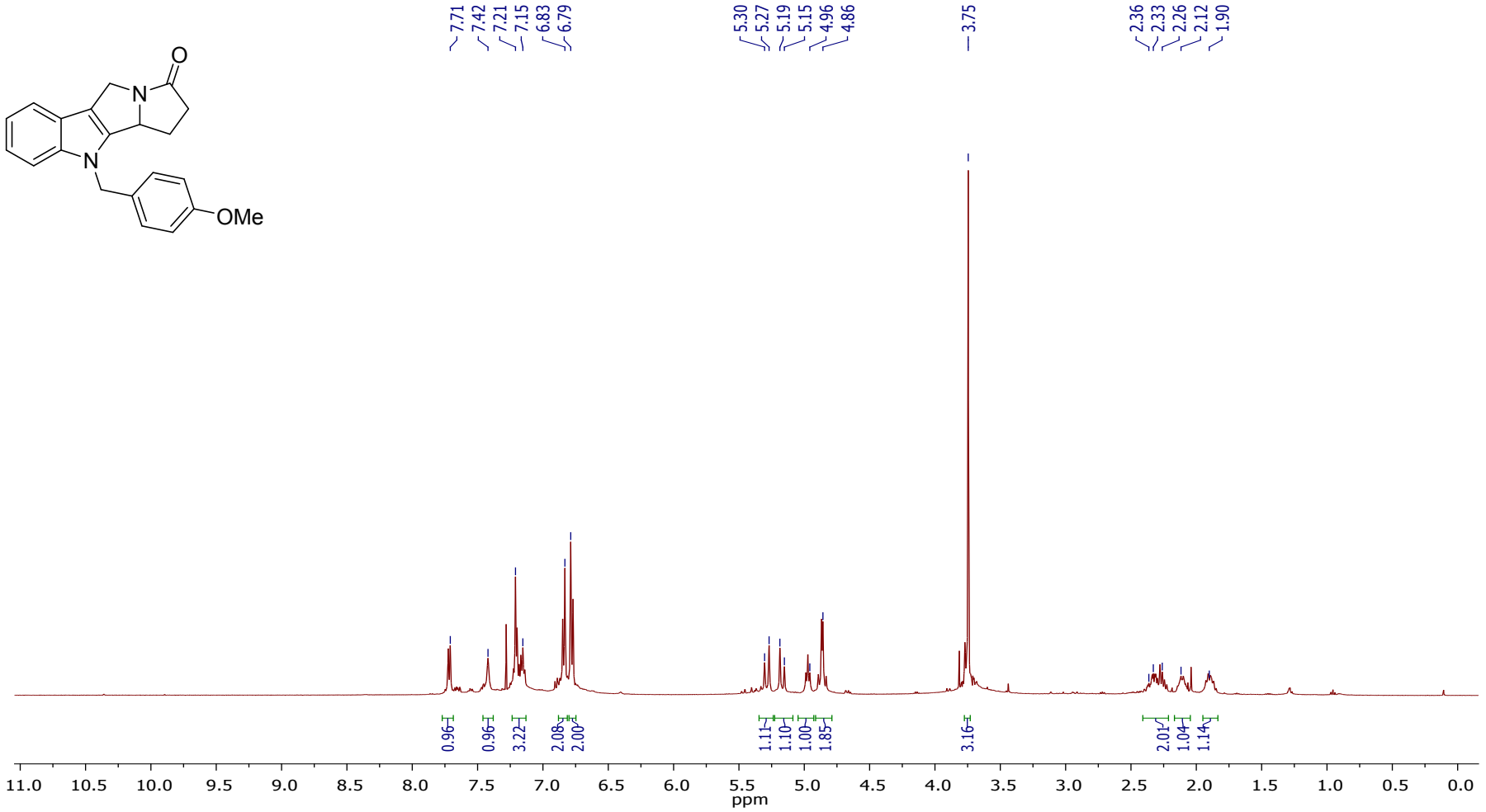
4-Methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5a)

^{13}C NMR ($CDCl_3$, 100 MHz)



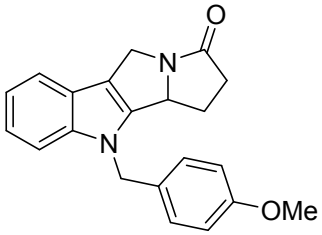
4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b)

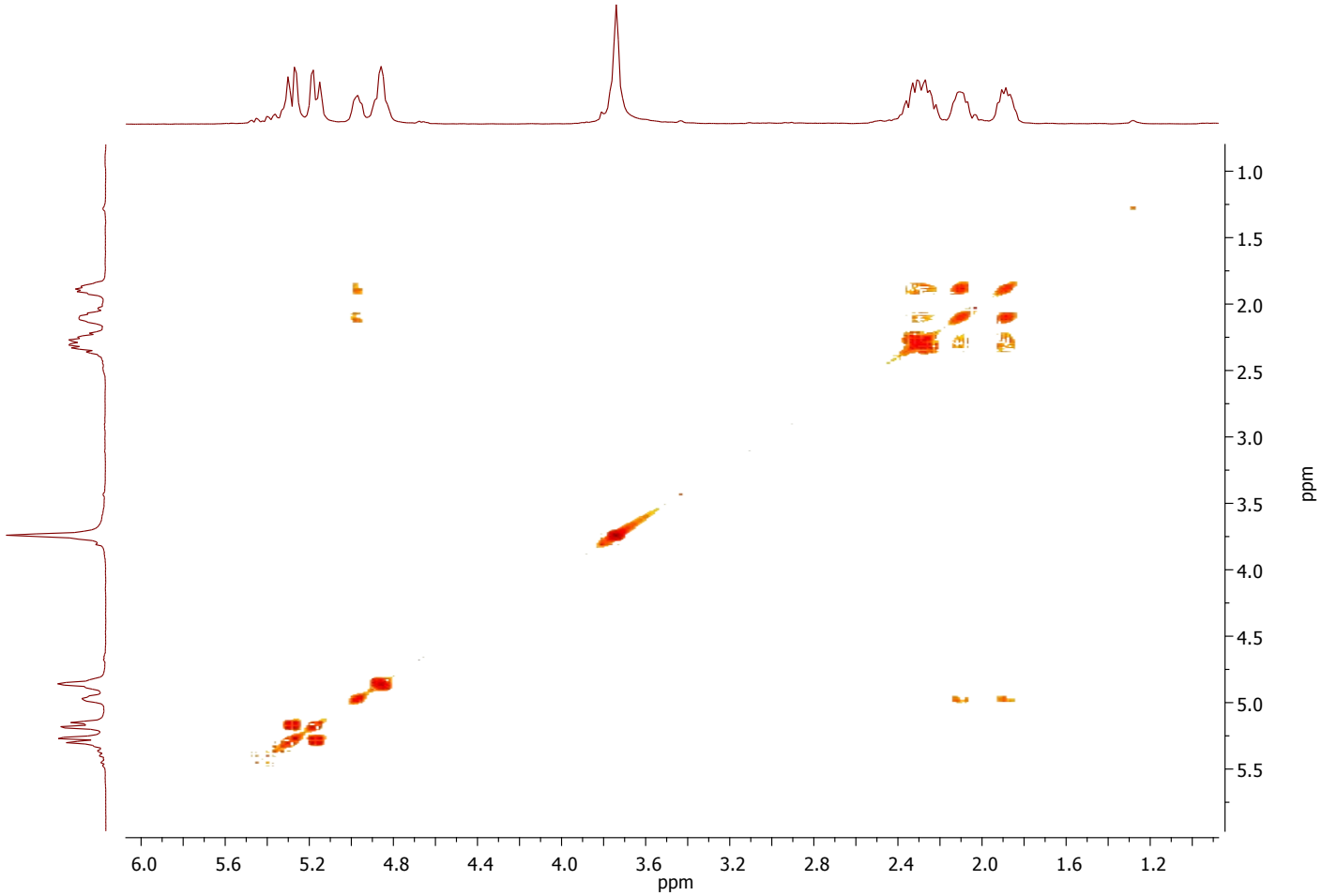
^{1}H NMR ($CDCl_3$, 600 MHz)



4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b)

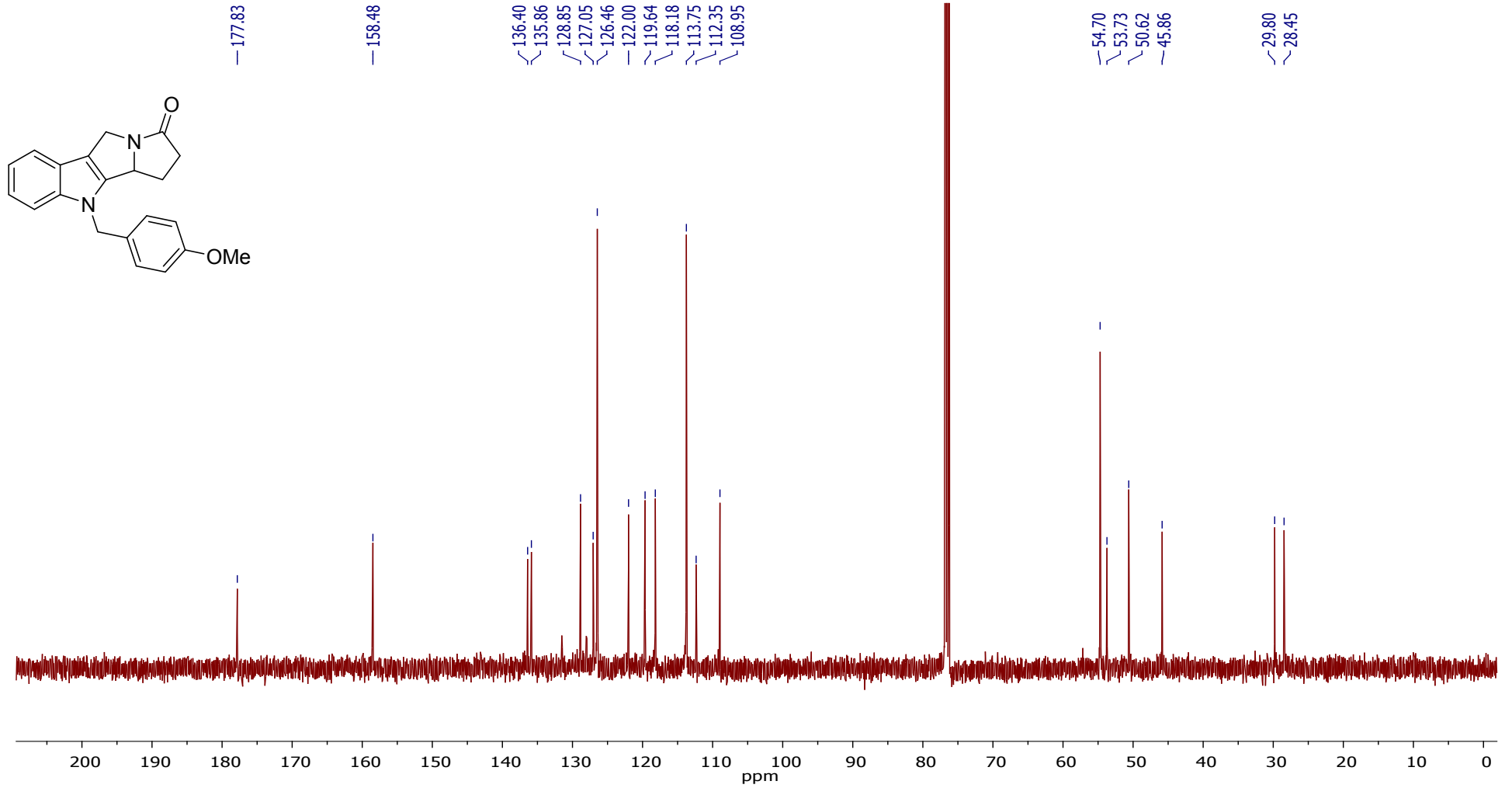
COSY ^{1}H-^{1}H ($CDCl_3$)





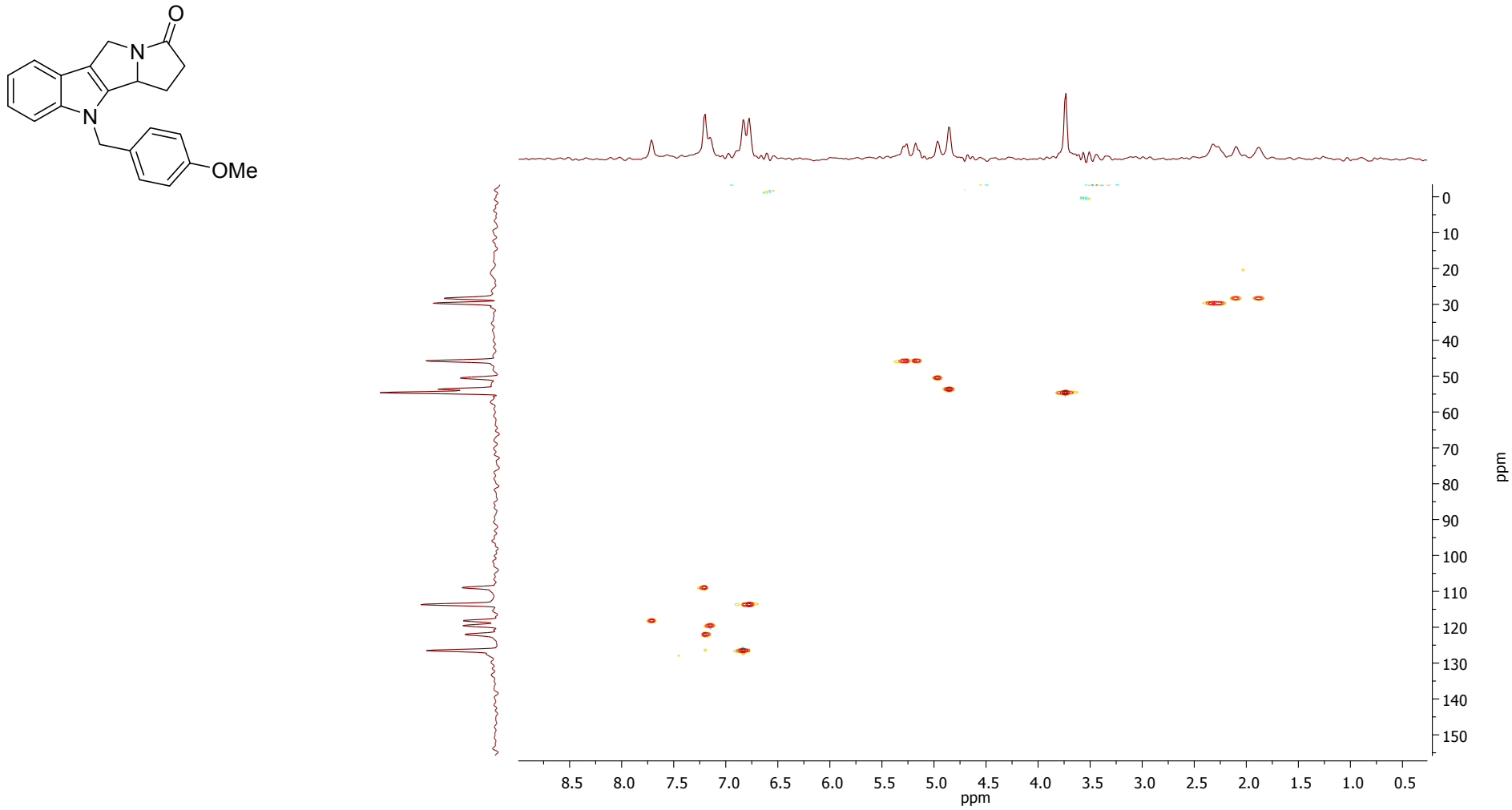
4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b)

^{13}C NMR ($CDCl_3$, 100 MHz)



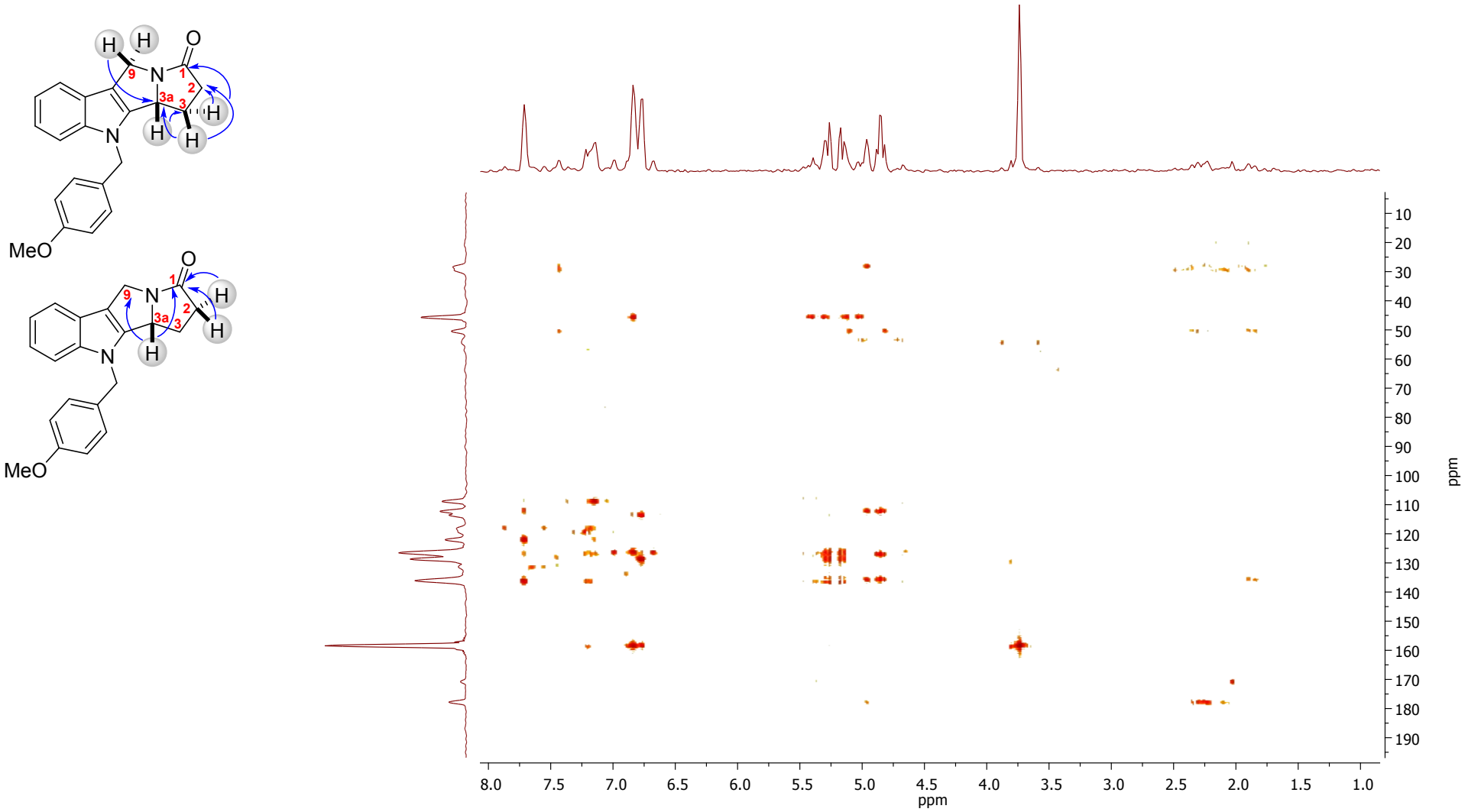
4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b)

HETCORR ^{1}H-^{13}C ($CDCl_3$)



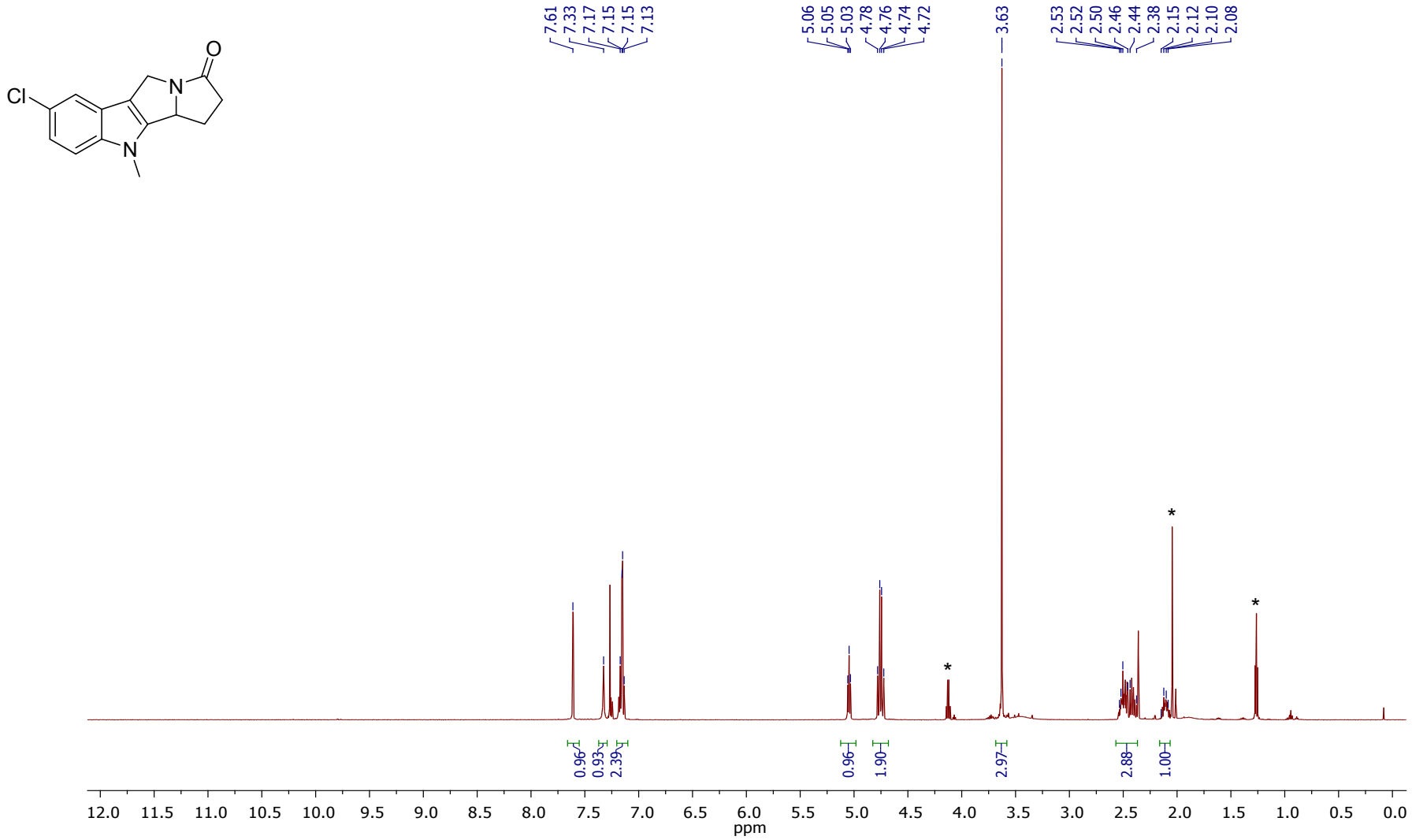
4-(4-Methoxybenzyl)-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5b)

HMBC ^{1}H-^{13}C ($CDCl_3$)



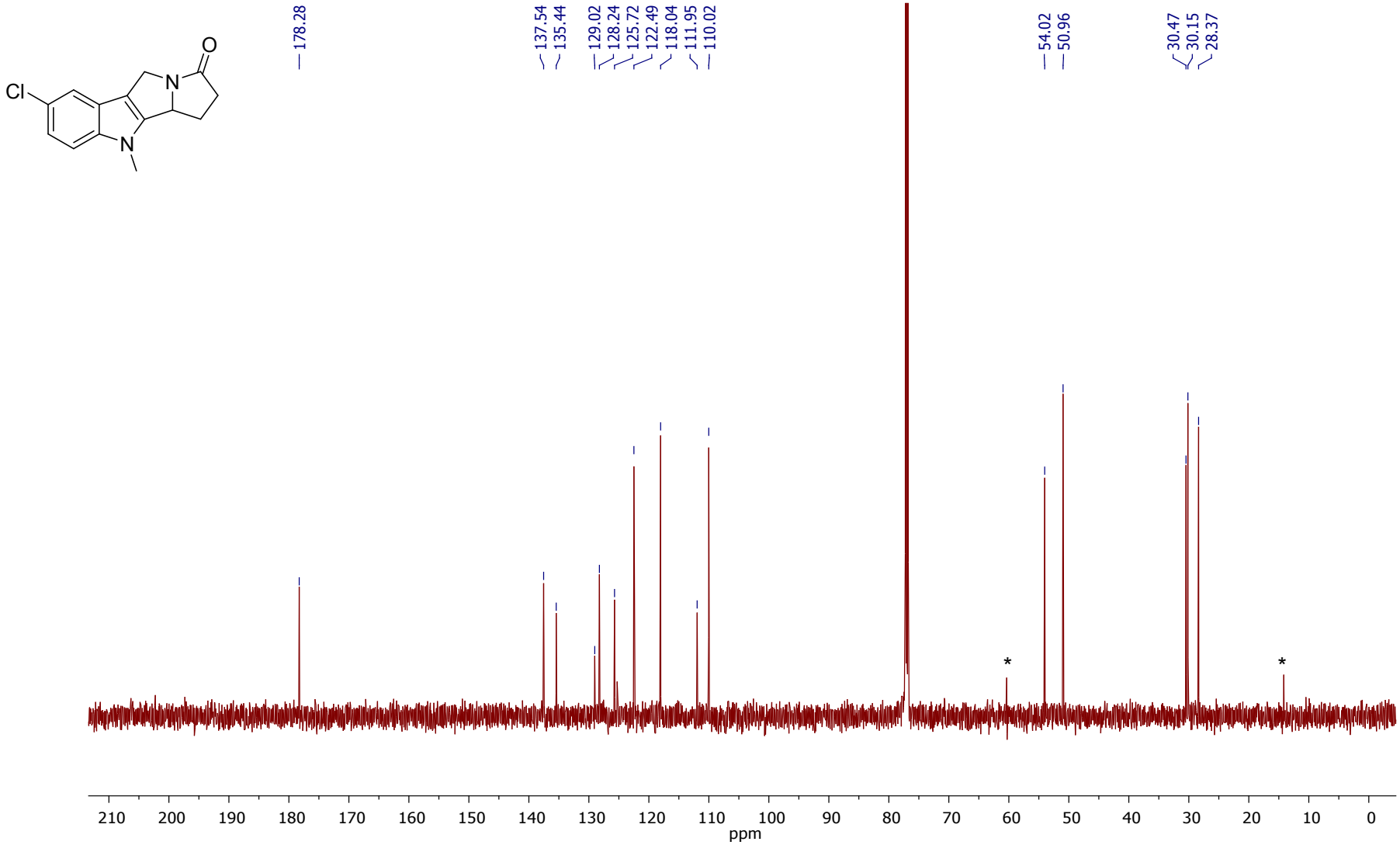
7-Chloro-4-methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5c)

^{1}H NMR ($CDCl_3$, 600 MHz)



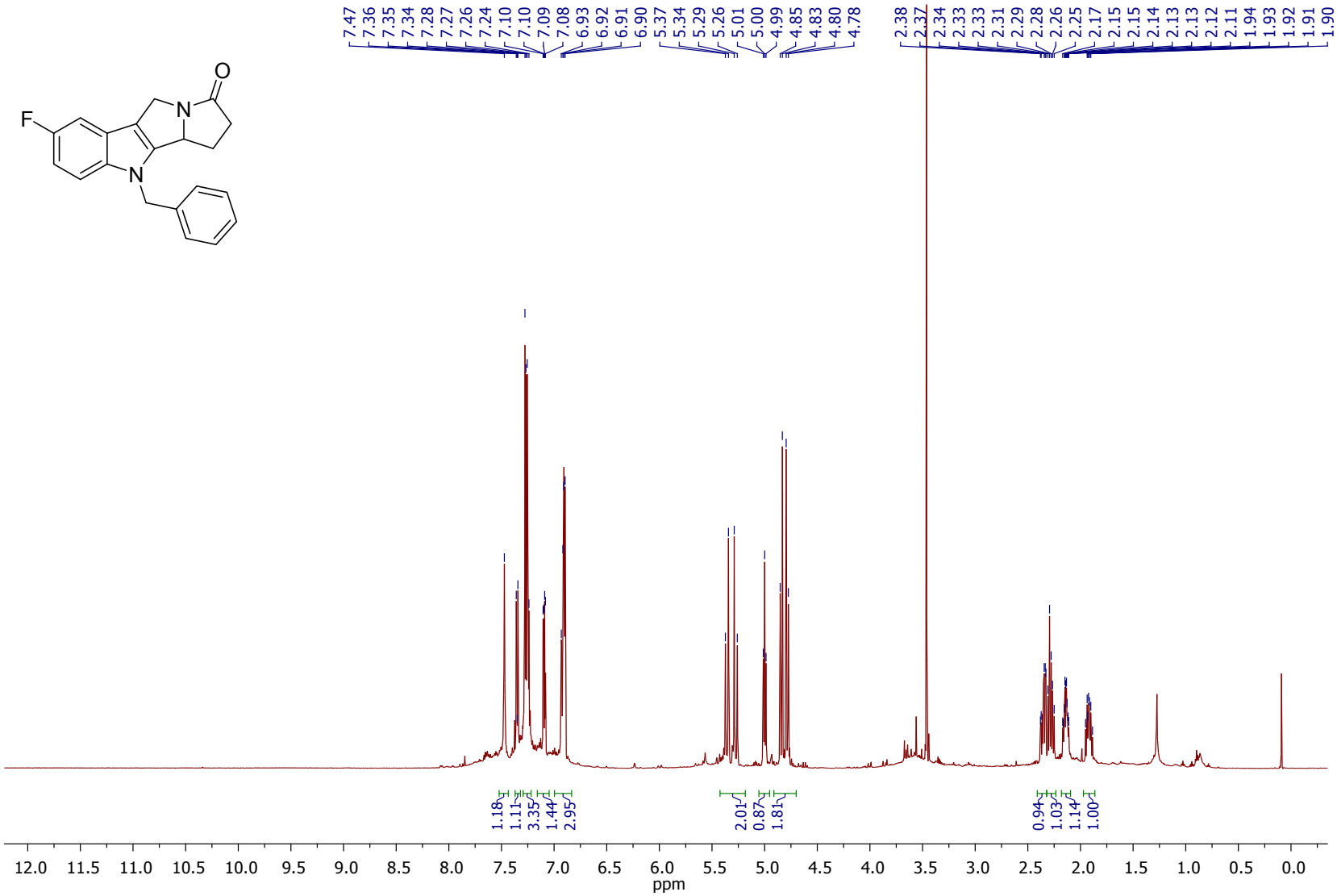
7-Chloro-4-methyl-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5c)

^{13}C NMR ($CDCl_3$, 100 MHz)



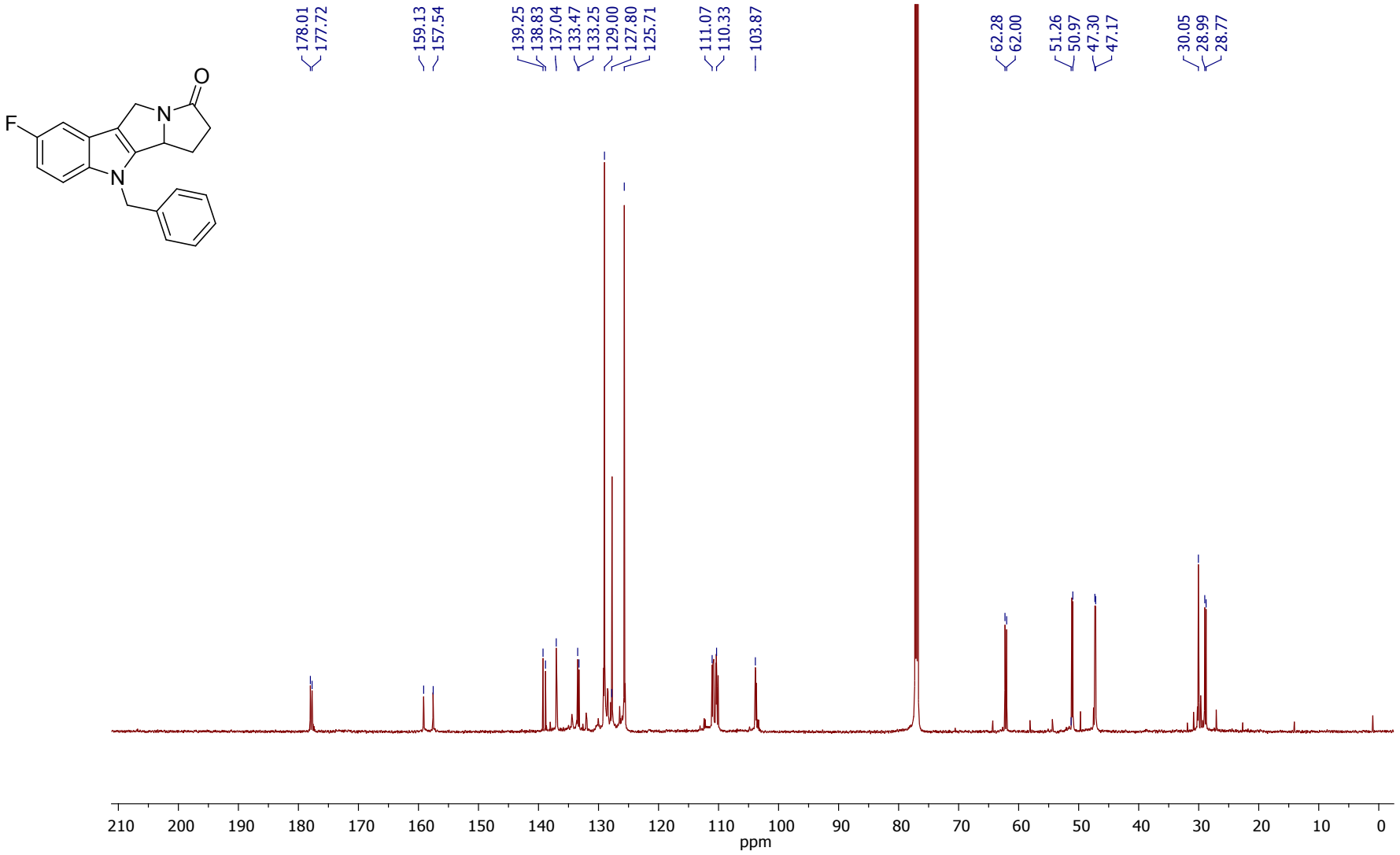
4-Benzyl-7-fluoro-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5d)

^{13}C NMR ($CDCl_3$, 100 MHz)



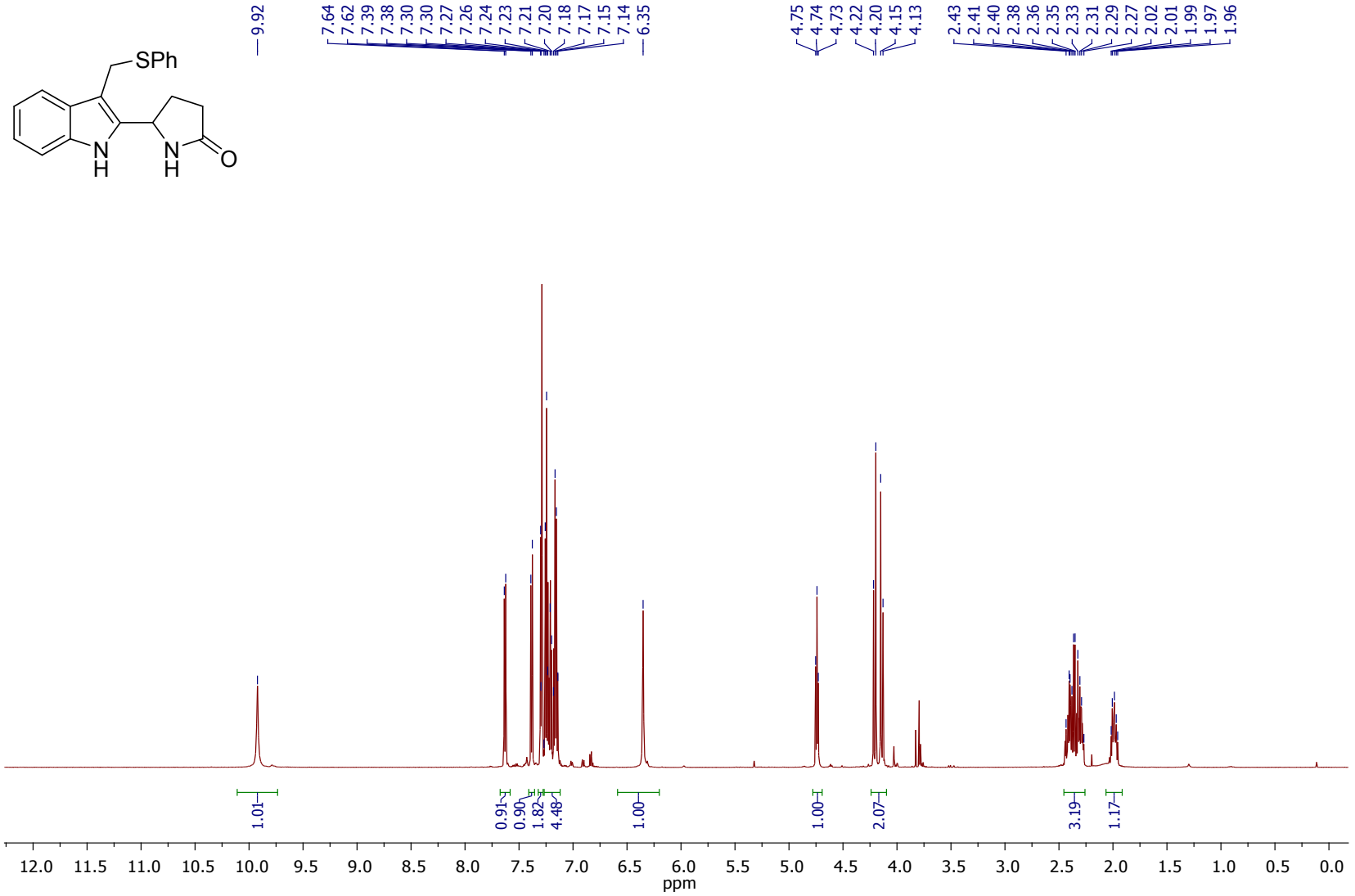
4-Benzyl-7-fluoro-3,3a,4,9-tetrahydropyrrolizino[1,2-*b*]indol-1(2*H*)-one (5d)

^{13}C NMR ($CDCl_3$, 100 MHz)



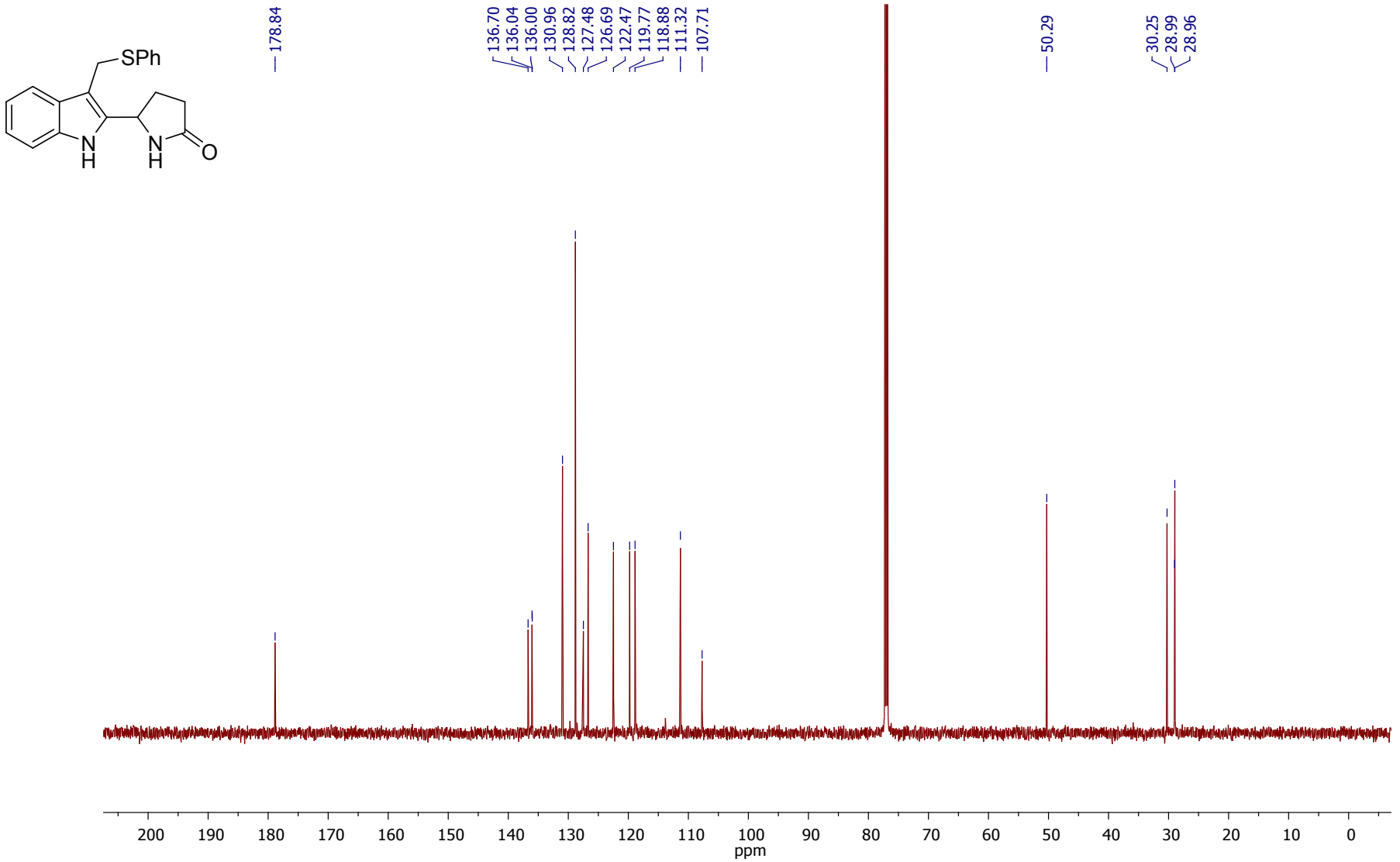
5-{3-[(Phenylsulfanyl)methyl]-1*H*-indol-2-yl}pyrrolidin-2-one (6)

^{1}H NMR ($CDCl_3$, 600 MHz)



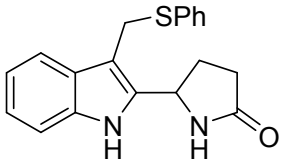
5-{3-[(Phenylsulfanyl)methyl]-1*H*-indol-2-yl}pyrrolidin-2-one (6)

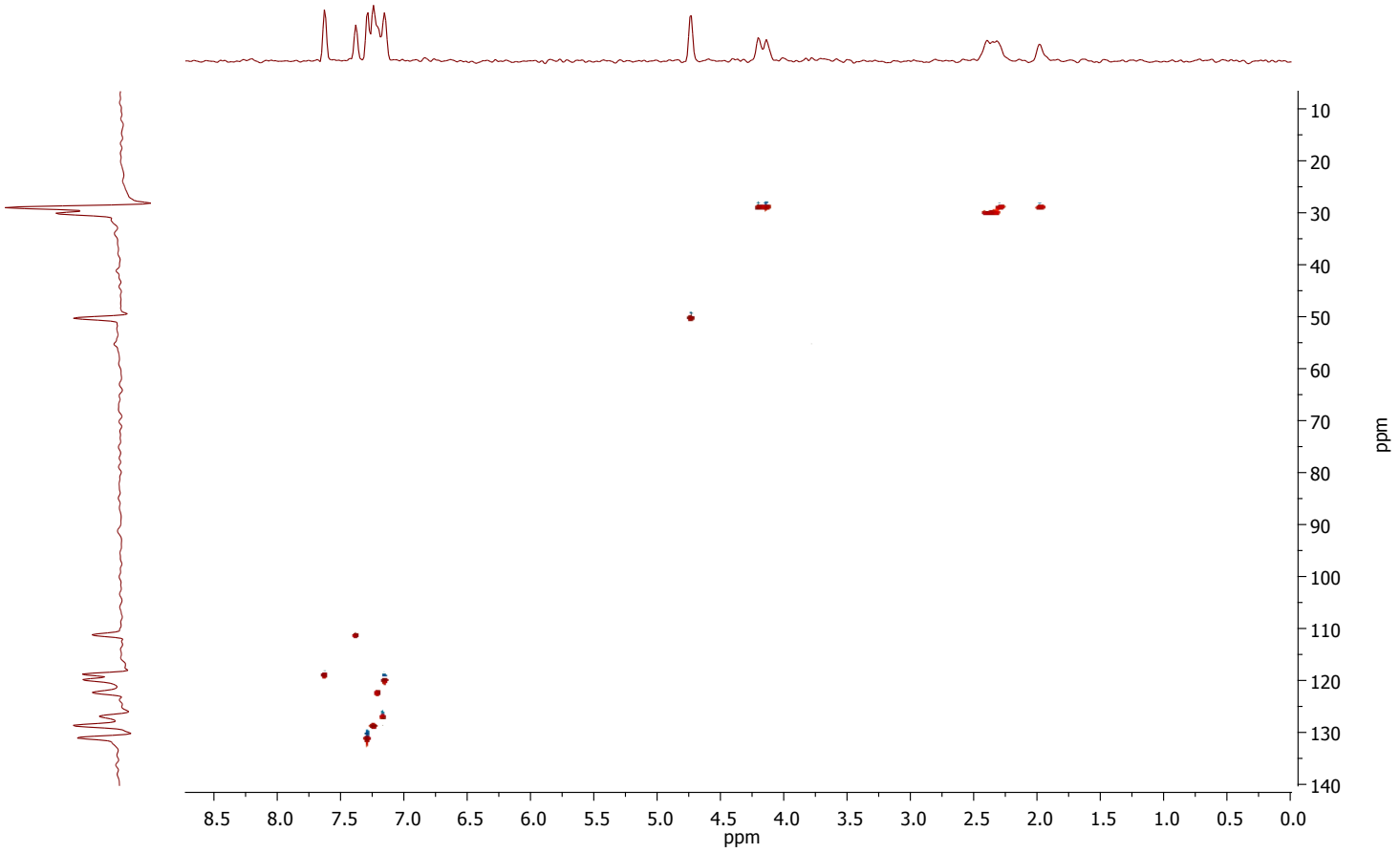
^{13}C NMR ($CDCl_3$, 100 MHz)



5-{3-[(Phenylsulfanyl)methyl]-1*H*-indol-2-yl}pyrrolidin-2-one (6)

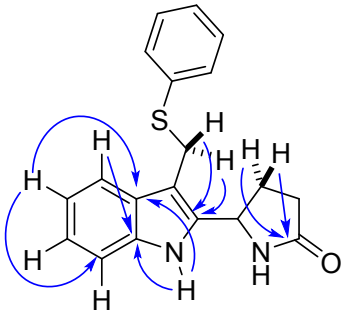
HSQC ^{1}H-^{13}C ($CDCl_3$)

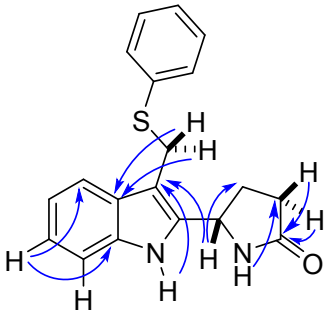


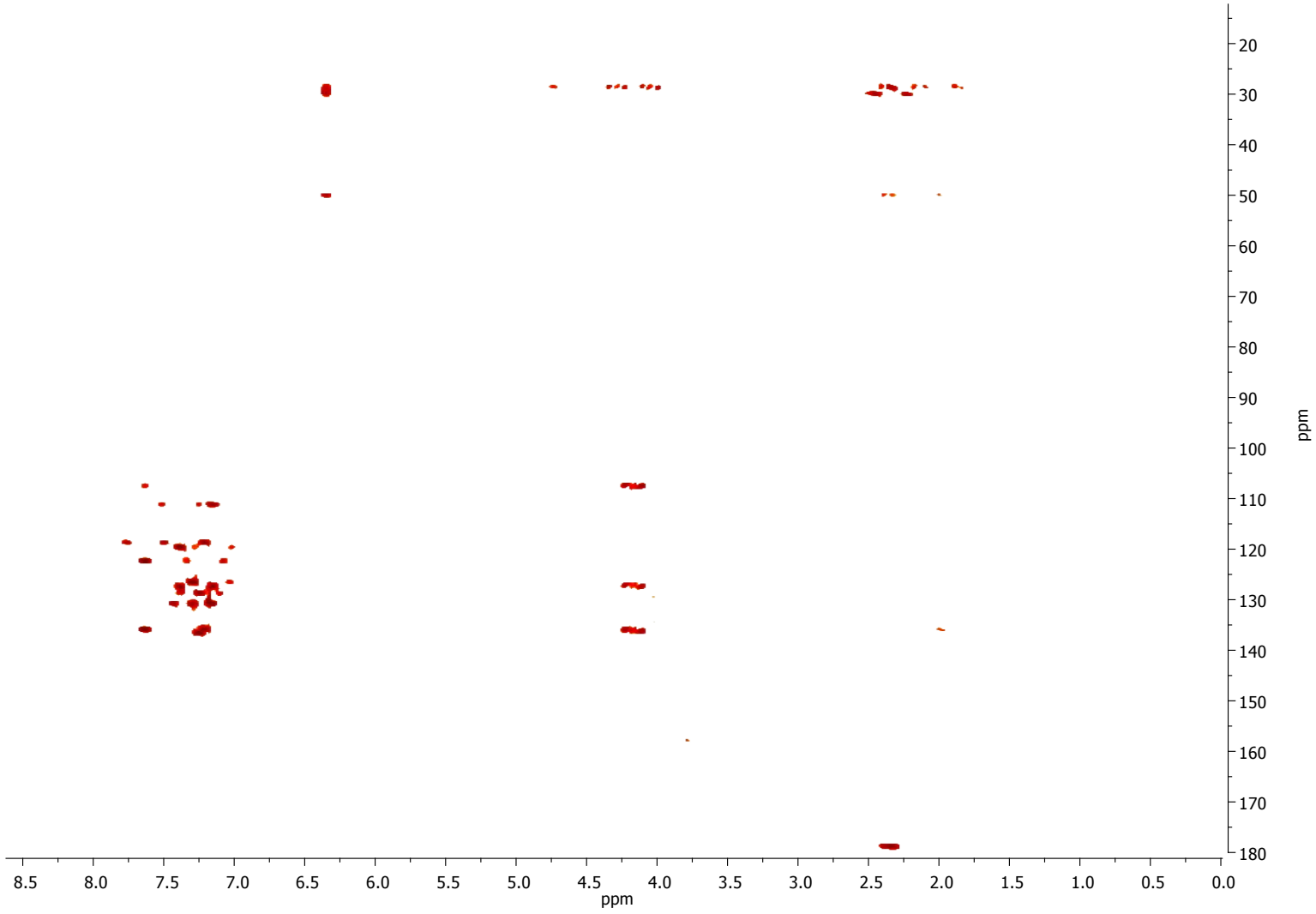


5-{3-[(Phenylsulfanyl)methyl]-1*H*-indol-2-yl}pyrrolidin-2-one (6)

HMBC ^{1}H-^{13}C ($CDCl_3$)

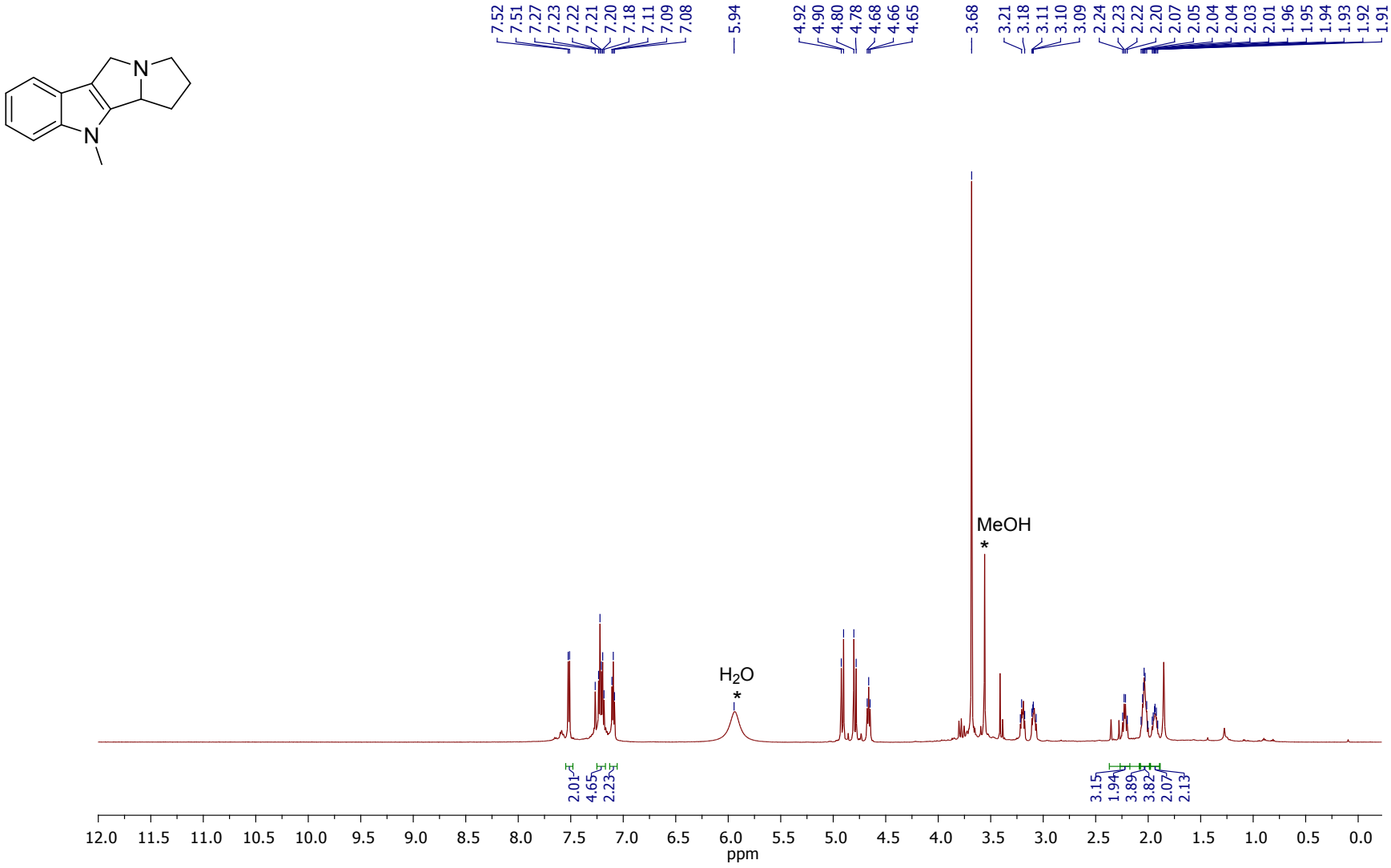






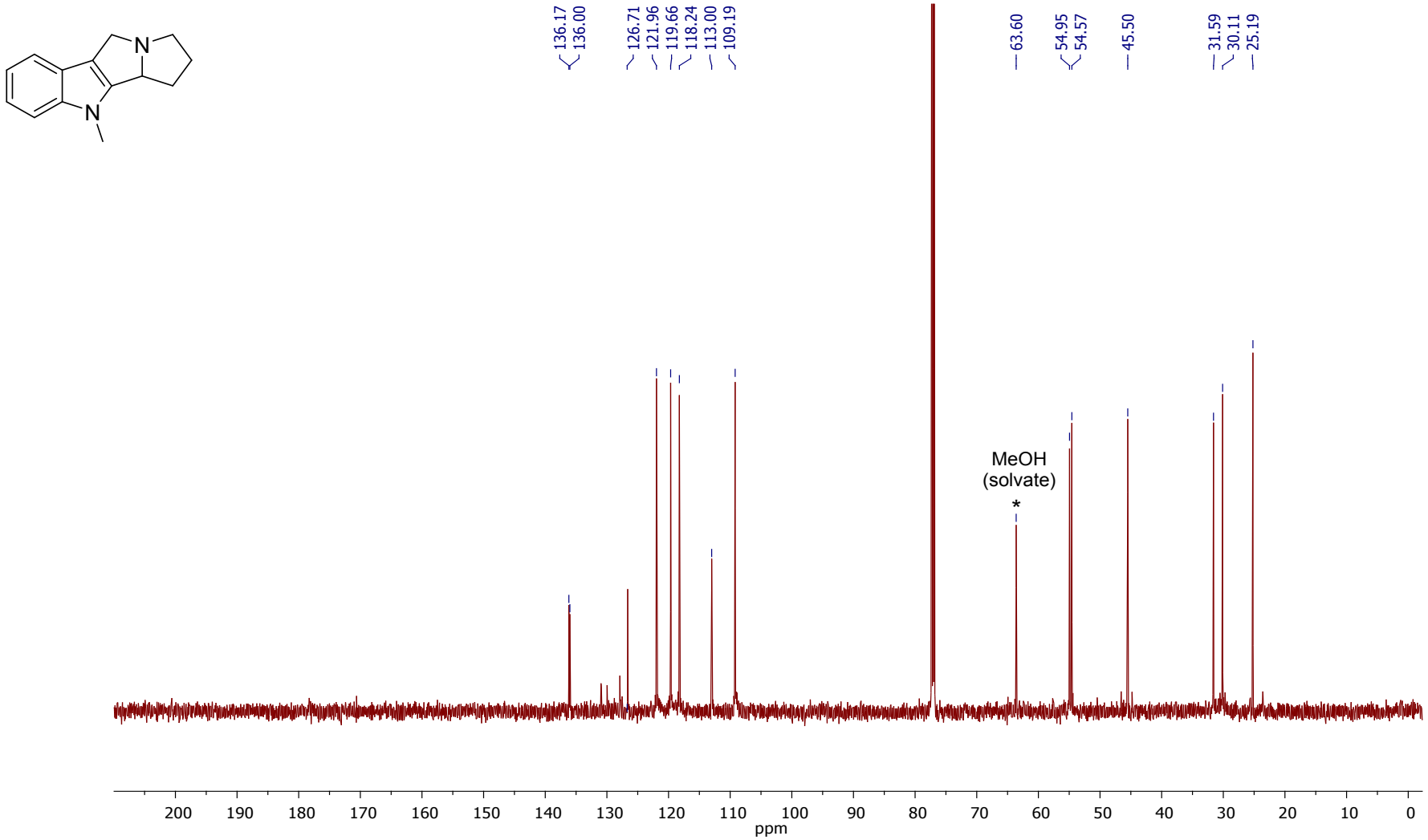
4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7a)

^{1}H NMR ($CDCl_3$, 600 MHz)



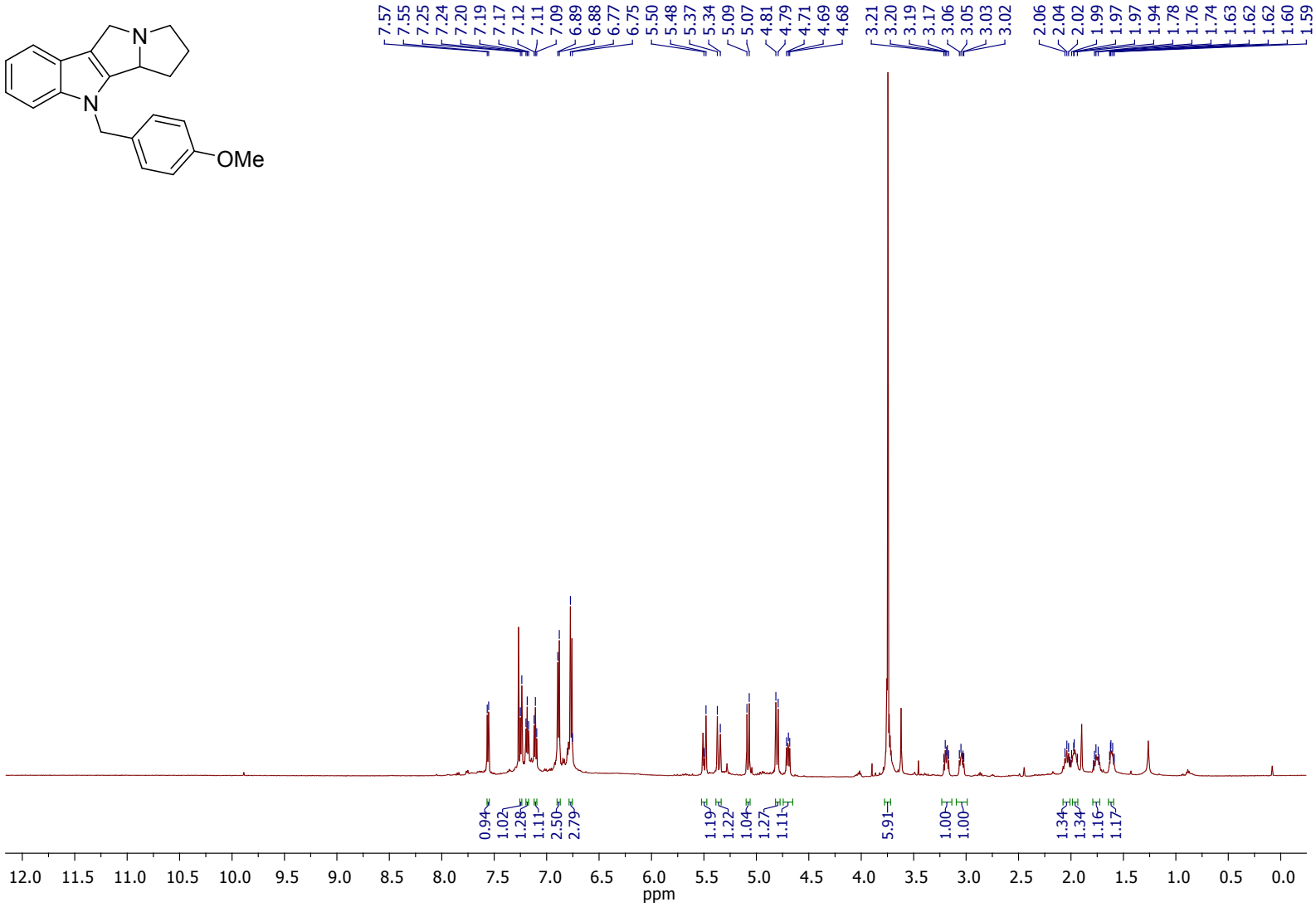
4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7a)

^{13}C NMR ($CDCl_3$, 100 MHz)



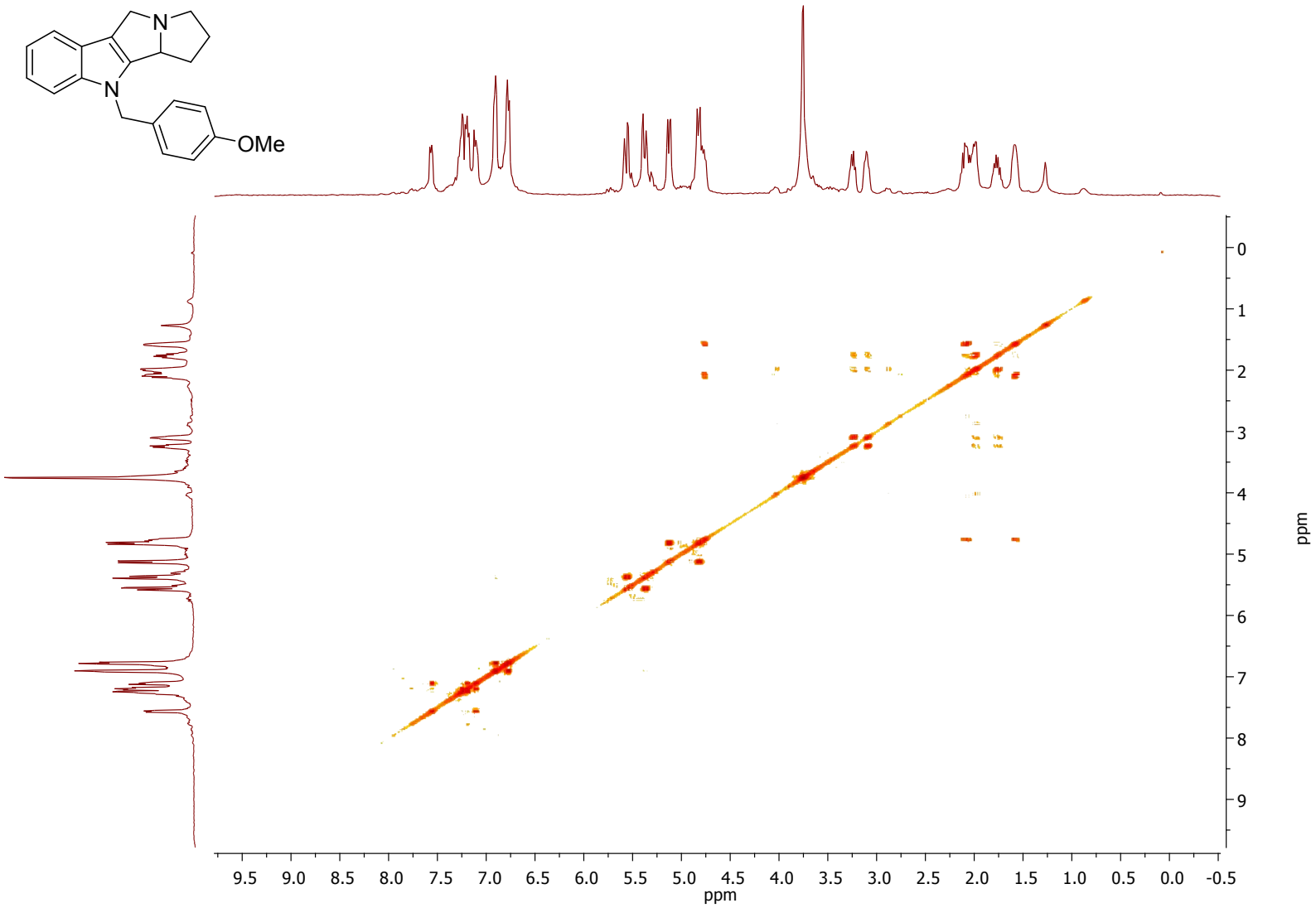
4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b)

^{1}H NMR ($CDCl_3$, 600 MHz)



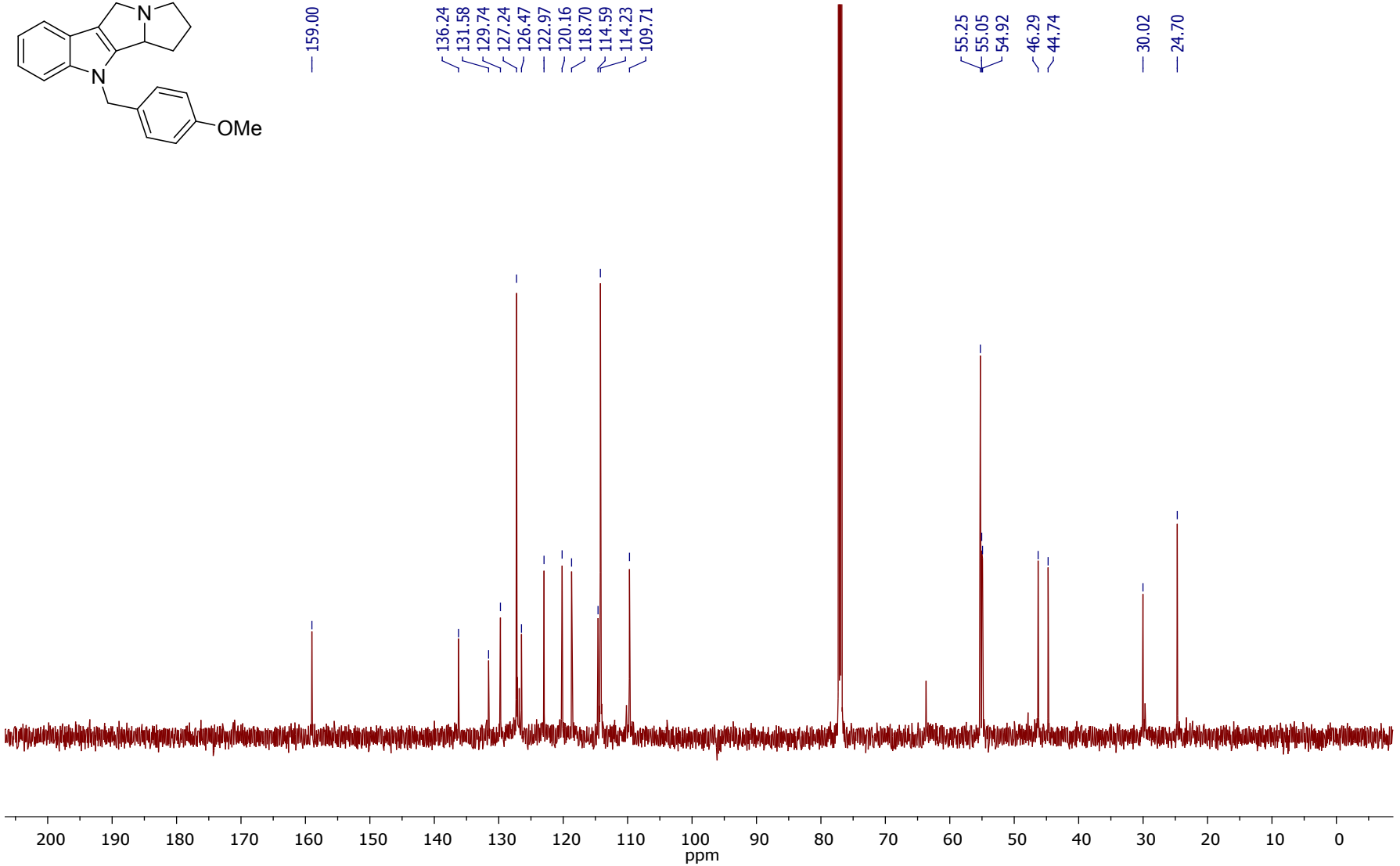
4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b)

COSY ^{1}H-^{1}H ($CDCl_3$)



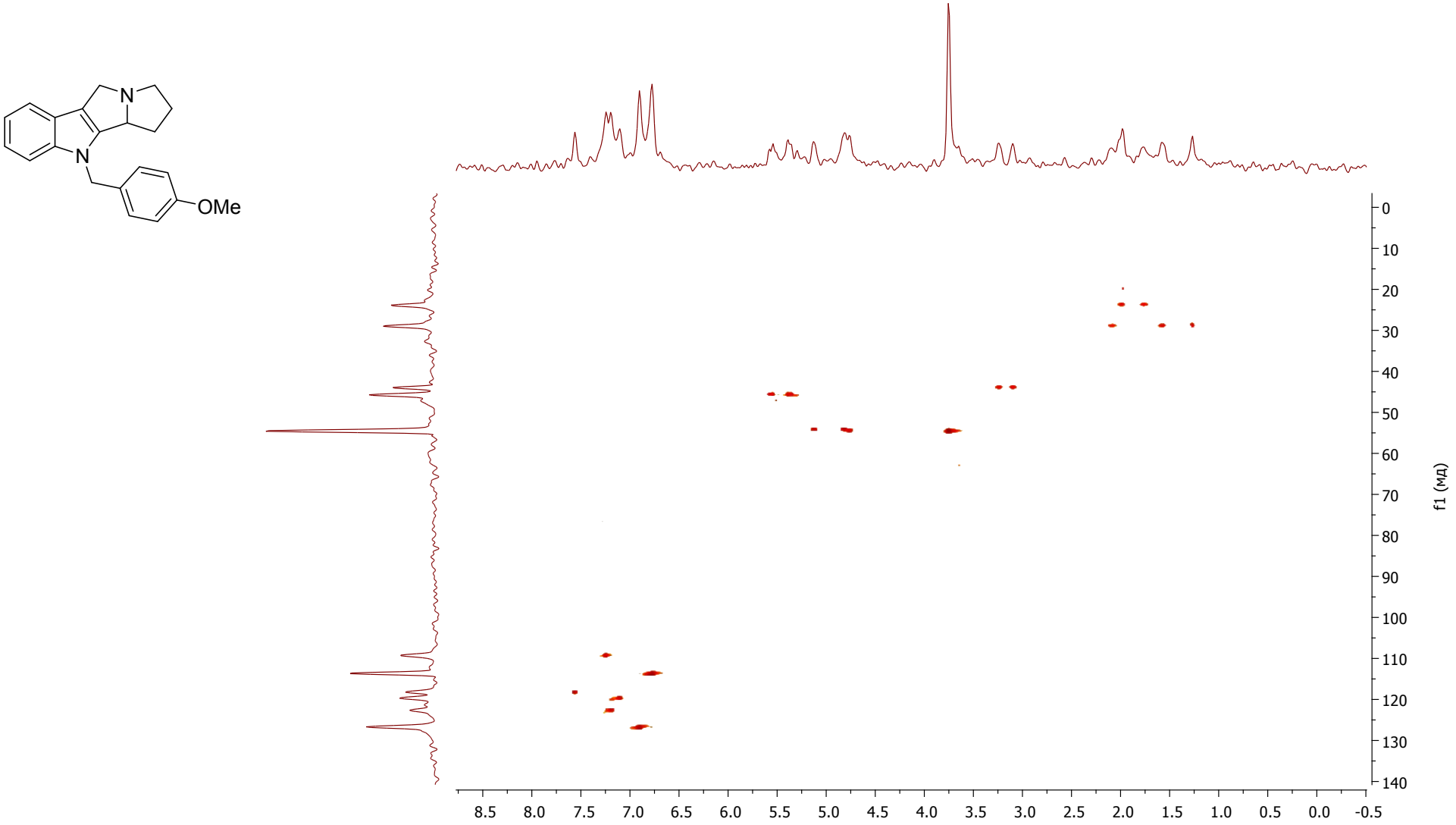
4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b)

^{13}C NMR ($CDCl_3$, 100 MHz)



4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b)

HSQC ^{1}H-^{13}C ($CDCl_3$)



4-(4-Methoxybenzyl)-1,2,3,3a,4,9-hexahydropyrrolizino[1,2-*b*]indole (7b)

HMBC ^{1}H-^{13}C ($CDCl_3$)