Synthesis of 3-aryl-8-oxo-5,6,7,8-tetrahydroindolizines *via* a palladium-catalyzed arylation and heteroarylation

Stéphanie Gracia, Clément Cazorla, Estelle Métay, Stéphane Pellet-Rostaing, and Marc Lemaire**

Supporting Information Index

Synthesis

NMR Spectra

Experimental Section

Starting materials were obtained from commercial suppliers and used without further purification. 1-Methyl-2-pyrrolidone was distilled prior to use. Flash chromatographic purification was carried out on 230-400 mesh silica gel 60. NMR spectra were recorded on DRX 300 Brücker FT spectrometers. Abbreviation was used as: s (singlet), d (doublet), dd (divided doublet), t (triplet), q (quadruplet), quin (quintuplet), m (multiplet).

Synthesis of 1-H-pyrrole-1-butanoic acid (3): 4-Aminobutyric acid (10.0 g, 97.0 mmol), H_2O (150 mL), NaOAc (8.0 g, 97.5 mmol), AcOH (50 mL) and 1,2-dichloroethane (150 mL) were mixed and heated at 90 °C. 2,5-Dimethoxytetrahydrofuran (12.5 mL, 12.8 g, 97.2 mmol) was added and at 90 °C for 15 h. The reaction mixture was quenched with aqueous HCl 1N and extracted with CH_2Cl_2. The pH was adjusted to 10 with saturated aqueous solution of $NHCO_3$ and the organic phase was removed. The aqueous layer was made acidic with aqueous HCl solution and extracted with CH_2Cl_2. The organic phase was dried over Na_2SO_4 and concentrated to afford 14.5 g (98%) of the desired product as yellow oil. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.18 (quin, 2H, J = 6.9 Hz), 2.42 (t, 2H, J = 6.9 Hz), 4.04 (t, 2H, J = 6.9 Hz), 6.29 (t, 2H, J = 2.1 Hz), 6.76 (t, 2H, J = 2.1 Hz), 11.62 (s, 1 H); ^{13}C NMR ($CDCl_3$, 75 MHz) : δ 26.9 (CH_2), 31.3 (CH_2), 48.8 (CH_2), 108.9 (CH), 121.1 (CH), 180.1 (C_q); HRMS[EI] calculated for $C_8H_{11}NO_2$: 153.0790 found: 153.0791.

Synthesis of 6,7-dihydroindolizin-8(5H)-one (4) : 4-(Pyrrol-1-yl)butanoic acid **3** (14.5 g, 94.8 mmol) was stirred in polyphosphoric acid (>84% phosphate as P_2O_5) (70 mL) at 30°C for 16 h. The reaction mixture was quenched with water (200 mL), and the resulting solution was extracted with CH_2Cl_2 (3 × 50 mL). The organic phases were combined, dried over Na_2SO_4, filtered and concentrated. Purification by column chromatography (silica gel, cyclohexane/ethyl acetate 8/2) afforded 12.9 g of *6,7-dihydroindolizin-8(5*H*)-one* (12.9 g, 97%) as a colorless oil. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.23 (m, 2 H), 2.53 (t, 2H, J = 6.2

Hz), 4.08 (t, 2H, *J* = 6.2 Hz), 6.21 (dd, 1H, *J* = 2.5, 4.1 Hz), 6.83 (t, 2H, *J* = 1.9 Hz), 6.97 (dd, 1H, *J* = 1.7, 4.1 Hz); ^{13}C NMR ($CDCl_3$,75 MHz): δ 23.9 (CH_2), 36.5 (CH_2), 45.5 (CH_2), 110.7 (CH), 114.3 (CH), 126.3 (CH), 187.7 (C_q); IR: 3110, 3099, 2960, 2950, 2924, 2888, 1647, 1525, 1482, 1388, 1338, 1325 cm^{-1}; HRMS[EI] calculated for C_8H_9NO: 135.0684 found: 135.0684.

Representative procedure for arylation of compound (4): 8-oxo-5,6,7,8-tetrahydroindolizine **4** (1 g, 7.35 mmol), KOAc (1.44 g, 14.7 mmol), $PdCl_2(PPh_3)_2$ (26 mg, 0.0367 mmol) and arylbromide (8.8 mmol) followed by freshly distilled NMP (4 mL) were added to a schlenk flask under argon atmosphere. The mixture was stirred at 100°C for 10 min. Then, water (23 µl, 1.3 mmol) was added to the solution. The reaction mixture was stirred at 100°C for the appropriate time then diluted with dichloromethane (30 mL), was washed with water (3x10 mL). The organic layer was dried (Na_2SO_4) and the solvent was removed under reduced pressure. Purification by column chromatography (silica gel, cyclohexane/ethyl acetate 8/2) afforded the desired compound **5 a-t**.

3-phenyl-8-oxo-5,6,7,8-tetrahydroindolizine (5a): 88%; white solid; Mp = 121-122°C; ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.17 (m, 2H), 2.55 (t, 2H, *J* = 6.2 Hz), 4.04 (t, 2H, *J* = 6.2 Hz), 6.27 (d, 1H, *J* = 4.1 Hz), 7.04 (d, 1H, *J* = 4.1 Hz), 7.37 (m, 5 H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 23.9 (CH_2), 36.3 (CH_2), 44.5 (CH_2), 111.9 (CH), 114.7 (CH), 122.4 (CH), 125.9 (2 CH), 129.2 (2 CH), 132.4 (C_q), 135.4 (C_q), 137.5 (C_q), 187.9 (CO); IR: 3056, 3029, 2946, 2880, 1646, 1532, 1508, 1454, 1384, 1333 cm^{-1}; HRMS[EI] calculated for $C_{14}H_{13}NO$: 211.0997 found: 211.0998.

3-(4-cyanophenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5b): 93%; yellow solid; Mp = 168-169°C; ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.26 (m, 2H), 2.63 (t, 2H, *J* = 6.4 Hz), 4.14 (t, 2 H, *J* = 5.74 Hz), 6.42 (d, 1H, *J* = 4.1 Hz), 7.09 (t, 1H, *J* = 4.1 Hz), 7.55 (td, 2H, *J* = 1.7, 8.1Hz), 7.72 (td, 2H, *J* = 1.78, 8.28 Hz); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 23.9 (CH_2), 36.2

(CH_2), 44.7 (CH_2), 111.8 (C_q), 112.3 (CH), 114.8 (CH), 118.7 (C_q), 129.3 (2 CH), 132.7 (C_q), 132.8 (2 CH), 136.3 (C_q), 136.9 (C_q), 187.9 (CO); IR: 3058, 3032, 2962, 2936, 2227, 1657, 1637, 1604, 1512, 1464, 1337 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{12}N_2O$: 236.0950 found: 236.0950.

3-(4-trifluoromethylphenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5c): 79%; yellow solid; Mp = 132-133°C; ^1H NMR ($CDCl_3$, 300 MHz): δ 2.27 (m, 2 H), 2.65 (t, 2H, *J* = 6.4 Hz), 4.14 (t, 2H, *J* = 5.83 Hz), 6.41 (d, 1H, *J* = 4.1 Hz), 7.12 (t, 1H, *J* = 4.1 Hz), 7.56 (d, 2H, *J* = 8.1Hz), 7.71 (d, 2H, *J* = 8.1 Hz); ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.9 (CH_2), 36.2 (CH_2), 44.5 (CH_2), 111.9 (CH), 114.7 (CH), 124.2 (C_q, J^1C-F = 270.6 Hz), 125.9 (2 CH, J^3C-F = 11.45 Hz), 129.2 (2 CH), 130.3 (C_q, J^2C-F = 32.73 Hz), 132.3 (C_q), 135.4 (C_q, J^5C-F = 2.18 Hz), 137.52 (C_q), 187.8 (CO); 19F NMR ($CDCl_3$, 122MHz): -63.3024; IR: 2956, 2885, 1654, 1615, 1515, 1317, 1126 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{12}F_3NO$: 279.0871 found: 279.0871.

3-(4-nitrophenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5d): 82%; orange solid; Mp = 184-185°C; ^1H NMR ($CDCl_3$, 300 MHz): δ 2.19 (m, 2 H), 2.51 (t, 2H, *J* = 6.4 Hz), 4.08 (t, 2H, *J* = 5.74 Hz), 6.34 (d, 1H, *J* = 4.1 Hz), 6.94 (t, 1H, *J* = 4.1 Hz), 7.51 (dd, 2H, *J* = 2.1, 6.9 Hz), 8.15 (dd, 2H, *J* = 1.9, 6.9 Hz) ; ^{13}C NMR ($CDCl_3$,75MHz) : δ 23.9 (CH_2), 36.3 (CH_2), 44.8 (CH_2), 112.7 (CH), 114.9 (CH), 124.4 (2 CH), 129.4 (2 CH), 133.0 (C_q), 136.5 (C_q), 138.2 (C_q), 147.4 (C_q), 187.9 (CO); IR: 2968, 2927, 2869, 1660, 1596, 1506, 1330 cm^{-1}; HRMS[EI] calculated for $C_{14}H_{12}N_2O$: 256.0848 found: 256.0848.

3-(4-acetylphenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5e): 71%; yellow solid; Mp = 159-160°C; ^1H NMR ($CDCl_3$, 300MHz) : δ 2.22 (m, 2H), 2.60 (m, 5H), 4.13 (t, 2H, *J* = 5.74 Hz), 6.39 (d, 1H, *J* = 4.1 Hz), 7.06 (t, 1H, *J* = 4.1 Hz), 7.51 (d, 2H, *J* = 8.4 Hz), 7.99 (d, 2H, *J* = 8.4 Hz) ; ^{13}C NMR ($CDCl_3$,75MHz) : δ 23.8 (CH_2), 26.8 (CH_3), 36.2 (CH_2), 44.6 (CH_2), 111.9 (CH), 114.6 (CH), 128.8 (2CH), 128.9 (2CH), 132.4 (C_q), 136.2 (C_q), 136.4 (C_q), 137.8

(C_q), 187.8 (CO), 197.5 (CO); IR: 3095, 2959, 2921, 1676, 1651, 1604, 1508, 1465, 1336, 1248 cm^{-1}; HRMS[EI] calculated for $C_{16}H_{15}NO_2$: 253.1103 found: 253.1104.

3-(4-methylbenzoyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5f): 84%; yellow solid; Mp = 165-166°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.24 (m, 2H), 2.62 (t, 2H, *J* = 6.4 Hz), 3.92 (s, 3H), 4.14 (t, 2H, *J* = 5.74 Hz), 6.4 (d, 1H, *J* = 4.1 Hz), 7.09 (t, 1H, *J* = 4.1 Hz), 7.5 (d, 2 H, *J* = 8.5 Hz), 8.08 (d, 2H, *J* = 8.5 Hz) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.9 (CH_2), 36.3 (CH_2), 44.6 (CH_2), 53.5 (CH_3), 111.9 (CH), 114.7 (CH), 128.7 (2 CH), 129.7 (C_q), 130.2 (2 CH), 132.4 (C_q), 136.2 (C_q), 137.9 (C_q), 166.8 (CO), 187.8 (CO); IR: 3113, 2943, 2891, 1713, 1660, 1429, 1334, 1279, 1102 cm^{-1}; HRMS[EI] calculated for $C_{16}H_{15}NO_3$: 269.1052 found: 269.1052.

3-(2-nitrophenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5g): 70%; yellow solid; Mp = 122-123°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.19 (m, 2H), 2.58 (t, 2H, *J* = 6.4 Hz), 3.77 (t, 2H, *J* = 5.84 Hz), 6.21 (d, 1H, *J* = 4.1 Hz), 7.04 (t, 1H, *J* = 4.1 Hz), 7.46 (dd, 1 H, *J* = 1.5, 7.53 Hz), 7.60 (m, 2H), 8.05 (dd, 1H, *J* = 1.1, 7.9 Hz) ; ^{13}C NMR ($CDCl_3$,75MHz) : δ 23.6 (CH_2), 36.2 (CH_2), 43.4 (CH_2), 111.4 (CH), 114.2 (CH), 124.8 (CH), 126.6 (C_q), 124.8 (CH), 126.6 (C_q), 130.4 (CH), 131.8 (C_q), 133.4 (CH), 133.5 (C_q), 149.4 (C_q), 187.7 (CO); IR: 2942, 2878, 1643, 1528, 1504, 1390, 1340 cm^{-1}; HRMS[EI] calculated for $C_{14}H_{12}N_2O_3$: 256.0848 found: 256.0847.

3-(4-methoxyphenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5i): 47%; yellow solid; Mp = 124-125°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.22 (m, 2H), 2.6 (t, 2H, *J* = 6.4 Hz), 3.84 (s,3H), 4.08 (t, 2H, *J* = 5.74 Hz), 6.28 (d, 1H, *J* = 4.1 Hz), 6.97 (d, 2H, *J* = 8.8 Hz), 7.1 (d, 1H, *J* = 4.1 Hz), 7.35 (d, 2H, *J* = 8.85 Hz) ; ^{13}C NMR ($CDCl_3$,75MHz) : δ 23.9 (CH_2), 36.3 (CH_2), 44.3 (CH_2), 55.6 (CH_3), 110.9 (CH), 114.4 (CH), 114.7 (C_q), 116.8 (C_q), 124.3 (2 CH), 130.3 (2 CH), 131.3 (C_q), 139.4 (C_q), 160.9 (C_q), 187.6 (CO); IR: 2960, 2936, 2891, 2830, 1640, 1609,

1518, 1458, 1341, 1238 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{15}NO_2$: 241.1103 found: 241.1103.

3-(3-acetylphenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5k): 84%; yellow solid; Mp = 164-165°C; ^1H NMR ($CDCl_3$, 300MHz) : δ 2.17 (m, 2H), 2.54 (m, 5H), 4.06 (t, 2H, *J* = 5.64 Hz), 6.31 (d, 1H, *J* = 4.1 Hz), 7.01 (d, 1H, *J* = 4.1 Hz), 7.48 (t, 1H, *J* = 7.62 Hz), 7.56 (dd, 1H, *J* = 1.5, 6.42 Hz), 7.87 (dd, 1H, *J* = 1.32, 7.44 Hz), 7.94 (d, 1H, *J* = 1.5 Hz) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.8 (CH_2), 26.8 (CH_3), 36.2 (CH_2), 44.3 (CH_2), 111.5 (CH), 114.6 (CH), 128.2 (CH), 128.5 (CH), 129.3 (CH), 131.9 (C_q), 132.3 (C_q), 133.3 (CH), 137.7 (C_q), 138.0 (C_q), 187.7 (CO), 197.7 (CO); IR: 3062, 2960, 2873, 1667, 1649, 1499, 1339 cm^{-1}; HRMS[EI] calculated for $C_{16}H_{15}NO_2$: 253.1103 found: 253.1102.

3-(3-chlorophenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5l): 94%; yellow solid; Mp = 118-119°C; ^1H NMR ($CDCl_3$, 300MHz) : δ 2.26 (m, 2H), 2.64 (t, 2H, *J* = 6.3 Hz), 4.12 (t, 2H, *J* = 5.74 Hz), 6.36 (d, 1H, *J* = 4.1 Hz), 7.11 (d, 1H, *J* = 4.1 Hz), 7.33 (m, 4H) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.9 (CH_2), 36.4 (CH_2), 44.5 (CH_2), 111.7 (CH), 114.8 (CH), 127.2 (CH), 128.6 (CH), 129.0 (CH), 130.3 (CH), 132.1 (C_q), 133.7 (C_q), 134.9 (C_q), 137.7 (C_q), 187.8 (CO); IR: 3061, 2977, 2932, 2845, 1639, 1599, 1500, 1456, 1429, 1384, 1344, 1333, 1089, 1074, 1038 cm^{-1}; HRMS[EI] calculated for $C_{14}H_{12}ClNO$: 245.0607 found: 245.0607.

3-(3-methoxyphenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5m): 91%; yellow solid; Mp = 153-154°C; ^1H NMR ($CDCl_3$, 300MHz) : δ 2.24 (m, 2H), 2.63 (t, 2H, *J* = 6.4 Hz), 3.85 (s, 3H), 4.14 (dd, 2H, *J* = 5.82, 7.14 Hz), 6.36 (d, 1H, *J* = 4.1 Hz), 6.97 (m, 3H), 7.12 (d, 1H, *J* = 4.1 Hz), 7.36 (t, 1H, *J* = 7.89 Hz) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 24.0 (CH_2), 36.4 (CH_2), 44.5 (CH_2), 55.7 (CH_3), 111.4 (CH), 113.9 (CH), 114. 8 (CH), 115.0 (CH), 121.5 (CH), 130.1 (C_q), 131.8 (C_q), 133.2 (C_q), 139.3 (C_q), 160.0 (C_q), 187.8 (CO), IR: 3089, 2957, 2893, 2837, 1638, 1611, 1501, 1467, 1383, 1332, 1175, 1046 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{15}NO_2$: 241.1103 found: 241.1102.

3-(3-toluyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5n): 49%; yellow solid; Mp = 140-141°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.19 (m, 2H), 2.39 (s, 3H), 2.58 (t, 2H, *J* = 6.4 Hz), 4.09 (dd, 2H, *J* = 5.85, 7.17 Hz), 6.30 (d, 1H, *J* = 4.1 Hz), 7.08 (d, 1H, *J* = 4.1 Hz), 7.24 (m, 4H) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 21.6 (CH_3), 23.8 (CH_2), 36.1 (CH_2), 44.2 (CH_2), 111.0 (CH), 114.5 (CH), 125.9 (CH), 128.7 (CH), 129.1 (CH), 129.6 (CH), 131.5 (C_q), 131.6 (C_q), 138.5 (C_q), 139.4 (C_q), 187.6 (CO); IR: 2992, 2977, 2934, 2865, 1637, 1608, 1532, 1499, 1468, 1385, 1343, 1332 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{15}NO$: 225.1154 found: 225.1155.

3-(4-methoxy-2nitrophenyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5p): 56%; orange solid; Mp = 123-124°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.21 (m, 2H), 2.60 (t, 2H, *J* = 6.4 Hz), 3.76 (t, 2H, *J* = 5.5 Hz), 3.93 (s,3H), 6.19 (d, 1H, *J* = 3.8 Hz), 7.07 (d, 1H, *J* = 3.9 Hz), 7.20 (dd, 1H, *J* = 2.3, 8.5 Hz), 7.36 (d, 1H, *J* = 8.5 Hz), 7.57 (s, 1H) ; ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.9 (CH_2), 36. 6 (CH_2), 43.5 (CH_2), 55.6 (CH_3), 101.1 (CH), 104.5 (CH), 109.9 (C_q), 111.8 (CH), 114.6 (CH), 131.5 (C_q), 132.5 (CH), 136.1 (C_q), 147.2 (C_q), 161.7 (C_q), 187.9 (CO); IR: 3121, 3063, 2961, 2830, 1651, 1536, 1512, 1468, 1444, 1340, 1305, 1288, 1234, 1032 cm^{-1}; HRMS[EI] calculated for $C_{15}H_{14}N_2O_4$: 286.0954 found: 286.0954.

3-(3-quinolinyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5r): 78%; yellow solid; Mp = 190-191°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.19 (m, 2H), 2.53 (t, 2H, *J* = 6.4 Hz), 4.1 (t, 2H, *J* = 5.6 Hz), 6.39 (d, 1H, *J* = 4.1 Hz), 7.03 (d, 1H, *J* = 4.1 Hz), 7.48 (m, 1H), 7.64 (m, 1H), 7.76 (d, 1H, *J* = 8.1 Hz), 8.00 (d, 1H, *J* = 8.46 Hz), 8.09 (s, 1H), 8.88 (m, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.6 (CH_2), 36.0 (CH_2), 44.2 (CH_2), 111.9 (CH), 114.5 (CH), 124.8 (C_q), 127.4 (C_q), 127.5 (CH), 128.0 (CH), 129.3 (CH), 130.2 (CH), 132.2 (C_q), 135.0 (CH), 135.4 (C_q), 147.2 (C_q), 150.1 (CH), 187.6 (CO); IR: 3107, 2957, 2875, 1649, 1606, 1527, 1492, 1337 cm^{-1}; HRMS[EI] calculated for $C_{17}H_{14}N_2O$: 262.1106 found: 262.1107.

3-(1-naphtyl)-8-oxo-5,6,7,8-tetrahydroindolizine (5t): 74%; grey solid; Mp = 155-156°C; ^{1}H NMR ($CDCl_3$, 300MHz) : δ 2.15 (t, 2H, *J* = 5.5 Hz), 2.61 (t, 2H, *J* = 5.8 Hz), 3.74 (t, 2H, *J* = 5.6 Hz), 6.39 (d, 1H, *J* = 3.9 Hz), 7.23 (d, 1H, *J* = 3.8 Hz), 7.55 (m, 5H), 7.92 (m, 2H); ^{13}C NMR ($CDCl_3$, 75MHz) : δ 23.6 (CH_2), 36.0 (CH_2), 44.2 (CH_2), 111.9 (CH), 114.5 (CH), 124.8 (C_q), 127.4 (C_q), 127.5 (CH), 128.0 (CH), 129.3 (CH), 130.2 (CH), 132.2 (C_q), 135.0 (CH), 135.4 (C_q), 147.2 (C_q), 150.1 (CH), 187.6 (CO); IR: 3055, 2948, 2891, 2865, 1649, 1509, 1485, 1379, 1341 cm^{-1}; HRMS[EI] calculated for $C_{18}H_{15}NO$: 261.1154 found: 261.1154.

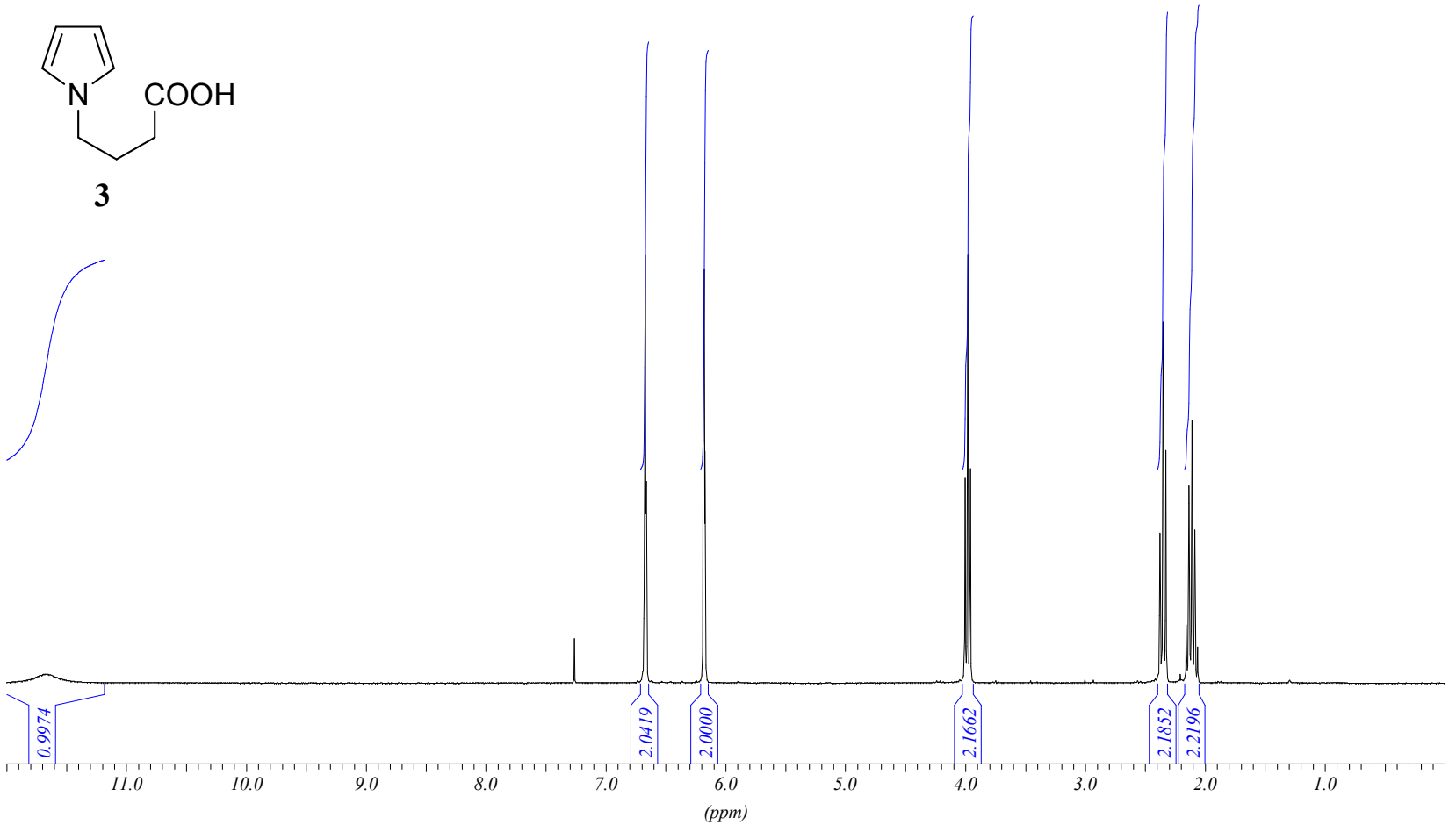
Preparation of 5,6,7,8-tetrahydroindolizine (10): To a cold (0°C) stirred suspension of aluminium chloride (1.47 g, 11.03 mmol) in dichloromethane (20 mL) was added *tert*-butylamine-borane (1.92 g, 22.06 mmol). The resulting mixture was allowed to stir at 0°C for 10 min. A solution of 6,7-dihydroindolizin-8(5H)-one (500 mg, 3.67 mmol) in dichloromethane (10 mL) was added. The resulting mixture was stirred at 0°C for 2 h. Cold dilute HCl (0.1 N, 20 mL) was added dropwise to the reaction mixture. The product was extracted with ethyl acetate. The combined organic extracts were washed with 0.1 N HCl twice and then with brine. Concentration of the organic extracts afforded an oil, which was purified by flash chromatography on silica gel (eluted with cyclohexane) to afford 447 mg (98%) of desired product as colourless oil. ^{1}H NMR ($CDCl_3$, 300MHz) : δ 1.91 (m, 2H), 2.00 (m,2H), 2.85 (t, 2H, *J* = 6.2 Hz), 4.01 (t, 2H, *J* = 6.03 Hz), 5.9 (m, 1H), 6.19 (t, 1H, *J* = 3.0 Hz), 6.58 (1, 1H, *J* = 1.86 Hz); ^{13}C NMR ($CDCl_3$, 75MHz) : δ 21.7 (CH_2), 23.5 (CH_2), 24.1 (CH_2), 44.5 (CH_2), 104.0 (CH), 107.6 (CH), 118.7 (CH), 129.3 (C_q); HRMS[EI] calculated for $C_8H_{11}N$: 121.0891 found: 121.0891.

Synthesis of 3-phenyl-5,6,7,8-tetrahydroindolizine (11): 70%; yellow oil; ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.90 (m, 4H), 2.89 (t, 2H, *J* = 6.1 Hz), 3.96 (t, 2H, *J* = 5.8 Hz), 5.95 (d, 1H, *J* = 3.6 Hz), 6.22 (d, 1H, *J* = 3.4 Hz), 7.28 (m, 1H), 7.37 (m, 4 H); ^{13}C NMR ($CDCl_3$, 75

MHz): δ 24.1 (CH_2), 24.4 (CH_2), 30.0 (CH_2), 45.1 (CH_2), 105.0 (CH), 108.4 (CH), 126.6 (CH), 128.6 (2 CH), 128.9 (2 CH), 130.8 (C_q), 132.8 (C_q), 134.0 (C_q); IR: 3098, 3063, 3027, 2928, 1600, 1508, 1446, 1380, 1332, 1072, 1026 cm^{-1}; HRMS[CI] calculated for $C_{14}H_{15}N$: 198.1283 found: 198.1283.

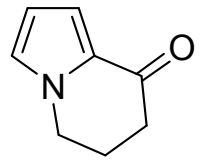
solvent: $CDCl_3$

frequency: 300 MHz



solvent: $CDCl_3$

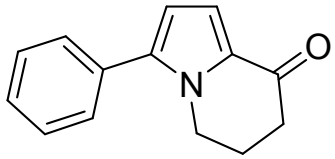
frequency: 300 MHz



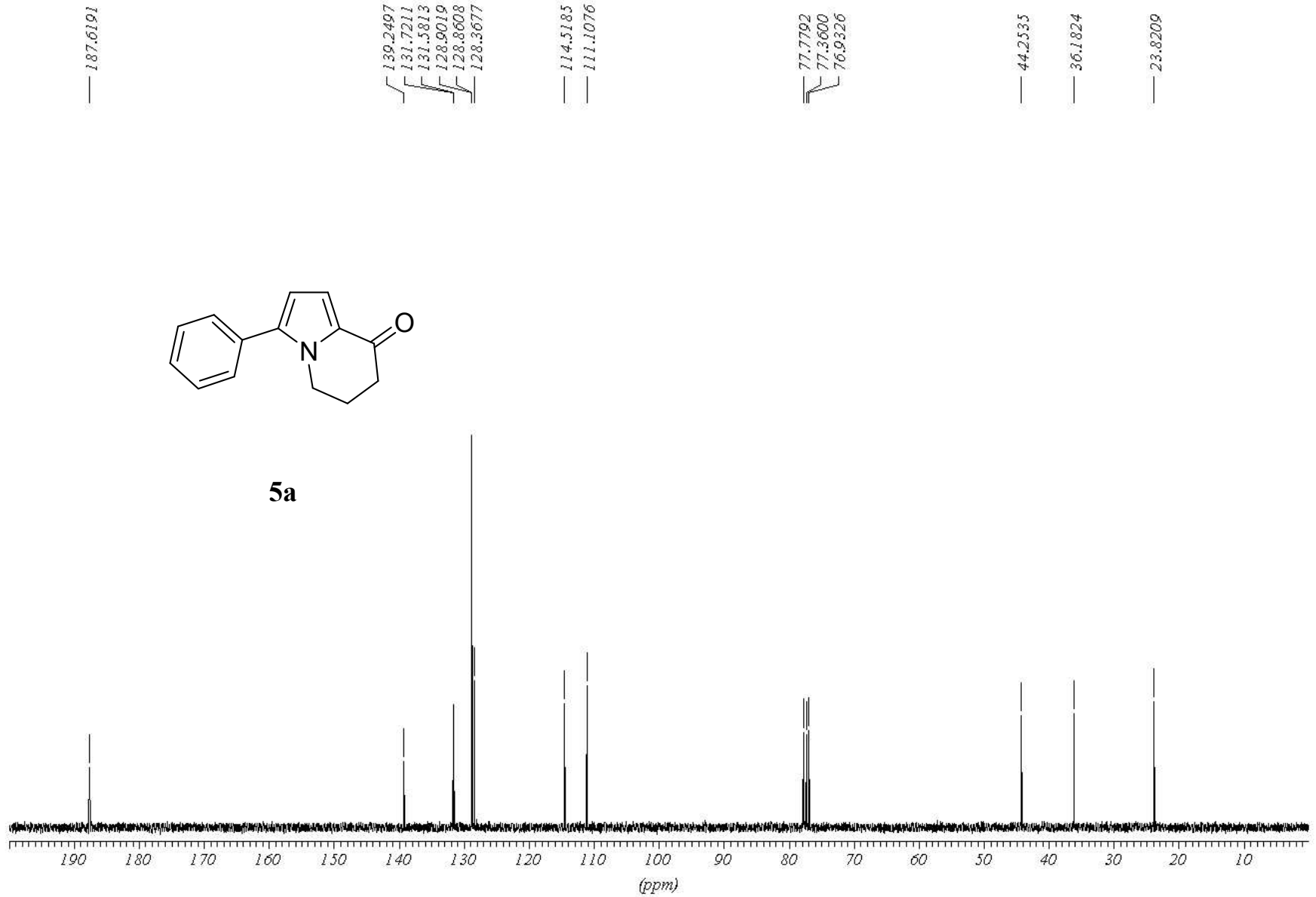
4

solvent: $CDCl_3$

frequency: 300 MHz



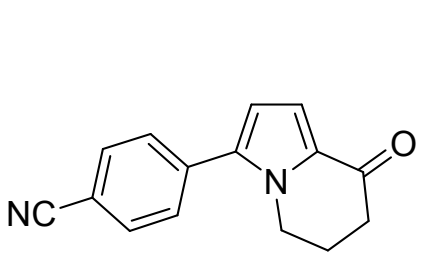
5a


187.6191
139.2497
131.7211
131.5813
128.9019
128.8608
128.3677
114.5185
111.1076
77.7792
77.3600
76.9326
44.2535
36.1824
23.8209
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

5a

solvent: $CDCl_3$

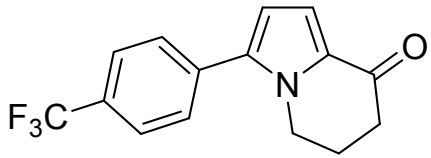
frequency: 300 MHz



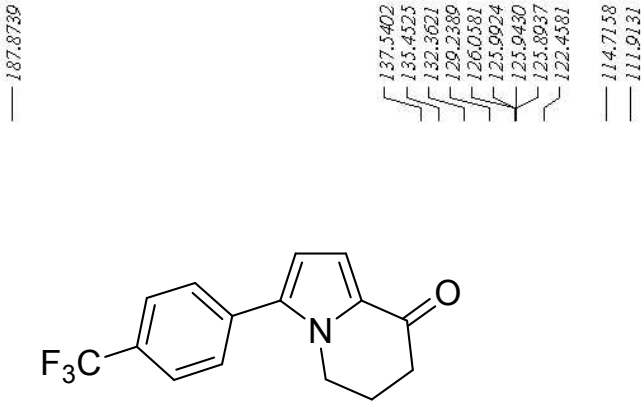
5b

solvent: $CDCl_3$

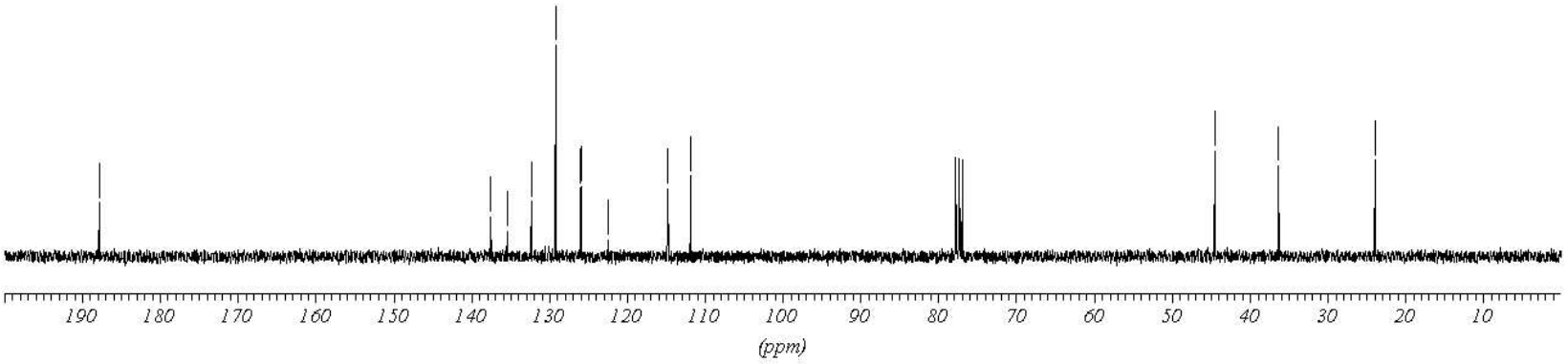
frequency: 300 MHz



5c

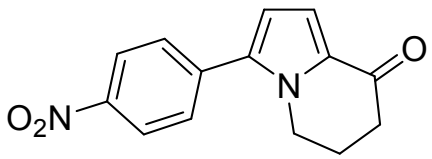

187.8739
137.5402
135.4525
132.3621
129.2389
126.0581
125.9924
125.9430
125.8937
122.4581
114.7158
111.9131
44.5412
36.2810
23.9195
O
N
F3C

5c


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

solvent: $CDCl_3$

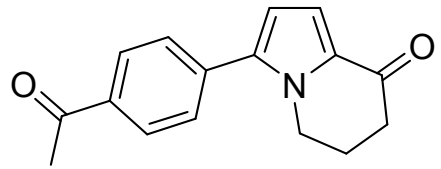
frequency: 300 MHz



5d

solvent: $CDCl_3$

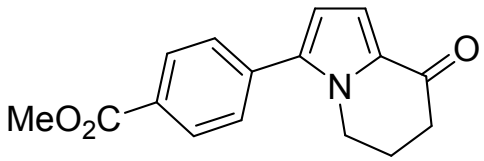
frequency: 300 MHz



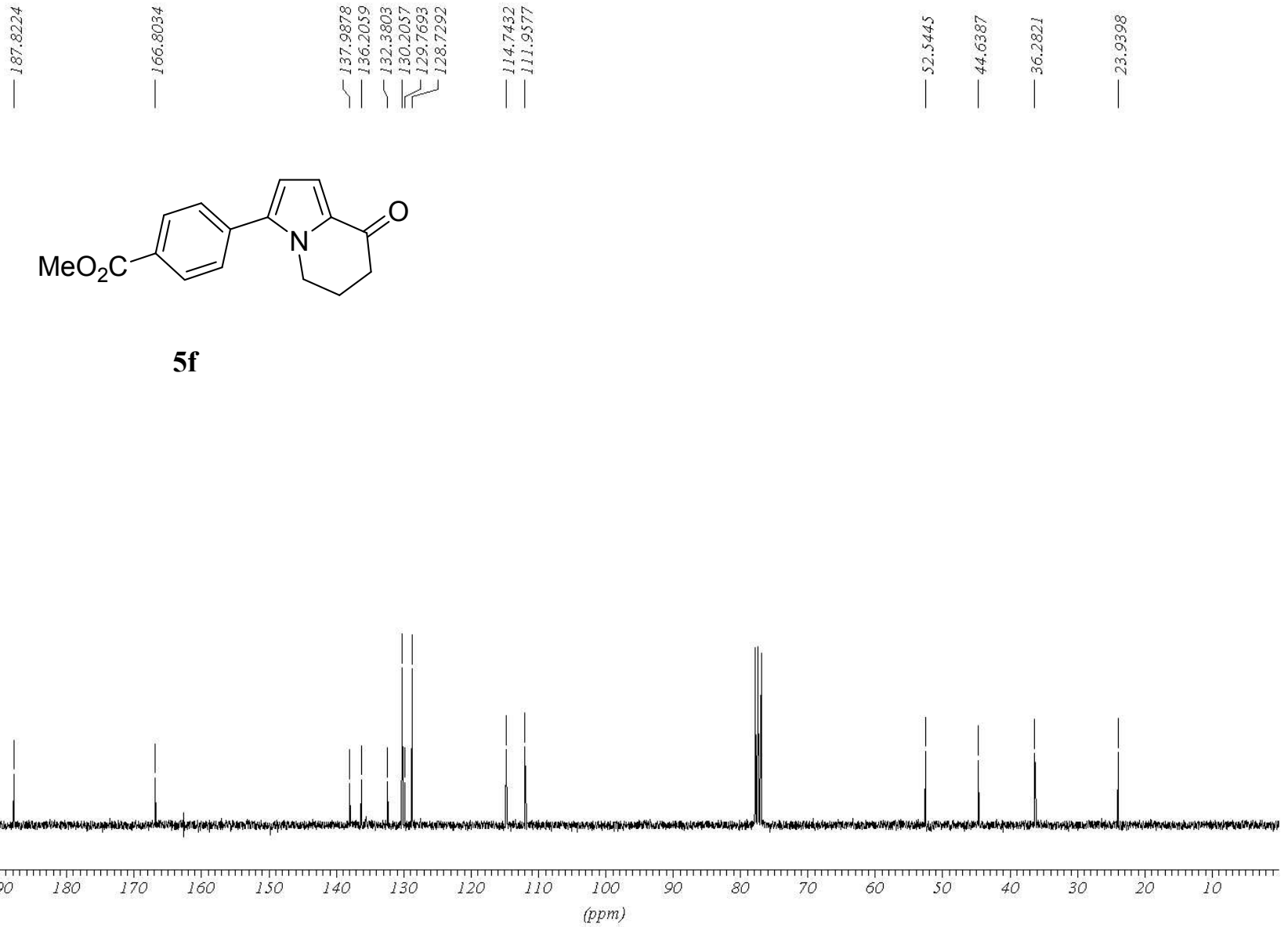
5e

solvent: $CDCl_3$

frequency: 300 MHz



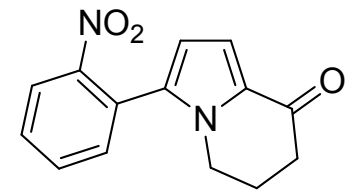
5f


187.8224
166.8034
137.9878
136.2059
132.3803
130.2057
129.7693
128.7292
114.7432
111.9577
52.5445
44.6387
36.2821
23.9398
MeO2C
N
O
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

5f

solvent: $CDCl_3$

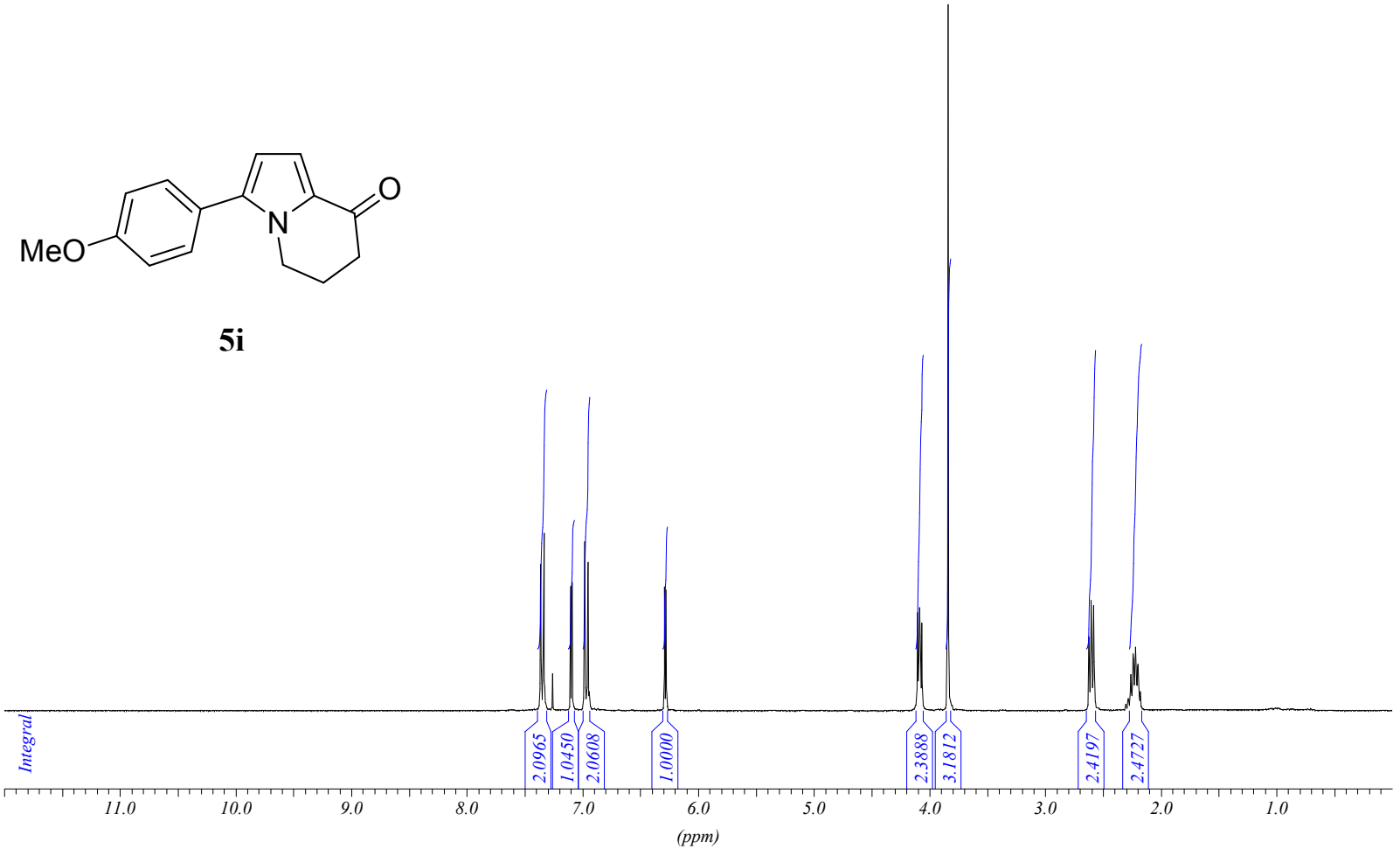
frequency: 300 MHz



5g

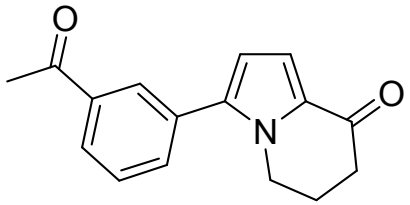
solvent: $CDCl_3$

frequency: 300 MHz



solvent: $CDCl_3$

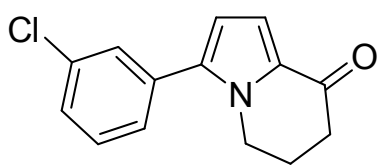
frequency: 300 MHz



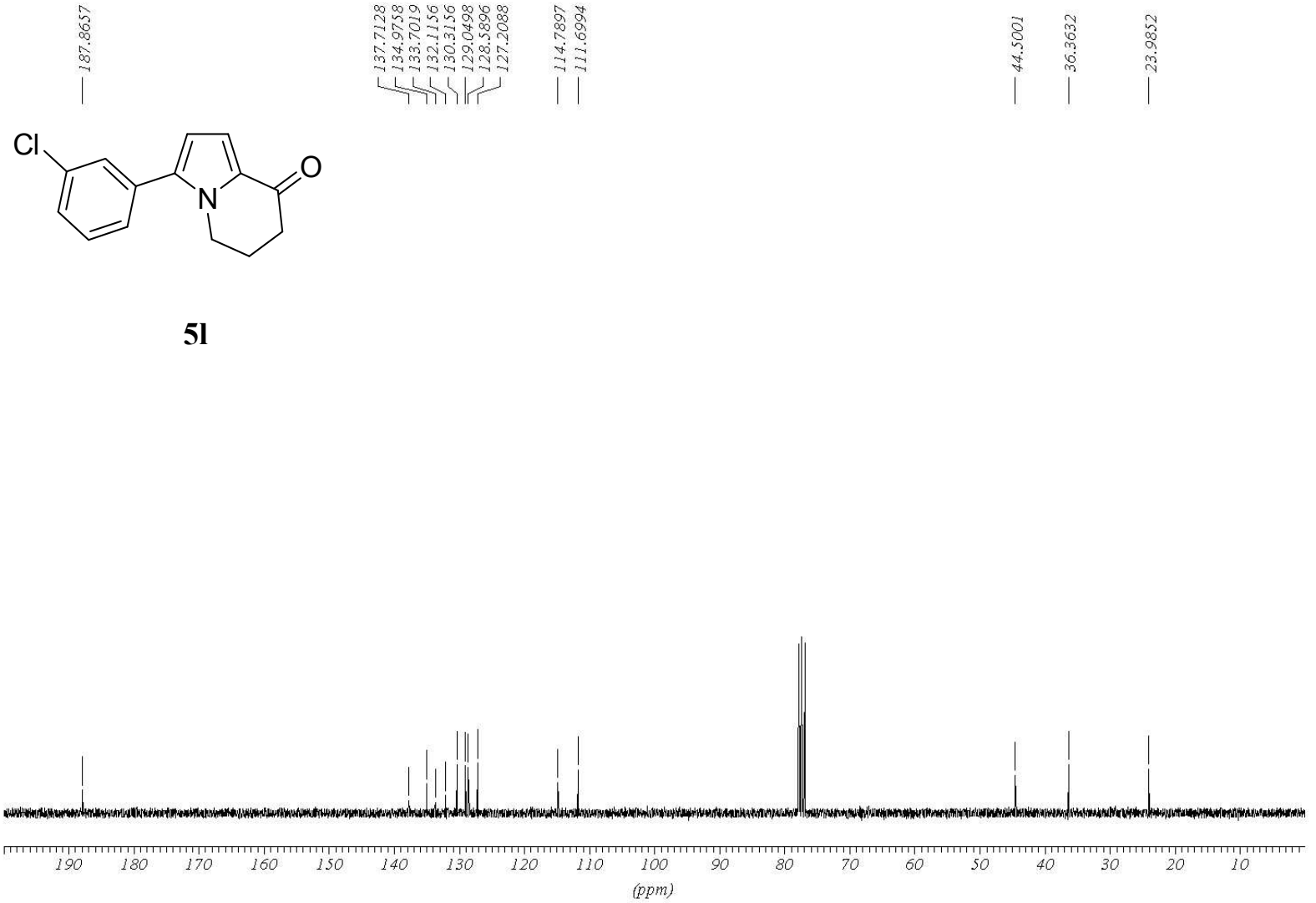
5k

solvent: $CDCl_3$

frequency: 300 MHz



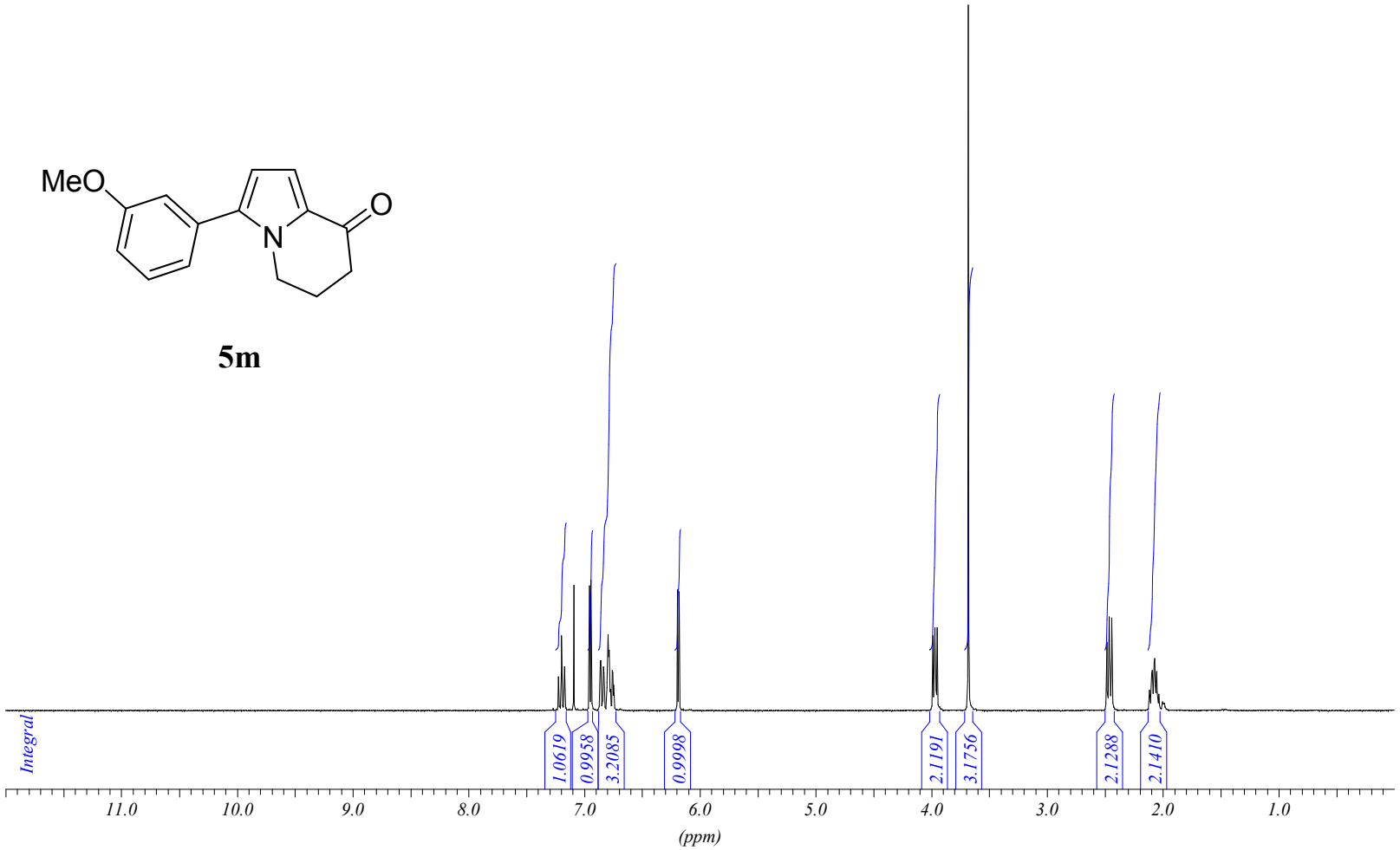
5l


187.8657
137.7128
134.9758
133.7019
132.1156
130.3156
129.0498
128.5896
127.2088
114.7897
111.6994
44.5001
36.3632
23.9852
Cl
N
O
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

5l

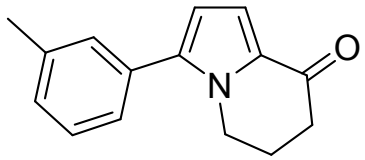
solvent: $CDCl_3$

frequency: 300 MHz

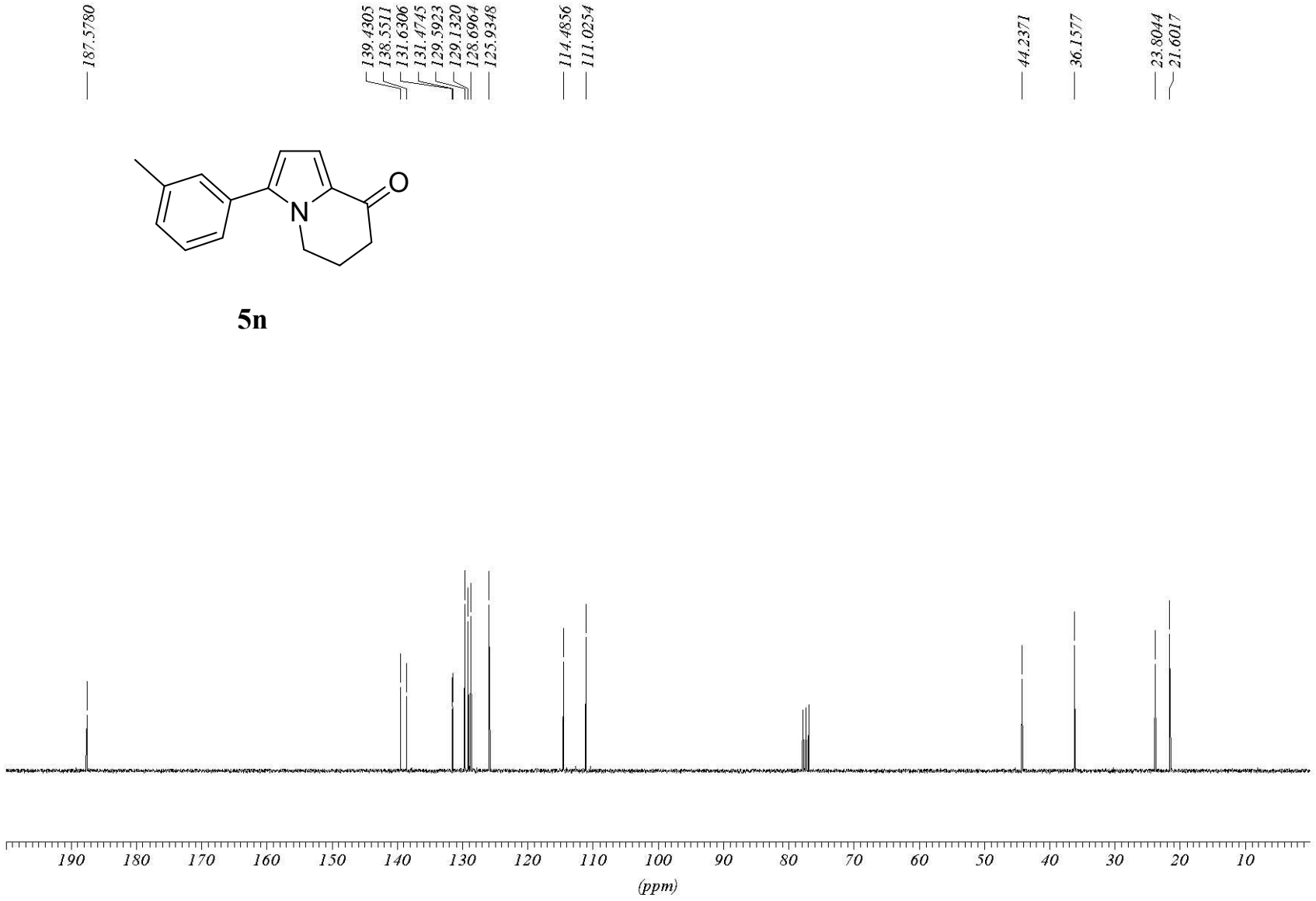


solvent: $CDCl_3$

frequency: 300 MHz



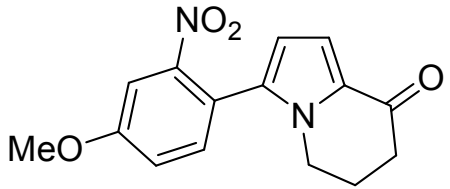
5n


187.5780
139.4305
138.5511
131.6306
131.4745
129.5923
129.1320
128.6964
125.9348
114.4856
111.0254
44.2371
36.1577
23.8044
21.6017
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

5n

solvent: $CDCl_3$

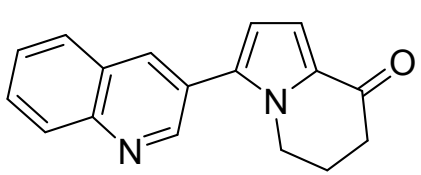
frequency: 300 MHz



5p

solvent: $CDCl_3$

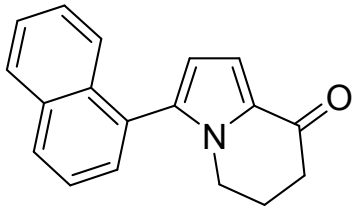
frequency: 300 MHz



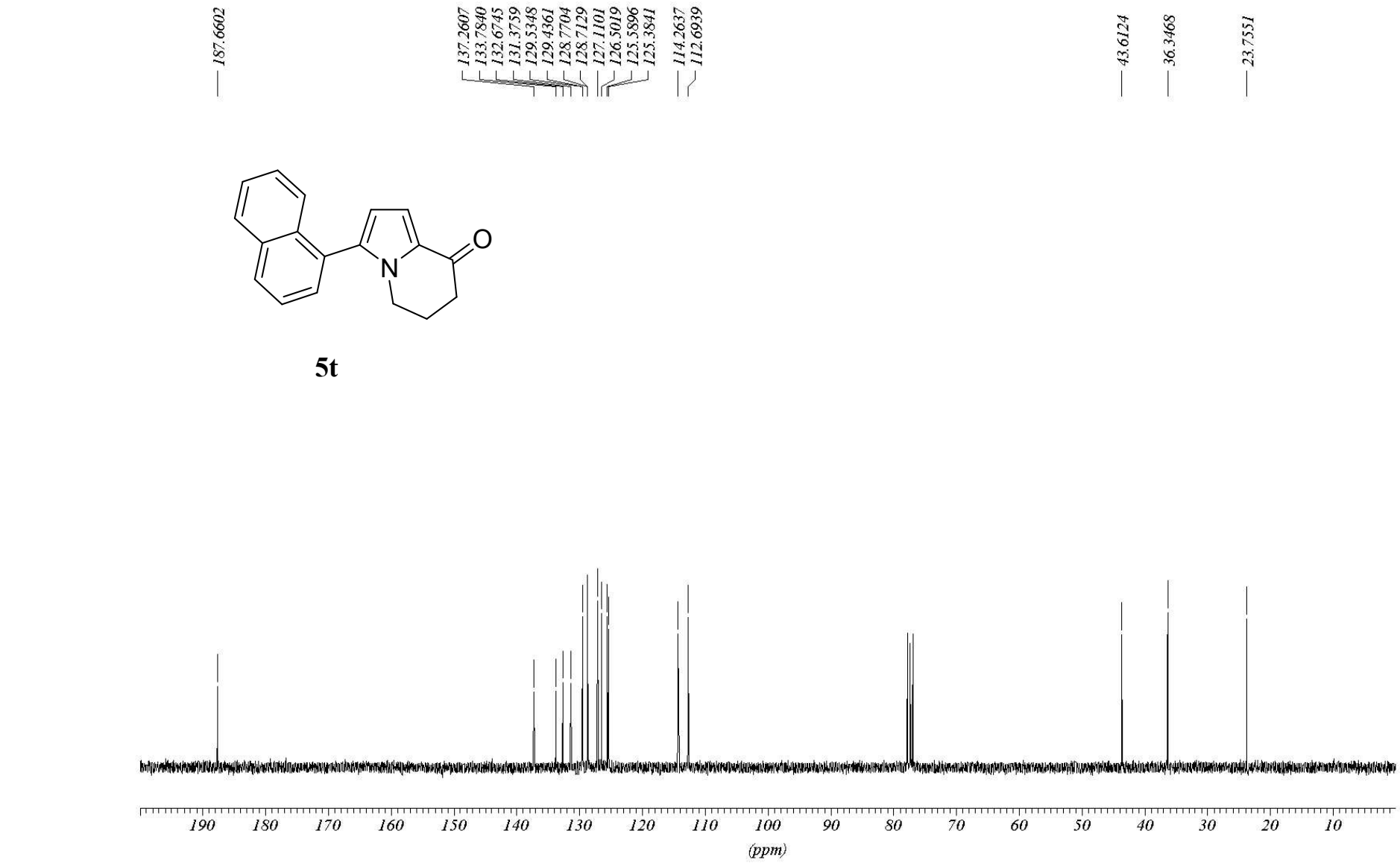
5r

solvent: $CDCl_3$

frequency: 300 MHz



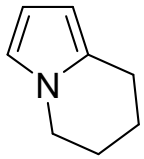
5t


187.6602
137.2607
133.7840
132.6745
131.3759
129.5348
129.4361
128.7704
128.7129
127.1101
126.5019
125.5896
125.3841
114.2637
112.6939
43.6124
36.3468
23.7551
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(ppm)

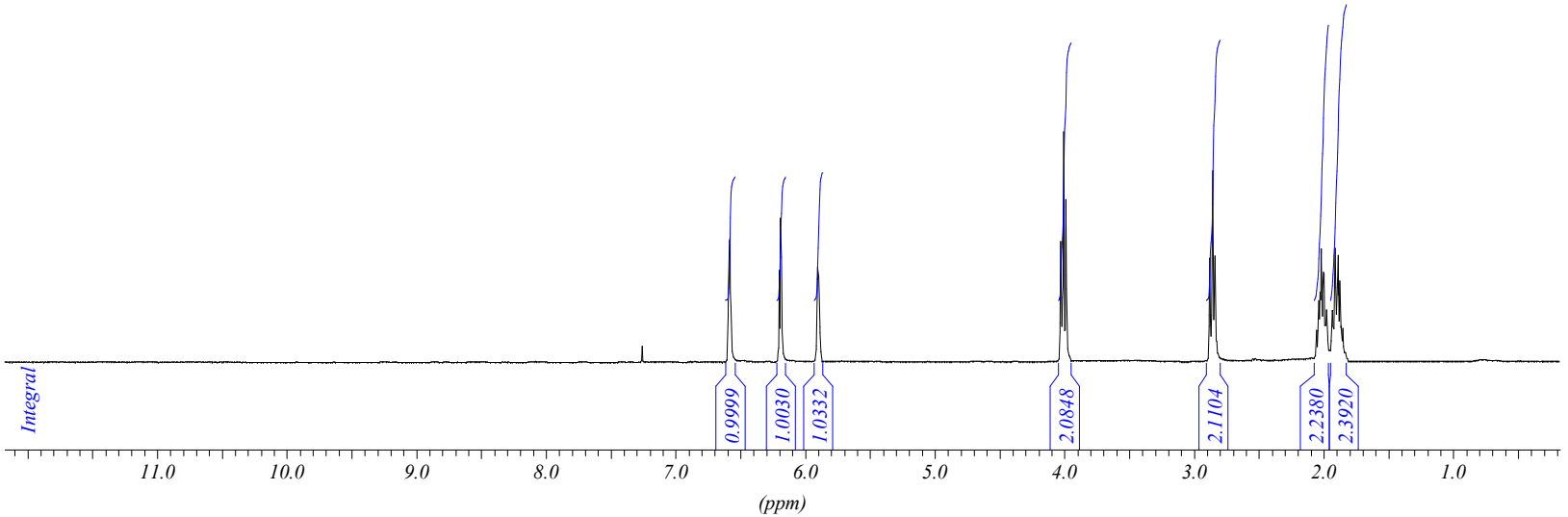
5t

solvent: $CDCl_3$

frequency: 300 MHz

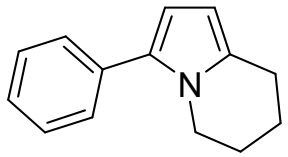


10



solvent: $CDCl_3$

frequency: 300 MHz



11