Cooperative Metal-Ligand Catalyzed Intramolecular Hydroamination and Hydroalkoxylation of Allenes using a Stable Iron Catalyst

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Contents

I- General Information

All reactions were carried out under an argon atmosphere using oven-dried glassware. The dry and degassed toluene was obtained from MBRAUN Solvent Purification System. All other chemicals were used as purchased without further purification. ^{1}H and ^{13}C spectra were recorded in $CDCl_3$ using Varian VNMR 600 or Inova 400 MHz spectrometer. The signals were referenced to residual chloroform (7.26 ppm, ^{1}H, 77.00 ppm, ^{13}C). Chemical shifts are reported in ppm, multiplicities are indicated by s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sext (sextet) and m (multiplet). IR spectra were recorded on a Perkin Elmer-100 spectrometer and are reported in terms of frequency of absorption (cm^{-1}). Mass spectra (EI-MS, 70 eV) were conducted on a Finnigan SSQ 7000 spectrometer. HRMS were recorded on a Thermo Scientific LTQ Orbitrap XL spectrometer. Analytical thin-layer chromatography (TLC) was performed using silica gel 60 pre-coated aluminium plates (Macherey-Nagel 0.20 mm thickness) with a fluorescent indicator UV254. Visualization was performed with standard phosphomolybdic acid stain (10g in 100 mL EtOH) or UV light. Column chromatography was performed using Macherey-Nagel Aluminium oxide 90 neutral (50–200 μm) and Macherey-Nagel Silica Gel (0.040–0.063 mm).

II- Catalyst optimization

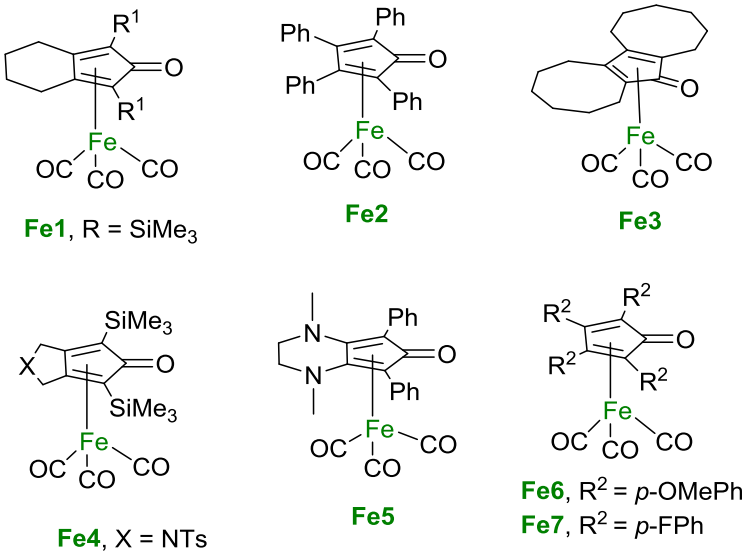
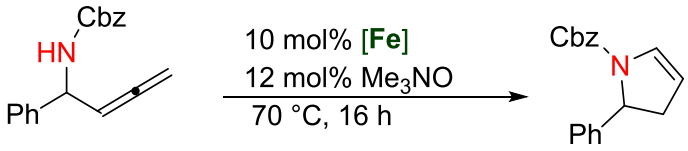


Table 1. Optimization of the reaction conditions.[a]



Entry	Cat.	Yield (%)[b]
1	**Fe1**	2
2	**Fe2**	98
3	**Fe3**	12
4	**Fe4**	12
5	**Fe5**	0
6	**Fe6**	43
7	**Fe7**	99

[a] The reactions were performed on 0.1 mmol scale with an iron complex and additive in 0.5 mL of toluene at 70 °C in a Schlenk tube under an inert atmosphere for 16h. [b] Yields were determined by the H^1 NMR analysis of the crude reaction mixture using mesitylen as an internal standard.

III - Experimental Procedures and Characterizations of the Products

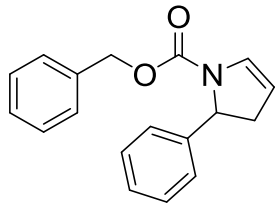
General methodology for transformation of α-allenic amines into 2,3-dihydropyrroles.

A 10 mL Schlenk tube equipped with a stir bar was charged with the allenic-amine **1** (0.5 mmol), **Fe1** (5 mol %), Me_3NO (6 mol %) and 1 mL of THF under argon. The reaction mixture was stirred at 70°C for 24 h. The reaction mixture was then purified by column chromatography on silica gel with hexane/ether as eluent to give the pure 2,3-dihydropyrroles **2a**-**k**.

General methodology for transformation of α-allenic alcohols into 2,3-dihydrofuranes.

A 10 mL Schlenk tube equipped with a stir bar was charged with the allenic alcohols **3** (1 mmol), **Fe1** (2.5 mol %), Me_3NO (4 mol %) and 1 mL of toluene under argon. The reaction mixture was stirred for 2 h at 70°C. The reaction mixture was then purified using a short chromatography column and neutral alumina with pentane/ether mixtures as eluent to give pure 2,3-dihydrofuranes **4a**-**r**.

Benzyl 2-phenyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2a)



Yield: (114 mg, 82% yield), colorless oil.

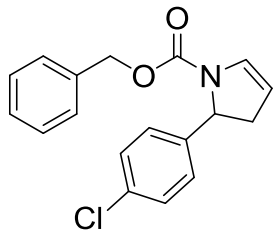
^{1}H NMR (600 MHz, Acetone-d6) (rotamers): 1H NMR (600 MHz, Acetone-d6) δ 7.39 – 7.18 (m, 9H), 6.92 (s, 1H), 6.79 – 6.78 (m, 1H), 5.23 – 5.22 (m, 1H), 5.15 – 4.93 (m, 3H), 3.36 – 3.25 (m, 1H), 2.50 – 2.42 (m, 1H).

^{13}C NMR (151 MHz, Acetone-d6) (rotamers): δ 153.2, 152.5, 145.7, 145.1, 137.9, 137.7, 130.9, 130.3, 129.5, 129.3, 129.0, 128.7, 128.4, 128.0, 126.3, 126.2, 107.4, 107.3, 67.3, 67.0, 61.0, 41.5, 40.2.

HRMS (ESI): calc. for $C_{18}H_{17}O_2NNa$ $[M + Na]^+$: 302.1152, found 302.1146

IR (ATR): *v* = 3035, 2938, 2328, 2096, 1881, 1701, 1614, 1498, 1410, 1326, 1207, 1124, 961, 903, 748, 701 cm^{-1}.

Benzyl 2-(4-chlorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2b)



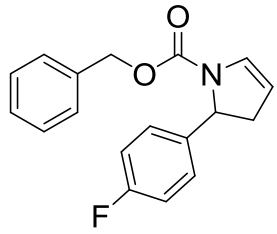
Yield: (123 mg, 78% yield), colorless oil.

^{1}H NMR (600 MHz, Acetone-d6) (rotamers) δ 7.31 – 7.20 (m, 8H), 6.94 (s, 1H), 6.78 – 6.76 (m, 1H), 5.24 – 4.91 (m, 4H), 3.36 – 3.29 (m, 1H), 2.50 – 2.42 (m, 1H).

^{13}C NMR (151 MHz, Acetone-d6) (rotamers) δ 144.6, 144.1, 137.9, 137.6, 133.1, 130.9, 130.3, 129.6, 129.4, 129.0, 128.8, 128.5, 128.2, 107.5, 107.3, 67.5, 67.2, 60.5, 41.3, 40.0.

HRMS (ESI): calc. for $C_{18}H_{16}O_2NClNa$ $[M + Na]^+$: 336.0762, found 336.0757

IR (ATR): *v* = 3035, 2942, 2860, 2327, 2092, 1995, 1895, 1703, 1619, 1491, 1409, 1324, 1208, 1125, 1090, 1013, 961, 904, 824, 750, 699 cm^{-1}.



Benzyl 2-(4-fluorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2c)

Yield: (128 mg, 86% yield), colorless oil.

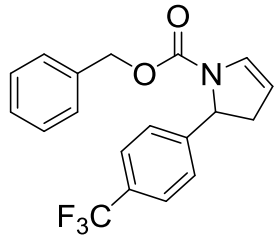
^{1}H NMR (600 MHz, $CDCl_3$) (rotamers) δ = 7.36-7.16 (m, 6H), 7.03-6.92 (m, 3H), 6.83-6.72 (m, 1H), 5.20-4.93 (m, 4H), 3.30 – 3.21 (m, 1H), 2.54 – 2.50 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) (rotamers) δ = 163.3, 160.9, 152.8, 140.2, 139.5, 136.5, 136.2, 132.0, 130.4, 130.2, 129.5, 128.6, 128.4, 128.2, 128.0, 127.7, 127.3, 115.6, 115.4, 106.9, 106.7, 67.3, 67.1, 60.0, 59.9, 40.8, 39.5.

^{19}F NMR (376 MHz, $CDCl_3$) (rotamers) δ = -115.45, -115.58.

HRMS (ESI): calc. for $C_{18}H_{16}O_2NFNa$ $[M + Na]^+$: 320.1057, found 320.1050

IR (ATR): *ν* = 3375, 3105, 2939, 2326, 2108, 1892, 1692, 1607, 1504, 1461, 1414, 1345, 1318, 1214, 1126, 1008, 974, 918, 892, 828, 739, 697 cm^{-1}.



Benzyl 2-(4-(trifluoromethyl)phenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2d)

Yield: (141 mg, 81% yield), colorless oil.

^{1}H NMR (600 MHz, C_6D_6) (rotamers) δ = 7.32-7.17 (m, 3H), 7.08-6.51 (m, 7H), 5.06 – 5.01 (m, 1H), 4.96 – 4.94 (m, 1H), 4.75 – 4.60 (m, 1H), 4.54 – 4.49 (m, 1H), 2.64 – 2.59 (m, 1H), 1.97 – 1.94 (m, 1H).

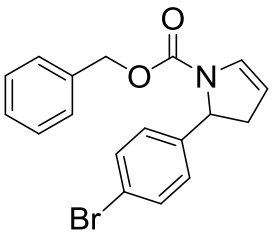
^{13}C NMR (151 MHz, C_6D_6) (rotamers) δ = 152.4, 152.0, 148.6, 148.0, 136.9, 136.5, 130.7, 129.7, 128.7, 128.6, 128.4, 128.4, 126.4, 126.0, 125.8 (q, *J* = 3.7 Hz), 124.1, 122.3, 106.2, 105.7, 67.5, 67.0, 60.3, 60.0, 40.4, 39.1.

^{19}F NMR (376 MHz, C_6D_6) δ = -62.09.

HRMS (ESI): calc. for $C_{19}H_{16}F_3O_2NNa$ $[M + Na]^+$: 370.1025, found 370.1017

IR (ATR): *ν* = 3316, 3103, 2922, 1959, 1696, 1616, 1541, 1466, 1413, 1320, 1260, 1208, 1158, 1122, 1062, 1014, 969, 927, 835, 800, 734, 693 cm^{-1}.

Benzyl 2-(4-bromophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2e)



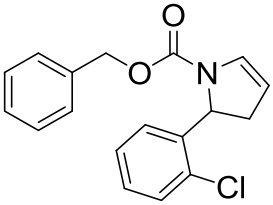
Yield: (107 mg, 60% yield), colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) (rotamers) δ = 7.47-7.34 (m, 4H), 7.25-7.19 (m, 3H), 7.09 – 7.08 (m, 1H), 6.90 –6.89 (m, 1H), 6.86-6.73 (m, 1H), 5.20-5.16 (m, 1H), 5.11-4.92 (m, 3H), 3.30 –3.22 (m, 1H), 2.54 –2.48 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) (rotamers) δ = 152.8, 152.2, 143.3, 142.7, 136.4, 136.1, 131.9, 131.7, 130.3, 129.6, 128.7, 128.4, 128.3, 128.3, 128.0, 127.7, 127.6, 127.5, 121.3, 121.1, 107.0, 106.7, 67.4, 67.1, 60.1, 60.0, 40.7, 39.5.

IR (ATR): ν = 3033, 2938, 2858, 2330, 2183, 2115, 1993, 1803, 1703, 1621, 1488, 1448, 1409, 1322, 1209, 1126, 1009, 959, 913, 820, 755, 699 cm^{-1}.

Benzyl 2-(2-chlorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2f)



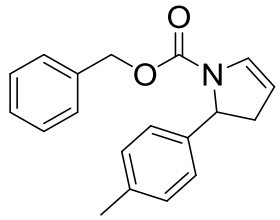
Yield: (116 mg, 74% yield), colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) (rotamers) δ = 7.38 (m, 3H), 7.19 (m, 5H), 6.93-6.76 (m, 2H), 5.62 – 5.60 (m, 1H), 5.21-4.97 (m, 3H), 3.39 – 3.32 (m, 1H), 2.45-2.37 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) (rotamers) δ = 152.8, 152.1, 141.4, 140.6, 136.5, 136.2, 131.9, 131.6, 130.1, 129.9, 129.6, 129.4, 129.1, 128.6, 128.3, 127.8, 127.4, 127.2, 126.8, 126.7, 125.9, 125.6, 107.2, 106.9, 67.4, 66.9, 57.9, 57.4, 39.6, 38.5.

HRMS (ESI): calc. for $C_{18}H_{16}O_2N^{35}Cl$ $[M + H]^+$: 313.0864, found 313.0857

Benzyl 2-(p-tolyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2g)



Yield: (101 mg, 69% yield), colorless oil.

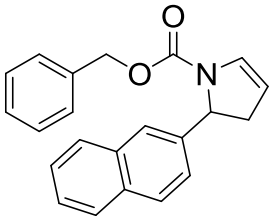
^{1}H NMR (600 MHz, Acetone-d6) (rotamers) 1H NMR (600 MHz, Acetone-d6) δ 7.38 – 7.11 (m, 8H), 6.92 (s, 1H), 6.78 – 6.76 (m, 1H), 5.20 – 4.92 (m, 4H), 3.33 – 3.23 (m, 1H), 2.49 – 2.40 (m, 1H), 2.32 – 2.29 (m, 3H).

^{13}C NMR (151 MHz, Acetone-d6) (rotamers) δ 153.2, 152.4, 142.8, 142.2, 137.7, 137.4, 130.9, 130.3, 130.0, 129.3, 128.9, 128.8, 128.7, 128.3, 128.0, 126.2, 107.3, 67.3, 67.0, 60.9, 41.5, 40.2, 21.1.

HRMS (ESI): calc. for $C_{19}H_{19}O_2NNa$ $[M + Na]^+$: 316.1308, found 316.1308

IR (ATR): ν = 3028, 2938, 1702, 1618, 1512, 1410, 1325, 1208, 1123, 962, 907, 808, 744, 700 cm^{-1}.

Benzyl 2-(naphthalen-2-yl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2h)



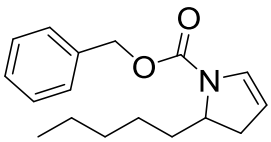
Yield: (133 mg, 81% yield)**,** colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) (rotamers) δ = 7.86-7.66 (m, 4H), 7.52-7.37 (m, 5H), 7.15-6.84 (m, 3H), 6.79 – 6.77 (m, 1H), 5.43-4.95 (m, 4H), 3.39 – 3.31 (m, 1H), 2.69 – 2.62 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) (rotamers) δ = 153.0, 152.2, 141.5, 140.8, 136.5, 136.0, 133.4, 133.0, 132.9, 132.7, 132.6, 130.4, 129.7, 128.9, 128.6, 128.4, 128.2, 128.1, 128.0, 127.7, 127.5, 127.4, 126.2, 126.1, 125.8, 124.4, 124.3, 123.8, 123.7, 107.1, 106.8, 67.2, 67.0, 60.8, 60.6, 40.7, 39.5.

HRMS (ESI): calc. for $C_{22}H_{19}O_2NNa$ $[M + Na]^+$: 352.1308, found 352.1309

Benzyl 2-pentyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2i)



Yield: (78 mg, 57% yield), colorless oil.

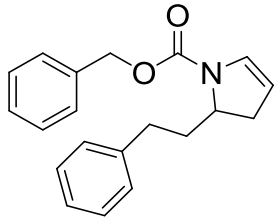
^{1}H NMR (600 MHz, Acetone-d6) (rotamers) δ 7.42 – 7.31 (m, 5H), 6.72 – 6.45 (m, 1H), 5.23 – 4.98 (m, 4H), 4.17 – 4.14 (m, 1H), 2.34 – 2.28 (m, 1H), 1.81 – 1.65 (m, 1H), 1.55 – 1.52 (m, 1H), 1.30 – 1.25 (m, 6H), 0.89 – 0.84 (m, 3H).

^{13}C NMR (151 MHz, Acetone-d6) (rotamers) δ 153.3, 152.5, 138.1, 138.0, 130.3, 129.6, 129.3, 128.8, 128.7, 108.0, 70.1, 67.1, 58.3, 57.8, 36.4, 35.3, 34.5, 32.5, 24.9, 24.7, 23.3, 14.4.

HRMS (ESI): calc. for $C_{17}H_{23}O_2NNa$ $[M + Na]^+$: 296.1621, found 296.1618

IR (ATR): *v* = 2929, 2860, 2323, 2100, 1897, 1701, 1618, 1412, 1329, 1211, 1123, 976, 894, 746, 701 cm^{-1}.

Benzyl 2-phenethyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2j)



Yield: (125 mg, 82% yield)**,** colorless oil.

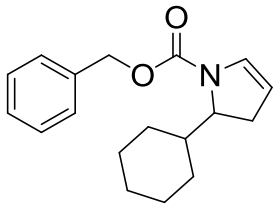
^{1}H NMR (600 MHz, Acetone-d6) (rotamers) δ 7.41 – 7.32 (m, 5H), 7.28 – 7.21 (m, 3H), 7.17 – 7.11 (m, 2H), 6.57 – 6.56 (m, 1H), 5.23 – 4.03 (m, 4H), 4.22 (s, 1H), 2.63 – 2.60 (m, 2H), 2.50 – 2.42 (m, 1H), 2.15 – 2.12 (m, 1H), 1.87 – 1.85 (m, 1H).

^{13}C NMR (151 MHz, Acetone-d6) (rotamers) δ 130.3, 129.7, 129.3, 129.2, 129.2, 129.0, 128.7, 126.6, 108.1, 67.3, 67.2, 58.0, 57.4, 37.1, 36.4, 36.2, 35.2, 31.4, 31.3.

HRMS (ESI): calc. for $C_{20}H_{21}O_2NNa$ $[M + Na]^+$: 330.1465, found 330.1460

IR (ATR): *v* = 3062, 3028, 2930, 2858, 2329, 2114, 1994, 1806, 1700, 1620, 1495, 1448, 1411, 1329, 1213, 1124, 1092, 1031, 999, 952, 909, 815, 750, 698 cm^{-1}

Benzyl 2-cyclohexyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2k)



Yield: (96 mg, 67% yield), colorless oil.

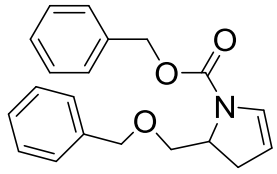
^{1}H NMR (600 MHz, C_6D_6) (rotamers) δ = 7.26-7.21 (m, 2H), 7.11-7.09 (m, 2H), 7.06-7.03 (m, 1H), 6.86-6.52 (m, 1H), 5.22-5.12 (m, 1H), 5.08-5.06 (m, 1H), 4.65-4.60 (m, 1H), 4.16-3.91 (m, 1H), 2.29-2.24 (m, 1H), 2.08-2.03 (m, 1H), 1.62-1.43 (m, 5H), 1.15-0.76 (m, 6H).

^{13}C NMR (151 MHz, C_6D_6) (rotamers) δ = 156.0, 152.5, 137.6, 137.4, 131.1, 130.0, 128.7, 128.6, 128.4, 107.7, 77.5, 67.1, 66.8, 62.2, 61.6, 54.5, 42.9, 41.4, 40.4, 31.9, 30.9, 29.5, 28.8, 27.0, 26.6, 26.4, 26.3, 25.8, 25.5.

HRMS (ESI): calc. for $C_{18}H_{23}O_2NNa$ $[M + Na]^+$: 308.1621, found 308.1621

IR (ATR): ν = 2919, 2339, 2094, 1700, 1409, 1332, 1114, 951, 722 cm^{-1}.

Benzyl 2-((benzyloxy)methyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2l)



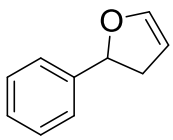
Yield: (97 mg, 60% yield)**,** colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) (rotamers) δ = 7.39-7.31 (m, 10H), 6.64-6.55 (m, 1H), 5.20-5.02 (m, 3H), 4.59-4.38 (m, 3H), 3.77-3.47 (m, 2H), 2.86-2.83 (m, 1H), 2.68-2.65 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) (rotamers) δ = 152.6, 152.2, 138.5, 138.3, 136.6, 136.5, 129.6, 128.9, 128.7, 128.6, 128.5, 128.4, 128.3, 128.1, 128.0, 127.6, 127.5, 108.0, 73.3, 70.5, 70.0, 67.1, 56.7, 56.3, 34.0, 32.9, 26.3, 25.3.

HRMS (ESI): calc. for $C_{20}H_{21}O_3N$ $[M + H]^+$: 323.1516, found 323.1517

2-Phenyl-2,3-dihydrofuran (4a)



Yield: (131 mg, 90%), colorless oil.

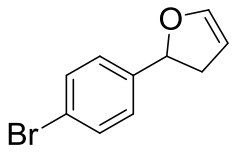
^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.40-7.36 (m, 4H), 7.32-7.31 (m, 1H), 6.48 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.4 Hz, 1H), 5.54 (dd, apparent m, 1H), 4.99-4.97 (m, 1H), 3.12 – 3.08 (m, 1H), 2.66 – 2.61 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 145.3, 143.1, 128.5, 127.6, 125.6, 99.1, 82.4, 37.9.

MS: (EI) m/z: 146([M^+], 10), 117 (34), 115 (65), 105 (34), 91 (47), 78 (24), 77 (77), 65 (23), 63 (44), 51 (100), 50 (61).

IR (ATR): ν = 3033, 2924, 2860, 2331, 2101, 1615, 1452, 1137, 1048, 930, 749, 700 cm^{-1}.

2-(4-Bromophenyl)-2,3-dihydrofuran (4b)



Yield: (203 mg, 91% yield), colorless oil.

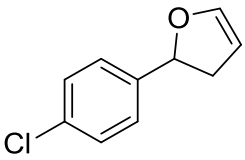
^{1}HNMR (400 MHz, $CDCl_3$) δ = 7.48 (d, J = 8.5 Hz, 2H), 7.23 (d, J = 8.4 Hz, 2H), 6.43 (ddd, apparent q $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 5.47 (dd, J_1 = 10.8, J_2 = 8.1 Hz, 1H), 4.95 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.08 (dddd, apparent ddt, J_1 = 15.4, J_2 = 10.8, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.55 (dddd, apparent ddt, J_1 = 15.2, J_2 = 8.2, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.2, 142.1, 131.6, 127.3, 121.4, 99.0, 81.6, 37.8.

MS: (EI) m/z: 226 ([M+H^+], 53), 197 (23), 195 (25), 145 (32), 117 (26), 116 (100), 115 (56), 89 (13).

IR (ATR): ν = 3099, 2925, 2858, 1619, 1487, 1135, 1049, 932, 818, 706 cm^{-1}.

2-(4-Chlorophenyl)-2,3-dihydrofuran (4c)



Yield: (155 mg, 86% yield), colorless oil.

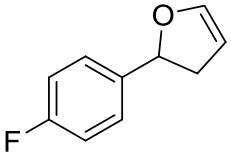
^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.34 – 7.28 (m, 4H), 6.44 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.4 Hz, 1H), 5.49 (dd, J_1 =10.8, J_2 = 8.2 Hz, 1H), 4.96 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.11-3.05 (m, 1H), 2.58-2.53 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 145.3, 141.6, 133.3, 128.7, 127.0, 99.0, 81.6, 37.9

MS: (EI) m/z: 180 ([M^+], 83), 179 (14), 153 (24), 151 (72), 145 (38), 117 (32), 116 (57), 115 (100), 89 (21).

IR (ATR): ν = 2925, 2860, 2325, 2096, 1909, 1734, 1615, 1489, 1342, 1138, 1047, 931, 824, 707 cm^{-1}.

2-(4-Fluorophenyl)-2,3-dihydrofuran (4d)



Yield: (149 mg, 91% yield), colorless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.34 – 7.30 (m, 2H), 7.05 – 6.99 (m, 2H), 6.42 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 5.47 (dd, J_1 = 10.7, J_2 = 8.3 Hz, 1H), 4.94 (q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.05 (dddd, apparent ddt, J_1 = 15.3, J_2 = 10.7, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.56 (dddd, apparent ddt, J_1 = 15.2, J_2 = 8.3, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H).

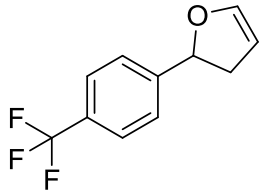
^{13}C NMR (101 MHz, $CDCl_3$) δ = 163.5, 145.2, 138.8 (d, J = 2.6 Hz), 127.3 (d, J = 8.1 Hz), 115.3 (d, J = 21.6 Hz), 99.0, 81.7, 37.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ = -115.0.

MS: (EI) m/z: 165 (23), 164([M^+], 100), 163 (30), 135 (91), 115 (25), 109 (28).

IR (ATR): ν = 2927, 2860, 2111, 1615, 1509, 1339, 1224, 1136, 1049, 935, 834, 705 cm^{-1}.

2-(4-(Trifluoromethyl)phenyl)-2,3-dihydrofuran (4e)



Yield: (161 mg, 75% yield), colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.62 (d, *J* = 8.2 Hz, 2H), 7.47 (d, *J* = 8.1 Hz, 2H), 6.47 (ddd, apparent q, , $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 5.57 (dd, J_1 = 10.9, $J_2 \approx$ 8.0 Hz, 1H), 4.97 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.14 (dddd, apparent ddt, J_1 = 15.5, J_2 = 10.9, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.57 (dddd, apparent ddt, J_1 = 15.2, J_2 = 8.0, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H).

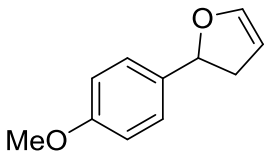
^{13}C NMR (151 MHz, $CDCl_3$) δ = 147.1, 145.3, 129.7 (q, *J* = 31 Hz), 125.7, 125.5 (q, *J* = 3.8 Hz), 123.5 (q, *J* = 272 Hz), 99.0, 81.4, 37.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ = -62.6.

MS: (EI) m/z: 214 ([M^+], 100), 195 (60), 185 (83). 165 (86), 145 (88), 127 (69), 115 (44), 83 (16).

IR (ATR): *v* = 2929, 2864, 1732, 1617, 1417, 1321, 1122, 1054, 934, 838, 709 cm^{-1}.

2-(4-Methoxyphenyl)-2,3-dihydrofuran (4f)



Yield: (162 mg, 92% yield), colorless oil.

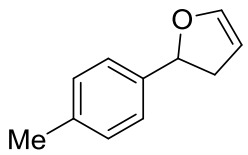
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.28 (d, *J* = 8.7 Hz, 2H), 6.88 (d, *J* = 8.6 Hz, 2H), 6.41 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.4 Hz, 1H), 5.45 (dd, J_1 = 10.6, J_2= 8.5 Hz, 1H), 4.94 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 3.79 (s, 3H), 3.02 (dddd, apparent ddt, J_1 = 15.2, J_2 = 10.6, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.60 (dddd, *J* = 15.1, 8.5, 2.6, 1.9 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 159.2, 145.2, 135.0, 127.0, 113.9, 99.0, 82.2, 55.3, 37.6.

MS: (EI) m/z: 177(20), 176([M^+], 100), 159 (16), 147 (75), 115 (13), 91 (15).

IR (ATR): *v* = 3020, 2924, 2861, 1617, 1514, 1451, 1136, 1049, 930, 810, 705 cm^{-1}.

2-(*p*-Tolyl)-2,3-dihydrofuran (4g)



Yield: (131 mg, 82% yield), colorless oil.

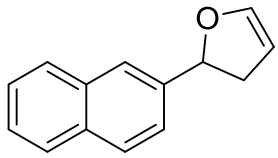
^{1}H NMR (300 MHz, $CDCl_3$) δ = 7.28 (d, *J* = 8.1 Hz, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 6.45 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.4 Hz, 1H), 5.50 (dd, J_1 = 10.7, J_2 = 8.4 Hz, 1H), 4.97 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.07 (dddd, apparent ddt, J_1 = 15.3, J_2 = 10.7, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.62 (dddd, apparent ddt, J_1 = 15.2, J_2 = 8.4, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.36 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ = 145.3, 140.0, 137.3, 129.2, 125.6, 99.0, 82.3, 37.8, 21.2.

MS: (EI) m/z: 161 (26), 160([M^+], 100), 159 (38), 145 (39), 131 (100), 115 (28), 91 (31).

IR (ATR): *v* = 2925, 2850, 2326, 2098, 1612, 1510, 1456, 1297, 1245, 1136, 1041, 930, 825, 705 cm^{-1}.

2-(Naphthalen-2-yl)-2,3-dihydrofuran (4h)



Yield: (186 mg, 95% yield), white solid.

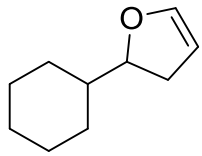
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.85 – 7.78 (m, 4H), 7.49 – 7.43 (m, 3H, 6.50 (m, 1H), 5.68 (dd, J_1 = 10.8, J_2 = 8.3 Hz, 1H), 4.99 (m, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 3.14 (dddd, apparent ddt, J_1 = 15.4, J_2 = 10.8, $J_3 \approx J_4 \approx$ 2.4, 1H), 2.68 (dddd, J_1 = 15.1, J_2 = 8.3, $J_3 \approx J_4 \approx$ 2.8 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.4, 140.2, 133.2, 132.9, 128.5, 128.0, 127.6, 126.2, 125.8, 124.3, 123.7, 99.1, 82.5, 37.9.

MS: (EI) m/z: 197 (22), 196 ([M^+], 100), 195 (26), 167 (88), 165 (37), 152 (17).

IR (ATR): *v* = 3058, 2924, 2856, 2093, 1619, 1599, 1506, 1266, 1133, 1047, 932, 818, 742, 707 cm^{-1}.

2-Cyclohexyl-2,3-dihydrofuran (4i)



Yield: (106 mg, 70% yield), colorless oil.

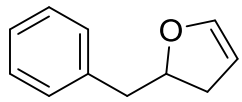
^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.28 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.4 Hz, 1H), 4.84 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 4.24 (ddd, J_1 = 10.3, J_2 = 9.1, J_3 = 6.9 Hz, 1H), 2.56 (dddd, apparent ddt, J_1 = 15.1, J_2 = 10.2, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.35 (dddd, apparent ddt, J_1= 15.2, J_2 = 9.1, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 1.89-1.85 (m, 1H), 1.77-1.73 (m, 2H), 1.69-1.62 (m, 2H), 1.53 – 1.46 (m, 1H), 1.28 – 1.13 (m, 3H), 1.05 – 0.97 (m, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 145.2, 99.1, 85.9, 43.0, 32.2, 28.6, 28.3, 26.5, 26.0, 25.8.

MS: (EI) m/z: 205 (16), 152([M^+], 52), 95 (31), 83 (95), 81 (54), 69 (39), 60 (34), 58 (60), 49 (48).

IR (ATR): ν = 2921, 2854, 2328, 2104, 1617, 1449, 1266, 1139, 1055, 944, 703 cm^{-1}.

2-Benzyl-2,3-dihydrofuran (4j)



Yield: (120 mg, 75% yield), colorless oil.

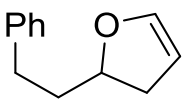
^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.32-7.30 (m, 3H), 7.26 – 7.22 (m, 2H), 6.29 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 4.87 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 4.82 – 4.77 (m, 1H), 3.05 (dd, J_1 = 13.8, J_2 = 7.1 Hz, 1H), 2.84 (dd, J_1 = 13.8, J_2 = 6.3 Hz, 1H), 2.66 (dddd, apparent ddt, J_1 = 14.9, J_2 = 10.0, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H), 2.37 (dddd, apparent ddt, J_1 = 15.1, J_2 = 7.5, $J_3 \approx J_4 \approx$ 2.4 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 144.9, 138.0, 129.3, 128.4, 126.4, 99.0, 81.8, 42.0, 34.2.

MS: (EI) m/z: 161 (26), 160 ([M^+], 100), 91 (42), 69 (46).

IR (ATR): ν = 3029, 2925, 2856, 1617, 1452, 1138, 1052, 952, 698 cm^{-1}.

2-Phenethyl-2,3-dihydrofuran (4k)



Yield: (138 mg, 79% yield), colorless oil.

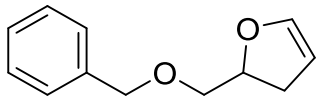
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.30 – 7.16 (m, 5H), 6.29 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 4.86 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 4.57-4.49 (m, 1H), 2.81-2.66 (m, 3H), 2.31-2.24 (m, 1H), 2.07-1.98 (m, 1H), 1.88-1.80 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.0, 141.8, 128.4(3), 128.3(5), 125.8, 98.9, 80.6, 37.9, 34.7, 31.8.

MS: (EI) m/z: 175 (21), 174([M^+], 77), 157 (11), 131 (18), 130 (100), 117 (43), 91 (74).

IR (ATR): ν = 3027, 2927, 2856, 2663, 2326, 2104, 1887, 1615, 1451, 1268, 1139, 1052, 906, 701 cm^{-1}.

2-((Benzyloxy)methyl)-2,3-dihydrofuran (4l)



Yield: (141 mg, 74% yield), colorless oil.

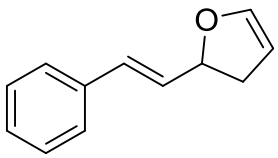
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.21 (m, 5H), 6.28 (q, J = 2.5 Hz, 1H), 4.86 (q, J = 2.6 Hz, 1H), 4.77 – 4.70 (m, 1H), 4.62 (d, J = 12.2 Hz, 1H), 4.56 (d, J = 12.2 Hz, 1H), 3.58 (dd, J = 10.3, 6.8 Hz, 1H), 3.49 (dd, J = 10.3, 4.3 Hz, 1H), 2.70-2.62 (m, 1H), 2.39-2.32 (m, 1H)

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.1, 138.1, 128.4, 127.7, 127.6, 99.0, 79.8, 73.4, 72.3, 31.6.

MS: (EI) m/z: 191 ([M+H^+], 28), 91 (100).

IR (ATR): ν = 3435, 3030, 2863, 2324, 2095, 1904, 1615, 1453, 1360, 1199, 1103, 973, 737 cm^{-1}.

(*E*)-2-styryl-2,3-dihydrofuran (4m)



Yield: (107 mg, 62% yield), colorless oil.

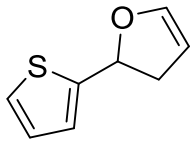
^{1}H NMR (600 MHz, $CDCl_3$) δ =7.41-7.39 (m, 2H), 7.33-7.31 (m, 2H), 7.26-7.24 (m, 1H), 6.61 (d, *J* = 15.8 Hz, 1H), 6.36 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx 2.4$ Hz, 1H), 6.31 (dd, J_1 = 15.8, J_2 = 7.1 Hz, 1H), 5.16 – 5.12 (m, 1H), 4.94 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx 2.6$ Hz, 1H), 2.90 – 2.85 (m, 1H), 2.52 – 2.47 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 145.1, 136.5, 131.1, 129.1, 128.5, 127.8, 126.6, 99.2, 81.7, 35.6.

MS: (EI) m/z: 172 ([M^+], 53), 144 (56), 143 (76), 129 (35), 128 (100), 116 (19), 115 (68), 104 (21).

IR (ATR): *v* = 3028, 2922, 2857, 2331, 2097, 1887, 1614, 1449, 1136, 1046, 963, 743, 698 cm^{-1}.

2-(Thiophen-2-yl)-2,3-dihydrofuran (4n)



Yield: (94 mg, 62% yield), colorless oil.

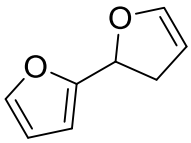
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.26-7.24 (m, 1H), 7.04-7.02 (m,1H), 6.97-6.95 (m, 1H), 6.37 (q, *J* = 2.5 Hz, 1H), 5.72 (dd, *J* = 10.4, 7.9 Hz, 1H), 4.98 (q, *J* = 2.6 Hz, 1H), 3.11-3.03 (m, 1H), 2.80-2.72 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.8, 144.8, 126.6, 125.0, 124.5, 99.2, 78.2, 37.8.

MS: (EI) m/z: 153 ([M+H^+], 100), 123 (28), 111 (74), 110 (33), 97 (42), 85 (18).

IR (ATR): *v* = 3433, 2942, 1722, 1660, 1420, 1243, 1168, 1015, 838, 703 cm^{-1}.

2,3-Dihydro-2,2'-bifuran (4o)



Yield: (118 mg, 86% yield), colorless oil.

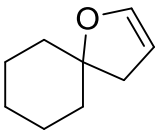
^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.42 (t, J=1.3 Hz, 1H), 6.36 – 6.34 (m, 3H), 5.50 (dd, J_1 = 10.5, J_2 = 8.8 Hz, 1H), 5.00 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 2.94-2.86 (m, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ = 153.9, 144.8, 142.8, 110.2, 107.4, 99.2, 75.4, 33.6.

MS: (EI) m/z: 136 ([M^+], 24), 107 (21), 85 (63), 83 (100), 79 (32), 77 (26), 52 (33).

IR (ATR): ν = 3448, 2924, 2860, 2642, 2105, 1740, 1455, 1365, 1217, 684 cm^{-1}.

1-Oxaspiro[4.5]dec-2-ene (4p)



Yield: (105 mg, 76% yield), colorless oil.

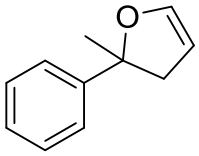
^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.21 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 4.74 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 2.33 (dd, apparent t, $J_1 \approx J_2 \approx$ 2.4 Hz, 2H), 1.71-1.65 (m, 4H), 1.56 – 1.50 (m, 2H), 1.45-1.37 (m, 4H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 144.0, 98.0, 86.4, 40.4, 37.1, 25.2, 23.0.

MS: (EI) m/z: 139 ([M+H^+], 33), 121 (26), 97 (28), 95 (31), 85 (28), 83 (33), 81 (33), 71 (45), 69 (48), 67 (33), 57 (100), 55 (96).

IR (ATR): ν = 2926, 2856, 2326, 2099, 1726, 1618, 1447, 1148, 1055, 702 cm^{-1}.

2-Methyl-2-phenyl-2,3-dihydrofuran (4q)



Yield: (147 mg, 92% yield), colorless oil.

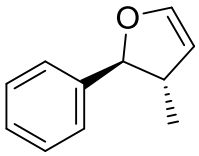
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.43-7.40 (m, 2H), 7.37 – 7.33 (m, 2H), 7.27 – 7.23 (m, 1H), 6.40 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.5 Hz, 1H), 4.86 (ddd, apparent q, $J_1 \approx J_2 \approx J_3 \approx$ 2.6 Hz, 1H), 2.87 – 2.75 (m, 2H), 1.66 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 147.7, 144.2, 128.2, 126.7, 124.4, 98.5, 87.2, 44.2, 29.1.

MS: (EI) m/z: 161 ([M+H$^+$], 10), 143 (13), 128 (15), 117 (35), 105 (100), 91 (38), 77 (62), 57 (32).

IR (ATR): ν = 1970, 1923, 2859, 2328, 2100, 1616, 1445, 1283, 1161, 1054, 913, 755, 700 cm^{-1}.

(*2S,3S*)-3-methyl-2-phenyl-2,3-dihydrofuran (4r)



Yield: (109 mg, 68% yield), colorless oil, obtained with *cis*-isomer in the ratio 4:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.24 (m, 5H), 6.43 (m, 1H), 4.93-4.91 (m, 2H), 2.98-2.91 (m, 1H), 1.21 (d, J = 6.7 Hz, 3H).

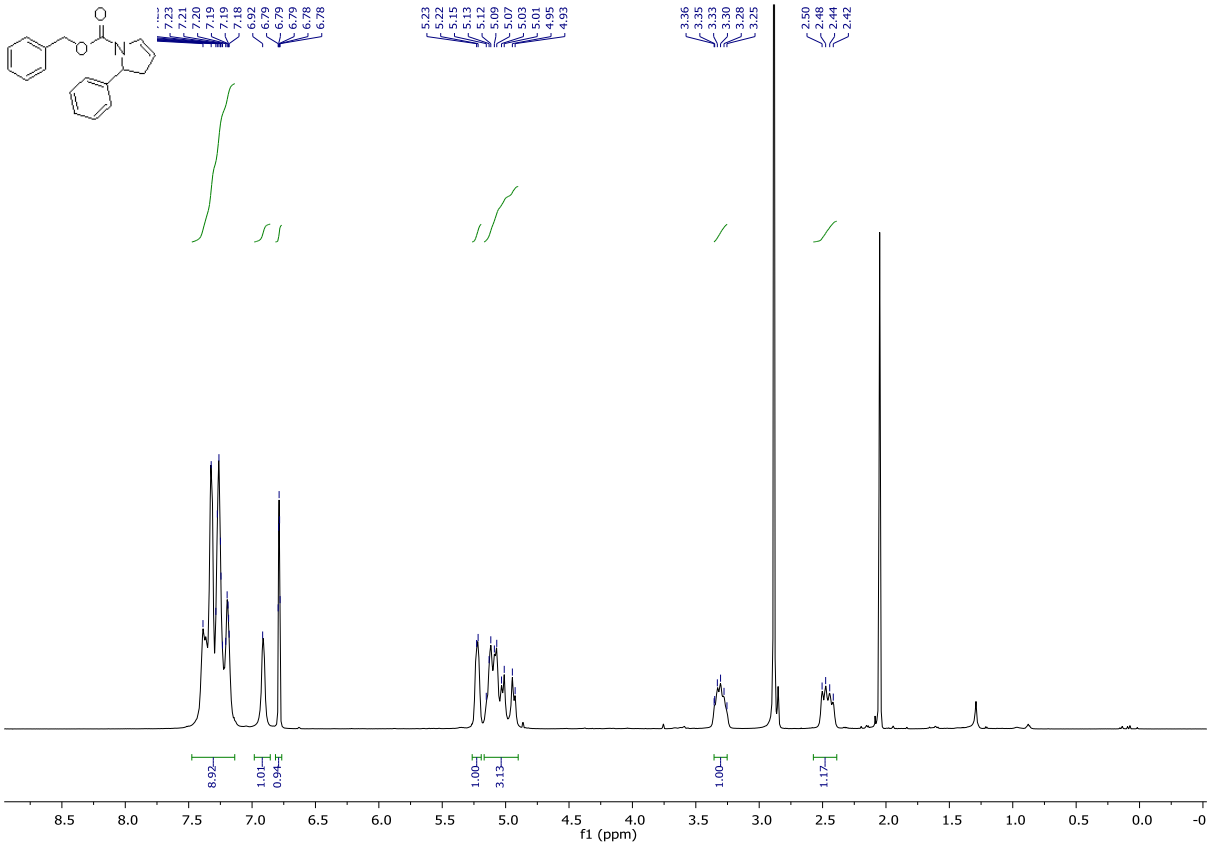
^{13}C NMR (101 MHz, $CDCl_3$) δ = 144.7, 142.4, 128.5, 127.7, 125.4, 105.8, 90.1, 45.9, 20.8.

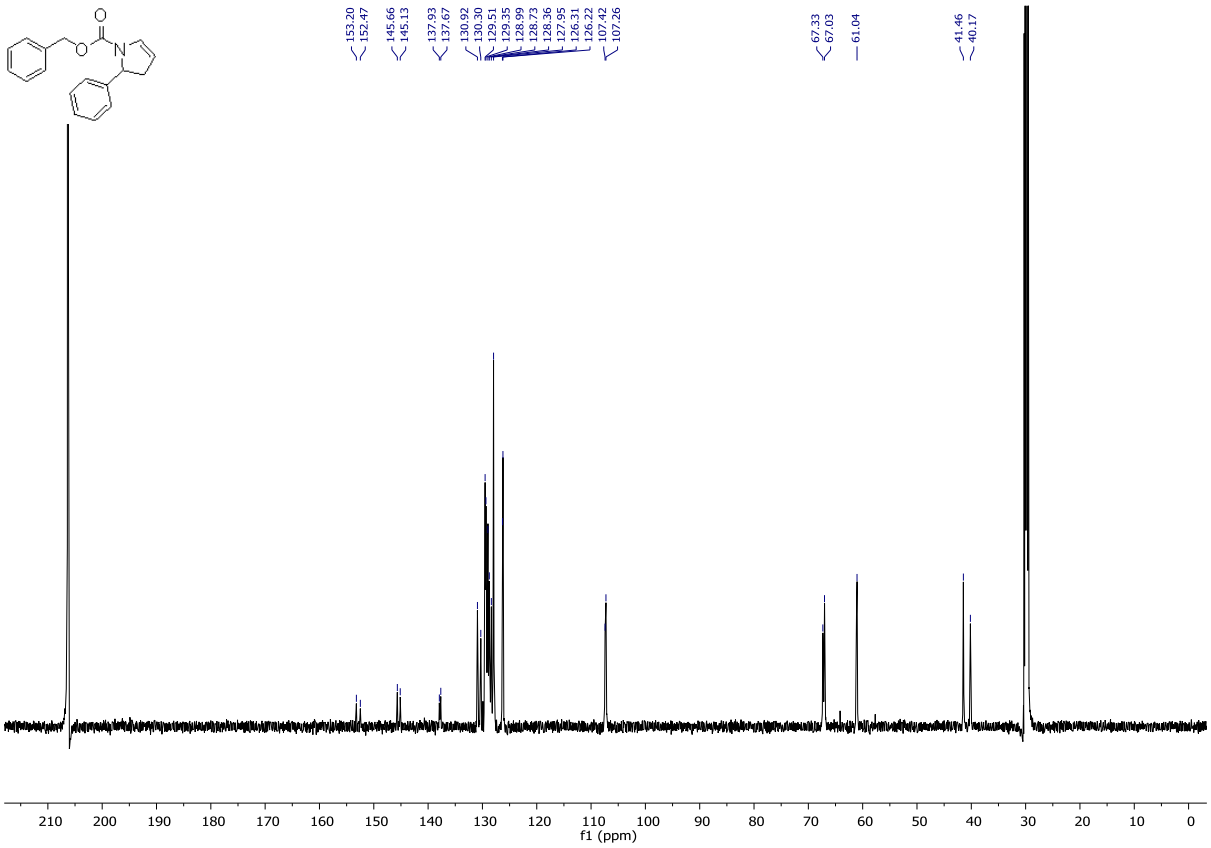
MS: (EI, 70) m/z: 161 ([M+H$^+$], 70), 143 (30), 131,2 (30), 105 (100), 91 (58), 77 (40).

IR (ATR): ν = 3441, 3035, 2937, 1723, 1452, 1371, 1261, 985, 756, 700 cm^{-1}.

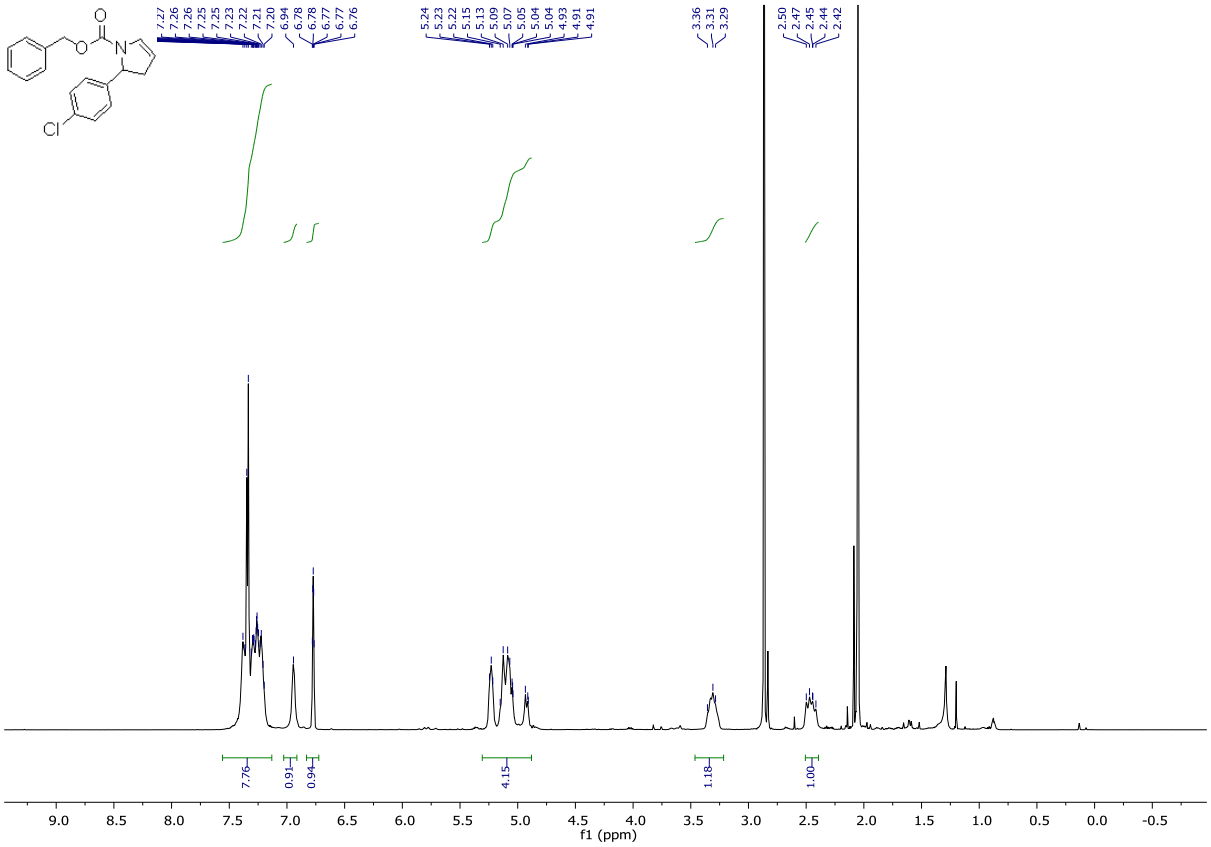
IV – NMR Spectra

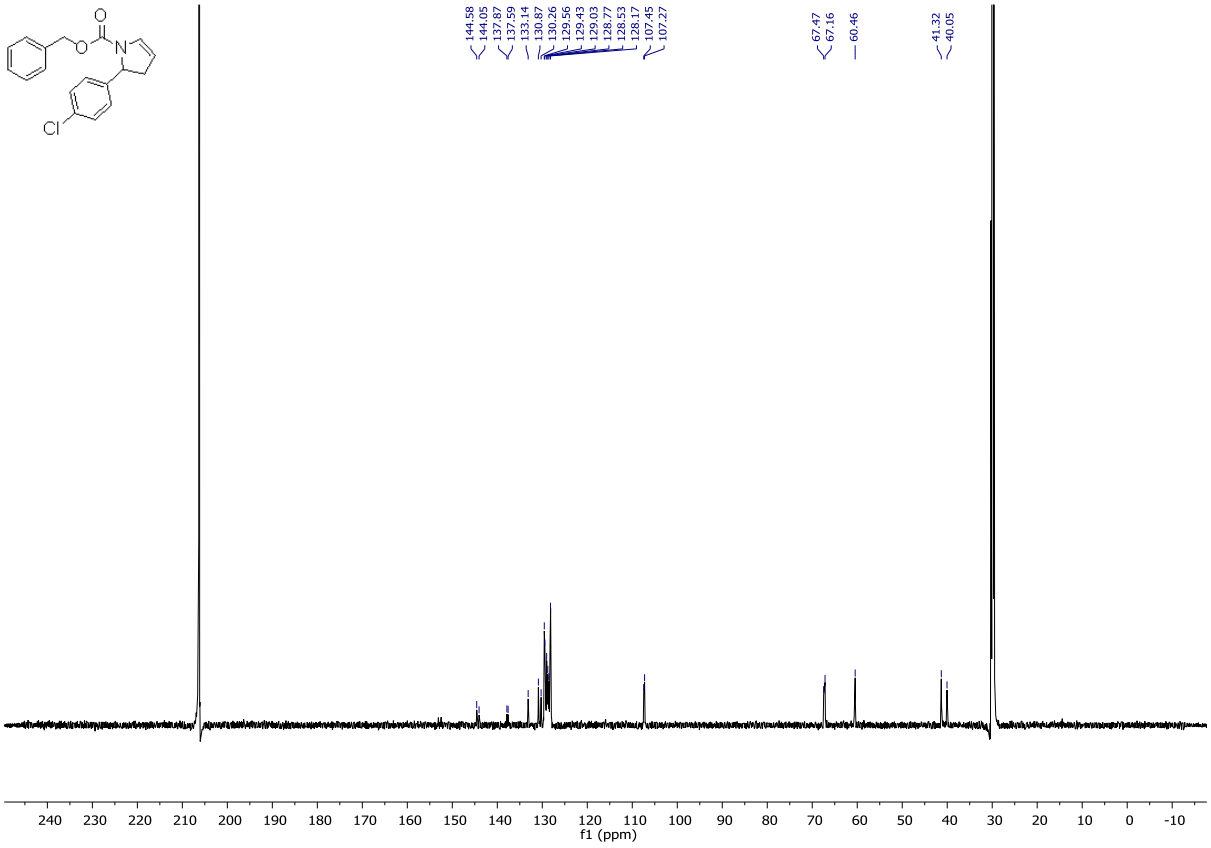
Benzyl 2-phenyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2a)



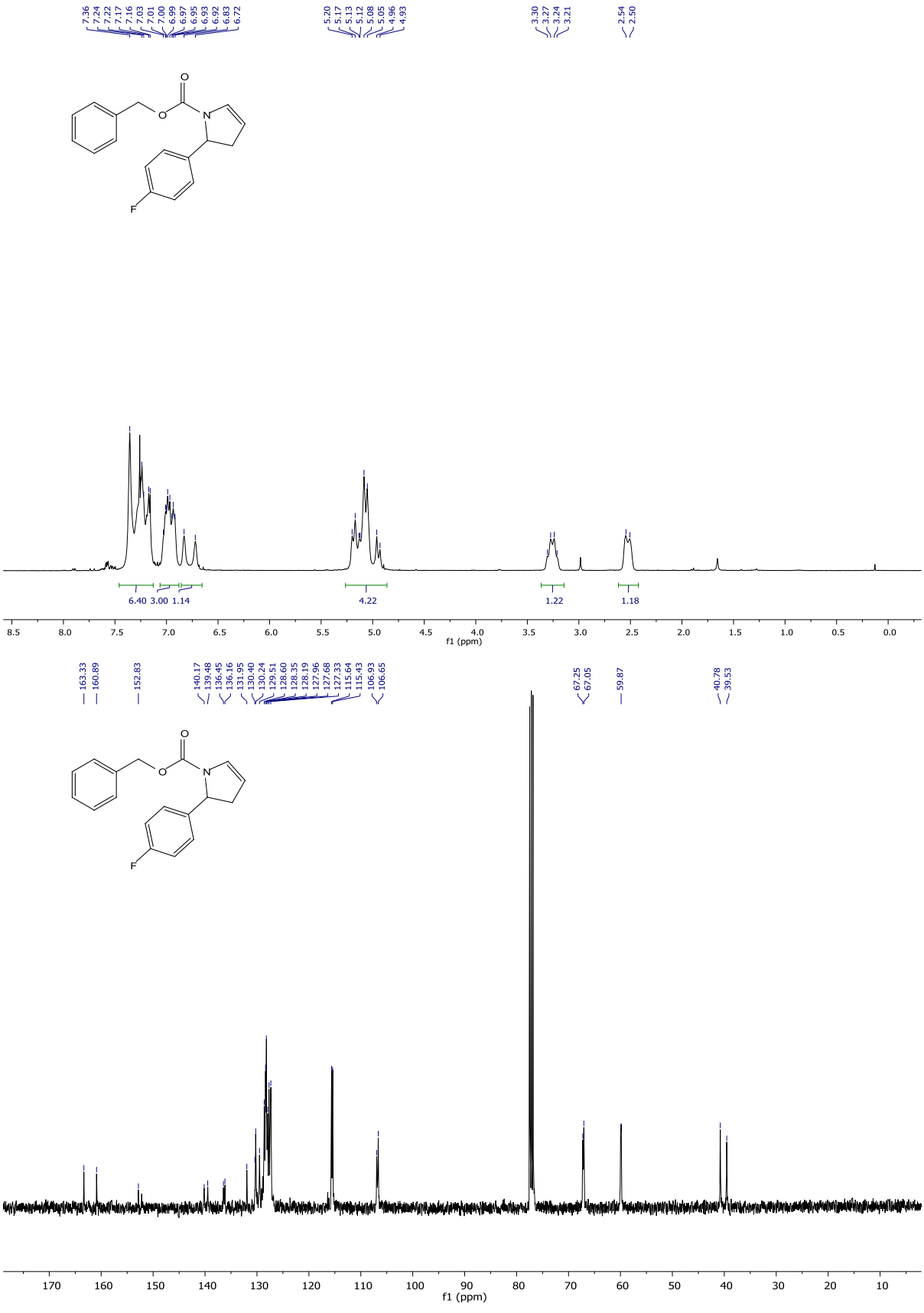


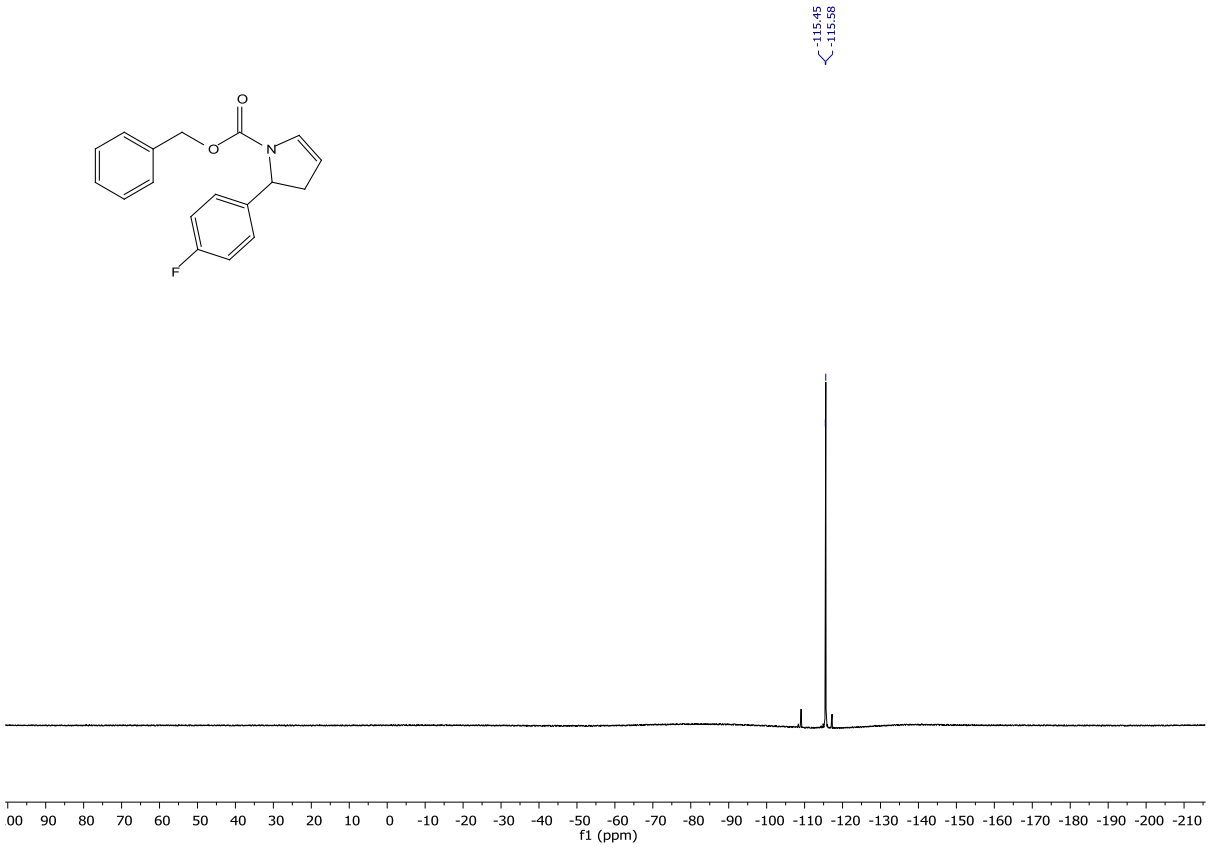
Benzyl 2-(4-chlorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2b)



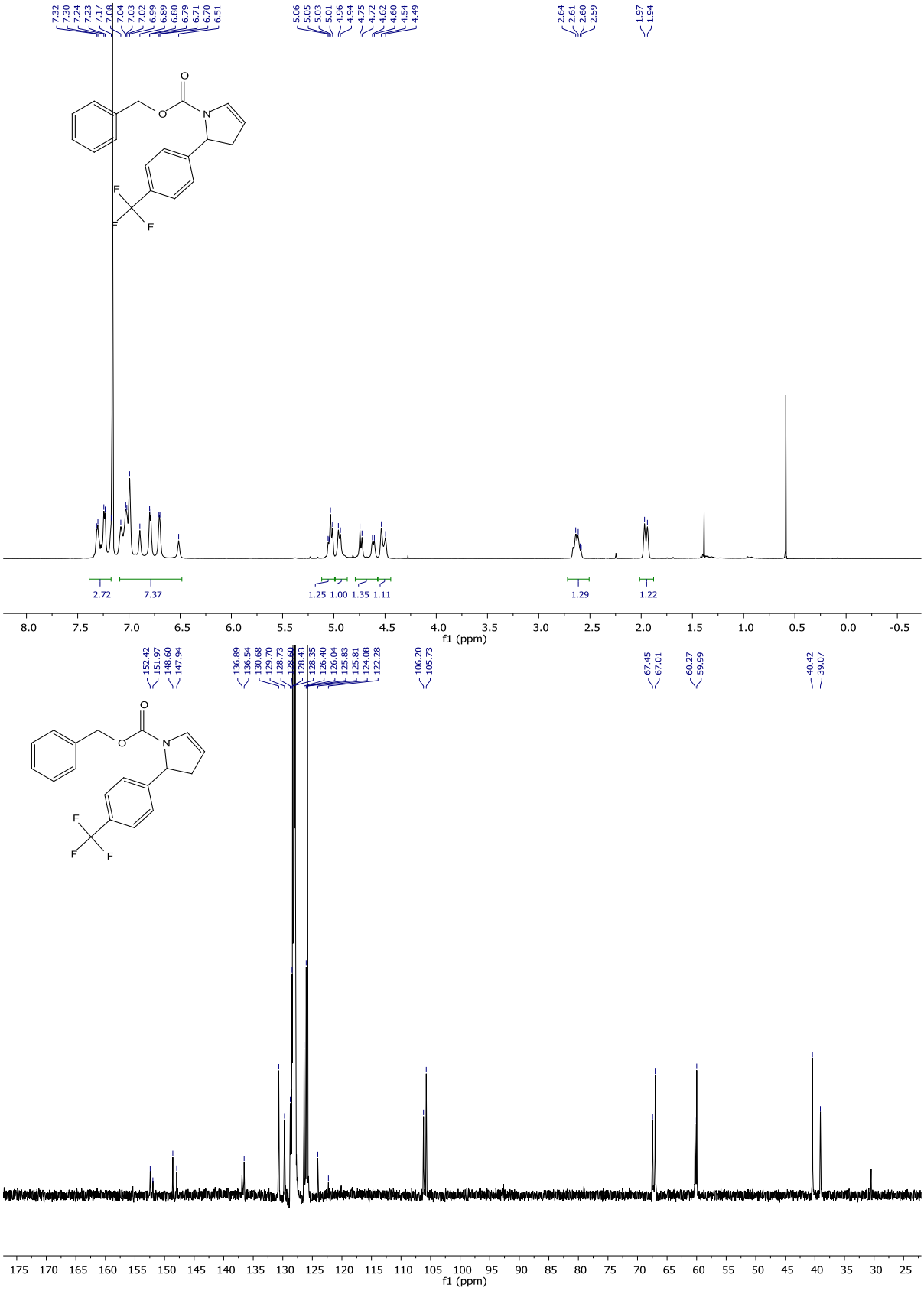


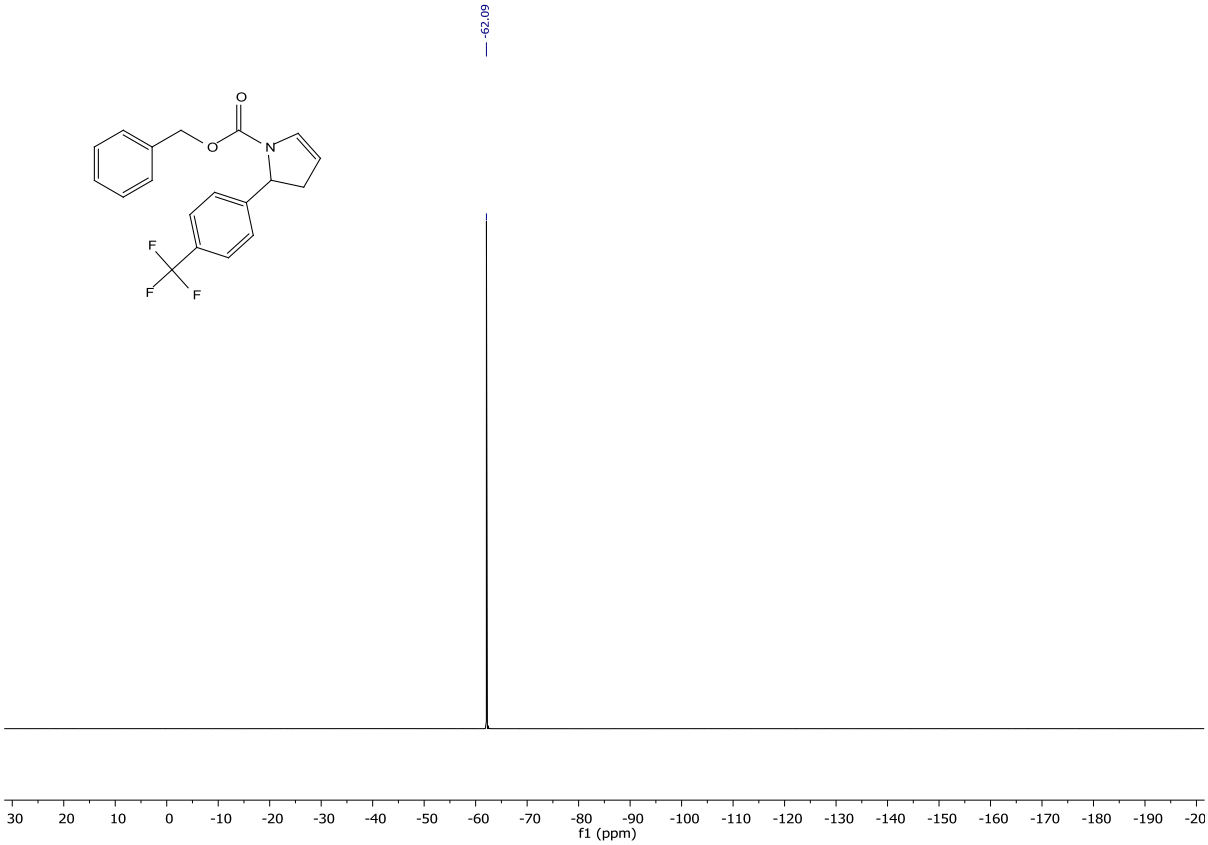
Benzyl 2-(4-fluorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2c)



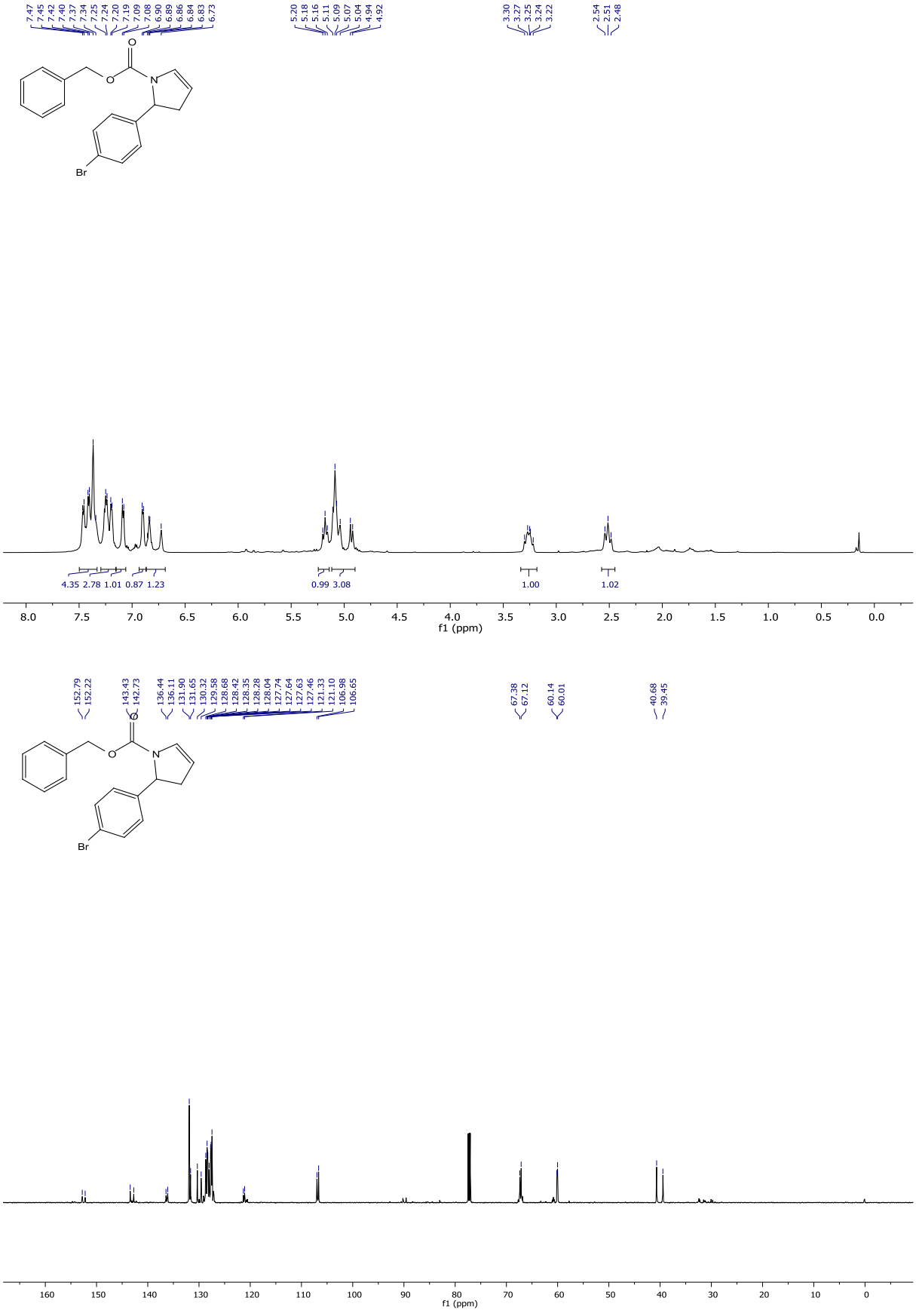

-115.45
-115.58
O
O
N
F
00 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

Benzyl 2-(4-(trifluoromethyl)phenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2d)

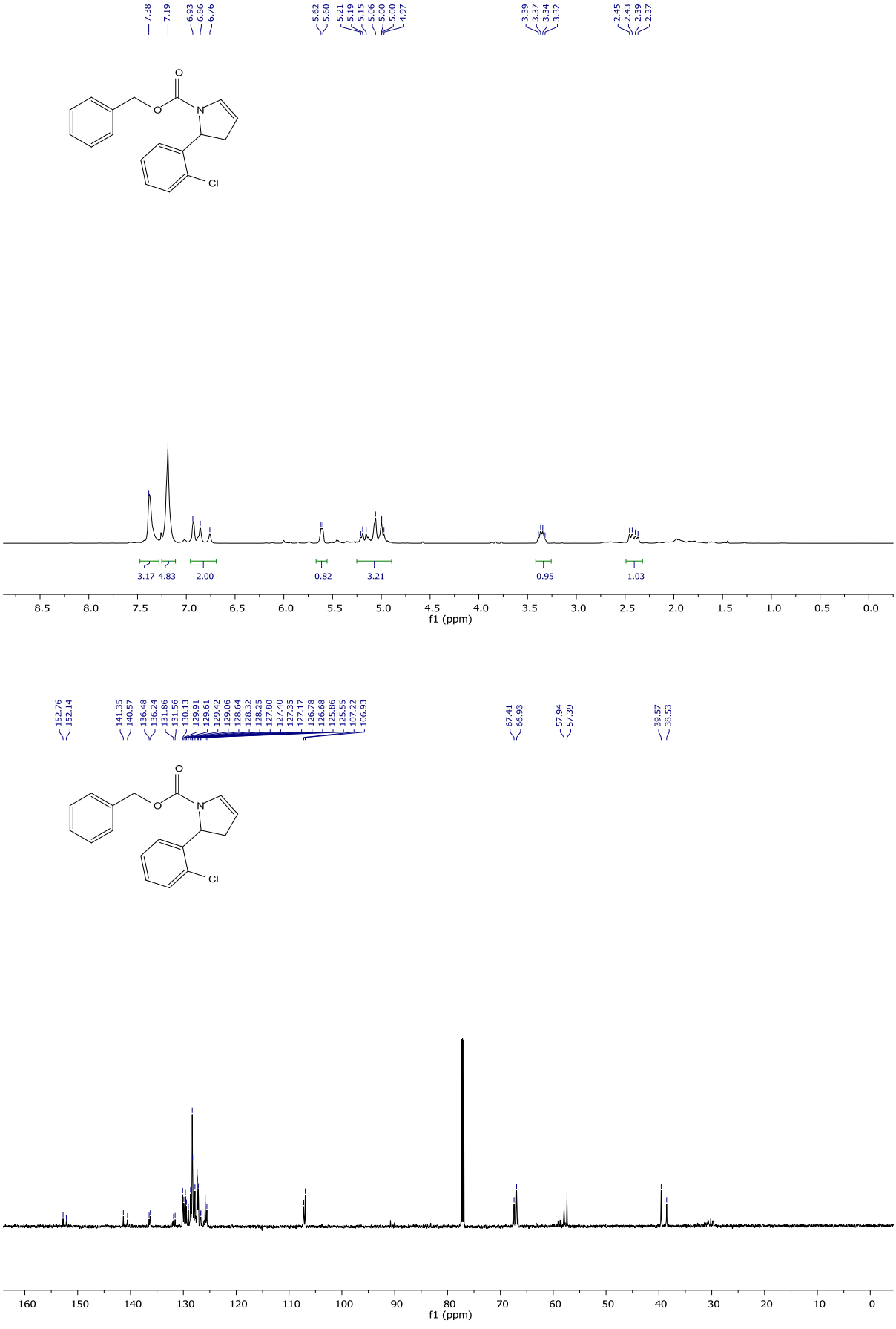



-62.09
O
O
N
F
F
F
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-20
f1 (ppm)

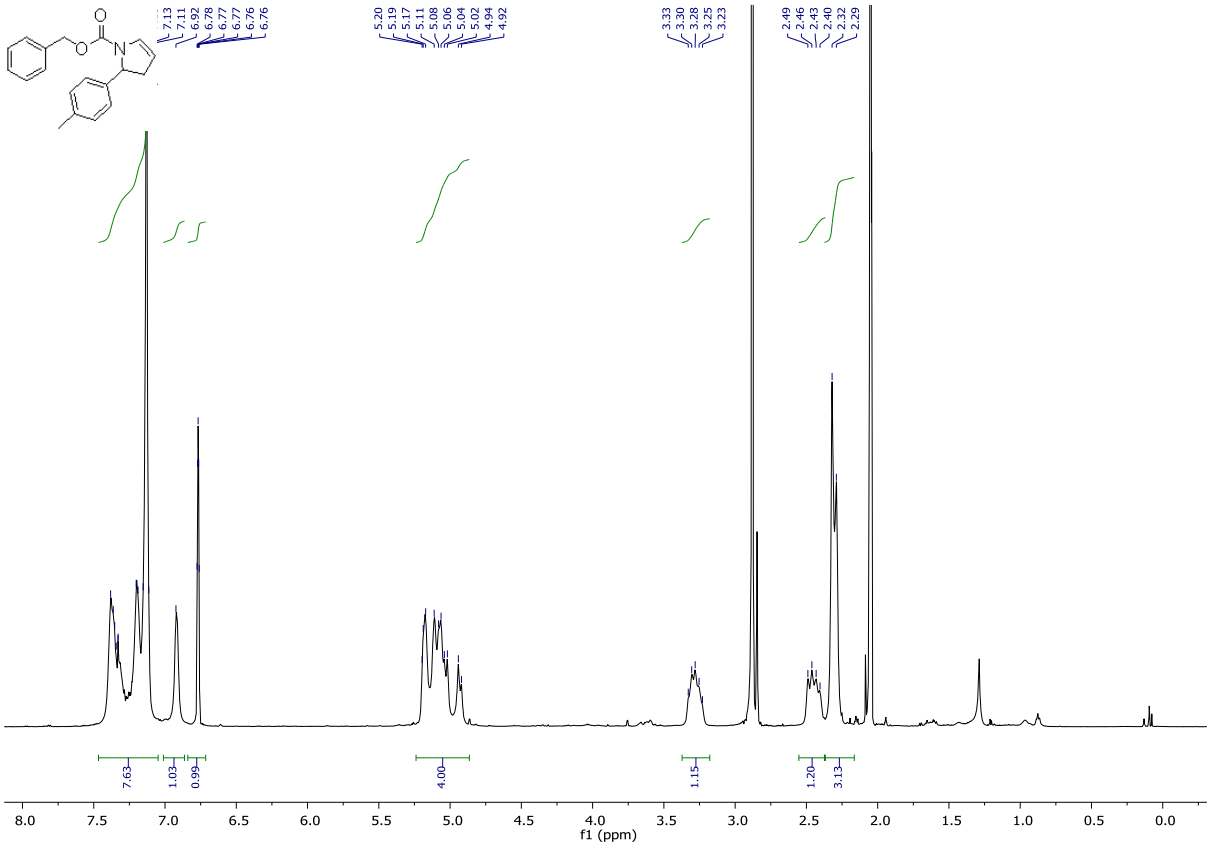
Benzyl 2-(4-bromophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2e)

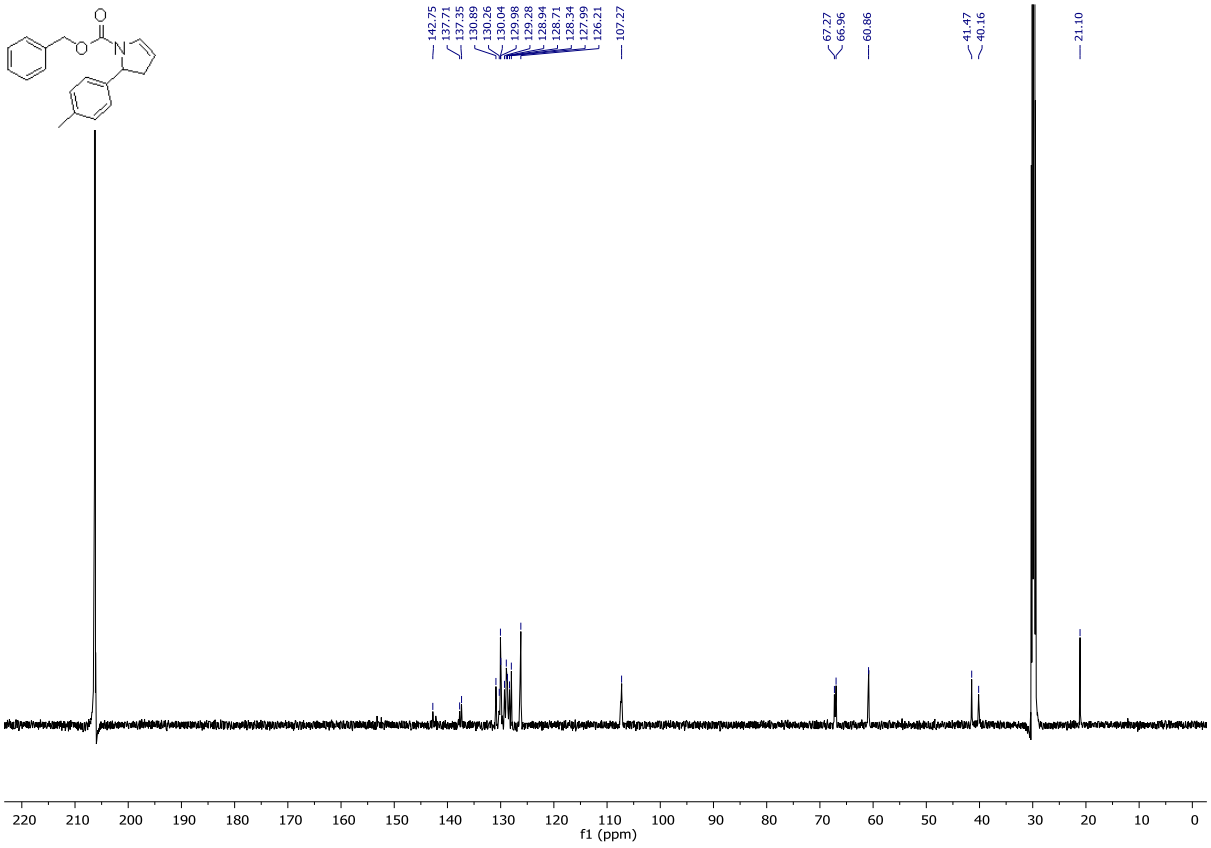


Benzyl 2-(2-chlorophenyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2f)

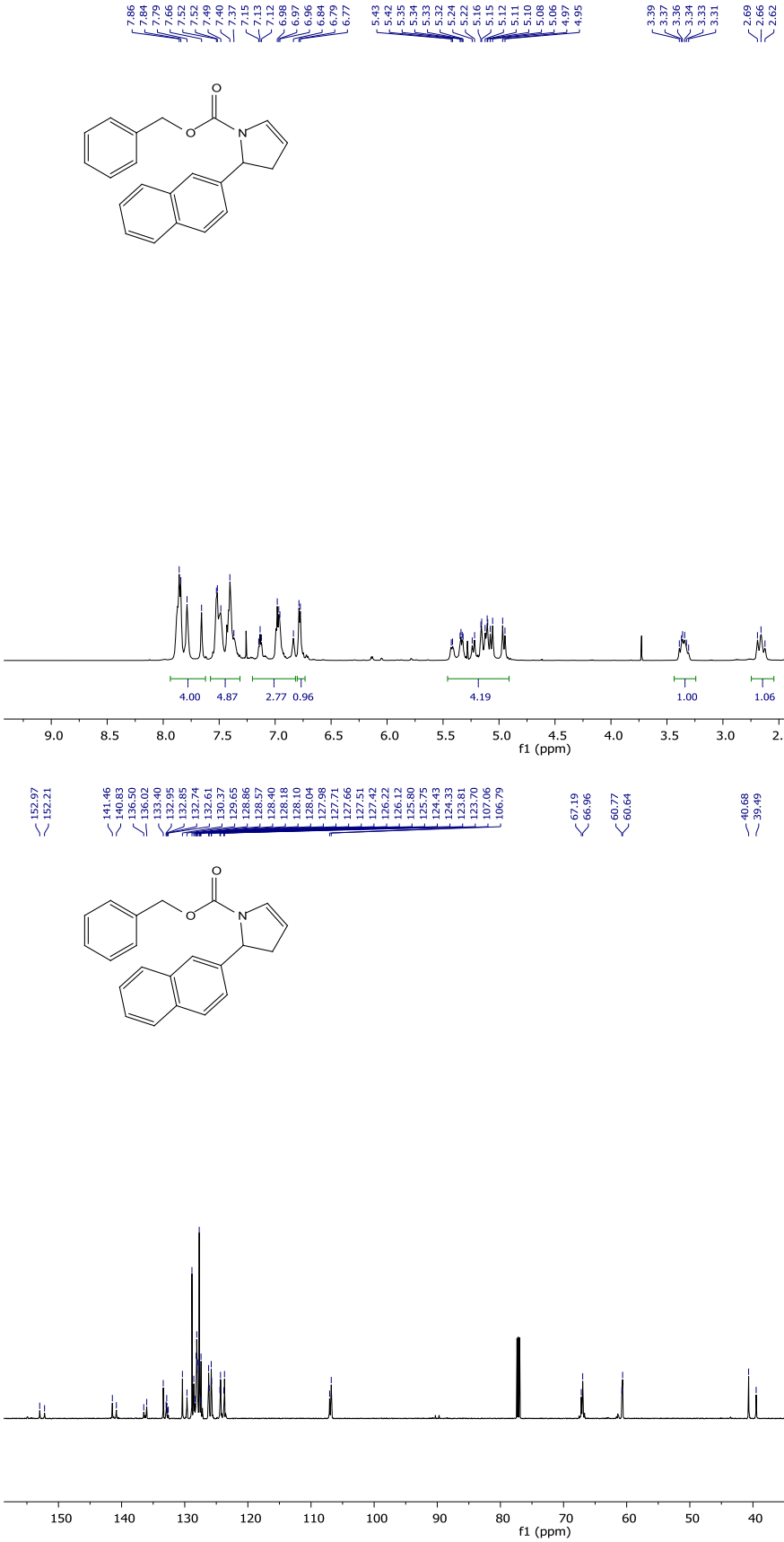


Benzyl 2-(p-tolyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2g)

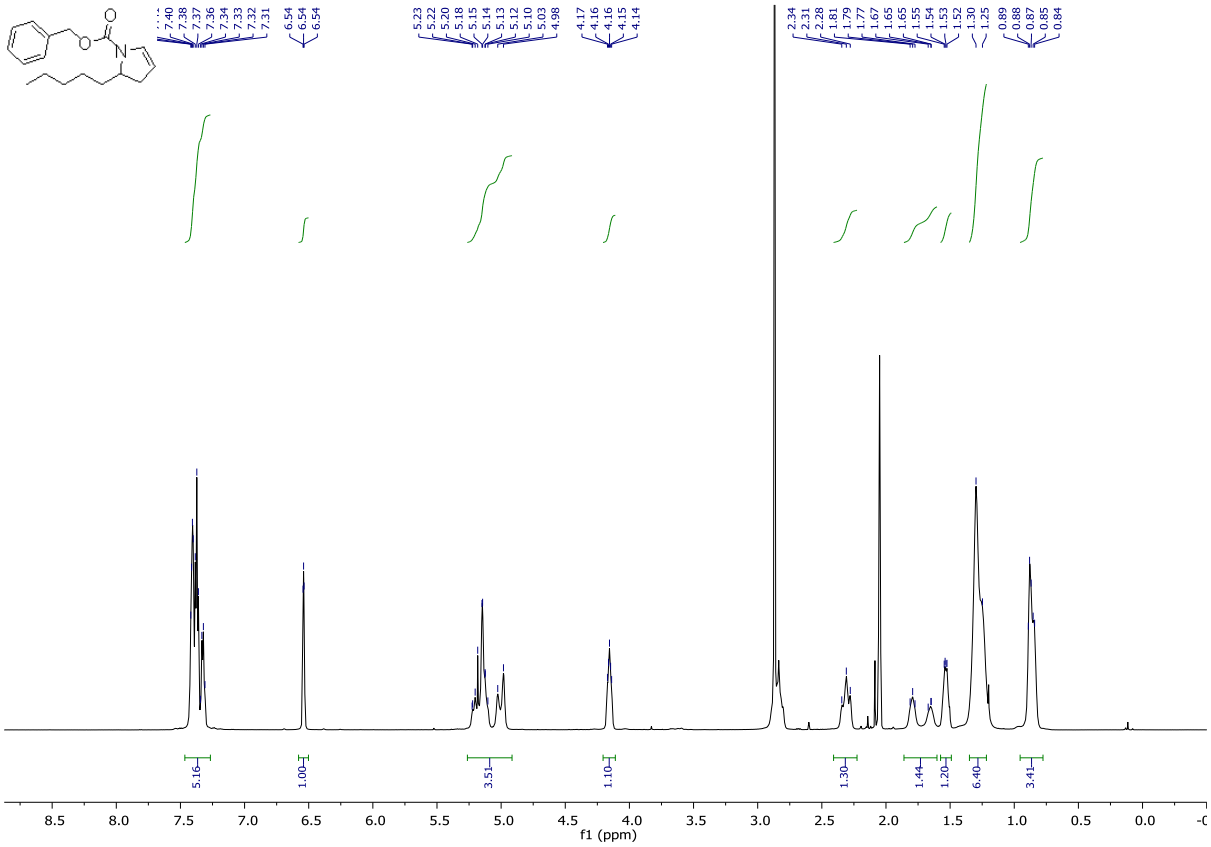


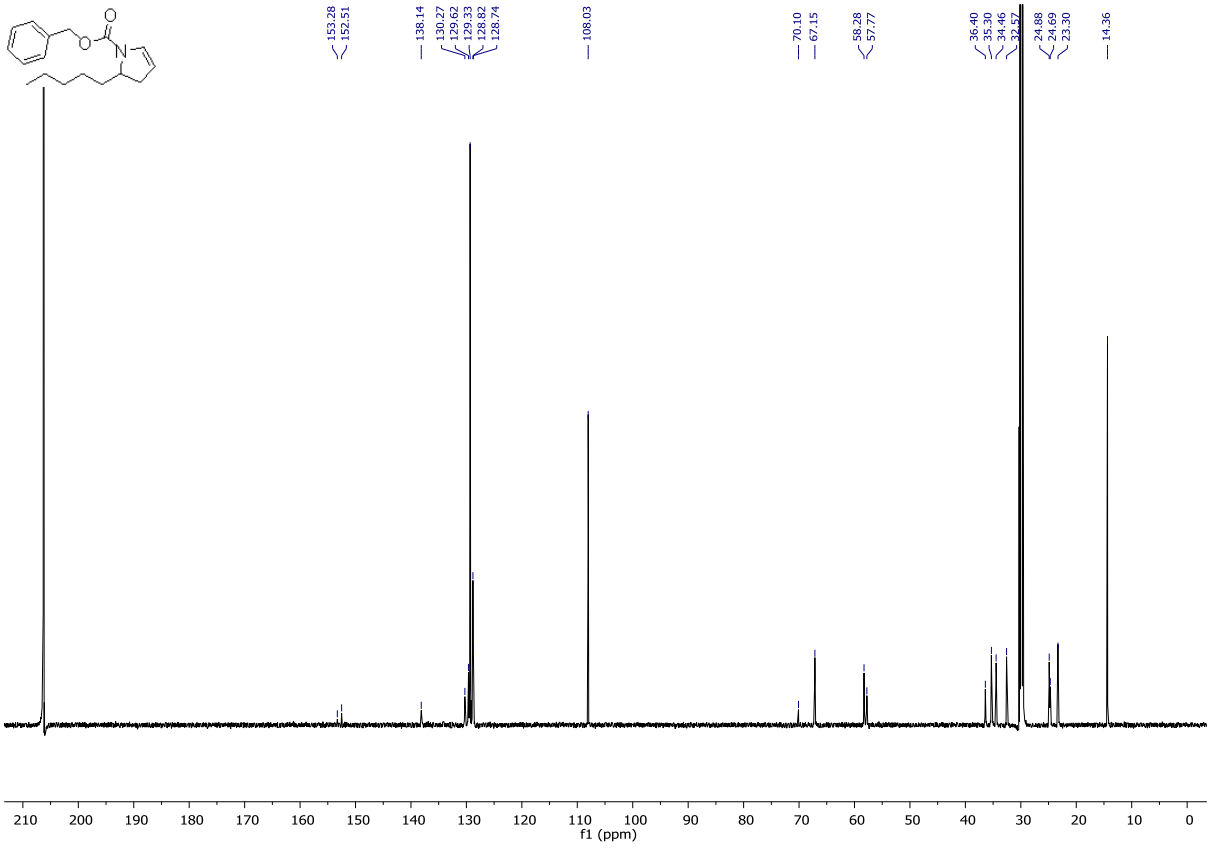


Benzyl 2-(naphthalen-2-yl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2h)

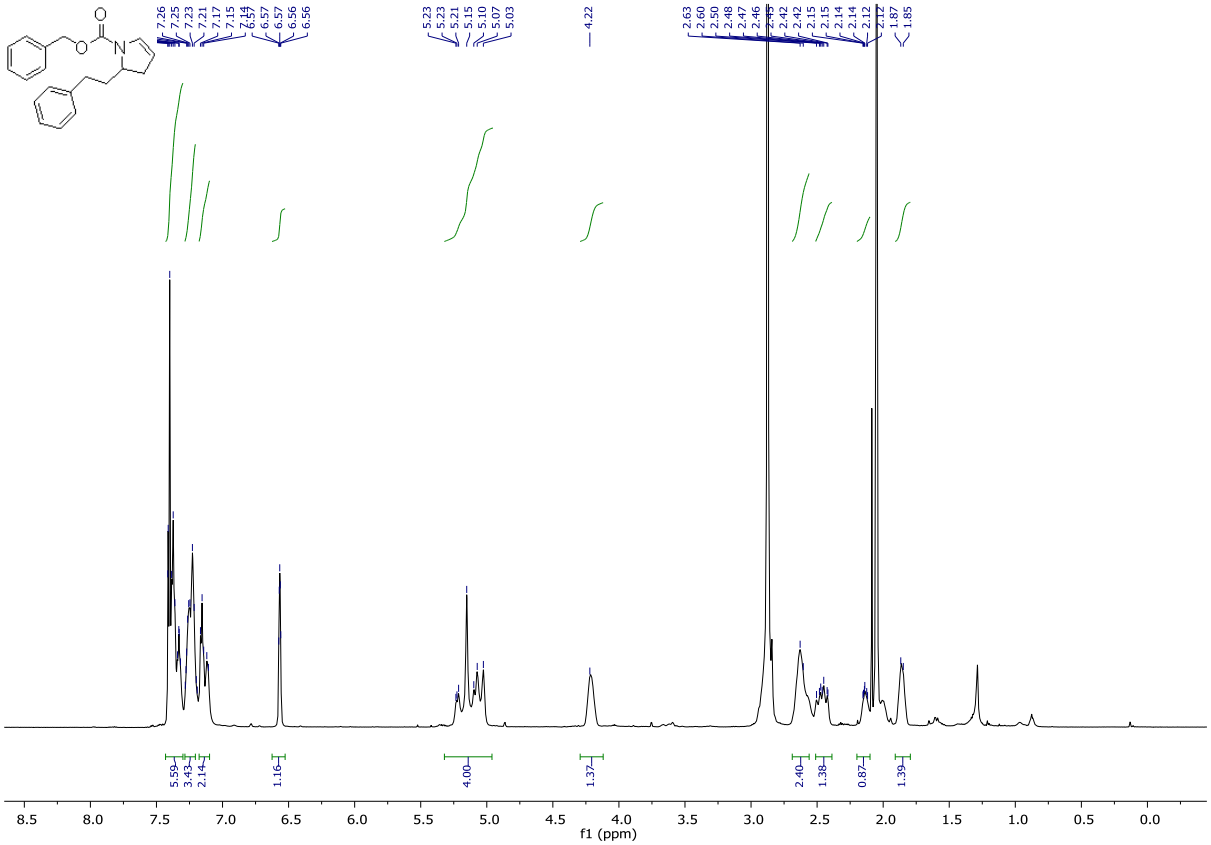


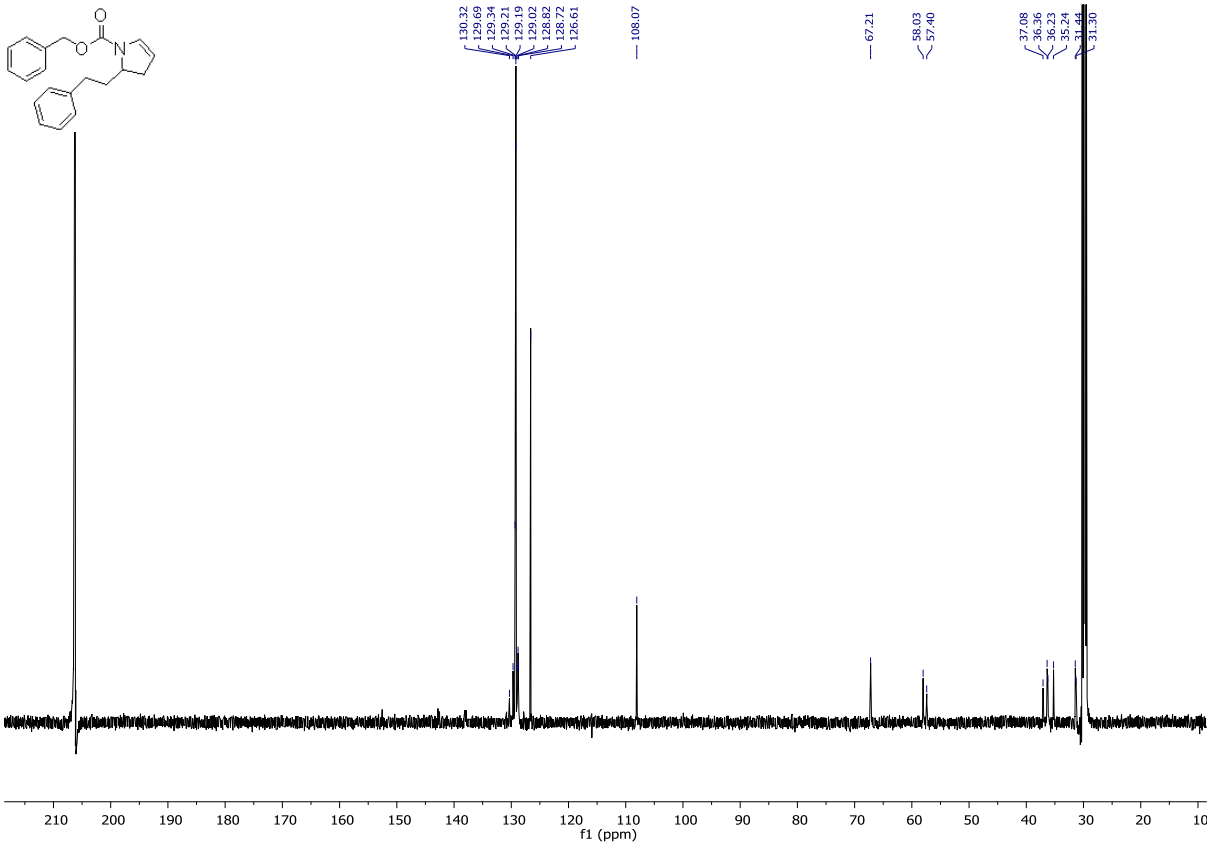
Benzyl 2-pentyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2i)



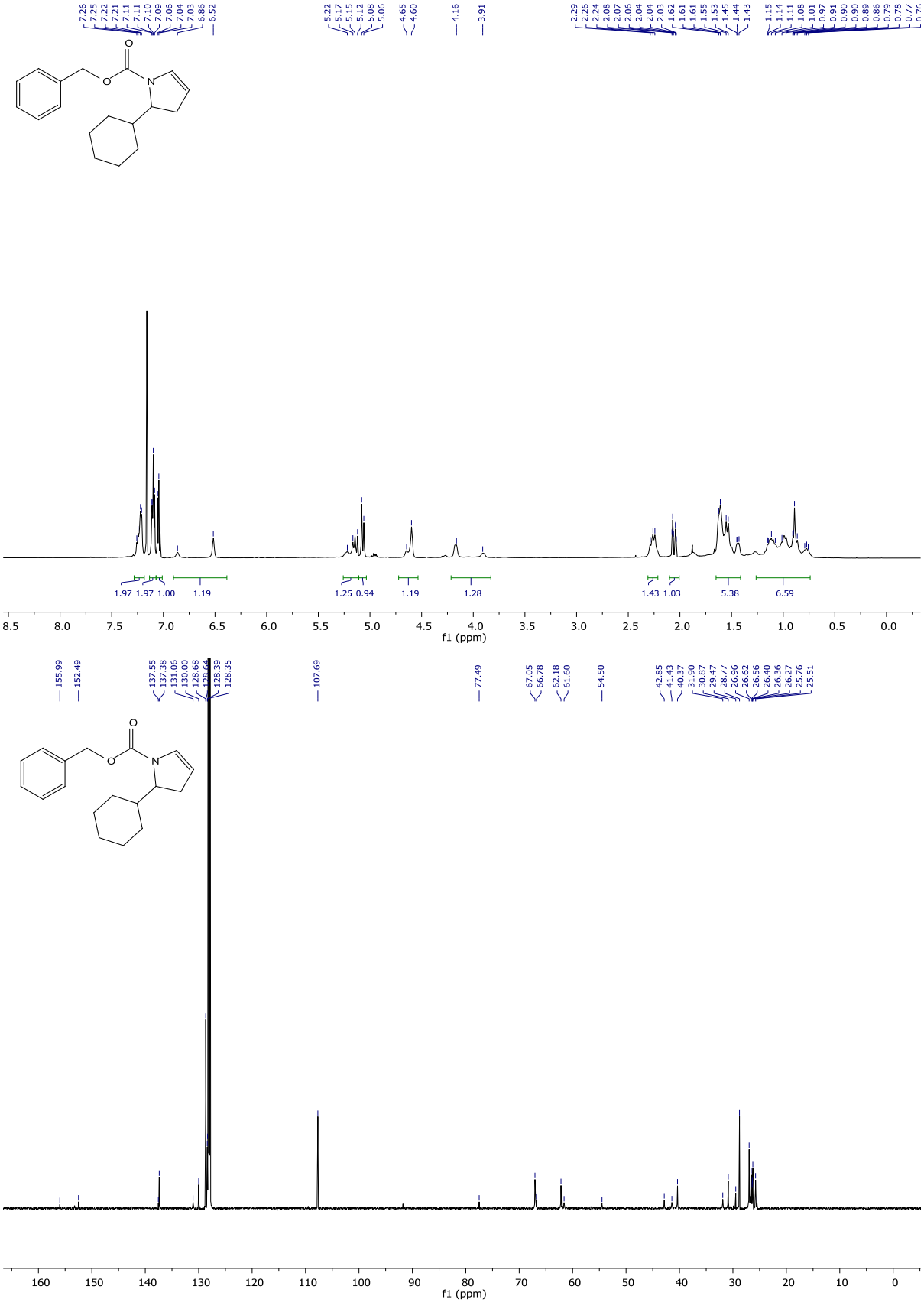


Benzyl 2-phenethyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2j)

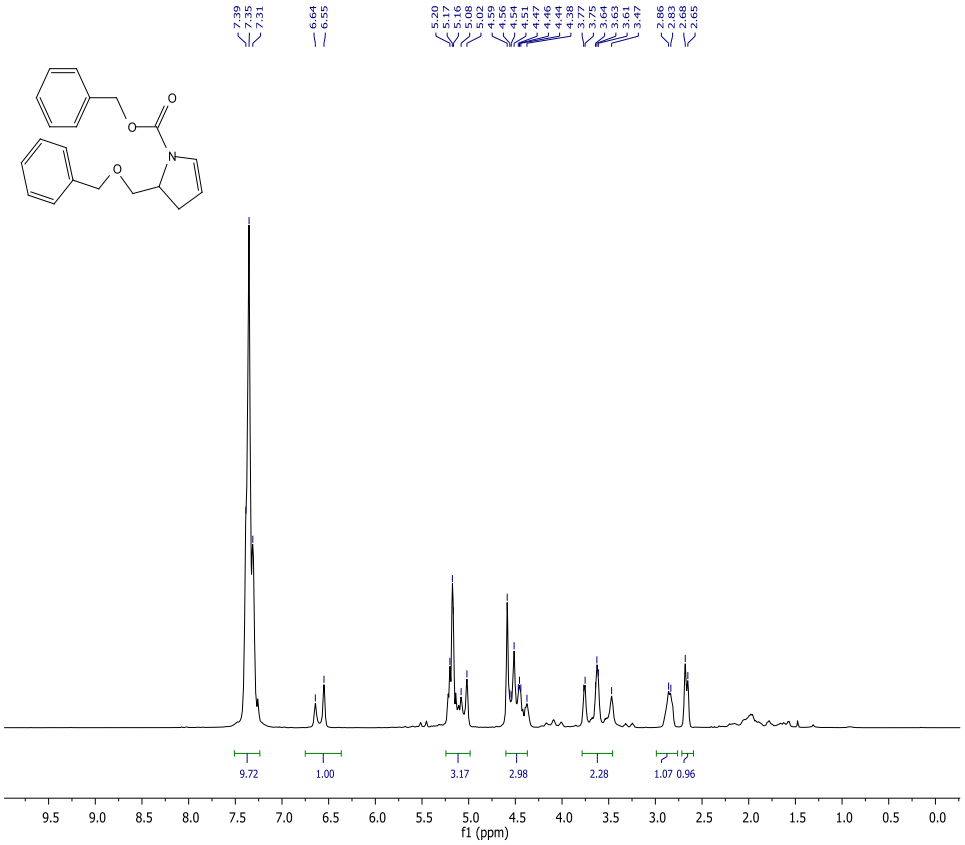


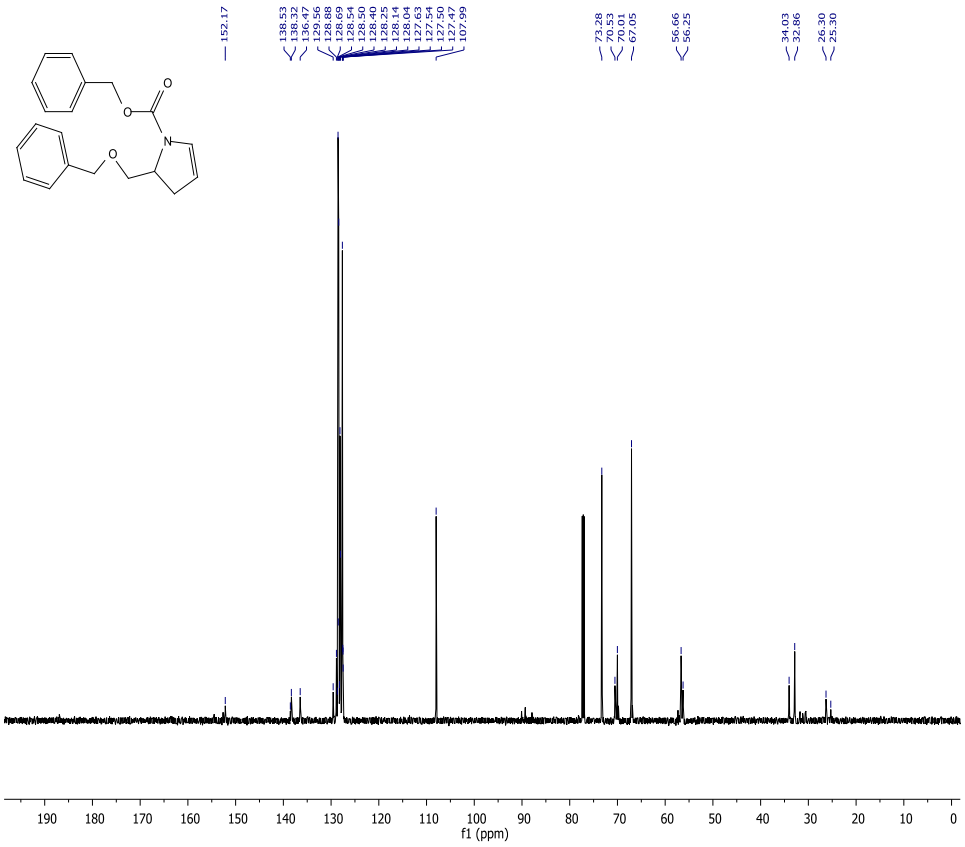


Benzyl 2-cyclohexyl-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2k)

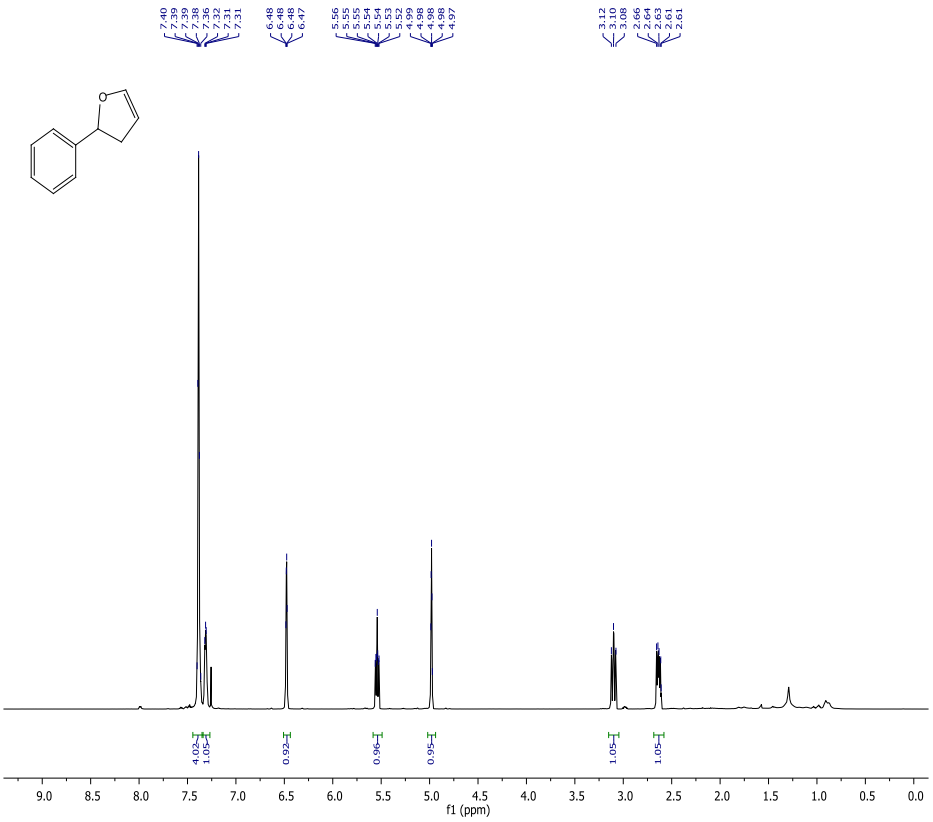


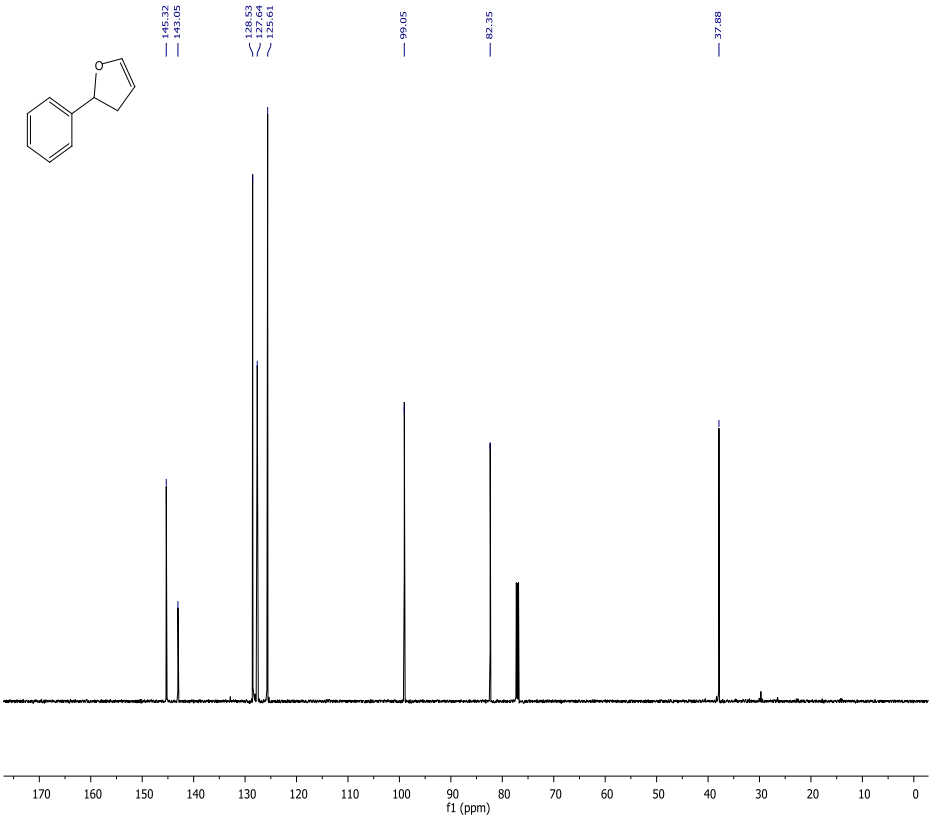
Benzyl 2-((benzyloxy)methyl)-2,3-dihydro-1*H*-pyrrole-1-carboxylate (2l)



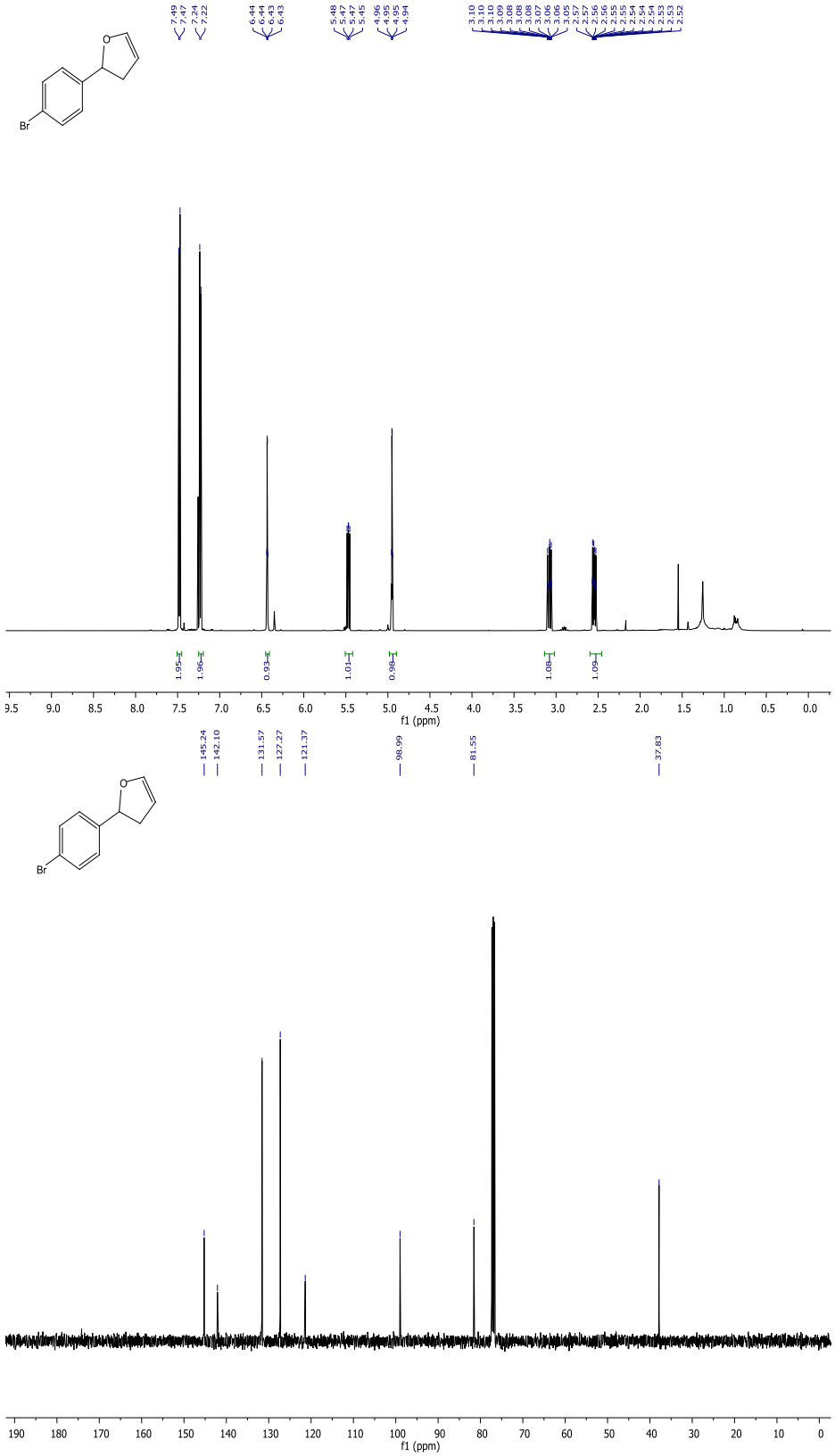


2-Phenyl-2,3-dihydrofuran (4a)

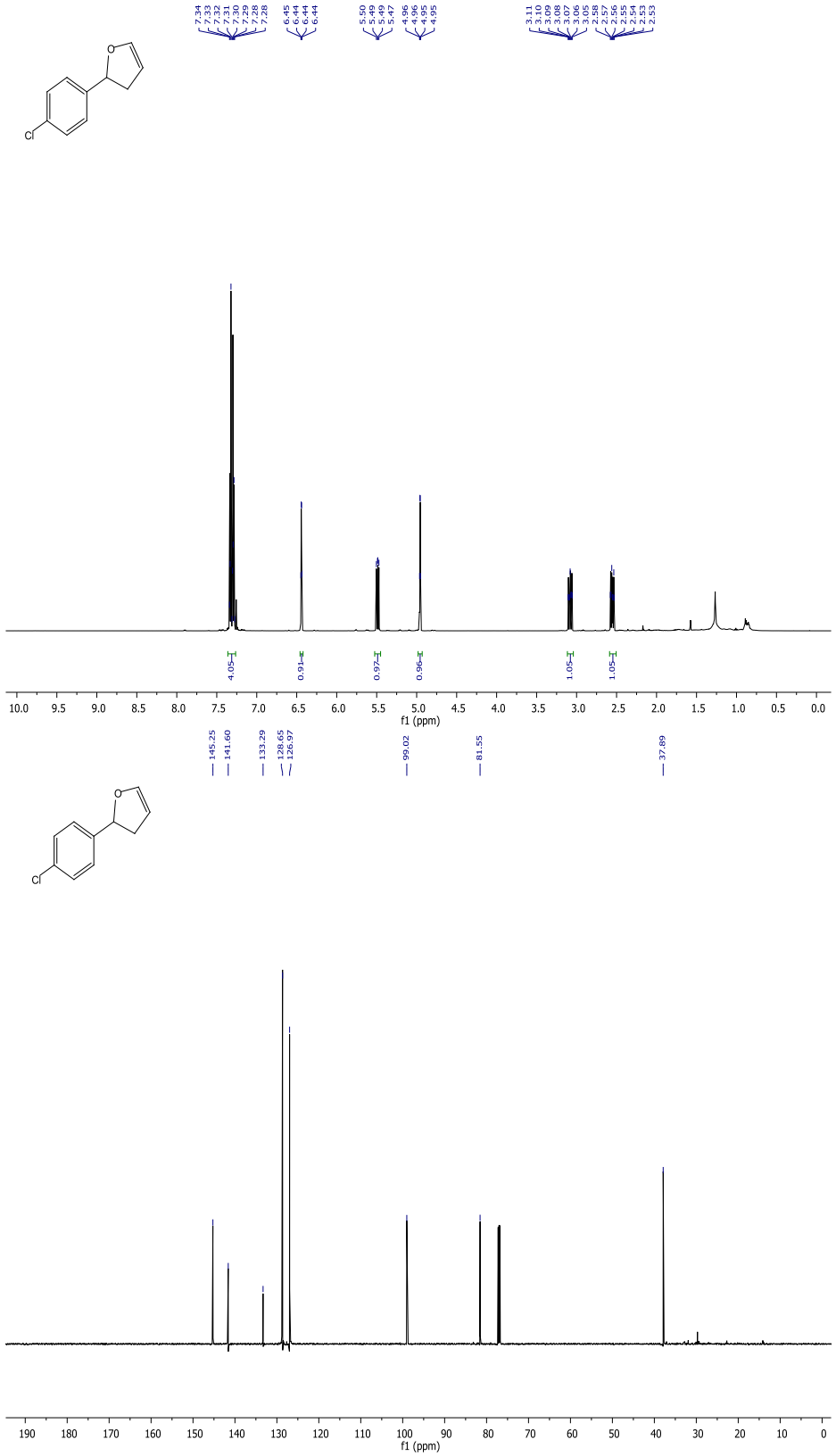




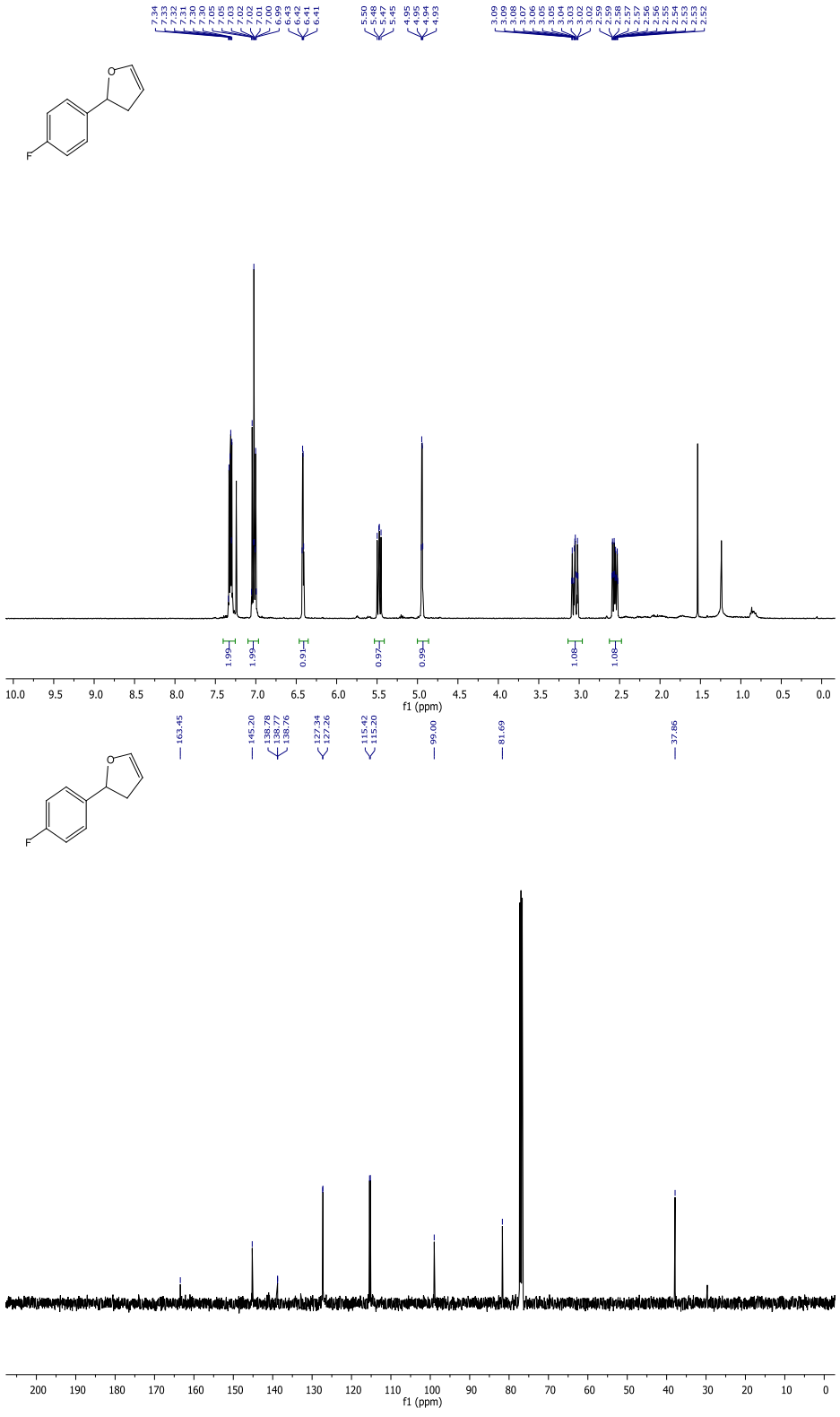
2-(4-Bromophenyl)-2,3-dihydrofuran (4b)

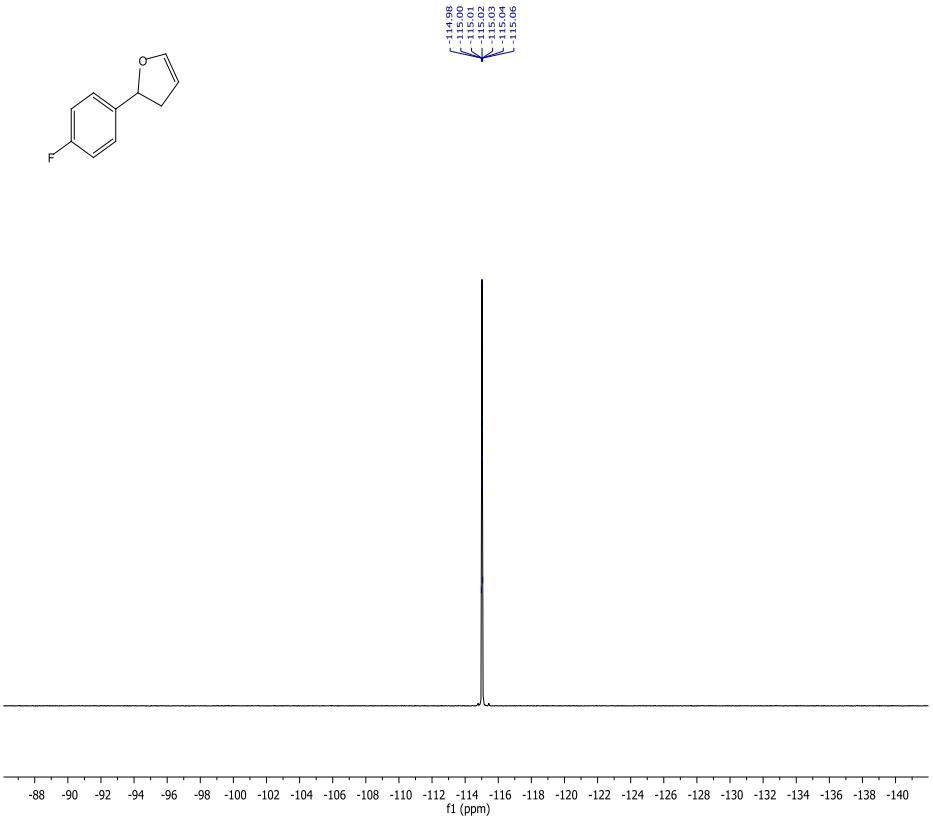


2-(4-Chlorophenyl)-2,3-dihydrofuran (4c)

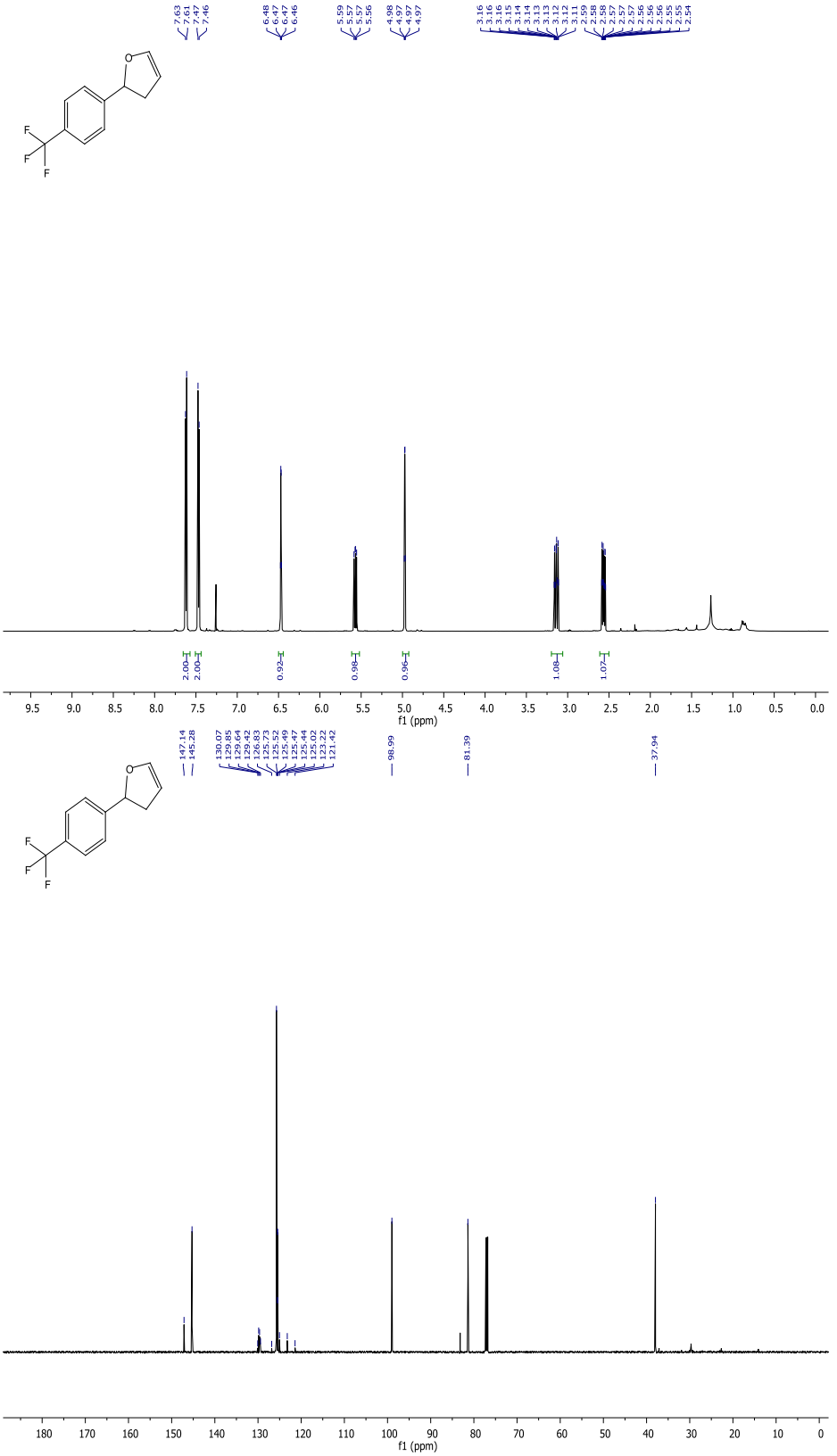


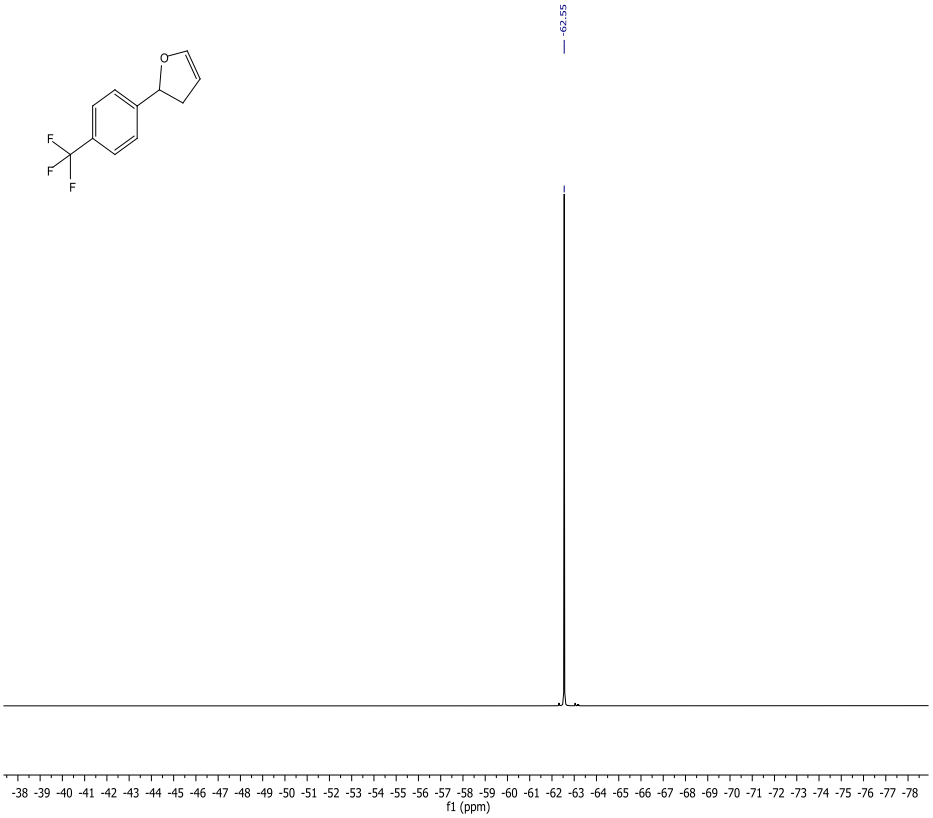
2-(4-Fluorophenyl)-2,3-dihydrofuran (4d)


7.34
7.33
7.32
7.31
7.30
7.05
7.05
7.03
7.02
7.02
7.01
7.00
6.99
6.43
6.42
6.41
6.41
5.50
5.48
5.47
5.45
4.95
4.95
4.94
4.93
3.09
3.09
3.08
3.07
3.06
3.05
3.05
3.04
3.03
3.02
3.02
2.59
2.58
2.57
2.57
2.56
2.56
2.55
2.54
2.53
2.53
2.52
O
F
1.99
1.99
0.91
0.97
0.99
1.08
1.08
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
163.45
145.20
138.78
138.77
138.76
127.34
127.26
115.42
115.20
99.00
81.69
37.86
O
F
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

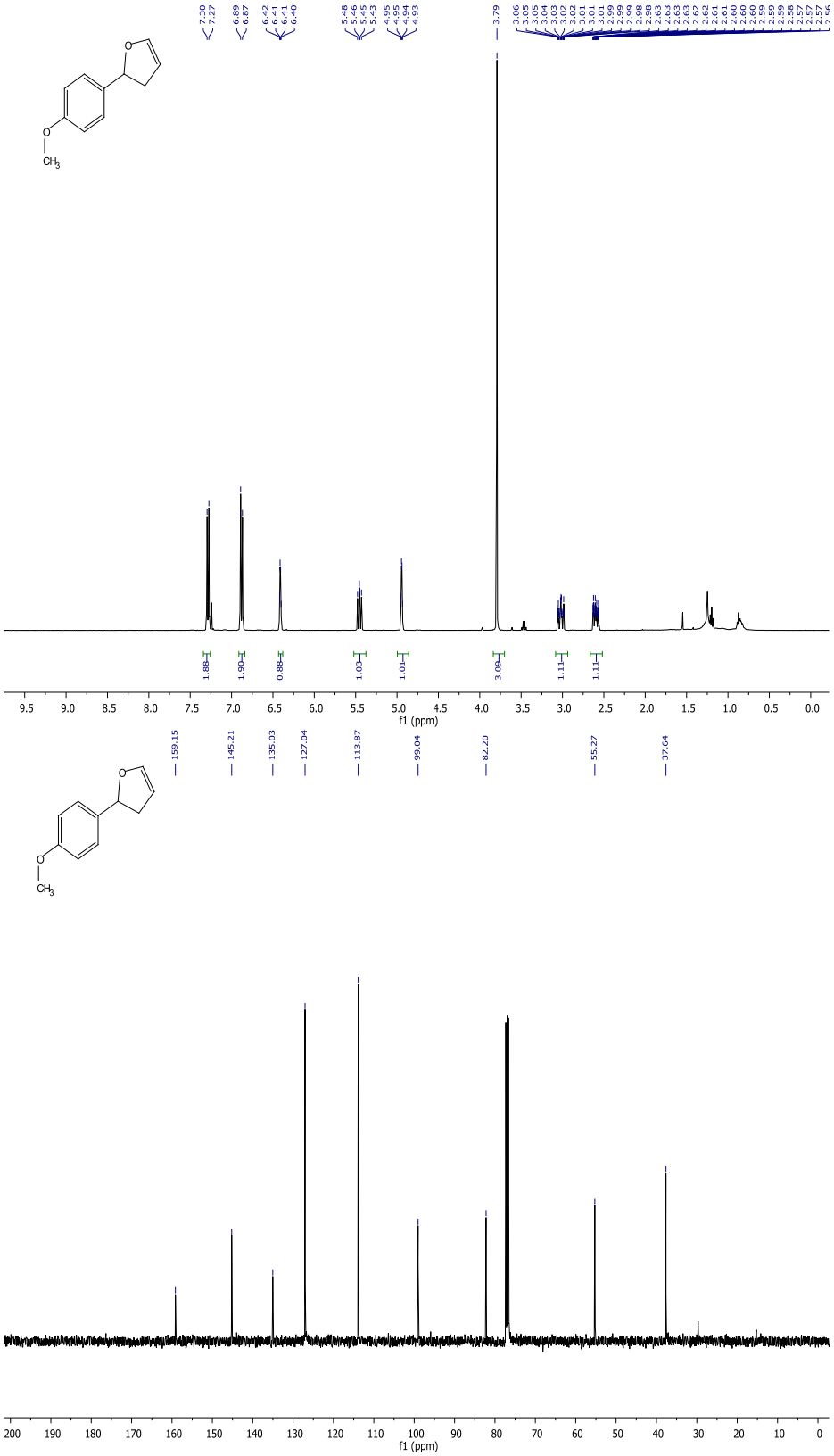

-114.98
-115.00
-115.01
-115.02
-115.03
-115.04
-115.06
O
F
-88 -90 -92 -94 -96 -98 -100 -102 -104 -106 -108 -110 -112 -114 -116 -118 -120 -122 -124 -126 -128 -130 -132 -134 -136 -138 -140
f1 (ppm)

2-(4-(Trifluoromethyl)phenyl)-2,3-dihydrofuran (4e)

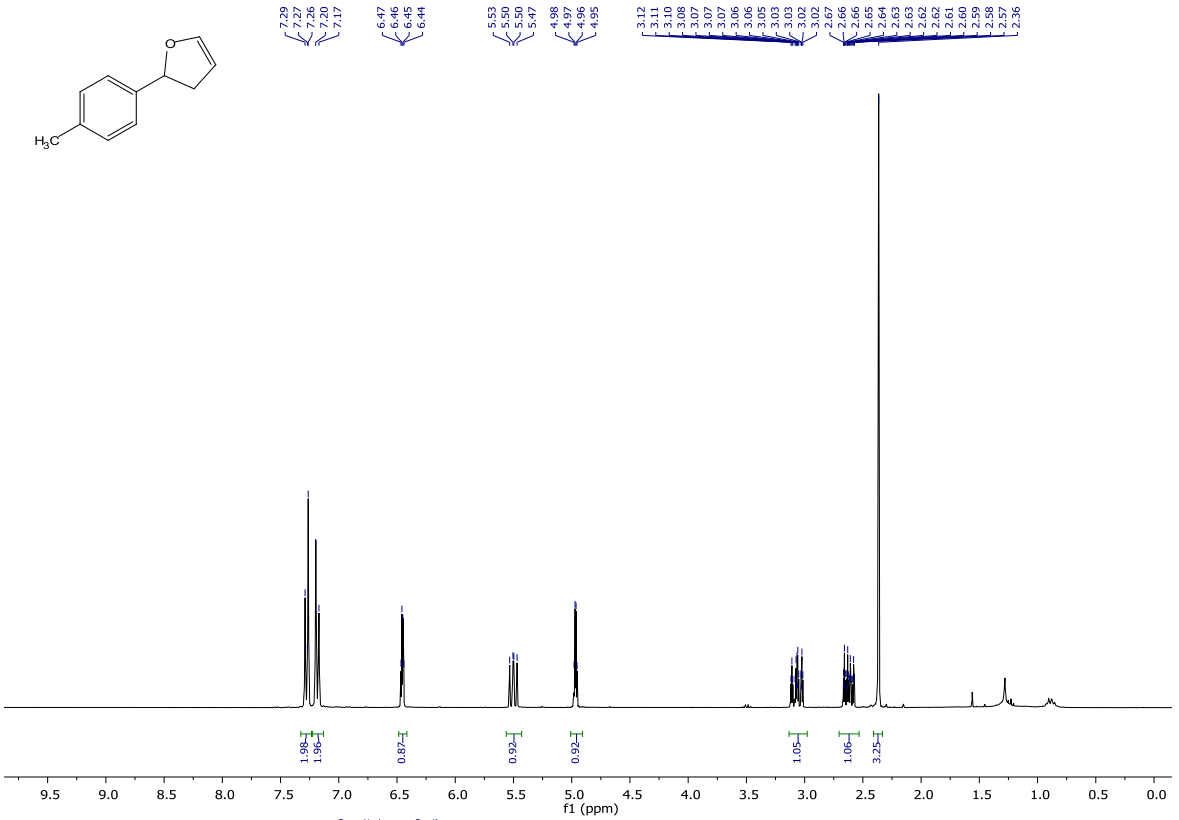



-62.55
F
F
F
O
-38 -39 -40 -41 -42 -43 -44 -45 -46 -47 -48 -49 -50 -51 -52 -53 -54 -55 -56 -57 -58 -59 -60 -61 -62 -63 -64 -65 -66 -67 -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78
f1 (ppm)

2-(4-Methoxyphenyl)-2,3-dihydrofuran (4f)



2-(p-Tolyl)-2,3-dihydrofuran (4g)


7.29
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4.95
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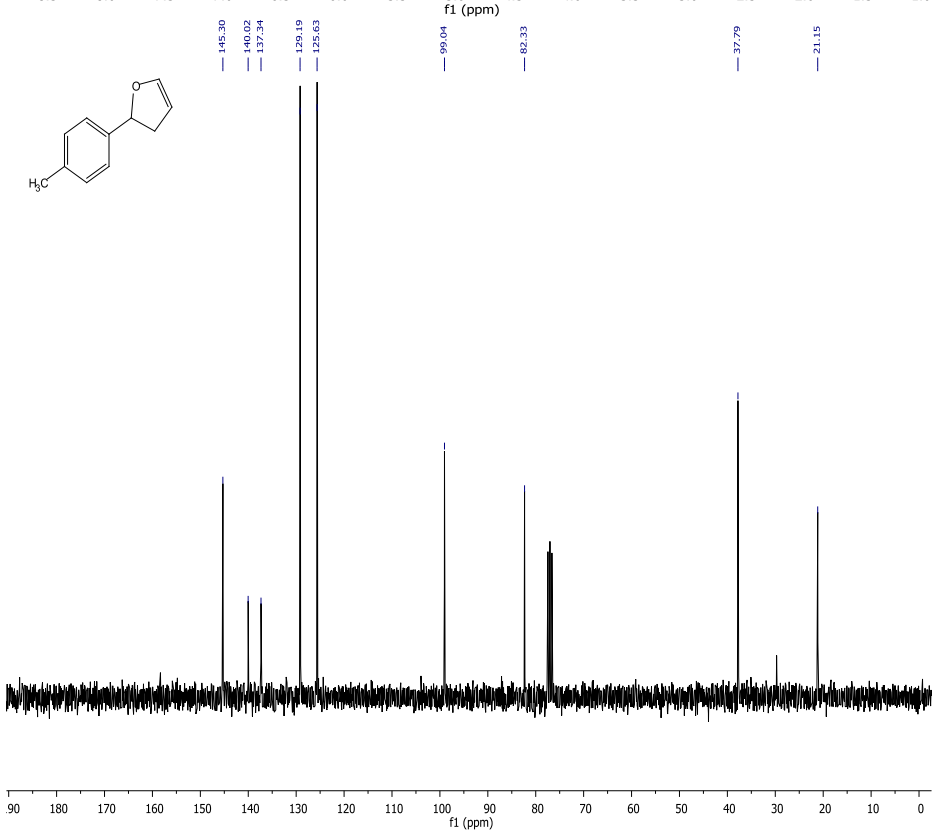
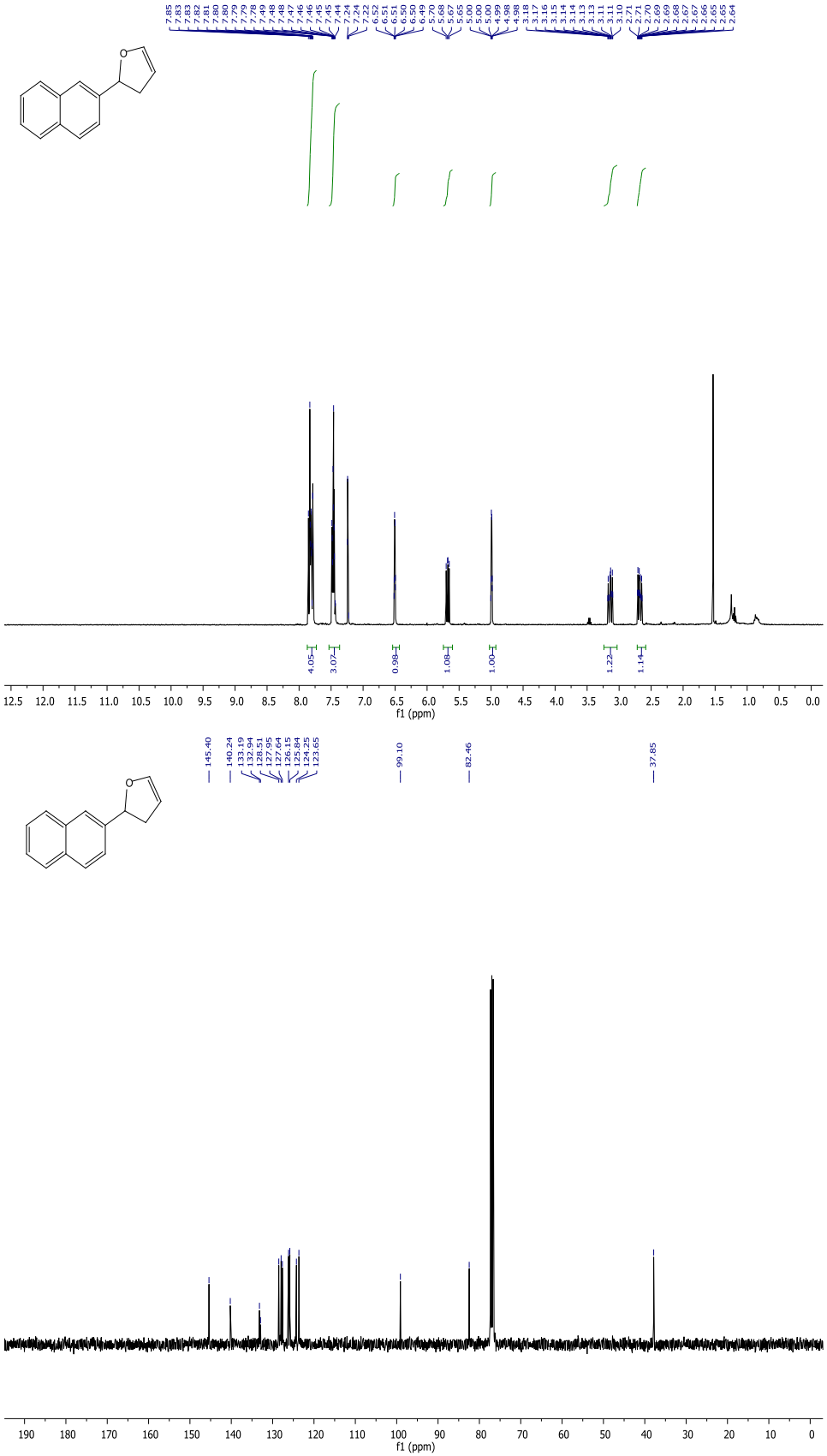
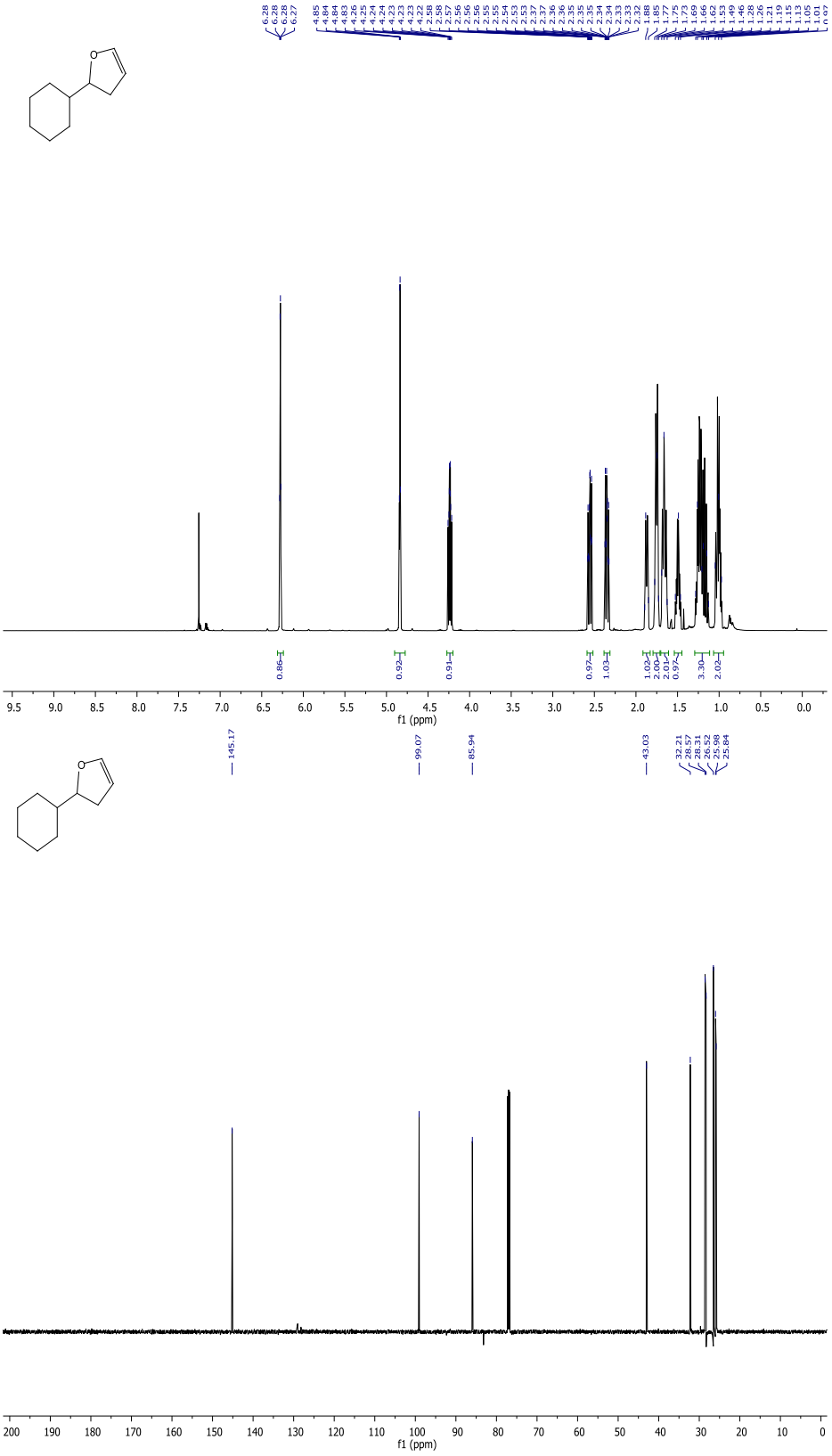
2.62
2.62
2.61
2.60
2.59
2.58
2.57
2.36
O
H3C
1.98
1.96
0.87
0.92
0.92
1.05
1.06
3.25
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


145.30
140.02
137.34
129.19
125.63
99.04
82.33
37.79
21.15
O
H3C
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

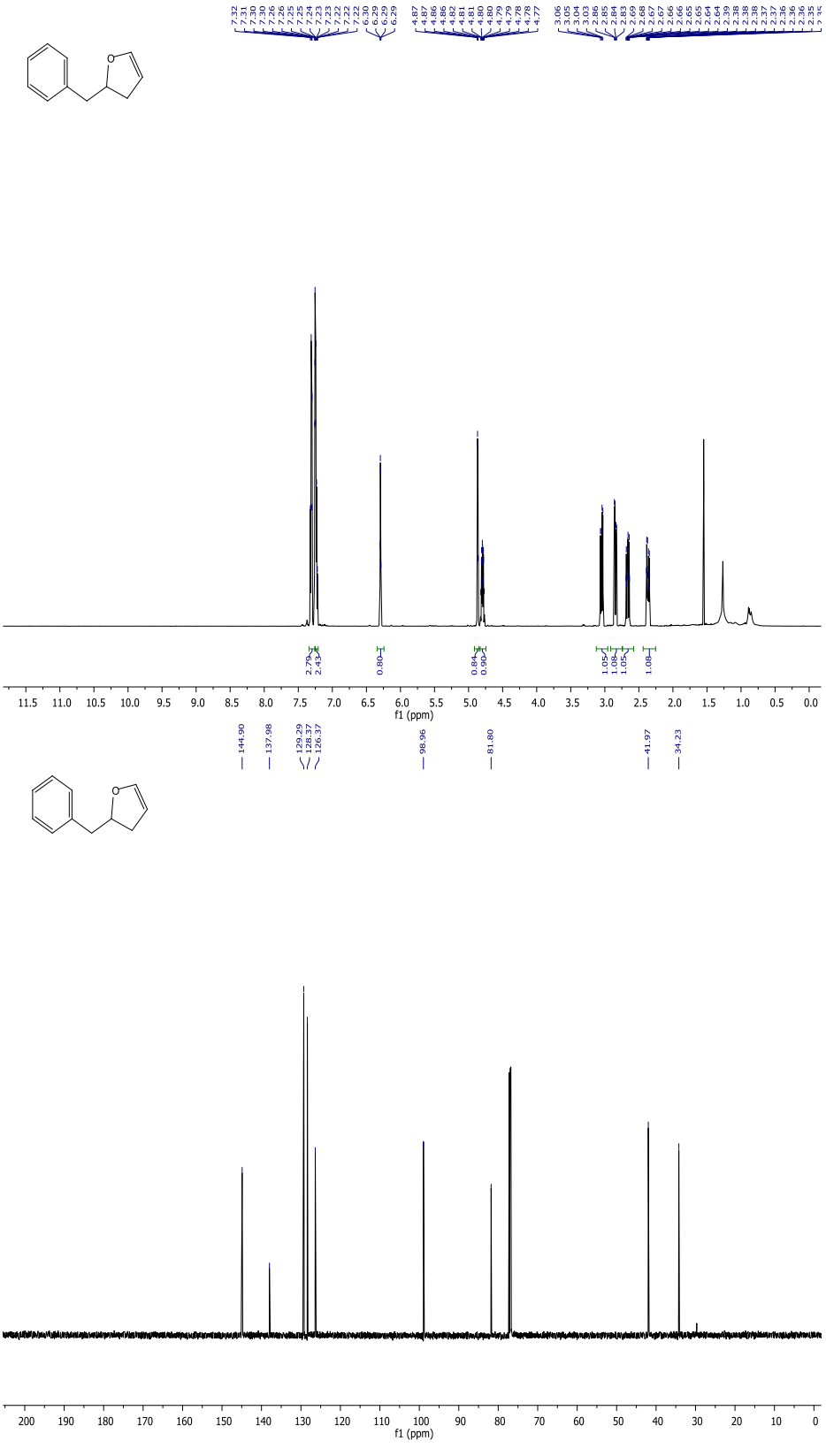
2-(Naphthalen-2-yl)-2,3-dihydrofuran (4h)



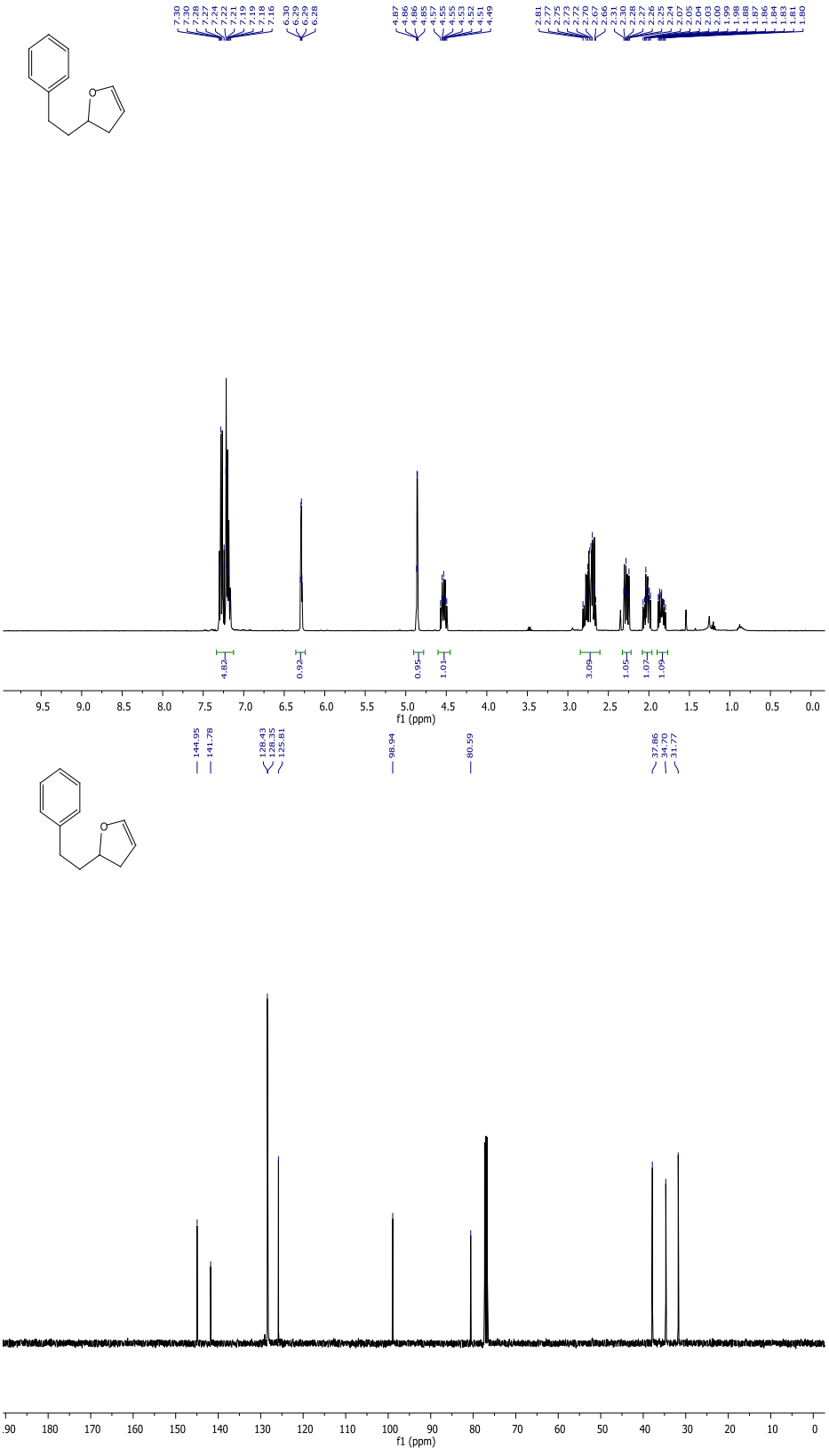
2-Cyclohexyl-2,3-dihydrofuran (4i)



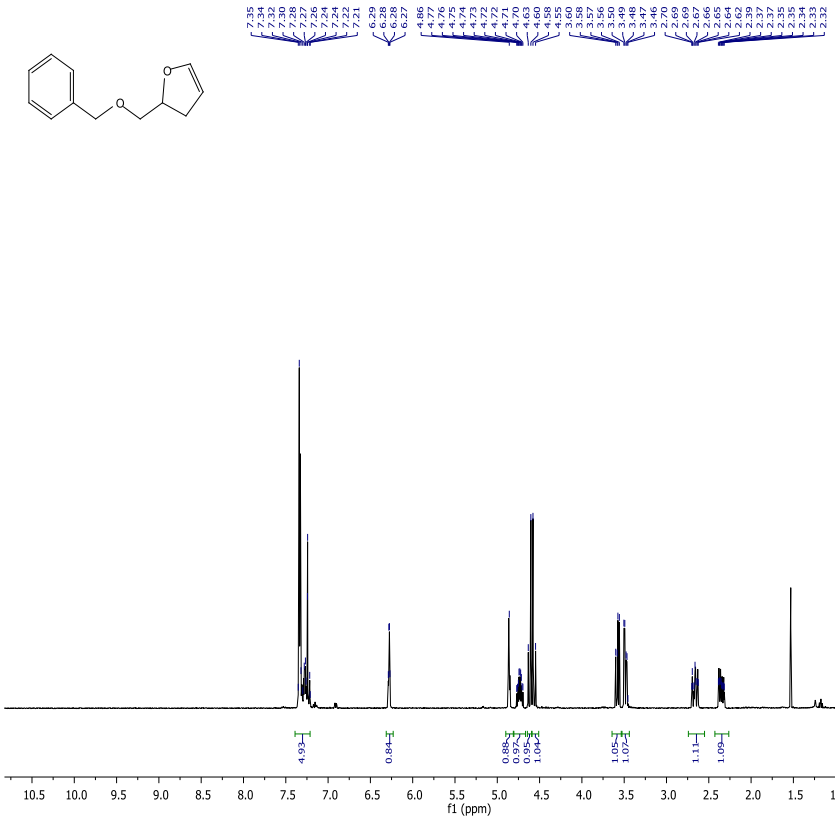
2-Benzyl-2,3-dihydrofuran (4j)



2-Phenethyl-2,3-dihydrofuran (4k)



2-((Benzyloxy)methyl)-2,3-dihydrofuran (4l)


7.35
7.34
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7.30
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7.26
7.24
7.24
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6.28
6.27
4.86
4.77
4.76
4.75
4.74
4.73
4.72
4.72
4.71
4.70
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4.60
4.58
4.55
3.60
3.58
3.57
3.56
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3.48
3.47
3.46
2.70
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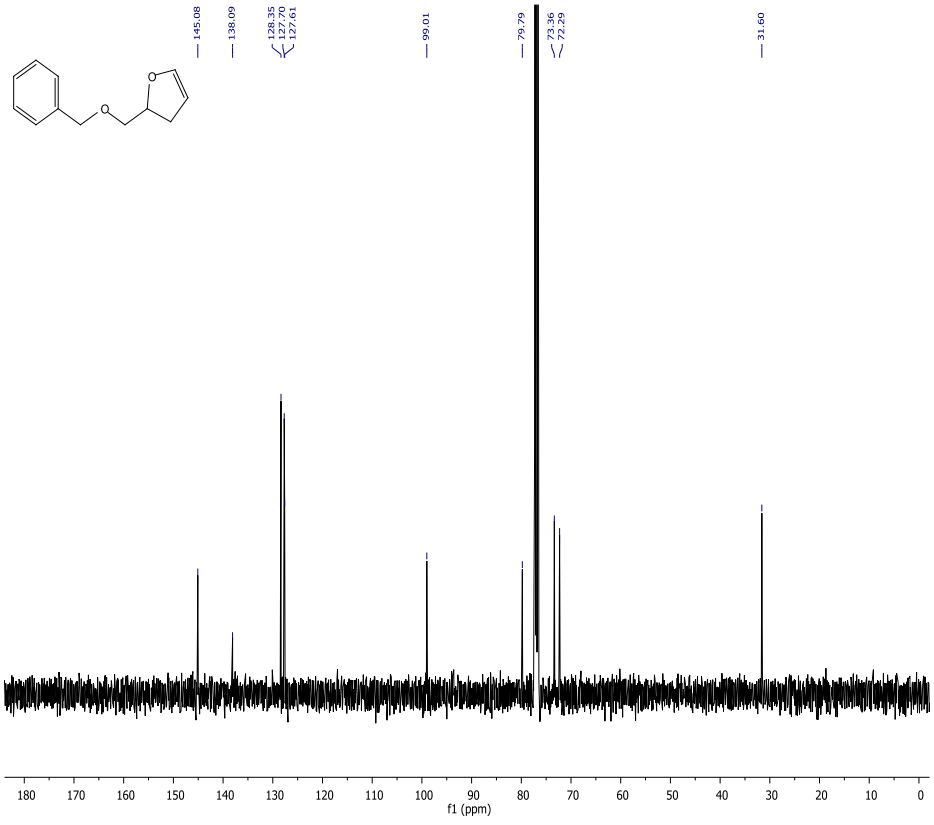
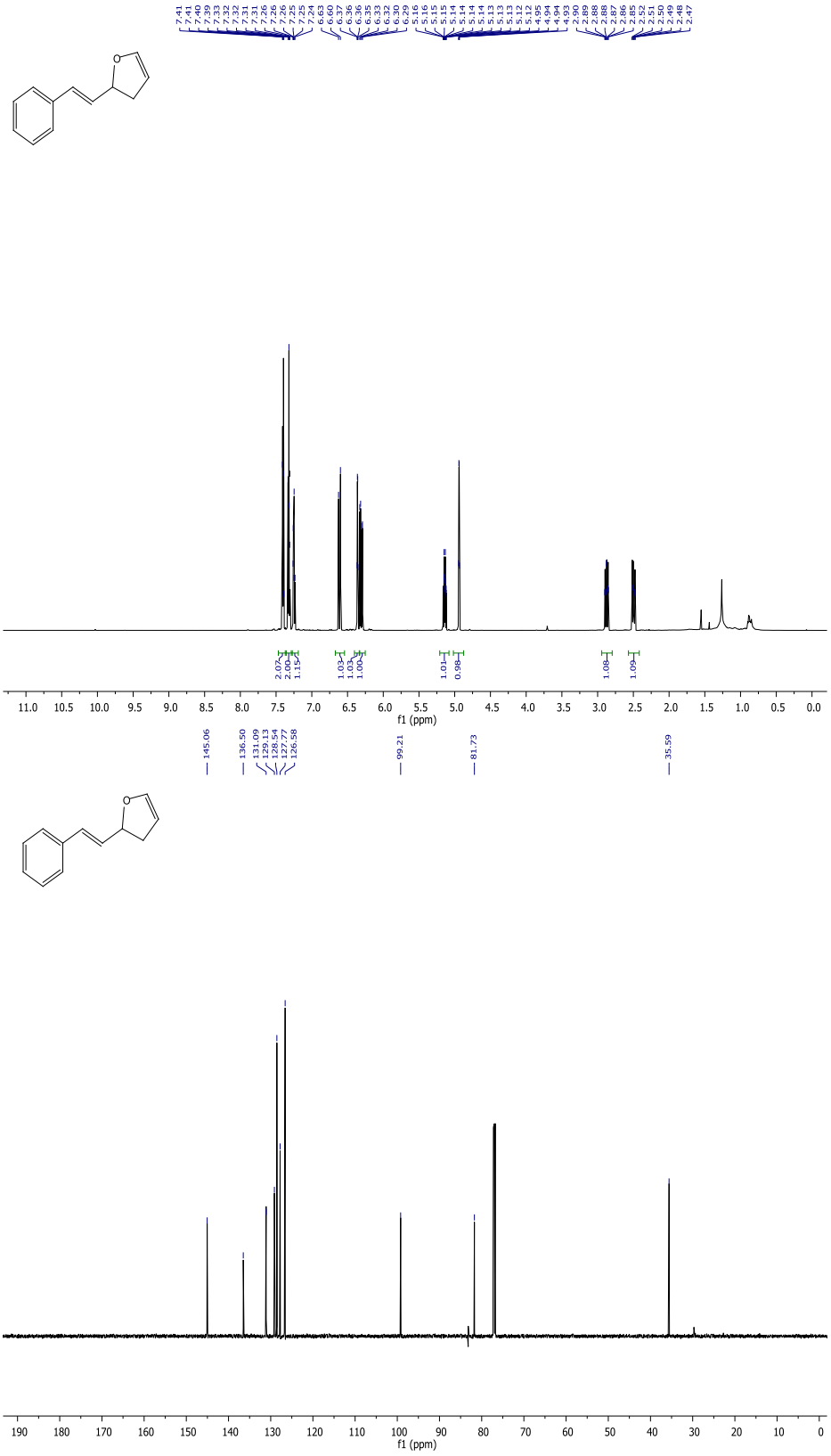
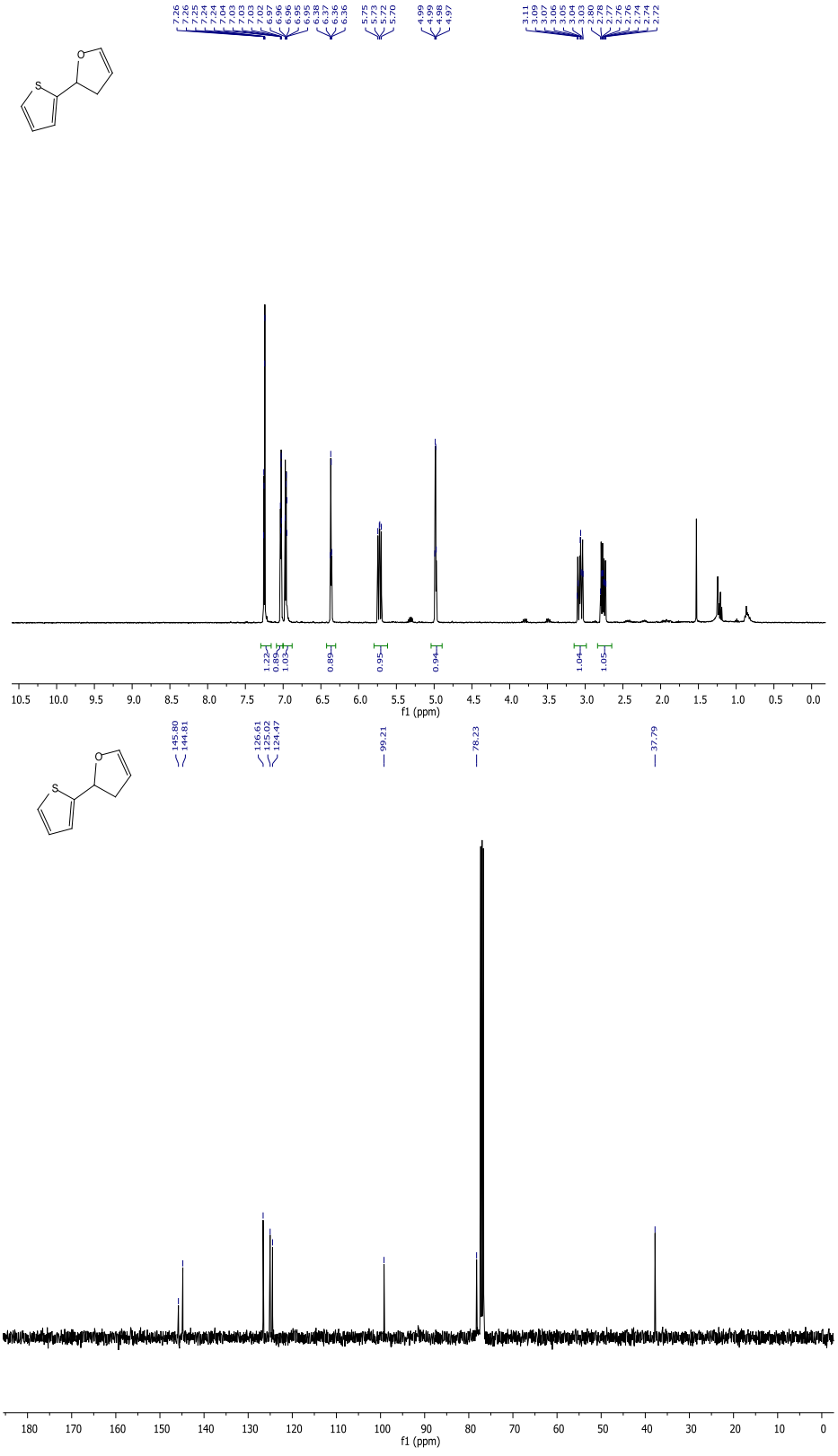
2.67
2.66
2.65
2.64
2.62
2.39
2.37
2.35
2.35
2.34
2.33
2.32
4.93
0.84
0.88
0.97
0.95
1.04
1.05
1.07
1.11
1.09
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


145.08
138.09
128.35
127.70
127.61
99.01
79.79
73.36
72.29
31.60
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

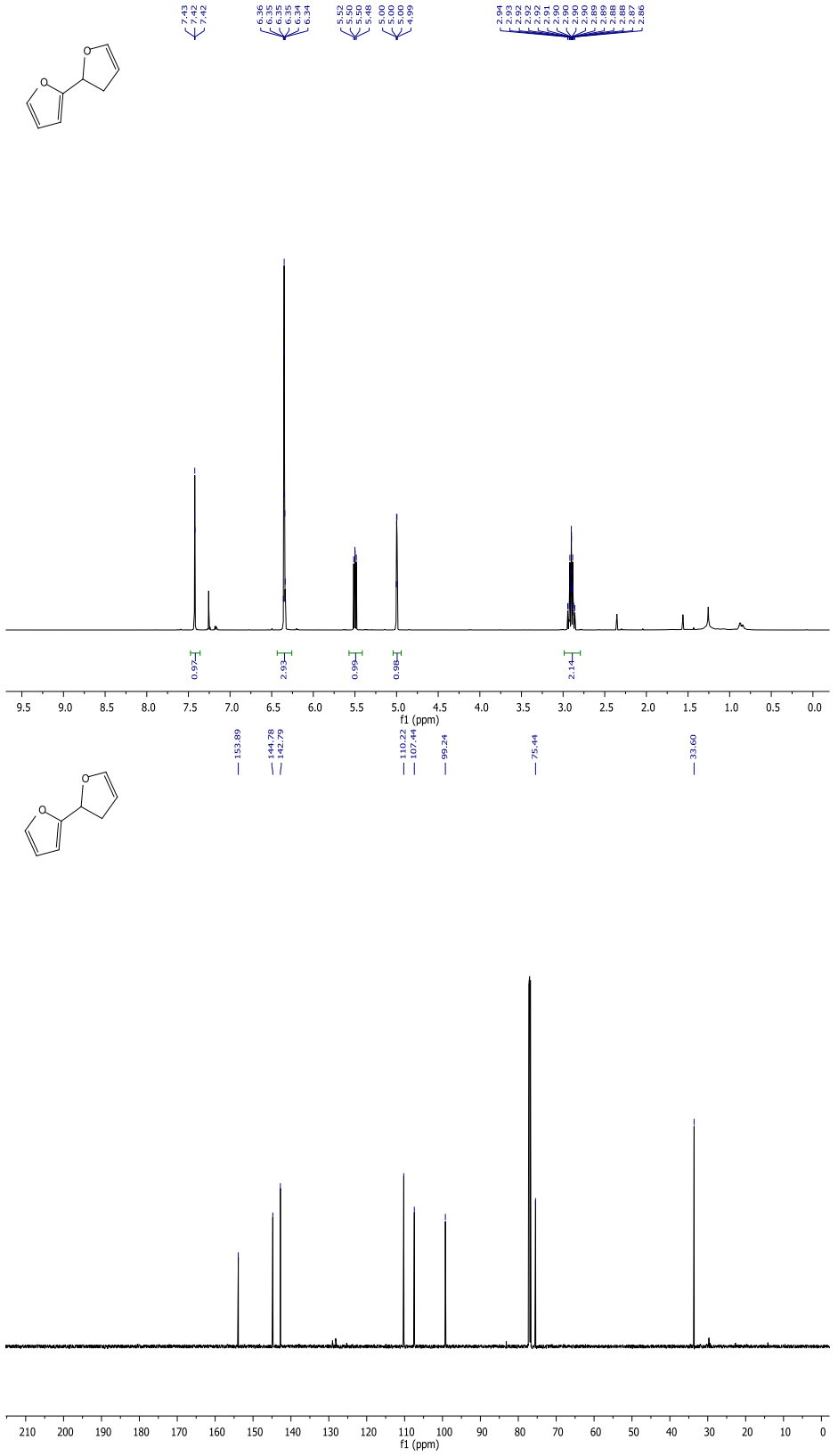
(E)-2-styryl-2,3-dihydrofuran (4m)



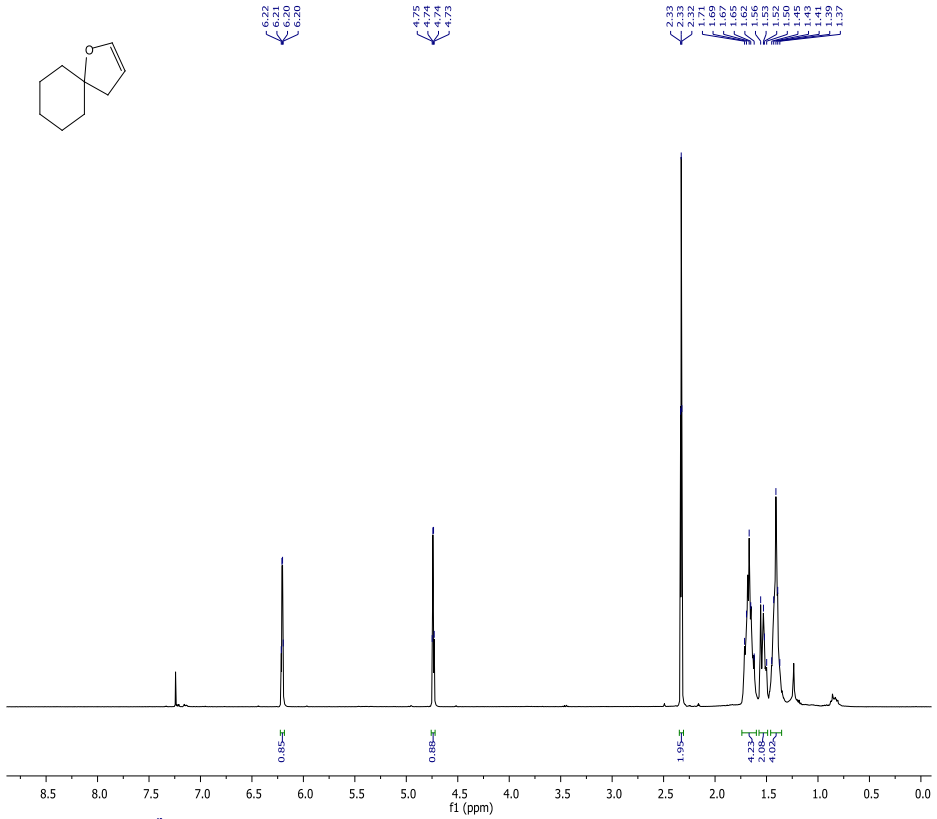
2-(Thiophen-2-yl)-2,3-dihydrofuran (4n)

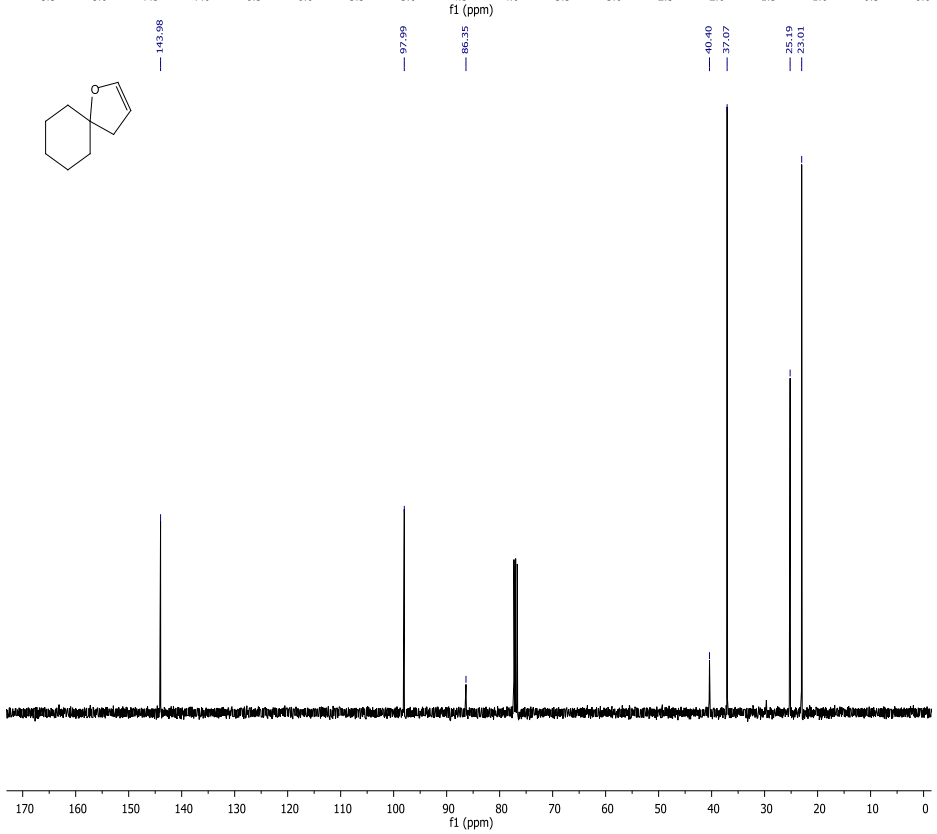


2,3-Dihydro-2,2'-bifuran (4o)

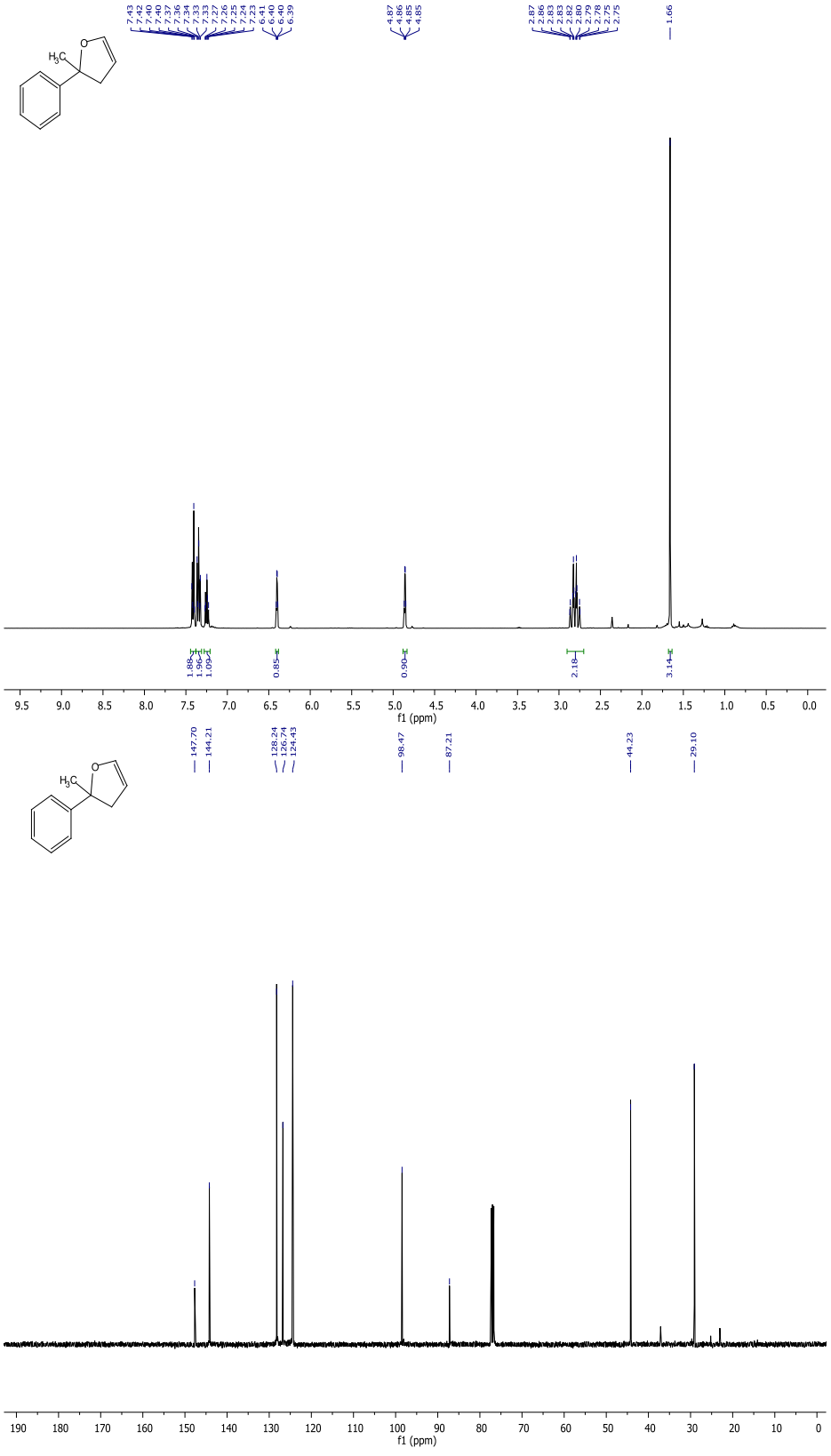


1-Oxaspiro[4.5]dec-2-ene (4p)





2-Methyl-2-phenyl-2,3-dihydrofuran (4q)



(2S,3S)-3-methyl-2-phenyl-2,3-dihydrofuran (4r)