A Chemoselective Electrochemical Birch Carboxylation of Pyridines

Supporting Information

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General Considerations

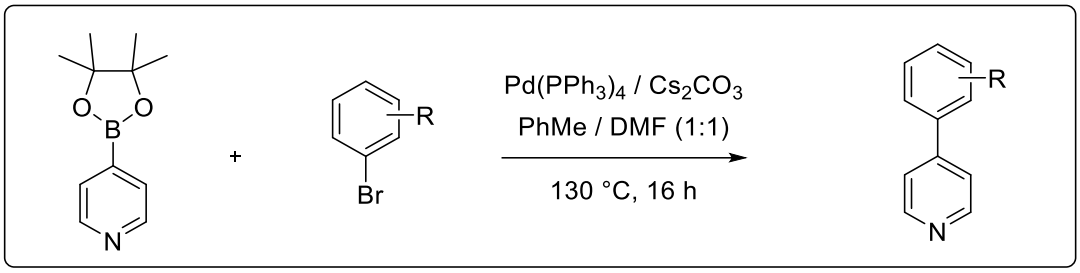
All reactions described were performed at ambient temperature and atmosphere unless otherwise specified. Column chromatography was carried out with 230-400 mesh silica gel (E. Merck, Silica Gel 60). Concentration and removal of trace solvents was done via an IKA rotary evaporator using an IKA RC2 Green Basic circulating cooler and an IKA VacStar pump. Electrochemical reactions were carried on IKA's ElectraSyn 2.0 instrument. Any trace solvents remaining were accounted for in yield calculations. Electrodes were cleaned and polished with sand paper before every reaction.

Nuclear magnetic resonance (NMR) spectra were recorded using deuterochloroform ($CDCl_3$), deuteromethanol (CD_3OD), or deuteroacetone (acetone-d_6) as the solvent. Signal positions (δ) are given in parts per million from tetramethylsilane (δ 0) and were measured relative to the signal of the solvent (^{1}H NMR: $CDCl_3$: δ 7.26; MeOD: δ 3.31; acetone-d6: 2.04; ^{13}C NMR: $CDCl_3$: δ 77.16; acetone-d6: 29.84; MeOD: 49.00). Coupling constants (*J* values) are given in Hertz (Hz) and are reported to the nearest 0.1 Hz. ^{1}H NMR spectral data are tabulated in the order: multiplicity (*s*, singlet; *d*, doublet; *t*, triplet; *q*, quartet; *sept*, septet; *m*, multiplet; *br* broad), coupling constants, number of protons. NMR spectra were recorded on either 400, 500, 600, or 700 MHz spectrometers. 2D NMR experiments such as COSY, HSQC, HMBC, and ROESY were used where necessary

High-resolution mass spectra were recorded using either electron impact (EI), electrospray ionization (ESI) or DART techniques by the mass spec lab at the University of Alberta

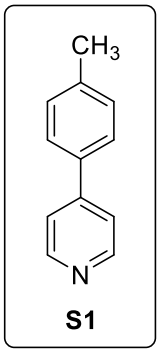
Preparation and Characterization of Starting Materials

General procedure 1 (GP-1): Synthesis of 4-aryl pyridines



4-pyridineboronic acid pinacol ester (1.2 equiv), bromoarene (1 equiv), and Cs_2CO_3 (6.0 equiv) were added to a 1:1 mixture of dry toluene / DMF (0.1 M) which was degassed with argon for 30 min. Subsequently, $Pd(PPh_3)_4$ (0.1 equiv) was added and the mixture was left to stir at 130℃ for 16h. Upon completion, as monitored by TLC analysis, the reaction mixture was cooled to room temperature, filtered through celite, and washed with EtOAc. The organic layers were combined and concentrated under reduced pressure. The crude reaction mixture was re-dissolved in ethyl acetate and washed with water, separated, dried over Na_2SO_4, and concentrated. The crude reaction mixture was then purified using flash chromatography to afford 4-aryl pyridines. If impurities were still present, the purified products were recrystallized in ethyl acetate as noted.

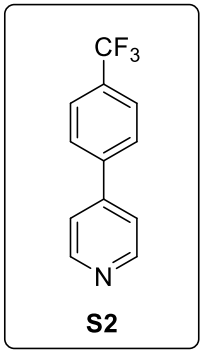
Synthesis of S1



Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.43 g, 7.00 mmol), 4-Bromo toluene (1.00 g, 5.80 mmol), Cs_2CO_3 (12.0 g, 34.8 mmol), $Pd(PPh_3)_4$ (0.670 g, 0.600 mmol) in toluene / DMF (60.0 mL) and purified with flash chromatography (30% EtOAc / hexanes) to afford **S1** as a white solid (0.790 g, 80% yield).

Spectroscopic data was consistent with reported data[1].

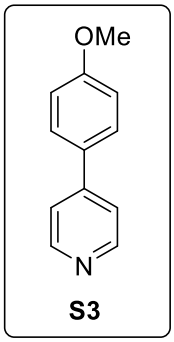
Synthesis of S2



Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.10 g, 5.40 mmol), 1-bromo-4-trifluoromethyl-benzene (1.00 g, 4.50 mmol), Cs_2CO_3 (8.76 g, 26.90 mmol), $Pd(PPh_3)_4$ (0.510 g, 0.450 mmol) in toluene / DMF (45.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S2** as a colourless oil (0.690 g, 70% yield).

Spectroscopic data was consistent with reported data[1].

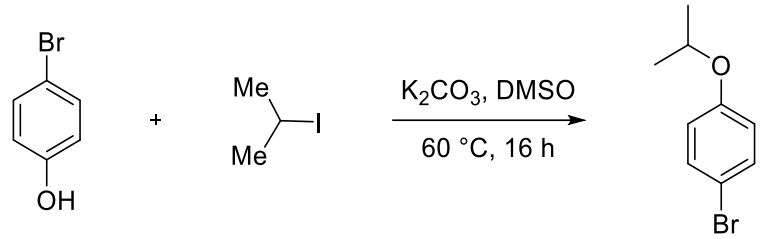
Synthesis of S3



Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.820 g, 4.00 mmol), 1-bromo-4-methoxy-benzene (0.500 g, 2.67 mmol), Cs_2CO_3 (5.20 g, 16.0 mmol), $Pd(PPh_3)_4$ (0.300 g, 0.267 mmol) in toluene / DMF (26.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S3** as a white solid (0.370 g, 75% yield).

Spectroscopic data was consistent with reported data[1].

Synthesis of S4

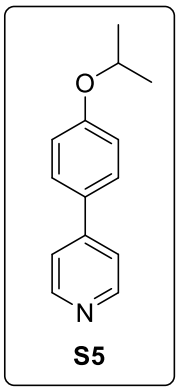


S4

To a round-bottom flask equipped with a stir bar was added 4-bromophenol (1.00 g, 5.80 mmol, 1.00 equiv), potassium carbonate (1.17 g, 8.70 mmol, 1.50 equiv), DMSO (3.00 mL), and 2-iodopropane (0.700 mL, 6.90 mmol, 1.20 equiv) and the reaction mixture was stirred at 60℃ for 16 h. Upon completion, as monitored by TLC analysis, the reaction mixture was quenched with water and extracted with EtOAc. The organic layers were combined, washed with brine, dried with Na_2SO_4, filtered, and concentrated under reduced pressure The crude product was then purified with flash chromatography (5% EtOAc / hexanes) to afford **S4** as a colourless oil (0.710 g, 3.30 mmol, 58% yield)

Spectroscopic data was consistent with reported data[2].

Synthesis of S5



S5

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.00 g, 4.88 mmol), **S4** (0.70 g, 3.25 mmol), Cs_2CO_3 (6.40 g, 19.5 mmol), $Pd(PPh_3)_4$ (0.370 g, 0.320 mmol) in toluene / DMF (32.0 mL) and purified using flash chromatography (40% EtOAc / hexanes) to afford **S5** as a white solid (0.620 g, 90%)

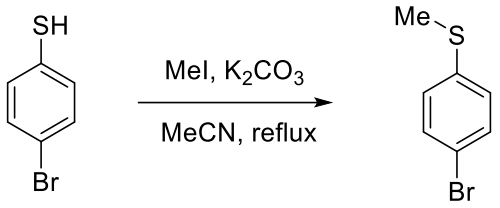
^{1}**H NMR** (400 MHz, $CDCl_3$) δ ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.61 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.65 – 7.52 (m, 2H), 7.46 (dd, *J* = 4.5, 1.7 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 4.61 (m), 1.37 (d, *J* = 6.1 Hz, 6H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 158.93, 150.21, 147.85, 130.03, 128.15, 121.01, 116.26, 70.04, 22.03.

HRMS (ESI): Expected mass [M+H^+]: 214.1226; found: 214.1126.

Melting point = 53 – 56 ℃

Synthesis of S6

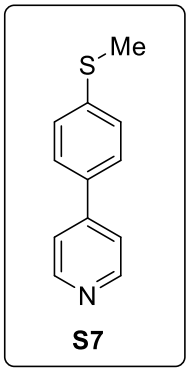


S6

To a solution of 4-bromo-benzenethiol (1.02 g, 5.40 mmol, 1.00 equiv) in dry MeCN (15.0 mL), was added iodomethane (0.600 mL, 10.8 mmol, 2.00 equiv) and K_2CO_3 (1.50 g, 10.8 mmol, 2.00 equiv). The reaction mixture was kept under reflux for 12 h. Upon completion, as monitored by TLC analysis, the reaction mixture was cooled to room temperature and concentrated under reduced pressure. The crude reaction mixture was re-dissolved in EtOAc, washed with water, separated, dried over Na_2SO_4, filtered, and concentrated under reduced pressure to afford **S6** as a colourless oil (0.90 g, 4.6 mmol, 84% yield)

Spectroscopic data was consistent with reported data[3].

Synthesis of S7

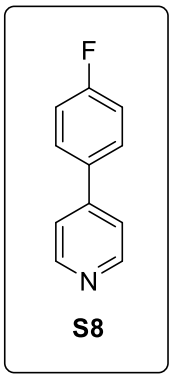


S7

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.43 g, 6.96 mmol), **S6** (0.940 g, 4.65 mmol), Cs_2CO_3 (9.10 g, 27.9 mmol), $Pd(PPh_3)_4$ (0.540 g, 0.470 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S7** as a white solid (0.580 g, 63% yield)

Spectroscopic data was consistent with reported data[4].

Synthesis of S8

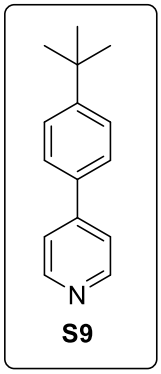


S8

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.880 g, 4.30 mmol), 1-bromo-4-fluoro-benzene (0.500 g, 2.85 mmol), Cs_2CO_3 (5.60 g, 17.2 mmol), $Pd(PPh_3)_4$ (0.330 g, 0.280 mmol) in toluene / DMF (30.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford the title compound as a yellow oil (0.430 g, 87% yield).

Spectroscopic data was consistent with reported data[5].

Synthesis of S9

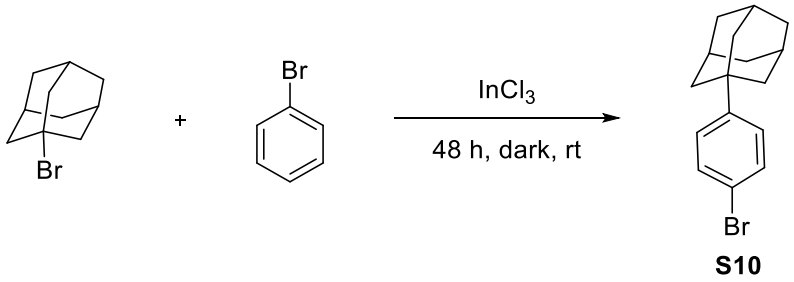


S9

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.40 g, 7.04 mmol), 1-bromo-4-*tert*-butyl-benzene (1.00 g, 4.69 mmol), Cs_2CO_3 (10.0 g, 42.2 mmol), $Pd(PPh_3)_4$ (0.540 g, 0.704 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S9** as a white solid (0.570 g, 57% yield).

Spectroscopic data was consistent with reported data[1].

Synthesis of S10



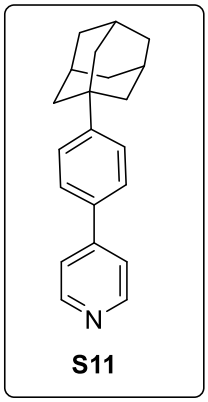
S10

To a round-bottom flask equipped with a stir bar was added 1-bromoadamantane (2.00 g, 9.29 mmol, 1.00 equiv), $InCl_3$ (0.160 g, 0.460 mmol, 0.050 equiv). Bromobenzene (24.0 mL) was then

added and the reaction mixture was left to stir at room temperature for 48 h in the dark. Upon completion, the reaction mixture was concentrated under reduced pressure. The resulting crude reaction mixture was dissolved in 30 mL hexanes washed with saturated $NaHCO_3$ (2x 30 mL) and brine. The organic layer was then separated, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the crude reaction mixture by silica column chromatography (hexanes, 100%) afforded **S10** (1.46 g, 6.87 mmol) in 74% yield as a white solid.

Spectroscopic data was consistent with reported data[6].

Synthesis of S11



S11

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.530 g. 2.58 mmol), 1-(4-bromo-phenyl)-adamantane (0.500 g, 1.72 mmol), Cs_2CO_3 (3.40 g, 10.3 mmol), $Pd(PPh_3)_4$ (0.200 g, 0.172 mmol) in toluene / DMF (17.0 mL) and purified with flash chromatography (30% EtOAc / hexanes) to afford **S11** as a white solid (0.270 g, 55% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 5.9 Hz, 2H), 7.61 (d, *J* = 8.3 Hz, 2H), 7.49 (t, *J* = 6.6 Hz, 4H), 2.13 (s, 3H), 1.96 (d, *J* = 2.0 Hz, 6H), 1.86 – 1.74 (m, 6H).

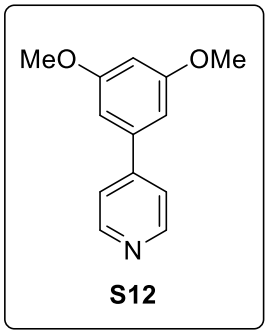
^{13}C NMR (126 MHz**,** $CDCl_3$**)** δ 152.60, 150.23, 148.18, 135.21, 126.71, 125.71, 121.45, 43.13, 36.76, 36.29, 28.92

HRMS (ESI): Expected mass [M+H$^+$]: 290.1903; found: 290.1903

Melting point = 110 – 113℃

Synthesis of S12

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.13 g, 5.52 mmol), 1-bromo-3,5-dimethoxy-benzene (1.00 g, 4.60 mmol), Cs_2CO_3 (9.00 g, 27.6 mmol), $Pd(PPh_3)_4$ (0.530 g, 0.460 mmol) in toluene / DMF (46.0 mL) and purified using flash



S12

chromatography (30% EtOAc / hexanes) as eluent to afford **S12** as a white solid (0.670 g, 67% yield).

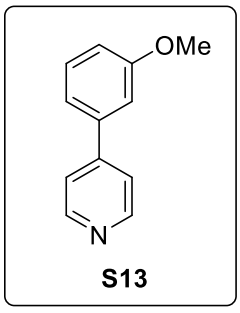
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67 – 8.62 (m, 2H), 7.50 – 7.45 (m, 2H), 6.75 (d, *J* = 2.2 Hz, 2H), 6.54 (t, *J* = 2.1 Hz, 1H), 3.85 (s, 6H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 161.35, 150.25, 148.35, 140.37, 121.74, 105.32, 100.76, 55.51.

HRMS (ESI): Expected mass [M+H$^+$]: 216.1019; found: 216.1018

Melting point = 53℃

Synthesis of S13

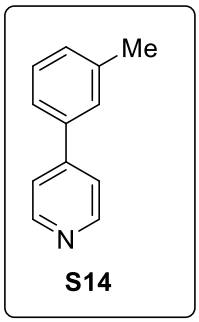


S13

Following GP-1 the compound was synthesized using pyridylboronic pinacol ester (2.60 g, 13.1 mmol), 1-bromo-3-methoxy-benzene (2.00 g, 10.9 mmol), Cs_2CO_3 (20.00 g, 65.5 mmol), $Pd(PPh_3)_4$ (1.20 g, 1.09 mmol) in toluene / DMF (110 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S13** as a colourless oil (1.50 g, 76% yield)

Spectroscopic data was consistent with reported data[1].

Synthesis of S14

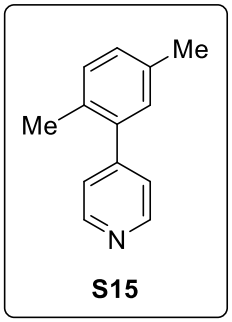


S14

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.90 g, 9.30 mmol), 1-bromo-3-methyl-benzene (1.00 g, 6.20 mmol), Cs_2CO_3 (12.0 g, 37.2 mmol), $Pd(PPh_3)_4$ (0.720 g, 0.620 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S14** as a colourless oil (0.760 g, 77% yield)

Spectroscopic data was consistent with reported data[1].

Synthesis of S15



S15

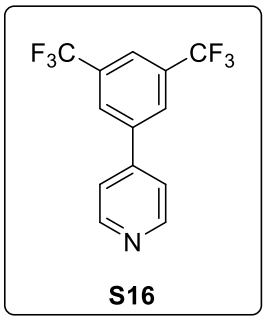
Following GP-1 the compound was synthesized using pyridylboronic pinacol ester (1.40 g, 6.48 mmol), 2-bromo-1,4-dimethyl-benzene (1.00 g, 5.40 mmol), Cs_2CO_3 (11.00 g, 32.40 mmol), $Pd(PPh_3)_4$ (0.620 g, 0.540 mmol) in toluene / DMF (54.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) as eluent to afford **S15** as a yellow oil (0.942 g, 95% yield)

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.62 (dd, *J* = 4.4, 1.7 Hz, 2H), 7.21 (dd, *J* = 4.4, 1.7 Hz, 2H), 7.16 (d, *J* = 7.8 Hz, 1H), 7.10 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.01 (s, 1H), 2.33 (s, 3H), 2.21 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 149.90, 149.60, 138.93, 135.59, 131.80, 130.63, 129.93, 129.10, 124.23, 20.89, 19.75

HRMS (ESI): Expected mass [M+H$^+$]: 183.112; found: 183.1121

Synthesis of S16



S16

Following GP-1 the compound was synthesized using pyridylboronic pinacol ester (0.43 g, 2.10 mmol), 1-bromo-3,5-bis-trifluoromethyl-benzene (0.500 g, 1.71 mmol), Cs_2CO_3 (3.40 g, 10.23 mmol), $Pd(PPh_3)_4$ (0.200 g, 0.171 mmol) in toluene / DMF (17.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S16** as a white solid (0.265 g, 54% yield)

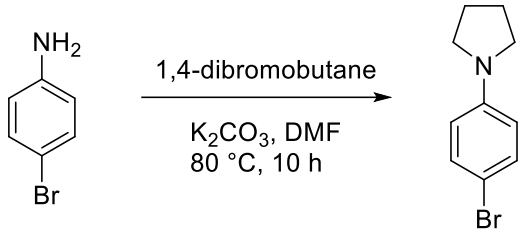
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.76 (d, *J* = 5.7 Hz, 2H), 8.05 (s, 2H), 7.95 (s, 1H), 7.53 (dd, *J* = 4.5, 1.6 Hz, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 150.8, 145.3, 140.48, 132.67 (q, *J* = 33.58 Hz), 127.21, 123.10 (q, *J* = 272.88 Hz), 122.65 (m), 121.59.

HRMS (ESI): Expected mass [M+H$^+$]: 292.0555; found: 292.0555

Melting point = 109 – 111℃

Synthesis of S17

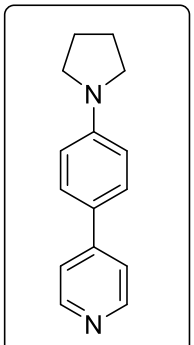


S17

To a suspension of 4-bromo-phenylamine (1.00 g, 5.74 mmol, 1.00 equiv) in DMF (6.00 mL) was added K_2CO_3 (0.870 g, 6.30 mmol, 1.10 equiv) The reaction mixture was then degassed with argon for 15 mins. 1,4-dibromobutane (0.750 mL, 6.30 mmol, 1.10 equiv) was added to the suspension and the reaction mixture was left to stir at 80℃ for 10 h. After completion, the reaction was cooled to room temperature and diluted with EtOAc and water. The organic layer was separated and washed with 1M HCl. The acid layers were combined and the pH was adjusted to 8 by adding 1M NaOH and then extracted with EtOAc. The organic layers were combined, dried with Na_2SO_4 and concentrated under reduced pressure. The crude product was purified with flash chromatography (100% hexanes) to obtain **S17** as a white solid (0.700 g, 3.12 mmol, 53% yield).

Spectroscopic data was consistent with reported data[7].

Synthesis of S18



S18

Following GP-1 the compound was synthesized using pyridylboronic pinacol ester (0.270 g, 1.34 mmol, 1.50 equiv), **S17** (0.200 g, 0.900 mmol, 1.00 equiv), Cs_2CO_3 (1.74 g, 5.34 mmol, 6.00 equiv), $Pd(PPh_3)_4$ (0.104 g, 0.090 mmol, 10 mol%) in toluene / DMF (16.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S18** as a light yellow solid (0.054 g, 27% yield).

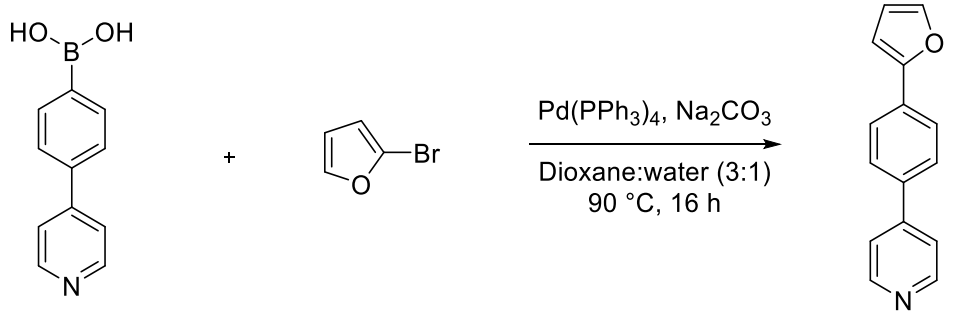
^{1}H NMR (700 MHz, $CDCl_3$) δ 8.59 – 8.45 (m, 2H), 7.61 – 7.50 (m, 2H), 7.46 (dd, *J* = 4.6, 1.6 Hz, 2H), 6.69 – 6.55 (m, 2H), 3.41 – 3.28 (m, 4H), 2.09 – 1.94 (m, 4H).

^{13}C NMR (176 MHz, $CDCl_3$) δ 149.99, 148.53, 148.21, 127.65, 124.07, 120.12, 111.95, 47.56, 25.47.

HRMS (ESI): Expected mass [M+H$^+$]: 225.1386; found: 225.1383

Melting point = 73 – 74℃

Synthesis of S19



S19

A solution of 4-(pyridin-4-yl)phenyl boronic acid (0.200 g, 2.04 mmol, 1.50 equiv) in dioxane (12.0 mL) and water (4.00 mL) was degassed for 15 mins. To the solution was added 2-bromofuran (0.200 g, 1.36 mmol, 1.00 equiv), $Pd(PPh_3)_4$ (0.080 g, 0.060 mmol, 0.050 equiv) and Na_2CO_3 (0.4300 g, 4.08 mmol, 3.00 equiv) and left to stir at 90℃ for 16 h. On completion, the reaction was quenched with water and extracted with EtOAc. The combined organic layers were dried with Na_2SO_4 and evaporated under reduced pressure to afford **S19** as a light-yellow solid (0.250 g, 1.13 mmol, 83% yield)

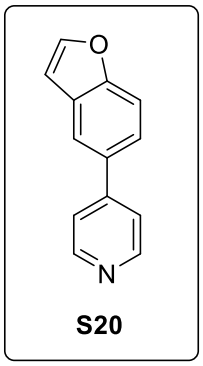
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.65 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.78 – 7.74 (m, 2H), 7.67 – 7.63 (m, 2H), 7.51 – 7.49 (m, 3H), 6.72 (dd, *J* = 3.4, 0.5 Hz, 1H), 6.50 (dd, *J* = 3.4, 1.8 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 153.23, 150.32, 147.62, 142.63, 136.63, 131.56, 127.27, 124.39, 121.26, 111.91, 106.02

HRMS (ESI): Expected mass [M+H$^+$]: 222.0913; found: 222.0913

Melting point = 167 ℃

Synthesis of S20



S20

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.26 g, 6.1 mmol), 5-bromo-benzofuran (1.00 g, 5.10 mmol), Cs_2CO_3 (10.0 g, 30.6 mmol), $Pd(PPh_3)_4$ (0.5900 g, 0.510 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) as eluent to afford **S20** as a white solid (0.770 g, 78%).

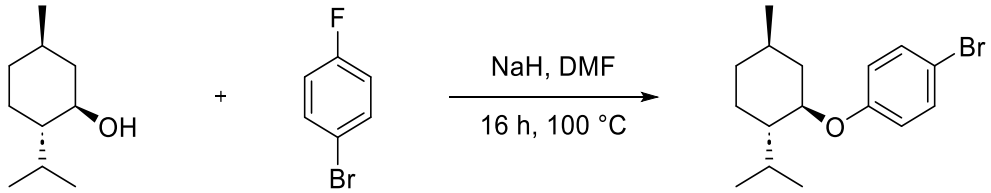
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.66 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.87 (dd, *J* = 1.8, 0.6 Hz, 1H), 7.69 (d, *J* = 2.2 Hz, 1H), 7.63 – 7.60 (m, 1H), 7.57 (dd, *J* = 8.6, 1.8 Hz, 1H), 7.54 (dd, *J* = 4.5, 1.7 Hz, 2H), 6.85 (dd, *J* = 2.2, 0.8 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 155.42, 150.25, 148.79, 146.07, 133.33, 128.27, 123.58, 121.93, 119.91, 112.03, 106.84

HRMS (ESI): Expected mass [M+H$^+$]: 196.0757; found: 196.0757

Melting point = 83 – 85 ℃

Synthesis of S21



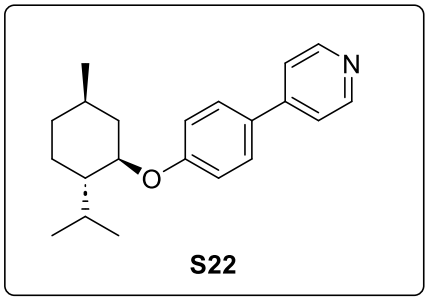
S21

To a solution of (L)-menthol (0.200 g, 1.26 mmol, 1.10 equiv), in DMF (2.00 mL), was added NaH (0.110 g of a 60% w/w dispersion in mineral oil, 2.80 mmol, 2.00 equiv) and left to stir for 30 mins at rt. 1-bromo-4-fluorobenzene (0.130 mL, 1.40 mmol, 1.20 equiv) was added to the mixture and left to stir at 100 ℃ for 16 h. On completion, the reaction was quenched with saturated NH_4Cl solution and extracted with EtOAc. The organic layers were combined and dried with Na_2SO_4 and

evaporated under reduced pressure to get the crude product which was purified using flash chromatography (100% hexanes) to afford **S21** as a colourless oil (0.300 g, 76% yield).

Spectroscopic data was consistent with reported data[2].

Synthesis of S22



S22

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.99 g, 4.80 mmol), **S22** (1.00 g, 3.30 mmol), Cs_2CO_3 (6.30 g, 19.3 mmol), $Pd(PPh_3)_4$ (0.380 g, 0.330 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) to afford **S22** as a white solid (0.840 g, 85% yield).

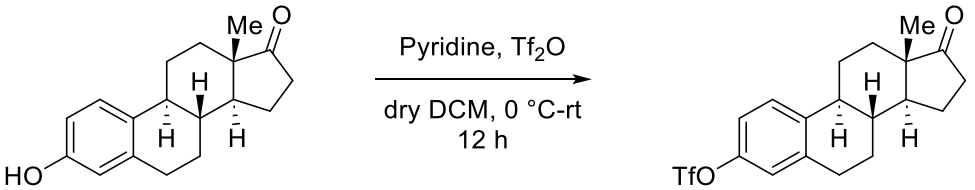
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.63 – 7.49 (m, 2H), 7.46 (dd, *J* = 4.5, 1.7 Hz, 2H), 7.09 – 6.79 (m, 2H), 4.11 (m, 1H), 2.34 – 2.05 (m, 2H), 1.83 – 1.68 (m, 2H), 1.61 – 1.38 (m, 2H), 1.19 – 0.95 (m, 3H), 0.94 (dd, *J* = 6.8, 1.9 Hz, 6H), 0.79 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 159.44, 150.20, 147.89, 129.95, 128.21, 121.00, 116.13, 48.04, 40.24, 34.49, 31.46, 26.20, 23.81, 22.15, 20.74, 16.68

HRMS (ESI): Expected mass [M+H$^+$]: 310.2165; found: 310.2163

Melting point = 139 – 140 ℃

Synthesis of S23



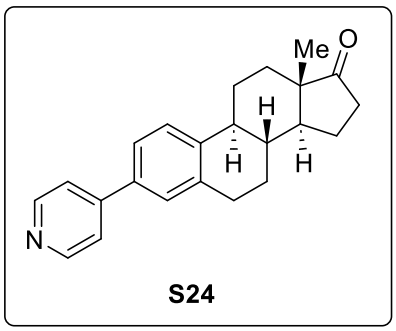
S23

To a solution of estrone (1.00 g, 3.70 mmol, 1.00 equiv) in dry DCM, pyridine (0.900 mL, 11.1 mmol, 3.00 equiv) was added at 0 ℃. The resulting solution was left to stir at 0 ℃ for 30 mins under argon atmosphere. Trifluoromethanesulfonic anhydride (0.740 mL, 4.400 mmol, 1.20 equiv) was

added dropwise into the solution and the solution was warmed to rt and left to stir for 12 h. Upon completion, as monitored by TLC, the reaction was quenched with water and extracted with Et_2O. The organic layers were combined, dried with Na_2SO_4, filtered, and evaporated under reduced pressure to obtain the crude product which was purified using flash chromatography (10% EtOAc / hexanes) to afford **S23** as a white solid (0.980 g, 65% yield).

Spectroscopic data was consistent with reported data[8].

Synthesis of S24



S24

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.920 g, 4.50 mmol), **S23** (1.50 g, 3.74 mmol), Cs_2CO_3 (7.30 g, 22.4 mmol), $Pd(PPh_3)_4$ (0.430 g, 0.374 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (50% EtOAc / hexanes) to afford **S24** as a white solid (0.980 g, 66%).

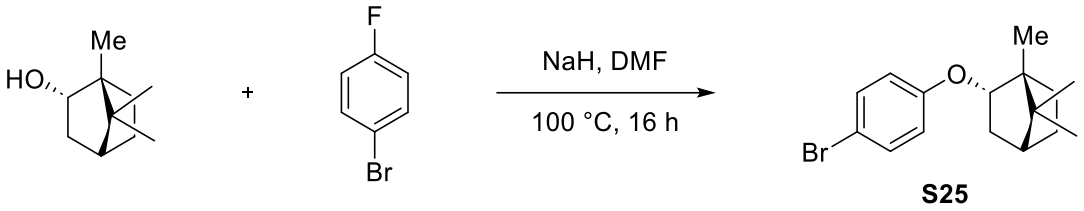
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 6.1 Hz, 2H), 7.57 – 7.33 (m, 5H), 3.09 – 2.92 (m, 2H), 2.62 – 2.29 (m, 3H), 2.25 – 1.93 (m, 4H), 1.78 – 1.38 (m, 6H), 0.93 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 220.58, 150.23, 148.12, 141.02, 137.40, 135.65, 127.56, 126.23, 124.34, 121.45, 50.54, 47.97, 44.45, 38.11, 35.86, 31.62, 29.52, 26.45, 25.75, 21.63, 13.87

HRMS (ESI): Expected mass [M+H$^+$]: 332.2009; found: 332.2008

Melting point = 201 – 203 ℃

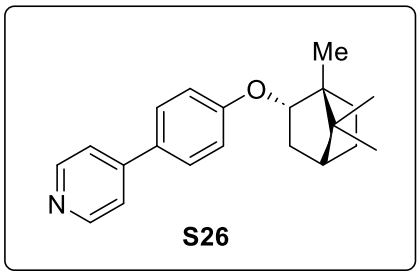
Synthesis of S25



To a solution of (-)-borneol (1.00 g, 6.50 mmol, 1.10 equiv), in DMF (12.0 mL), was added NaH (0.660 g of a 60% w/w dispersion in mineral oil, 11.80 mmol, 2.00 equiv) and left to stir for 30 mins at rt. 1-bromo-4-fluorobenzene (0.640 mL, 5.90 mmol, 1.00 equiv) was added to the mixture and left to stir at 100℃ for 16 h. On completion, the reaction was quenched with saturated NH_4Cl solution and extracted with EtOAc. The organic layers were combined and dried with Na_2SO_4 and evaporated under reduced pressure to get the crude product which was purified using flash chromatography (100% hexanes) to get **S25** as a white solid (1.10 g, 62% yield).

Spectroscopic data was consistent with reported data[8].

Synthesis of S26



Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (0.770 g, 3.90 mmol), **S25** (1.00 g, 3.24 mmol), Cs_2CO_3 (6.40 g, 19.4 mmol), $Pd(PPh_3)_4$ (0.370 g, 0.320 mmol) in toluene / DMF (60.0 mL) and purified using flash chromatography (30% EtOAc / hexanes) as to afford **S26** as a white solid (0.650 g, 65% yield).

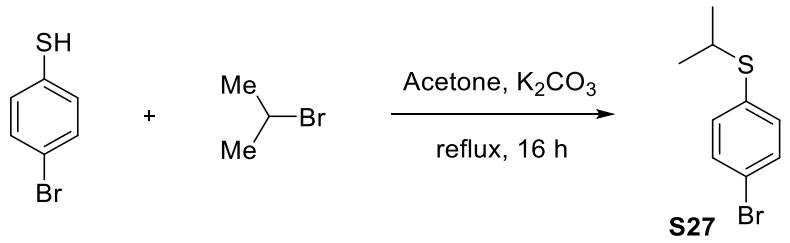
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60 (dd, *J* = 4.6, 1.5 Hz, 2H), 7.57 (d, *J* = 8.7 Hz, 2H), 7.45 (dd, *J* = 4.6, 1.5 Hz, 2H), 6.94 (d, *J* = 8.7 Hz, 2H), 4.43 – 4.33 (m, 1H), 2.52 – 2.16 (m, 2H), 1.86 – 1.69 (m, 2H), 1.44 – 1.07 (m, 3H), 1.02 – 0.87 (m, 9H)

^{13}C NMR (126 MHz, $CDCl_3$) δ 160.18, 150.20, 147.93, 129.80, 128.05, 121.00, 116.01, 83.11, 49.59, 47.67, 45.19, 36.83, 27.97, 26.80, 19.75, 19.00, 13.78.

HRMS (ESI): Expected mass [M+H$^+$]: 308.2009; found: 308.2009

Melting point = 132 ℃

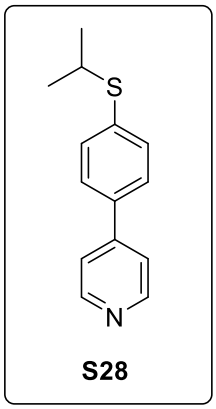
Synthesis of S27



To a solution of 4-bromo-benzenethiol (1.50 g, 7.90 mmol, 1.00 equiv) in anhydrous acetone (24.0 mL) was added K_2CO_3 (1.50 g, 11.0 mmol, 1.40 equiv) and 2-bromopropane (0.900 mL, 9.48 mmol, 1.20 equiv) under argon atmosphere. The reaction mixture was left under reflux for 16 h. After completion, the reaction mixture was cooled down and the acetone was evaporated under reduced pressure to afford crude **S27**. The crude product was dissolved in Et_2O and washed with water. The combined organic layers were dried using Na_2SO_4, filtered, and evaporated to obtain **S27** as a colourless oil (1.63 g, 88% yield)

Spectroscopic data was consistent with reported data[9].

Synthesis of S28



Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.10 g, 5.24 mmol), **S27** (1.00 g. 4.40 mmol), Cs_2CO_3 (8.60 g, 26.2 mmol), $Pd(PPh_3)_4$ (0.510 g, 0.440 mmol) in toluene / DMF (44.0 mL) and purified using flash chromatography (50% EtOAc / hexanes) to afforded **S28** as a yellow solid (0.950 g, 95% yield).

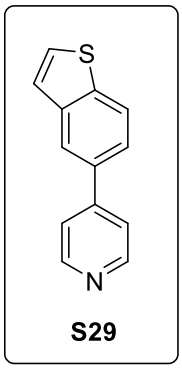
^{1}H NMR (400 MHz, $CDCl_3$**)** δ 8.64 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.62 – 7.51 (m, 2H), 7.53 – 7.39 (m, 4H), 3.53 – 3.38 (m, 1H), 1.34 (d, *J* = 6.7 Hz, 6H)

^{13}C NMR (176 MHz, $CDCl_3$) δ 150.28, 147.52, 137.60, 135.90, 131.32, 127.21, 121.24, 37.77, 23.06.

HRMS (ESI): Expected mass [M+H$^+$]: 230.0995; found: 230.0998

Melting point = 55 ℃

Synthesis of S29



S29

Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.20 g, 5.63 mmol), 5-bromo-benzo[b]thiophene (1.00 g, 4.70 mmol), Cs_2CO_3 (9.20 g, 28.2 mmol), $Pd(PPh_3)_4$ (0.540 g, 0.470 mmol) in toluene / DMF (48.0 mL) and purified using flash chromatography (50% EtOAc / hexanes) to afford **S29** as a white solid (0.940 g, 95% yield).

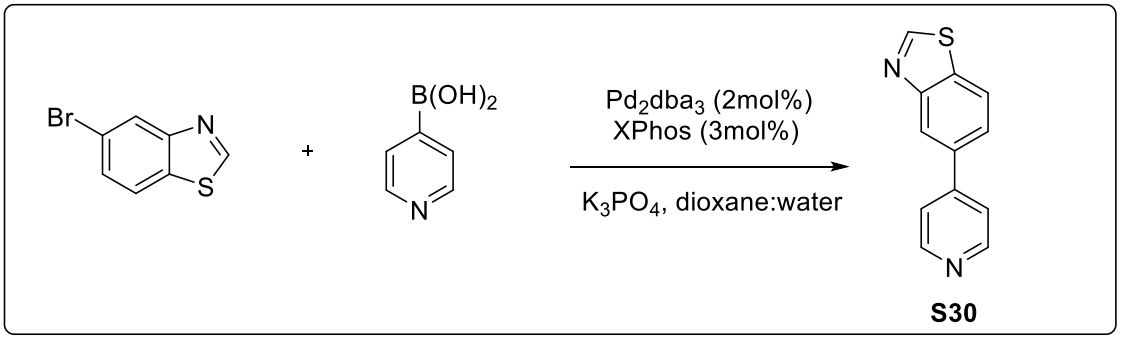
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (dd, *J* = 4.5, 1.6 Hz, 2H), 8.09 (d, *J* = 1.6 Hz, 1H), 7.99 (d, *J* = 8.4 Hz, 1H), 7.62 (dd, *J* = 8.4, 1.7 Hz, 1H), 7.58 (dd, *J* = 4.5, 1.7 Hz, 2H), 7.53 (d, *J* = 5.4 Hz, 1H), 7.42 (dd, *J* = 5.4, 0.6 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 150.31, 148.55, 140.48, 140.28, 134.55, 127.72, 124.09, 123.20, 123.15, 122.09, 121.87.

HRMS (ESI): Expected mass [M+H$^+$]: 212.0527; found: 212.0528

Melting point = 123 – 127 ℃

Synthesis of S30



S30

In a RB flask equipped with a stir bar was added dioxane (3.00 mL) and water (1.00 mL), Pd_2dba_3 (0.090 g, 0.0093 mmol, 2 mol%) and XPhos (0.007 g, 0.0141 mmol, 3 mol%) was added to it and stir at RT for 1 h. After 1 h, 5-bromo-benzothiazole (0.100 g, 0.470 mmol, 1.00 equiv), 4-pyridineboronic acid pinacol ester (0.087 g, 0.705 mmol, 1.50 equiv), and K_3PO_4 (0.200 g, 0.940

mmol, 2.00 equiv) was added to the solution and stirred at 100℃ for 12 h. After completion, reaction was cooled down, quenched with water, and extracted with EtOAc. The organic layers were combined and evaporated under vacuum to obtain crude **S30** which was purified using flash chromatography (70% EtOAc / hexanes) to afford **S30** as a white solid (0.090 g, 90% yield).

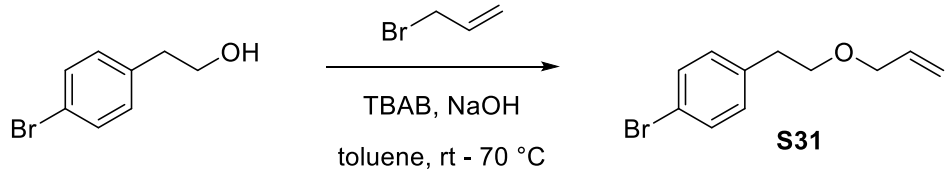
^{1}H NMR (600 MHz, $CDCl_3$) δ 9.04 (s, 1H), 8.68 (dd, *J* = 4.6, 1.4 Hz, 2H), 8.38 (d, *J* = 1.6 Hz, 1H), 8.03 (d, *J* = 8.3 Hz, 1H), 7.68 (dd, *J* = 8.3, 1.7 Hz, 1H), 7.56 (dd, *J* = 4.6, 1.6 Hz, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 155.18, 154.02, 150.44, 147.72, 136.67, 134.48, 124.44, 122.57, 122.01, 121.83.

HRMS (ESI): Expected mass [M+H$^+$]: 213.0481; found: 213.0479

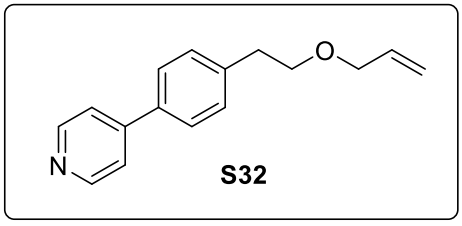
Melting point = 134℃

Preparation of S31



Compound was prepared by reported method[10].

Preparation of S32



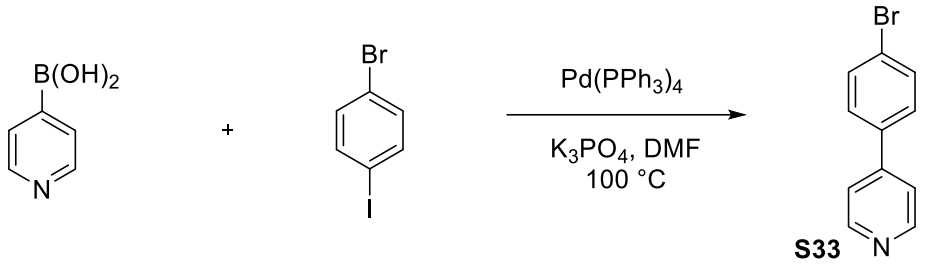
Following GP-1 the compound was synthesized using 4-pyridineboronic acid pinacol ester (1.10 g, 5.40 mmol), **S31** (1.00 g, 4.50 mmol), Cs_2CO_3 (8.70 g, 26.7 mmol), $Pd(PPh_3)_4$ (0.520 g, 0.450 mmol) in toluene / DMF (45.0 mL) and purified using flash chromatography (50% EtOAc / hexanes) to afford **S32** as a colourless oil (0.640 g, 65%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 – 8.50 (m, 2H), 7.57 (d, *J* = 8.2 Hz, 2H), 7.49 (dd, *J* = 4.5, 1.6 Hz, 2H), 7.35 (d, *J* = 8.2 Hz, 2H), 6.03 – 5.76 (m, 1H), 5.35 – 5.08 (m, 2H), 4.01 (dt, *J* = 5.6, 1.3 Hz, 2H), 3.69 (t, *J* = 7.0 Hz, 2H), 2.96 (t, *J* = 7.0 Hz, 2H)

^{13}C NMR (126 MHz, $CDCl_3$) δ 150.24, 148.15, 140.37, 136.03, 134.76, 129.71, 126.95, 121.47, 116.96, 71.95, 70.86, 36.07.

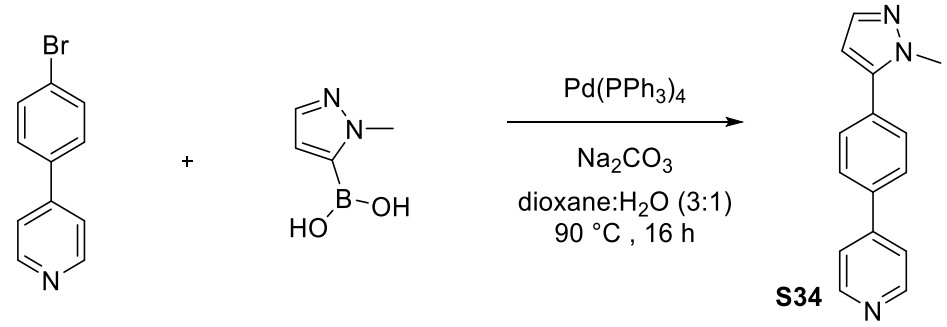
HRMS (ESI): Expected mass [M+H$^+$]: 240.1383; found: 240.138

Preparation of S33



Compound was prepared by reported method[11].

Preparation of S34



To a solution of **S33** (0.230 g, 1.00 mmol, 1.00 equiv) in dioxane:water (3:1) (8.00 mL), was added 1-Methyl-1H-pyrazole-5-boronic acid (0.190 g, 1.50 mmol, 1.50 equiv), Na_2CO_3 (0.320 g, 3.00 mmol, 3.00 equiv). The reaction mixture was degassed with N_2 for 15 mins and $Pd(PPh_3)_4$ (0.060 g, 0.050 mmol, 5 mol%) was added. The reaction mixture was then heated to 90℃ for 16 h. Upon completion, the reaction mixture was cooled down, quenched with water, and extracted with EtOAc. The organic layers were combined, dried over Na_2SO_4, filtered, and evaporated under pressure to afford crude product **S34**. The crude product was purified using flash chromatography (20 – 30% EtOAc/DCM) to obtain **S34** as a light -yellow solid (0.157 g, 67% yield).

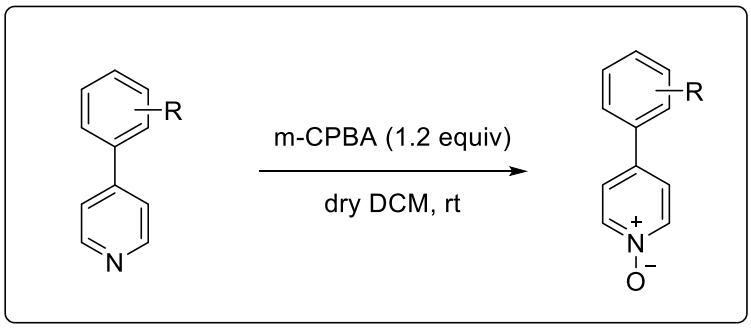
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (s, 2H), 7.73 (d, *J* = 8.4 Hz, 2H), 7.58 – 7.47 (m, 5H), 6.36 (d, *J* = 1.9 Hz, 1H), 3.94 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 150.28, 147.57, 142.73, 138.70, 138.06, 131.54, 129.42, 127.33, 121.58, 106.37, 37.68.

HRMS (ESI): Expected mass [M+H$^+$]: 236.1182; found: 236.1183

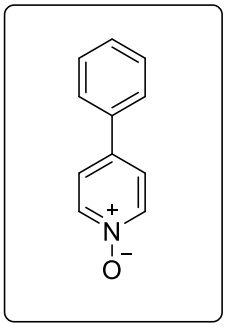
Melting point = 135 ℃

General procedure 2: Synthesis of 4-aryl pyridine *N*-oxides



To a solution of 4-aryl pyridine in dry CH_2Cl_2, was added *m*CPBA (1.20 equiv) under argon atmosphere and stirred at rt for 24 h. Reaction was monitored using TLC and after completion DCM was evaporated under reduced pressure and purified using flash chromatography (5-10% MeOH/EtOAc) to obtain pure *N*-oxide.

Preparation of S35



Following general procedure 2, 4-phenyl pyridine (0.780 g, 5.00 mmol, 1.00 equiv), dry CH_2Cl_2 (5.00 mL), *m*CPBA (1.70 g, 6.00 mmol, 1.20 equiv) was used and crude was purified using flash chromatography (10% MeOH/EtOAc) as eluent to obtain **S35** as a white solid (0.800 g, 94% yield).

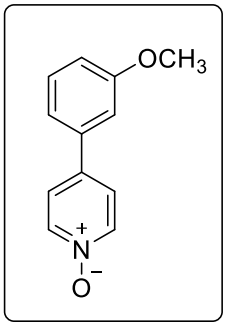
^{1}H NMR (500 MHz, CD_3OD) δ 8.47 – 8.19 (m, 2H), 7.86 (d, *J* = 5.1 Hz, 2H), 7.76 (d, *J* = 6.9 Hz, 2H), 7.54 – 7.34 (m, 3H).

^{13}C NMR (126 MHz, CD_3OD) δ 143.61, 140.51, 136.95, 130.82, 130.50, 127.83, 125.52.

HRMS (ESI): Expected mass [M+H$^+$]: 172.0757; found: 172.0757

Melting point = 114 – 116 ℃

Preparation of S36



Following general procedure 2, 4-(3-Methoxy-phenyl)-pyridine (0.180 g, 1.00 mmol, 1.00 equiv), dry CH_2Cl_2 (5.00 mL), *m*CPBA (0.340 g, 1.20 mmol, 1.20 equiv) was used and crude was purified using flash chromatography (10% MeOH/EtOAc) to obtain **S36** as a yellow solid (0.180 g, 93% yield).

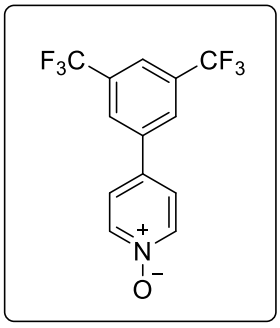
^{1}H NMR (500 MHz, CD_3OD) δ 8.35 – 8.30 (m, 2H), 7.80 (d, *J* = 7.2 Hz, 2H), 7.40 (t, *J* = 8.0 Hz, 1H), 7.31 – 7.20 (m, 2H), 7.02 (dd, *J* = 8.3, 2.4 Hz, 1H), 3.85 (s, 3H).

^{13}C NMR (126 MHz, CD_3OD) δ 161.96, 143.36, 140.42, 138.28, 131.59, 125.57, 120.08, 116.24, 113.40, 55.94.

HRMS (ESI): Expected mass [M+H$^+$]: 202.0863; found: 202.0861

Melting point = 121 – 124℃

Preparation of S37



Following general procedure 2, 4-(3,5-bis-trifluoromethyl-phenyl)-pyridine (0.220 g, 0.770 mmol, 1.00 equiv), dry CH_2Cl_2 (5.00 mL), *m*CPBA (0.260 g, 0.920 mmol, 1.20 equiv) was used and crude was purified using flash chromatography (5% MeOH/EtOAc) to obtain **S37** as a white solid (0.120 g, 52% yield)

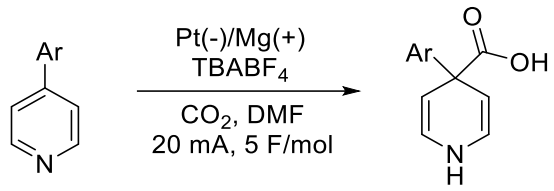
^{1}H NMR (500 MHz, CD_3OD) δ 8.46 – 8.40 (m, 2H), 8.37 (s, 2H), 8.08 (s, 1H), 7.99 (d, *J* = 7.3 Hz, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 140. 87, 139.89, 139.54, 133.81 (q, *J* = 33.57 Hz), 128.53, 126.30, 124.65 (q, *J* = 272.26 Hz), 123.83 (m)

HRMS (ESI): Expected mass [M+H$^+$]: 308.0505; found: 308.0508

Melting point = 163 – 165℃

General Procedure A: Electrochemical Dearomative-Carboxylation of Pyridines



A 5.0 mL ElectraSyn vial was charged with 4-(hetero)arylpyridine and tetrabutylammonium tetrafluoroborate (0.25 mmol, 1.0 equiv.) in DMF (2.5 – 3.0 mL). The vial was then capped with an ElectraSyn vial cap equipped with a platinum cathode and a magnesium anode and the reaction mixture was stirred until it became homogenous. A balloon filled with CO_2 was used to bubble CO_2 into the reaction mixture prior to starting the reaction and then continued for the duration of the electrolysis (**Figure S1**). Electrolysis was performed at 20 mA current and 5 F/mol charge. Following electrolysis, the ElectraSyn vial cap was removed and 3M HCl was added dropwise with stirring into the reaction mixture until solution becomes transparent. The content of the vial was transferred to a separatory funnel and the electrodes were rinsed with ethyl acetate (ca. 2 mL) and the aqueous layer was extracted using ethyl acetate (10 mL). The organic layer was washed several times with ice cold water (~100 mL×5) to remove the existing DMF. The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure to obtain the crude product.

The crude product can be purified by making a suspension of it in DCM followed by adding hexane, which results in precipitation of the product. The precipitate is then filtered using filter paper and a Buchner funnel. The residue was washed thoroughly with DCM to obtain the pure product (**Figure S1.C**).

Note: The dihydropyridines are sensitive to light and air and in order to perform subsequent reactions the RB flask was wrapped in aluminium foil and the air inside the RB flask was evacuated and filled with argon. Further reactions were performed at quick succession to avoid re-aromatization.

Graphical guide:

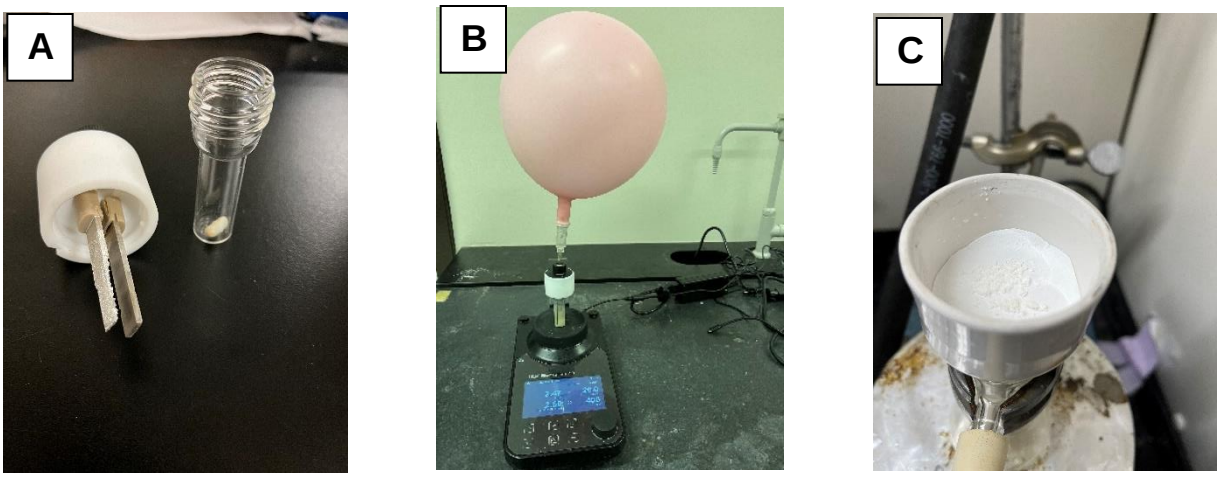
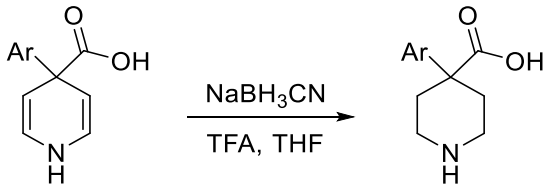


Figure S1: A) Electrodes (Mg anode and Pt cathode) and 5 mL vial with a stir bar; **B)** Electrochemical set up with CO_2 balloon; **C)** Product obtained after filtration

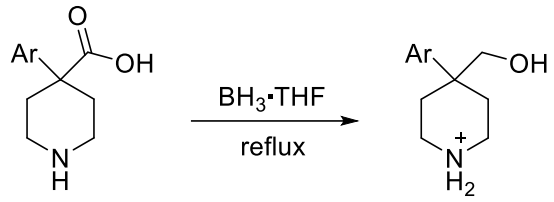
General Procedure B: Reduction of 1,4-Dihydropyridine



The dihydropyridines obtained in GP-A was dissolved in dry THF (4.0 mL) followed by addition of TFA (0.1 mL, 5.0 mmol) and $NaBH_3CN$ (0.043g, 2.7 mmol) under an argon atmosphere. The resulting reaction mixture was left to stir at RT for 2h. Upon completion of the reaction, the reaction mixture was evaporated under reduced pressure to obtain the crude product as a sticky solid. The crude product was used for next reaction without further purification.

Note: As the intermediate DHP was not isolated, the equivalence of $NaBH_3CN$ and TFA was calculated based on the 4-aryl pyridine weight.

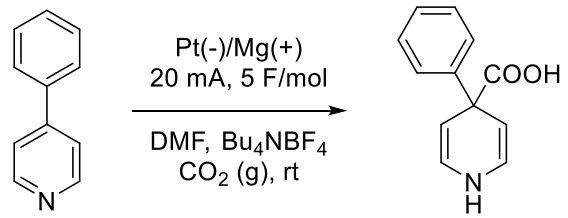
General Procedure C: Carboxylic Acid Reduction



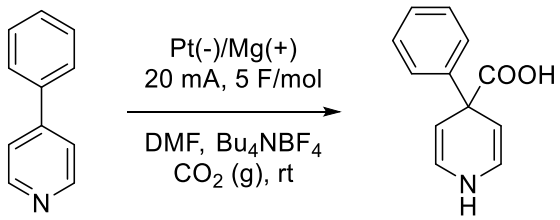
BH_3.THF (1M in THF) (2.0 mL, 6.0 eq) was added to the crude obtained in GP-B under argon atmosphere and refluxed for 2h. The reaction mixture was allowed to cool and quenched with MeOH. The resulting mixture was evaporated and a 1:1 solution of 6N HCl (5 mL) and MeOH (5.0 mL) was added and refluxed for 1h. The reaction was allowed to cool down and MeOH was evaporated under reduced pressure. 6N NaOH was added to the reaction mixture until pH becomes ~14. This was then extracted three times with DCM. The combined organic layers were washed with water and brine, dried with Na_2SO_4 and concentrated under reduced pressure to obtain the amino alcohol. A suspension of the amino alcohol was made in Et_2O (10.0 mL) after which HCl (2M in Et_2O) was added and left to stir for 15 mins. After which the stirring was stopped and the precipitate was allowed to settle to the bottom of the flask. The supernatant liquid was removed using a syringe and then the solid was triturated with acetone to obtain the pure salt of amino alcohol.

Note: For some substrates BH_3.THF was required in 12.0 equiv and also reflux duration was 16 h. This is indicated in their respective procedures.

Optimization table 1:

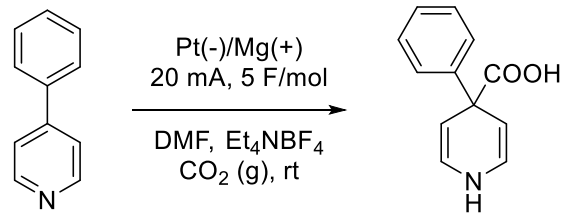


Entry	Variation from above	Yield (%)
1	None	63
2	Mg as anode and Sn as cathode	trace
3	Mg as anode and Ti as cathode	47
4	Mg as anode and Ni as cathode	trace
5	Mg as anode and Cu as cathode	54
6	Mg as anode and steel as cathode	44
7	Mg as anode and Co as cathode	18
8	Mg as anode and graphite as cathode	18
9	Mg as anode and GC as cathode	34
10	60 °C instead of rt	28
11	80 °C instead of rt	trace
12	0 °C instead of rt	11
13	5 mA instead of 20 mA	trace
14	15 mA instead of 20 mA	62
15	22 mA instead of 20 mA	28
16	DMA solvent instead of DMF	24
17	DMSO instead of DMF	no reaction
18	dry DMF instead of DMF	50
19	Bu_4NI instead of Bu_4NBF_4	10
20	Me_4NPF_6 instead of Bu_4NBF_4	no reaction
21	MeCN instead of DMF	no reaction



Entry	Variation from above	Yield (%)
22	Et_4NBF_4 instead of Bu_4NBF_4	70
23	Me_4NBF_4 instead of Bu_4NBF_4	no reaction
24	Bu_4NOAc instead of Bu_4NBF_4	no reaction
25	Et_4NBF_4 + 20 μL H_2O	trace
26	Bu_4NClO_4 instead of Bu_4NBF_4	trace
27	Bu_4NBr instead of Bu_4NBF_4	22
28	NH_4Cl instead of Bu_4NBF_4	no reaction

Optimization table 2:

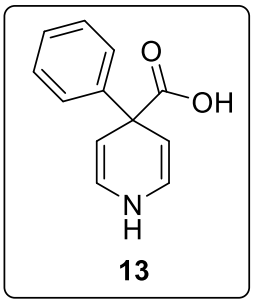


Entry	Variation from above	Yield (%)
1	None	70
2	Mg as anode and Sn as cathode	no reaction
3	Mg as anode and Ti as cathode	25
4	Mg as anode and Ni as cathode	54
5	Mg as anode and Al as cathode	no reaction
6	Mg as anode and steel as cathode	7
7	Mg as anode and Co as cathode	trace
8	Mg as anode and graphite as cathode	23
9	Mg as anode and GC as cathode	trace
10	Mg as anode and Ni foam as cathode	70
11	Zn as anode and Pt as cathode	55
12	Zn as anode and Ni foam as cathode	undesired product
13	10 mA instead of 20 mA	34
14	15 mA instead of 20 mA	45
15	25 mA instead of 20 mA	18
16	30 mA instead of 20 mA	trace
17	3 F/mol instead of 5 F/mol	64
18	4 F/mol instead of 5 F/mol	66
19	6 F/mol instead of 5 F/mol	13

Preparation and Characterization of 1,4-Dihydropyridines and piperidines

Note: Due to the instability of 1,4-dihydropyridines, HRMS, ^{13}C and melting point data could not be obtained.

Preparation of 13

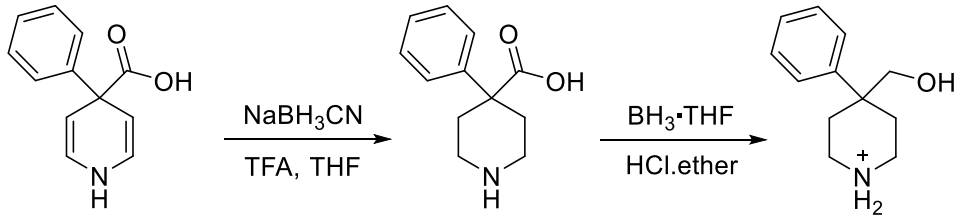


13

Following the General Procedure A with 4-phenyl-pyridine (0.038 g, 0.25 mmol) afforded **13** as a white solid. The ^{1}H NMR yield was determined to be 63% with dibromomethane as the internal standard.

Data for **13**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.37 – 7.27 (m, 4H), 7.25 – 7.17 (m, 1H), 7.02 (d, *J* = 8.6 Hz, 2H), 5.31 (d, *J* = 8.6 Hz, 2H).

Preparation of 49



13 **58** **49**

Following General Procedure B, the crude reaction mixture of **13** treated with $NaBH_3CN$ (0.043 g, 5.4 mmol) and TFA (0.10 mL, 10.0 mmol) in THF (4.0 mL) afforded crude product **58** as a sticky solid. Following General Procedure C, crude product **58** dissolved in BH_3-THF (2.0 mL) afforded **49** as a white solid (5.0 mg, 11% over 3 steps).

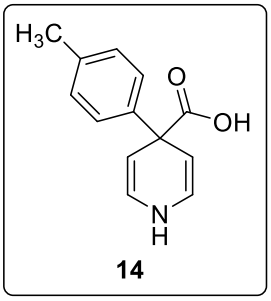
Data for **49**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.58 – 7.27 (m, 4H), 7.24 (ddd, *J* = 7.1, 3.8, 1.8 Hz, 1H), 3.48 (s, 2H), 3.09 (dt, *J* = 13.0, 4.0 Hz, 2H), 2.76 (td, *J* = 12.9, 2.7 Hz, 2H), 2.30 (d, *J* = 14.5 Hz, 2H), 2.06 – 1.91 (m, 2H).

^{13}C NMR (176 MHz, CD_3OD) δ 143.46, 129.77, 128.35, 127.51, 72.51, 43.46, 42.59, 31.27.

HRMS (ESI): Expected mass [M^+]: 192.1383; found: 192.1381

Melting point = 166 ℃

Preparation of 14

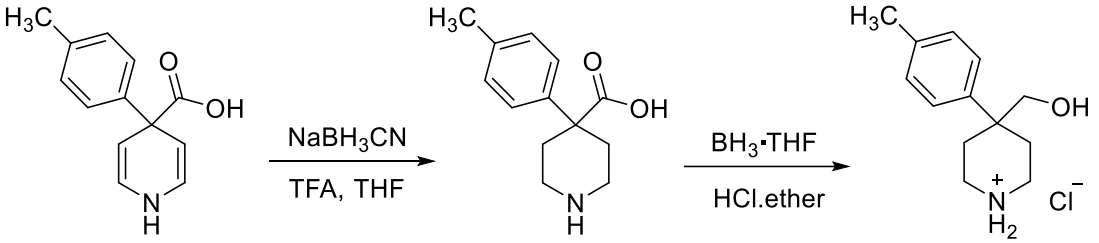


14

Following the General Procedure A with **S1** (0.042 g, 0.25 mmol) afforded **14** as a white solid. The ^{1}H NMR yield was determined to be 42% with dibromomethane as the internal standard.

Data for **14**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.20 – 7.12 (m, 4H), 7.03 – 6.98 (m, 2H), 5.28 (d, *J* = 8.7 Hz, 2H), 2.30 (s, 3H)

Preparation of 14A



14 **14I** **14A**

Following General Procedure B, the crude reaction mixture of **14** treated with $NaBH_3CN$ (0.043 g, 5.4 mmol) and TFA (0.10 mL, 10.0 mmol) in THF (4.0 mL) afforded crude product **14I** as a sticky solid. Following General Procedure C, crude product **14I** dissolved in BH_3-THF (2.0 mL) afforded **14A** as a white solid (0.017 g, 28 % over 3 steps).

Data for **14A**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.26 (dd, *J* = 27.2, 8.2 Hz, 4H), 3.46 (s, 2H), 3.35-3.28 (2H)*, 2.90 (td, *J* = 12.7, 2.5 Hz, 2H), 2.41 (d, *J* = 14.4 Hz, 2H), 2.32 (s, 3H), 2.18 – 2.07 (m, 2H).

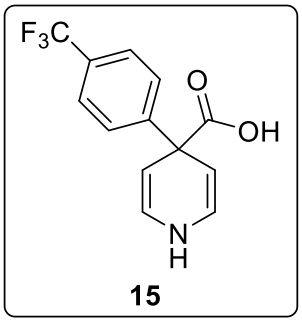
^{13}C NMR (126 MHz, CD_3OD) δ 138.79, 137.71, 130.74, 128.09, 72.34, 42.82, 42.11, 29.25, 20.94.

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 206.1539; found: 206.154.

Melting point = 232℃

Preparation of 15



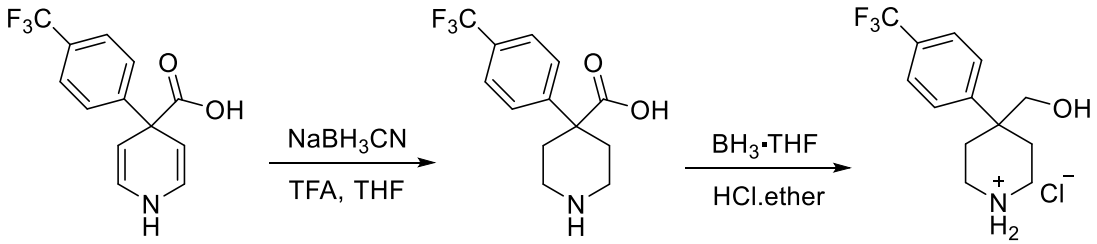
15

Following the General Procedure A with S2 (0.055 g, 0.25 mmol) afforded **15** as a white solid The ^{1}H NMR yield was determined to be 75% with dibromomethane as the internal standard.

Data for **15**: **^{1}H NMR** (400 MHz, acetone-d_6) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.59 (d, *J* = 8.2 Hz, 2H), 7.12 – 7.09 (m, 2H), 5.40 (d, *J* = 8.7 Hz, 2H)

^{19}F NMR (376 MHz, acetone-d_6) δ -62.97

Preparation of 46



15 **15I** **46**

Following General Procedure B, the crude reaction mixture of **15** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **15I** as a sticky solid. Following General Procedure C, crude product **15I** dissolved in BH_3-THF (2.0 mL) afforded **46** as a white solid (0.016 g, 22 % over 3 steps).

Data for **46**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.68 (dd, *J* = 26.4, 8.5 Hz, 4H), 3.54 (s, 2H), 3.38-3.32 (2H)*, 2.97 – 2.85 (m, 2H), 2.48 (d, *J* = 15.1 Hz, 2H), 2.17 (ddd, *J* = 11.7, 10.2, 3.9 Hz, 2H).

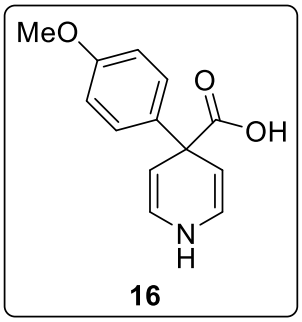
^{13}**C NMR** (125 MHz, CD_3OD): δ 142.27, 130.12 (q, *J* = 33.1 Hz), 129.14, 126.75 (q, *J* = 3.61 Hz), 124.62 (q, *J* = 270.94), 71.56, 43.37, 42.01, 29.35

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M+H$^+$]: 260.1257; found: 260.1254

Melting point = 145 ℃

Preparation of 16

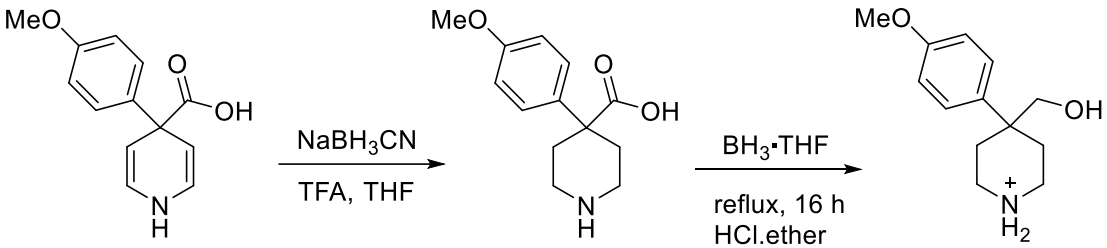


16

Following the General Procedure A with **S3** (0.046 g, 0.25 mmol) afforded **16** as a white solid. The ^{1}H NMR yield was determined to be 53% with dibromomethane as the internal standard.

Data for **16**: **^{1}H NMR** (600 MHz, CD_3OD): δ 7.20 (d, *J* = 8.7 Hz, 2H), 7.00 (d, *J* = 8.3 Hz, 2H), 6.88 (d, *J* = 8.7 Hz, 2H), 5.28 (d, *J* = 8.3 Hz, 2H), 3.77 (d, *J* = 6.4 Hz, 3H);

Preparation of 16A



16 **16I** **16A**

Following General Procedure B, the crude reaction mixture of **16** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **16I** as a sticky solid. Following General Procedure C, crude product **16I** dissolved in BH_3-THF (4.0 mL) afforded **16A** as a white solid (5.0 mg, 8 % over 3 steps).

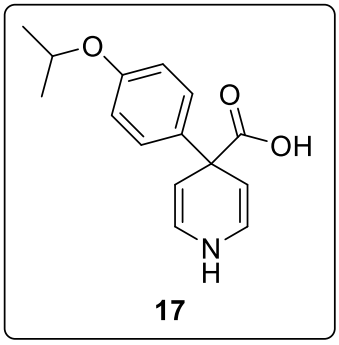
Data for **16A**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.31 (d, *J* = 8.8 Hz, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 3.79 (s, 3H), 3.44 (s, 2H), 3.23 – 3.09 (m, 2H), 2.82 (t, *J* = 12.3 Hz, 2H), 2.30 (d, *J* = 14.6 Hz, 2H), 2.07 – 1.95 (m, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 159.84, 134.34, 129.38, 115.30, 72.58, 55.73, 42.71, 42.36, 30.43.

HRMS (ESI): Expected mass [M $^{+}$]: 222.1489; found: 222.1489.

Melting point = 212 – 215℃

Preparation of 17

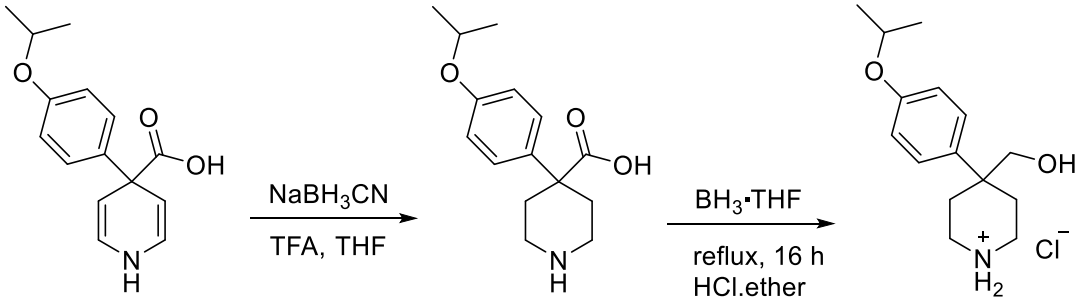


17

Following the General Procedure A with **S5** (0.053 g, 0.25 mmol) afforded **17** as a white solid The ^{1}H NMR yield was determined to be 48% with dibromomethane as the internal standard.

Data for **17**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.18 (d, *J* = 8.8 Hz, 2H), 7.00 (d, *J* = 8.6 Hz, 2H), 6.86 (d, *J* = 8.8 Hz, 2H), 5.29 (d, *J* = 8.6 Hz, 2H), 4.56 (dt, *J* = 12.1, 6.0 Hz, 1H), 1.28 (d, *J* = 6.0 Hz, 6H);

Preparation of 17A



17 **17I** **17A**

Following General Procedure B, the crude reaction mixture of **17** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **17I** as a sticky solid. Following General Procedure C, crude product **17I** dissolved in BH_3-THF (4.0 mL) afforded **17A** as a white solid (8.5 mg, 12 % over 3 steps).

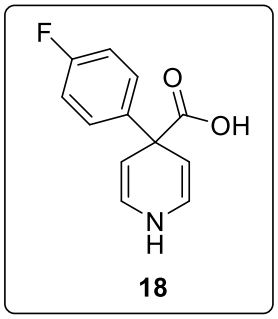
Data for **17A**: **^{1}H NMR** (600 MHz, CD_3OD): δ 7.32-7.28 (m, 2H), 6.96-6.91 (m, 2H), 4.59 (dt, *J* = 12.1, 6.0 Hz, 1H), 3.44 (s, 2H), 3.42 (m, 2H), 2.91 (td, *J* = 12.7, 2.2 Hz, 2H), 2.38 (d, J = 14.6, 2H), 2.21-2.0 (m, 2H), 1.30 (d, *J* = 6.0 Hz, 6H).

^{13}C NMR (126 MHz, CD_3OD) δ 158.15, 133.38, 129.33, 117.37, 72.39, 70.94, 42.51, 42.10, 29.31, 22.37

HRMS (ESI): Expected mass [M+H$^+$]: 250.1802; found: 250.18.

Melting point = 230 – 232 ℃

Preparation of 18



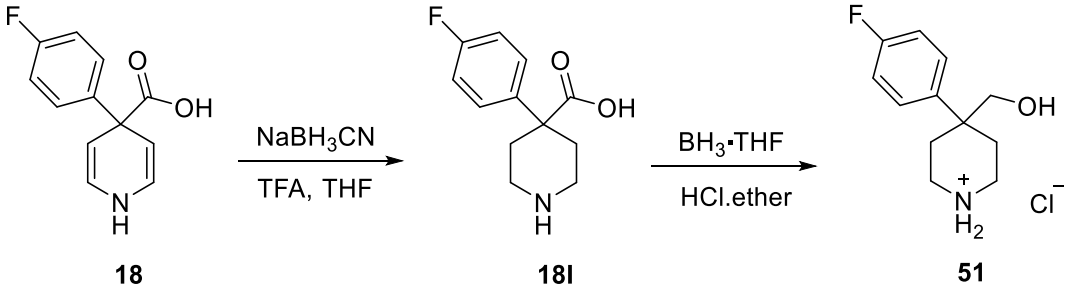
18

Following the General Procedure A with **S8** (0.043 g, 0.25 mmol) afforded **18** as a white solid. The ^{1}H NMR yield was determined to be 55% with dibromomethane as the internal standard.

Data for **18**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.35 – 7.27 (m, 2H), 7.10 – 6.99 (m, 4H), 5.32 – 5.26 (m, 2H).

^{19}F NMR (376 MHz, CD_3OD) δ -118.31

Preparation of 51



18 **18I** **51**

Following General Procedure B, the crude reaction mixture of **18** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **18I** as a sticky solid. Following General Procedure C, crude product **18I** dissolved in BH_3-THF (2.0 mL) afforded **51** as a white solid (8.0 mg, 28 % over 3 steps).

Data for **51**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.45 (dd, *J* = 8.9, 5.2 Hz, 2H), 7.14 (t, *J* = 8.8 Hz, 2H), 3.48 (s, 2H), 3.33 (2H)*, 2.90 (td, *J* = 12.8, 2.7 Hz, 2H), 2.40 (d, *J* = 15.0 Hz, 2H), 2.18 – 2.05 (m, 2H).

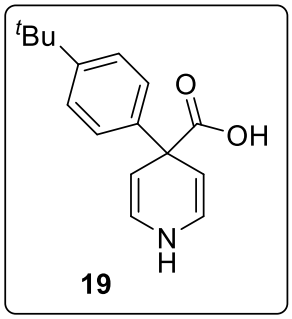
^{13}C NMR (126 MHz, CD_3OD) δ 163.10 (d, *J* = 244.68 Hz), 138.22, 130.23 (d, *J* = 7.92 Hz), 116.57 (d, *J* = 21.19 Hz), 72.01, 42.77, 42.06, 29.61.

* 2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 210.1289; found: 210.129.

Melting point = 208 – 210℃

Preparation of 19

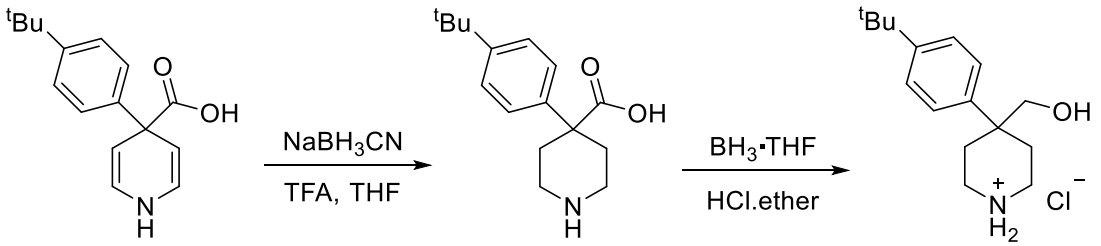


19

Following the General Procedure A with 4-(4-*tert*-Butyl-phenyl)-pyridine (0.052 g, 0.25 mmol) afforded **19** as a white solid. The ^{1}H NMR yield was determined to be 60% with dibromomethane as the internal standard.

Data for **19**: **^{1}H NMR** (600 MHz, CD_3OD): δ 7.37 (d, *J* = 8.5 Hz, 2H), 7.21 (d, *J* = 8.5 Hz, 2H), 7.02 (d, *J* = 8.5 Hz, 2H), 5.27 (d, *J* = 8.5 Hz, 2H), 1.30 (s, 9H);

Preparation of 19A



19 **19I** **19A**

Following General Procedure B, the crude reaction mixture of **19** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **19I** as a sticky solid. Following General Procedure C, crude product **19I** dissolved in BH_3-THF (2.0 mL) afforded **19A** as a white solid (0.010 g, 14 % over 3 steps).

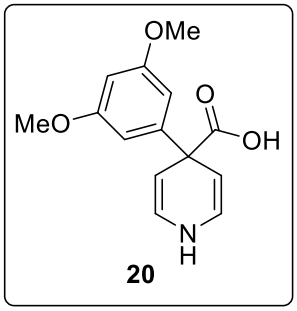
Data for **19A**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.41 (d, *J* = 8.5 Hz, 2H), 7.31 (d, J = 8.5 Hz, 2H), 3.44 (s, 2H), 3.04 (d, *J* = 12.9 Hz, 2H), 2.74 (t, *J* = 11.2 Hz, 2H), 2.26 (d, *J* = 14.1 Hz, 2H), 2.01-1.77 (m, 2H), 1.31 (s, 9H).

^{13}C NMR (126 MHz, CD_3OD) δ 150.27, 140.49, 128.12, 126.63, 72.78, 43.20, 42.70, 35.17, 31.78, 31.63

HRMS (ESI): Expected mass [M+H$^+$]: 248.2009; found: 248.2007.

Melting point = 255℃

Preparation of 20

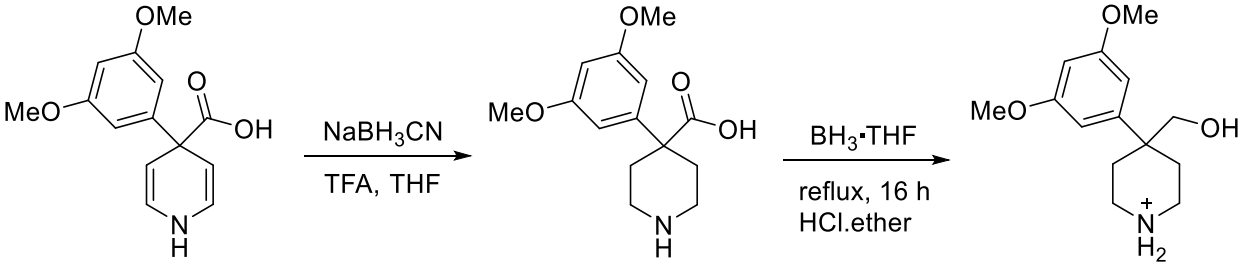


20

Following the General Procedure A with **S12** (0.053 g, 0.25 mmol) afforded **20** as a white solid The ^{1}H NMR yield was determined to be 57% with dibromomethane as the internal standard.

Data for **20**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.03 (d, *J* = 8.6 Hz, 2H), 6.45 (d, *J* = 2.2 Hz, 2H), 6.36 (t, *J* = 2.2 Hz, 1H), 5.27 (d, *J* = 8.6 Hz, 2H), 3.75 (s, 6H)

Preparation of 20A



20 **20I** **20A**

Following General Procedure B, the crude reaction mixture of **20** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **20I** as a sticky solid. Following General Procedure C, crude product **20I** dissolved in BH_3-THF (4.0 mL) afforded **20A** as a white solid (9.0 mg, 12 % over 3 steps).

Data for **20A**: **^{1}H NMR** (600 MHz, CD_3OD) δ 6.53 (d, *J* = 2.1 Hz, 2H), 6.44 (t, *J* = 2.0 Hz, 1H), 3.79 (s, 6H), 3.47 (s, 2H), 3.33 (2H)* , 2.94 (dd, *J* = 12.3, 11.0 Hz, 2H), 2.37 (d, *J* = 14.7 Hz, 2H), 2.13 – 2.05 (m, 2H).

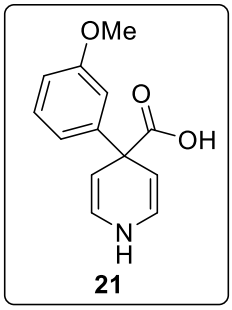
^{13}C NMR (126 MHz, CD_3OD) δ 163.01, 144.44, 106.75, 99.19, 72.10, 55.84, 43.39, 42.20, 29.41

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 252.1594; found: 252.1593.

Melting point = 227℃

Preparation of 21

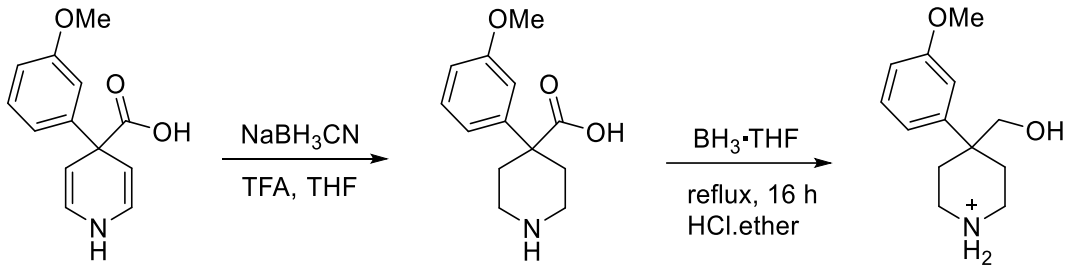


21

Following the General Procedure A with **S13** (0.046 g, 0.25 mmol) afforded **21** as a white solid. The ^{1}H NMR yield was determined to be 43% with dibromomethane as the internal standard.

Data for **21**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.25 (t, *J* = 8.0 Hz, 1H), 7.04 – 7.00 (m, 2H), 6.89 – 6.77 (m, 3H), 5.32 – 5.29 (m, 2H), 3.77 (s, 3H);

Preparation of 50



21 **21I** **50**

Following General Procedure B, the crude reaction mixture of **21** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **21I** as a sticky solid. Following General Procedure C, crude product **21I** dissolved in BH_3-THF (4.0 mL) afforded **50** as a white solid (21.0 mg, 32% over 3 steps).

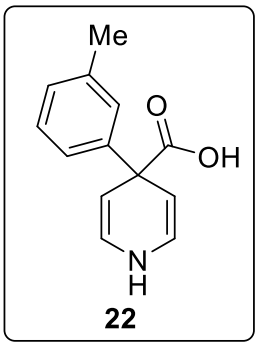
Data for **50**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.34 (t, *J* = 8.0 Hz, 1H), 7.04 – 6.96 (m, 1H), 6.95 (t, *J* = 2.1 Hz, 1H), 6.87 (dd, *J* = 8.2, 1.9 Hz, 1H), 3.81 (s, 3H), 3.48 (s, 2H), 3.34 (m, 2H), 2.93 (td, *J* = 12.7, 2.4 Hz, 2H), 2.41 (d, *J* = 14.5 Hz, 2H), 2.19 – 2.04 (m, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 161.84, 143.63, 131.17, 120.29, 114.79, 112.77, 72.16, 55.74, 43.20, 42.17, 29.34

HRMS (ESI): Expected mass [M^+]: 222.1489; found: 222.1486.

Melting point = 215℃

Preparation of 22

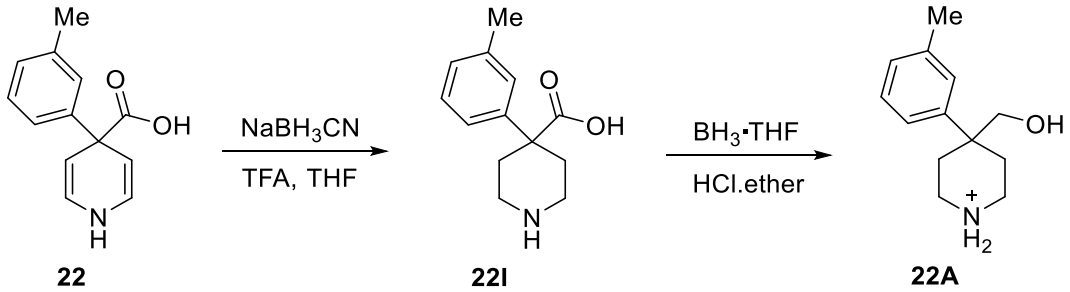


22

Following the General Procedure A with **S14** (0.042 g, 0.25 mmol) afforded **22** as a white solid. The ^{1}H NMR yield was determined to be 35% with dibromomethane as the internal standard.

Data for **22**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.21 (t, *J* = 7.6 Hz, 1H), 7.13 – 6.97 (m, 5H), 5.30 (d, *J* = 8.6 Hz, 2H), 2.32 (s, 3H);

Preparation of 30A



22 **22I** **22A**

Following General Procedure B, the crude reaction mixture of **22** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **22I** as a sticky solid. Following General Procedure C, crude product **22I** dissolved in BH_3-THF (2.0 mL) afforded **22A** as a white solid (8.5 mg, 14 % over 3 steps).

Data for **22A**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.30 (t, *J* = 7.7 Hz, 1H), 7.26 – 7.18 (m, 2H), 7.11 (d, *J* = 7.4 Hz, 1H), 3.46 (s, 2H), 3.33 – 3.27 (2H)*, 2.91 (td, *J* = 12.7, 2.6 Hz, 2H), 2.42 (d, *J* = 14.1 Hz, 2H), 2.37 (s, 3H), 2.15 – 2.04 (m, 2H).

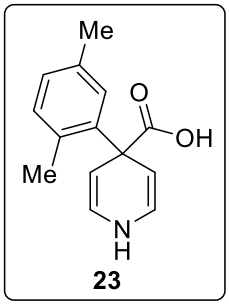
^{13}C NMR (176 MHz, CD_3OD) δ 141.90, 139.82, 129.98, 128.74, 128.64, 125.15, 72.28, 43.04, 42.18, 30.15, 29.38.

*2H merged with CD_3OD confirmed by COSY NMR

HRMS (ESI): Expected mass [M^+]: 206.1539; found: 206.1539.

Melting point = 236 – 238℃

Preparation of 23

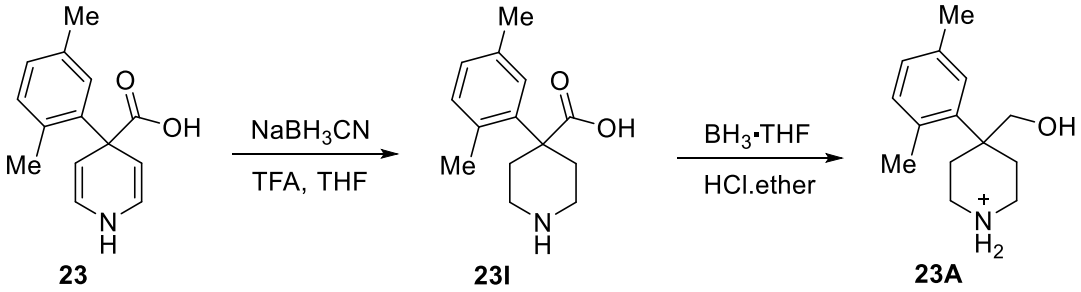


23

Following the General Procedure A with **S15** (0.045 g, 0.25 mmol) afforded **23** as a yellow solid. The ^{1}H NMR yield was determined to be 50% with dibromomethane as the internal standard.

Data for **23: ^{1}H NMR** (400 MHz, CD_3OD) δ 7.20 (d, *J* = 8.0 Hz, 1H), 7.17 – 7.11 (m, 2H), 7.06 (d, *J* = 8.4 Hz, 2H), 5.15 (d, *J* = 8.4 Hz, 2H), 2.29 (s, 3H), 2.27 (s, 3H).

Preparation of 23A



23 **23I** **23A**

Following General Procedure B, the crude reaction mixture of **23** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **23I** as a stikcky solid. Following General Procedure C, crude product **23I** dissolved in BH_3-THF (2.0 mL) afforded **23A** as a white solid (7.6 mg, 12 % over 3 steps).

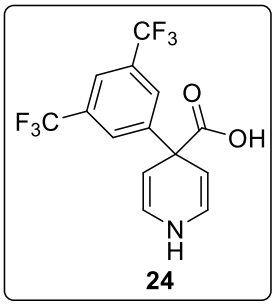
Data for **23A**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.13 (s, 1H), 7.09 (d, *J* = 7.8 Hz, 1H), 7.00 (d, *J* = 7.7 Hz, 1H), 3.64 (s, 2H), 3.35 (s, 2H), 2.94 (t, *J* = 12.6 Hz, 2H), 2.66 (d, *J* = 14.8 Hz, 2H), 2.45 (s, 3H), 2.32 (s, 3H), 2.20 – 2.05 (m, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 138.53, 137.17, 135.24, 134.84, 131.00, 128.97, 69.27, 45.20, 42.27, 30.22, 24.23, 21.21.

HRMS (ESI): Expected mass [M^+]: 220.1696; found: 220.1695.

Melting point = 251℃

Preparation of 24



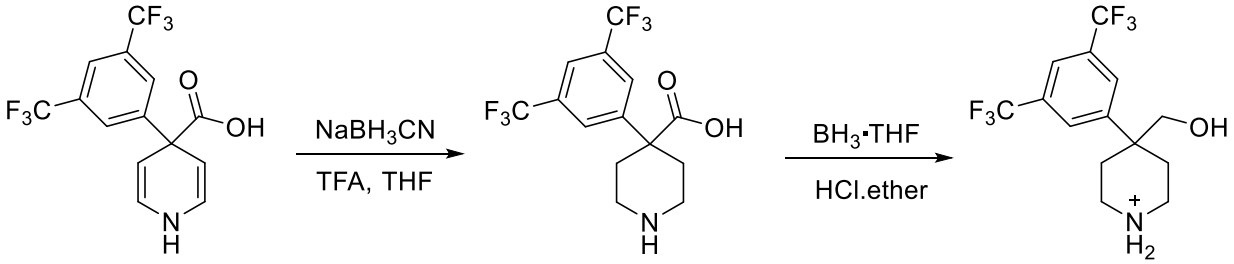
24

Following the General Procedure A with **S16** (0.072 g, 0.25 mmol) afforded **24** as a orange solid. The ^{1}H NMR yield was determined to be 36% with dibromomethane as the internal standard.

Data for **24**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.87 (s, 3H), 7.15 (d, *J* = 8.6 Hz, 2H), 5.35 (d, *J* = 8.6 Hz, 2H).

^{19}F NMR (376 MHz, CD_3OD) δ -64.33

Preparation of 48



24 **24I** **48**

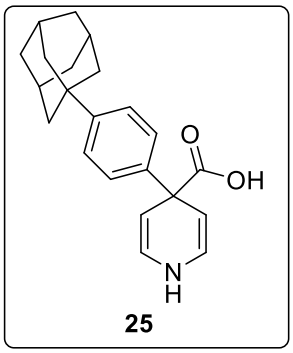
Following General Procedure B, the crude reaction mixture of **24** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **24I** as a sticky solid. Following General Procedure C, crude product **24I** dissolved in BH_3-THF (2.0 mL) afforded **48** as a white solid (0.020 g, 22 % over 3 steps).

Data for **48**: **^{1}H NMR** (400 MHz, CD_3OD) δ 8.00 (s, 2H), 7.90 (s, 1H), 3.64 (s, 2H), 3.43 – 3.36 (m, 2H), 3.05 – 2.95 (m, 2H), 2.46 (d, *J* = 16.1 Hz, 2H), 2.30 – 2.15 (m, 2H).

^{13}**C NMR** (125 MHz, CD_3OD): δ 147.25, 133.08 (q, *J* = 33.07 Hz), 128.93, 124.95 (q, *J* = 272.01 Hz), 121.85 (m), 70.05, 43.18, 41.78, 29.39

HRMS (ESI): Expected mass [M^+]: 328.1131; found: 328.1130.

Preparation of 25

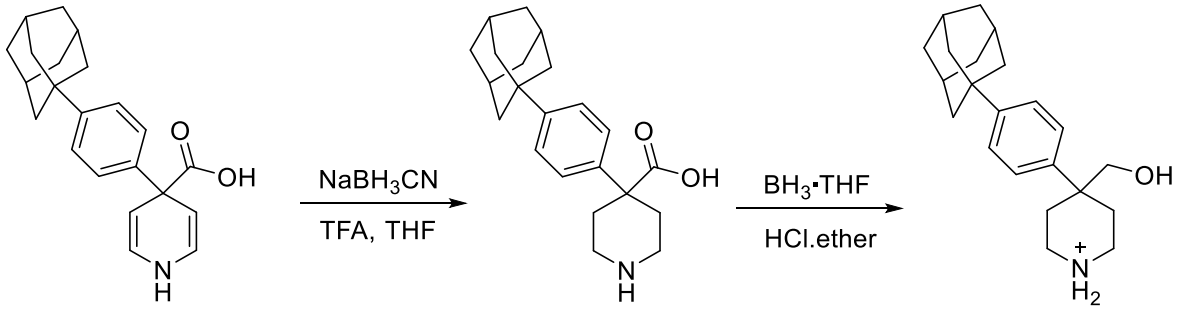


25

Following the General Procedure A with **S11** (0.072 g, 0.25 mmol) afforded **25** as a white solid. The ^{1}H NMR yield was determined to be 30% with dibromomethane as the internal standard.

Data for **25**: ^{1}**H NMR** (400 MHz, CD_3OD): δ 7.45 – 7.28 (m, 2H), 7.27 – 7.14 (m, 2H), 7.01 (d, *J* = 8.6 Hz, 2H), 5.27 (d, *J* = 8.6 Hz, 2H), 2.07 (s, 3H), 1.92 (d, *J* = 2.6 Hz, 6H), 1.81 (s, 6H);

Preparation of 25A



25 **25I** **25A**

Following General Procedure B, the crude reaction mixture of **25** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **25I** as a sticky solid. Following General Procedure C, crude product **25I** dissolved in BH_3-THF (2.0 mL) afforded **25A** as a white solid (9.0 mg, 10% over 3 steps).

Data for **25A**: ^{1}**H NMR** (400 MHz, CD_3OD) δ 7.39 (dd, *J* = 29.9, 8.6 Hz, 4H), 3.45 (s, 2H), 3.35-3.26 (2H)*, 3.00 – 2.83 (m, 2H), 2.43 (d, *J* = 14.4 Hz, 2H), 2.12 (dd, *J* = 19.8, 7.5 Hz, 5H), 1.94 (d, *J* = 2.6 Hz, 6H), 1.82 (q, *J* = 12.2 Hz, 6H).

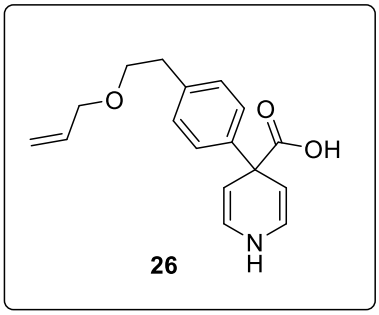
^{13}**C NMR** (126 MHz, CD_3OD) δ 151.25, 138.77, 127.92, 126.63, 72.38, 44.37, 42.82, 42.15, 37.88, 37.06, 30.46, 29.23

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 326.2478; found: 326.2479.

Melting point = 256℃

Preparation of 26



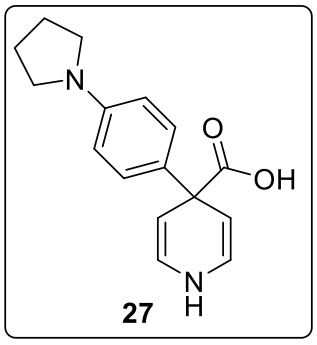
26

Following the General Procedure A with S31 (0.059 g, 0.25 mmol) afforded **26** as a white solid. The ^{1}H NMR yield was determined to be 45% with dibromomethane as the internal standard.

Data for **26**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.20 (d, *J* = 2.2 Hz, 4H), 7.01 (d, *J* = 8.6 Hz, 2H), 5.86 (ddd, *J* = 16.0, 10.6, 5.4 Hz, 1H), 5.30 (d, *J* = 8.6 Hz, 2H), 5.22 (dd, *J* = 17.25, 1.65 Hz, 1H), 5.12 (dd, *J* = 10.45, 1.33, 1H), 3.95 (d, *J* = 5.6 Hz, 2H), 3.62 (t, *J* = 6.9 Hz, 2H), 2.83 (t, *J* = 6.9 Hz, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 177.02, 154.03, 144.48, 139.05, 136.09, 130.29, 127.27, 117.18, 108.97, 72.78, 72.22, 51.19, 36.72.

Preparation of 27



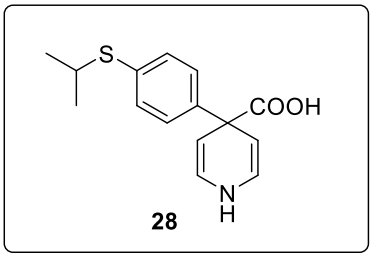
27

Following the General Procedure A with S18 (0.056 g, 0.25 mmol) afforded **27** as a yellow solid. The ^{1}H NMR yield was determined to be 35% with dibromomethane as the internal standard.

^{1}H NMR (700 MHz, CD_3OD) δ 7.08 (d, *J* = 8.8 Hz, 2H), 6.97 (d, *J* = 8.7 Hz, 2H), 6.54 (d, *J* = 8.8 Hz, 2H), 5.25 (d, *J* = 8.7 Hz, 2H), 3.26 – 3.23 (m, 4H), 2.01 – 1.99 (m, 4H).

Note: ^{13}C NMR and HRMS data of **27** could not be collected due to rapid re-aromatization.

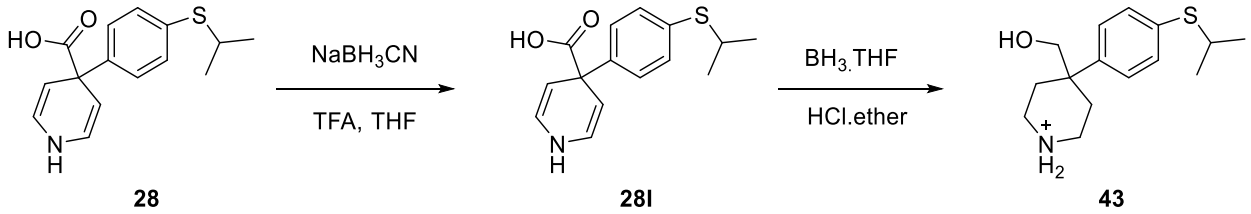
Preparation of 28



Following the General Procedure A with **S28** (0.057 g, 0.25 mmol) afforded **28** as a white solid. The ^{1}H NMR yield was determined to be 41% with dibromomethane as the internal standard.

Data for **28**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.36 (d, *J* = 8.5 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.04 (d, *J* = 8.6 Hz, 2H), 5.27 (d, *J* = 8.6 Hz, 2H), 3.37 (dt, *J* = 13.4, 6.7 Hz, 1H), 1.25 (d, *J* = 6.7 Hz, 6H)

Preparation of 28A



Following General Procedure B, the crude reaction mixture of **28** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **28I** as a sticky solid. Following General Procedure C, crude product **28I** dissolved in BH_3-THF (2.0 mL) afforded **43** as a white solid (0.025 g, 34% over 3 steps).

Data for **43**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.49 – 7.26 (m, 4H), 3.48 (s, 2H), 3.41 (dt, *J* = 13.3, 6.7 Hz, 1H), 3.33 (2H)*, 2.91 (td, *J* = 12.7, 2.7 Hz, 2H), 2.41 (d, *J* = 14.9 Hz, 2H), 2.13 (ddd, *J* = 15.4, 10.0, 3.8 Hz, 2H), 1.28 (d, *J* = 6.7 Hz, 6H).

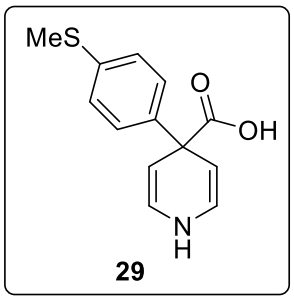
^{13}C NMR (176 MHz, CD_3OD) δ 140.63, 135.80, 132.95, 128.80, 71.95, 42.88, 42.05, 38.85, 29.24, 23.50.

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (DART-MS): Expected mass [$M+H^+$]: 266.1573; found: 266.1571

Melting point = 161℃

Preparation of 29

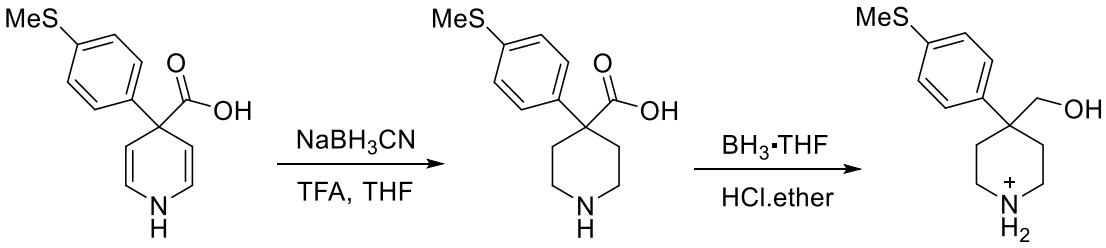


29

Following the General Procedure A with S7 (0.050 g, 0.25 mmol) afforded **29** as a white solid. The ^{1}H NMR yield was determined to be 57% with dibromomethane as the internal standard.

Data for **29**: ^{1}**H NMR** (600 MHz, CD_3OD): δ 7.27 – 7.20 (m, 4H), 7.02 (d, *J* = 8.6 Hz, 2H), 5.27 (d, *J* = 8.6 Hz, 2H), 2.45 (s, 3H);

Preparation of 47



29 **29I** **47**

Following General Procedure B, the crude reaction mixture of **29** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **29I** as a sticky solid. Following General Procedure C, crude product **29I** dissolved in BH_3-THF (2.0 mL) afforded **47** as a white solid (0.011 g, 17 % over 3 steps).

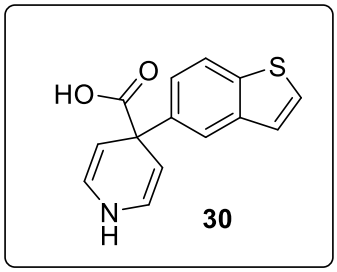
Data for **47**: ^{1}**H NMR** (400 MHz, CD_3OD): δ 7.33 (q, *J* = 8.8 Hz, 4H), 3.45 (s, 2H), 3.26 (m, 2H), 2.97-2.81 (m, 2H), 2.47 (s, 3H), 2.38 (d, J = 14.8 Hz, 2H), 2.17-1.97 (m, 2H).

^{13}**C NMR** (126 MHz, CD_3OD) δ 138.83, 138.76, 128.81, 128.12, 72.20, 42.88, 42.17, 29.53, 15.63.

HRMS (ESI): Expected mass [M^+]: 238.126; found: 238.126.

Melting point = 219℃

Preparation of 30

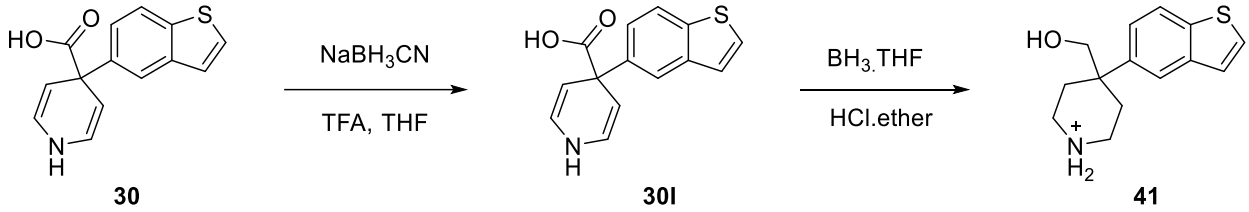


30

Following the General Procedure A with **S29** (0.052 g, 0.25 mmol) afforded **30** as a white solid. The ^{1}H NMR yield was determined to be 41%with dibromomethane as the internal standard.

Data for **30**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.86 (d, *J* = 8.5 Hz, 1H), 7.75 (d, *J* = 1.4 Hz, 1H), 7.56 (d, *J* = 5.4 Hz, 1H), 7.35 (d, *J* = 5.4 Hz, 1H), 7.32 (dd, *J* = 8.5, 1.6 Hz, 1H), 7.06 (d, *J* = 8.5 Hz, 2H), 5.38 (d, *J* = 8.6 Hz, 2H).

Preparation of 41



30 **30I** **41**

Following General Procedure B, the crude reaction mixture of **30** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **30I** as a sticky solid. Following General Procedure C, crude product **30I** dissolved in BH_3-THF (2.0 mL) afforded **41** as a white solid (0.027 g, 39 % over 3 steps).

Data for **41**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.93 (dd, *J* = 9.6, 5.0 Hz, 2H), 7.58 (d, *J* = 5.4 Hz, 1H), 7.45 – 7.32 (m, 2H), 3.54 (s, 2H), 3.33 (2H)*, 2.93 (td, *J* = 12.7, 2.3 Hz, 2H), 2.51 (d, *J* = 14.8 Hz, 2H), 2.24 – 2.09 (m, 2H).

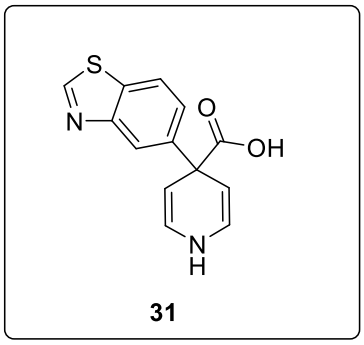
^{13}C NMR (126 MHz, CD_3OD) δ 141.94, 139.69, 138.32, 128.18, 125.14, 124.36, 123.97, 123.59, 72.44, 43.23, 42.22, 29.87

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 248.1104; found: 248.1105.

Melting point = 245 – 148 ℃

Preparation of 31



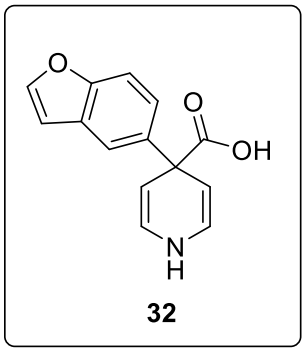
31

Following the General Procedure A with **S30** (0.053 g, 0.25 mmol) afforded **31** as a yellow solid. The ^{1}H NMR yield was determined to be 45% with dibromomethane as the internal standard.

Data for **31**: **^{1}H NMR** (600 MHz, CD_3OD) δ 9.23 (s, 1H), 8.01 (dd, *J* = 15.2, 5.1 Hz, 2H), 7.48 (dd, *J* = 8.5, 1.8 Hz, 1H), 7.15 – 6.96 (m, 2H), 5.43 – 5.34 (m, 2H).

^{13}C NMR (126 MHz, CD_3OD) δ 176.56, 154.44, 153.84, 145.64, 133.47, 125.42, 123.64, 123.46, 121.60, 108.65.

Preparation of 32

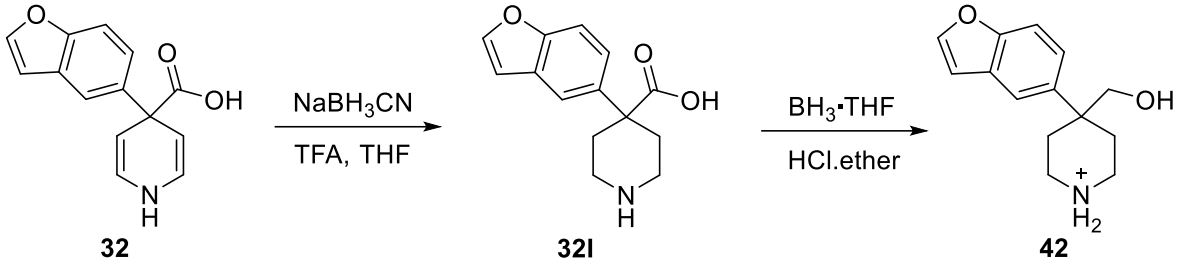


32

Following the General Procedure A with **S20** (0.048 g, 0.25 mmol) afforded **32** as a white solid. The ^{1}H NMR yield was determined to be 57% with dibromomethane as the internal standard.

Data for **32**: **^{1}H NMR** (600 MHz, CD_3OD): δ 7.73 (s, 1H), 7.54 (s, 1H), 7.46 (d, *J* = 8.7 Hz, 1H), 7.26 (d, *J* = 8.7 Hz, 1H), 7.04 (d, *J* = 8.3 Hz, 2H), 6.82 (s, 1H), 5.37 (d, *J* = 8.3 Hz, 2H);

Preparation of 42



32 **32I** **42**

Following General Procedure B, the crude reaction mixture of **32** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **32I** as a sticky solid. Following General Procedure C, crude product **32I** dissolved in BH_3-THF (2.0 mL) afforded **42** as a white solid (0.012 g, 18% over 3 steps).

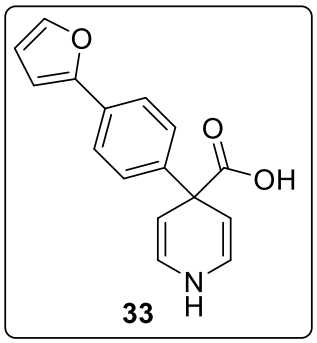
Data for **42**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.76 (d, *J* = 2.0 Hz, 1H), 7.70 (d, *J* = 1.7 Hz, 1H), 7.54 (d, *J* = 8.7 Hz, 1H), 7.37 (dd, *J* = 8.7, 1.7 Hz, 1H), 6.86 (d, *J* = 2.0 Hz, 1H), 3.36 (m, 2H), 3.52 (s, 2H), 2.96 (t, *J* = 11.7 Hz, 2H), 2.51 (d, *J* = 14.7 Hz, 2H), 2.24 – 2.13 (m, 2H).

^{13}C NMR (176 MHz, CD_3OD) δ 155.27, 147.10, 136.32, 129.57, 124.29, 121.14, 112.53, 107.74, 72.51, 43.12, 42.10, 29.69.

HRMS (ESI): Expected mass [M^+]: 232.1332; found: 232.1332.

Melting point = 227℃

Preparation of 33

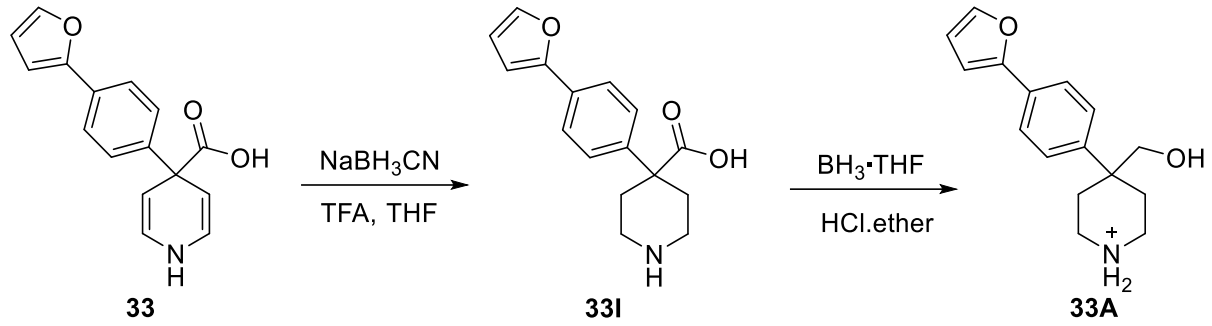


33

Following the General Procedure A with **S19** (0.055 g, 0.25 mmol) afforded **33** as a white solid. The ^{1}H NMR yield was determined to be 80% with dibromomethane as the internal standard.

Data for **33**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.65 (d, *J* = 8.5 Hz, 2H), 7.52 (d, *J* = 1.4 Hz, 1H), 7.35 – 7.29 (m, 2H), 7.05 (d, *J* = 8.6 Hz, 2H), 6.72 (d, *J* = 3.3 Hz, 1H), 6.48 (dd, *J* = 3.3, 1.8 Hz, 1H), 5.29 (d, *J* = 8.6 Hz, 2H).

Preparation of 33A



Following General Procedure B, the crude reaction mixture of **33** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **33I** as a sticky solid. Following General Procedure C, crude product **33I** dissolved in BH_3-THF (2.0 mL) afforded **33A** as a white solid (8.0 mg, 11% over 3 steps).

Data for **33A**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.74 (d, *J* = 8.5 Hz, 2H), 7.55 (d, *J* = 1.3 Hz, 1H), 7.46 (d, *J* = 8.5 Hz, 2H), 6.77 (d, *J* = 3.3 Hz, 1H), 6.51 (dd, *J* = 3.4, 1.8 Hz, 1H), 3.51 (s, 2H), 3.36 (2H)*, 2.94 (t, *J* = 11.5 Hz, 2H), 2.45 (d, *J* = 14.7 Hz, 2H), 2.21 – 2.05 (m, 2H).

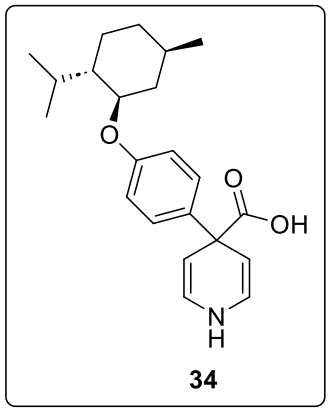
^{13}C NMR (126 MHz, CD_3OD) δ 154.86, 143.54, 141.12, 131.01, 128.68, 125.30, 112.78, 106.30, 72.08, 43.08, 42.14, 29.28.

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 258.1489; found: 258.1489.

Melting point = 236℃

Preparation of 34

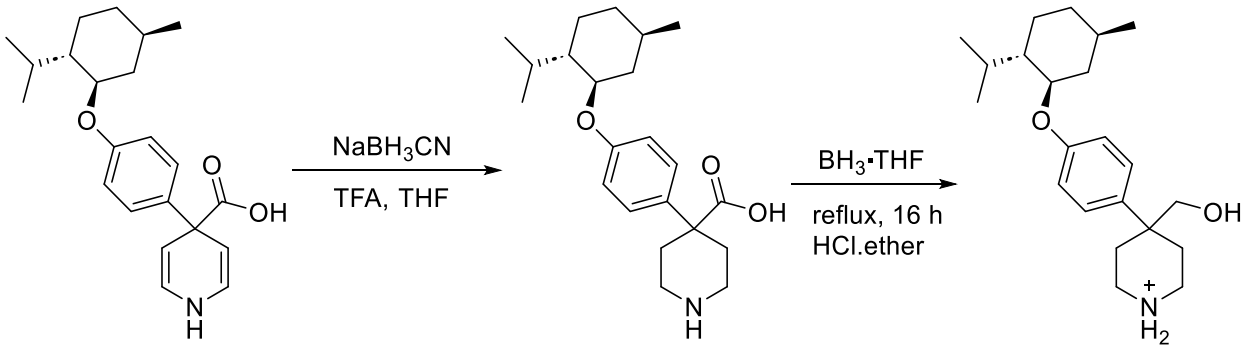


34

Following the General Procedure A with **S21** (0.077 g, 0.25 mmol) afforded **34** as a yellow solid. The ^{1}H NMR yield was determined to be 35% with dibromomethane as the internal standard.

Data for **34**: **^{1}H NMR** (400 MHz, CD_3OD): δ 7.19 (t, *J* = 11.0 Hz, 2H), 7.10 – 6.94 (m, 2H), 6.92 – 6.75 (m, 2H), 5.52 – 5.08 (m, 2H), 4.28 – 3.94 (m, 1H), 2.37 – 2.04 (m, 2H), 1.94 – 1.58 (m, 2H), 1.62 – 1.34 (m, 2H), 1.30 – 1.05 (m, 1H), 1.06 – 0.84 (m, 8H), 0.78 (t, *J* = 8.4 Hz, 3H)

Preparation of 34A



34 **34I** **34A**

Following General Procedure B, the crude reaction mixture of **34** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **34I** as a sticky solid. Following General Procedure C, crude product **34I** dissolved in BH_3-THF (4.0 mL) afforded **34A** as a white solid (0.010 g, 12% over 3 steps).

Data for **34A**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.30 (d, *J* = 8.8 Hz, 2H), 6.95 (d, *J* = 8.7 Hz, 2H), 4.11 (td, *J* = 10.5, 4.1 Hz, 1H), 3.44 (s, 2H), 3.35-3.27 (2H)* , 2.92 (t, *J* = 12.7 Hz, 2H), 2.39 (d, *J* = 14.8 Hz, 2H), 2.22 – 2.02 (m, 4H), 1.80 – 1.65 (m, 2H), 1.60 – 1.38 (m, 3H), 1.16 (ddd, *J* = 16.1, 13.5, 3.7 Hz, 1H), 0.97 (dd, *J* = 12.4, 3.1 Hz, 1H), 0.92 (dd, *J* = 6.8, 2.9 Hz, 6H), 0.78 (d, *J* = 7.0 Hz, 3H).

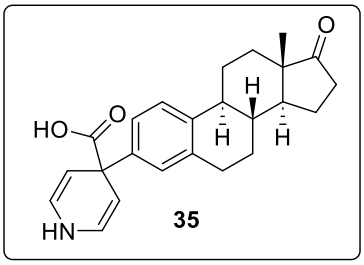
^{13}C NMR (126 MHz, CD_3OD) δ 158.49, 133.28, 129.44, 117.03, 78.25, 72.45, 42.52, 42.10, 41.54, 35.73, 32.47, 29.33, 27.50, 24.94, 22.58, 21.09, 17.14

*2H peak merging with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 346.2741; found: 346.2742.

Melting point = 245 – 248℃

Preparation of 35

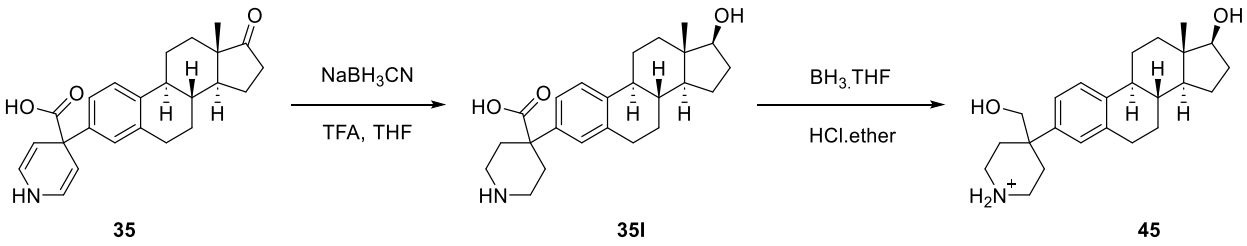


35

Following the General Procedure A with **S22** (0.082 g, 0.25 mmol) afforded **35** as a yellow solid. The ^{1}H NMR yield was determined to be 44% with dibromomethane as the internal standard.

Data for **35**: **^{1}H NMR** (600 MHz, CD_3OD) δ 7.23 (d, *J* = 8.2 Hz, 2H), 7.03 (d, *J* = 8.2 Hz, 1H), 7.00 – 6.97 (m, 2H), 5.25 (d, *J* = 8.5 Hz, 2H), 3.05 – 2.95 (m, 1H), 2.95 – 2.81 (m, 2H), 2.52 – 2.36 (m, 2H), 2.24 (dd, *J* = 13.8,7.0 Hz, 1H), 2.18 – 1.98 (m, 3H), 1.93 – 1.83 (m, 1H), 1.70 – 1.37 (m, 1H), 0.98 – 0.83 (m, 3H).

Preparation of 45



35 **35I** **45**

Following General Procedure B, the crude reaction mixture of **35** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **35I** as a sticky solid. Following General Procedure C, crude product **35I** dissolved in BH_3-THF (2.0 mL) afforded **45** as a white solid (0.031 g, 31% over 3 steps).

Data for **45**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.30 (d, *J* = 8.2 Hz, 1H), 7.13 (d, *J* = 8.3 Hz, 1H), 7.08 (s, 1H), 3.66 (t, *J* = 8.5 Hz, 1H), 3.43 (s, 2H), 3.12 (d, *J* = 12.9 Hz, 2H), 2.90 – 2.73 (m, 4H), 2.34 (ddd, *J* = 25.5, 14.7, 8.9 Hz, 3H), 2.21 (td, *J* = 11.3, 4.0 Hz, 1H), 2.10 – 1.87 (m, 4H), 1.71 (ddd, *J* = 11.9, 10.8, 3.1 Hz, 1H), 1.59 – 1.13 (m, 8H), 0.77 (s, 3H).

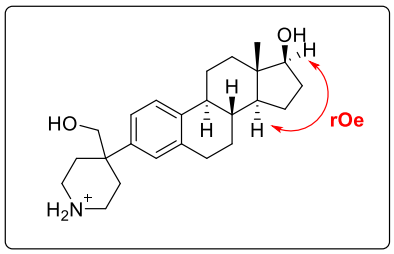
^{13}C NMR (126 MHz, CD_3OD) δ 139.89, 138.14, 128.81, 126.89, 125.53, 82.47, 72.71, 66.93, 51.42, 45.65, 44.40, 43.02, 42.55, 40.31, 38.06, 30.84, 30.76, 28.55, 27.42, 24.10, 15.51, 11.75.

HRMS (ESI): Expected mass [M^+]: 370.2741; found: 370.2741.

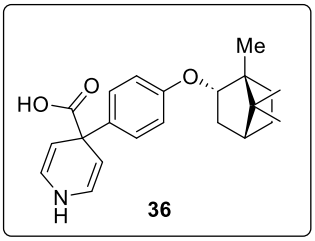
Melting point = 258 – 260 ℃

Stereochemical assignment for 45

Analysis of 2D ROESY of **45** supported the indicated stereochemistry.



Preparation of 36

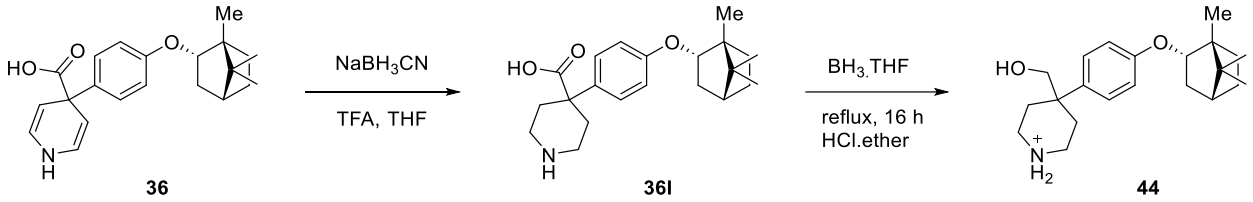


36

Following the General Procedure A with **S23** (0.076 g, 0.25 mmol) afforded **36** as a yellow solid. The ^{1}H NMR yield was determined to be 38% with dibromomethane as the internal standard.

Data for **36**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.16 (d, *J* = 8.5 Hz, 2H), 6.99 (d, *J* = 8.1 Hz, 2H), 6.80 (d, *J* = 8.5 Hz, 2H), 5.27 (d, *J* = 8.0 Hz, 2H), 4.35 (d, *J* = 8.2 Hz, 1H), 2.46 – 2.36 (m, 1H), 2.27 – 2.18 (m, 1H), 1.75 (ddd, *J* = 23.4, 11.8, 8.0 Hz, 2H), 1.40 – 1.18 (m, 3H), 1.06 – 0.96 (m, 3H), 0.96 – 0.89 (m, 6H).

Preparation of 44



Following General Procedure B, the crude reaction mixture of **36** treated with $NaBH_3CN$ (0.043 g, 2.7 mmol) and TFA (0.10 mL, 5.0 mmol) in THF (4.0 mL) afforded crude product **36I** as a sticky solid. Following General Procedure C, crude product **36I** dissolved in BH_3-THF (4.0 mL) afforded **44** as a white solid (0.017 g, 19 % over 3 steps).

Data for **44**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.30 (d, *J* = 8.8 Hz, 2H), 6.90 (d, *J* = 8.8 Hz, 2H), 4.43 – 4.28 (m, 1H), 3.44 (s, 2H), 3.35-3.26 (2H)*, 2.92 (t, *J* = 11.9 Hz, 2H), 2.44 (ddd, *J* = 27.8, 15.3, 9.5 Hz, 3H), 2.30 – 2.20 (m, 1H), 2.17 – 2.04 (m, 2H), 1.81 (ddd, *J* = 12.0, 7.8, 3.5 Hz, 1H), 1.73 (t, *J* = 4.5 Hz, 1H), 1.37 (td, *J* = 12.0, 2.7 Hz, 1H), 1.31 – 1.16 (m, 1H), 1.04 (dd, *J* = 13.3, 3.3 Hz, 1H), 0.99 (s, 3H), 0.94 (d, *J* = 7.9 Hz, 6H).

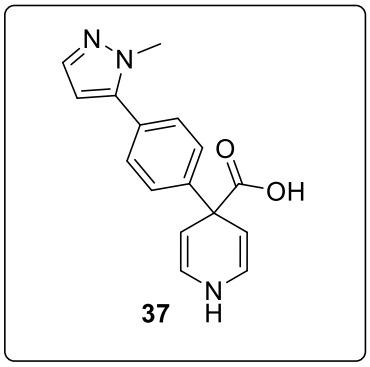
^{13}C NMR (126 MHz, CD_3OD) δ 159.31, 133.05, 129.28, 116.91, 84.03, 72.46, 50.48, 46.59, 42.52, 42.10, 37.93, 29.31, 28.95, 27.80, 20.15, 19.35, 14.10.

* 2H peaks are merged with CD_3OD peak confirmed by COSY

HRMS (ESI): Expected mass [M^+]: 344.2584; found: 344.2584.

Melting point = 223℃

Preparation of 37



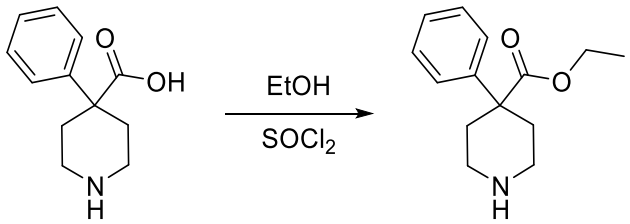
37

Following the General Procedure A with S34 (0.058 g, 0.25 mmol) afforded **37** as a white solid. The ^{1}H NMR yield was determined to be 15% with dibromomethane as the internal standard.

Data for **37: ^{1}H NMR** (500 MHz, CD_3OD) δ 7.45 (m, 5H), 7.07 (d, *J* = 8.1 Hz, 2H), 6.34 (s, 1H), 5.32 (d, *J* = 8.1 Hz, 2H), 3.84 (s, 3H).

Note: ^{13}C NMR and HRMS data of 45 could not be collected due to rapid re-aromatization.

Preparation of 59



58 **59**

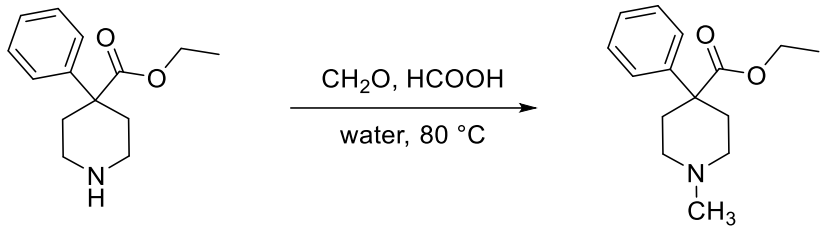
To a solution of crude **58** (0.18 g, 0.90 mmol, 1.0 equiv.) in EtOH (1.5 mL) thionyl chloride (0.26 mL, 3.6 mmol, 4.0 equiv) was added at 0°C. The reaction mixture was refluxed for 7 h, followed by concentration of the reaction mixture in vacuo. The resulting mixture was washed with 10% NaOH and extracted with DCM three times. The organic layers were combined and evaporated to obtain the product as a crude mixture which was purified using flash chromatography by priming the column using 10% Et_3N in hexane and using 10% MeOH/DCM as eluent (0.11 g, 52% yield) to afford **59** as light yellow oil.

Data for **59**: **^{1}H NMR** (400 MHz, CD_3OD) δ 7.42 – 7.30 (m, 4H), 7.25 (ddd, *J* = 7.1, 3.9, 1.3 Hz, 1H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.05 (dt, *J* = 13.4, 3.7 Hz, 2H), 2.85 – 2.73 (m, 2H), 2.55 (d, *J* = 13.4 Hz, 2H), 1.17 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, CD_3OD) δ 175.69, 143.99, 129.71, 128.28, 126.76, 62.20, 50.46, 44.39, 34.84, 14.31

HRMS (ESI): Expected mass [M+H$^+$]: 234.1489; found: 234.1487

Preparation of 56



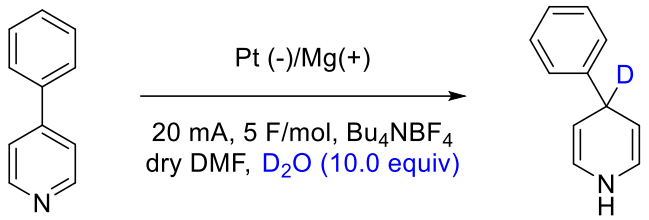
59 **56**

To a solution of amine **59** (0.042 g, 0.18 mmol) in water (0.50 mL) was added formic acid (24 µL, 3.6 equiv) and 37% aqueous CH_2O (32 µL, 2.2 equiv). The mixture was heated at 80℃ for 18 h. After completion, reaction was cooled down and 1M HCl was added and extracted with DCM. The aqueous phase was basified to pH 11 using 3N NaOH and again extracted with DCM. This organic layer was evaporated under reduced pressure to obtain the crude product which was purified using flash chromatography to obtain the pure compound (0.022 g, 50% yield) as colourless oil.

Data for **56: ^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.36 (m, 2H), 7.35 – 7.29 (m, 2H), 7.27 – 7.19 (m, 1H), 4.13 (q, *J* = 7.1 Hz, 2H), 2.76 (t, *J* = 21.3 Hz, 2H), 2.58 (d, *J* = 12.8 Hz, 2H), 2.27 (s, 3H), 2.15 (dd, *J* = 22.1, 10.6 Hz, 2H), 1.98 (t, *J* = 11.1 Hz, 2H), 1.18 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 174.40, 143.01, 128.51, 126.95, 125.82, 60.81, 53.61, 48.79, 46.34, 34.04, 14.09.
HRMS (ESI): Expected mass [M+H$^+$]: 248.1645; found: 248.1643

Deuterium labelling experiment



12 **65**

A 5 mL dry ElectraSyn vial was charged with 4-phenylpyridine **12** and tetrabutylammonium tetrafluoroborate (0.25 mmol, 1.0 equiv.) in dry DMF (2.5 – 3.0 mL). Added to this solution was D_2O (45 µL, 10.0 equiv) and mixed well. The vial was then capped with an ElectraSyn vial cap equipped with a platinum cathode and a magnesium anode and the reaction mixture was stirred until it became homogenous. Electrolysis was performed at 20 mA current and 5 F/mol charge. After completion of the electrolysis, the contents of the vial were transferred to a separatory funnel and the electrodes were rinsed with ethyl acetate (ca. 2 mL) and the aqueous layer was extracted using ethyl acetate (10 mL). The organic layer was washed several times with ice cold water (~100 mL×5) to remove the existing DMF. The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure to obtain the crude product of **65** with 75% D incorporation. Due to instability of the compound, purification was not performed and ^{1}H NMR of crude was obtained (**Figure S2**).

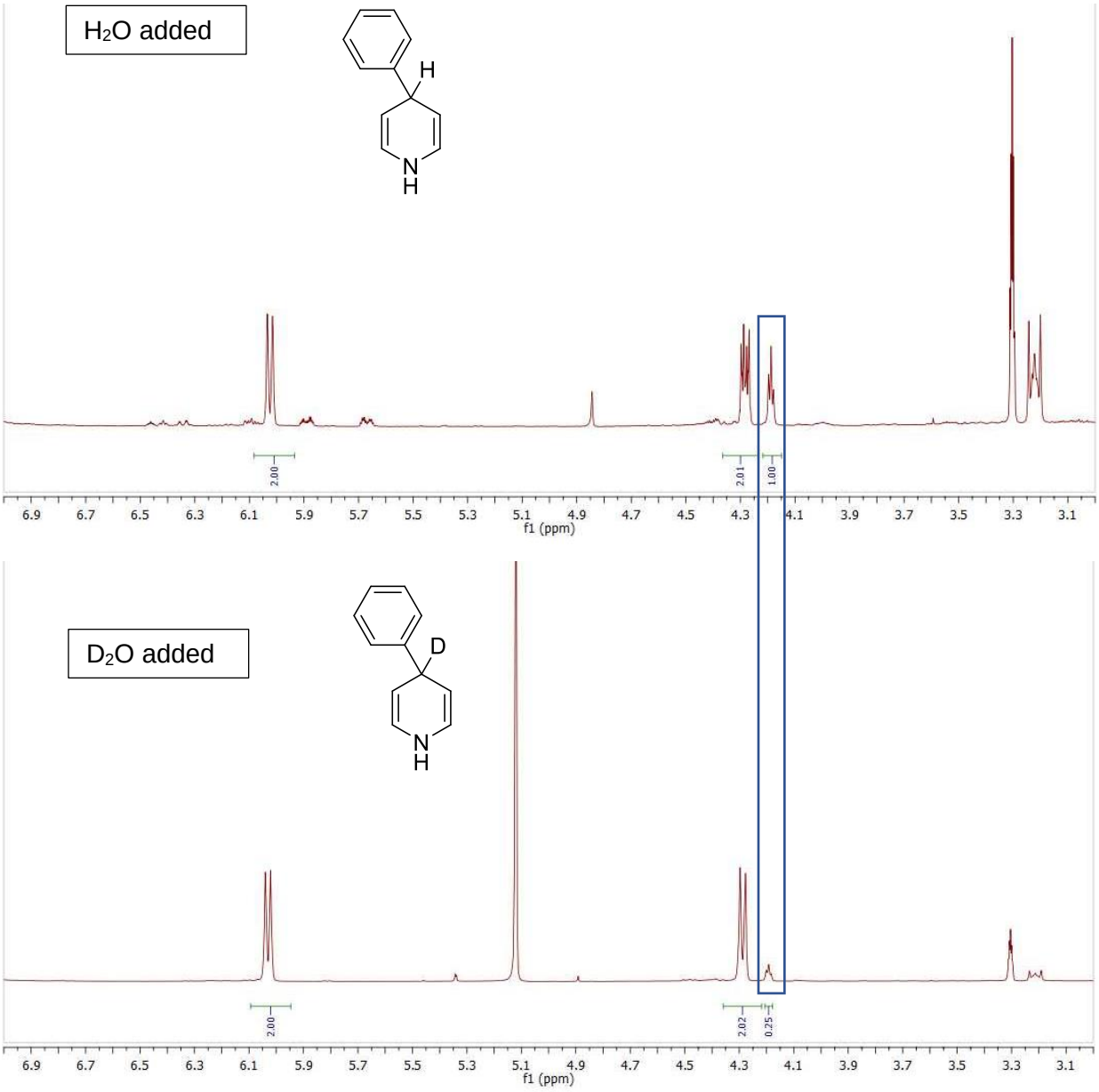


Figure S2: Crude ^{1}H NMR of D labelling experiment when H_2O and D_2O are added to the reaction (Crude NMR's taken in CD_3OD solvent and 400 MHz instrument)

Cyclic Voltammetry (CV) studies

The cyclic voltammogram were recorded on Pine Instruments model AFCBP1 potentiostat. The measurement cell equipped with a 3 mm glassy carbon disk as the working electrode, a platinum coated plate as the counter electrode, and an Ag/AgCl reference electrode was used. The results were recorded using DMF (6.0 mL) as solvent, Bu_4NBF_4 (0.08 M) as the supporting electrolyte. The results were recorded under ambient air conditions at room temperature, sweeping reductively from the initial potential of -1 V to the final potential of -1 V in the scan rate of 120 mVs^{-1}. Prior to use, the solvent DMF was deoxygenated by nitrogen bubbling for 0.5 h. And the glassy carbon working electrode was polished with alumina powder before every use.

CV Specifications:

Segments: 3

Initial potential: -1 V

Upper potential: -0.9 V

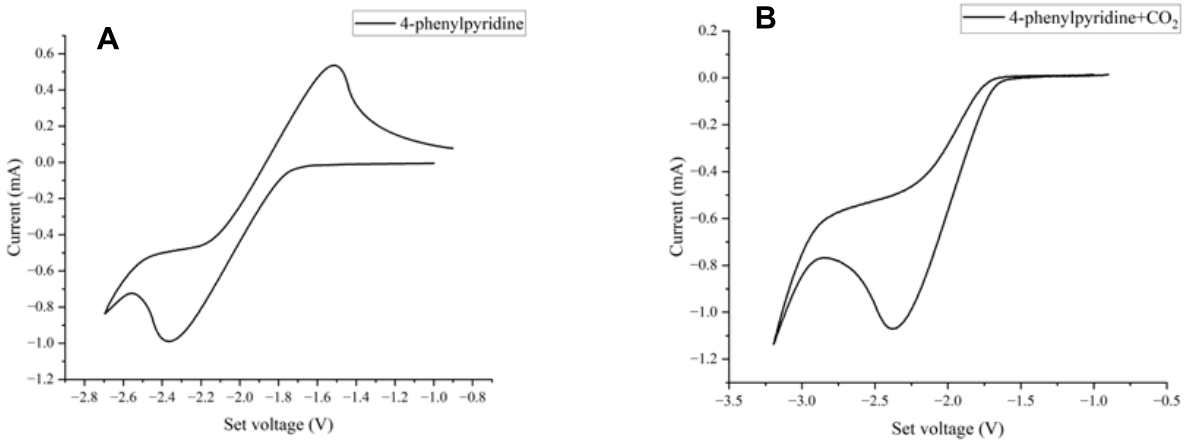
Lower potential: -2.7 V

Final potential: -1 V

Sweep rate: 120 mV/s

Current: 1 mA

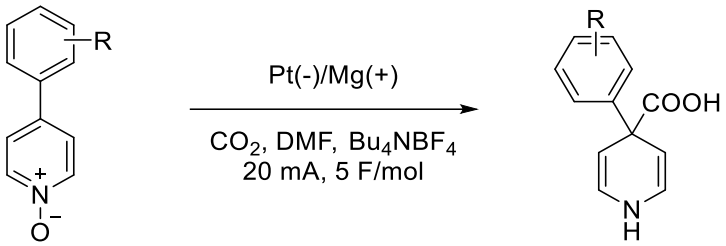
Figure S3:



A) Cyclic voltammetry of 4-phenylpyridine (0.08 M) in DMF as solvent and Bu_4NBF_4 (0.08 M) as electrolyte **B)** Cyclic voltammetry of 4-phenylpyridine (0.08 M) in DMF as solvent and

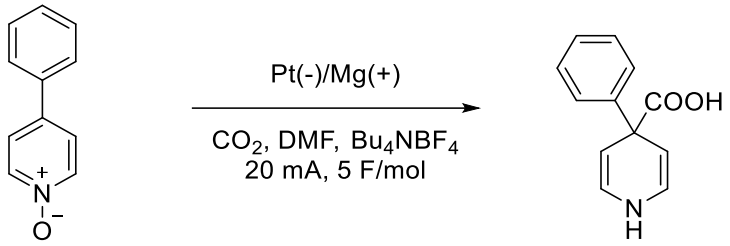
Bu_4NBF_4 (0.08 M) as electrolyte and CO_2 gas was purged into it for 20 minutes prior to CV measurements.

General procedure (GP- D) for electrochemical dearomative - carboxylation of 4-aryl pyridine N-oxides



A 5 mL ElectraSyn vial was charged with 4-(hetero)arylpyridine N-oxide and tetrabutylammonium tetrafluoroborate (0.25 mmol, 1.0 equiv.) in DMF (2.5 – 3.0 mL). The vial was then capped with an ElectraSyn vial cap equipped with a platinum cathode and a magnesium anode and the reaction mixture was stirred until it became homogenous. A balloon filled with CO_2 was used to bubble CO_2 into the reaction mixture prior to starting the reaction and then continued for the duration of the electrolysis. Electrolysis was performed at 20 mA current and 5 F/mol charge. Following electrolysis, the ElectraSyn vial cap was removed and 3M HCl was added dropwise with stirring into the reaction mixture until solution becomes transparent. The content of the vial was transferred to a separatory funnel and the electrodes were rinsed with ethyl acetate (ca. 2 mL) and the aqueous layer was extracted using ethyl acetate (10 mL). The organic layer was washed several times with ice cold water (~100 mL x 5) to remove the existing DMF. The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure to obtain the crude product.

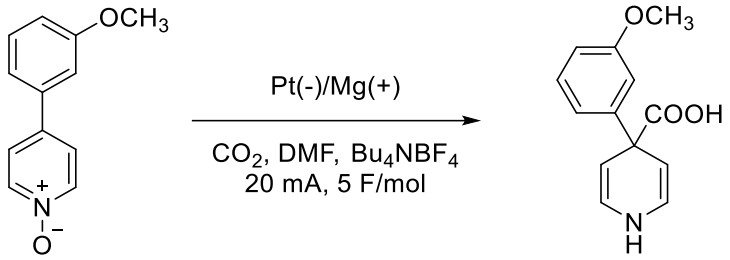
Preparation of 21 from N-oxide of 4-phenyl pyridine



S35 **13**

Following GP-D, using *N*-oxide **S35** (0.042 g, 0.25 mmol, 1.0 equiv), Bu_4NBF_4 (0.082 g, 0.25 mmol, 1.0 equiv) was subjected to electrochemical conditions to afford the product **13** in 47% NMR yield.

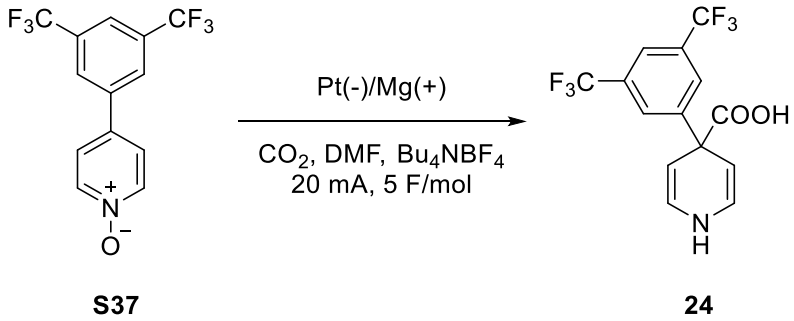
Preparation of 29 from S36



S36 **21**

Following GP-D, using *N*-oxide **S36** (0.050 g, 0.25 mmol, 1.0 equiv), Bu_4NBF_4 (0.082 g, 0.25 mmol, 1.0 equiv) was subjected to electrochemical conditions to afford the product **21** in 48% NMR yield.

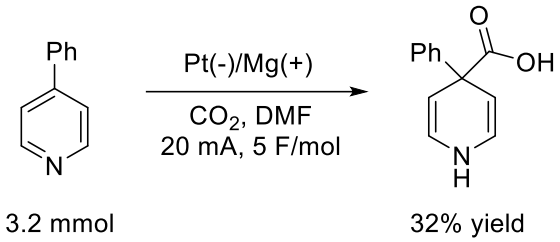
Preparation of 32 from S37



S37 **24**

Following GP-D, using *N*-oxide **S37** (0.076 g, 0.25 mmol, 1.0 equiv), Bu_4NBF_4 (0.082 g, 0.25 mmol, 1.0 equiv) was subjected to electrochemical conditions to afford the product **24** in 52% NMR yield.

Scale-up of reductive electrochemical carboxylation



3.2 mmol 32% yield

A 20 mL ElectraSyn vial was charged with 4-phenylpyridine (0.5 g, 3.2 mmol, 1.0 equiv.) and tetrabutylammonium tetrafluoroborate (1.05 g, 3.2 mmol, 1.0 equiv.) in DMF (18.0 mL). The vial was then capped with an ElectraSyn vial cap equipped with a platinum cathode and a magnesium anode and the reaction mixture was stirred until it became homogenous. A CO_2 cylinder was connected using a tubing attached to a needle which was dipped into the reaction mixture and CO_2 was bubbled at moderate rate (**Figure S4.B**). Electrolysis was performed at 20 mA current and 5 F/mol charge. Following electrolysis, the ElectraSyn vial cap was removed and 3M HCl was added dropwise with stirring into the reaction mixture until solution becomes transparent. The content of the vial was transferred to a separatory funnel and the electrodes were rinsed with ethyl acetate (ca. 2 mL) and the aqueous layer was extracted using ethyl acetate. The organic layer was washed several times with ice cold water (~100 mL×5) to remove the existing DMF. The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure to obtain the crude product.

The crude product was purified by making a suspension of it in DCM followed by adding hexane, which results in precipitation of the product. The precipitate is then filtered using a Buchner funnel and the residue was washed thoroughly with DCM to obtain the pure product (0.21 g, 32%).

Graphical guide:

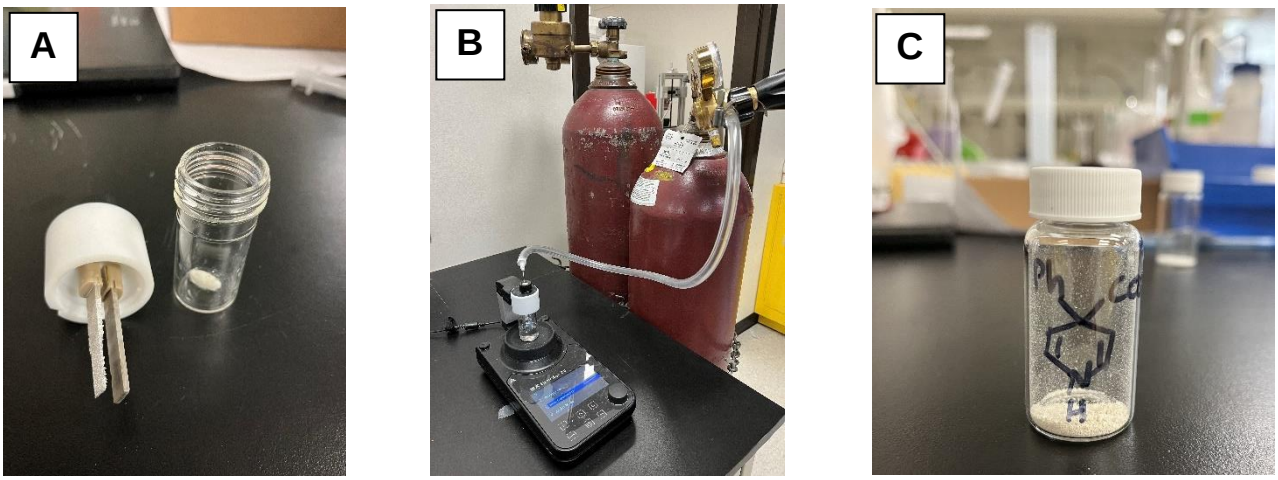


Figure S4: A) Electrodes (Mg as anode and Pt as cathode) and 20 mL vial with a stir bar; **B)** Large scale electrochemical set up; **C)** Product obtained after reaction

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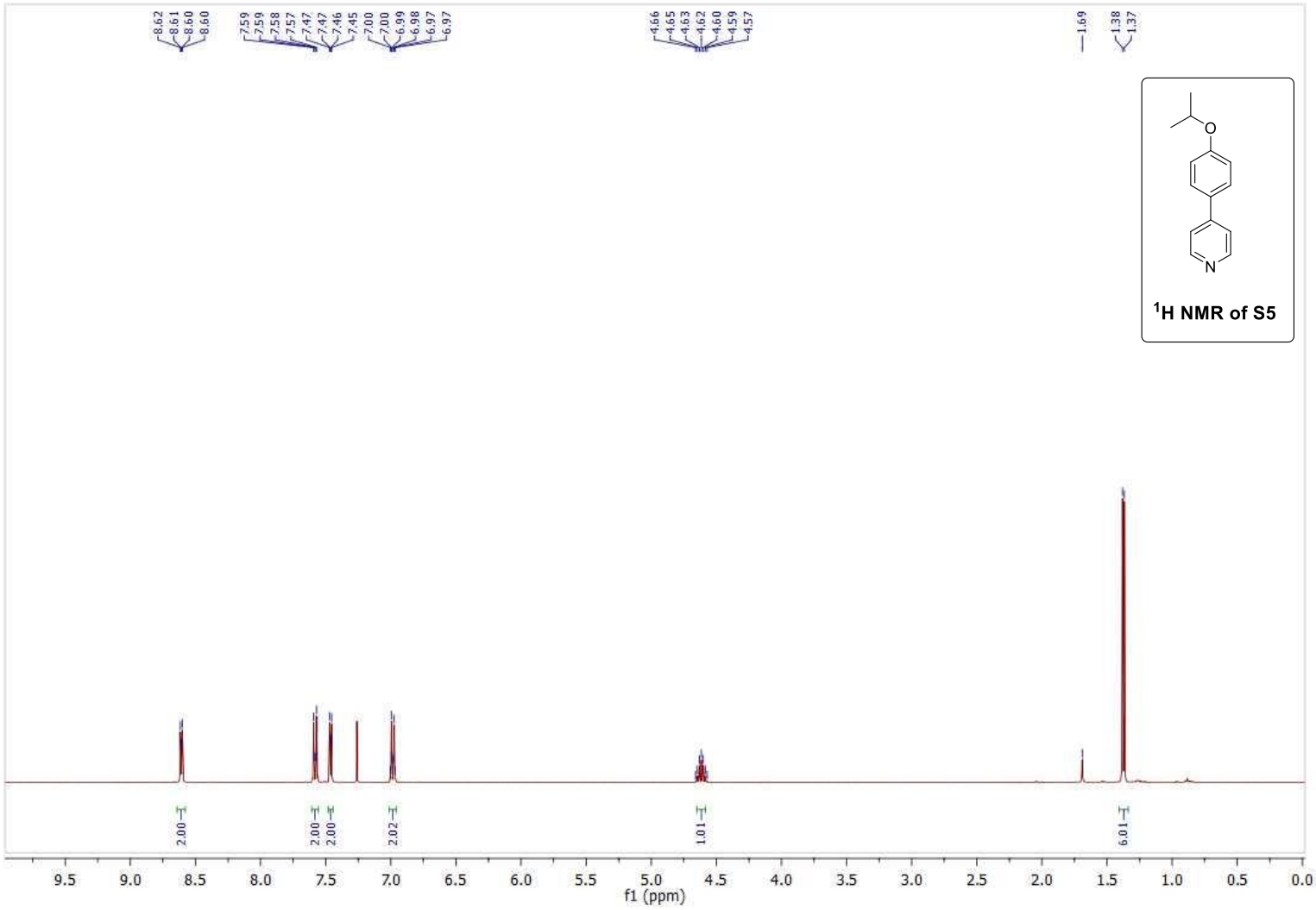
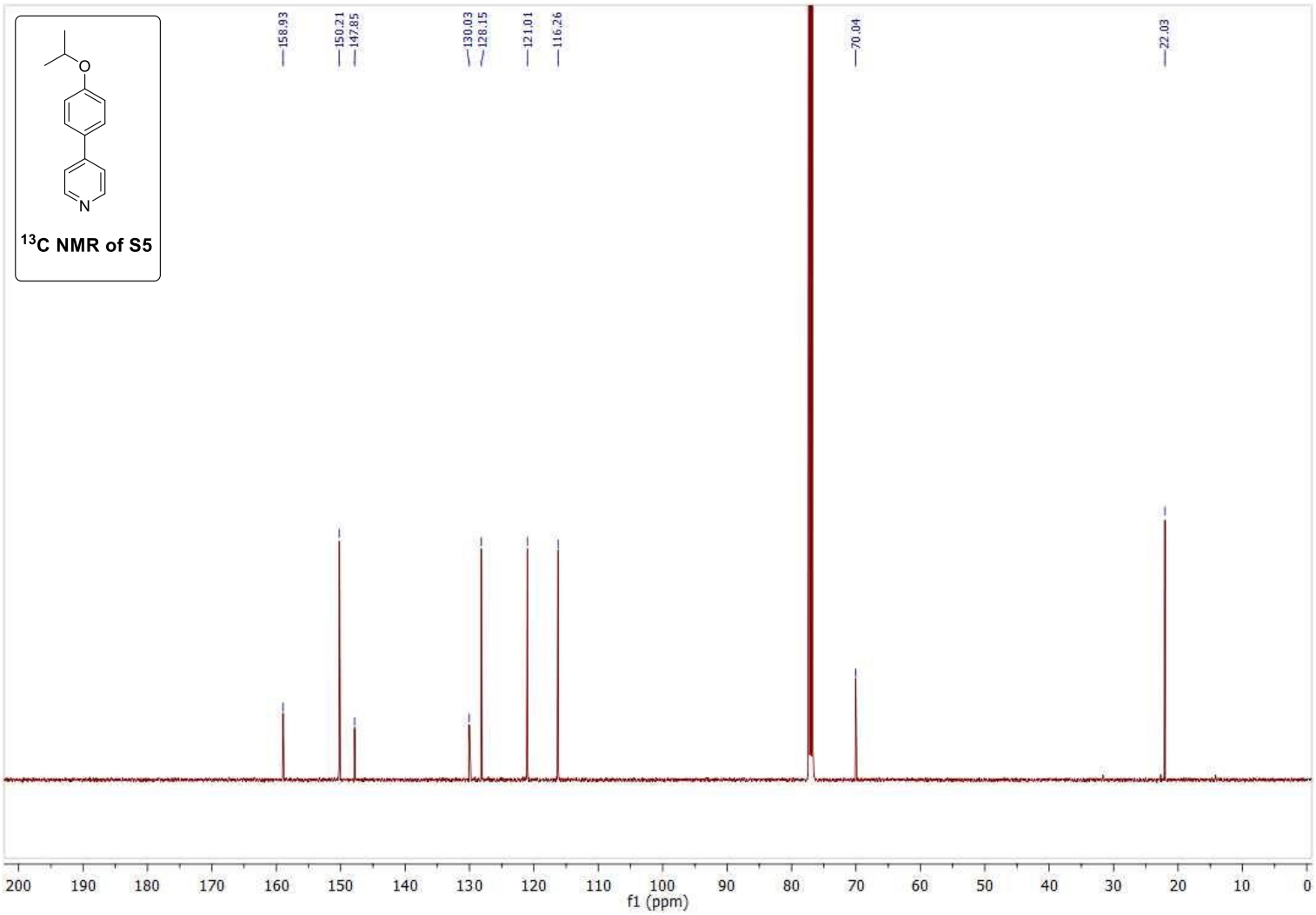
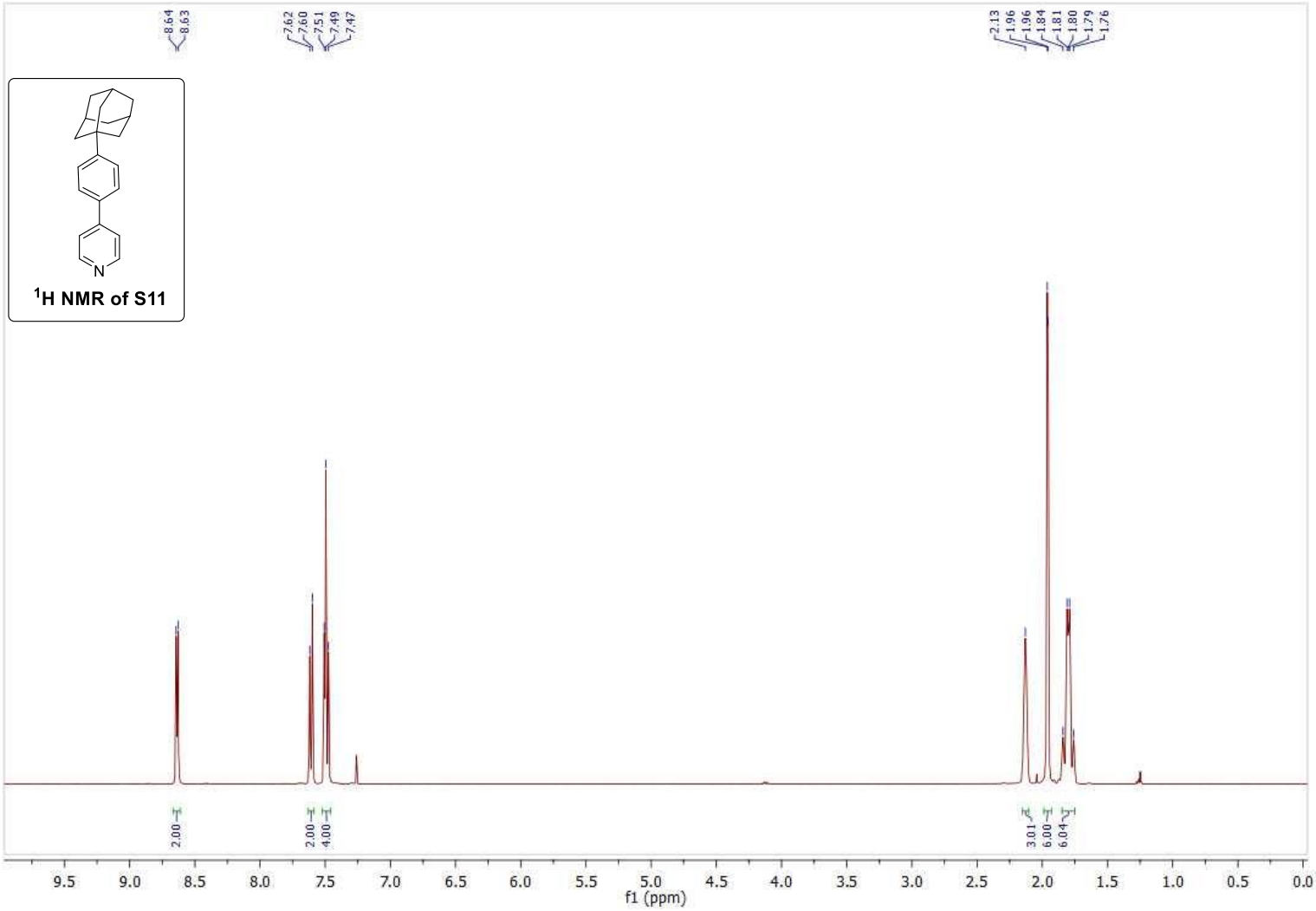
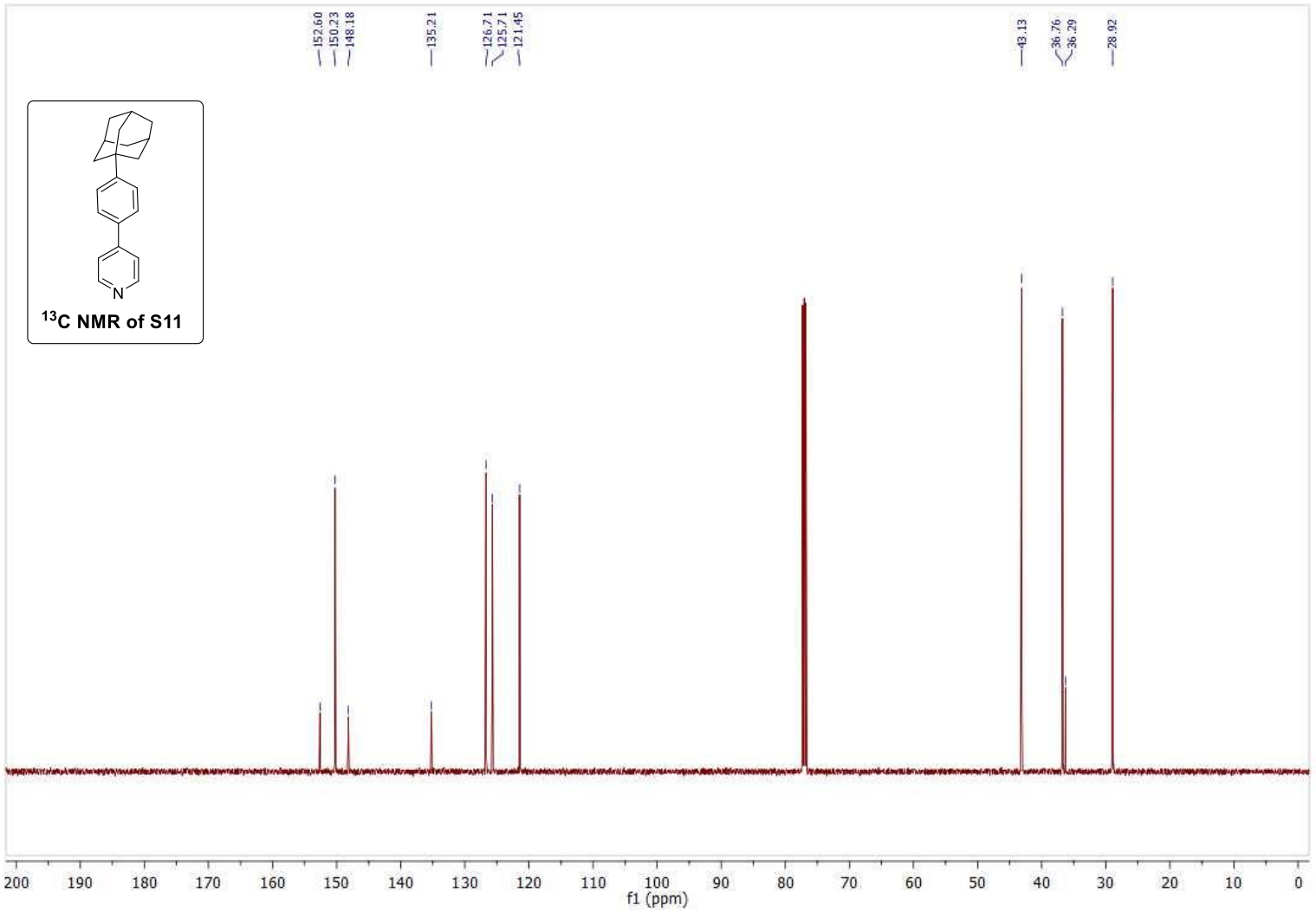

8.62
8.61
8.60
8.60
7.59
7.59
7.58
7.57
7.47
7.47
7.46
7.45
7.00
7.00
6.99
6.98
6.97
6.97
4.66
4.65
4.63
4.62
4.60
4.59
4.57
1.69
1.38
1.37
O
N
2.00
2.00
2.00
2.02
1.01
6.01
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

^{1}H NMR of S5

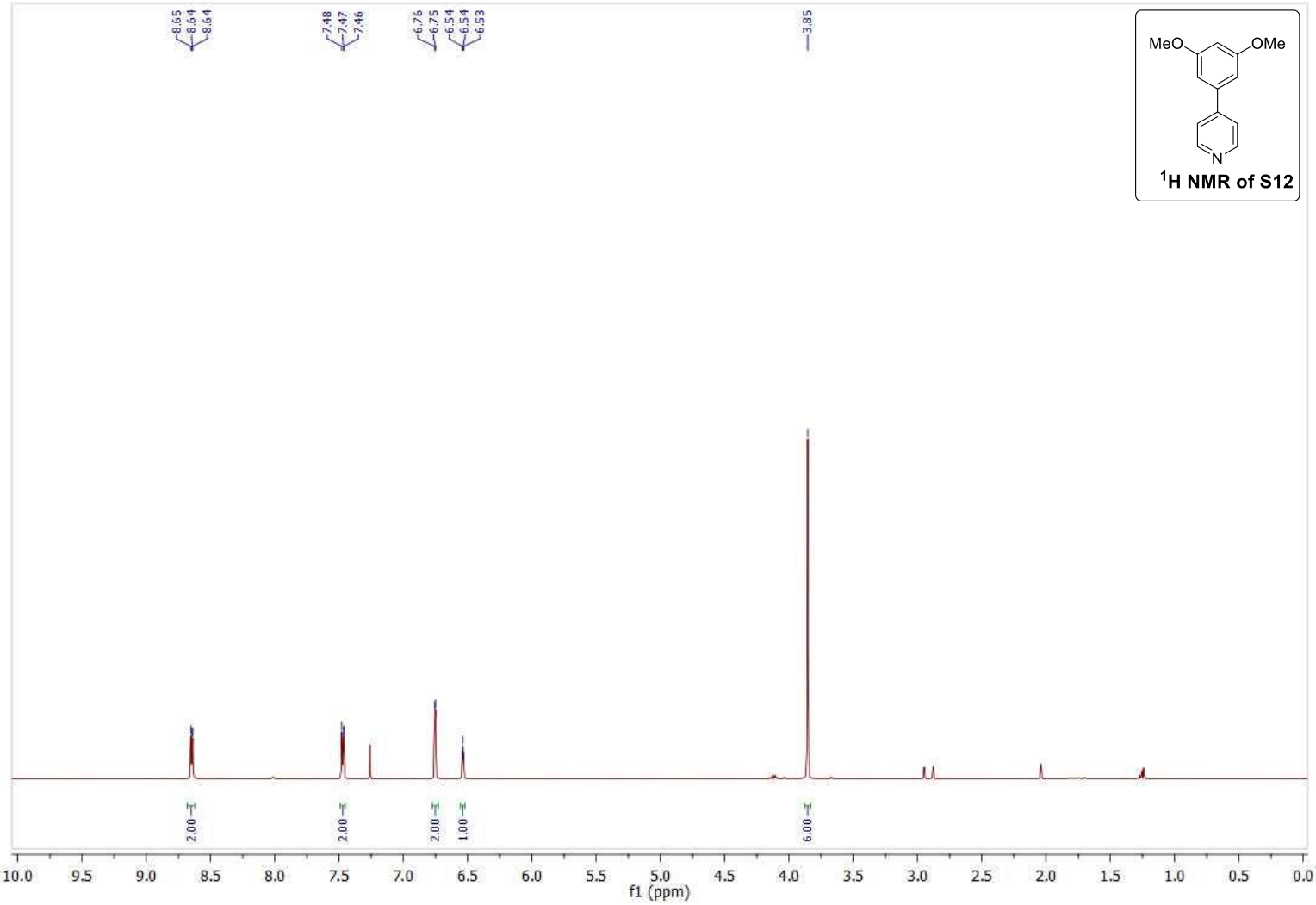

158.93
150.21
147.85
130.03
128.15
121.01
116.26
70.04
22.03
O
N
^{13}C NMR of S5
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.64
8.63
7.62
7.60
7.51
7.49
7.47
2.13
1.96
1.96
1.84
1.81
1.80
1.79
1.76
N
2.00
2.00
4.00
3.01
6.00
6.04
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)

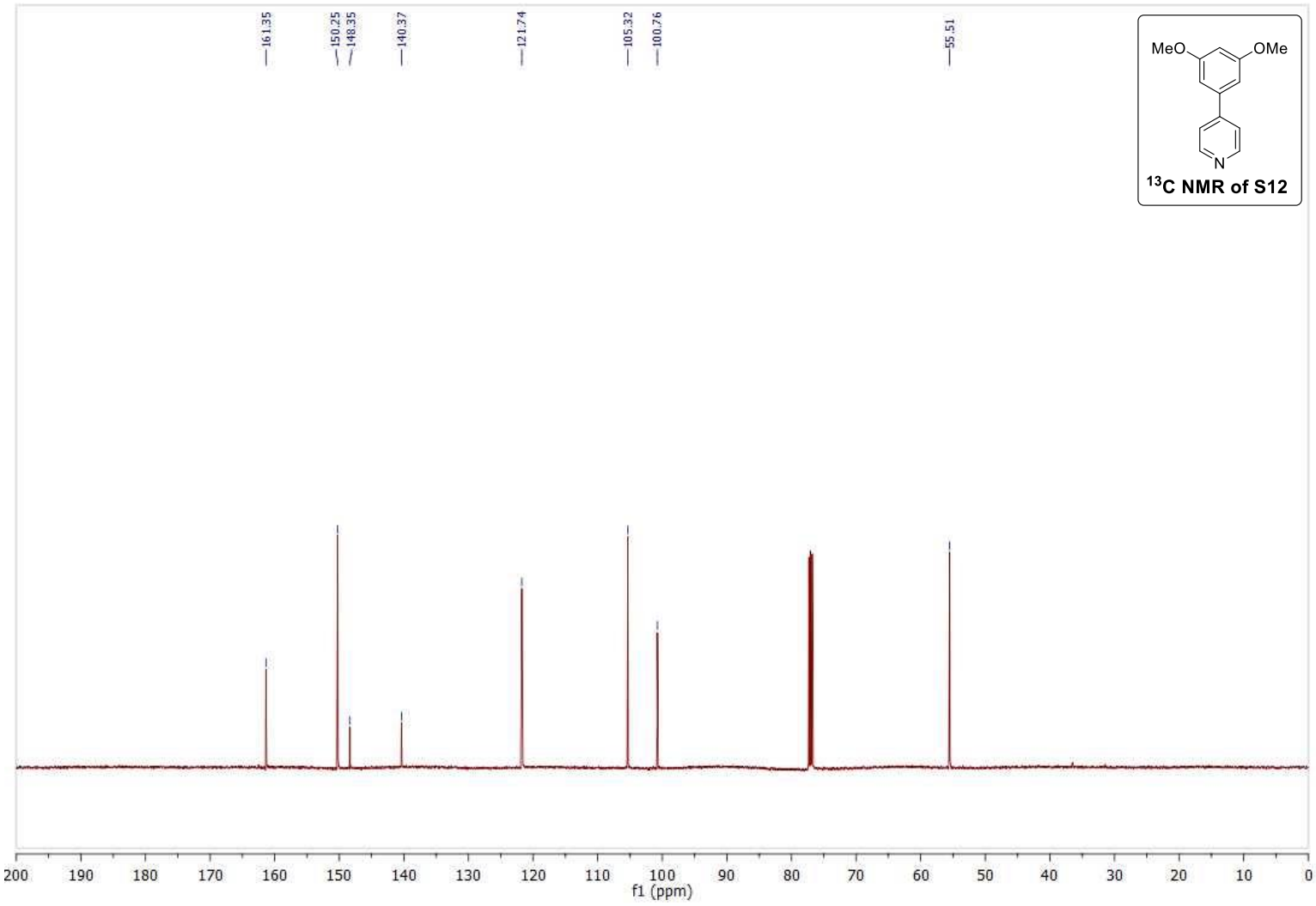
^{1}H NMR of S11

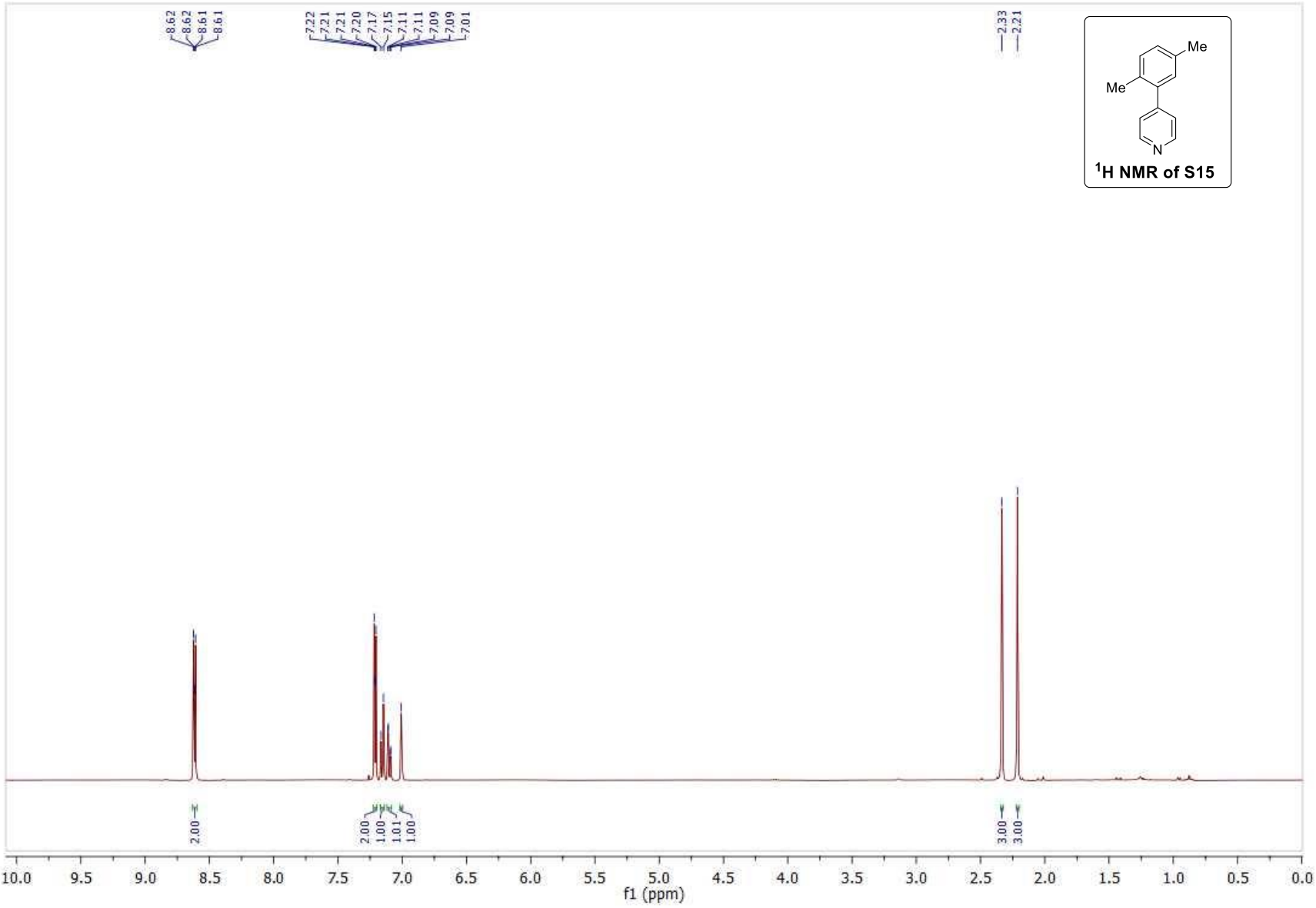


^{13}C NMR of S11

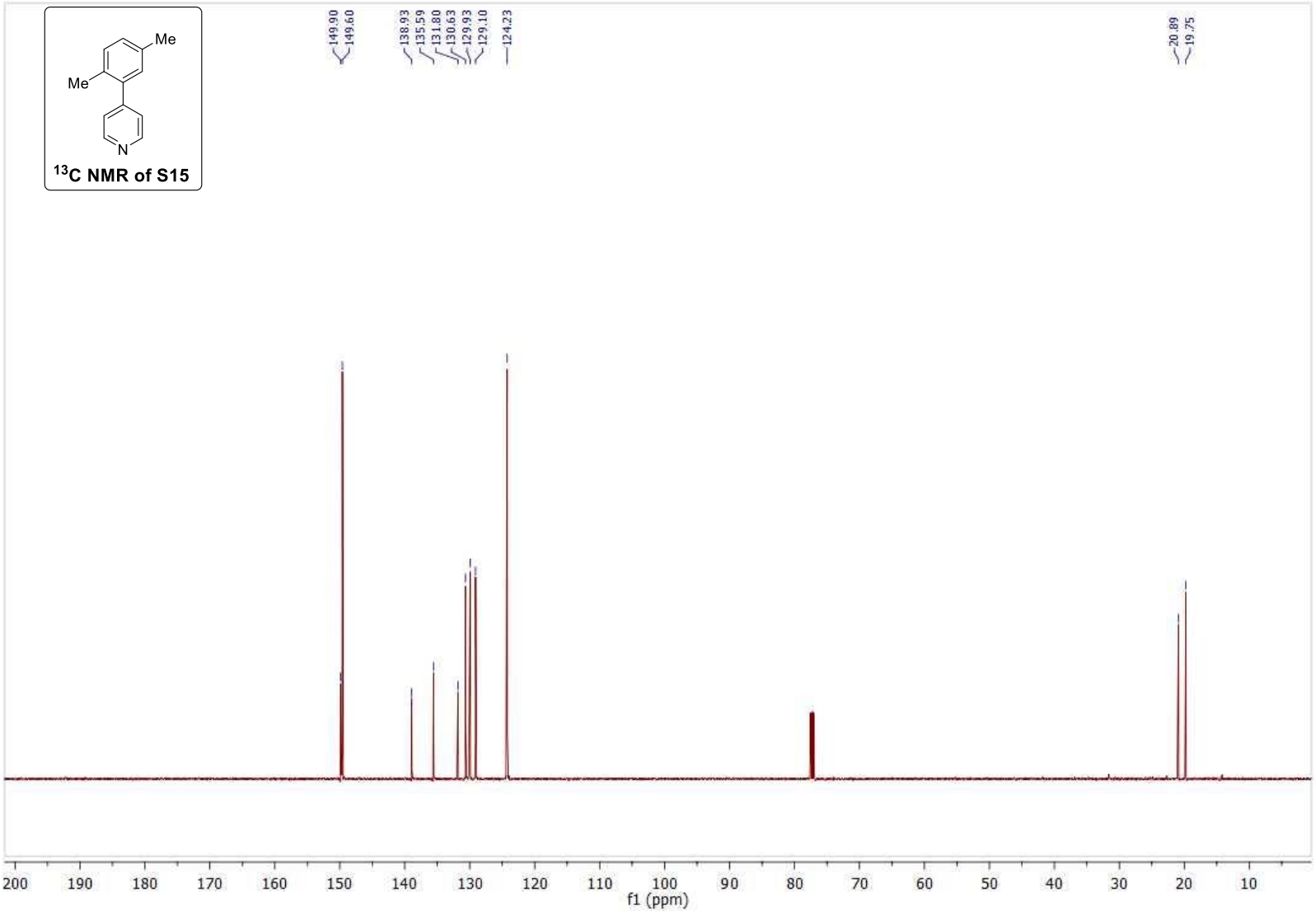

8.65
8.64
8.64
7.48
7.47
7.46
6.76
6.75
6.54
6.54
6.53
3.85
MeO
OMe
N
2.00
2.00
2.00
1.00
6.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

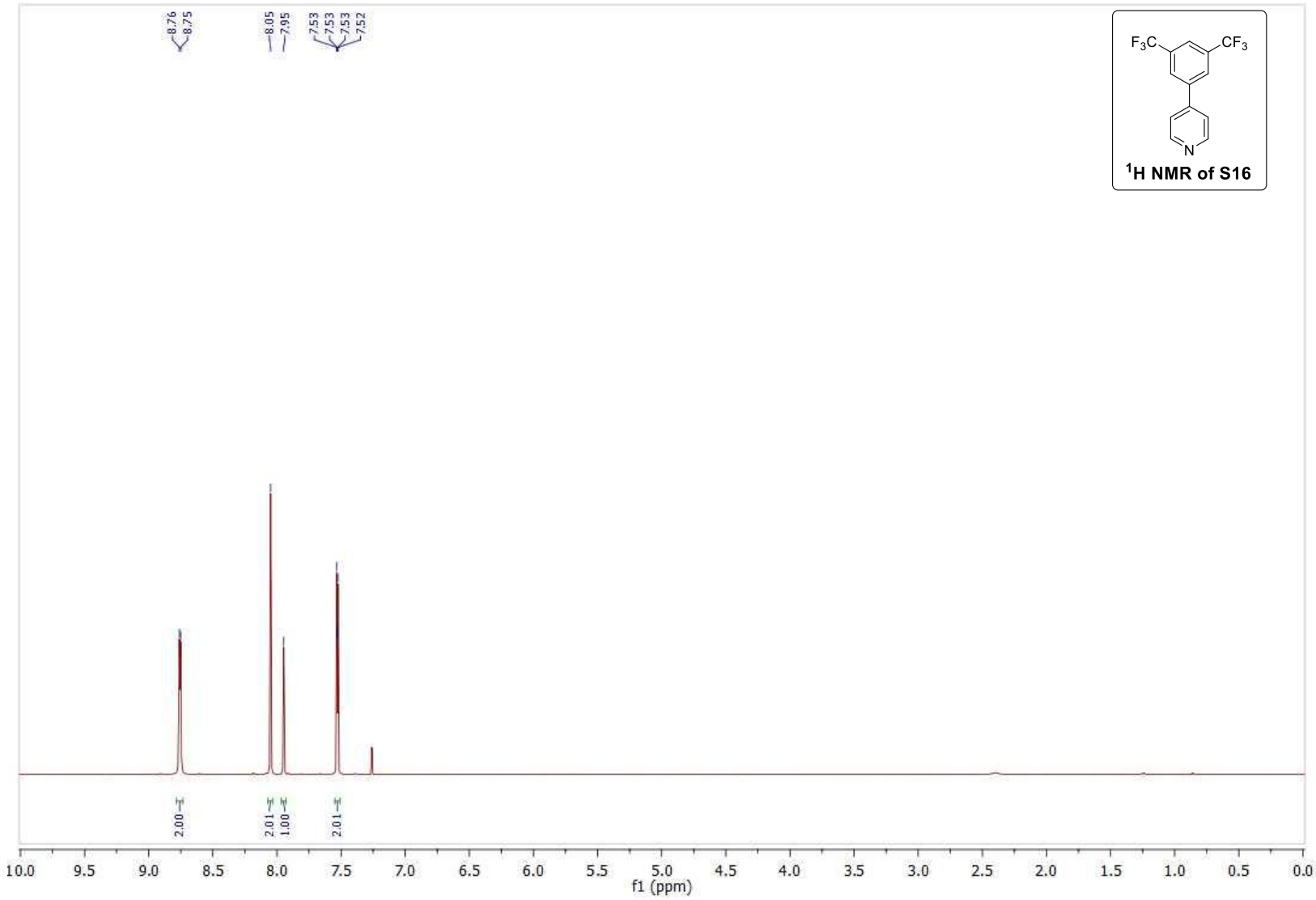
^{1}H NMR of S12

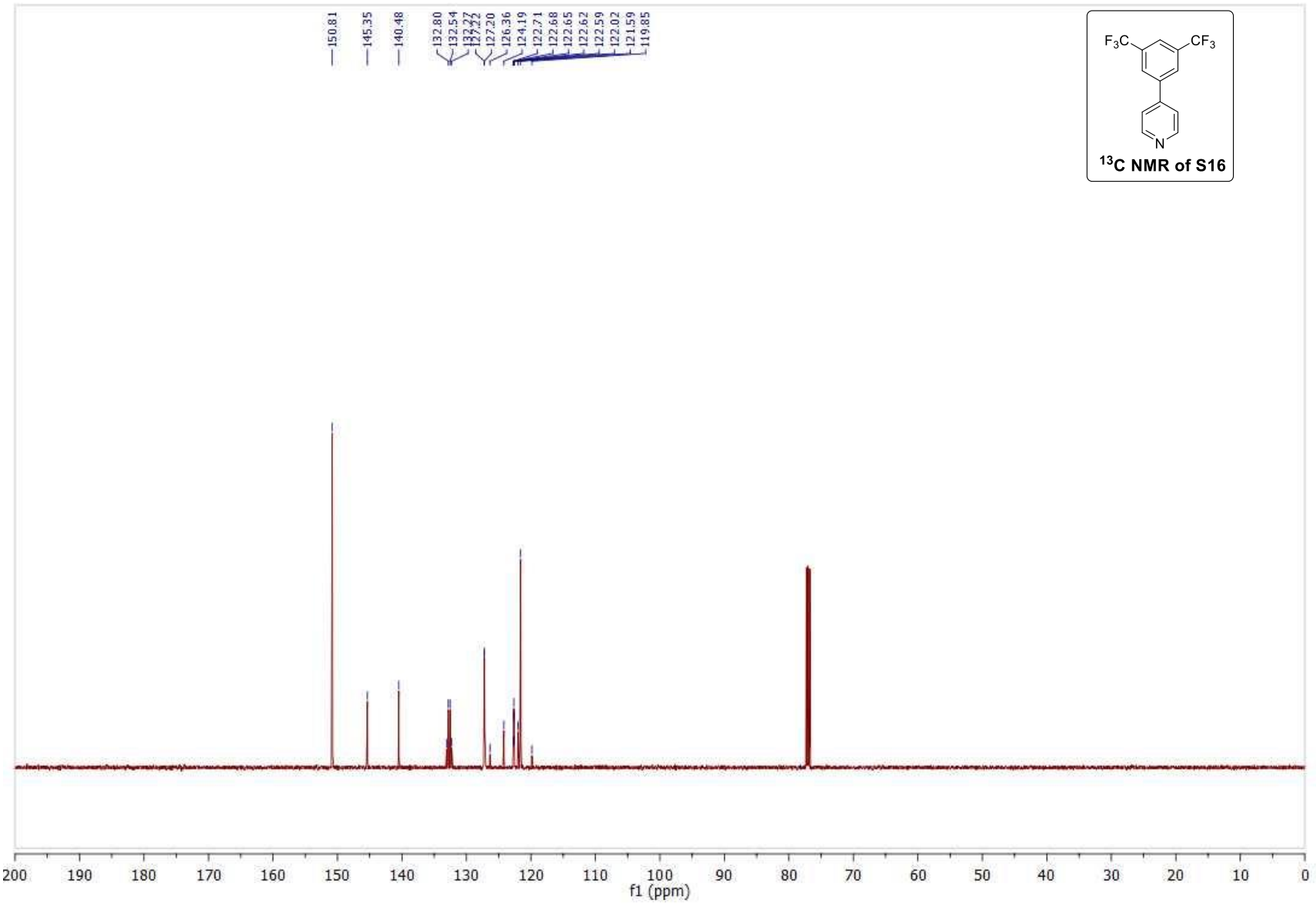

161.35
150.25
148.35
140.37
121.74
105.32
100.76
55.51
MeO
OMe
N
^{13}C NMR of S12
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.62
8.62
8.61
8.61
7.22
7.21
7.21
7.20
7.17
7.15
7.11
7.11
7.09
7.09
7.01
2.33
2.21
Me
Me
N
2.00
2.00
1.00
1.01
1.00
3.00
3.00
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)

^{1}H NMR of S15


Me
Me
N
^{13}C NMR of S15
149.90
149.60
138.93
135.59
131.80
130.63
129.93
129.10
124.23
20.89
19.75
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


8.76
8.75
8.05
7.95
7.53
7.53
7.53
7.52
F3C
CF3
N
1H NMR of S16
2.00
2.01
1.00
2.01
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)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132.54
127.20
126.36
124.19
122.71
122.68
122.65
122.62
122.59
122.02
121.59
119.85
F3C
CF3
N
13C NMR of S16
200
190
180
170
160
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140
130
120
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90
80
70
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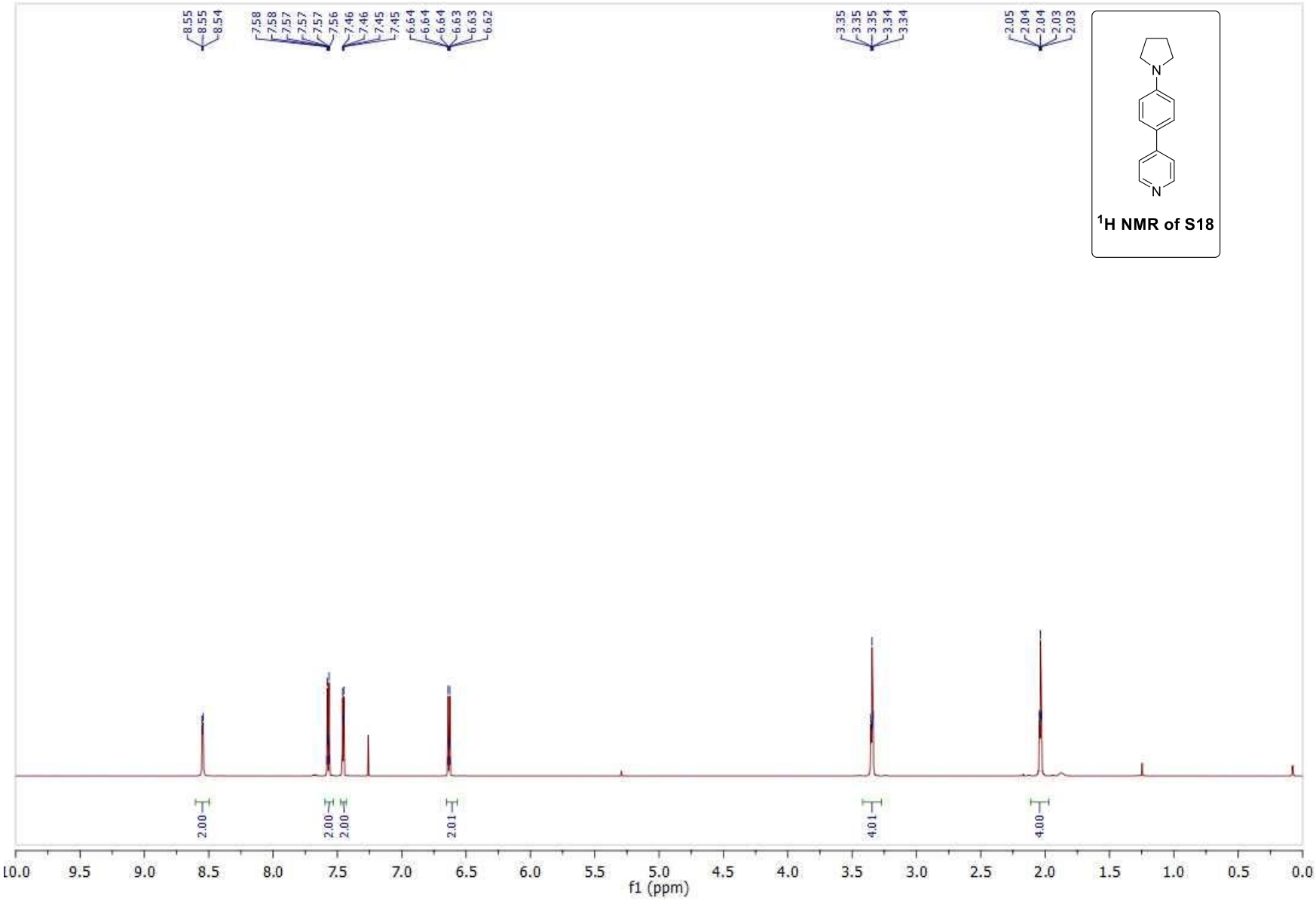
50
40
30
20
10
0
f1 (ppm)


8.55
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7.45
6.64
6.64
6.64
6.63
6.63
6.62
3.35
3.35
3.35
3.34
3.34
2.05
2.04
2.04
2.03
2.03
N
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2.00
2.00
2.01
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10.0
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9.0
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7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
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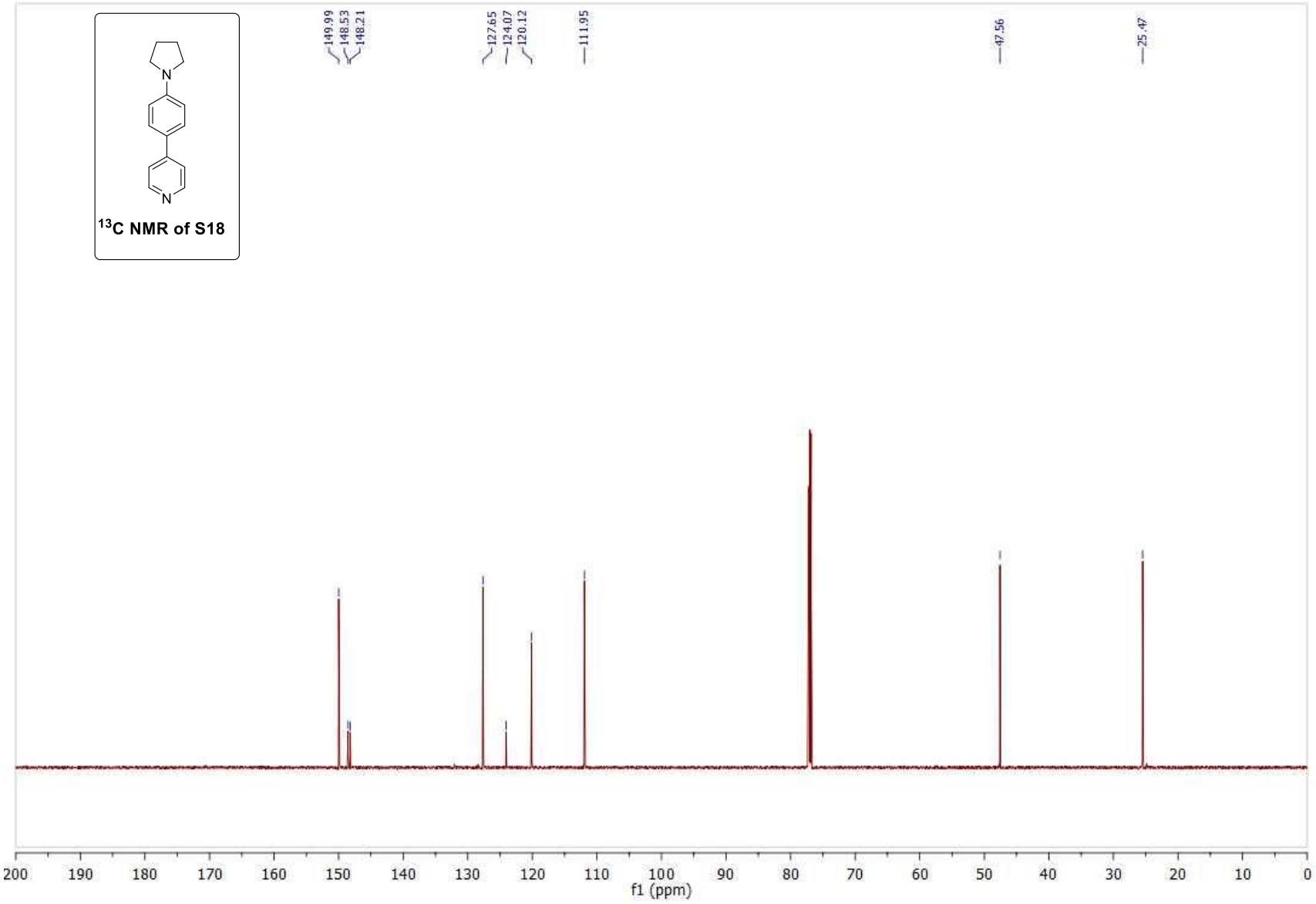
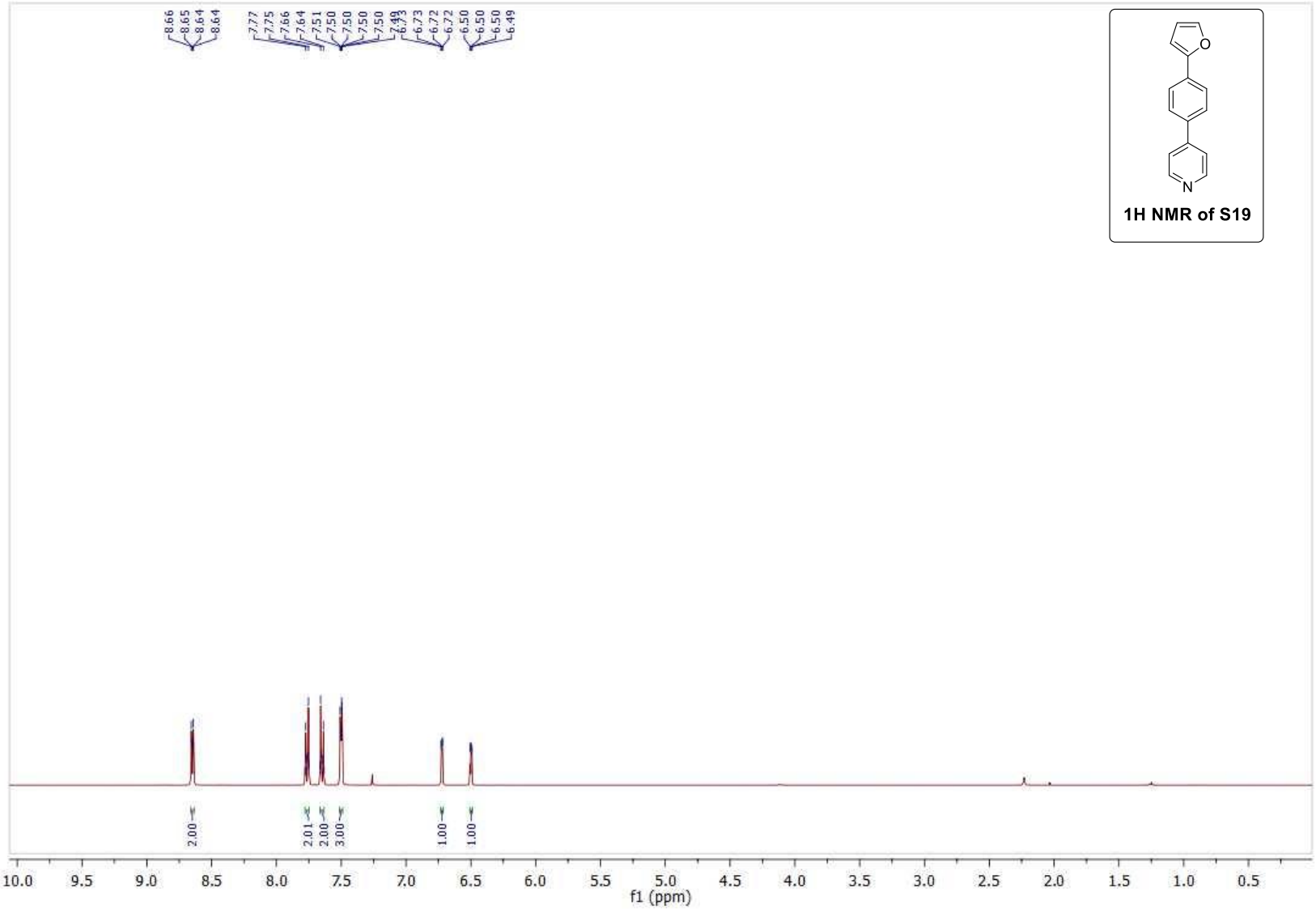
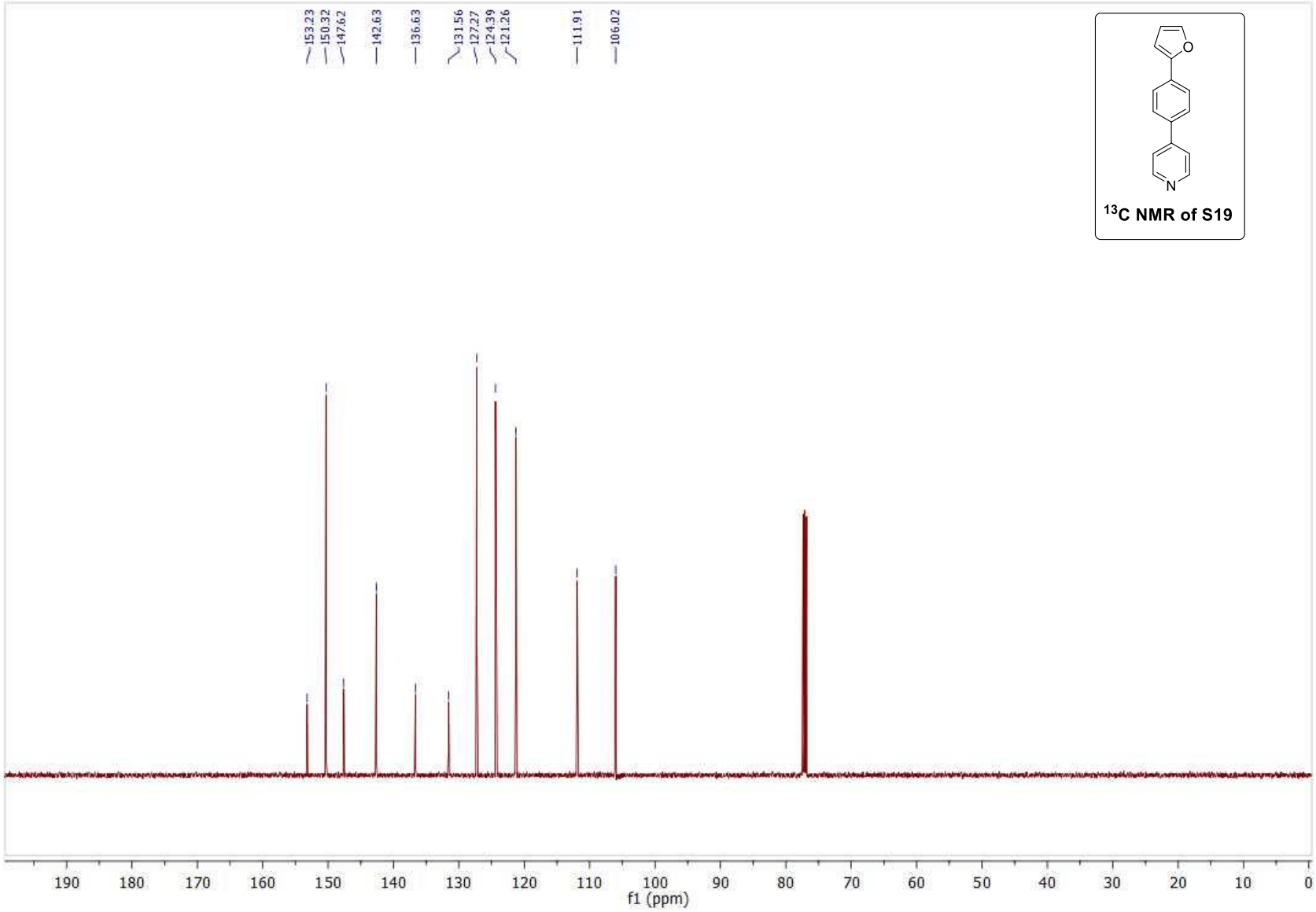
1.5
1.0
0.5
0.0
f1 (ppm)

^{1}H NMR of S18

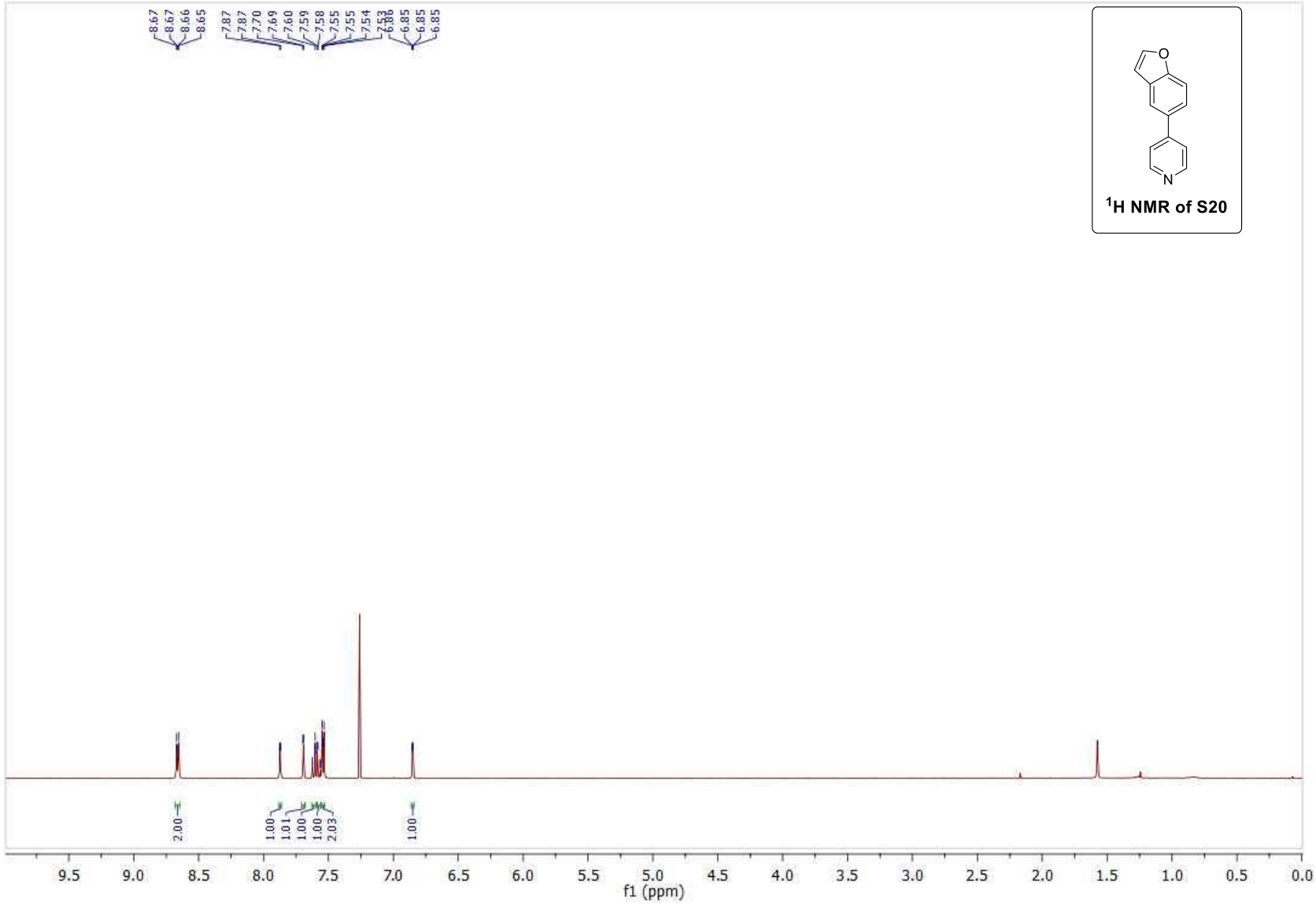


^{13}C NMR of S18

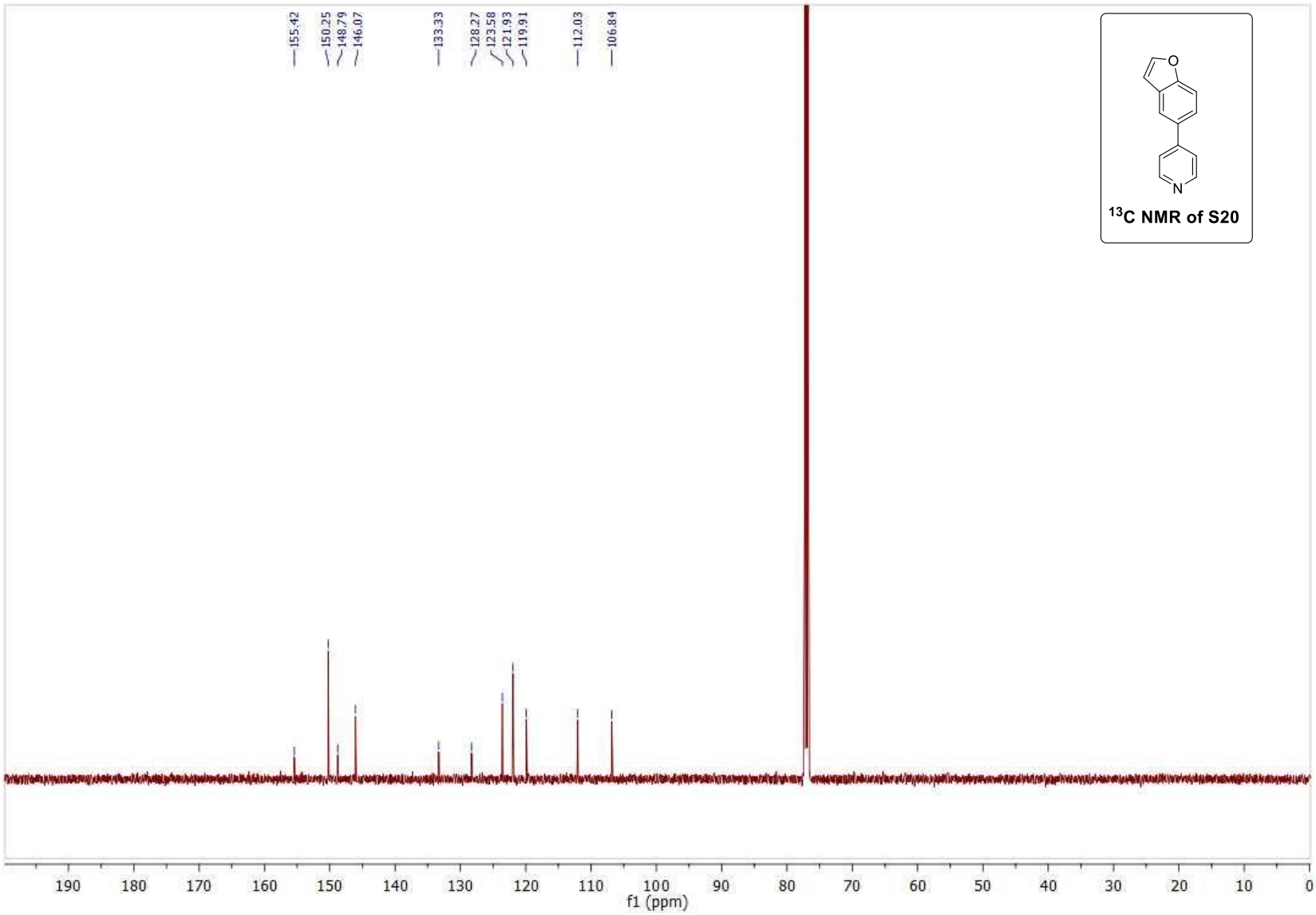

8.66
8.65
8.64
8.64
7.77
7.75
7.66
7.64
7.51
7.50
7.50
7.50
7.50
7.49
6.73
6.72
6.72
6.50
6.50
6.50
6.49
O
N
1H NMR of S19
2.00
2.01
2.00
3.00
1.00
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)



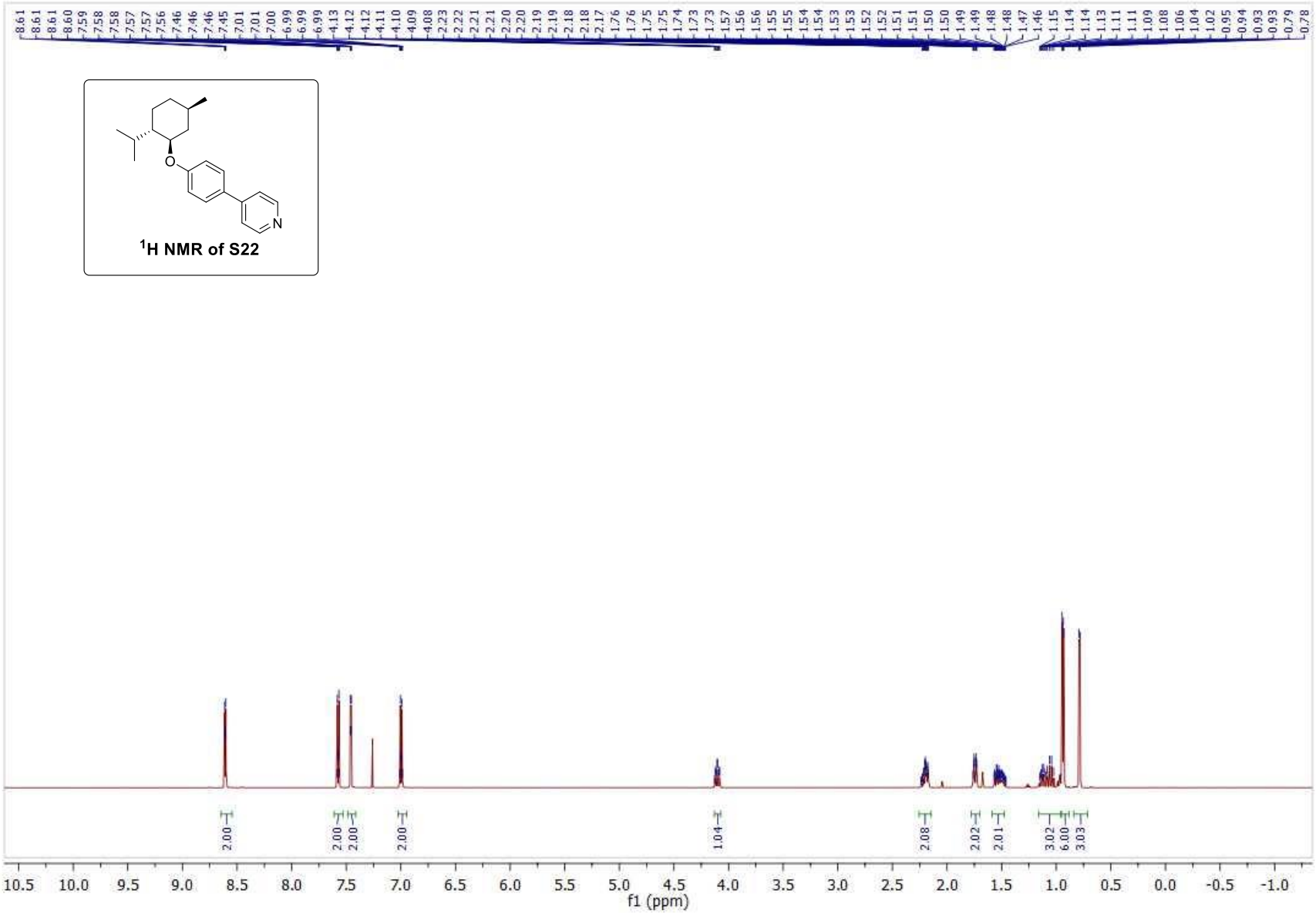
^{13}C NMR of S19

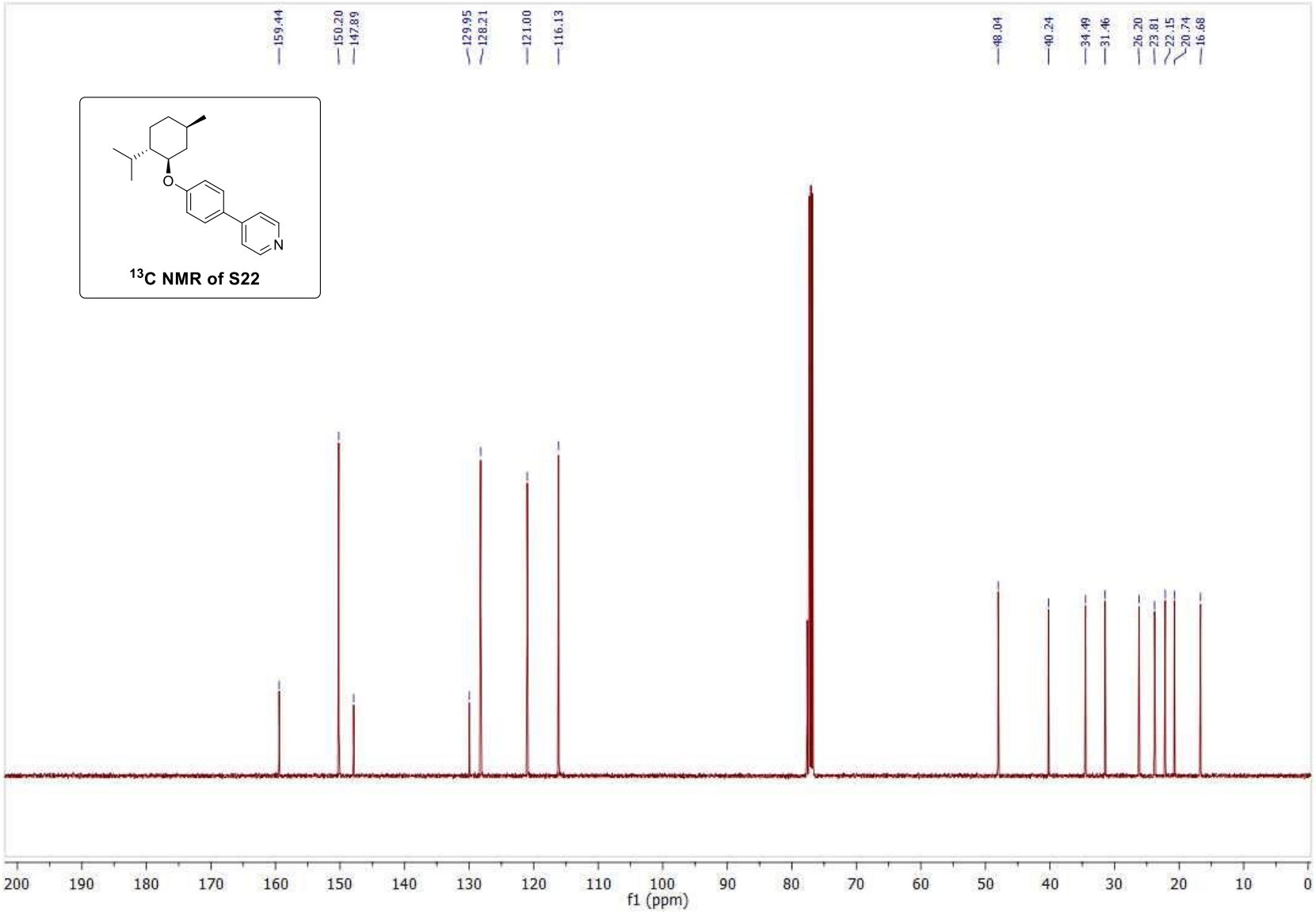

8.67
8.67
8.66
8.65
7.87
7.87
7.70
7.69
7.60
7.59
7.58
7.55
7.55
7.54
7.53
6.86
6.85
6.85
O
N
2.00
1.00
1.01
1.00
1.00
2.03
1.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

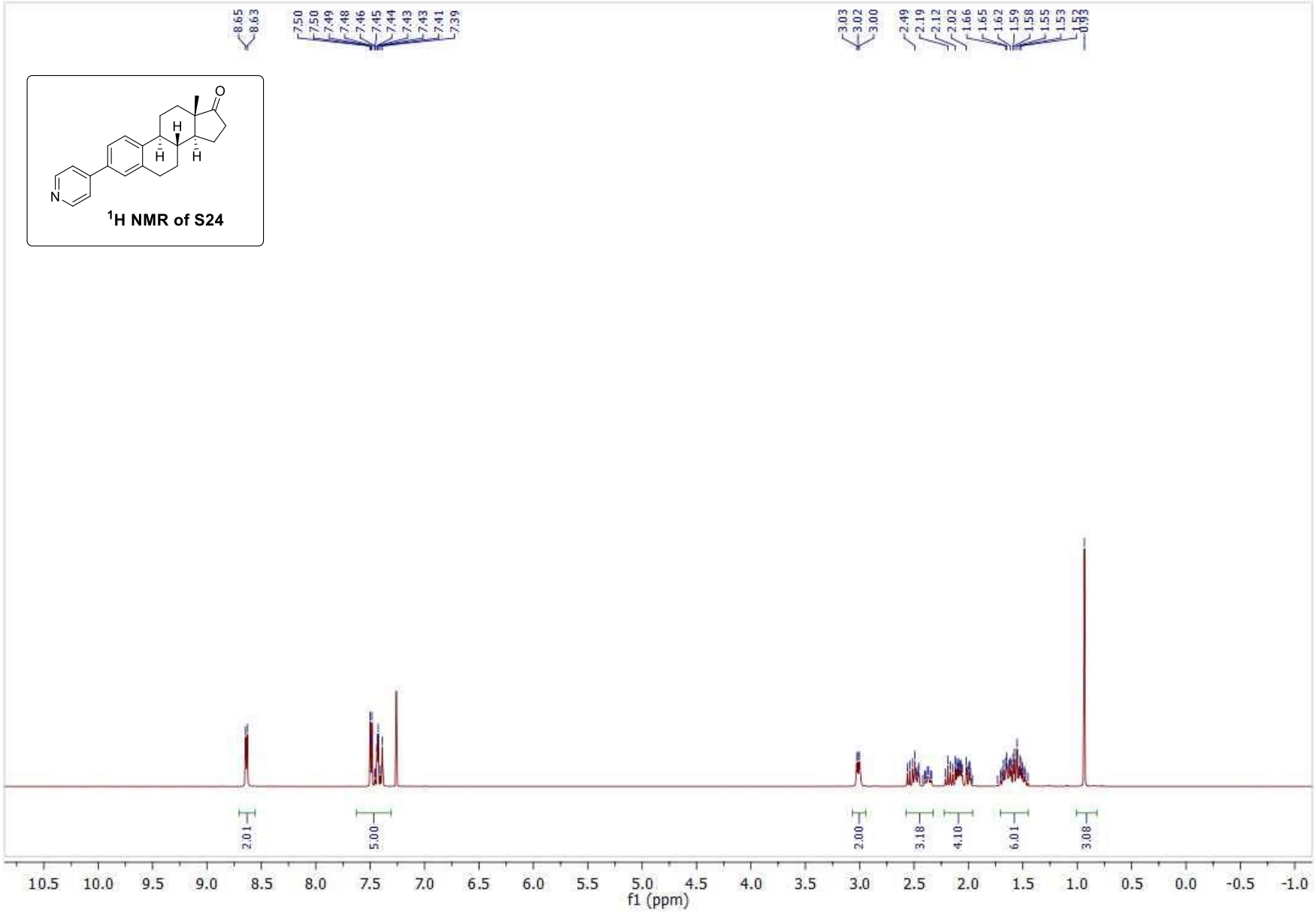
^{1}H NMR of S20



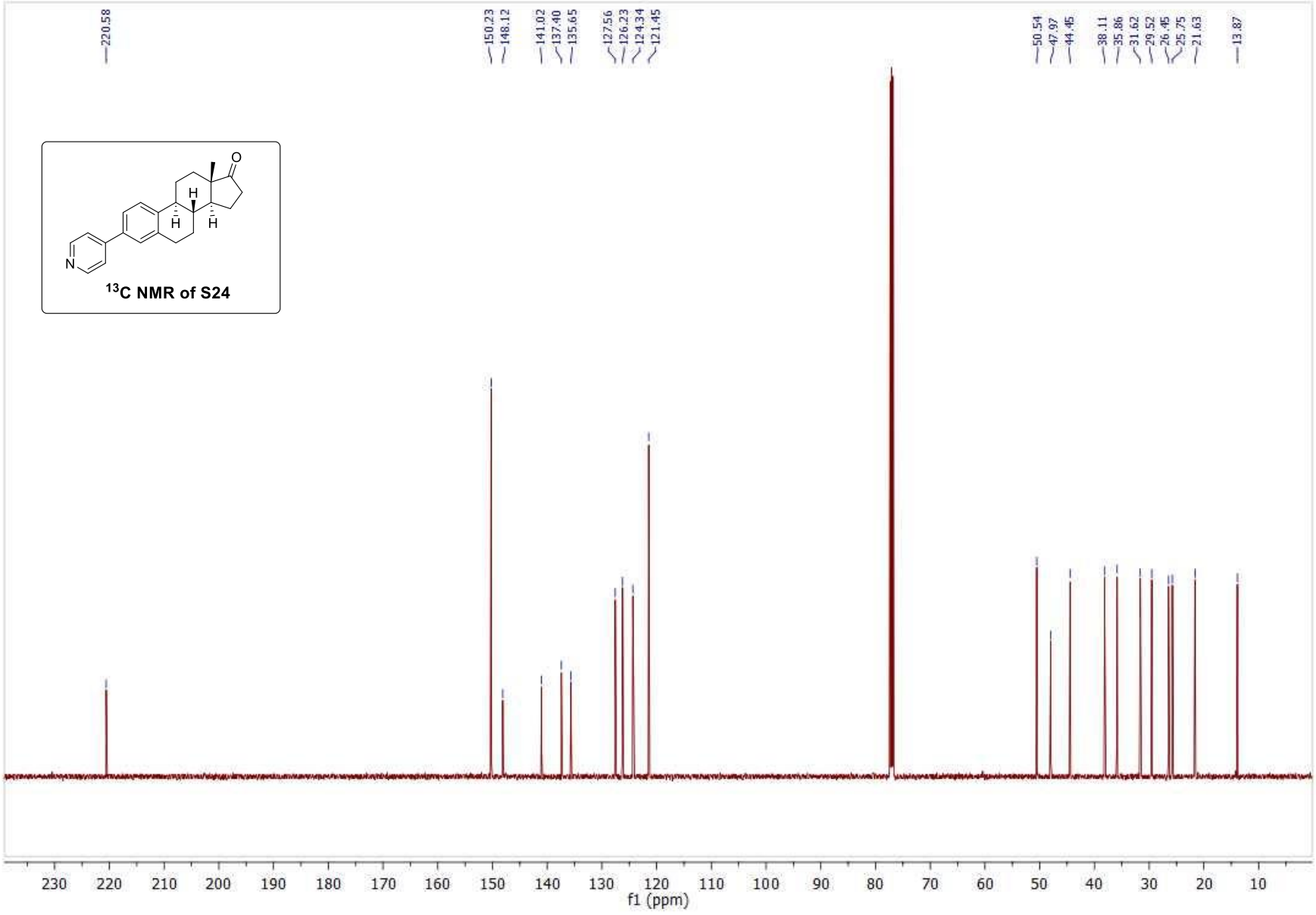
^{13}C NMR of S20

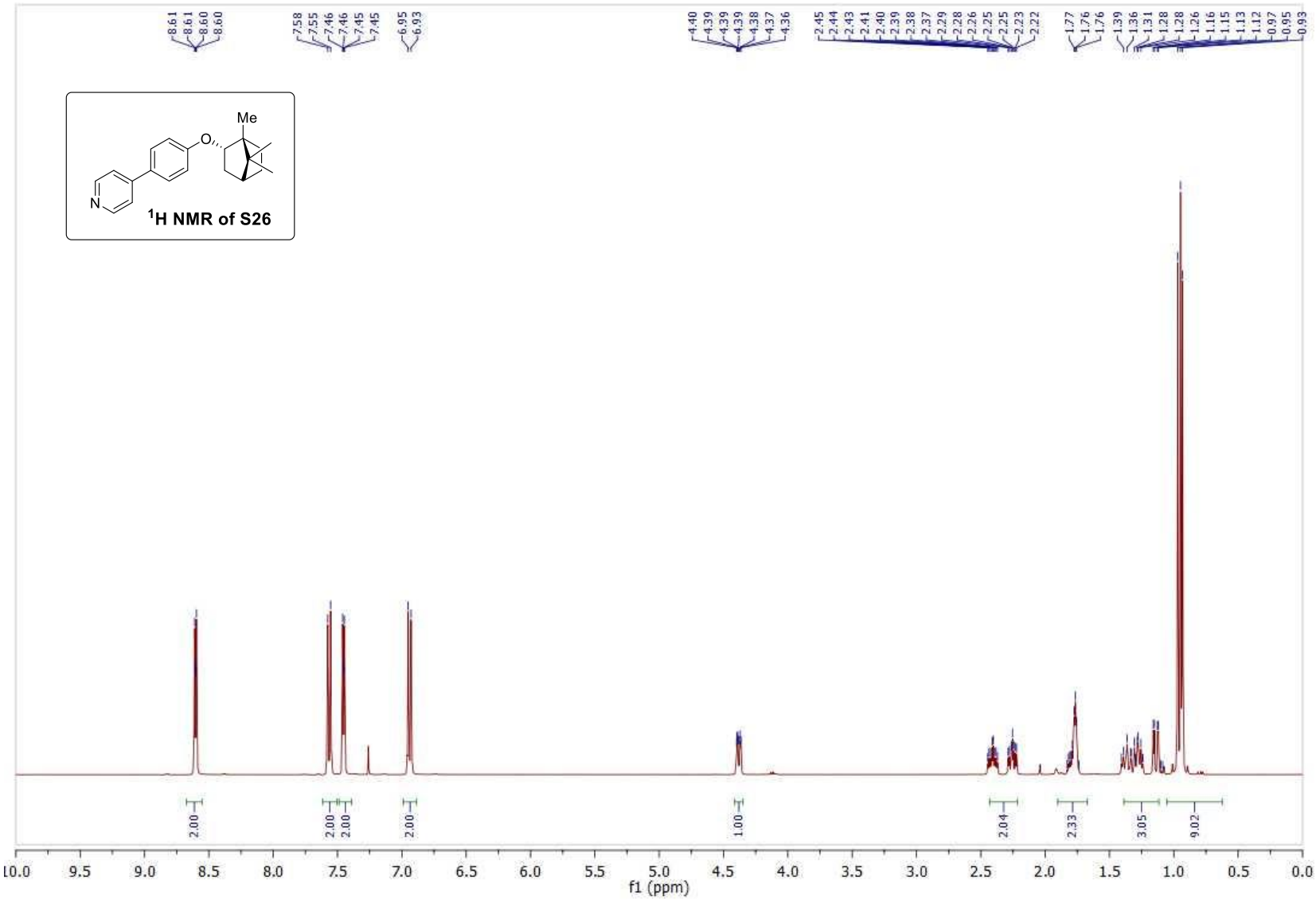

O
N
1H NMR of S22
f1 (ppm)

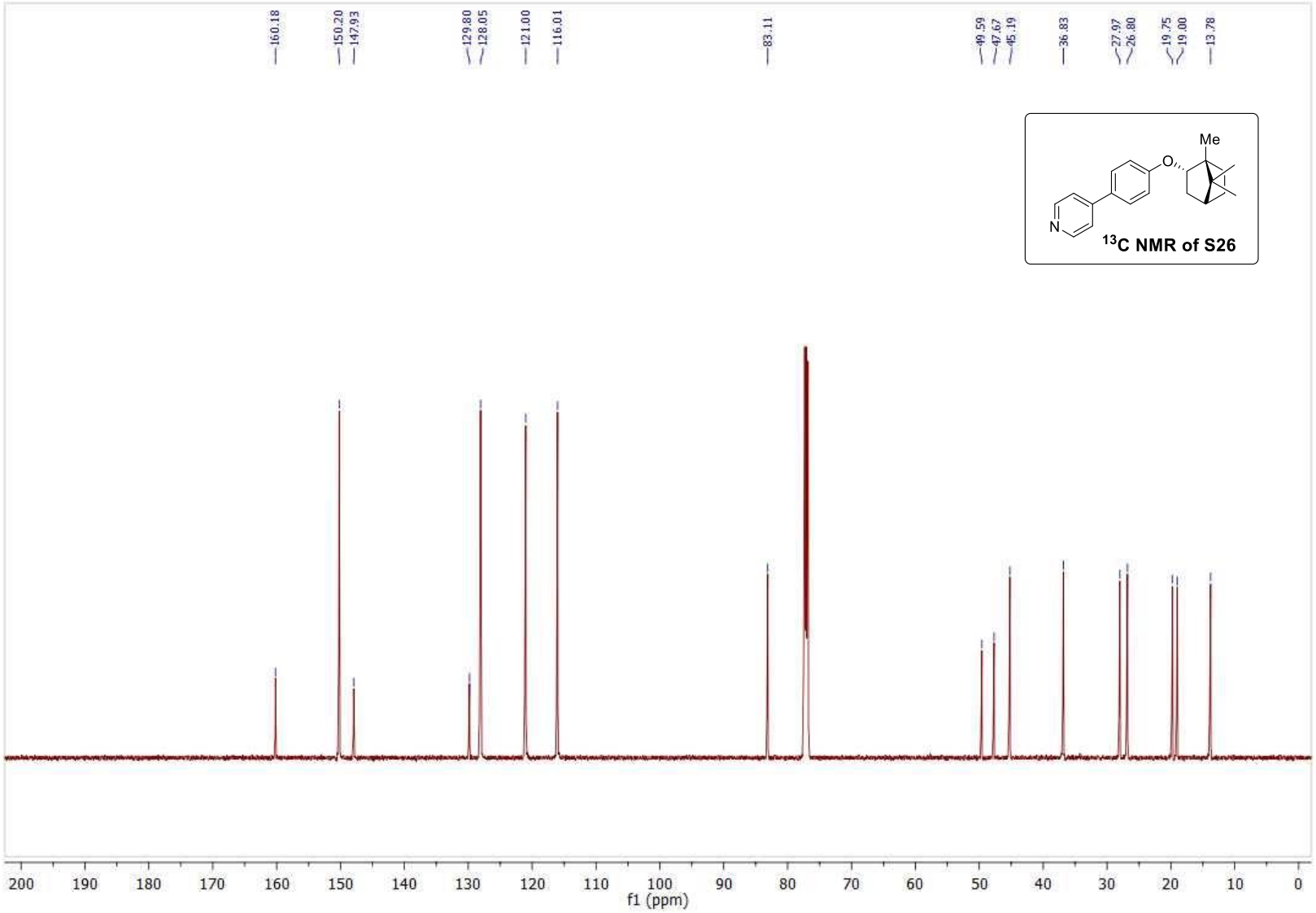

159.44
150.20
147.89
129.95
128.21
121.00
116.13
48.04
40.24
34.49
31.46
26.20
23.81
22.15
20.74
16.68
O
N
^{13}C NMR of S22
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.65
8.63
7.50
7.50
7.49
7.48
7.46
7.45
7.44
7.43
7.43
7.41
7.39
3.03
3.02
3.00
2.49
2.19
2.12
2.02
1.66
1.65
1.62
1.59
1.58
1.55
1.53
1.52
0.93
O
H
H
H
N
2.01
5.00
2.00
3.18
4.10
6.01
3.08
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
-0.5
-1.0
f1 (ppm)

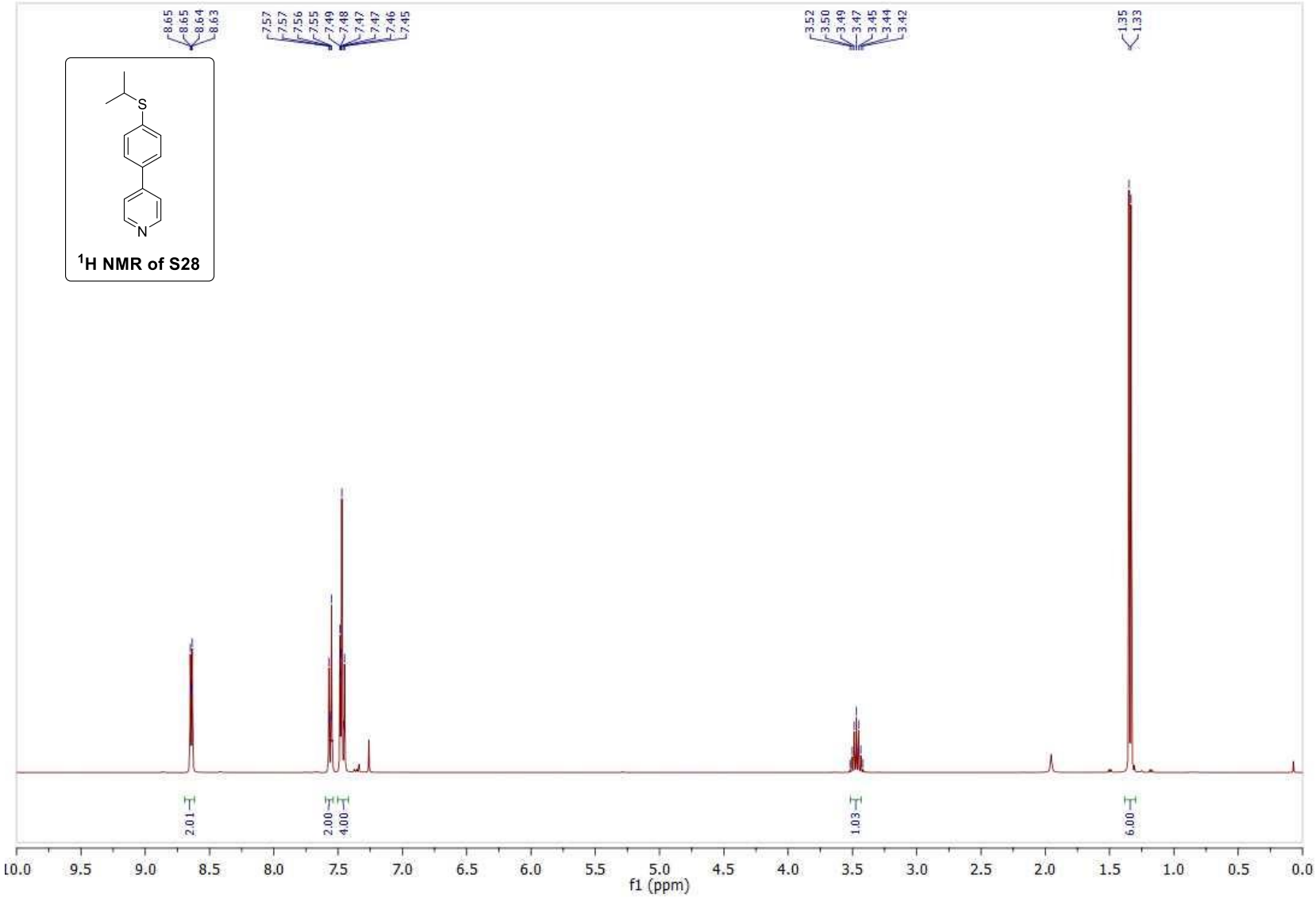
^{1}H NMR of S24


220.58
150.23
148.12
141.02
137.40
135.65
127.56
126.23
124.34
121.45
50.54
47.97
44.45
38.11
35.86
31.62
29.52
26.45
25.75
21.63
13.87
O
H
H
H
N
13C NMR of S24
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

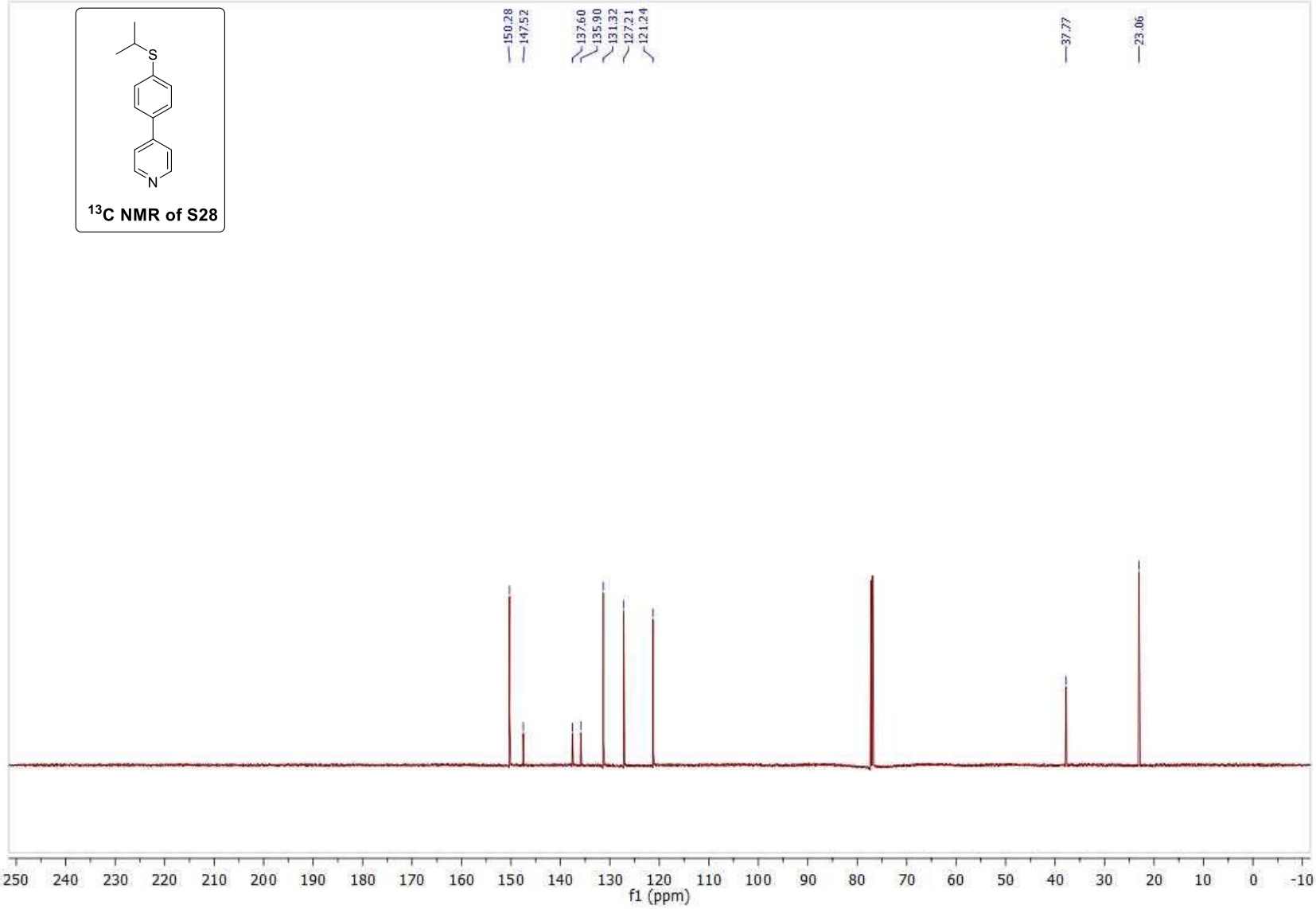

Me
O
N
1H NMR of S26
8.61
8.61
8.60
8.60
7.58
7.55
7.46
7.46
7.45
7.45
6.95
6.93
4.40
4.39
4.39
4.39
4.38
4.37
4.36
2.45
2.44
2.43
2.41
2.40
2.39
2.38
2.37
2.29
2.28
2.26
2.25
2.25
2.23
2.22
1.77
1.76
1.76
1.39
1.36
1.31
1.28
1.28
1.26
1.16
1.15
1.13
1.12
0.97
0.95
0.93
2.00
2.00
2.00
2.00
1.00
2.04
2.33
3.05
9.02
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)



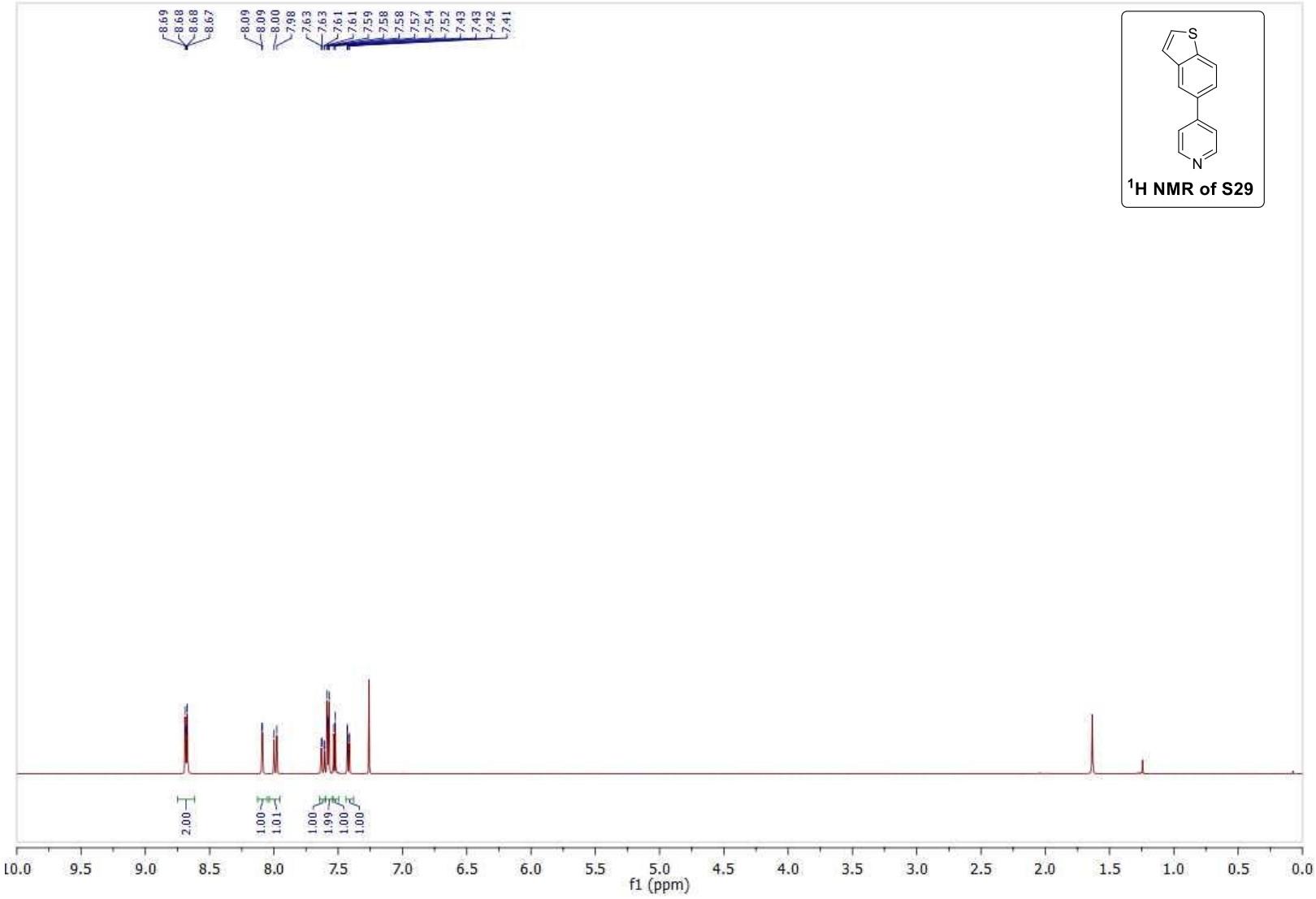
^{13}C NMR of S26

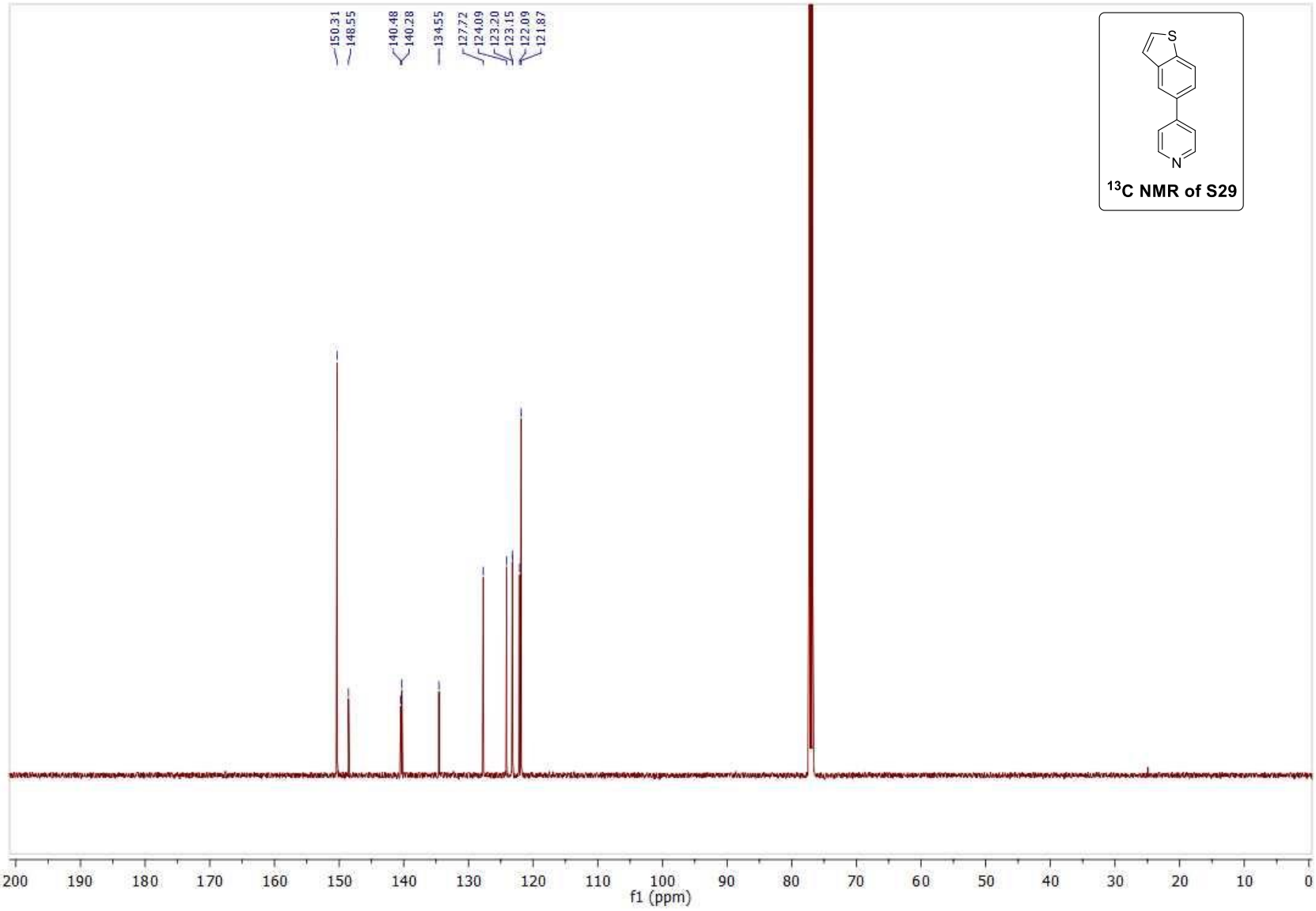

8.65
8.65
8.64
8.63
7.57
7.57
7.56
7.55
7.49
7.48
7.47
7.47
7.46
7.45
3.52
3.50
3.49
3.47
3.45
3.44
3.42
1.35
1.33
S
N
2.01
2.00
4.00
1.03
6.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

^{1}H NMR of S28

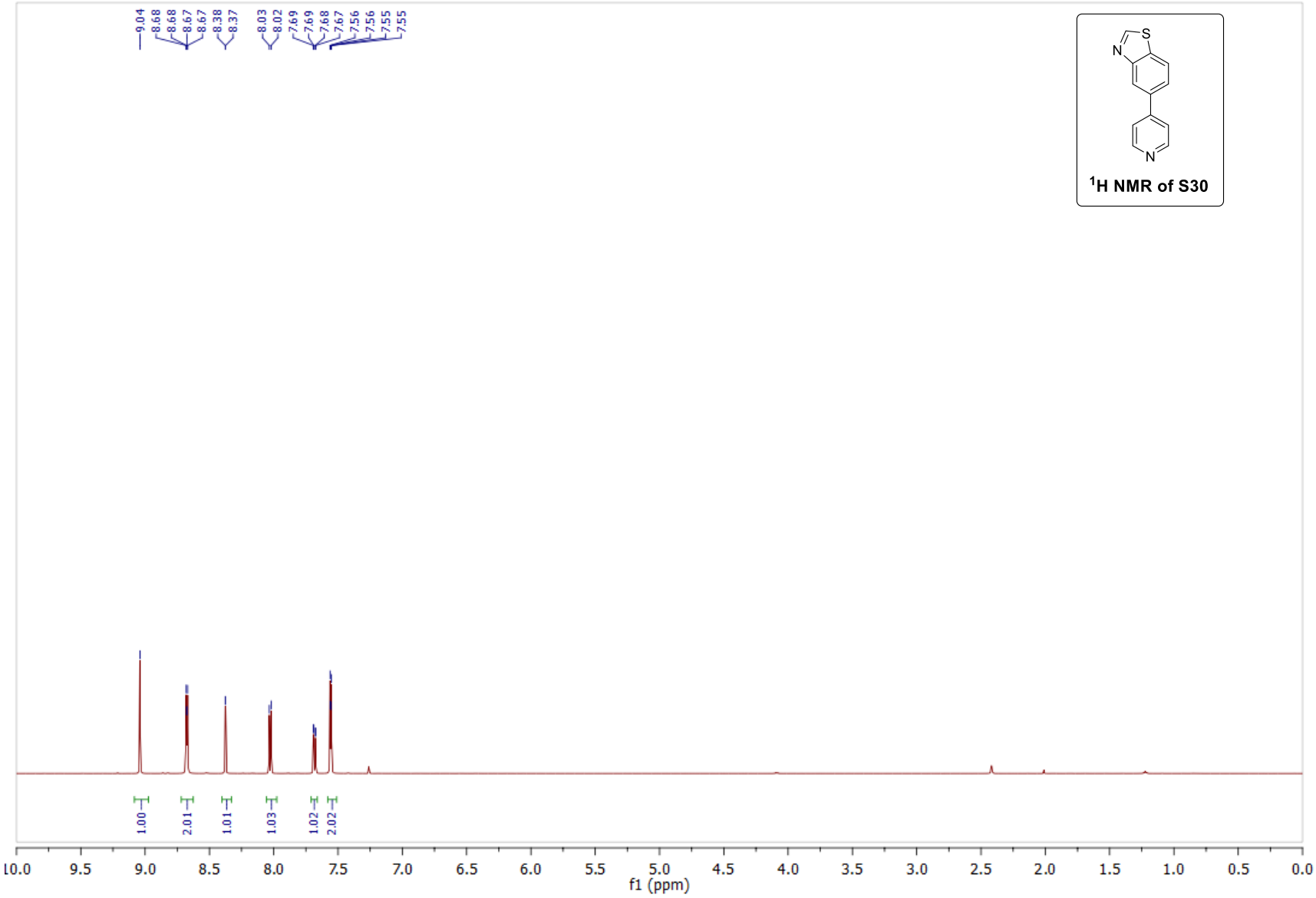


^{13}C NMR of S28

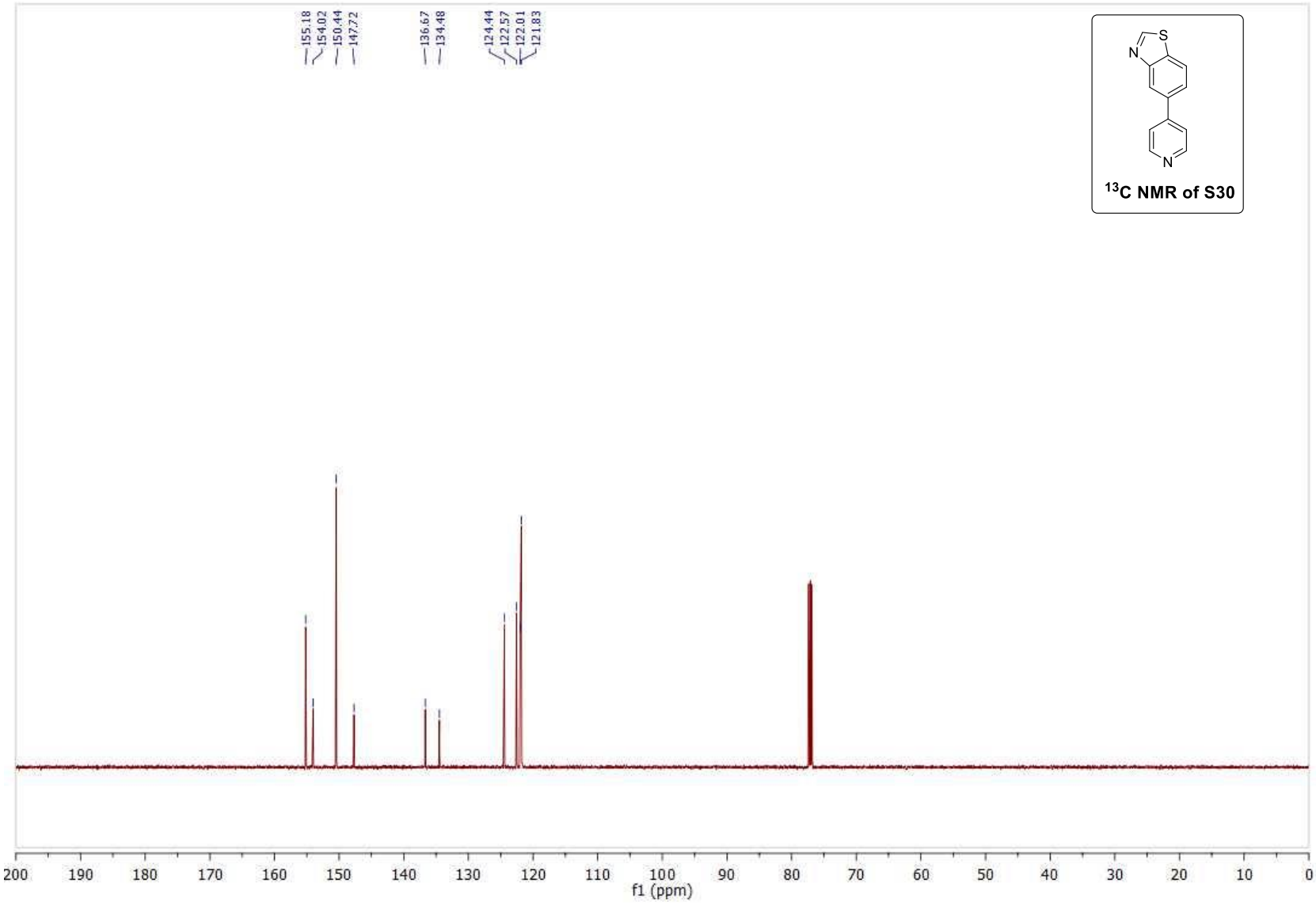

8.69
8.68
8.68
8.67
8.09
8.09
8.00
7.98
7.63
7.63
7.61
7.61
7.59
7.58
7.58
7.57
7.54
7.52
7.43
7.43
7.42
7.41
S
N
1H NMR of S29
2.00
1.00
1.01
1.00
1.99
1.00
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



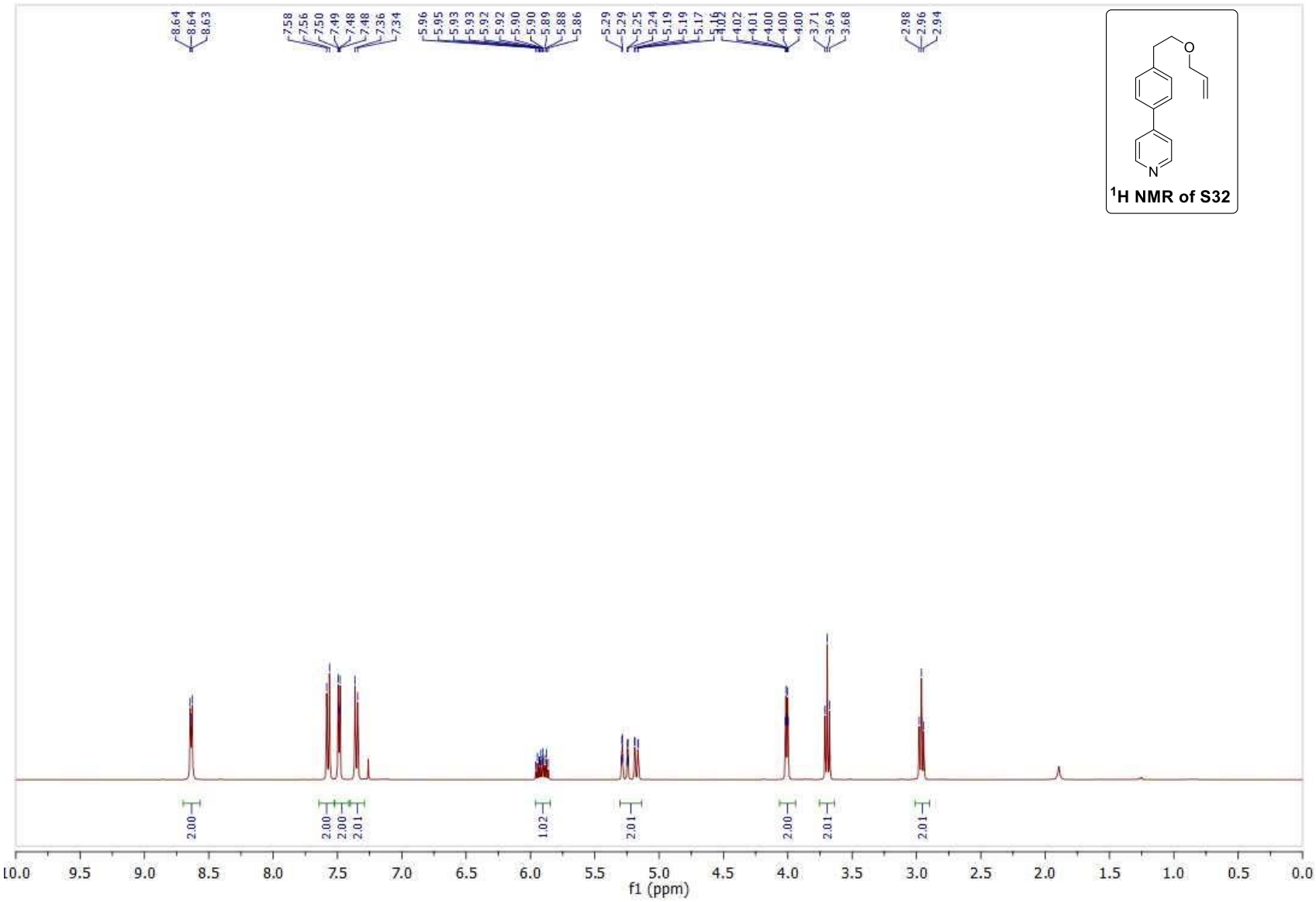
^{13}C NMR of S29


9.04
8.68
8.68
8.67
8.67
8.38
8.37
8.03
8.02
7.69
7.69
7.68
7.67
7.56
7.56
7.55
7.55
1.00
2.01
1.01
1.03
1.02
2.02
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)
S
N
N

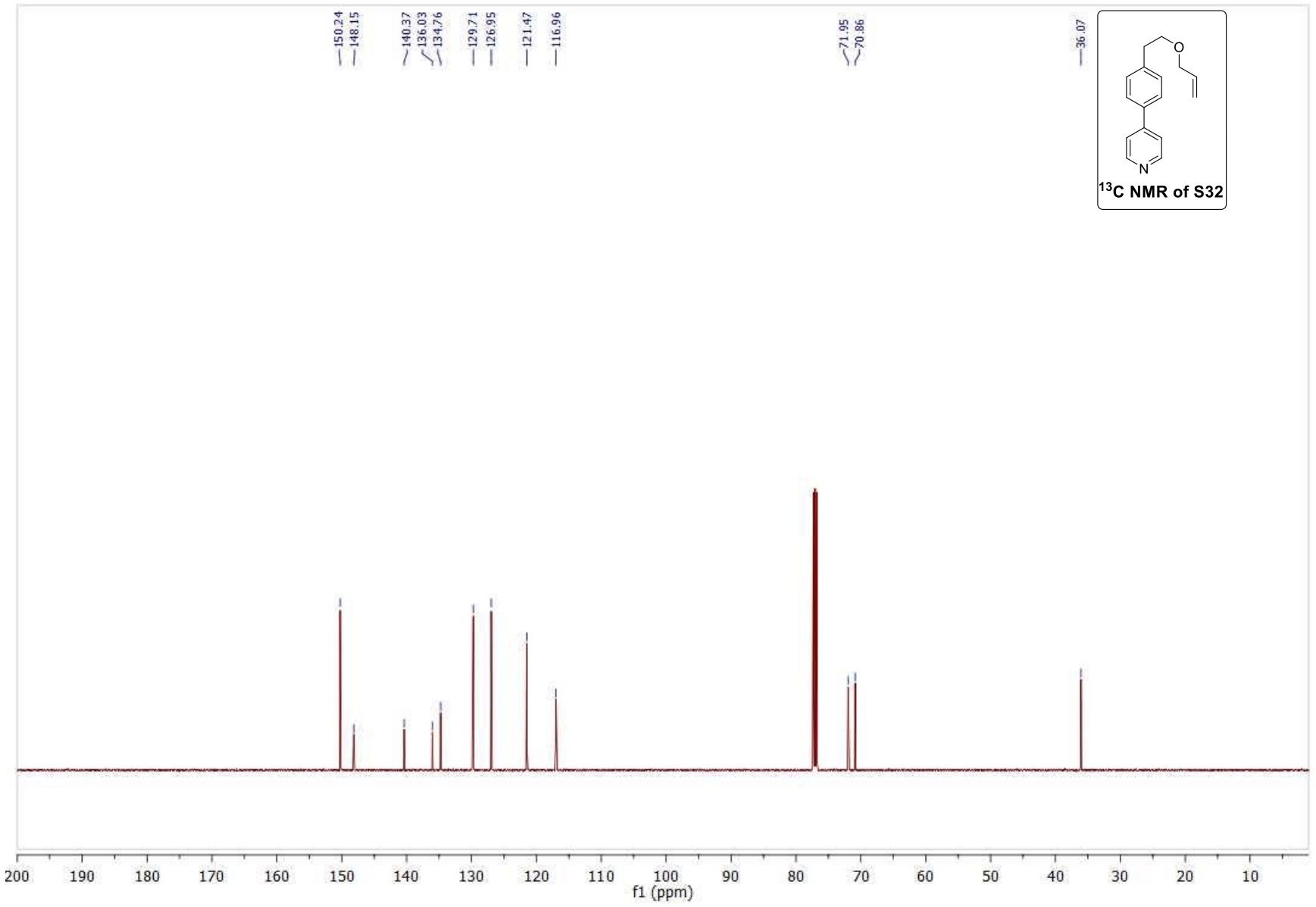
^{1}H NMR of S30

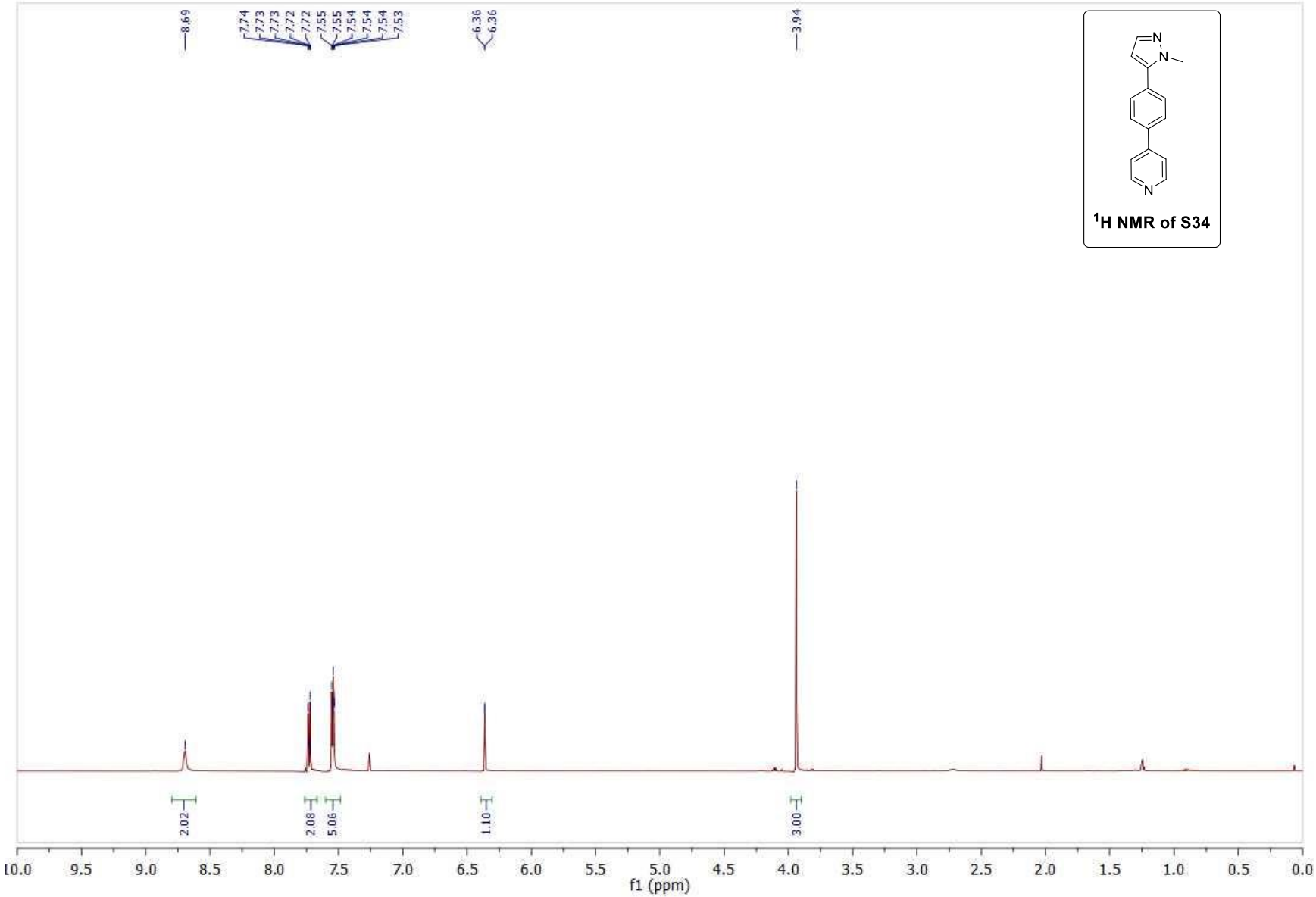


^{13}C NMR of S30

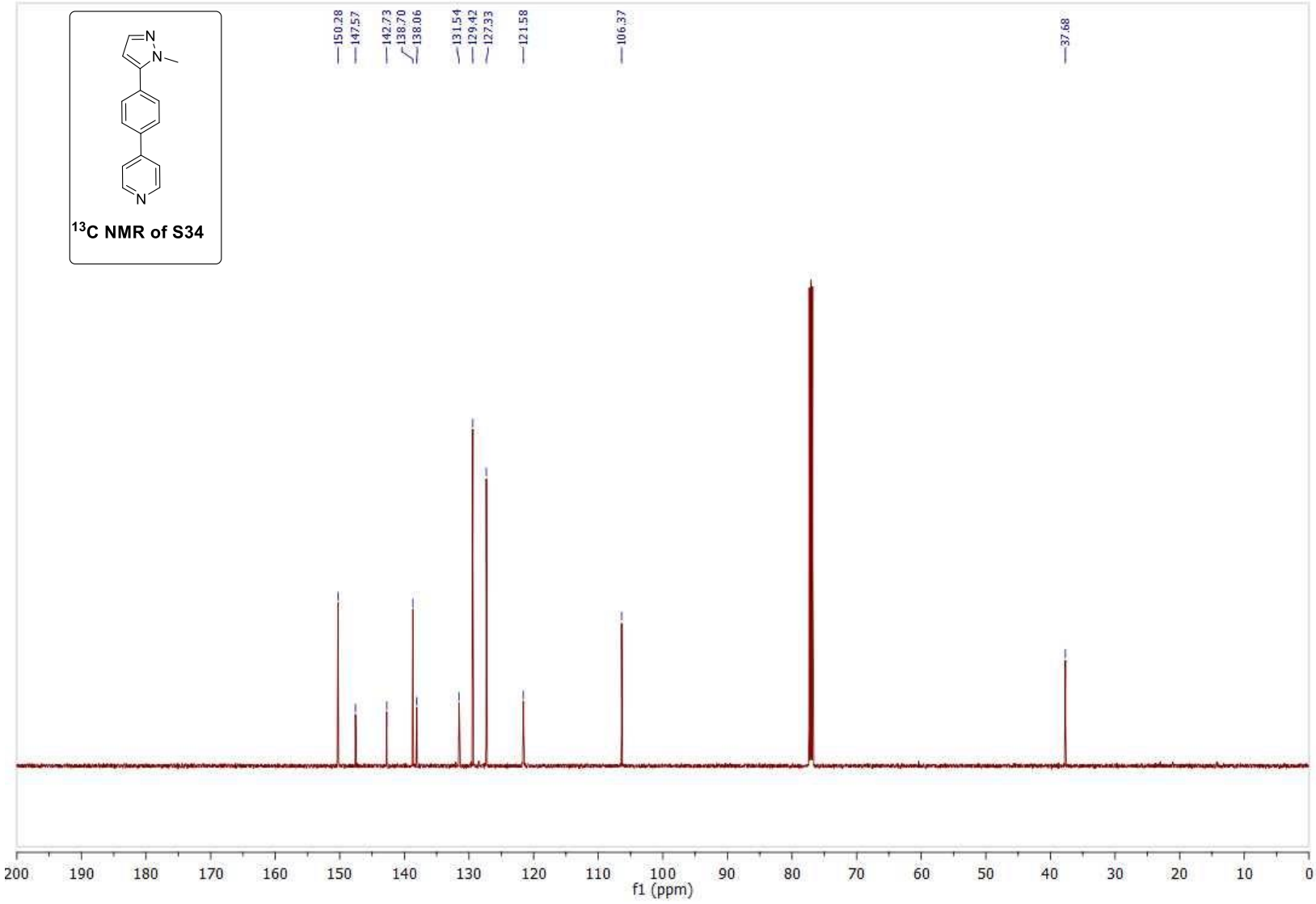

8.64
8.64
8.63
7.58
7.56
7.50
7.49
7.48
7.48
7.36
7.34
5.96
5.95
5.93
5.93
5.92
5.92
5.90
5.90
5.89
5.88
5.86
5.29
5.29
5.25
5.24
5.19
5.19
5.17
4.02
4.01
4.00
4.00
4.00
3.71
3.69
3.68
2.98
2.96
2.94
O
N
2.00
2.00
2.00
2.01
1.02
2.01
2.00
2.01
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

^{1}H NMR of S32

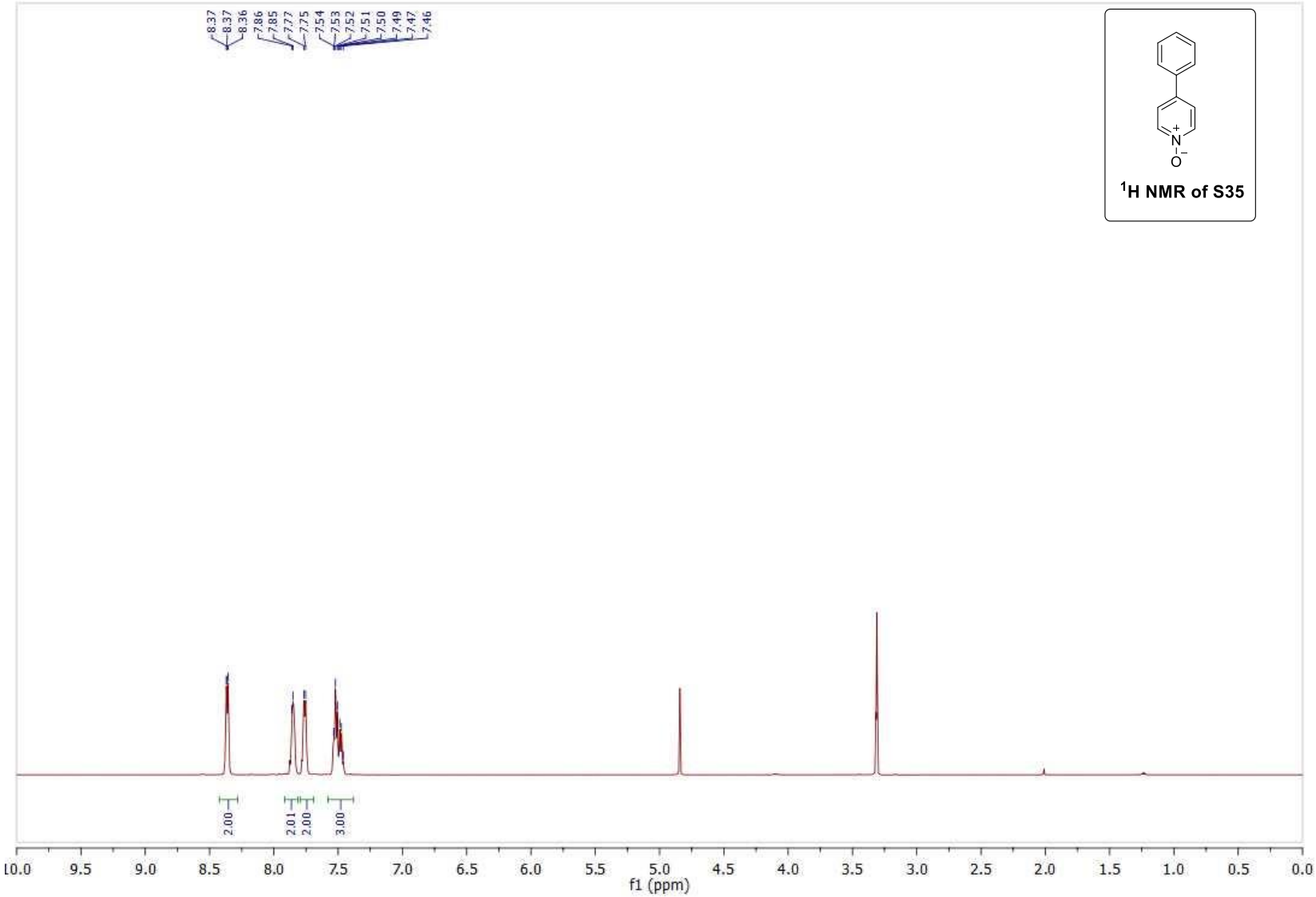

150.24
148.15
140.37
136.03
134.76
129.71
126.95
121.47
116.96
71.95
70.86
36.07
O
N
^{13}C NMR of S32
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


8.69
7.74
7.73
7.73
7.72
7.72
7.55
7.55
7.54
7.54
7.54
7.53
6.36
6.36
3.94
2.02
2.08
5.06
1.10
3.00
f1 (ppm)

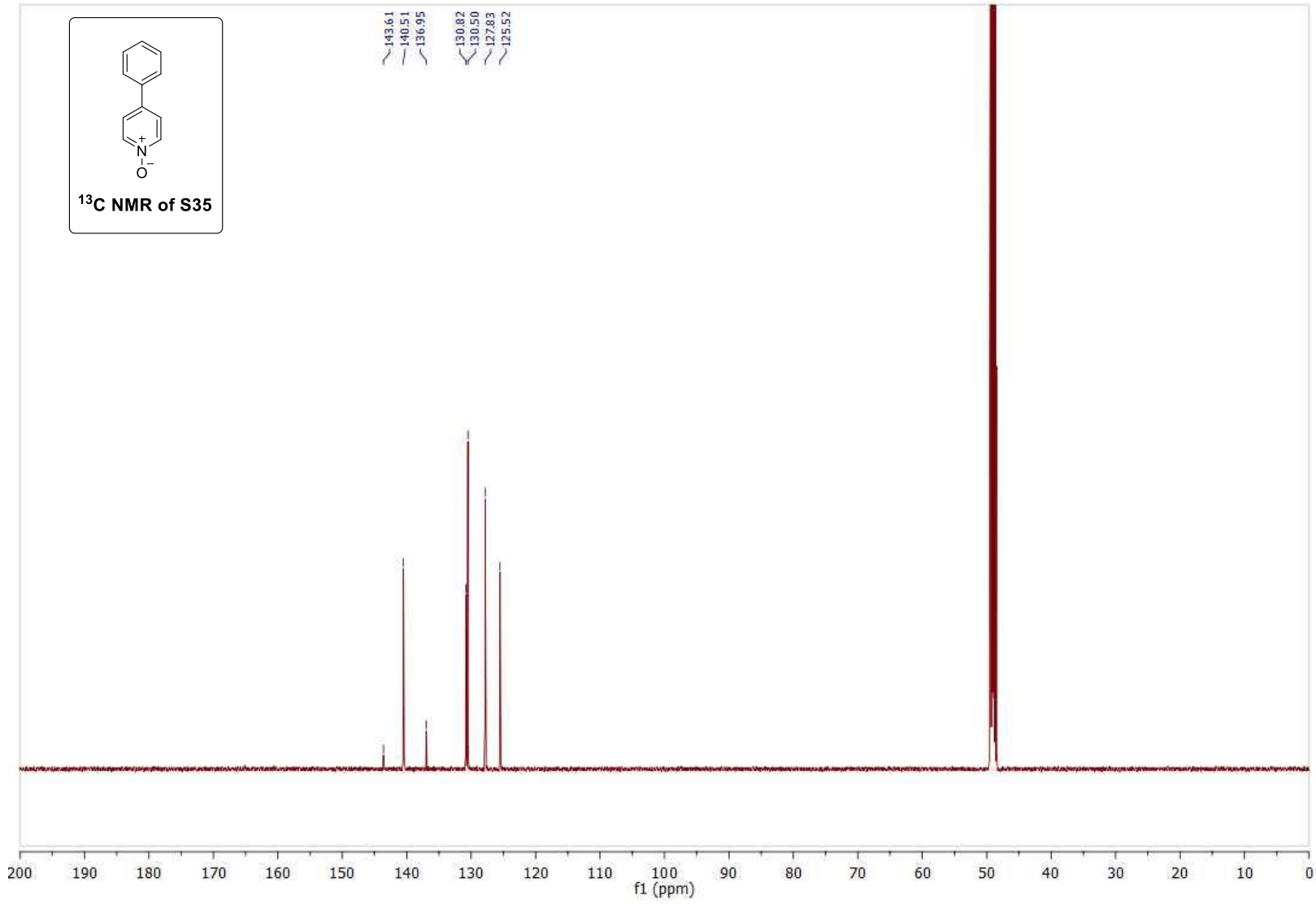
^{1}H NMR of S34



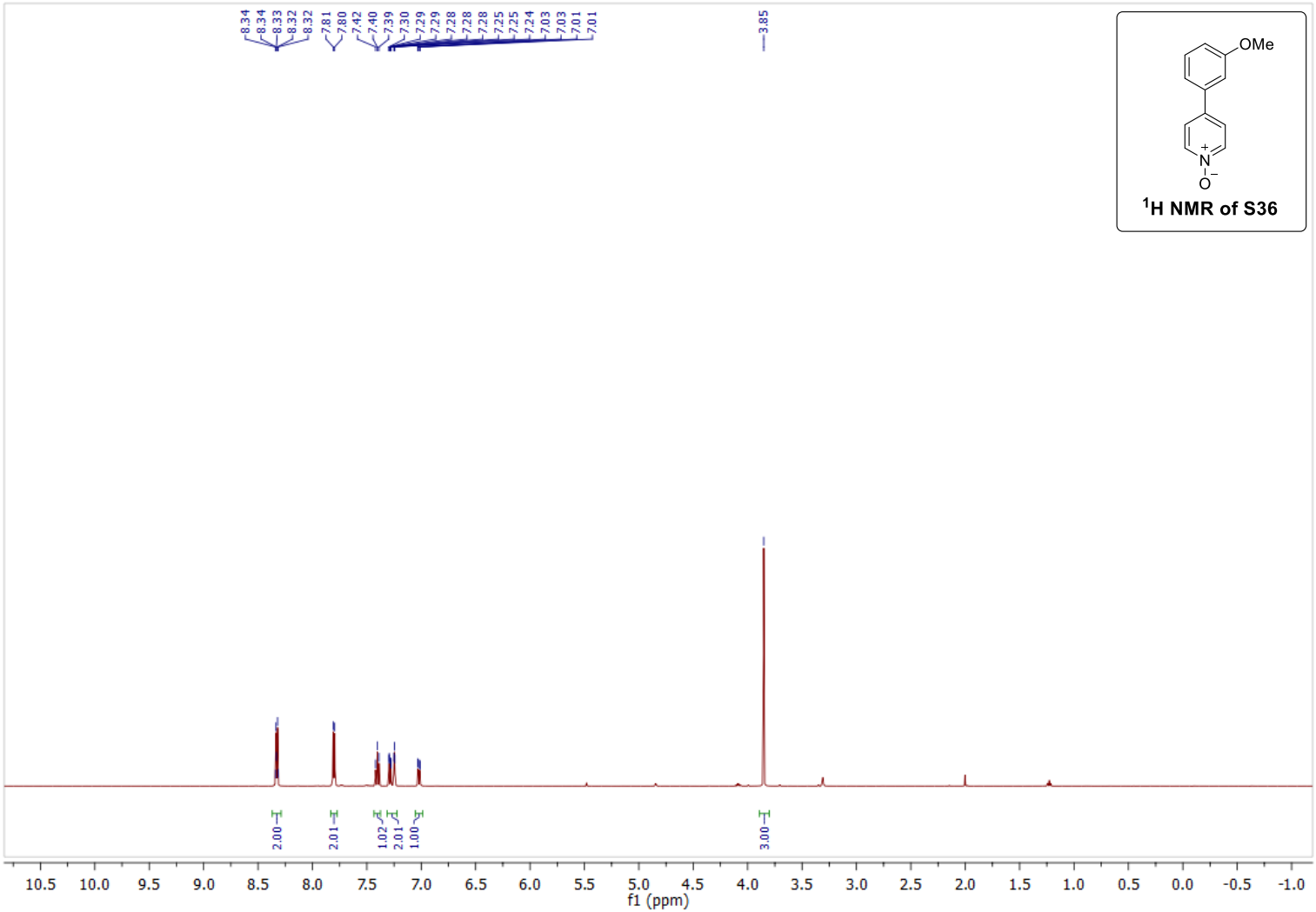
^{13}C NMR of S34


8.37
8.37
8.36
7.86
7.85
7.77
7.75
7.54
7.53
7.52
7.51
7.50
7.49
7.47
7.46
2.00
2.01
2.00
3.00
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)

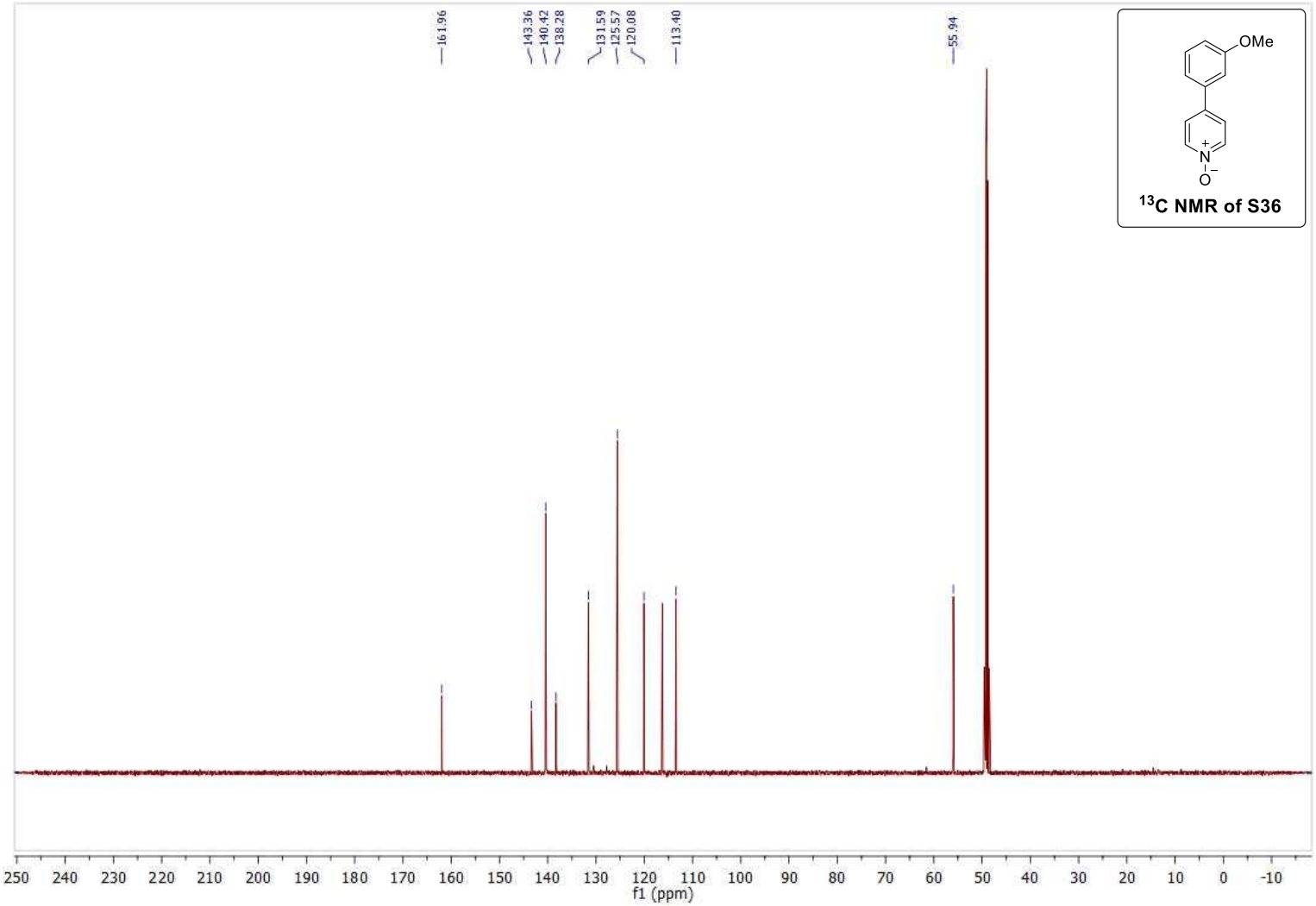
^{1}H NMR of S35

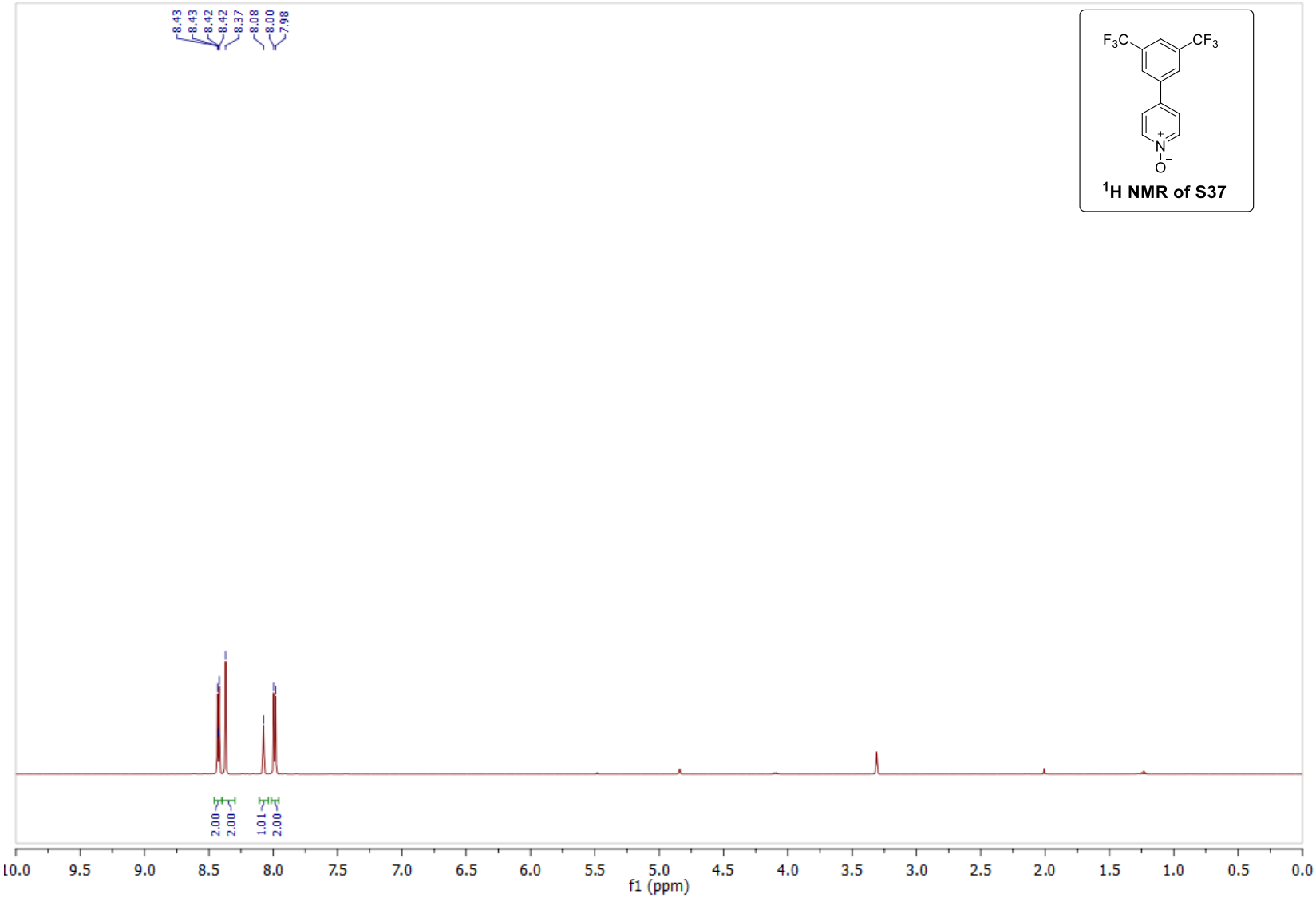


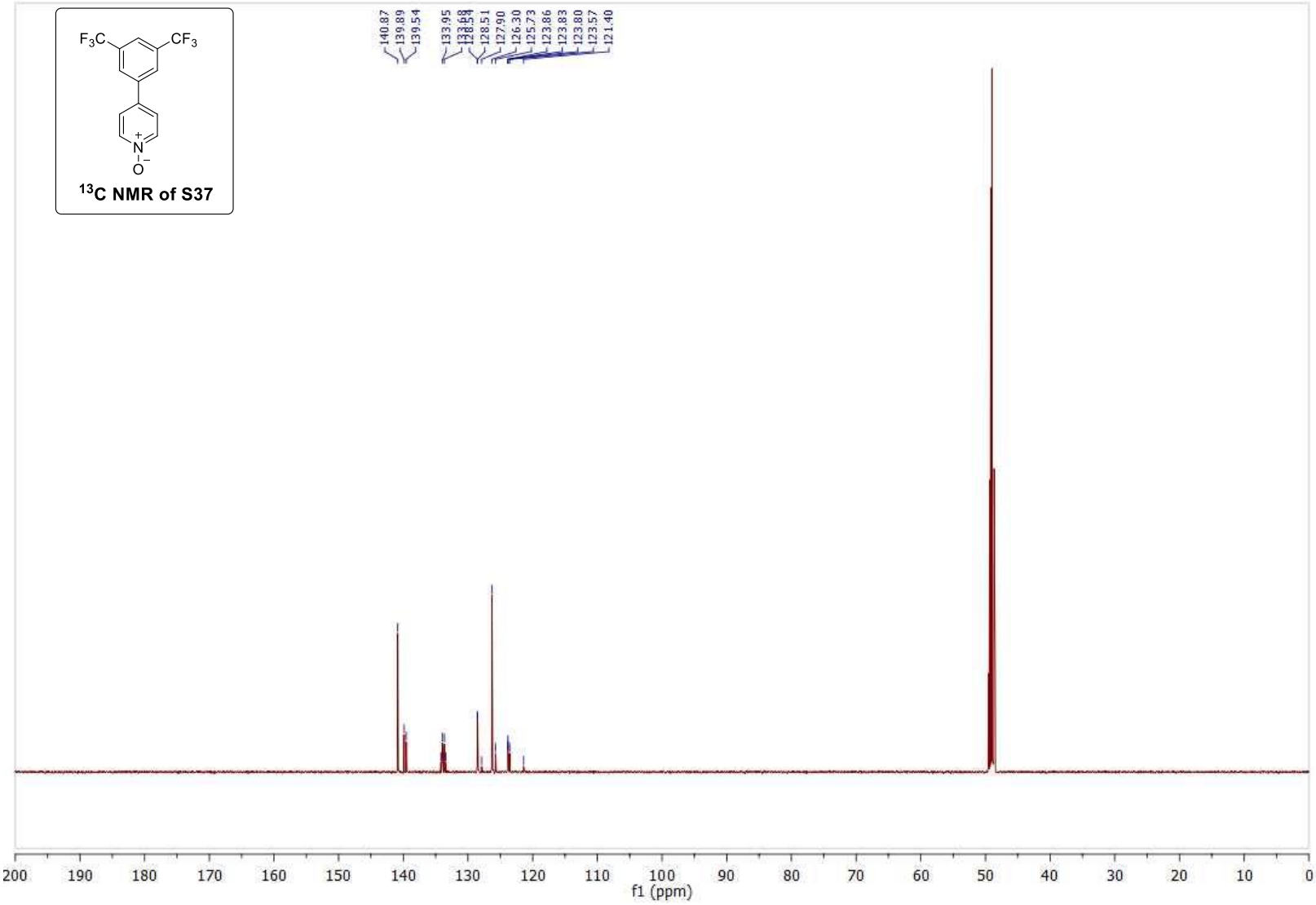
^{13}C NMR of S35


8.34
8.34
8.33
8.32
8.32
7.81
7.80
7.42
7.40
7.39
7.30
7.29
7.29
7.28
7.28
7.28
7.25
7.25
7.24
7.03
7.03
7.01
7.01
3.85
OMe
N
O
2.00
2.01
1.02
2.01
1.00
3.00
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 -0.5 -1.0
f1 (ppm)

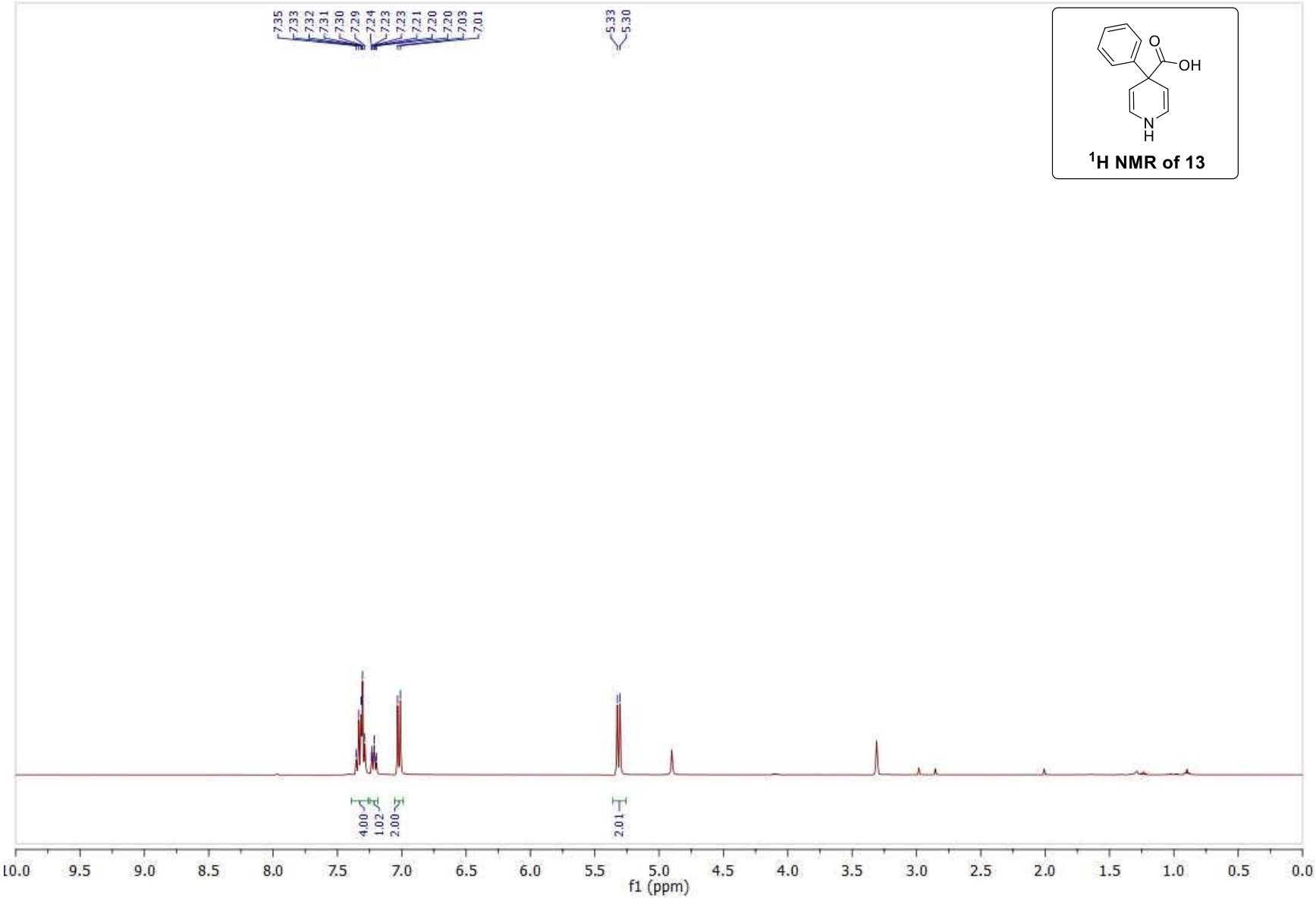
^{1}H NMR of S36

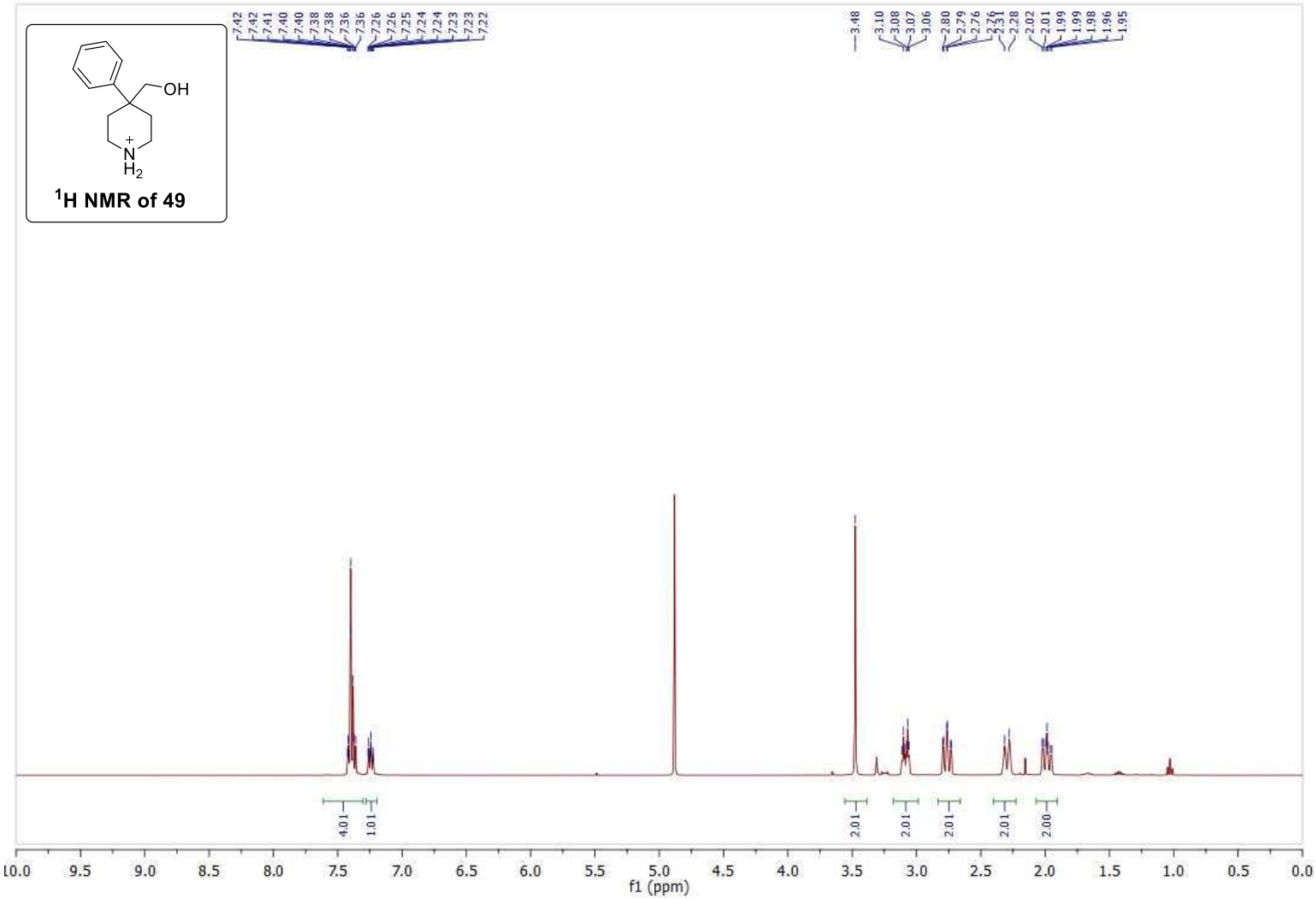

161.96
143.36
140.42
138.28
131.59
125.57
120.08
113.40
55.94
OMe
N
O
13C NMR of S36
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

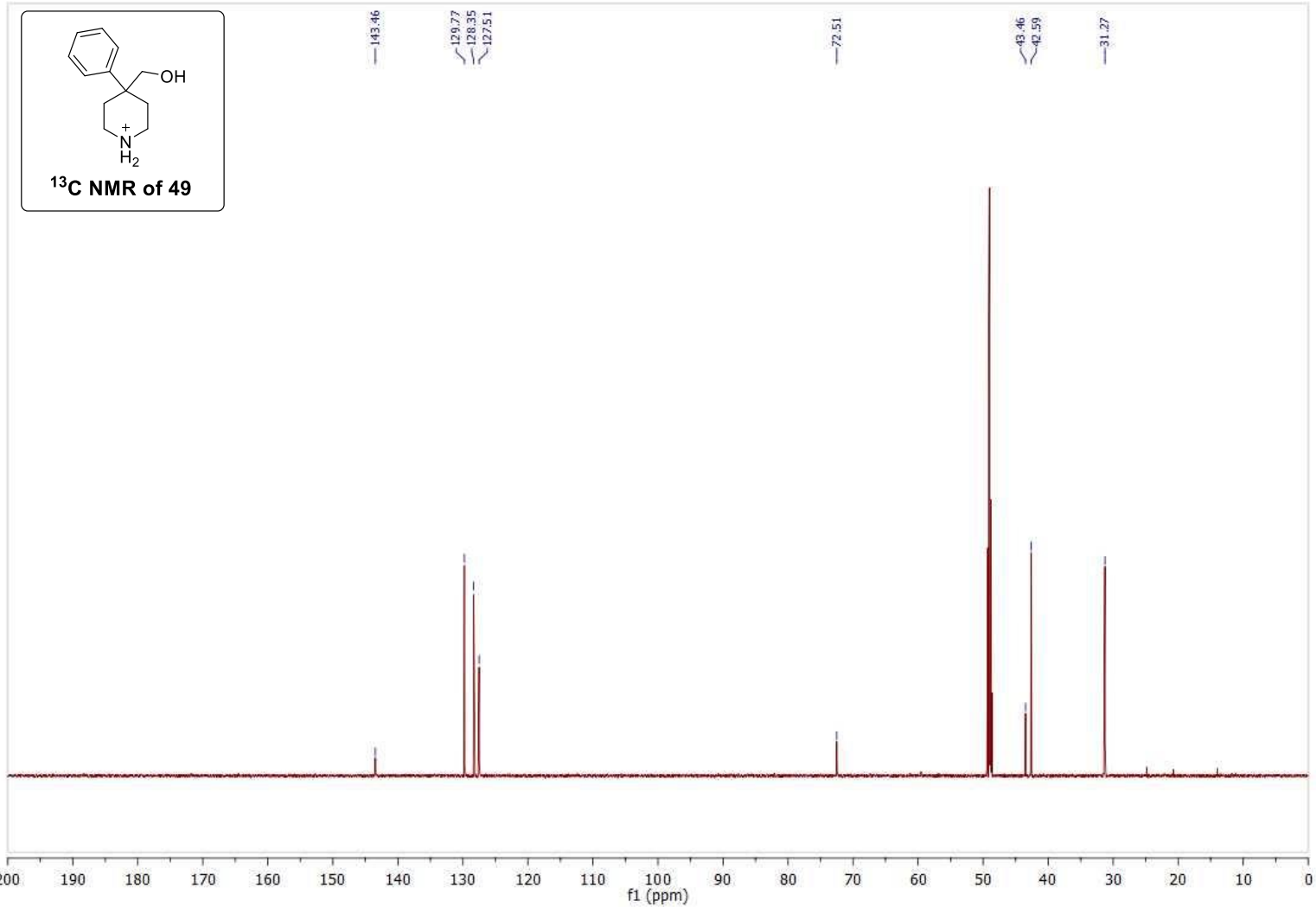

8.43
8.43
8.42
8.42
8.37
8.08
8.00
7.98
F3C
CF3
N
O
1H NMR of S37
2.00
2.00
1.01
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

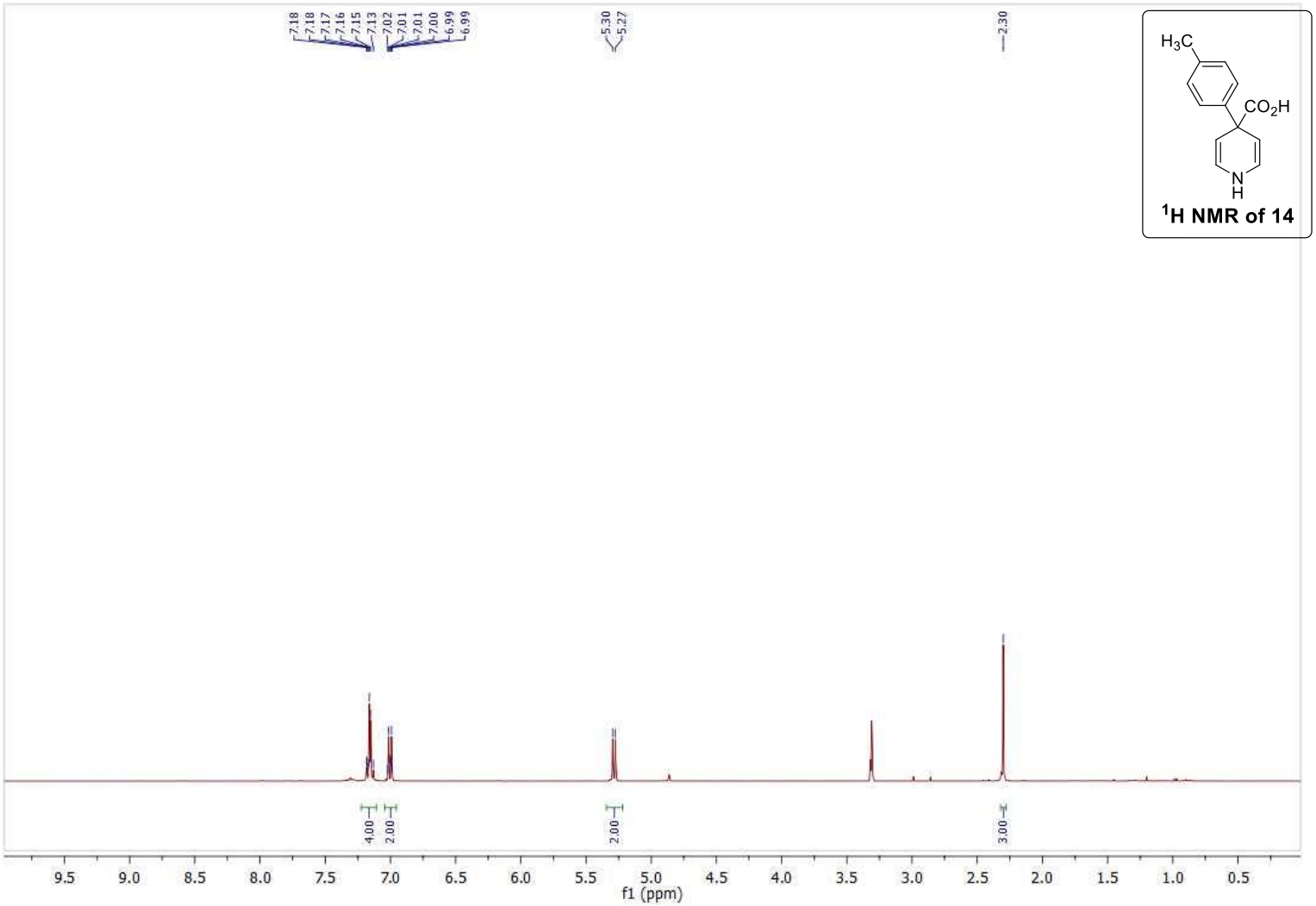


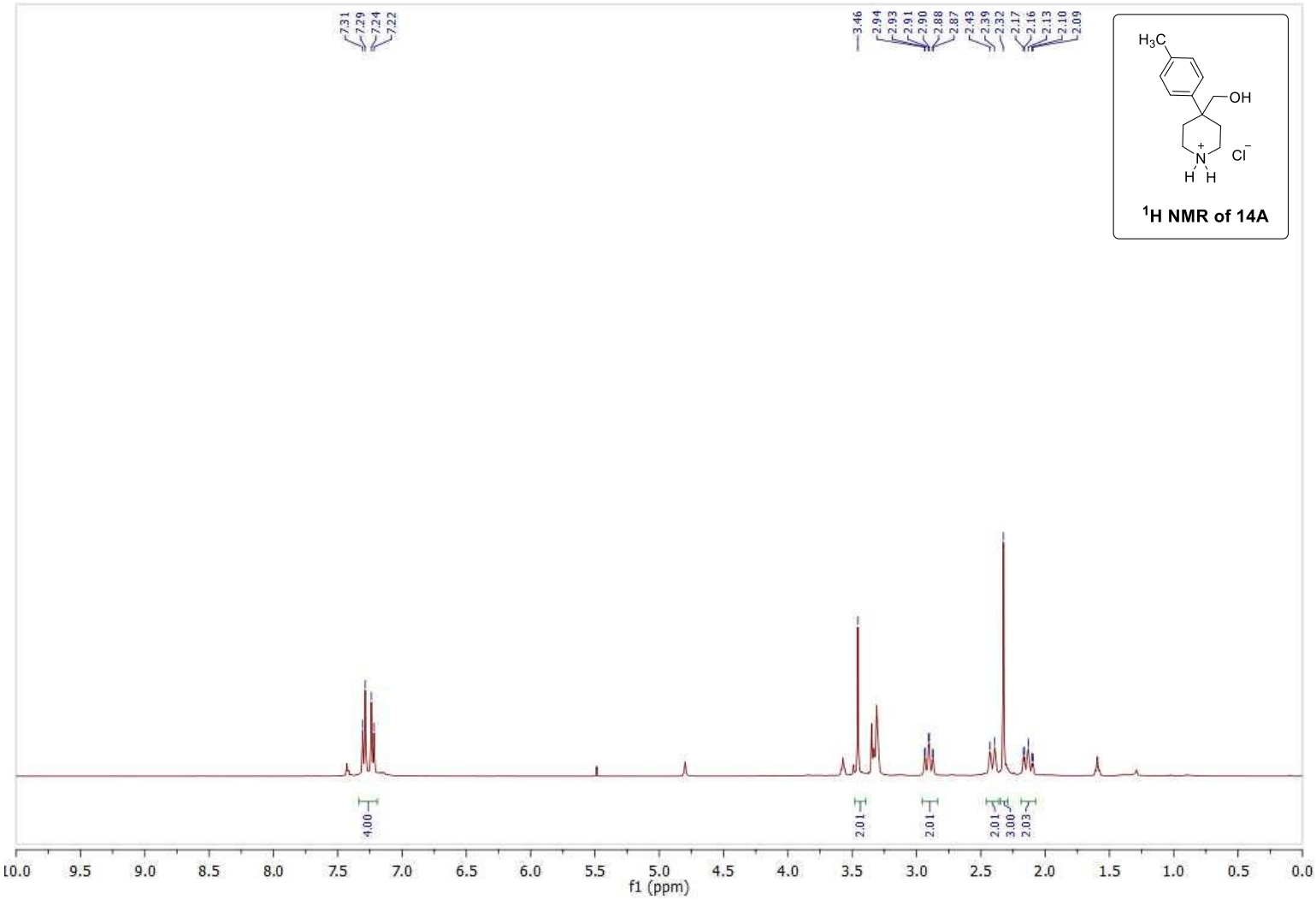
^{13}C NMR of S37

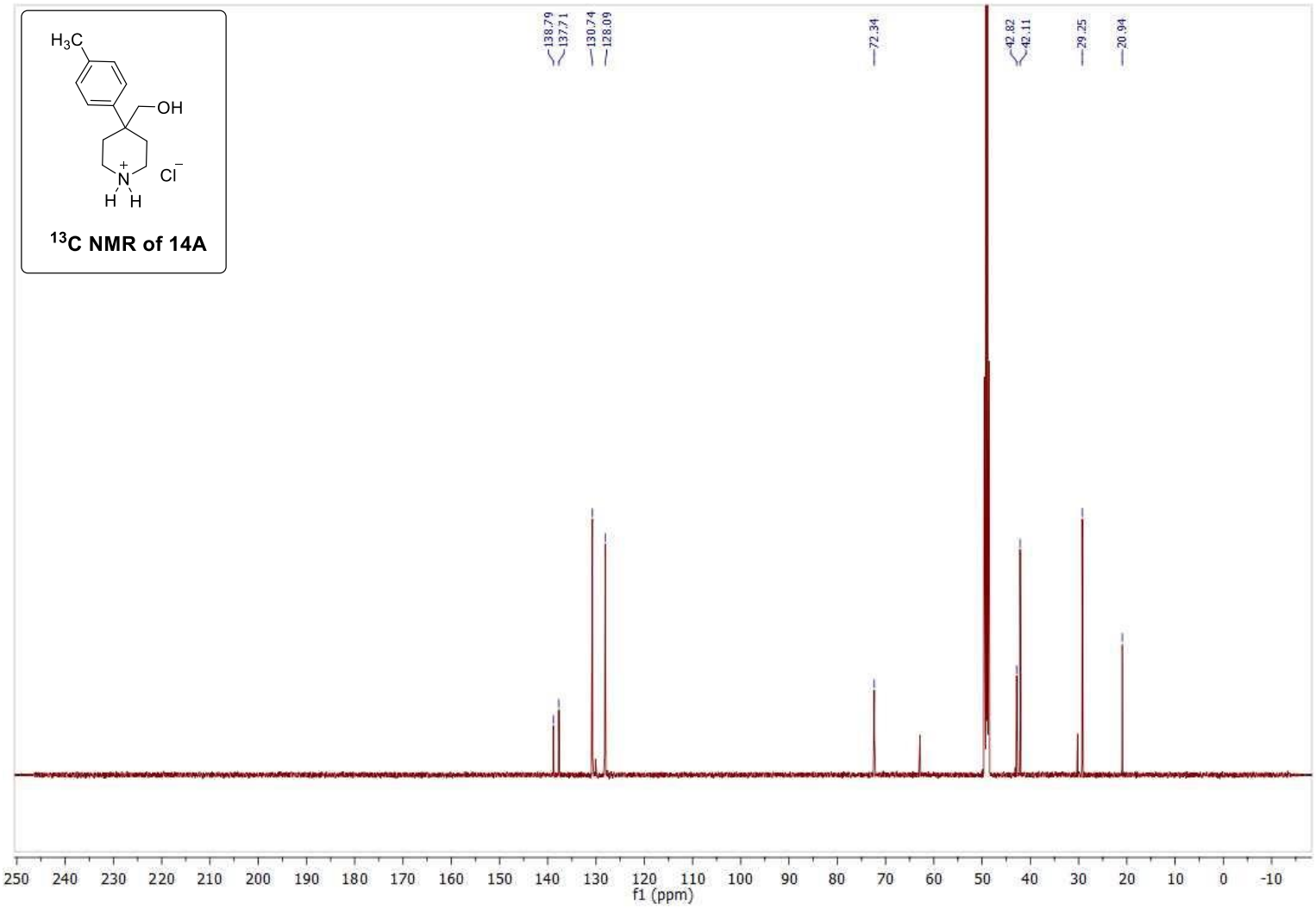

7.35
7.33
7.32
7.31
7.30
7.29
7.24
7.23
7.23
7.21
7.20
7.20
7.03
7.01
5.33
5.30
O
OH
N
H
1H NMR of 13
4.00
1.02
2.00
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

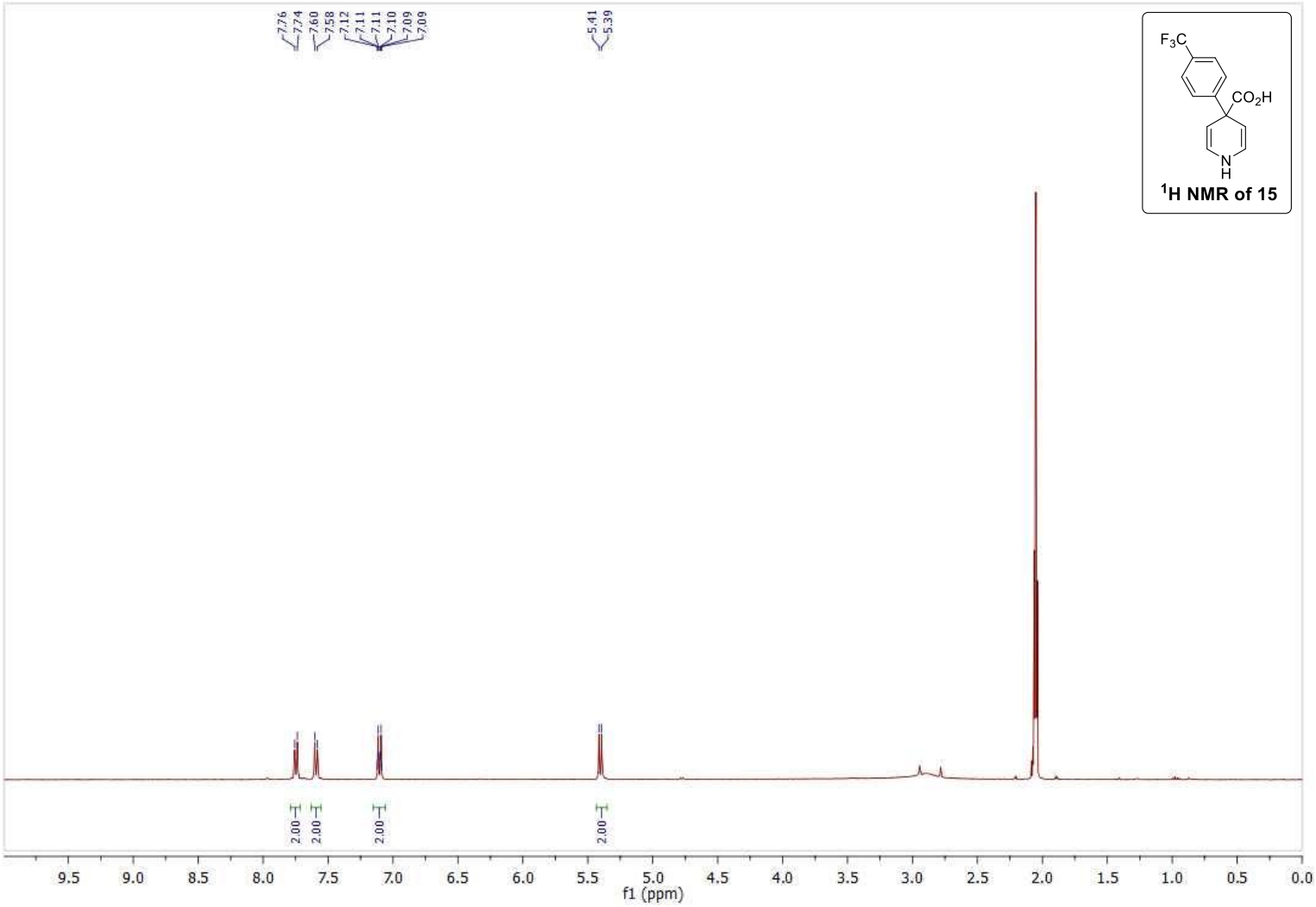

OH
N
H2
1H NMR of 49
7.42
7.42
7.41
7.40
7.40
7.38
7.38
7.36
7.36
7.26
7.26
7.25
7.24
7.24
7.23
7.23
7.22
3.48
3.10
3.08
3.07
3.06
2.80
2.79
2.76
2.31
2.28
2.02
2.01
1.99
1.99
1.98
1.96
1.95
4.01
1.01
2.01
2.01
2.01
2.01
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

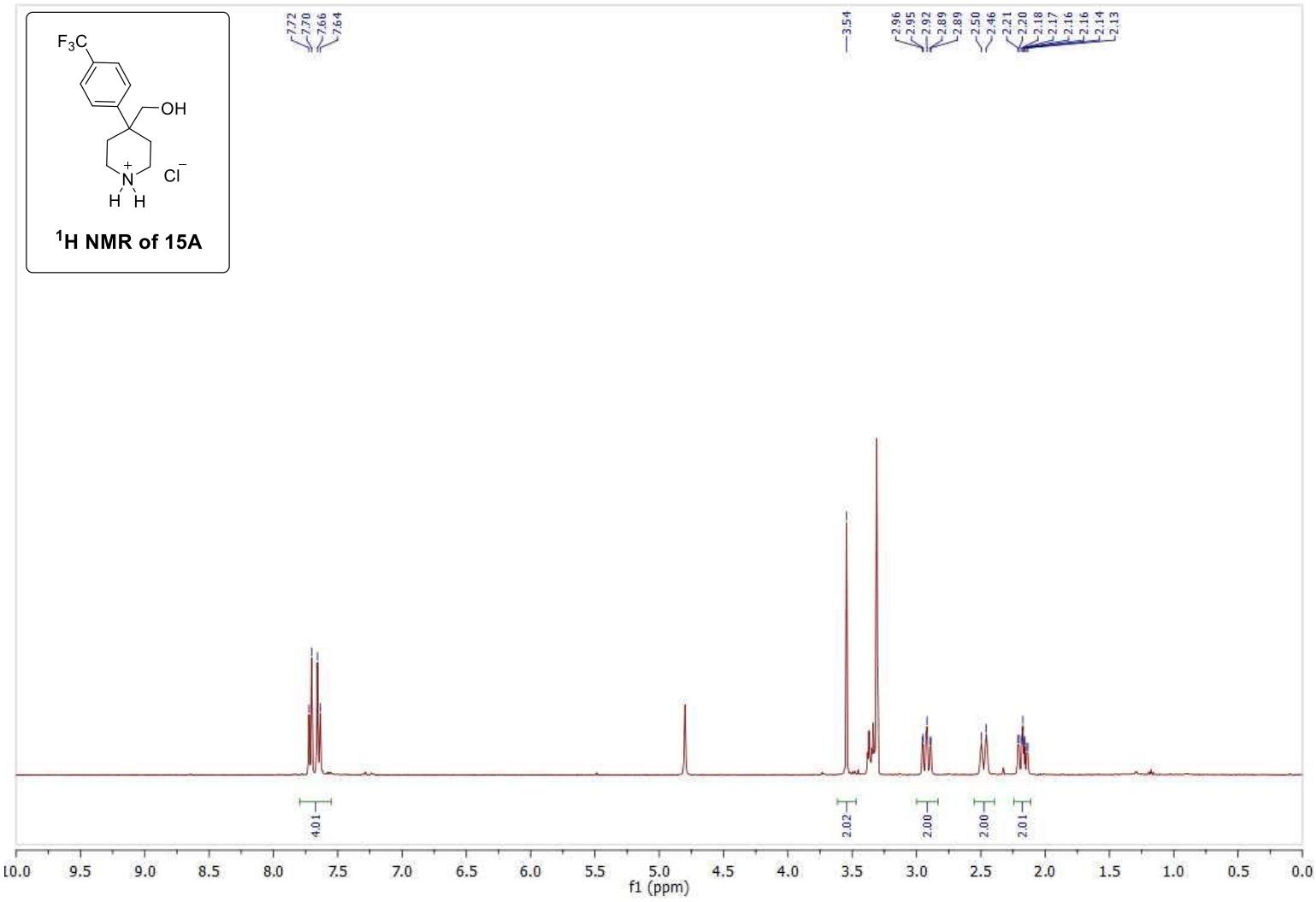

OH
N
H2
13C NMR of 49
143.46
129.77
128.35
127.51
72.51
43.46
42.59
31.27
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

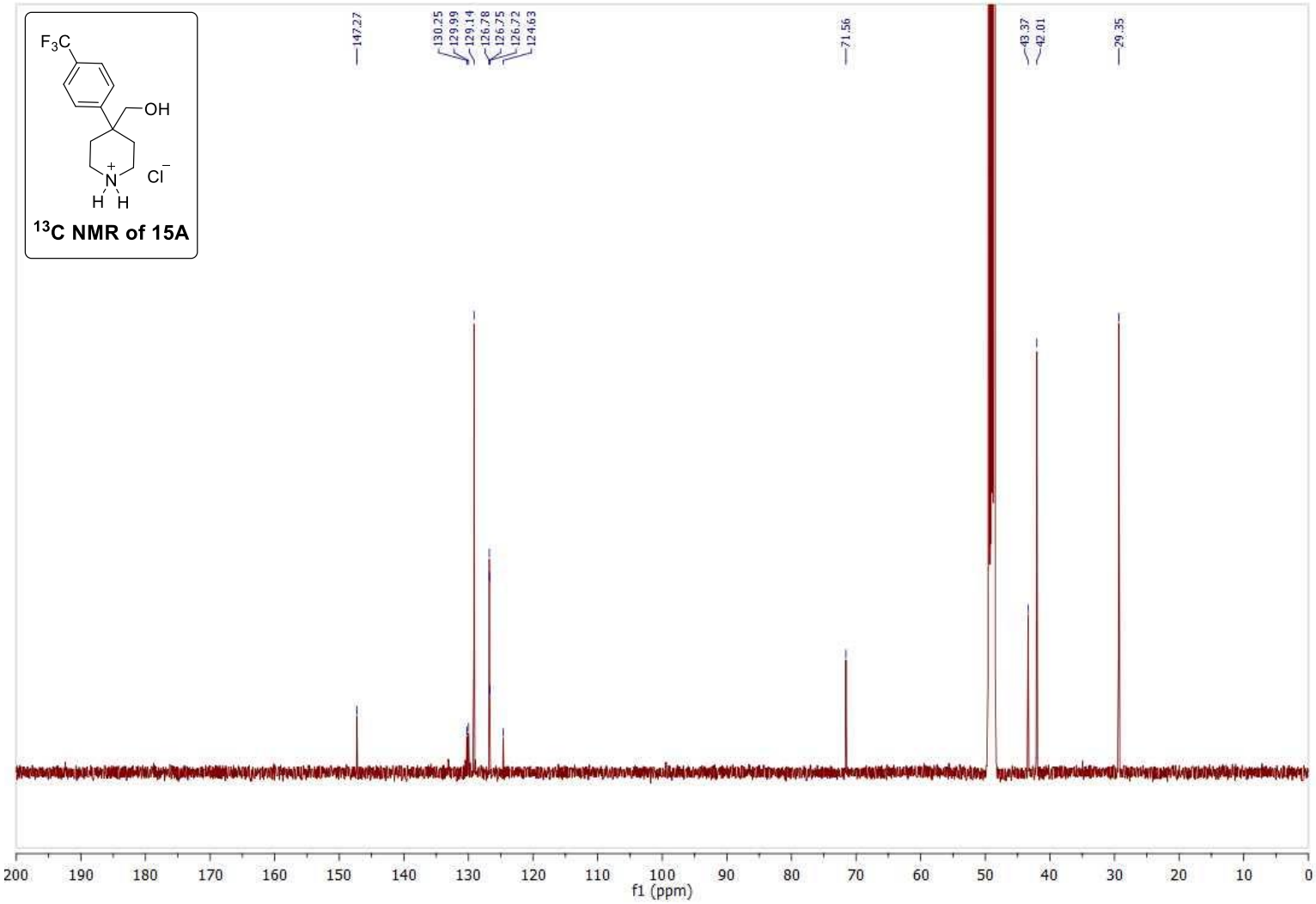

7.18
7.18
7.17
7.16
7.15
7.13
7.02
7.01
7.01
7.00
6.99
6.99
5.30
5.27
2.30
H3C
CO2H
N
H
1H NMR of 14
4.00
2.00
2.00
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

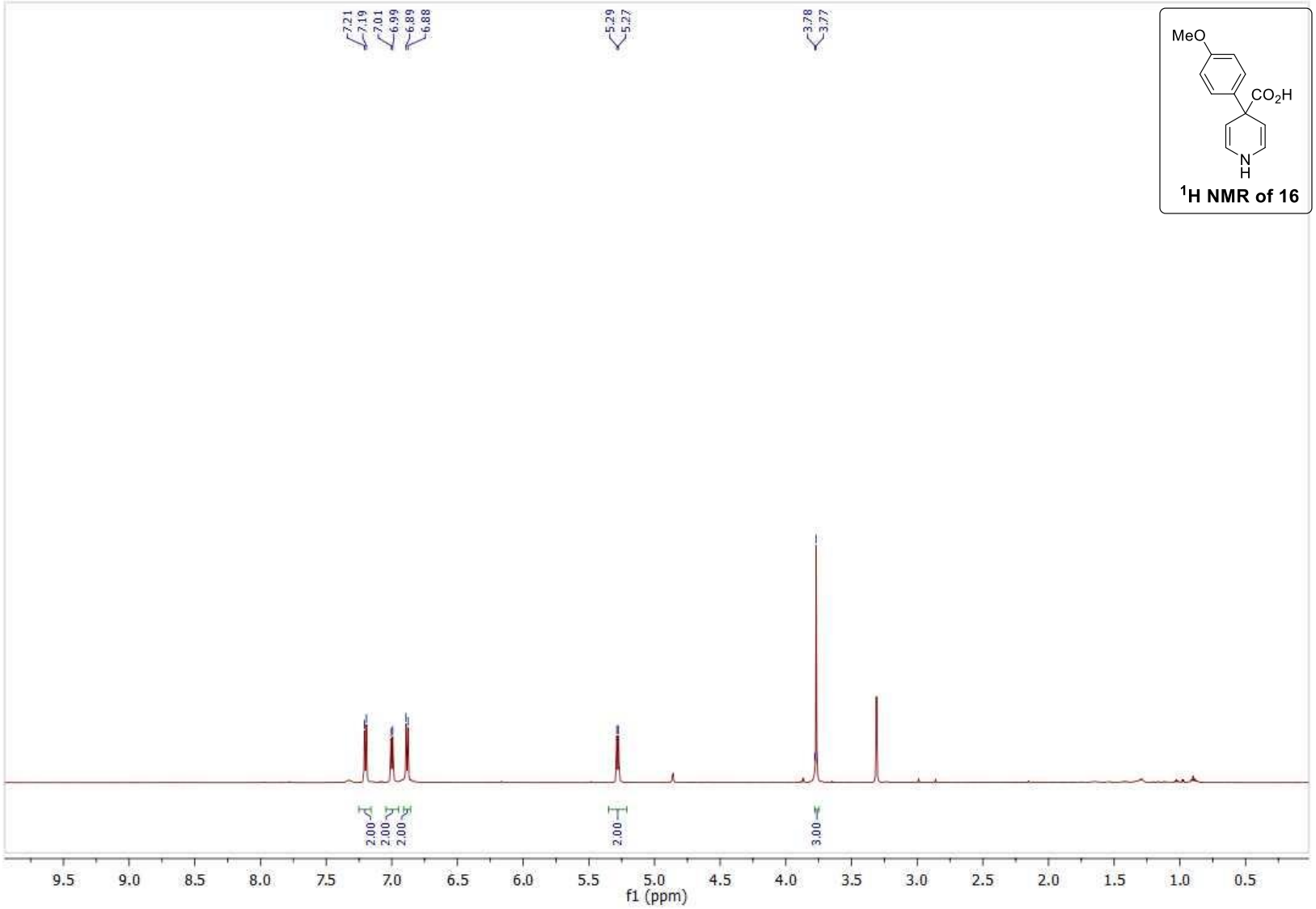

7.31
7.29
7.24
7.22
3.46
2.94
2.93
2.91
2.90
2.88
2.87
2.43
2.39
2.32
2.17
2.16
2.13
2.10
2.09
H3C
OH
Cl−
N+
H H
1H NMR of 14A
4.00
2.01
2.01
2.01
3.00
2.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

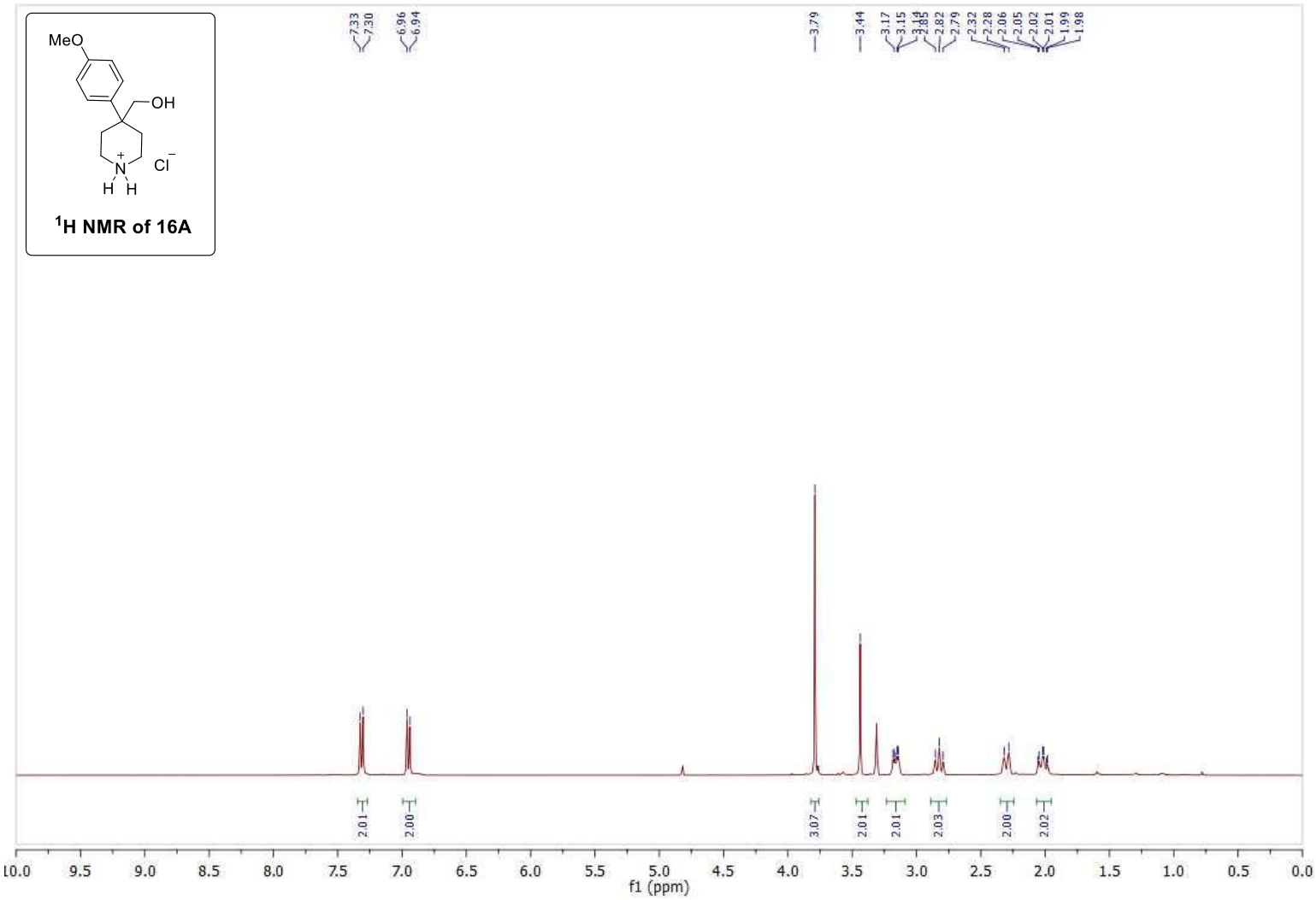

H3C
OH
Cl−
N+
H H
13C NMR of 14A
138.79
137.71
130.74
128.09
72.34
42.82
42.11
29.25
20.94
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

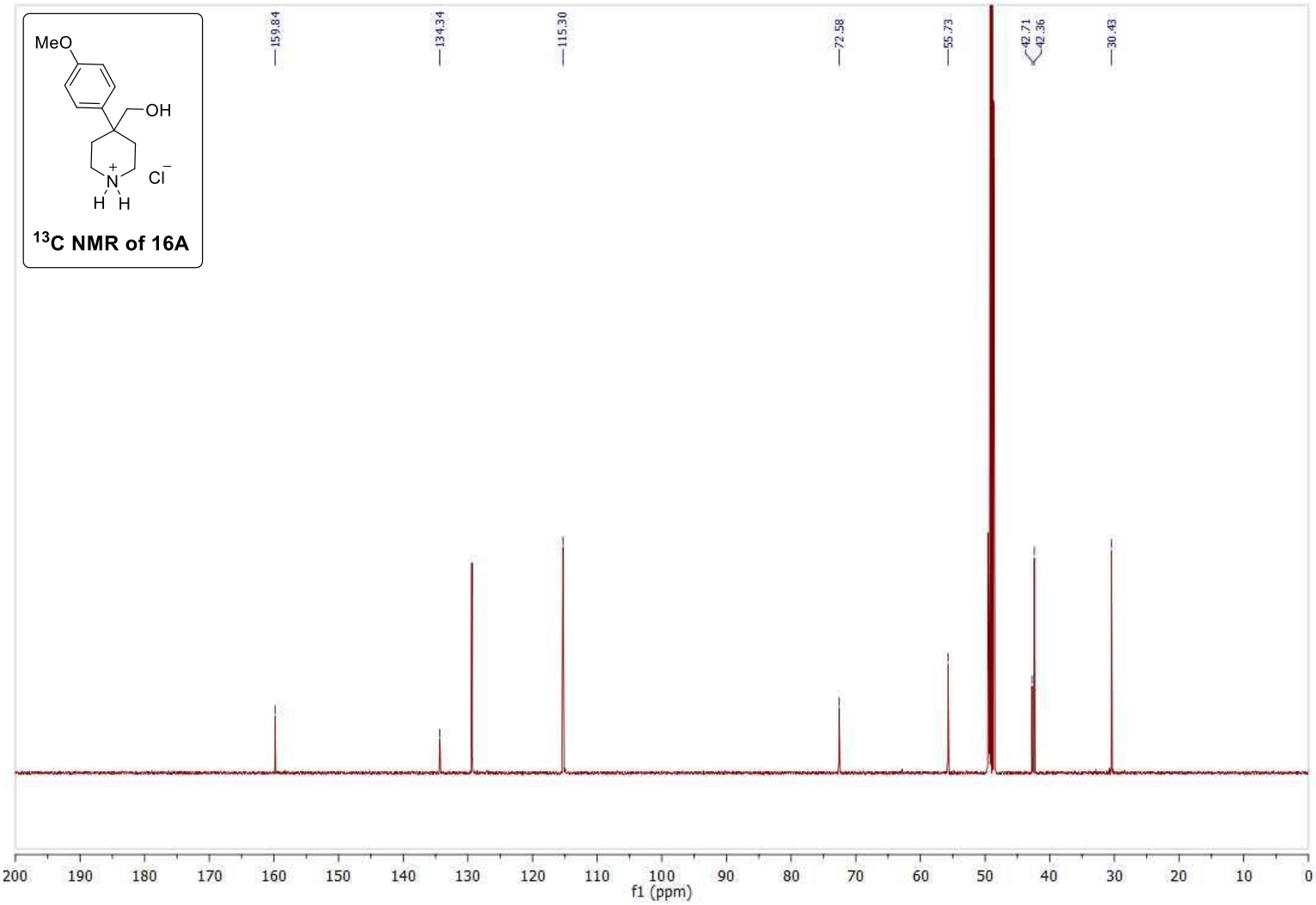

7.76
7.74
7.60
7.58
7.12
7.11
7.11
7.10
7.09
7.09
5.41
5.39
F3C
CO2H
N
H
1H NMR of 15
2.00
2.00
2.00
2.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

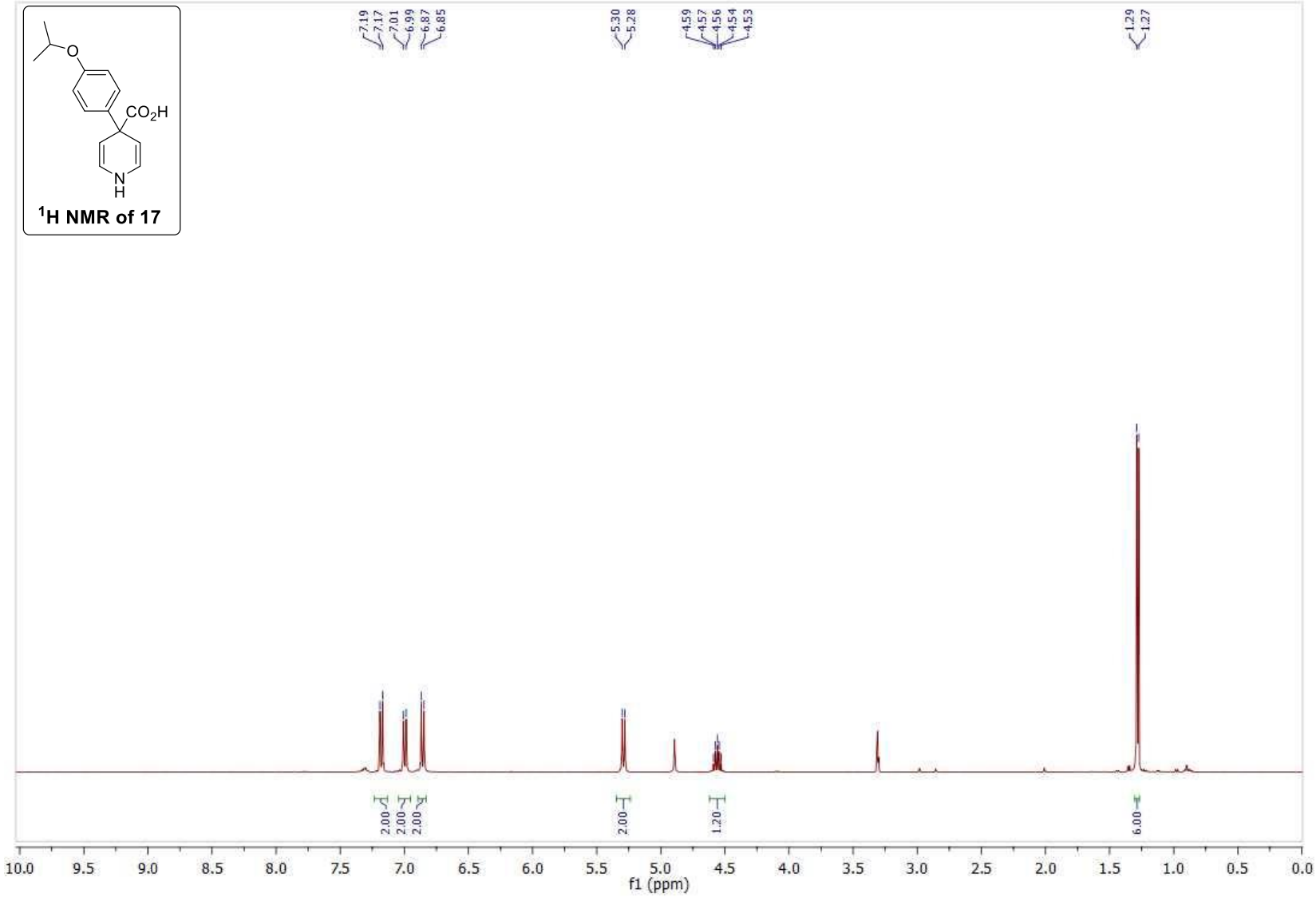

F3C
OH
Cl−
H H
1H NMR of 15A
7.72
7.70
7.66
7.64
3.54
2.96
2.95
2.92
2.89
2.89
2.50
2.46
2.21
2.20
2.18
2.17
2.16
2.16
2.14
2.13
4.01
2.02
2.00
2.00
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

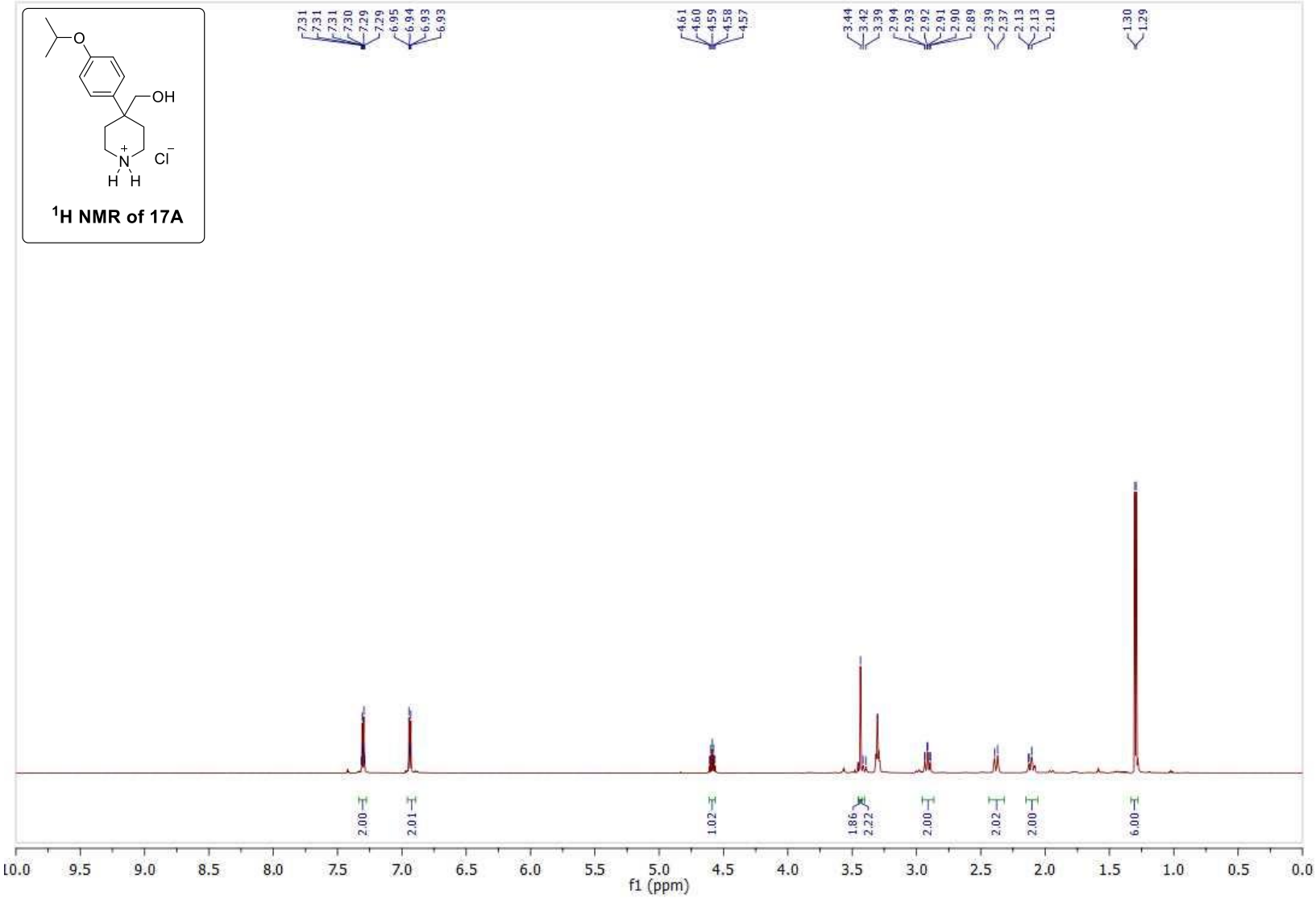

F3C
OH
Cl−
H H
13C NMR of 15A
147.27
130.25
129.99
129.14
126.78
126.75
126.72
124.63
71.56
43.37
42.01
29.35
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

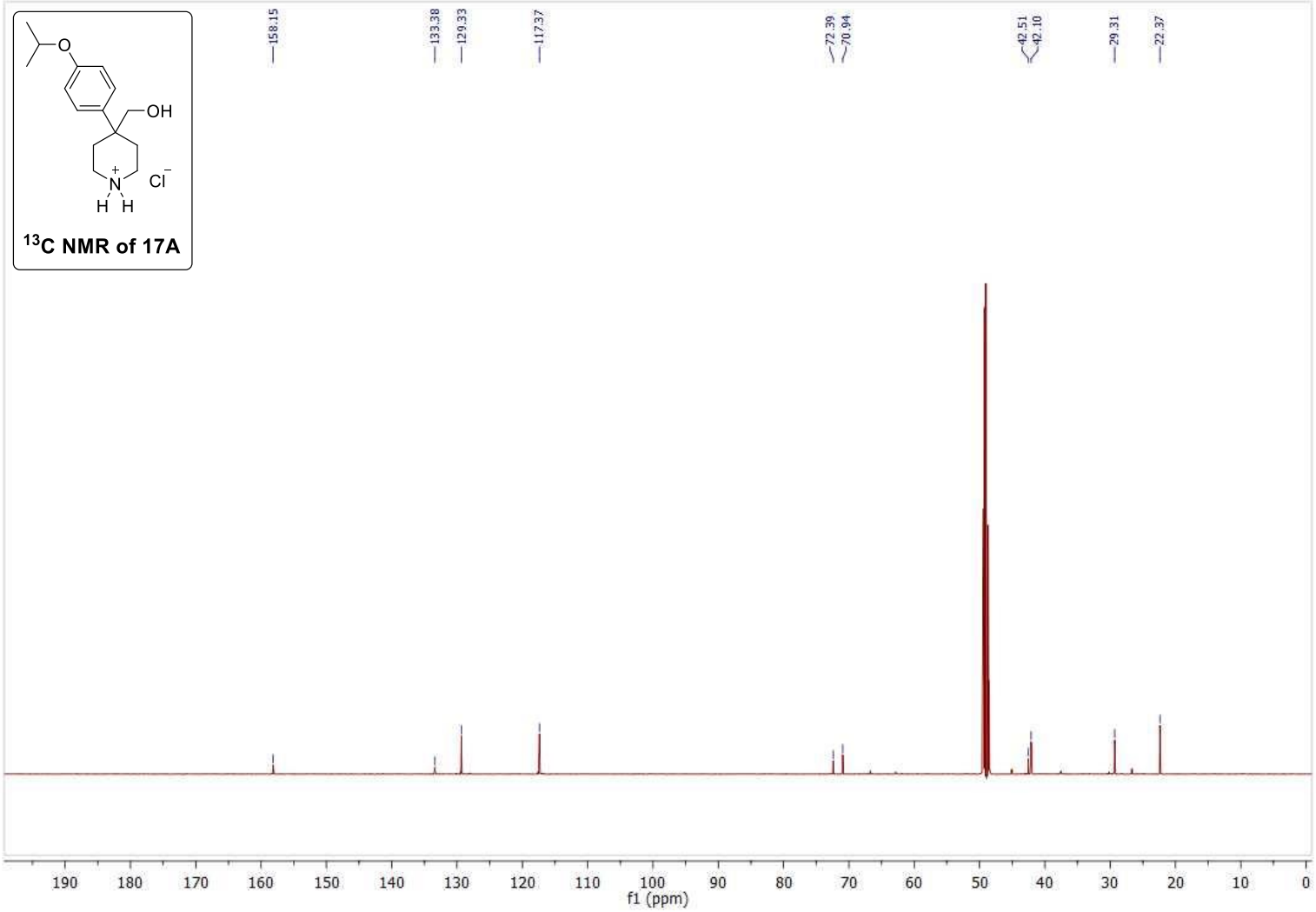

7.21
7.19
7.01
6.99
6.89
6.88
5.29
5.27
3.78
3.77
MeO
CO2H
N
H
1H NMR of 16
2.00
2.00
2.00
2.00
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


MeO
OH
Cl⁻
H H
¹H NMR of 16A
7.33
7.30
6.96
6.94
3.79
3.44
3.17
3.15
3.14
2.85
2.82
2.79
2.32
2.28
2.06
2.05
2.02
2.01
1.99
1.98
2.01
2.00
3.07
2.01
2.01
2.03
2.00
2.02
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)

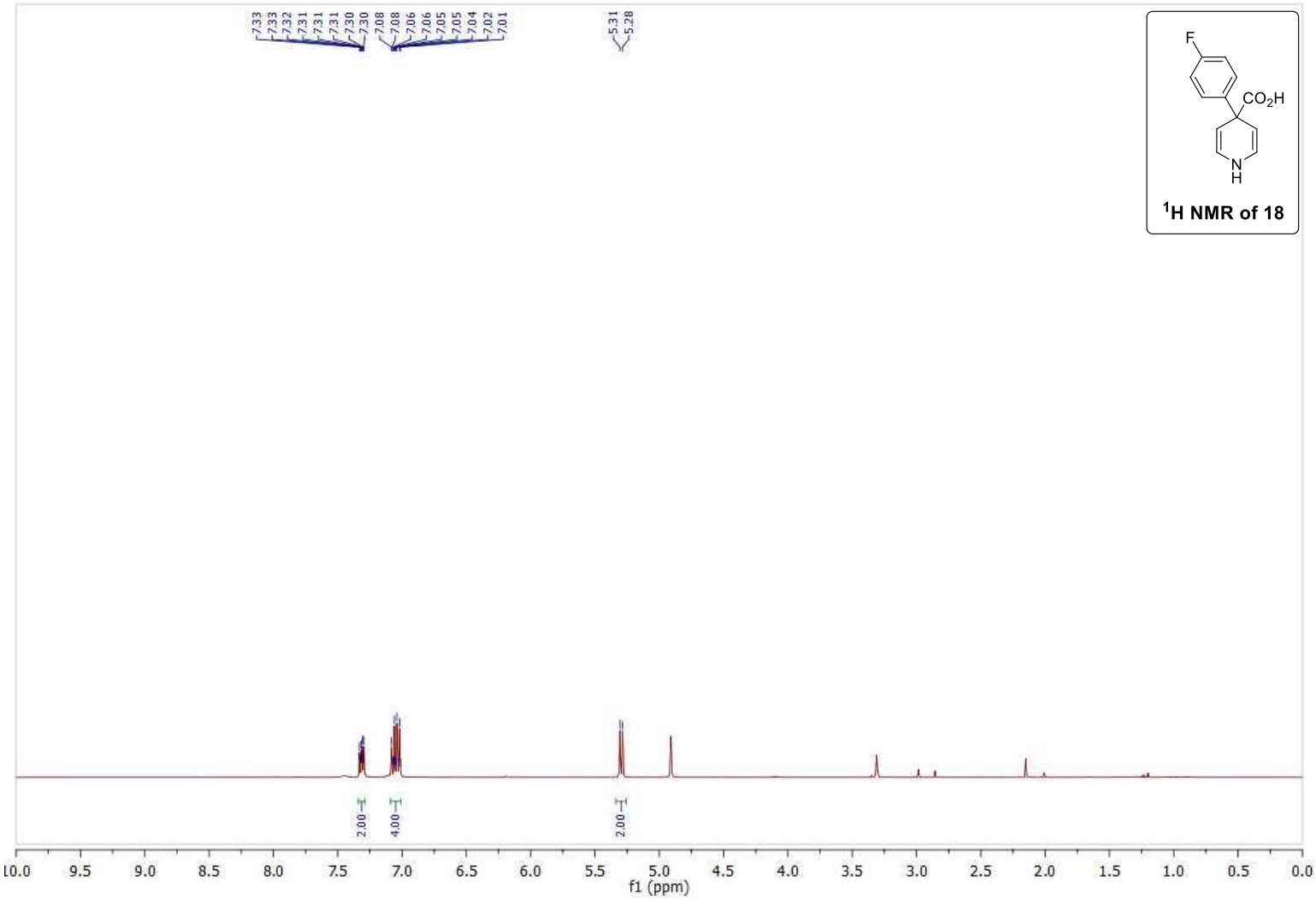

MeO
OH
Cl⁻
H H
13C NMR of 16A
159.84
134.34
115.30
72.58
55.73
42.71
42.36
30.43
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

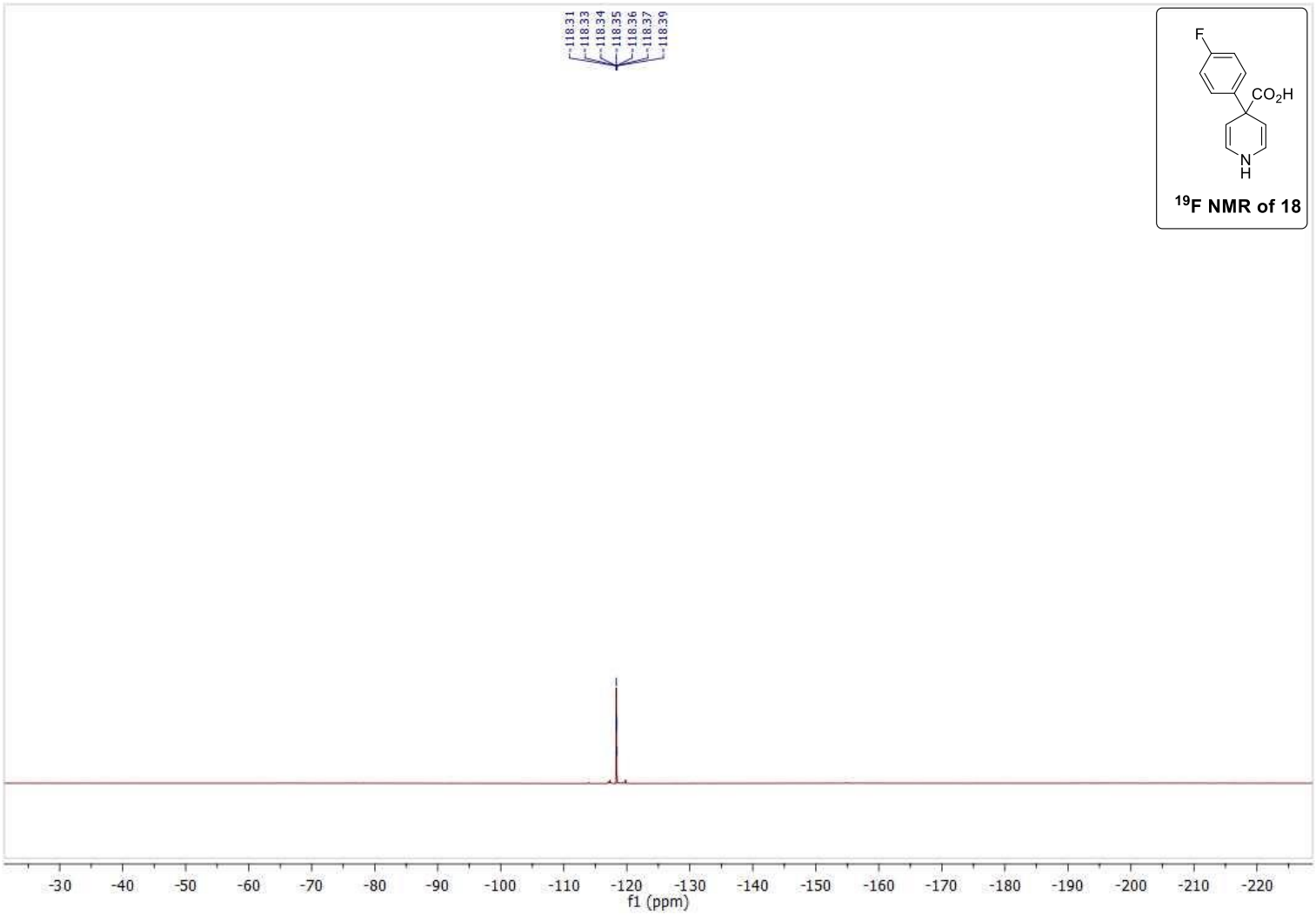

^{1}H NMR of 17
7.19
7.17
7.01
6.99
6.87
6.85
5.30
5.28
4.59
4.57
4.56
4.54
4.53
1.29
1.27
2.00
2.00
2.00
2.00
1.20
6.00
f1 (ppm)

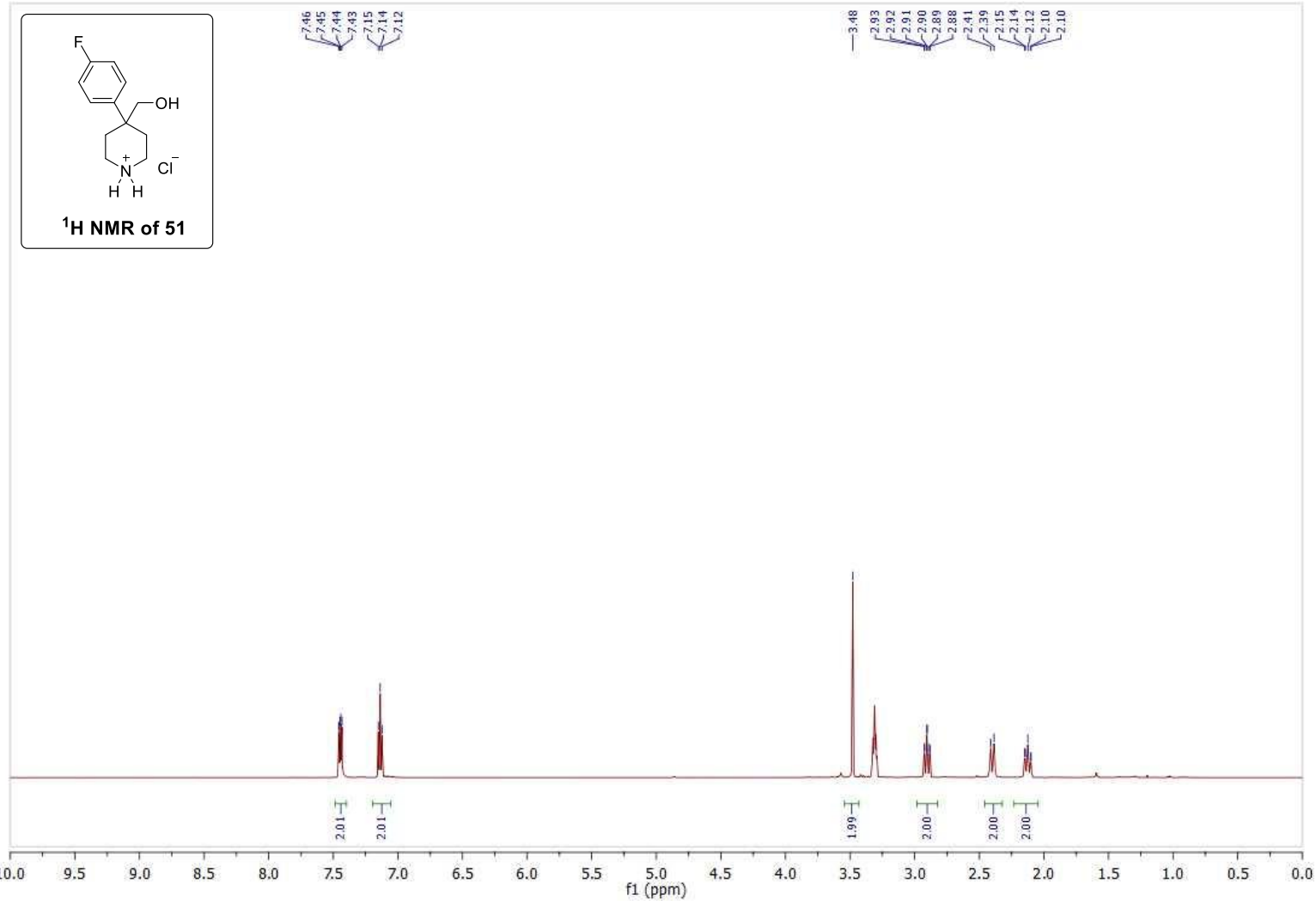

O
OH
N
H H
Cl⁻
1H NMR of 17A
7.31
7.31
7.31
7.30
7.29
7.29
6.95
6.94
6.93
6.93
4.61
4.60
4.59
4.58
4.57
3.44
3.42
3.39
2.94
2.93
2.92
2.91
2.90
2.89
2.39
2.37
2.13
2.13
2.10
1.30
1.29
2.00
2.01
1.02
1.86
2.22
2.00
2.02
2.00
6.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

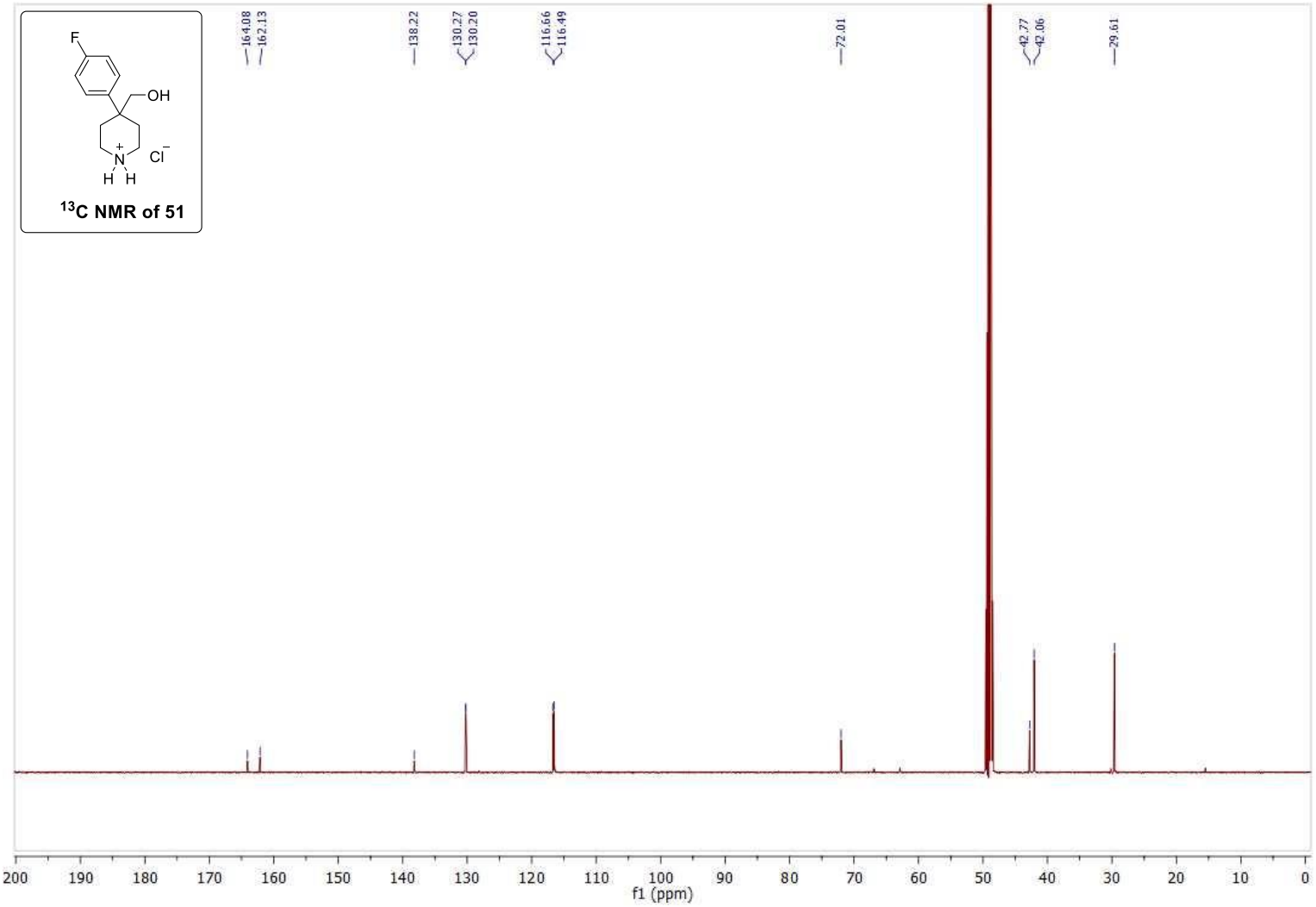


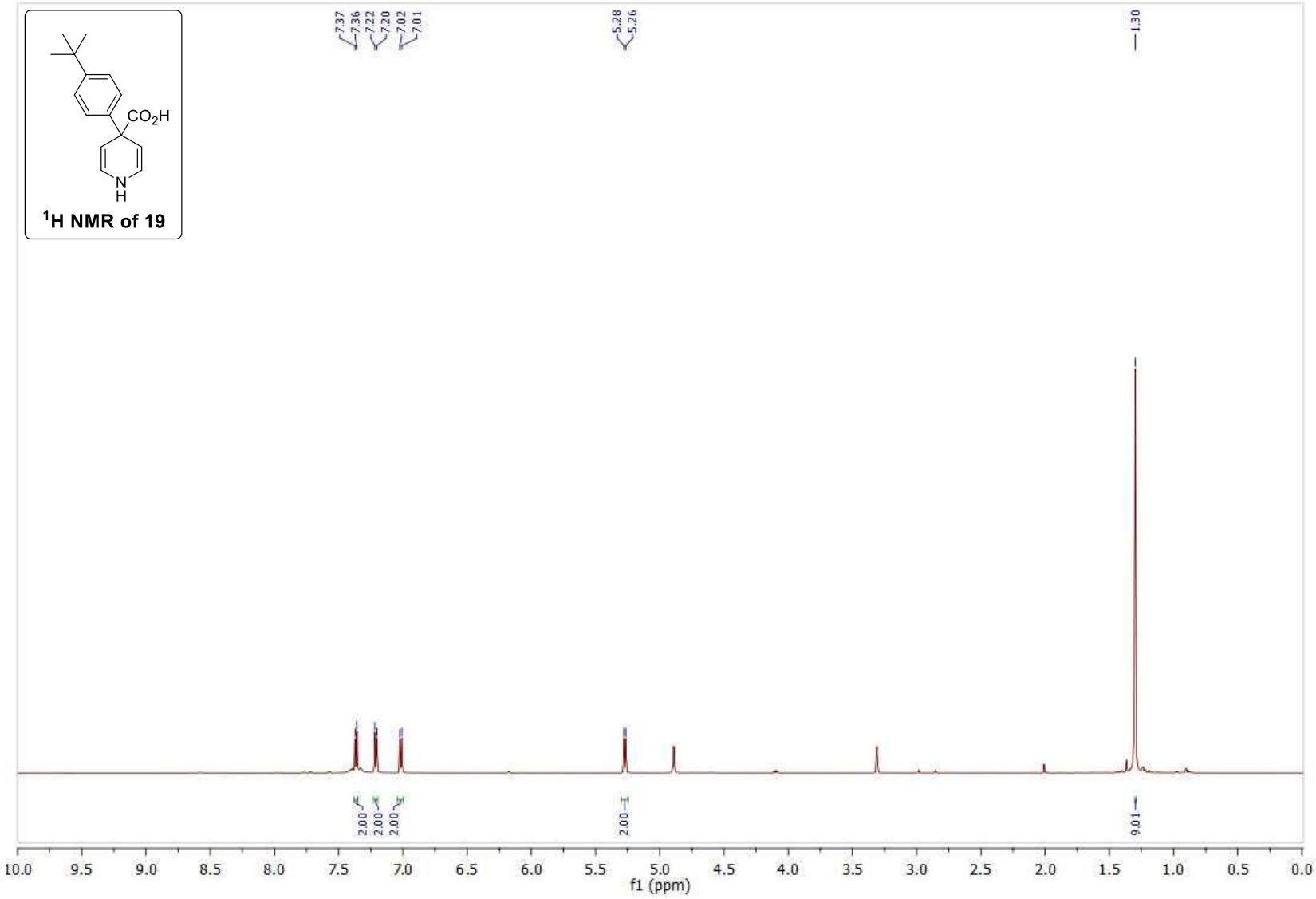
^{13}C NMR of 17A

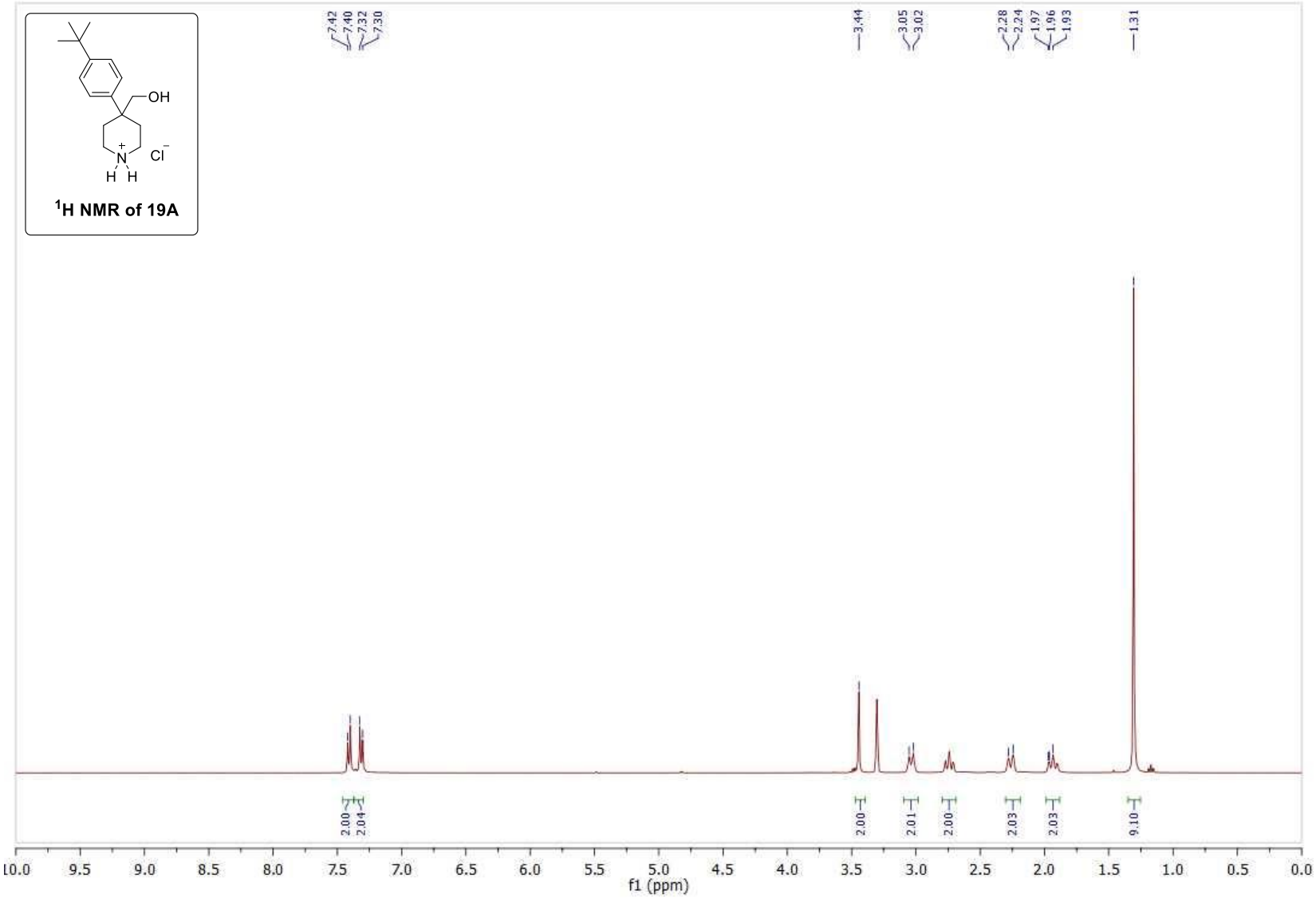

7.33
7.33
7.32
7.31
7.31
7.31
7.30
7.30
7.08
7.08
7.06
7.06
7.05
7.05
7.04
7.02
7.01
5.31
5.28
F
CO2H
N
H
1H NMR of 18
2.00
4.00
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


118.31
118.33
118.34
118.35
118.36
118.37
118.39
F
CO2H
N
H
19F NMR of 18
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
f1 (ppm)

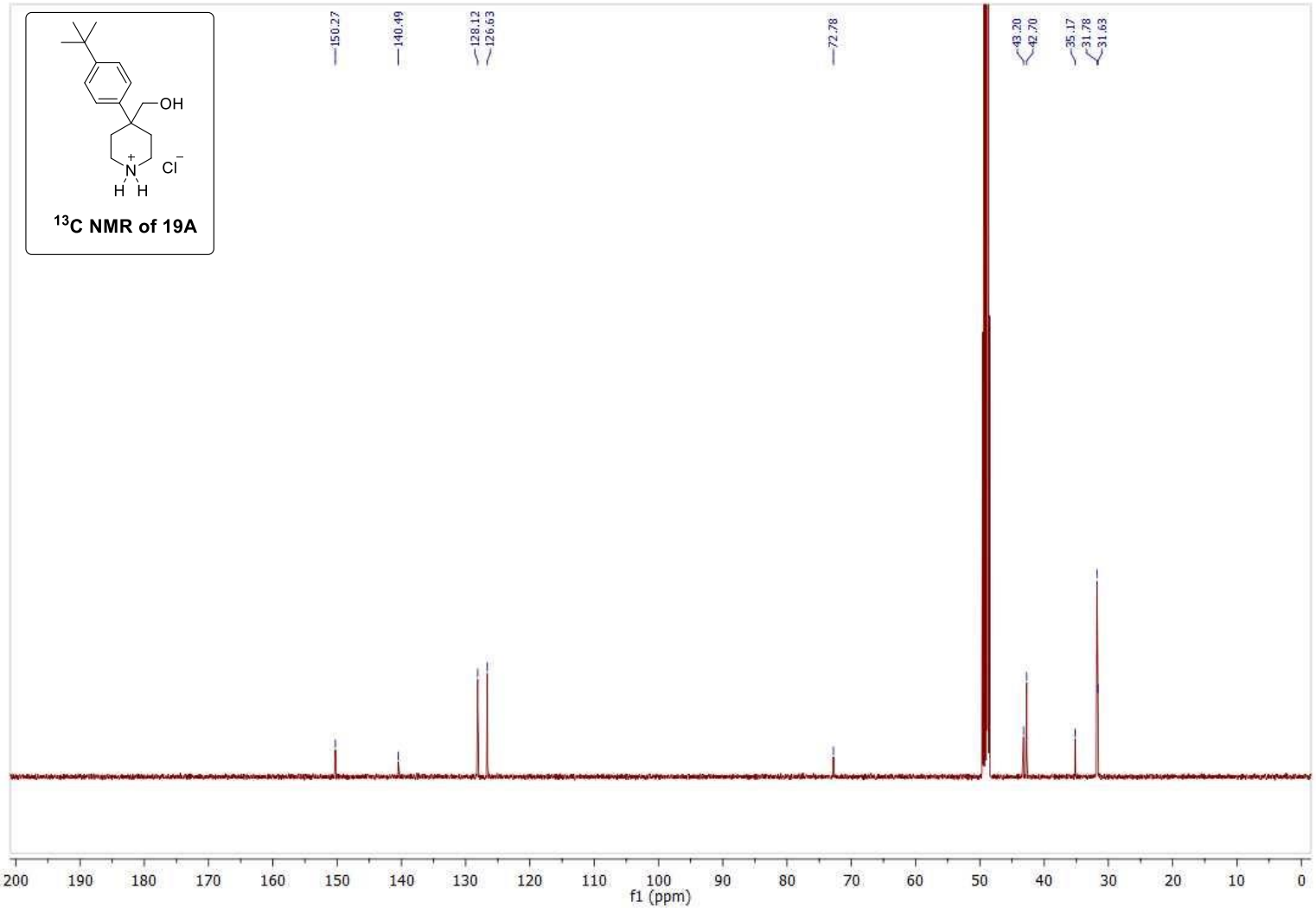

F
OH
Cl⁻
H H
1H NMR of 51
7.46
7.45
7.44
7.43
7.15
7.14
7.12
3.48
2.93
2.92
2.91
2.90
2.89
2.88
2.41
2.39
2.15
2.14
2.12
2.10
2.10
2.01
2.01
1.99
2.00
2.00
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

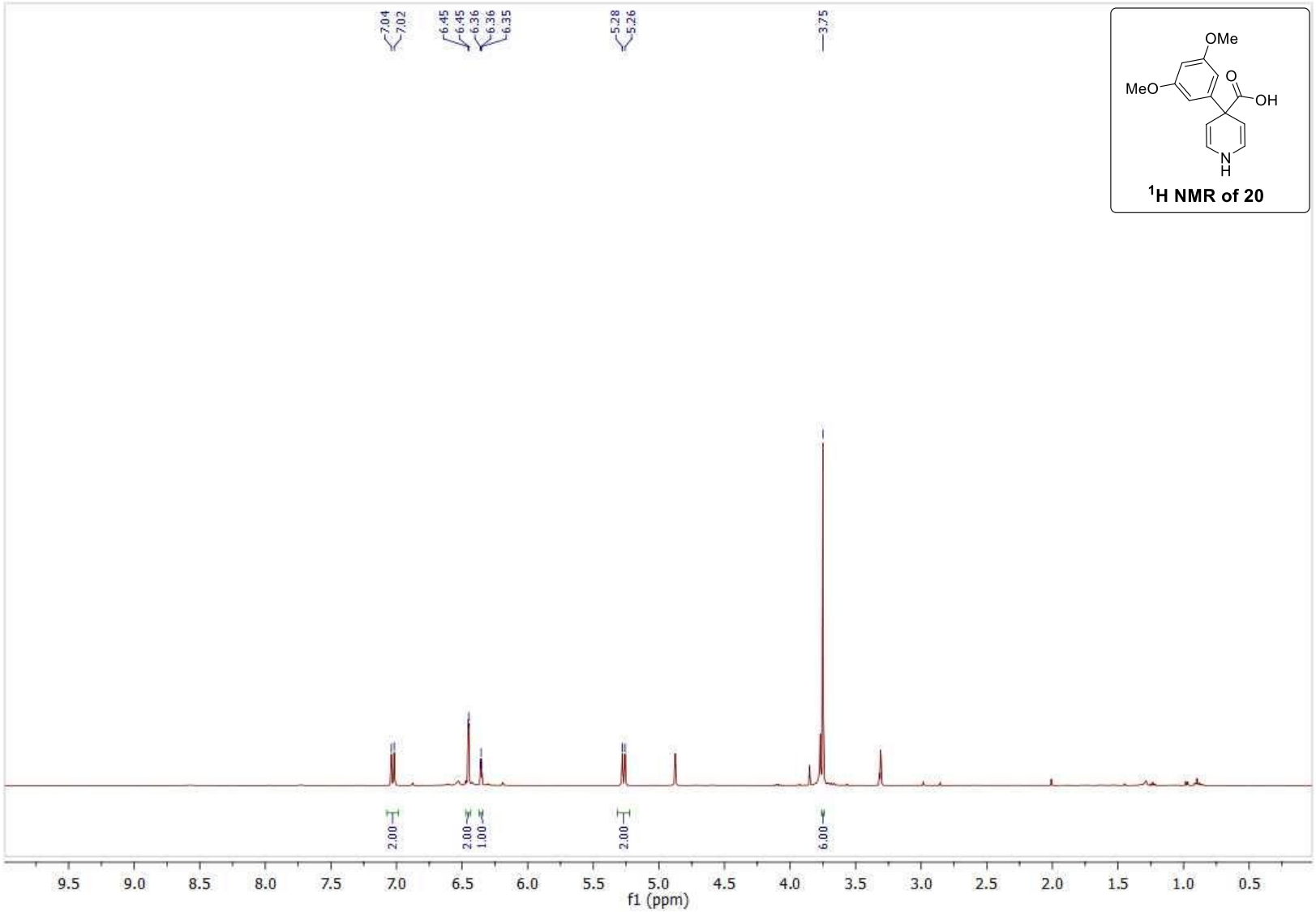

F
OH
Cl⁻
H H
13C NMR of 51
164.08
162.13
138.22
130.27
130.20
116.66
116.49
72.01
42.77
42.06
29.61
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

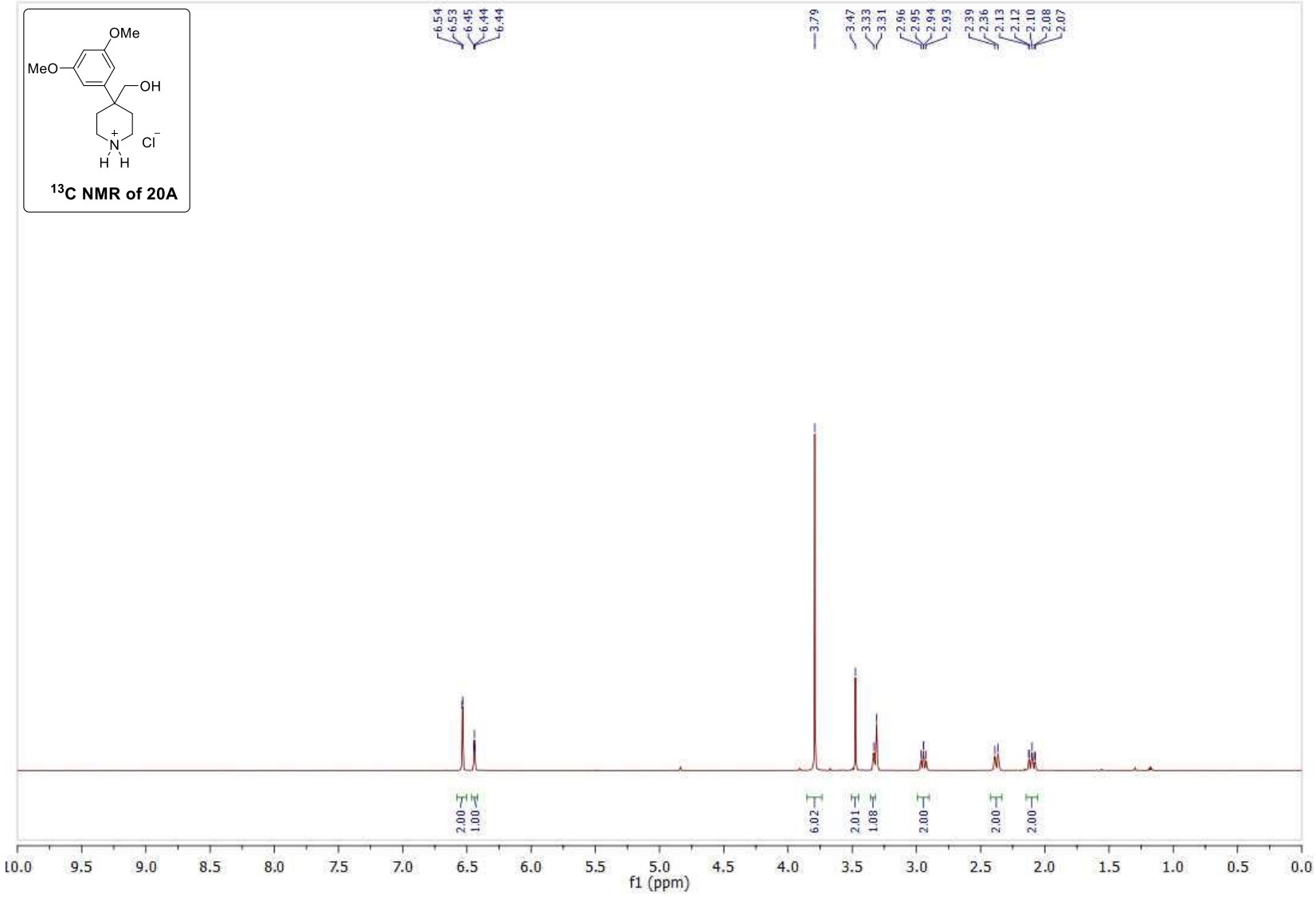

CO2H
N
H
1H NMR of 19
7.37
7.36
7.22
7.20
7.02
7.01
5.28
5.26
1.30
2.00
2.00
2.00
2.00
9.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

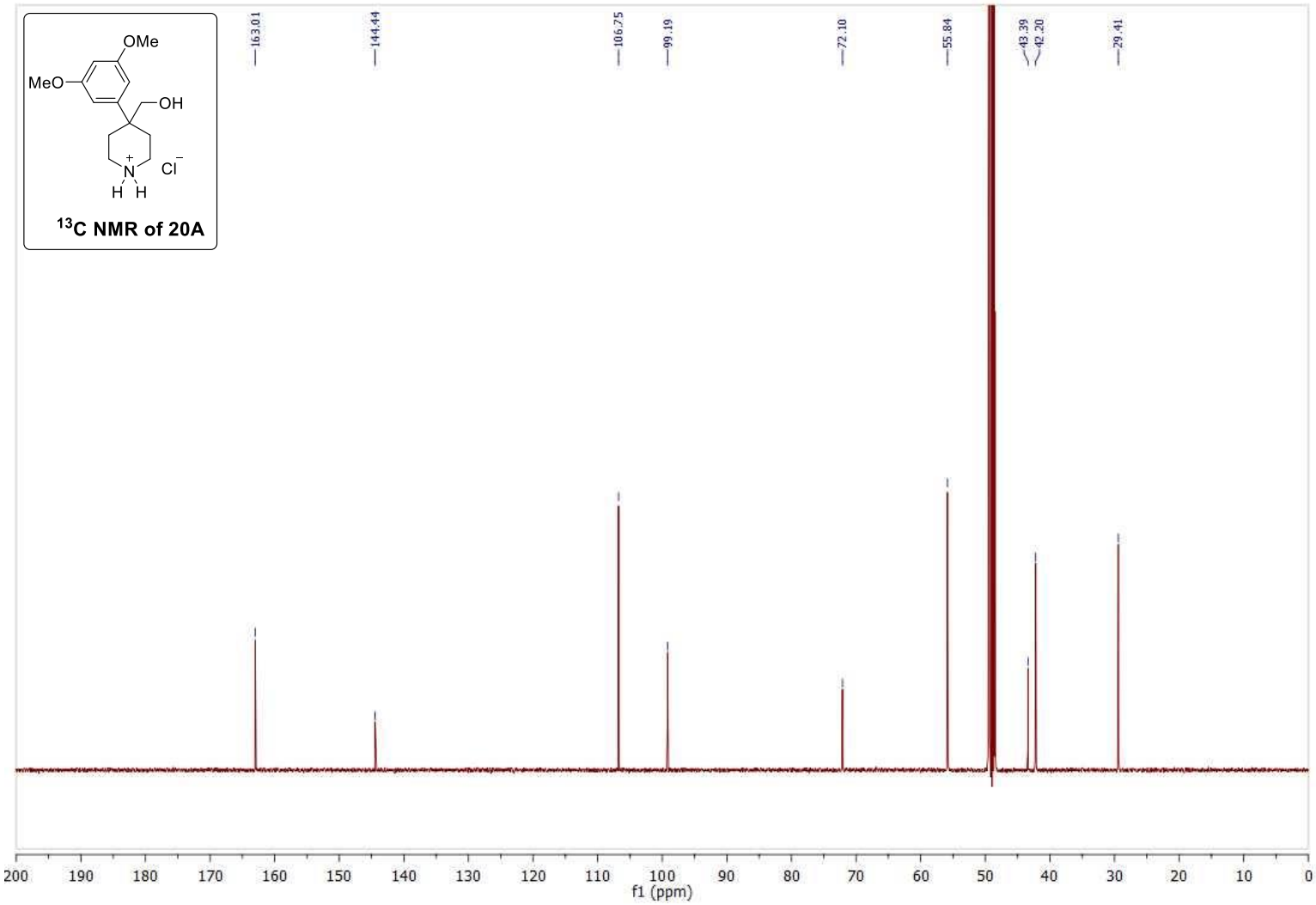

OH
Cl⁻
H H
7.42
7.40
7.32
7.30
3.44
3.05
3.02
2.28
2.24
1.97
1.96
1.93
1.31
2.00
2.04
2.00
2.01
2.00
2.03
2.03
9.10
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

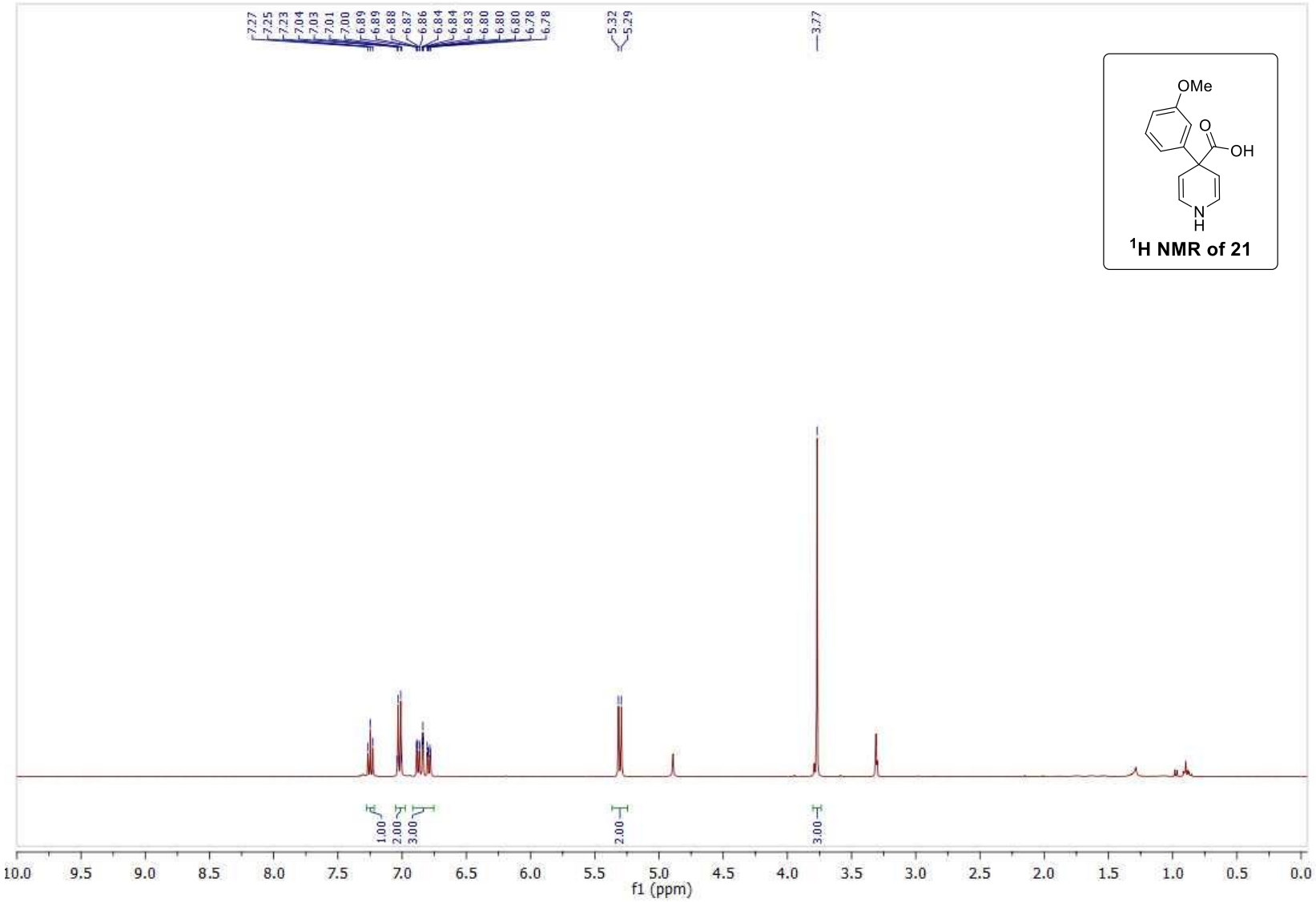
^{1}H NMR of 19A

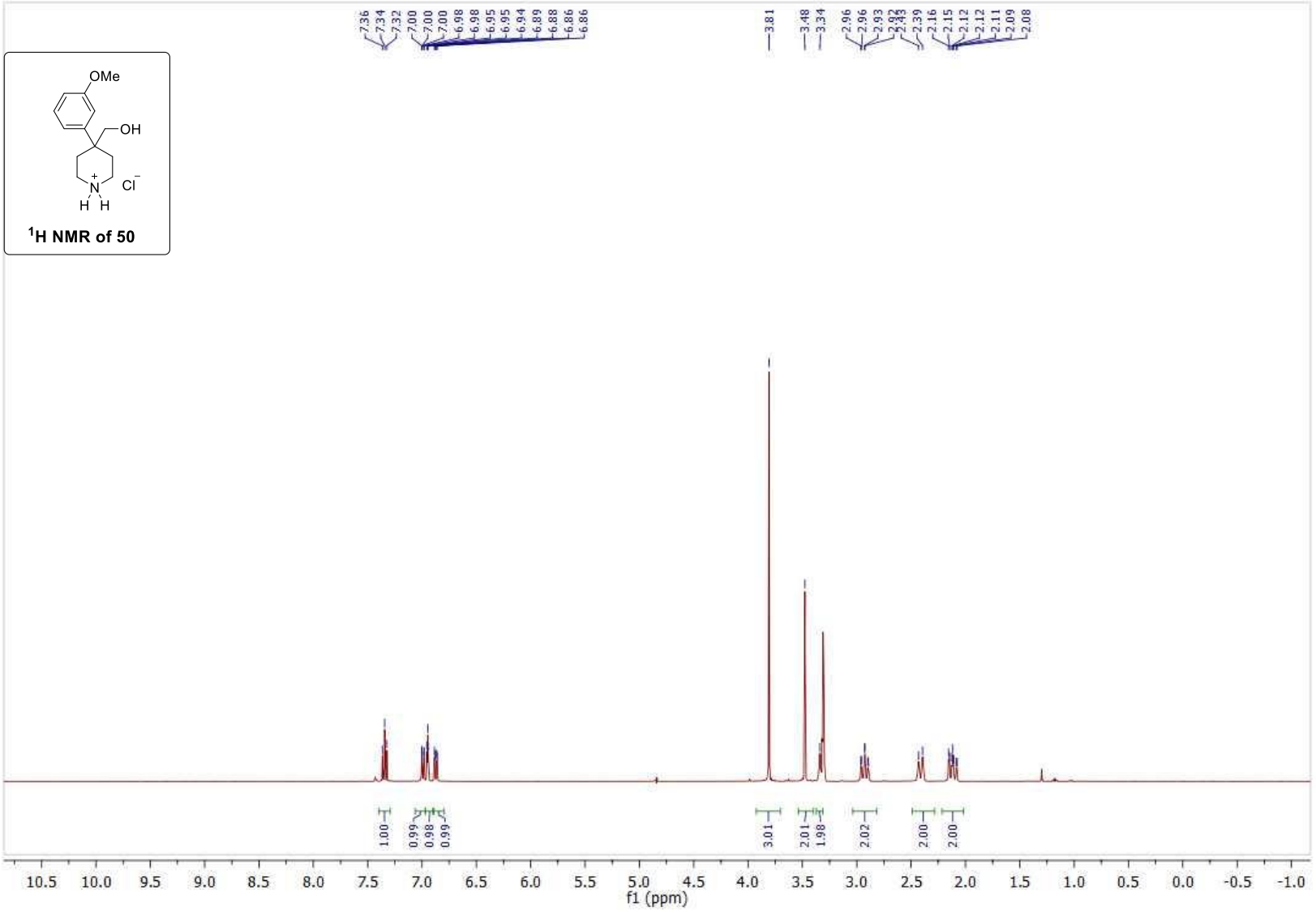

150.27
140.49
128.12
126.63
72.78
43.20
42.70
35.17
31.78
31.63
OH
Cl⁻
H H
13C NMR of 19A
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.04
7.02
6.45
6.45
6.36
6.36
6.35
5.28
5.26
3.75
OMe
MeO
O
OH
N
H
^{1}H NMR of 20
2.00
2.00
1.00
2.00
6.00
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
f1 (ppm)

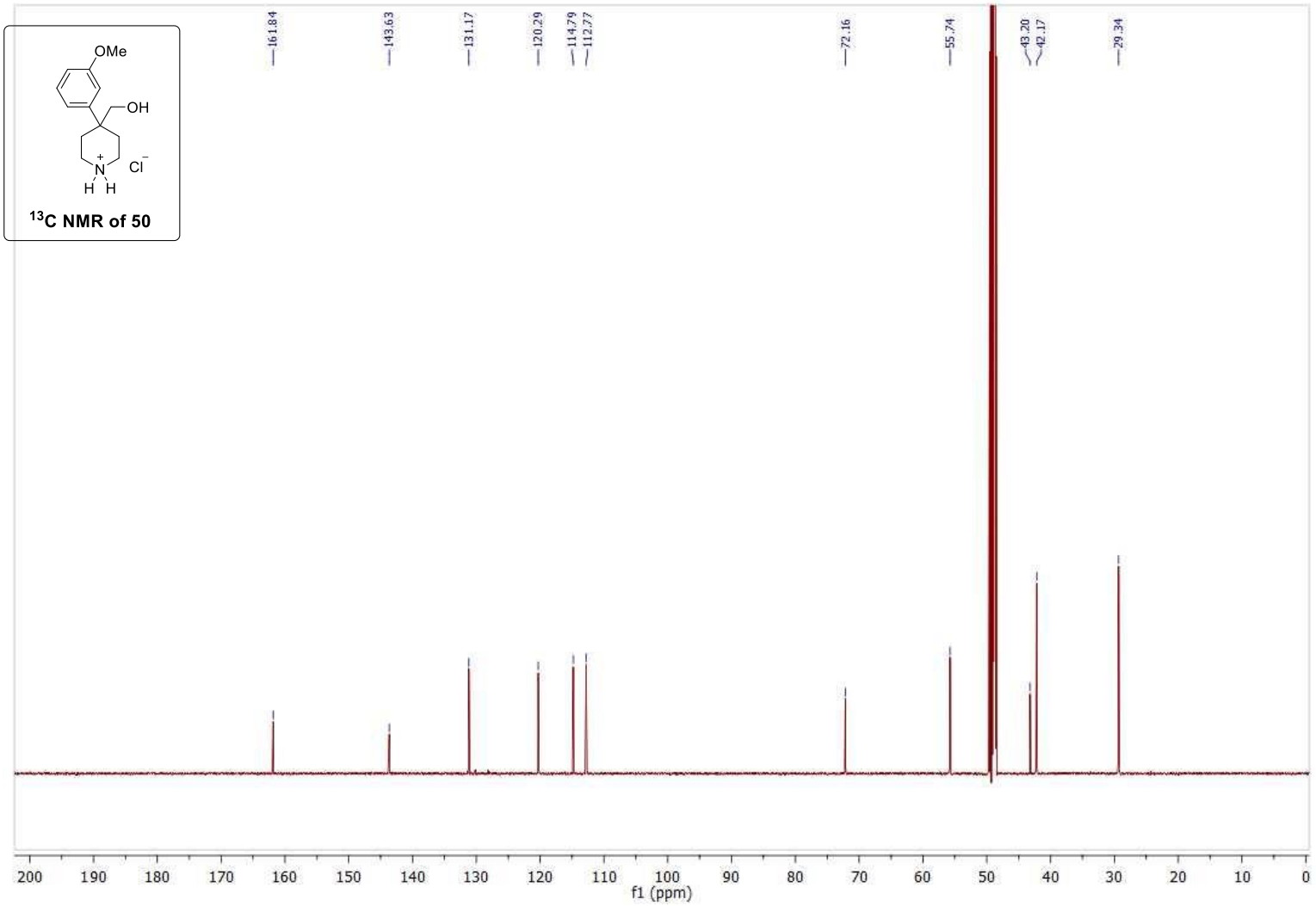

OMe
MeO
OH
Cl⁻
H H
13C NMR of 20A
6.54
6.53
6.45
6.44
6.44
3.79
3.47
3.33
3.31
2.96
2.95
2.94
2.93
2.39
2.36
2.13
2.12
2.10
2.08
2.07
2.00
1.00
6.02
2.01
1.08
2.00
2.00
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


OMe
MeO
OH
Cl⁻
H H
13C NMR of 20A
163.01
144.44
106.75
99.19
72.10
55.84
43.39
42.20
29.41
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

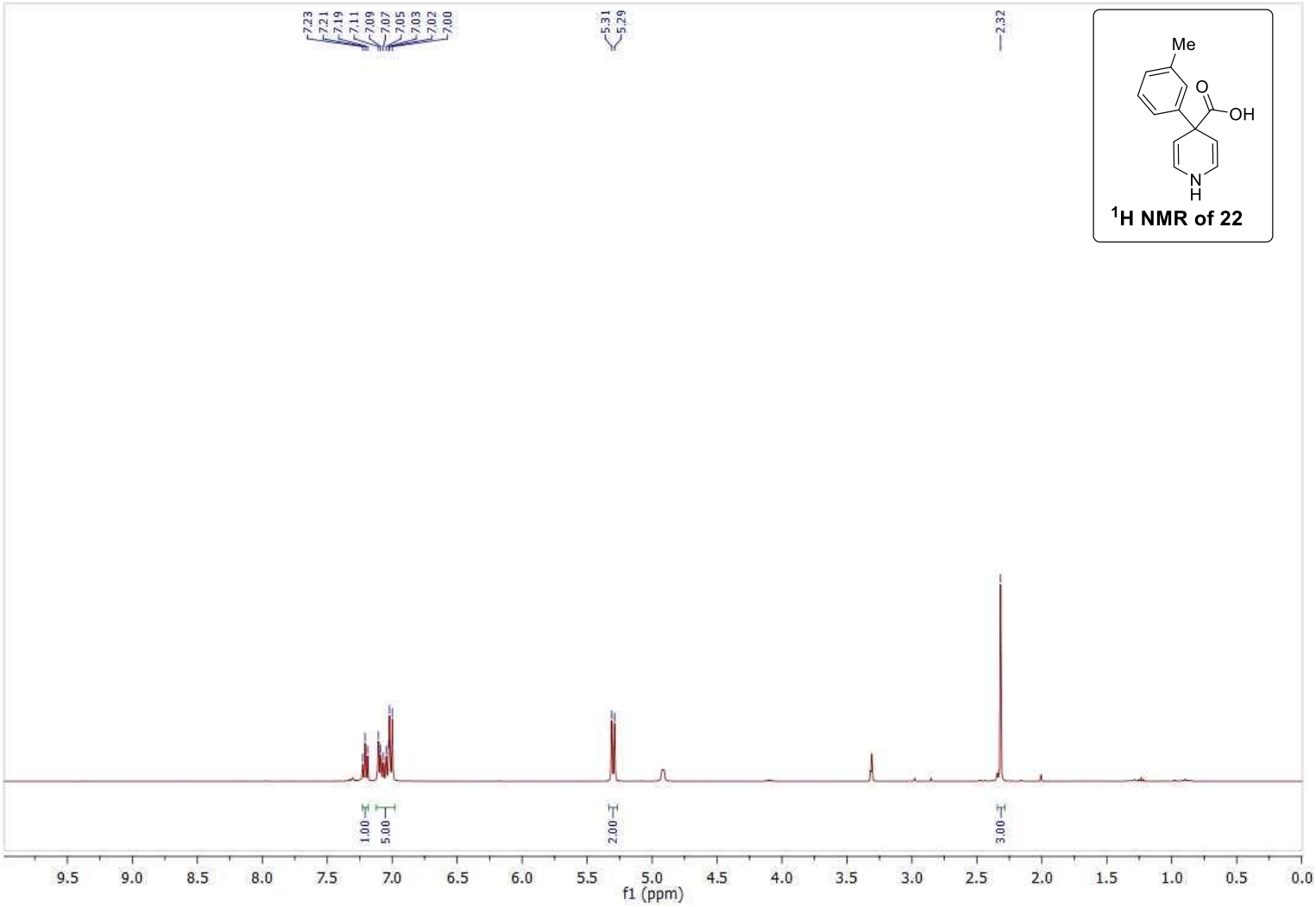

7.27
7.25
7.23
7.04
7.03
7.01
7.00
6.89
6.89
6.88
6.87
6.86
6.84
6.84
6.83
6.80
6.80
6.80
6.78
6.78
5.32
5.29
3.77
OMe
O
OH
N
H
1H NMR of 21
1.00
2.00
3.00
2.00
3.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

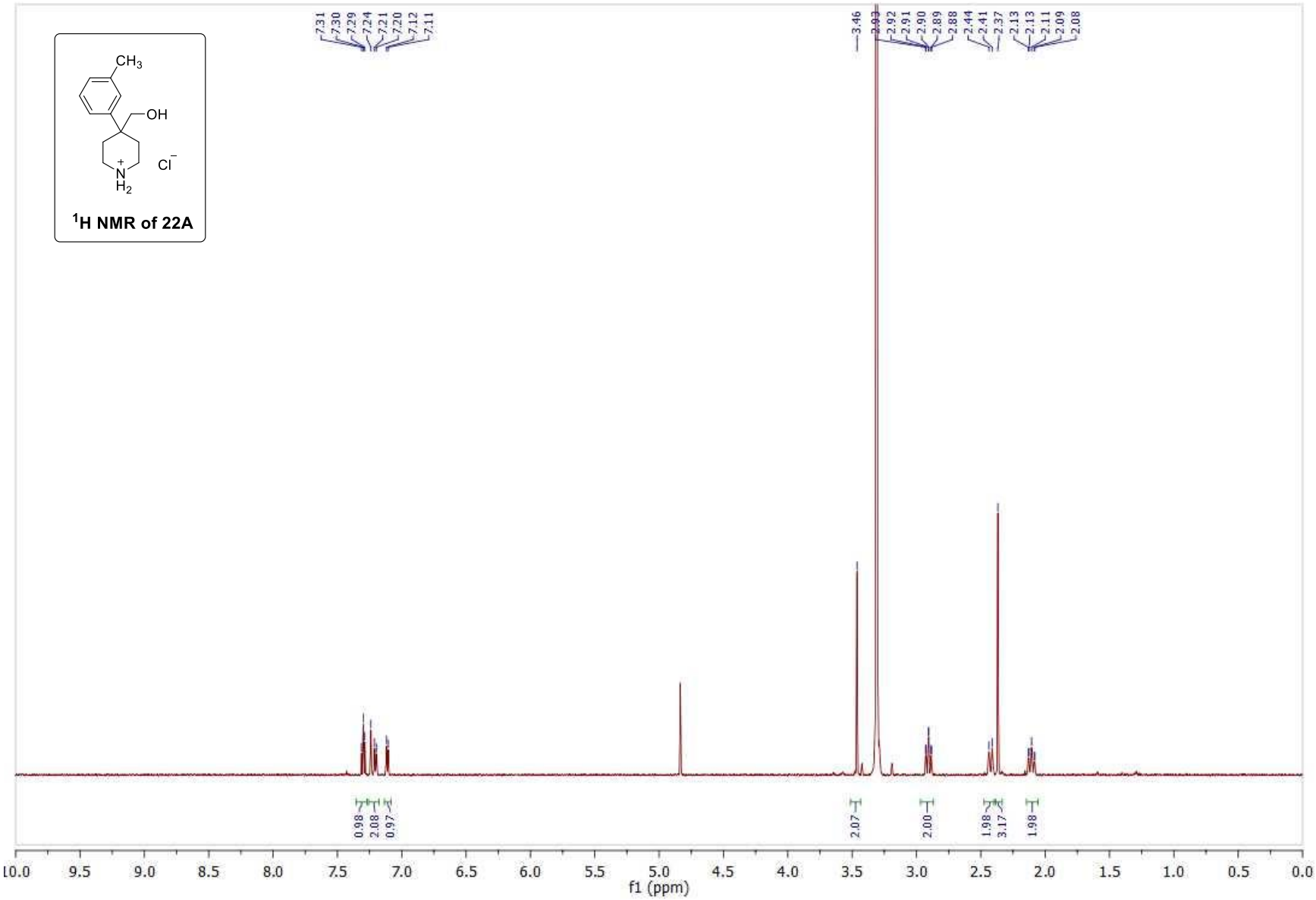

OMe
OH
Cl⁻
H H
7.36
7.34
7.32
7.00
7.00
7.00
6.98
6.98
6.95
6.95
6.94
6.89
6.88
6.86
6.86
3.81
3.48
3.34
2.96
2.96
2.93
2.92
2.43
2.39
2.16
2.15
2.12
2.12
2.11
2.09
2.08
1.00
0.99
0.98
0.99
3.01
2.01
1.98
2.02
2.00
2.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

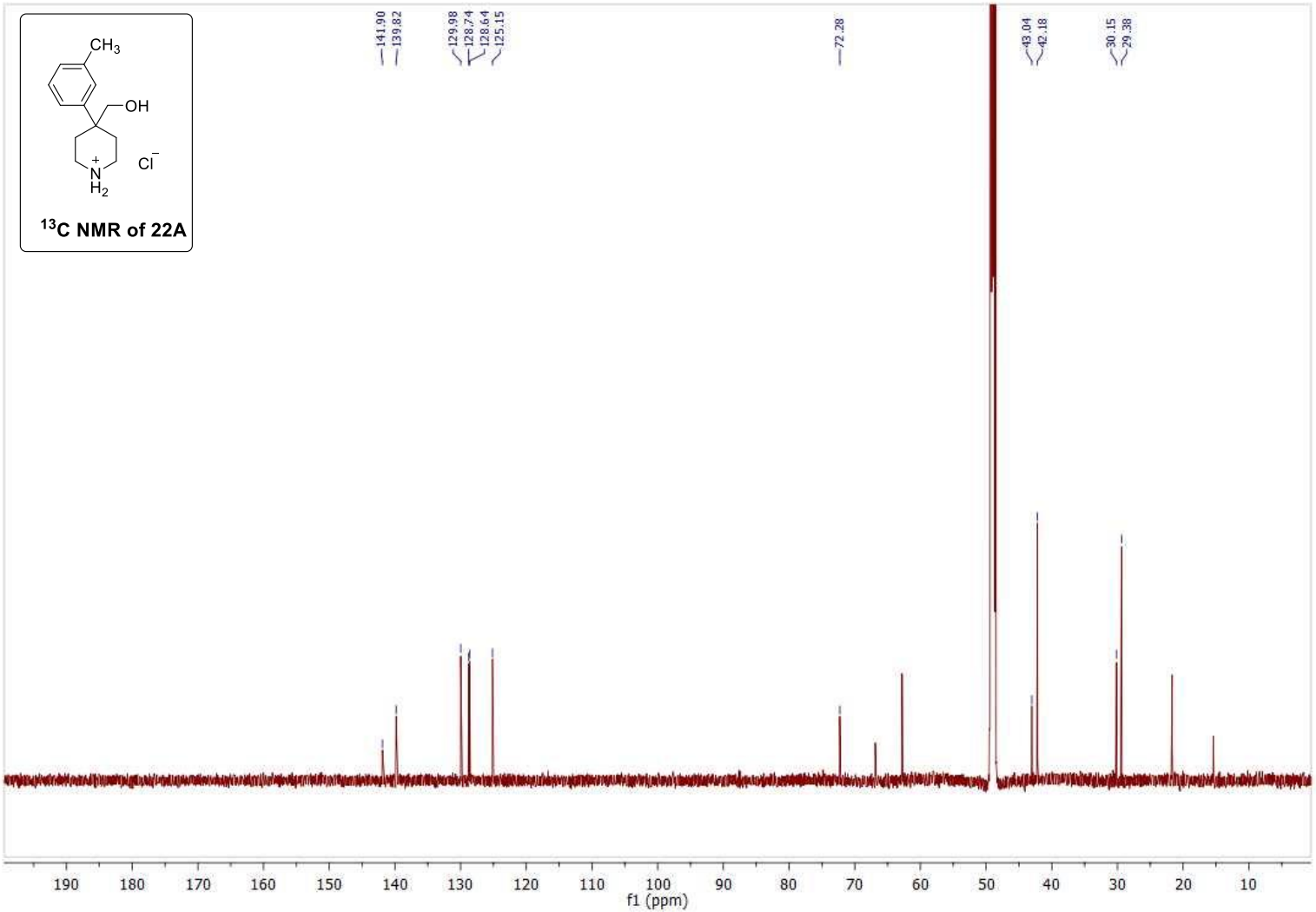
^{1}H NMR of 50

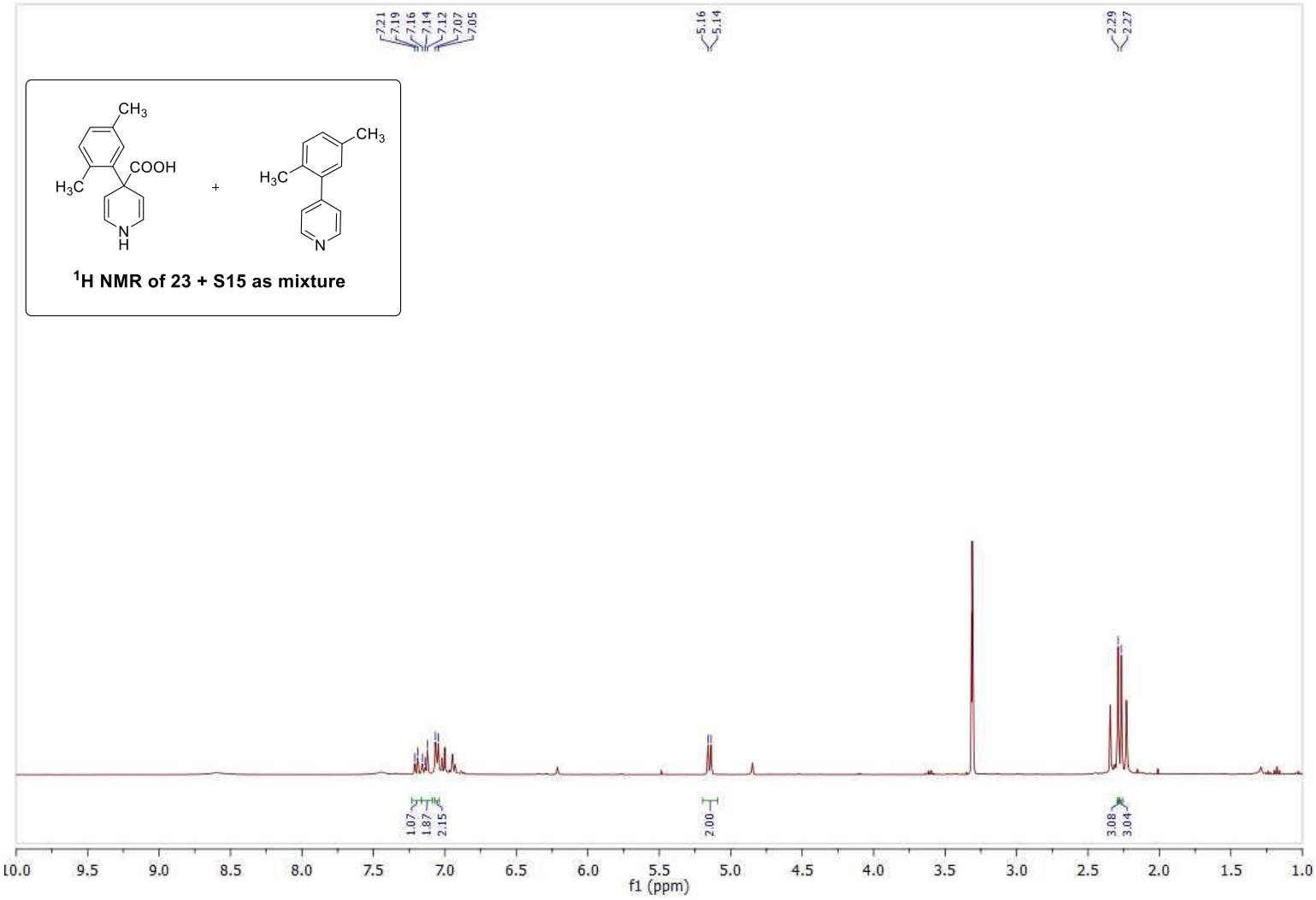

OMe
OH
Cl⁻
H H
161.84
143.63
131.17
120.29
114.79
112.77
72.16
55.74
43.20
42.17
29.34
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

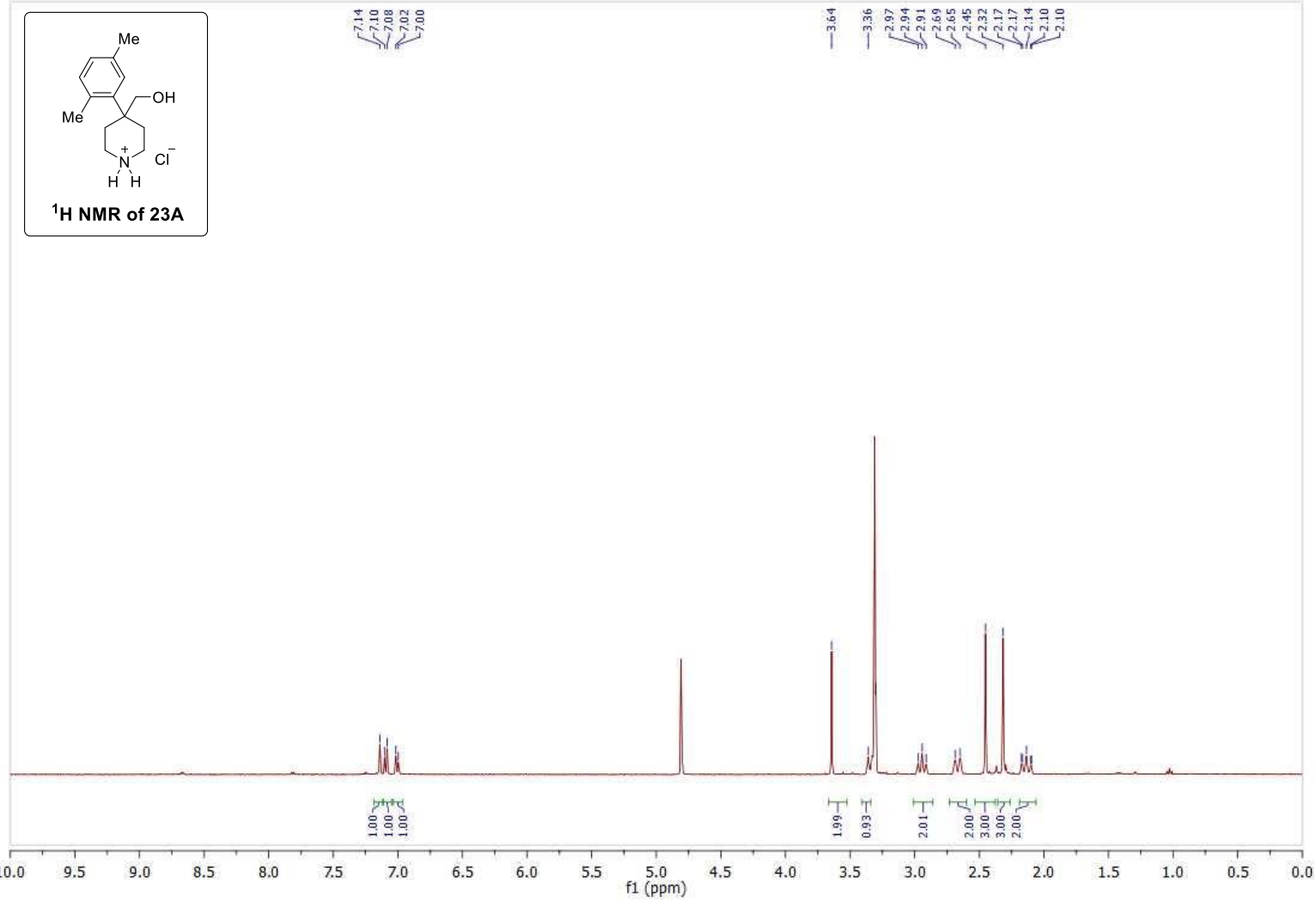
^{13}C NMR of 50

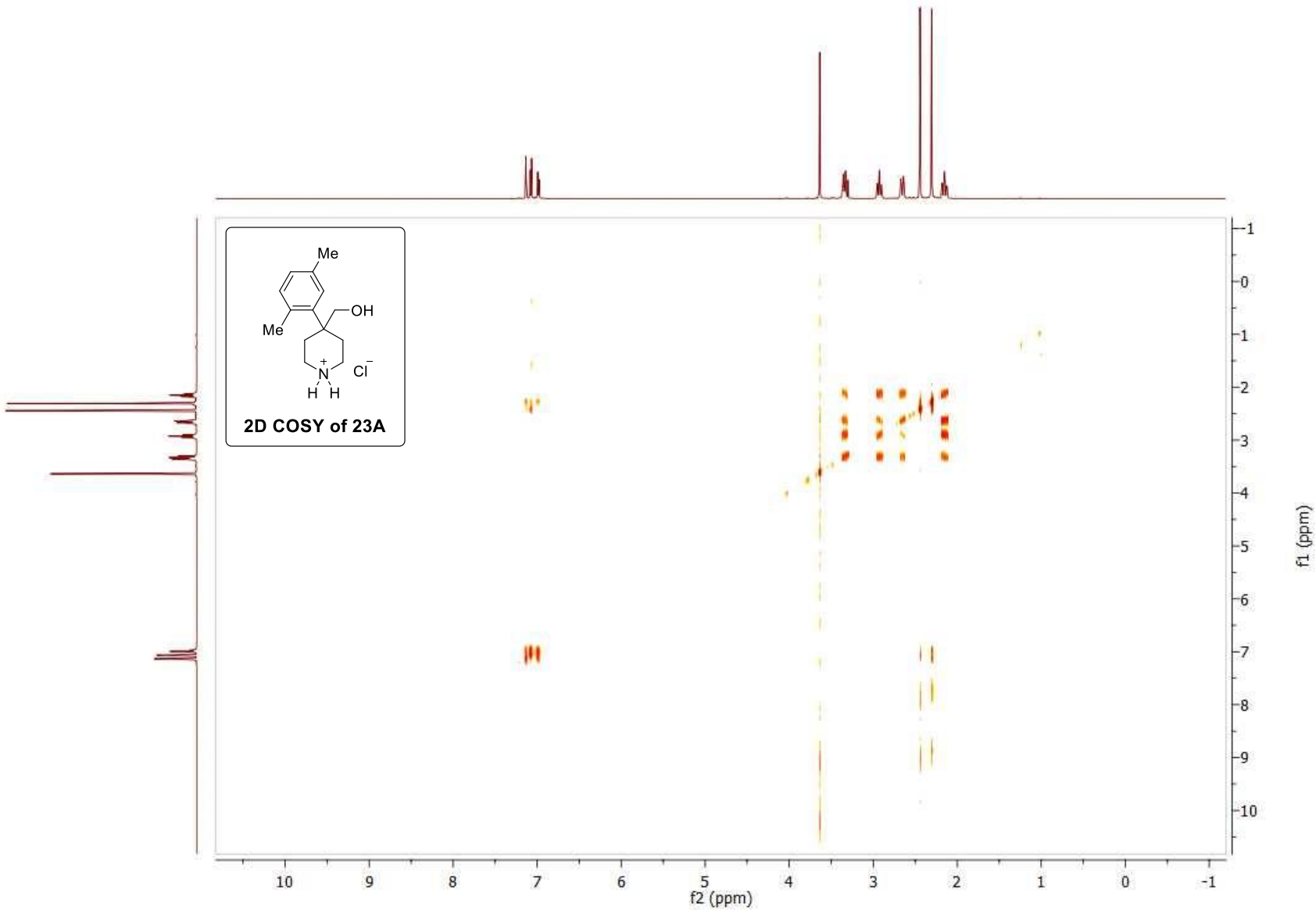

7.23
7.21
7.19
7.11
7.09
7.07
7.05
7.03
7.02
7.00
5.31
5.29
2.32
Me
O
OH
N
H
1H NMR of 22
1.00
5.00
2.00
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

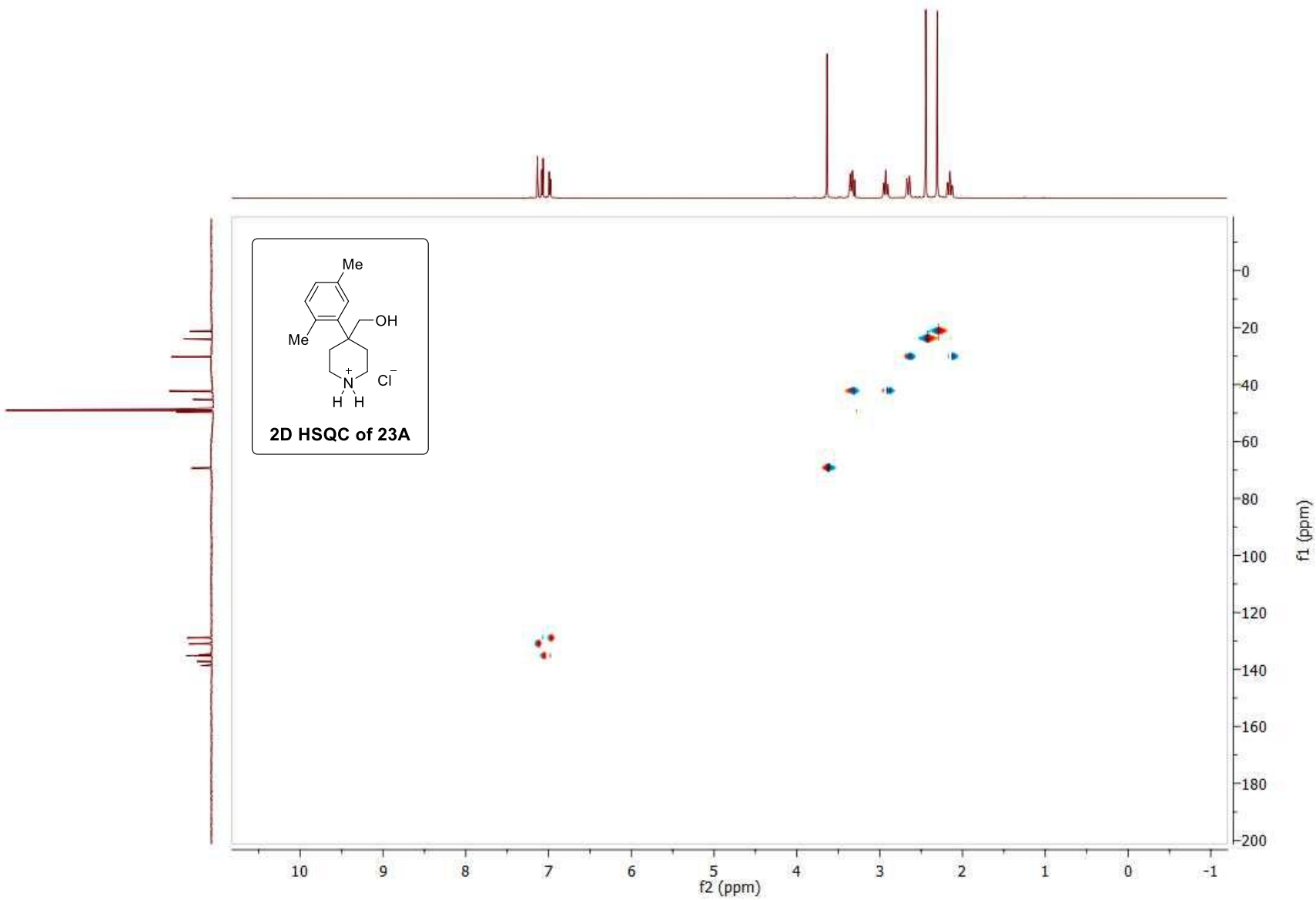

CH3
OH
Cl−
N+
H2
1H NMR of 22A
7.31
7.30
7.29
7.24
7.21
7.20
7.12
7.11
3.46
2.93
2.92
2.91
2.90
2.89
2.88
2.44
2.41
2.37
2.13
2.13
2.11
2.09
2.08
0.98
2.08
0.97
2.07
2.00
1.98
3.17
1.98
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

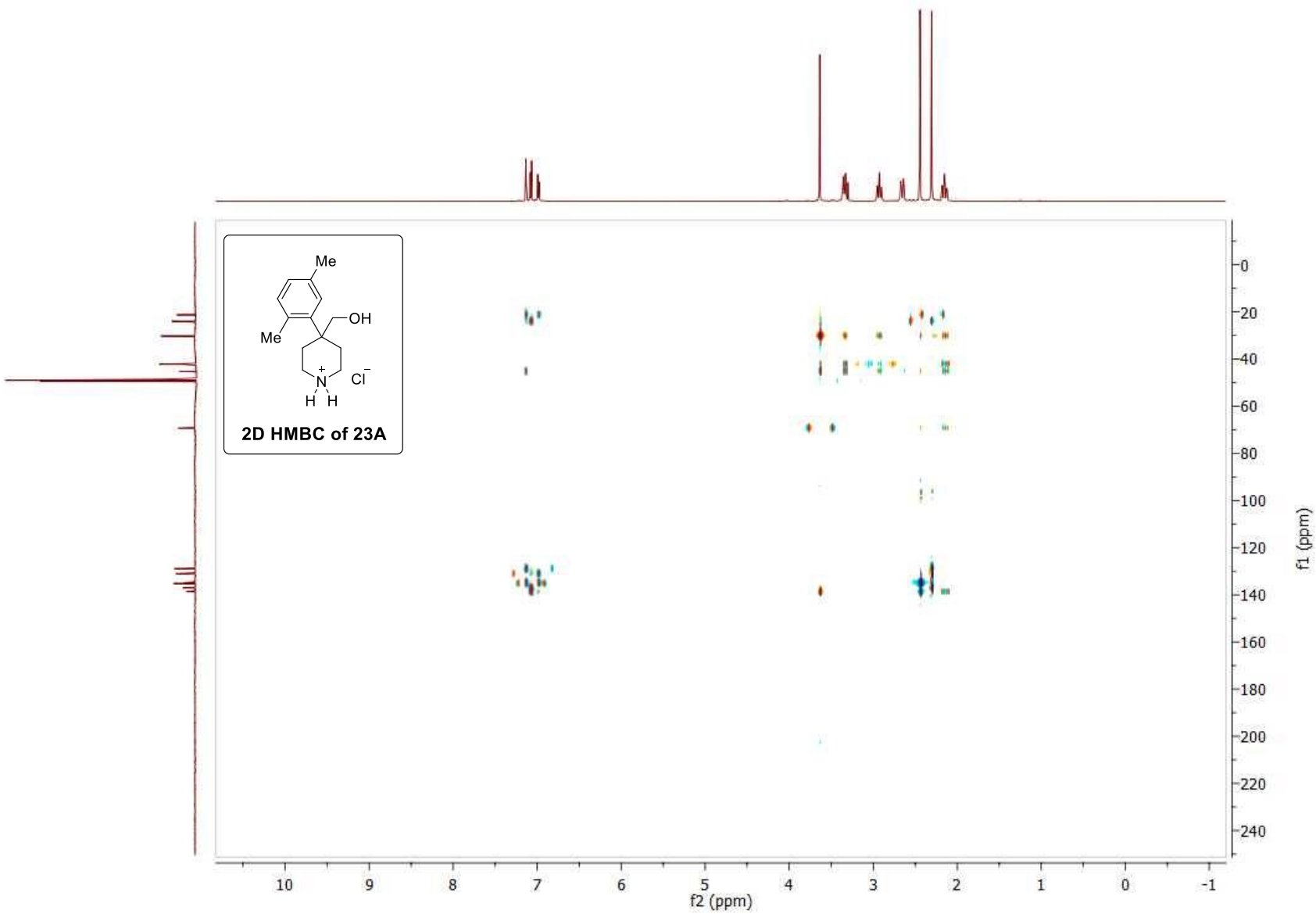

CH3
OH
Cl−
N+
H2
13C NMR of 22A
141.90
139.82
129.98
128.74
128.64
125.15
72.28
43.04
42.18
30.15
29.38
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

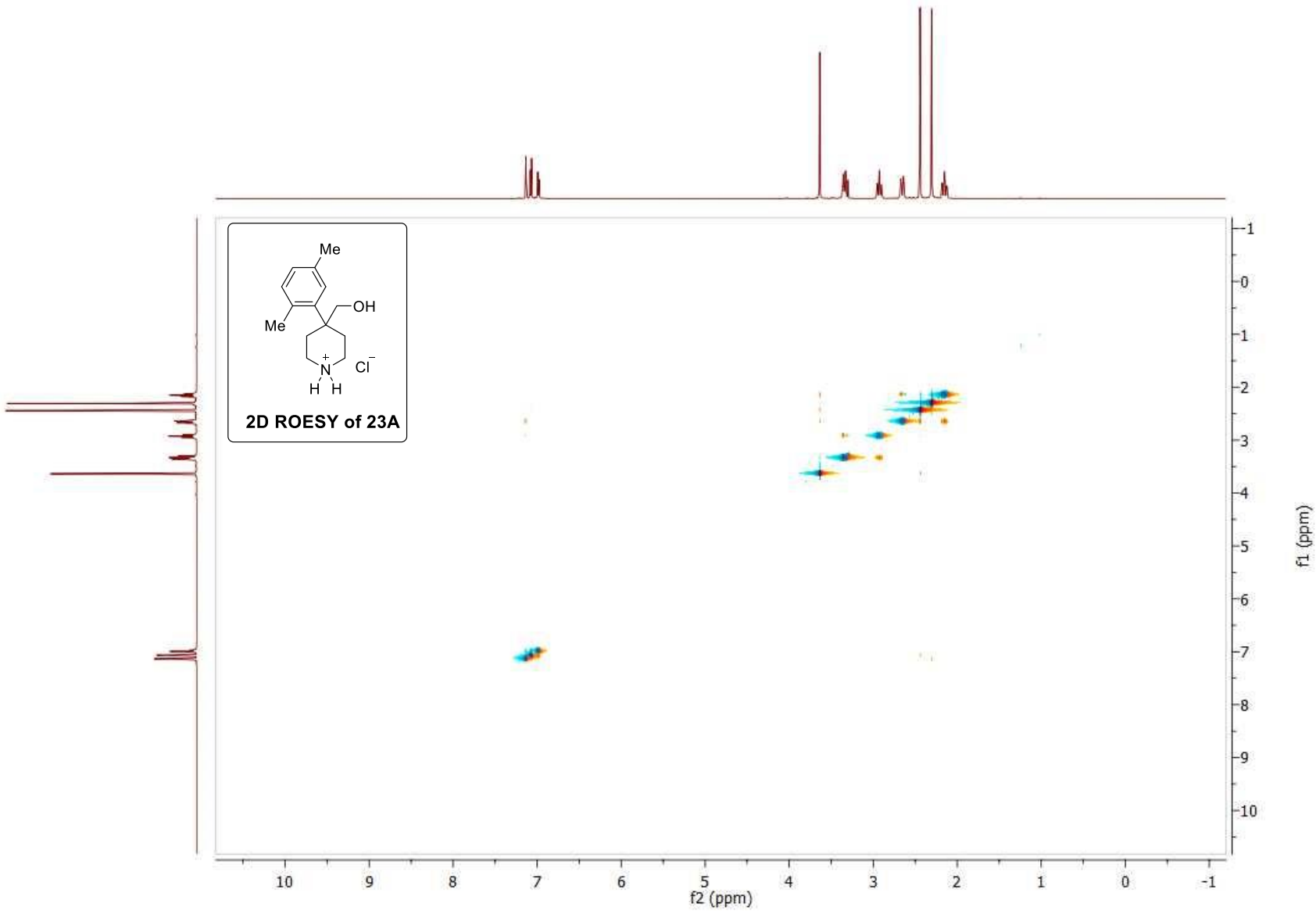

7.21
7.19
7.16
7.14
7.12
7.07
7.05
5.16
5.14
2.29
2.27
CH3
COOH
H3C
N
H
+
CH3
H3C
N
1H NMR of 23 + S15 as mixture
1.07
1.87
2.15
2.00
3.08
3.04
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f1 (ppm)

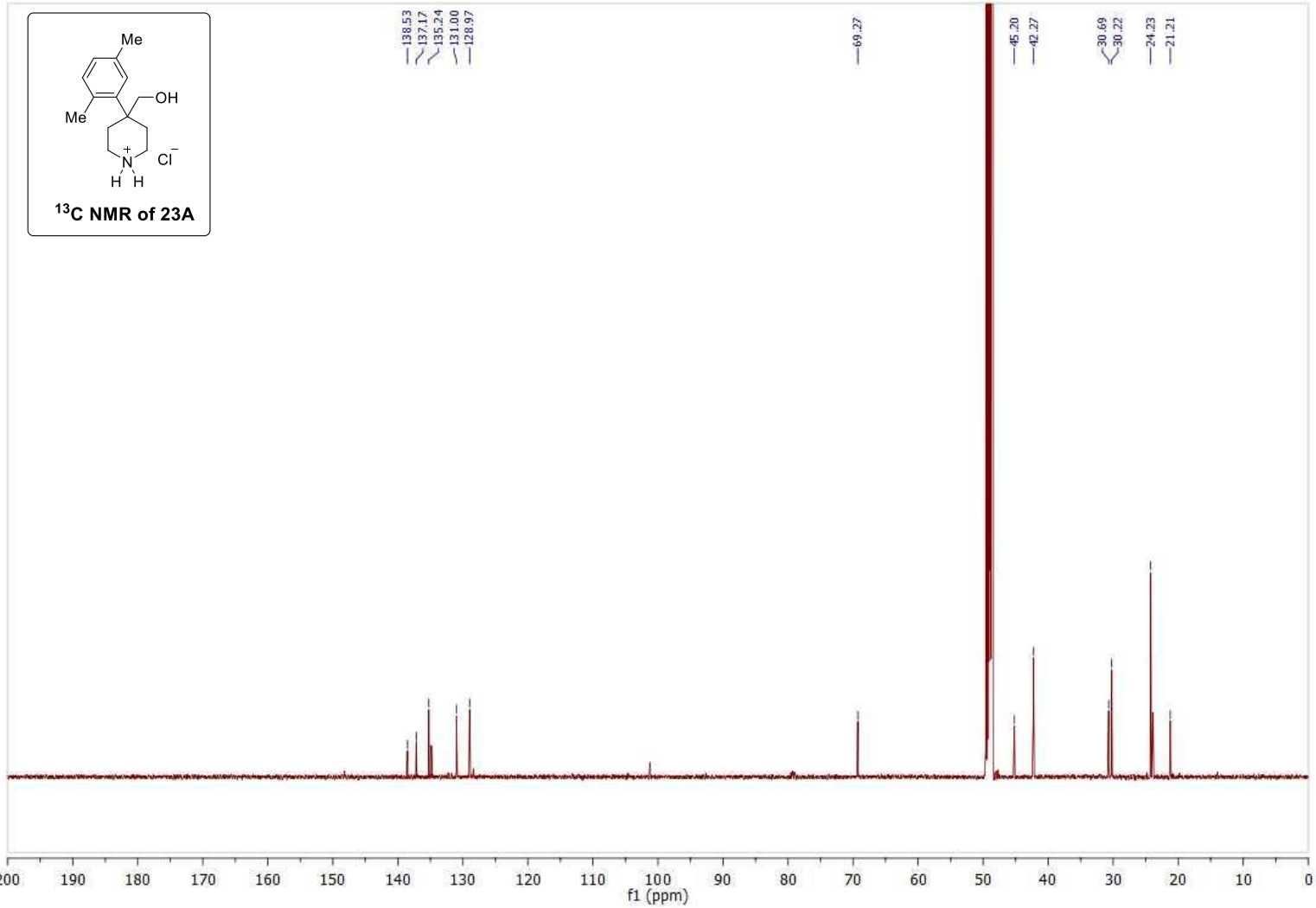

Me
OH
Me
N
H H
Cl
1H NMR of 23A
7.14
7.10
7.08
7.02
7.00
3.64
3.36
2.97
2.94
2.91
2.69
2.65
2.45
2.32
2.17
2.17
2.14
2.10
2.10
1.00
1.00
1.00
1.99
0.93
2.01
2.00
3.00
3.00
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

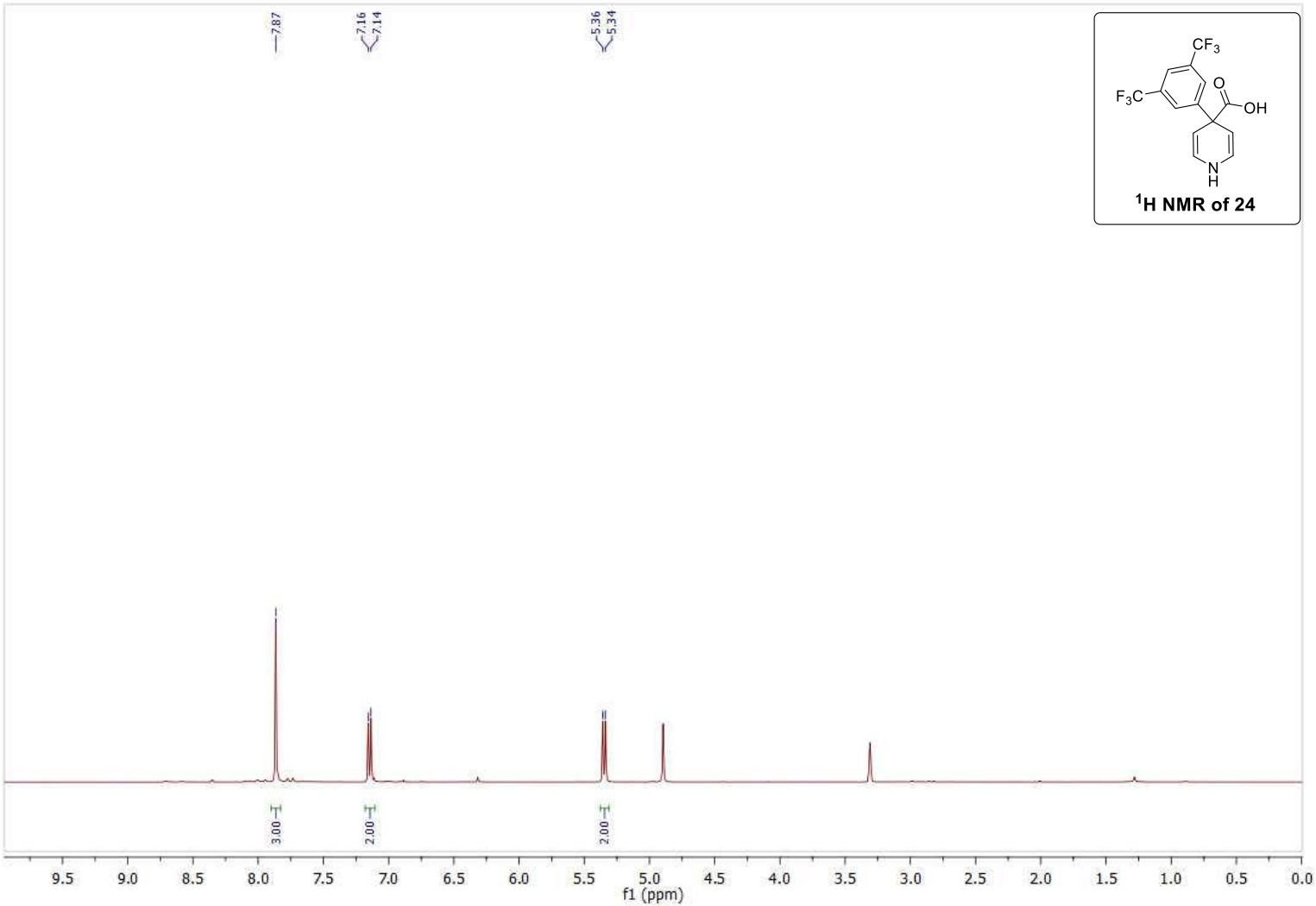

Me
Me
OH
Cl⁻
N
H H
2D COSY of 23A
f2 (ppm)
f1 (ppm)

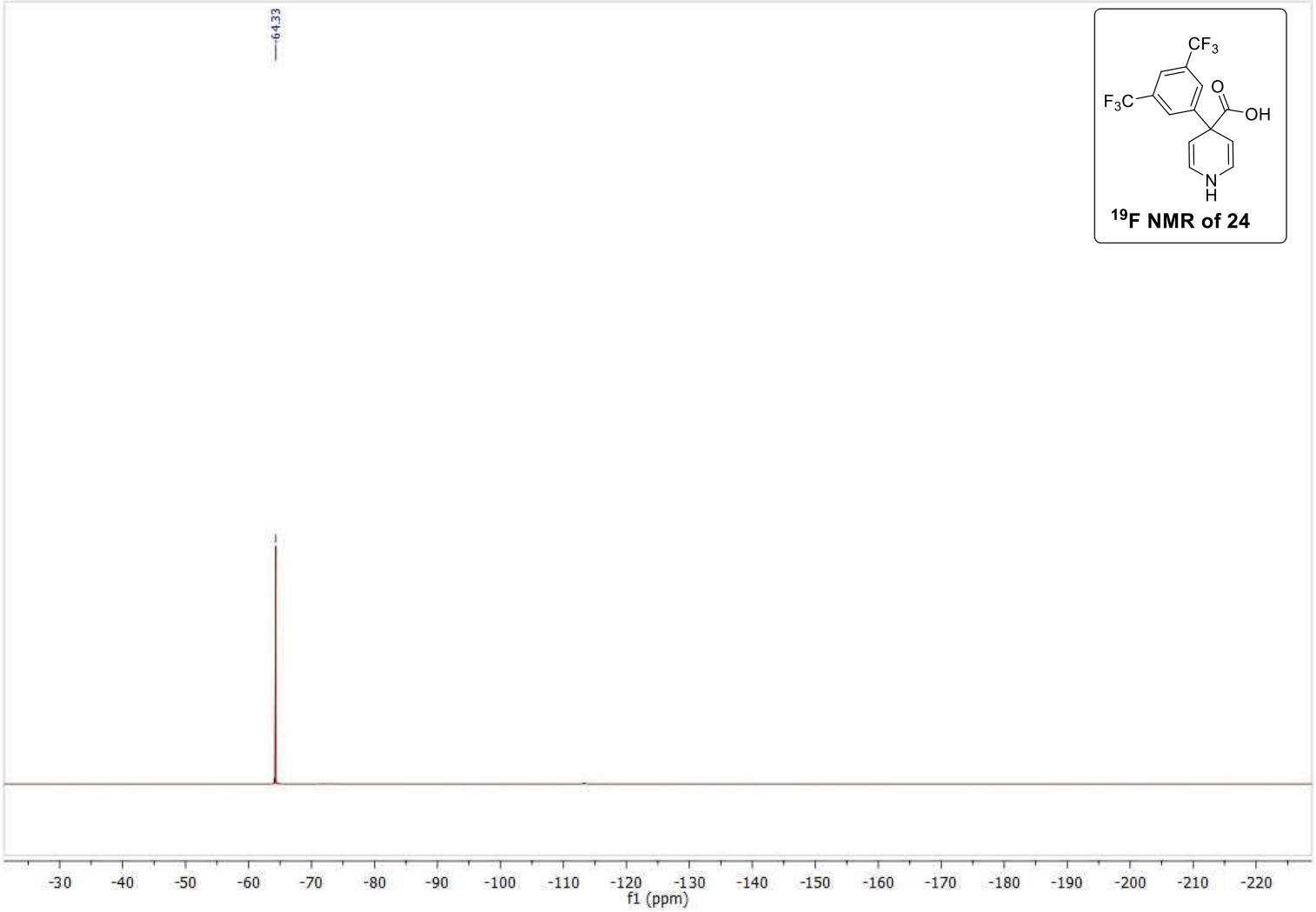

Me
OH
Me
Cl⁻
N⁺
H H
2D HSQC of 23A
f2 (ppm)
f1 (ppm)

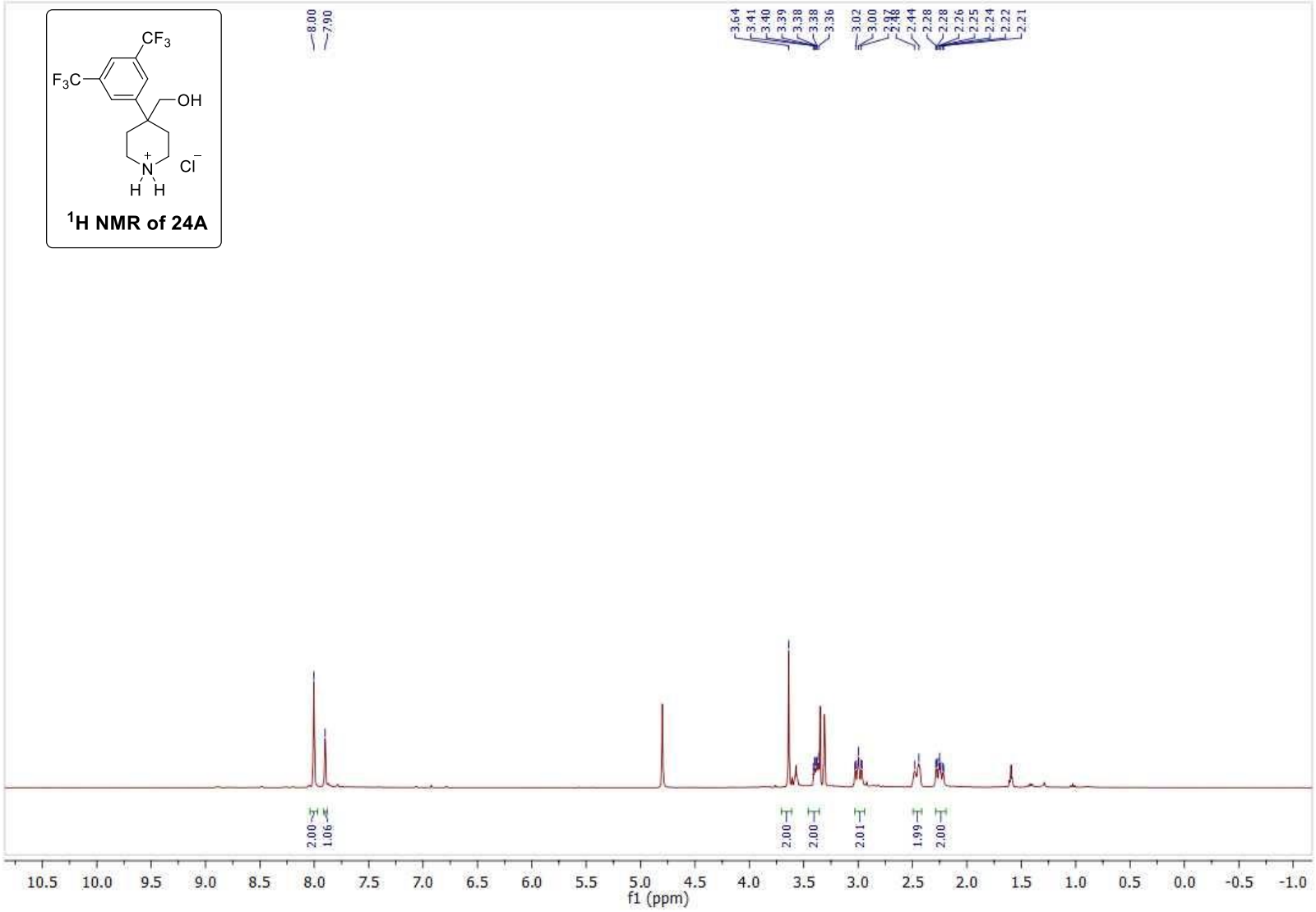

Me
OH
Me
Cl⁻
H H
2D HMBC of 23A
10
9
8
7
6
5
4
3
2
1
0
-1
f2 (ppm)
0
20
40
60
80
100
120
140
160
180
200
220
240
f1 (ppm)

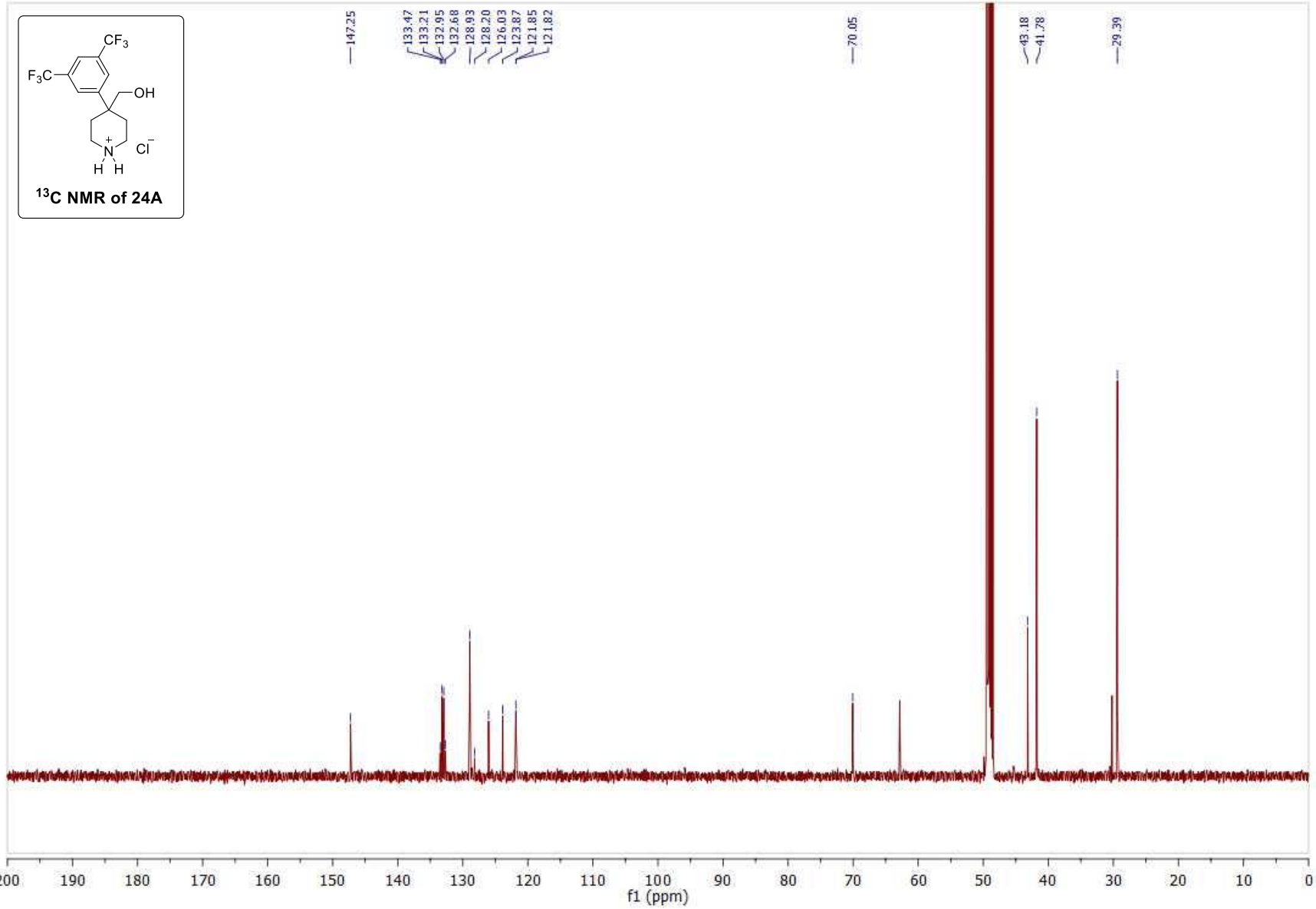

Me
OH
Me
Cl
H H
2D ROESY of 23A
10
9
8
7
6
5
4
3
2
1
0
-1
f2 (ppm)
-1
0
1
2
3
4
5
6
7
8
9
10
f1 (ppm)


Me
OH
Me
N
H H
Cl
13C NMR of 23A
138.53
137.17
135.24
131.00
128.97
69.27
45.20
42.27
30.69
30.22
24.23
21.21
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

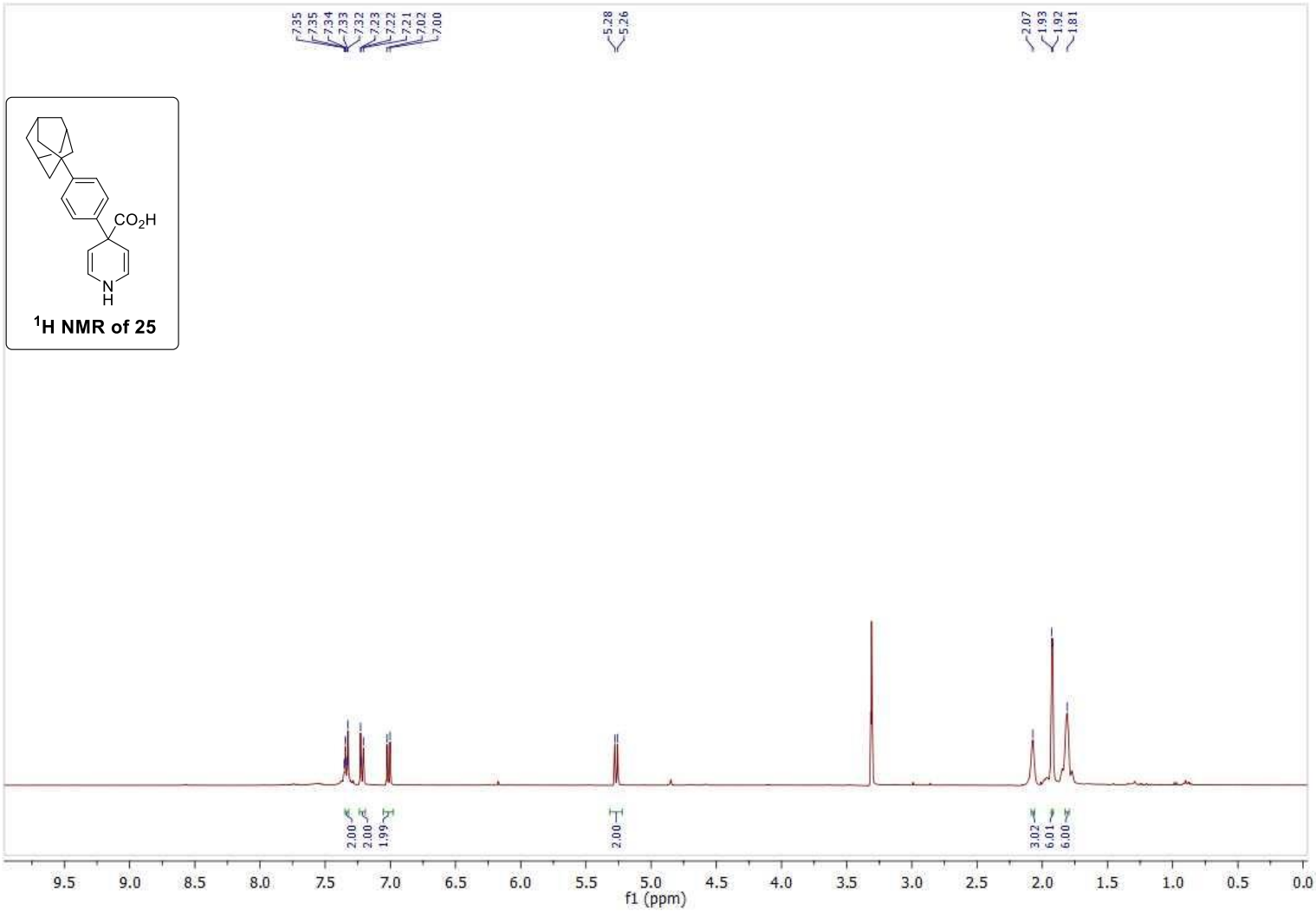

7.87
7.16
7.14
5.36
5.34
CF3
F3C
O
OH
N
H
1H NMR of 24
3.00
2.00
2.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

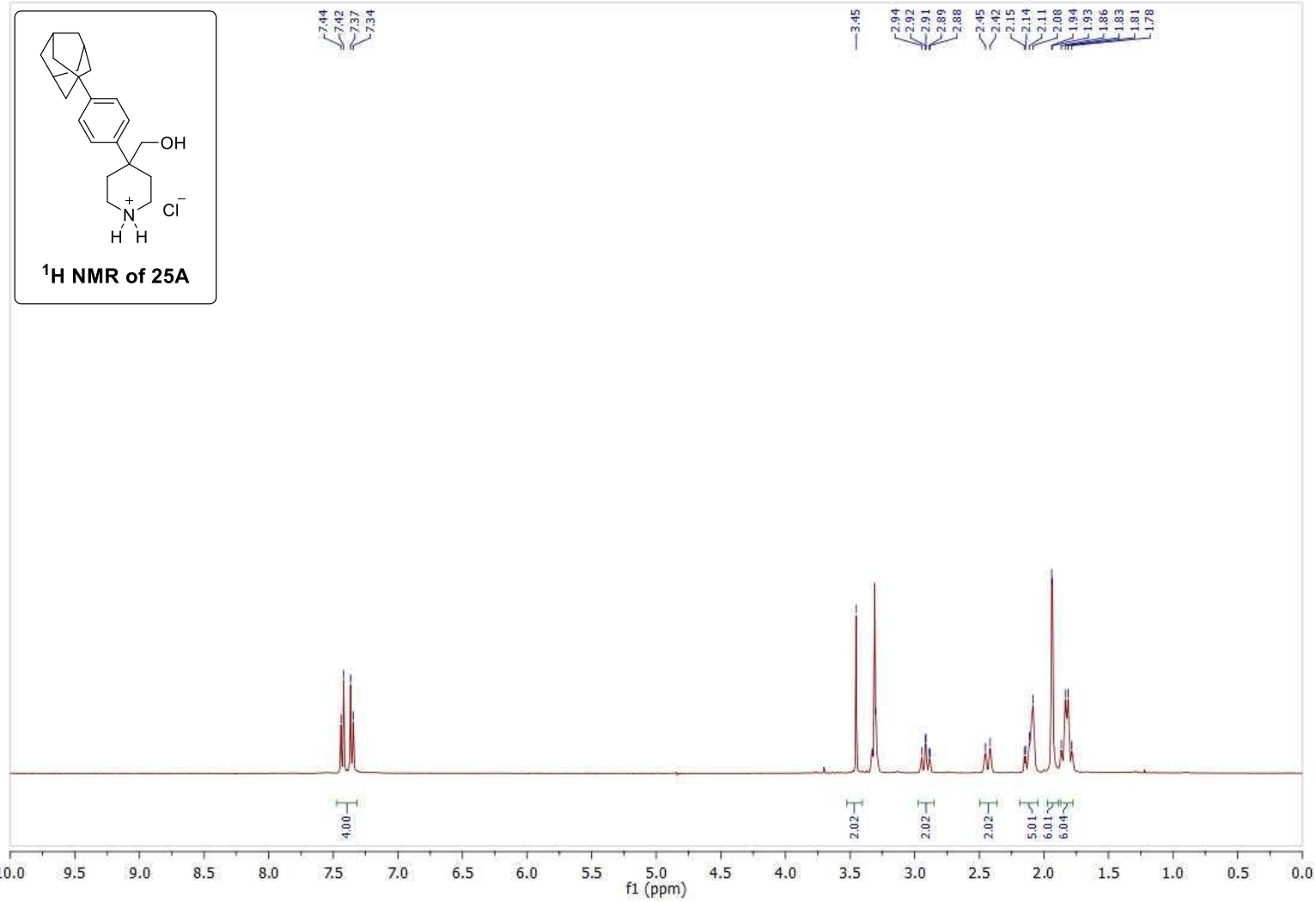

-64.33
CF3
F3C
O
OH
N
H
19F NMR of 24
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
f1 (ppm)

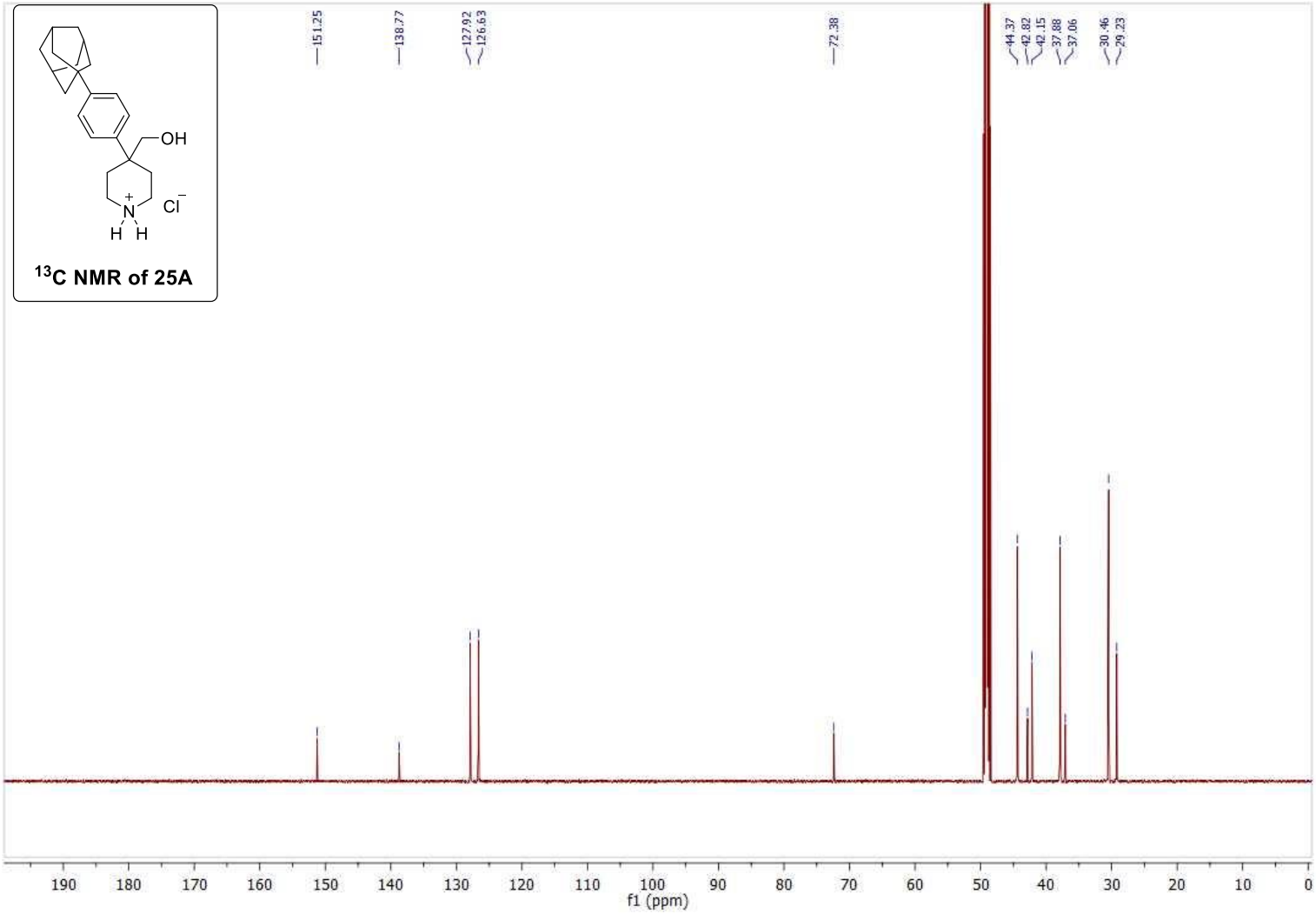

CF3
F3C
OH
N
H H
Cl−
1H NMR of 24A
8.00
7.90
3.64
3.41
3.40
3.39
3.38
3.38
3.36
3.02
3.00
2.44
2.28
2.28
2.26
2.25
2.24
2.22
2.21
2.00
1.06
2.00
2.00
2.01
1.99
2.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)



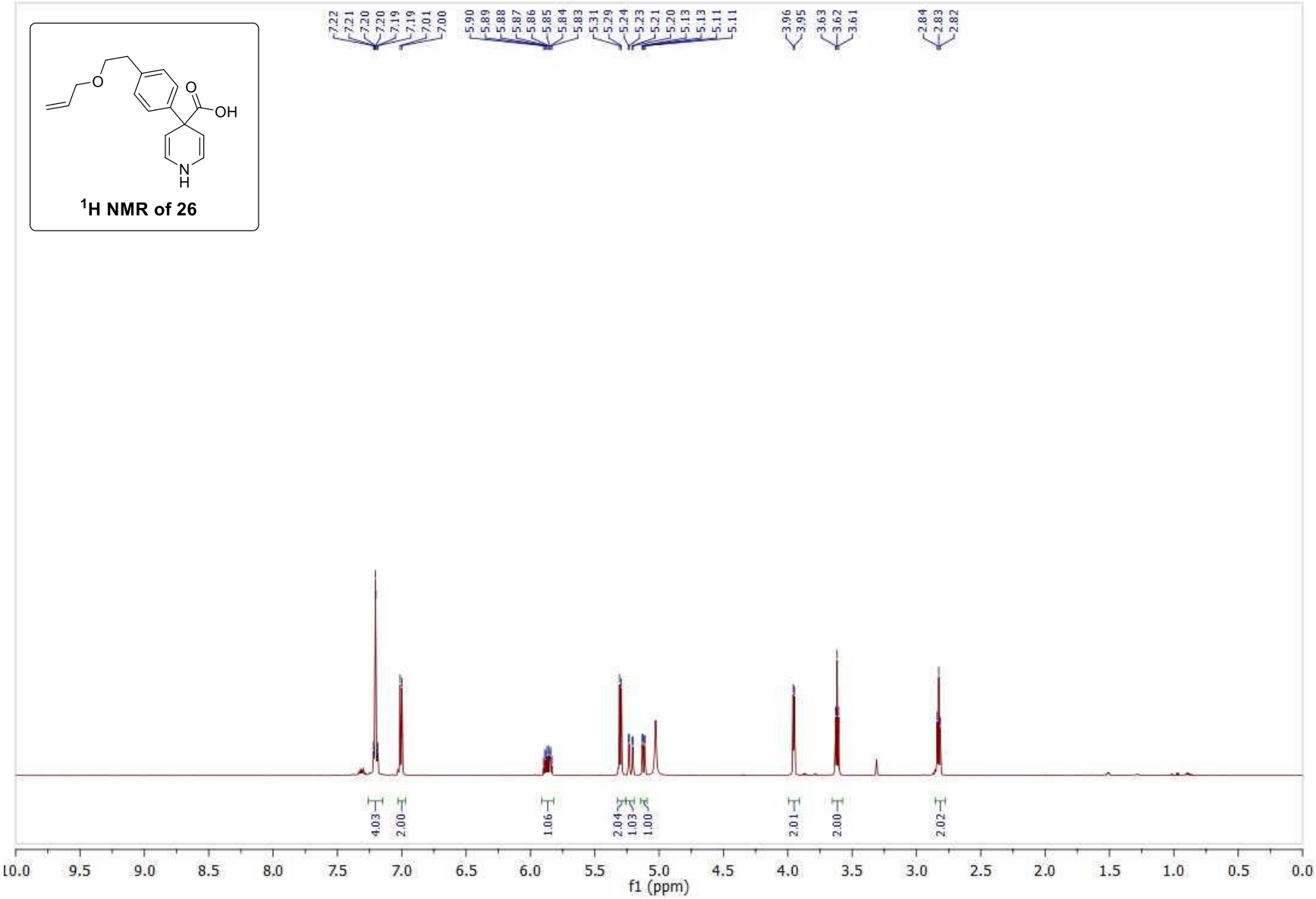
^{13}C NMR of 24A


7.35
7.35
7.34
7.33
7.32
7.23
7.22
7.21
7.02
7.00
5.28
5.26
2.07
1.93
1.92
1.81
CO2H
N
H
1H NMR of 25
2.00
2.00
1.99
2.00
3.02
6.01
6.00
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)

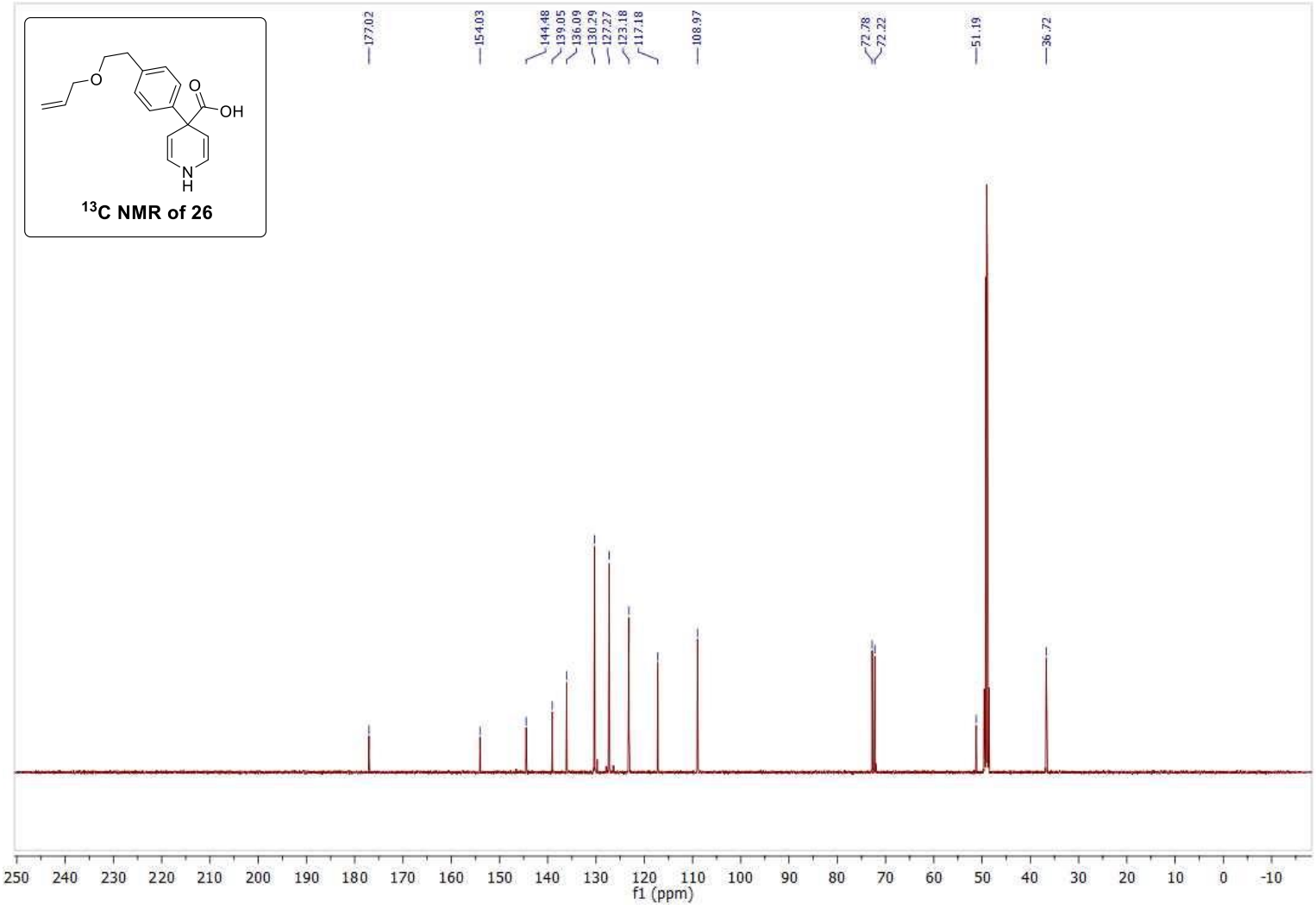

OH
Cl
N
H H
1H NMR of 25A
7.44
7.42
7.37
7.34
3.45
2.94
2.92
2.91
2.89
2.88
2.45
2.42
2.15
2.14
2.11
2.08
1.94
1.93
1.86
1.83
1.81
1.78
4.00
2.02
2.02
2.02
5.01
6.01
6.04
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

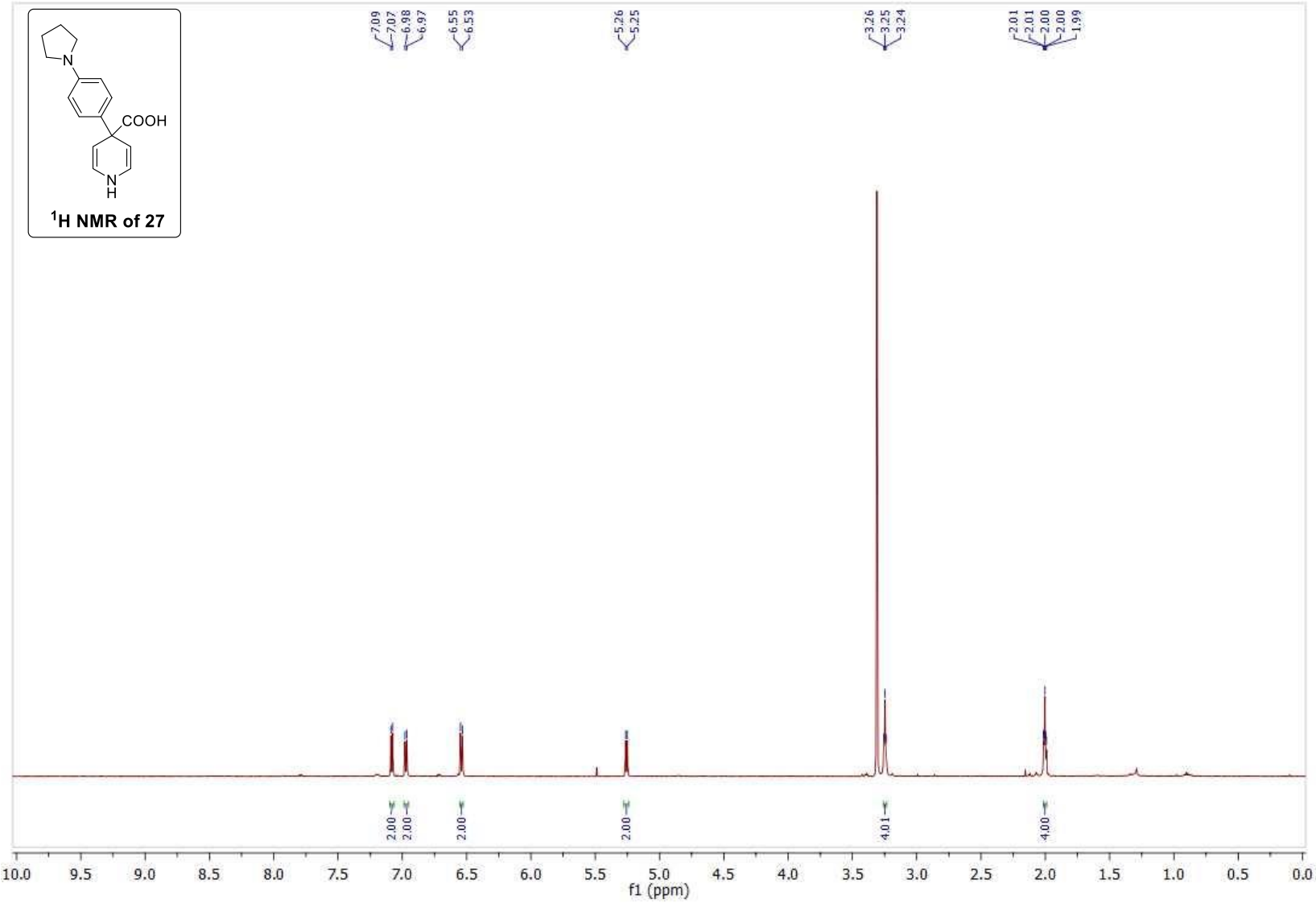


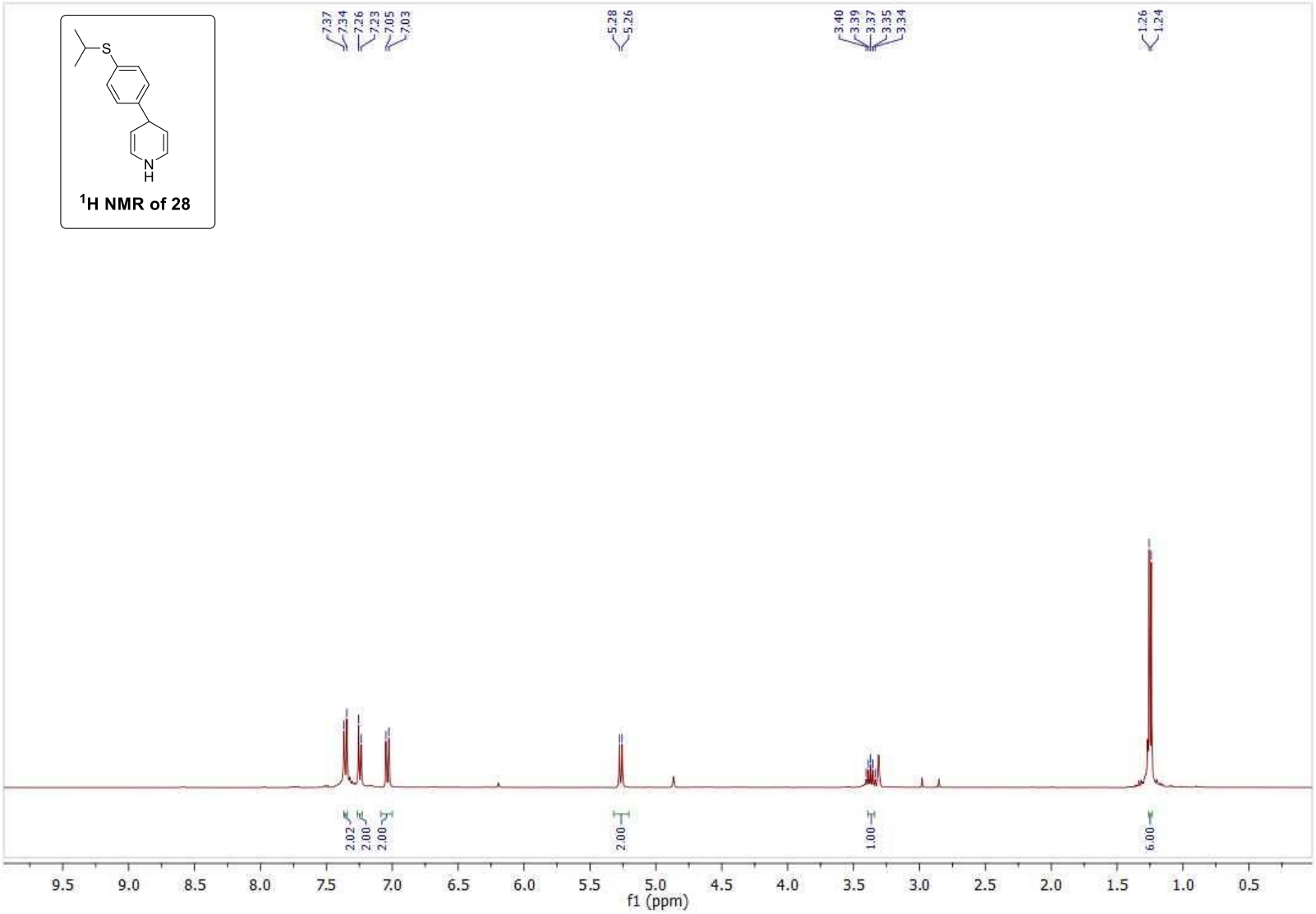
^{13}C NMR of 25A


O
O
OH
N
H
7.22
7.21
7.20
7.20
7.19
7.19
7.01
7.00
5.90
5.89
5.88
5.87
5.86
5.85
5.84
5.83
5.31
5.29
5.24
5.23
5.21
5.20
5.13
5.13
5.11
5.11
3.96
3.95
3.63
3.62
3.61
2.84
2.83
2.82
4.03
2.00
1.06
2.04
1.03
1.00
2.01
2.00
2.02
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)

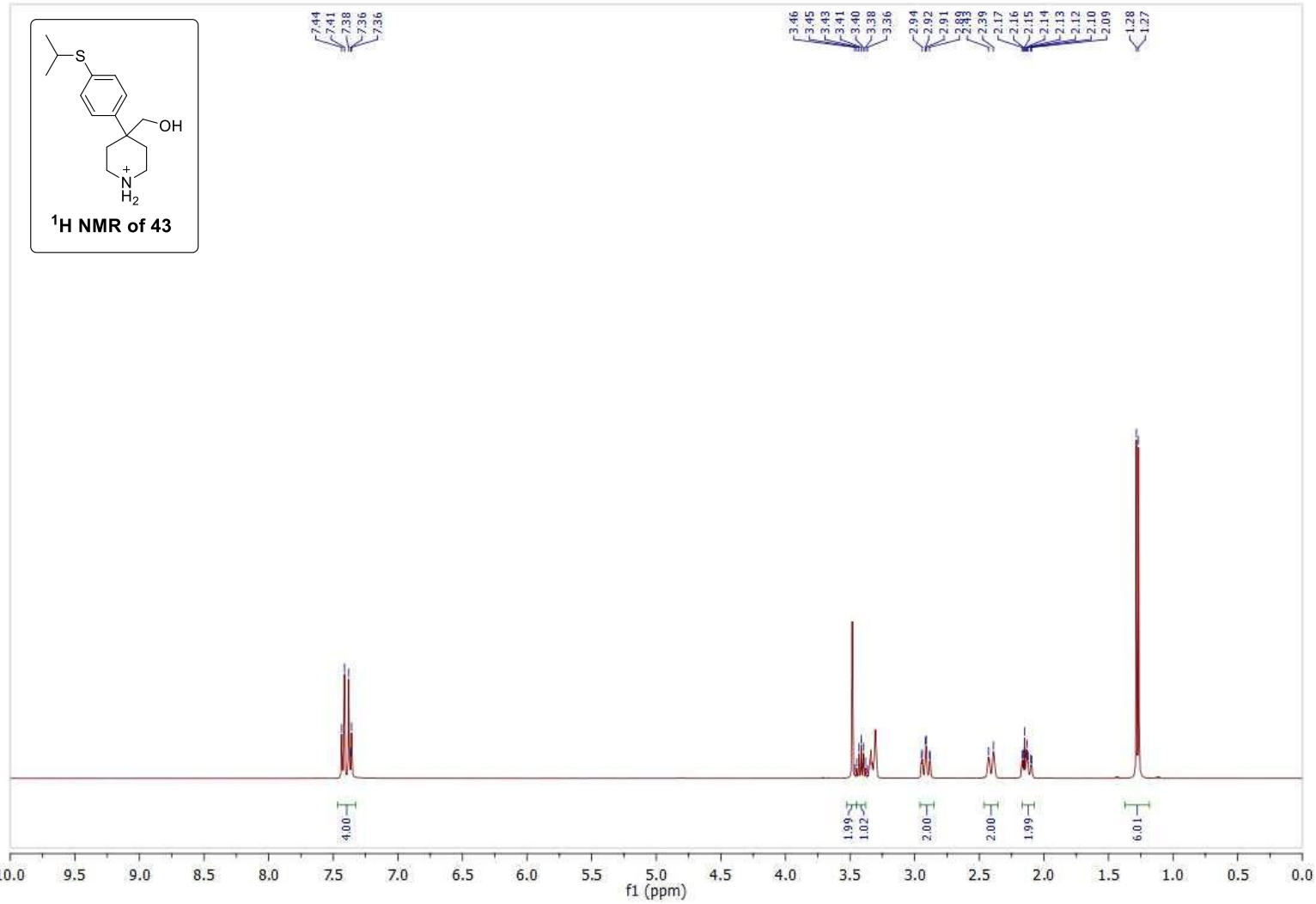
^{1}H NMR of 26

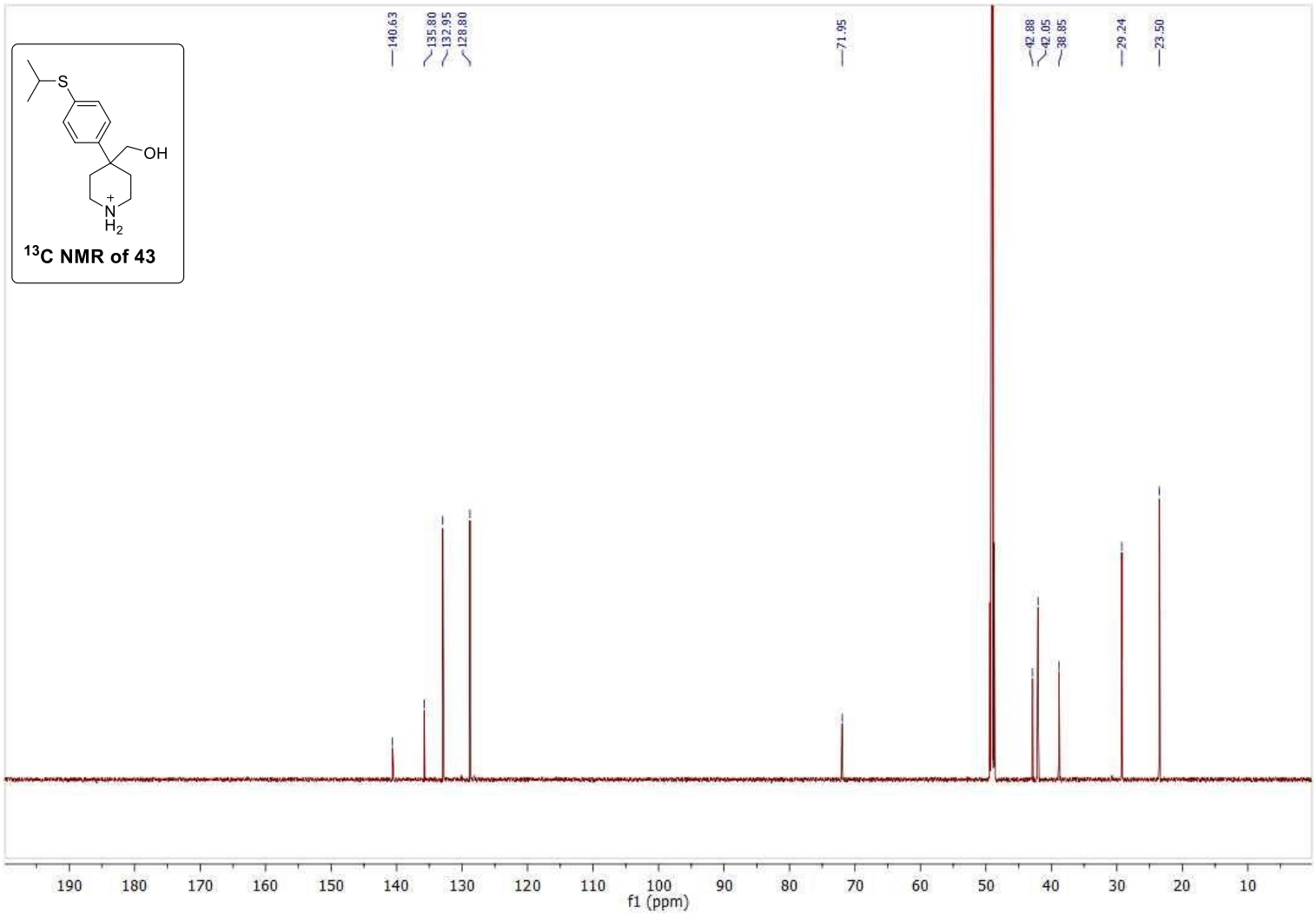

177.02
154.03
144.48
139.05
136.09
130.29
127.27
123.18
117.18
108.97
72.78
72.22
51.19
36.72
O
O
OH
N
H
13C NMR of 26
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


COOH
N
H
^{1}H NMR of 27
7.09
7.07
6.98
6.97
6.55
6.53
5.26
5.25
3.26
3.25
3.24
2.01
2.01
2.00
2.00
1.99
2.00
2.00
2.00
2.00
4.01
4.00
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)

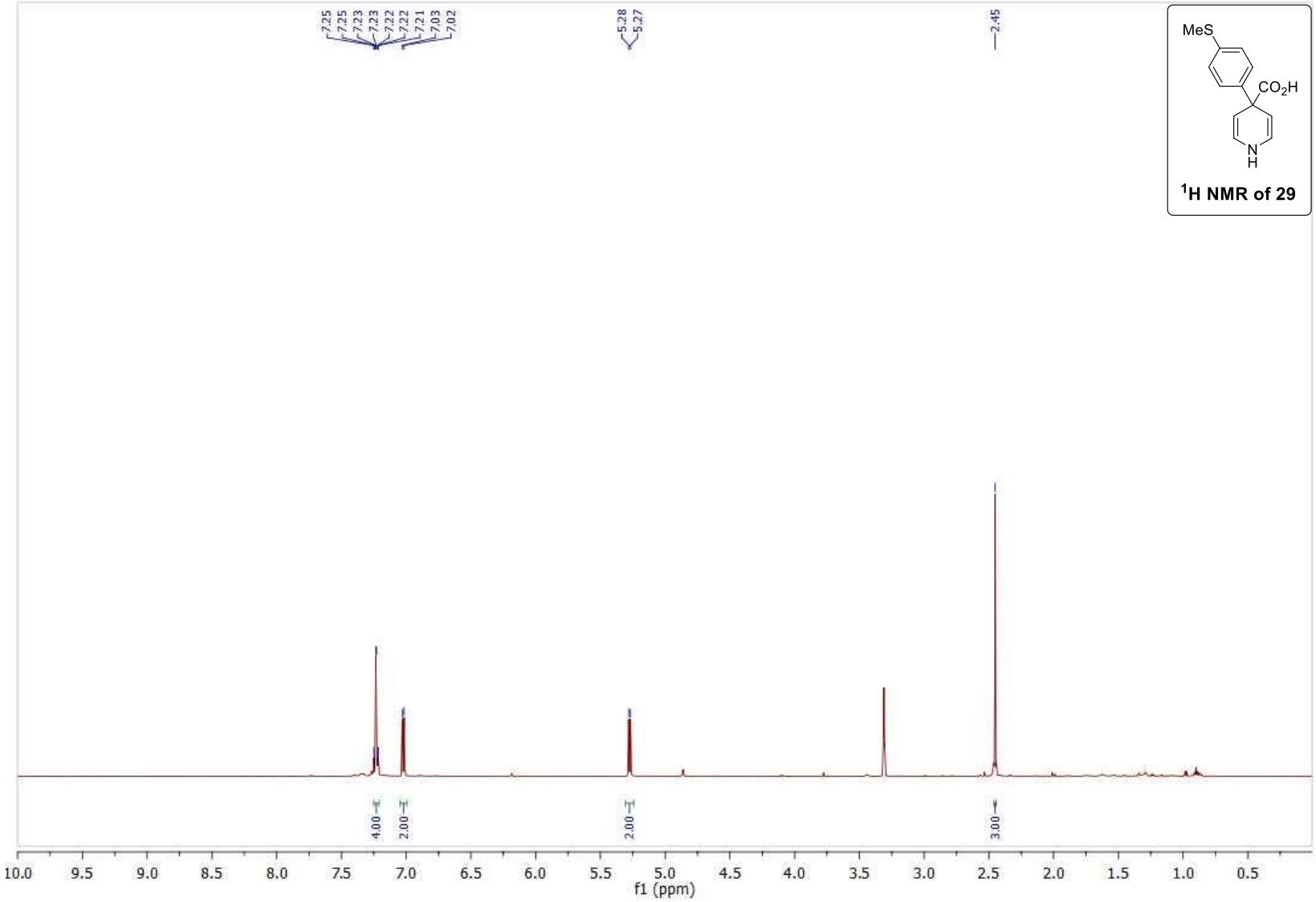

7.37
7.34
7.26
7.23
7.05
7.03
5.28
5.26
3.40
3.39
3.37
3.35
3.34
1.26
1.24
S
N
H
2.02
2.00
2.00
2.00
1.00
6.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

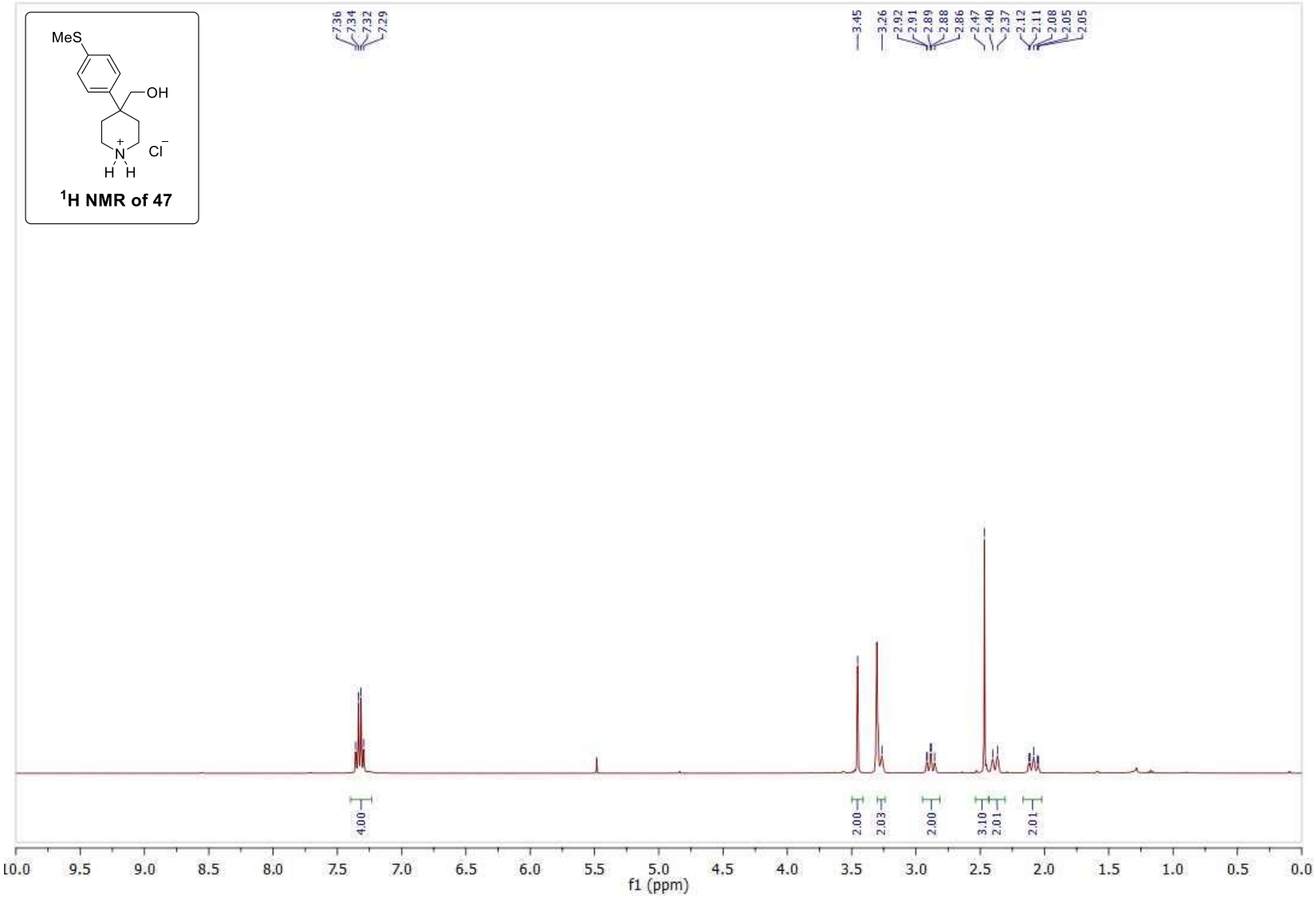
^{1}H NMR of 28

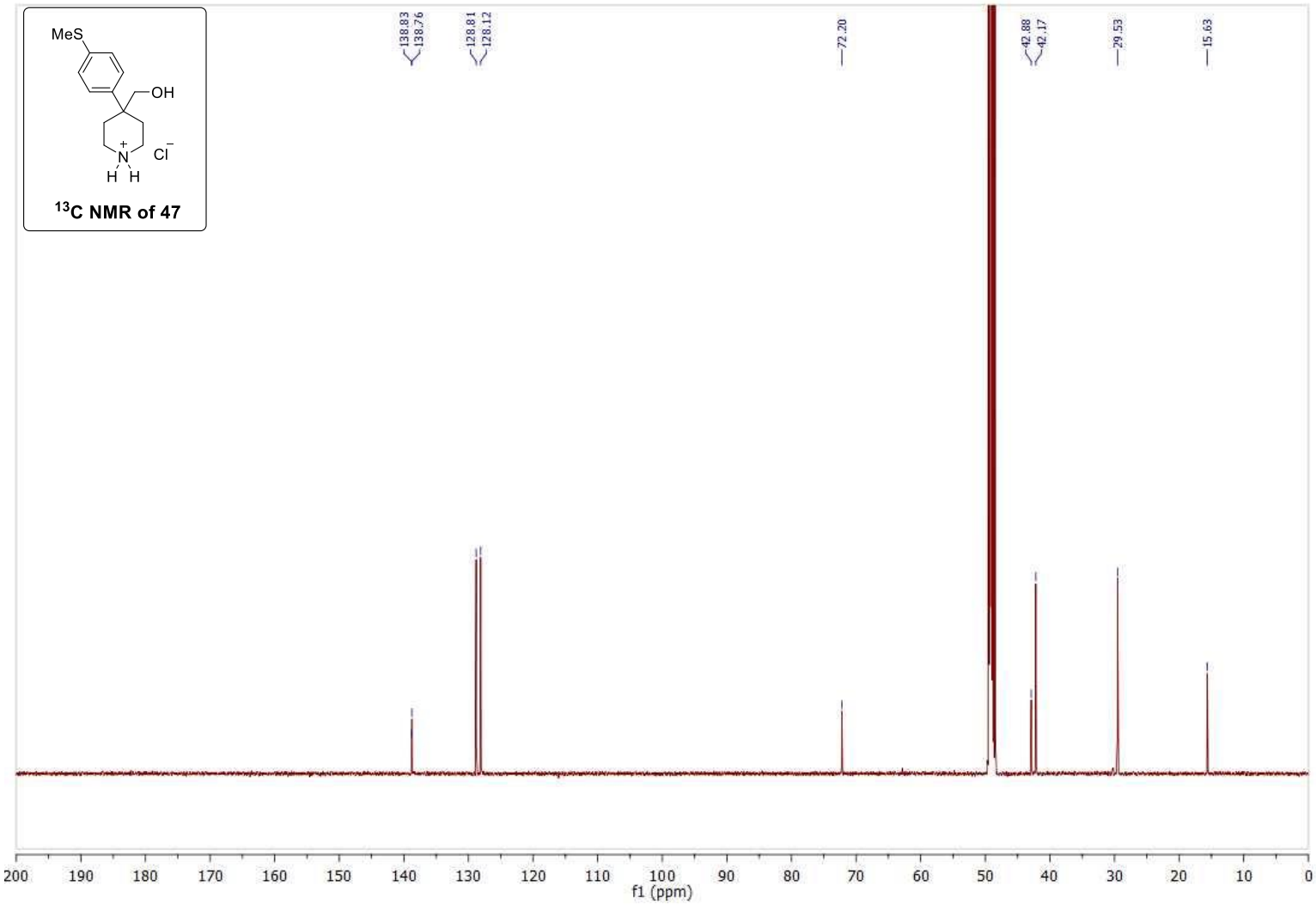

S
OH
N
H2
1H NMR of 43
7.44
7.41
7.38
7.36
7.36
3.46
3.45
3.43
3.41
3.40
3.38
3.36
2.94
2.92
2.91
2.89
2.43
2.39
2.17
2.16
2.15
2.14
2.13
2.12
2.10
2.09
1.28
1.27
4.00
1.99
1.02
2.00
2.00
1.99
6.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

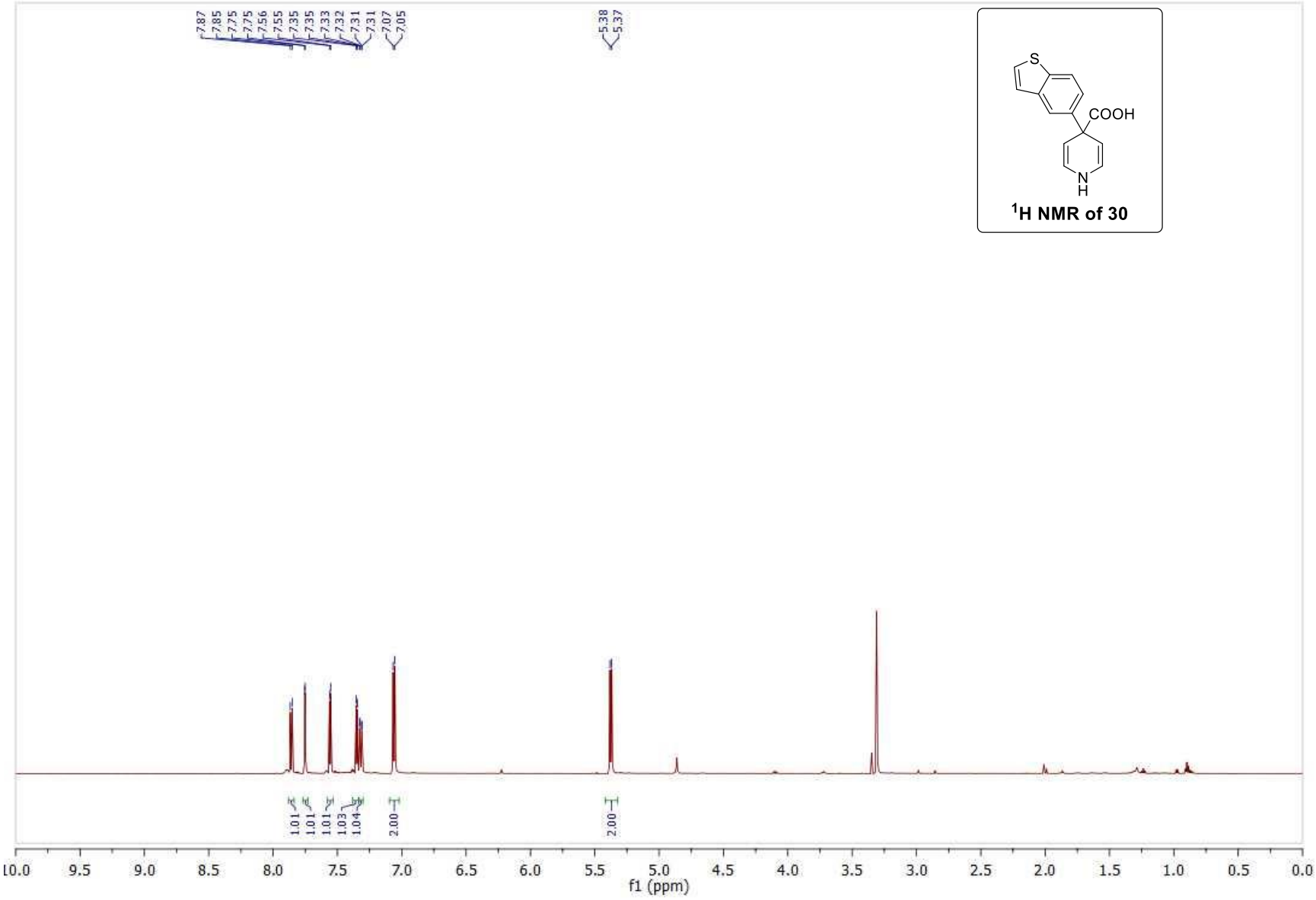

140.63
135.80
132.95
128.80
71.95
42.88
42.05
38.85
29.24
23.50
S
OH
N
H2
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

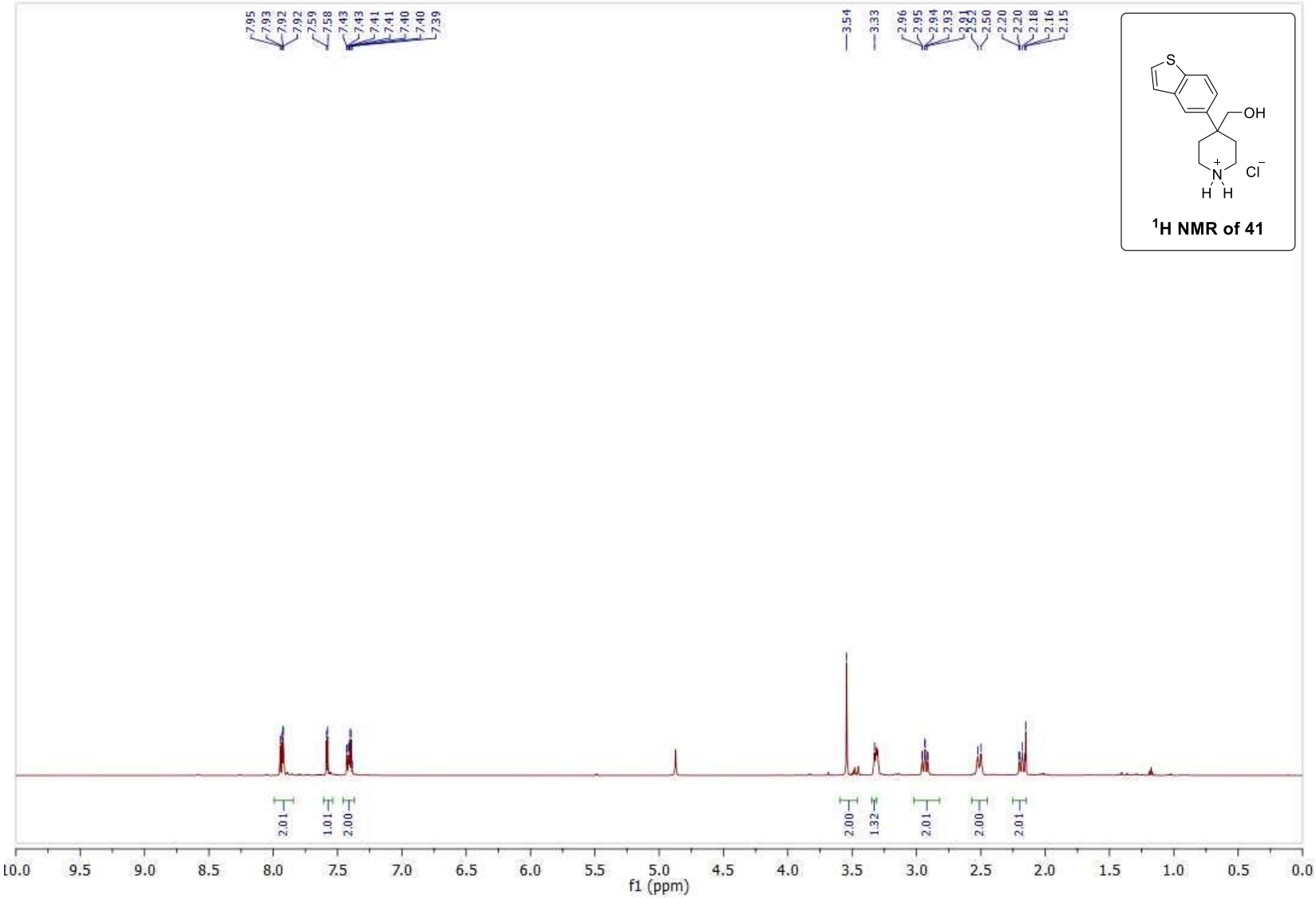
^{13}C NMR of 43


7.25
7.25
7.23
7.23
7.22
7.22
7.21
7.03
7.02
5.28
5.27
2.45
MeS
CO2H
N
H
1H NMR of 29
4.00
2.00
2.00
3.00
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
f1 (ppm)

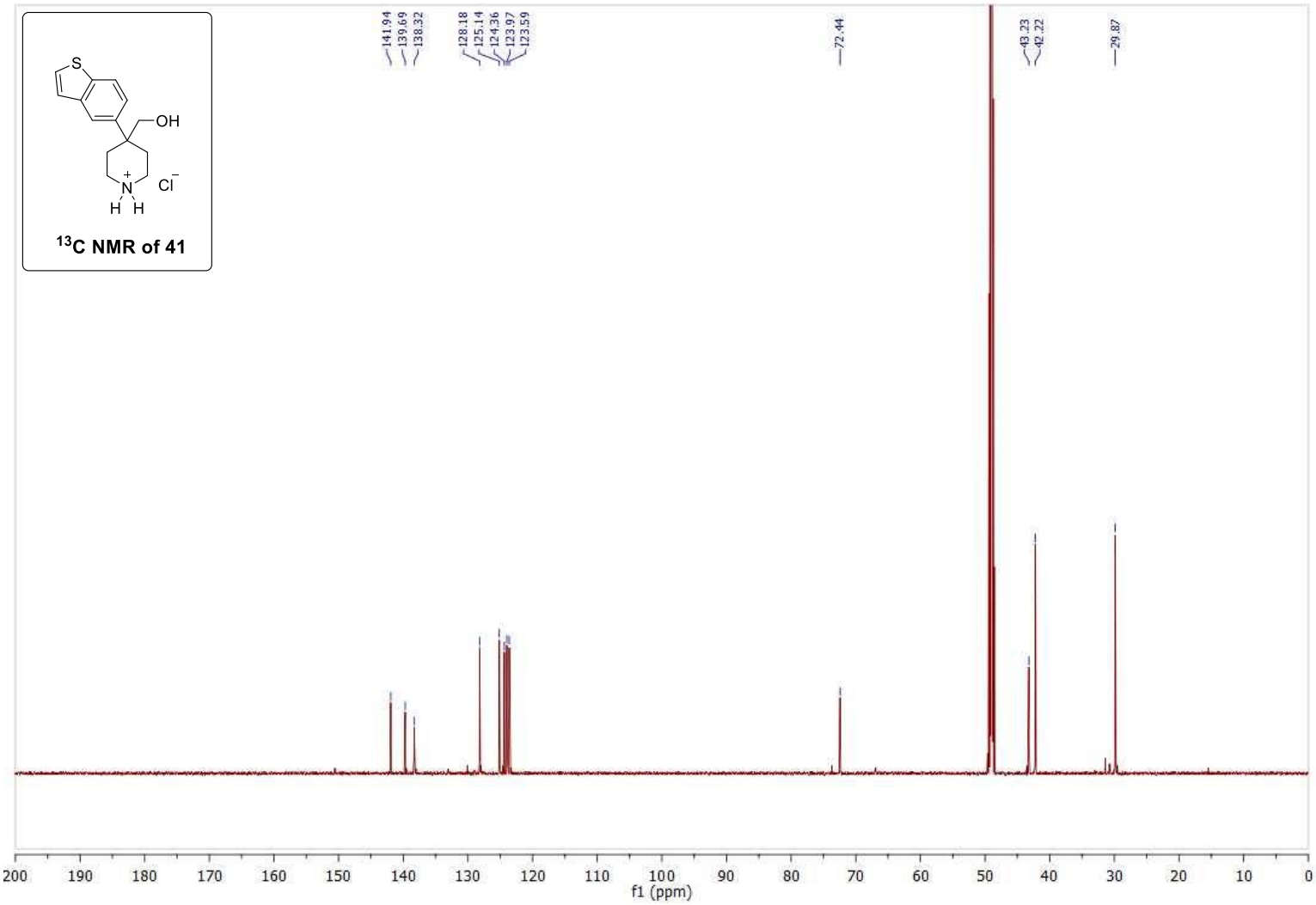

MeS
OH
N
H H
Cl⁻
¹H NMR of 47
7.36
7.34
7.32
7.29
3.45
3.26
2.92
2.91
2.89
2.88
2.86
2.47
2.40
2.37
2.12
2.11
2.08
2.05
2.05
4.00
2.00
2.03
2.00
3.10
2.01
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

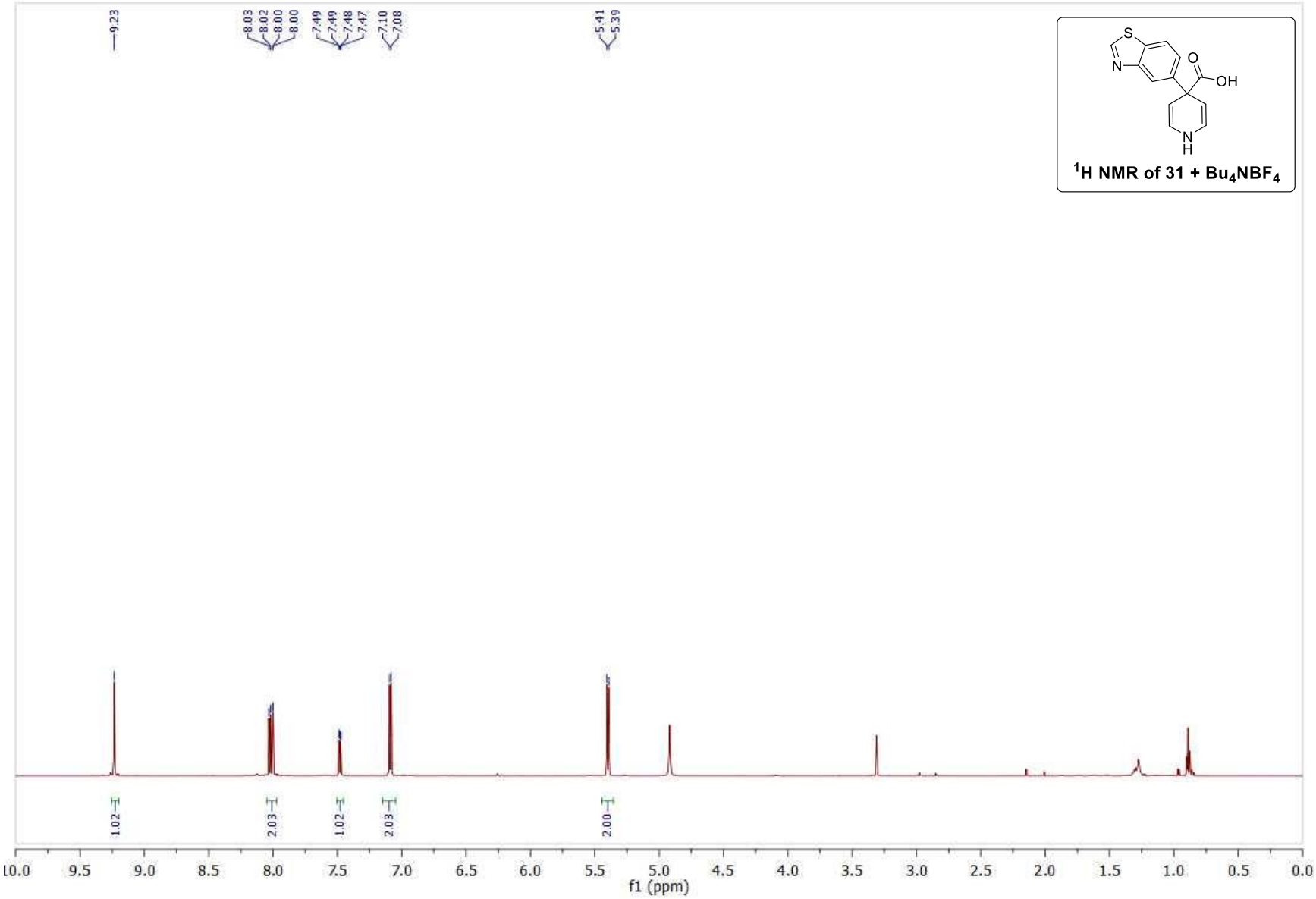

MeS
OH
Cl⁻
H H
13C NMR of 47
138.83
138.76
128.81
128.12
72.20
42.88
42.17
29.53
15.63
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.87
7.85
7.75
7.75
7.56
7.55
7.35
7.35
7.33
7.32
7.31
7.31
7.07
7.05
5.38
5.37
S
COOH
N
H
1H NMR of 30
1.01
1.01
1.01
1.03
1.04
2.00
2.00
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)

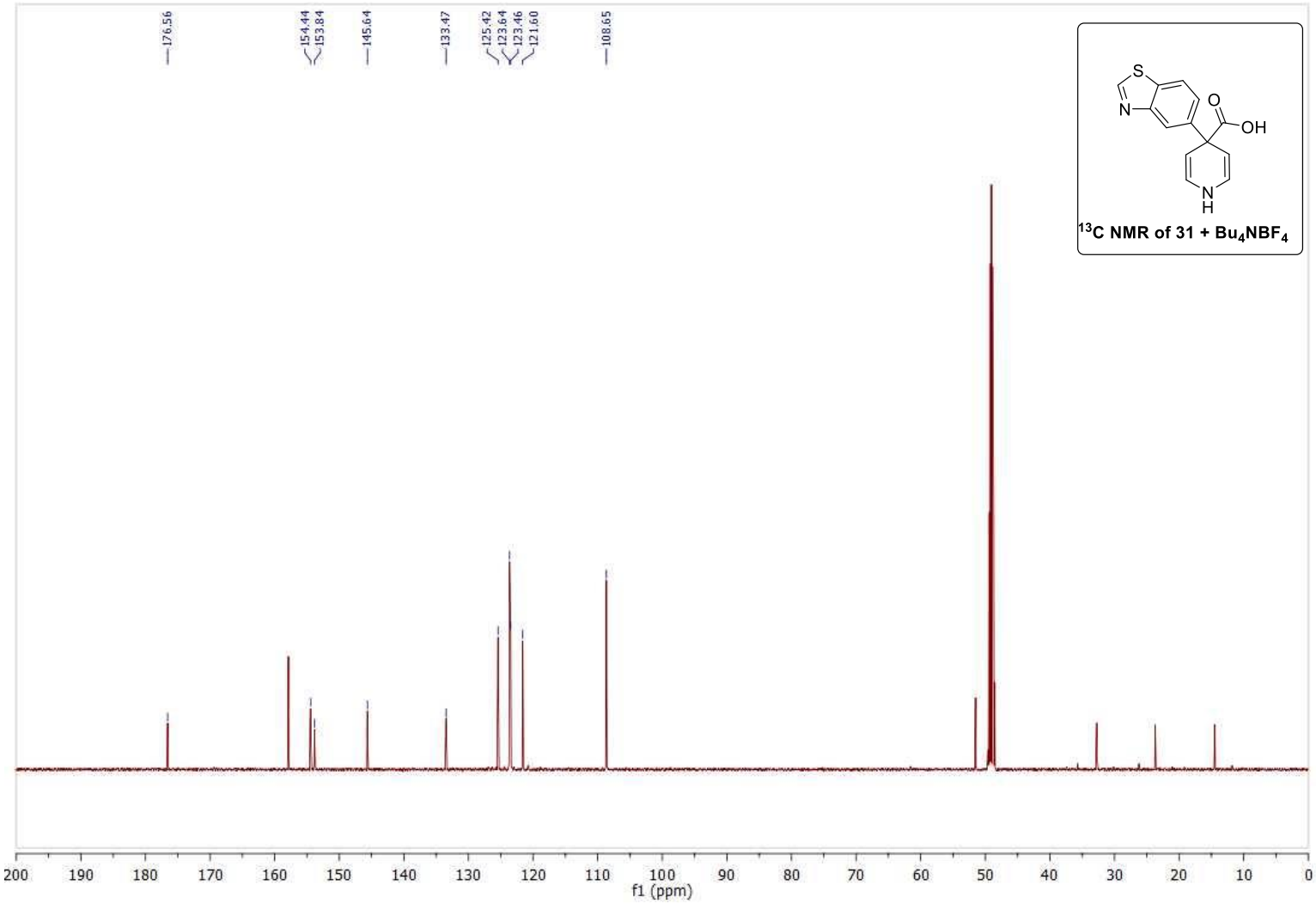

7.95
7.93
7.92
7.92
7.59
7.58
7.43
7.43
7.41
7.41
7.40
7.40
7.39
3.54
3.33
2.96
2.95
2.94
2.93
2.91
2.52
2.50
2.20
2.20
2.18
2.16
2.15
S
OH
N
H H
Cl⁻
2.01
1.01
2.00
2.00
1.32
2.01
2.00
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

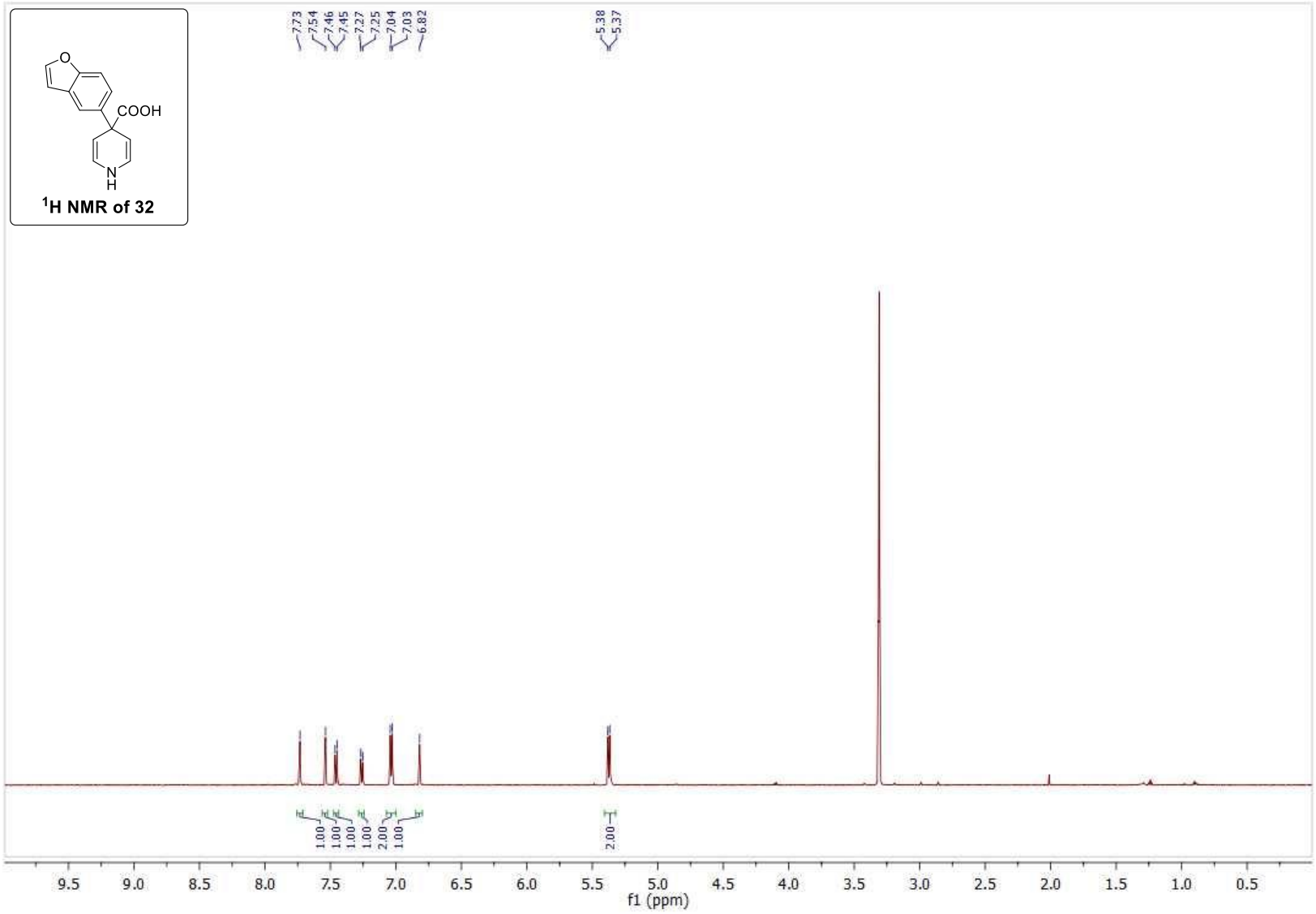
^{1}H NMR of 41

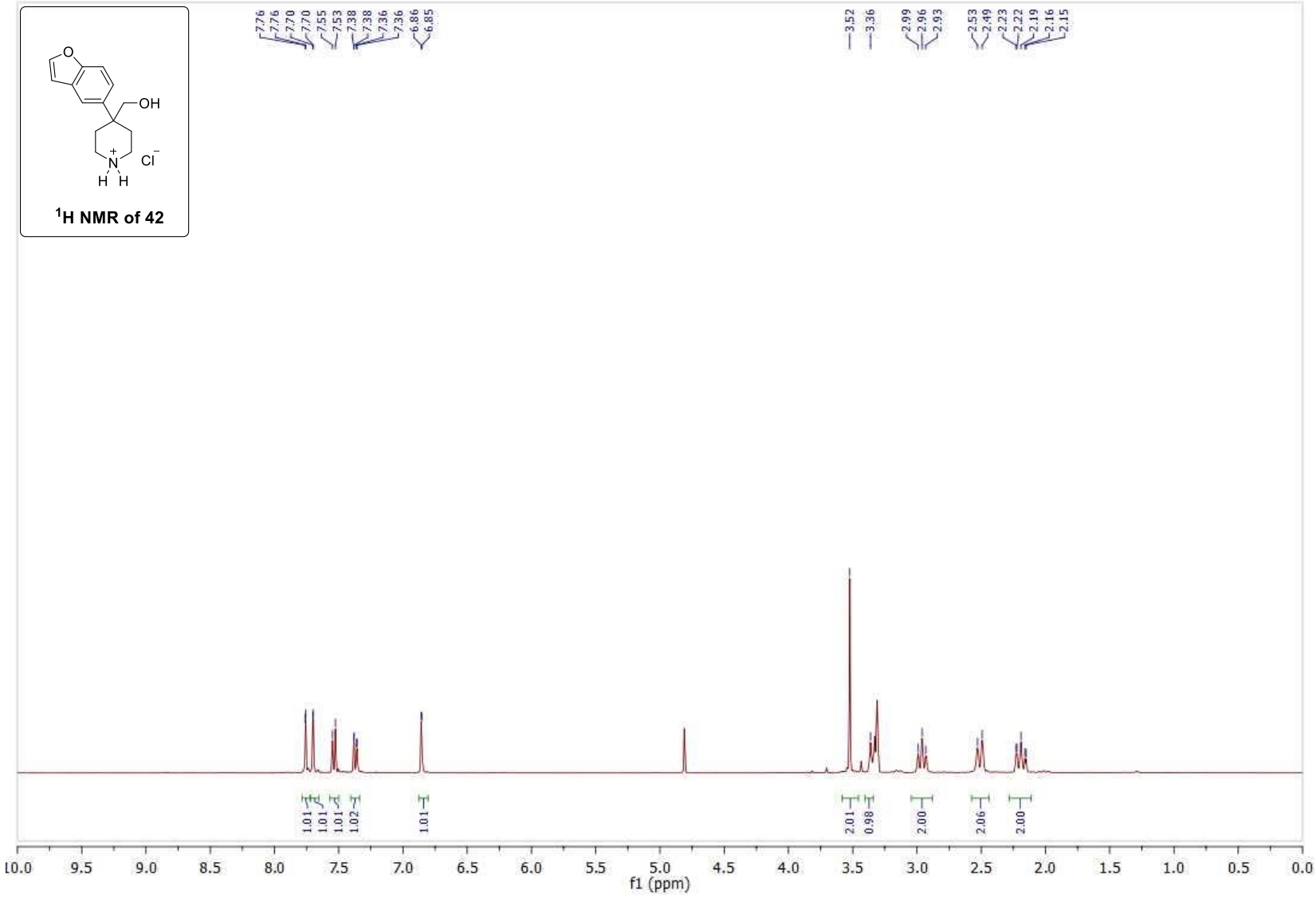

S
OH
N
H H
Cl
13C NMR of 41
141.94
139.69
138.32
128.18
125.14
124.36
123.97
123.59
72.44
43.23
42.22
29.87
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



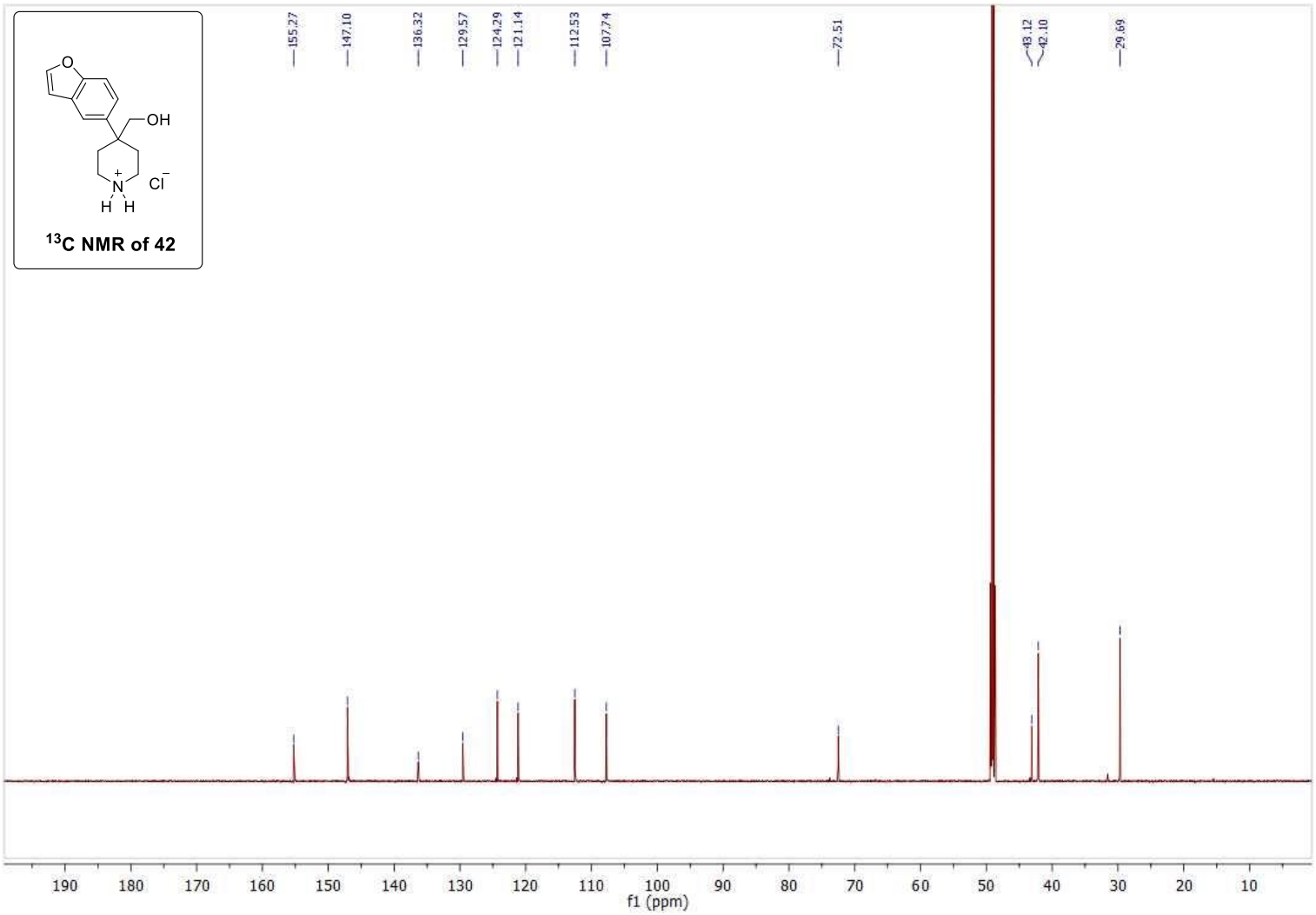
^{1}H NMR of 31 + Bu_4NBF_4


176.56
154.44
153.84
145.64
133.47
125.42
123.64
123.46
121.60
108.65
S
N
O
OH
N
H
^{13}C NMR of 31 + Bu_4NBF_4
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

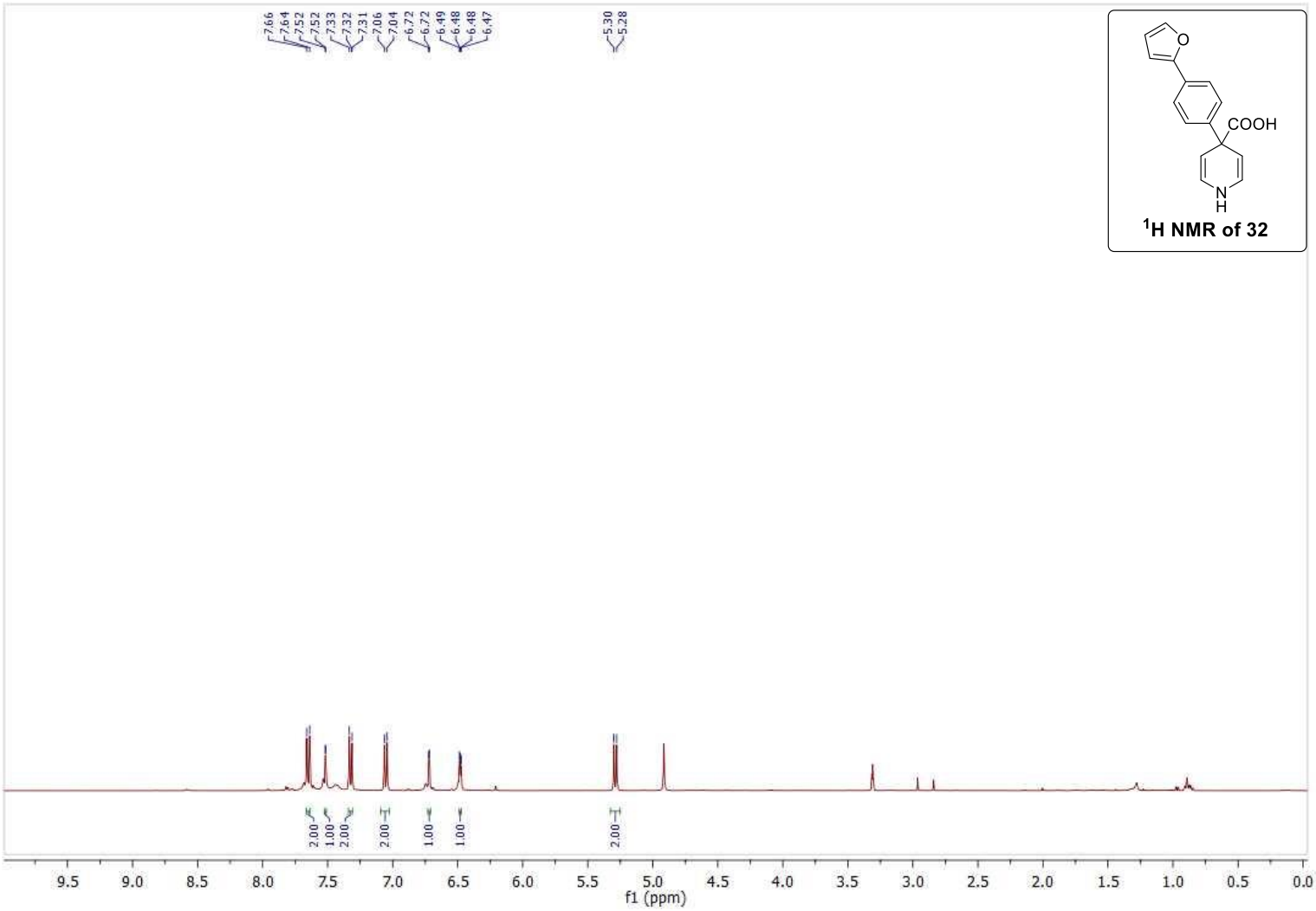

COOH
N
H
^{1}H NMR of 32
7.73
7.54
7.46
7.45
7.27
7.25
7.04
7.03
6.82
5.38
5.37
1.00
1.00
1.00
1.00
2.00
1.00
2.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


OH
Cl⁻
H H
7.76
7.76
7.70
7.70
7.55
7.53
7.38
7.38
7.36
7.36
6.86
6.85
3.52
3.36
2.99
2.96
2.93
2.53
2.49
2.23
2.22
2.19
2.16
2.15
1.01
1.01
1.01
1.02
1.01
2.01
0.98
2.00
2.06
2.00
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)

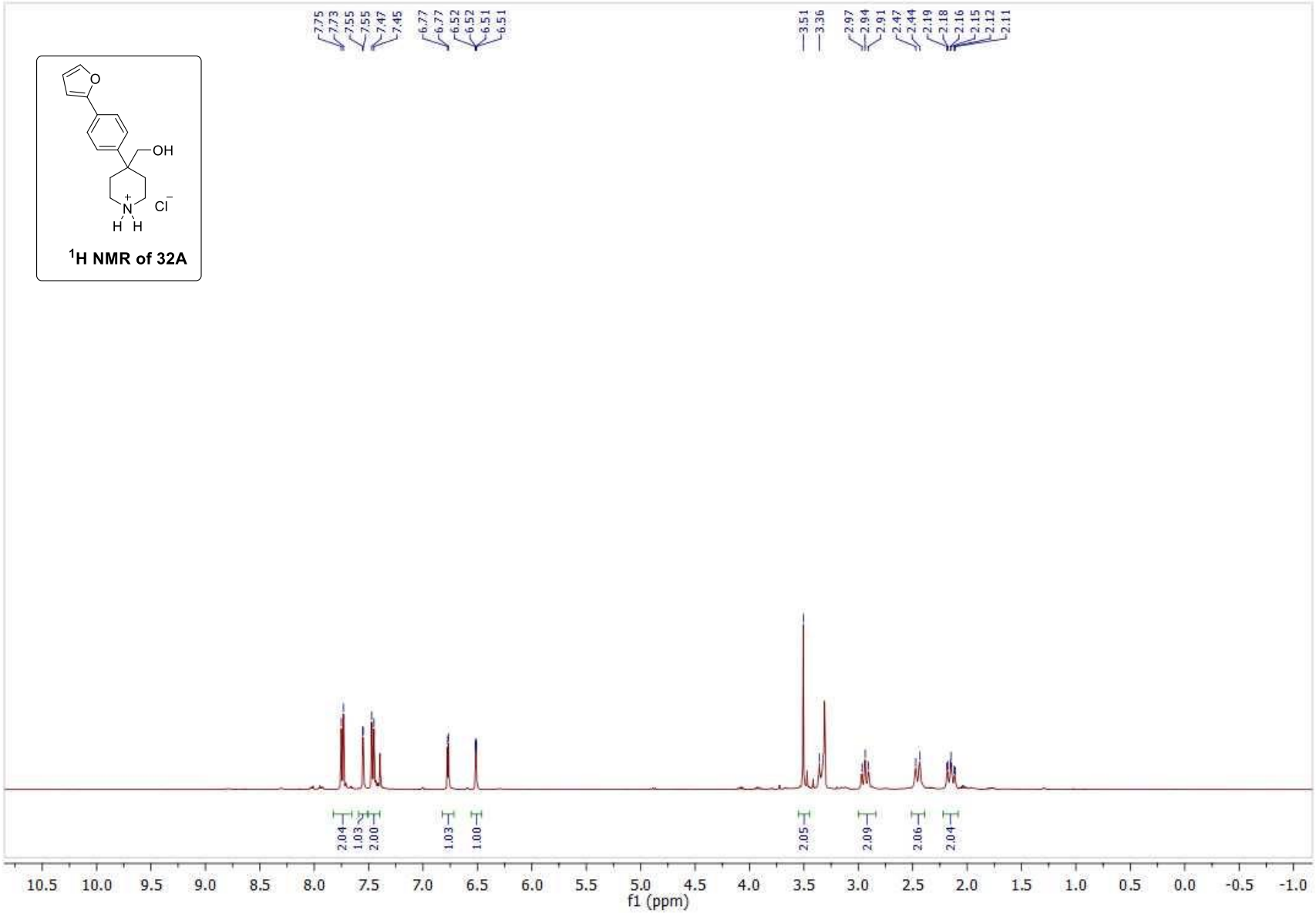
^{1}H NMR of 42


155.27
147.10
136.32
129.57
124.29
121.14
112.53
107.74
72.51
43.12
42.10
29.69
OH
Cl
H H
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

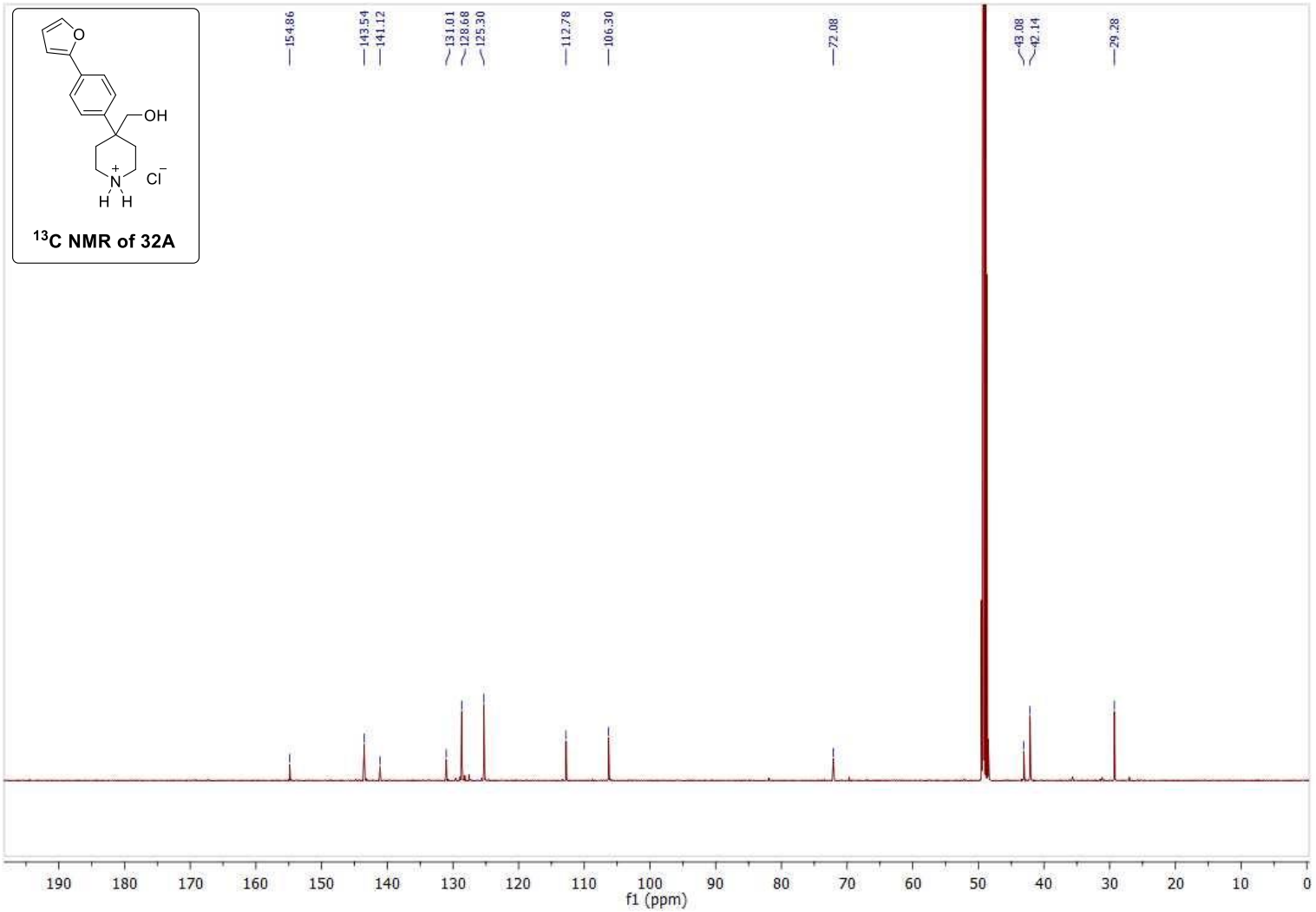
^{13}C NMR of 42


7.66
7.64
7.52
7.52
7.33
7.32
7.31
7.06
7.04
6.72
6.72
6.49
6.48
6.48
6.47
5.30
5.28
O
COOH
N
H
2.00
1.00
2.00
2.00
1.00
1.00
2.00
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)

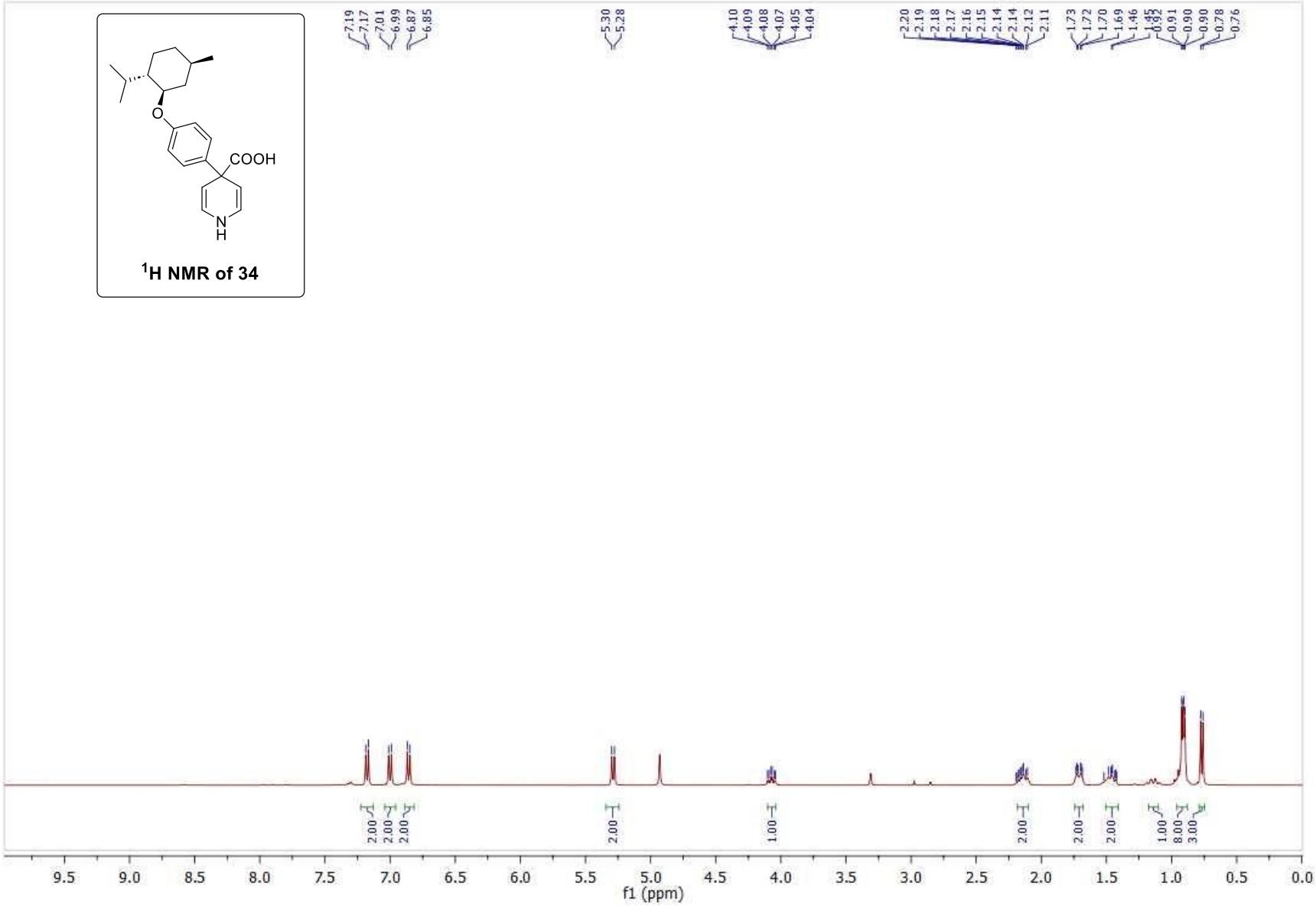
^{1}H NMR of 32

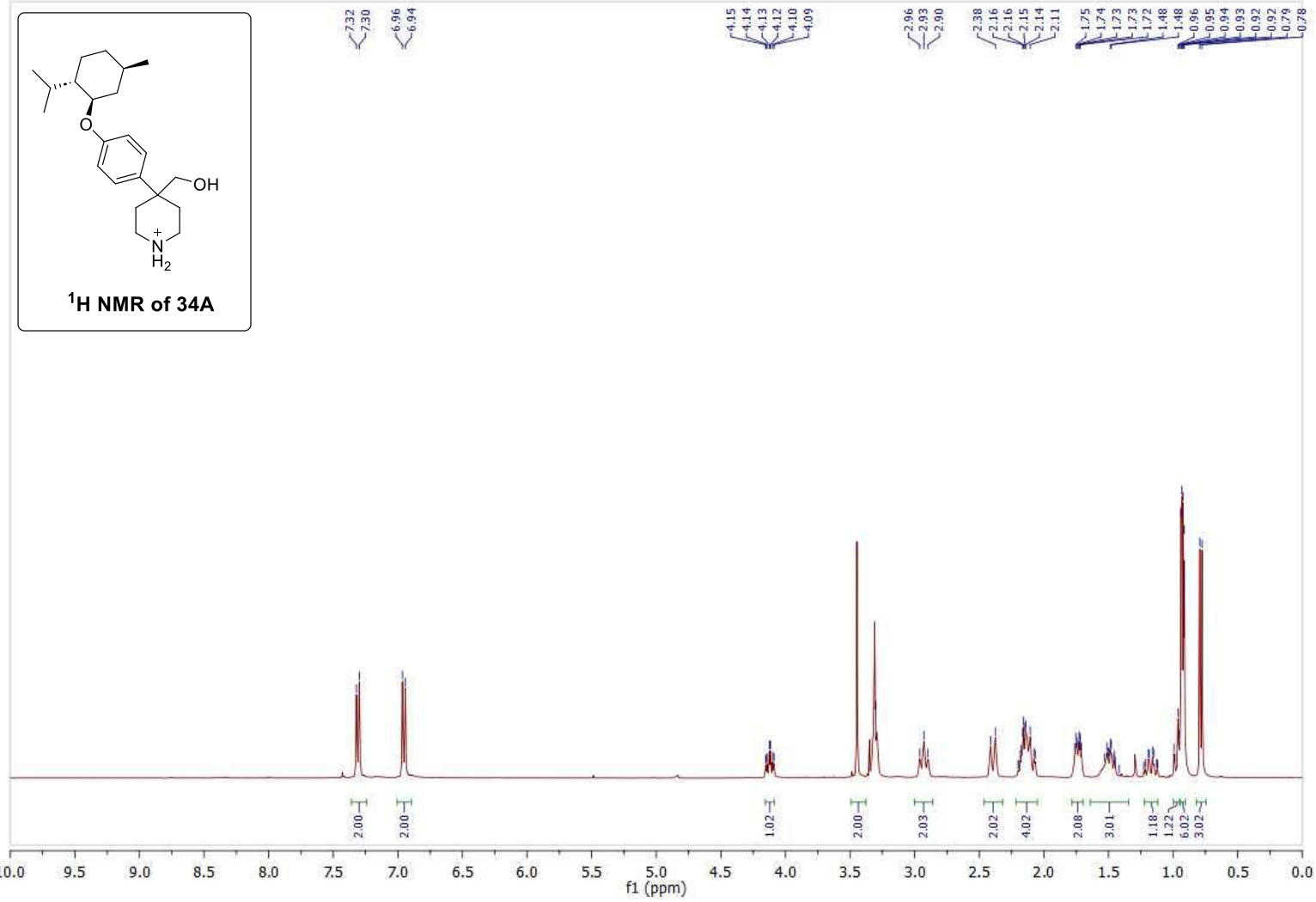

7.75
7.73
7.55
7.55
7.47
7.45
6.77
6.77
6.52
6.52
6.51
6.51
3.51
3.36
2.97
2.94
2.91
2.47
2.44
2.19
2.18
2.16
2.15
2.12
2.11
OH
Cl
H H
2.04
1.03
2.00
1.03
1.00
2.05
2.09
2.06
2.04
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

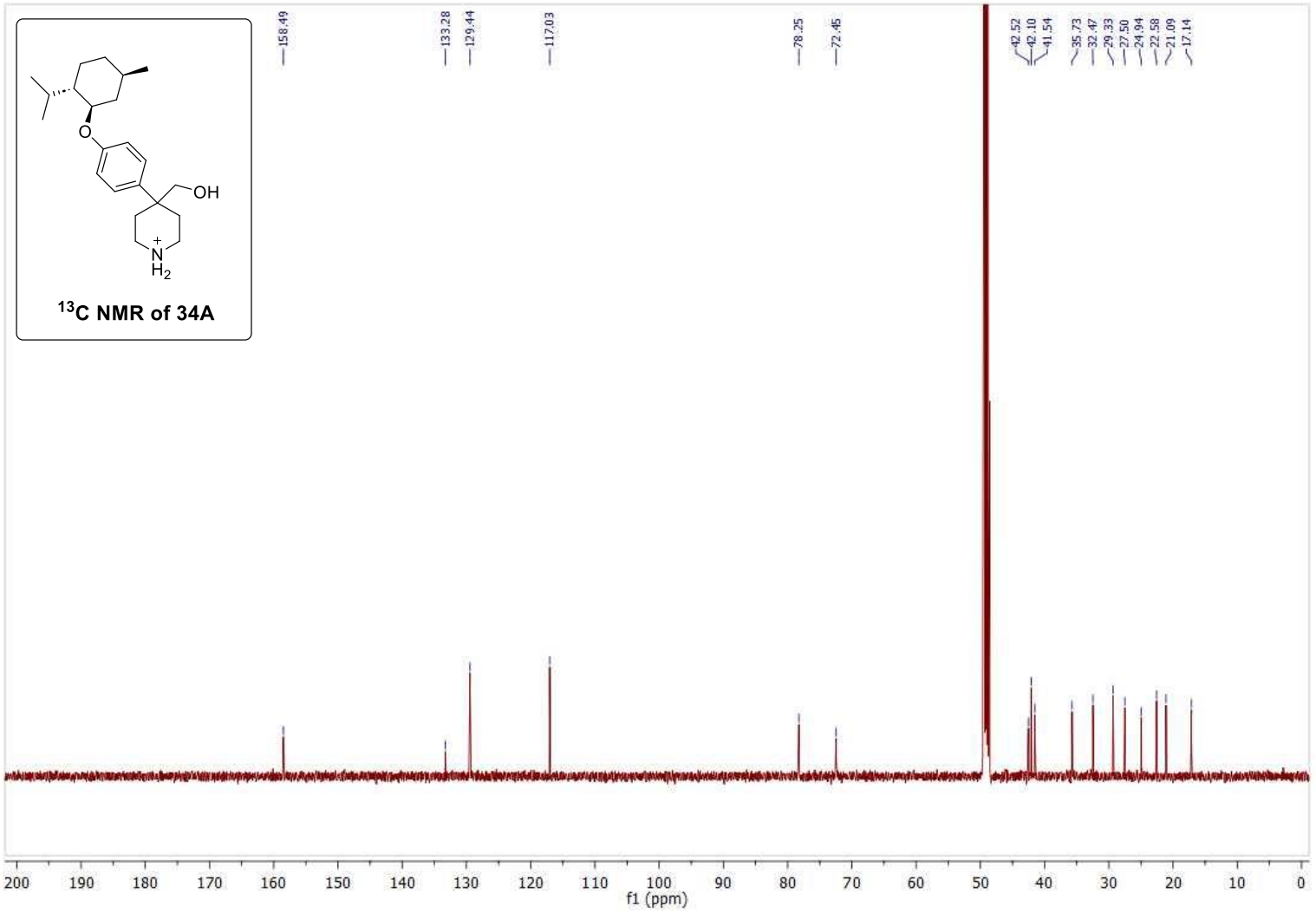
^{1}H NMR of 32A



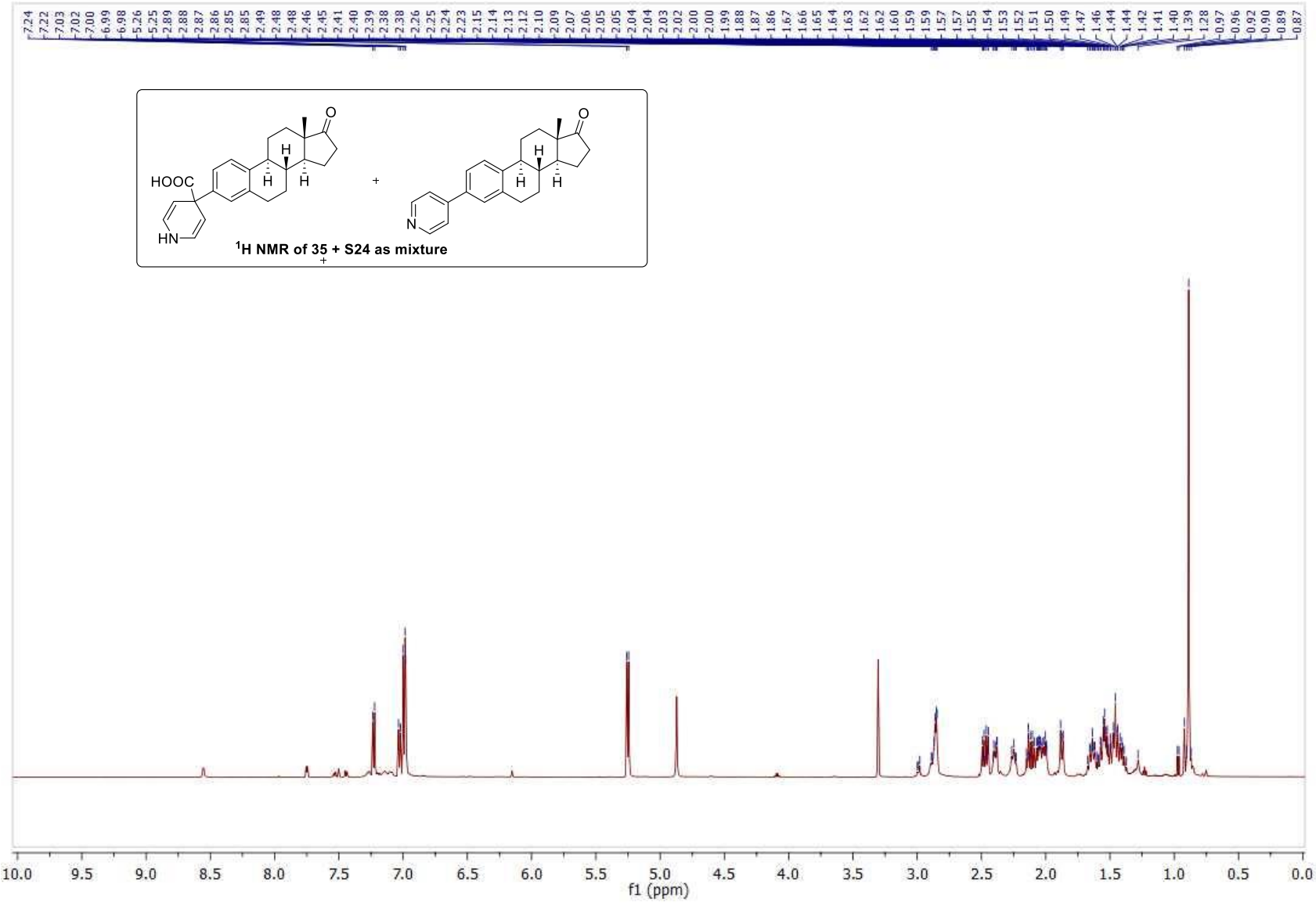
^{13}C NMR of 32A

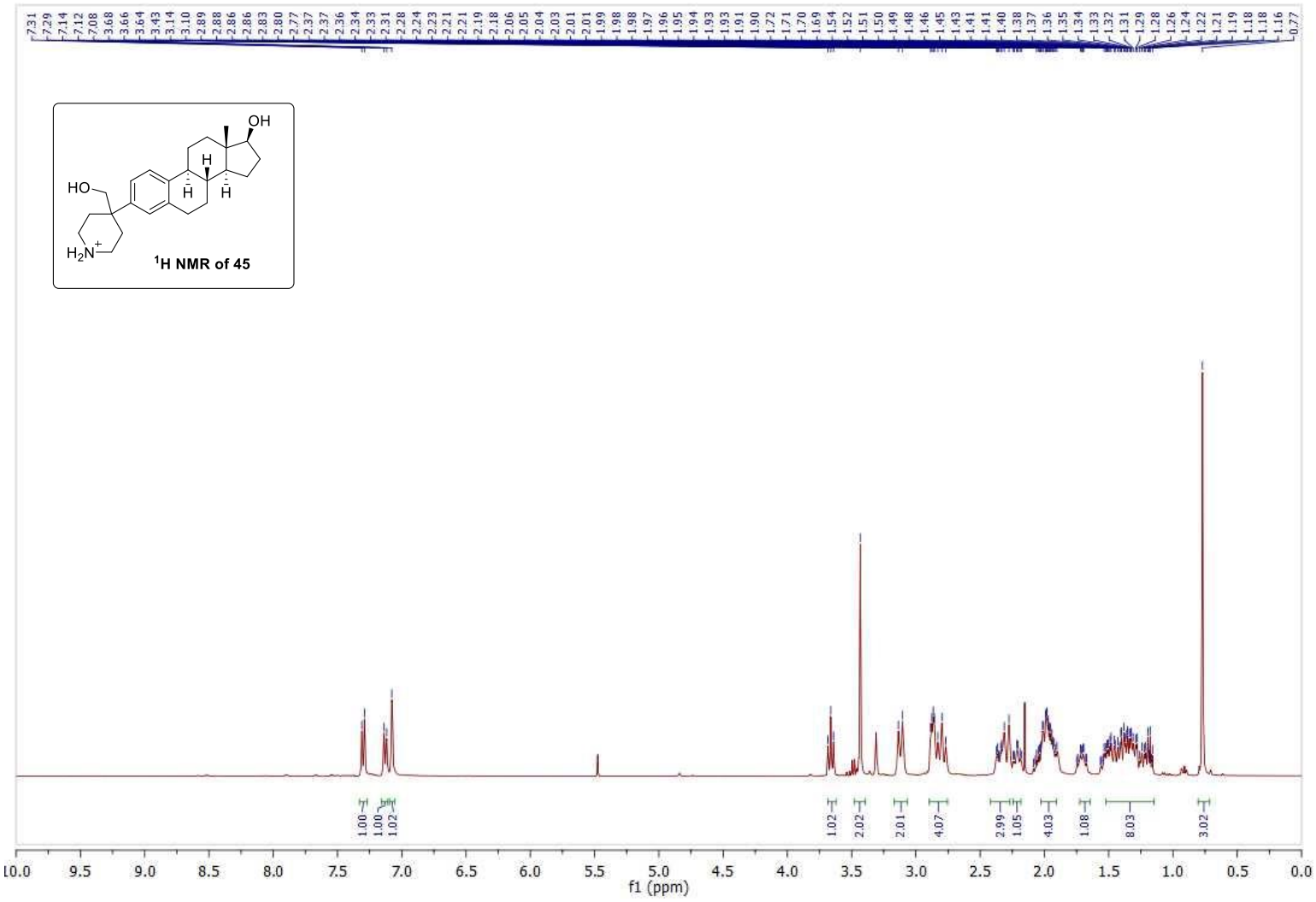

COOH
O
N
H
^{1}H NMR of 34
f1 (ppm)

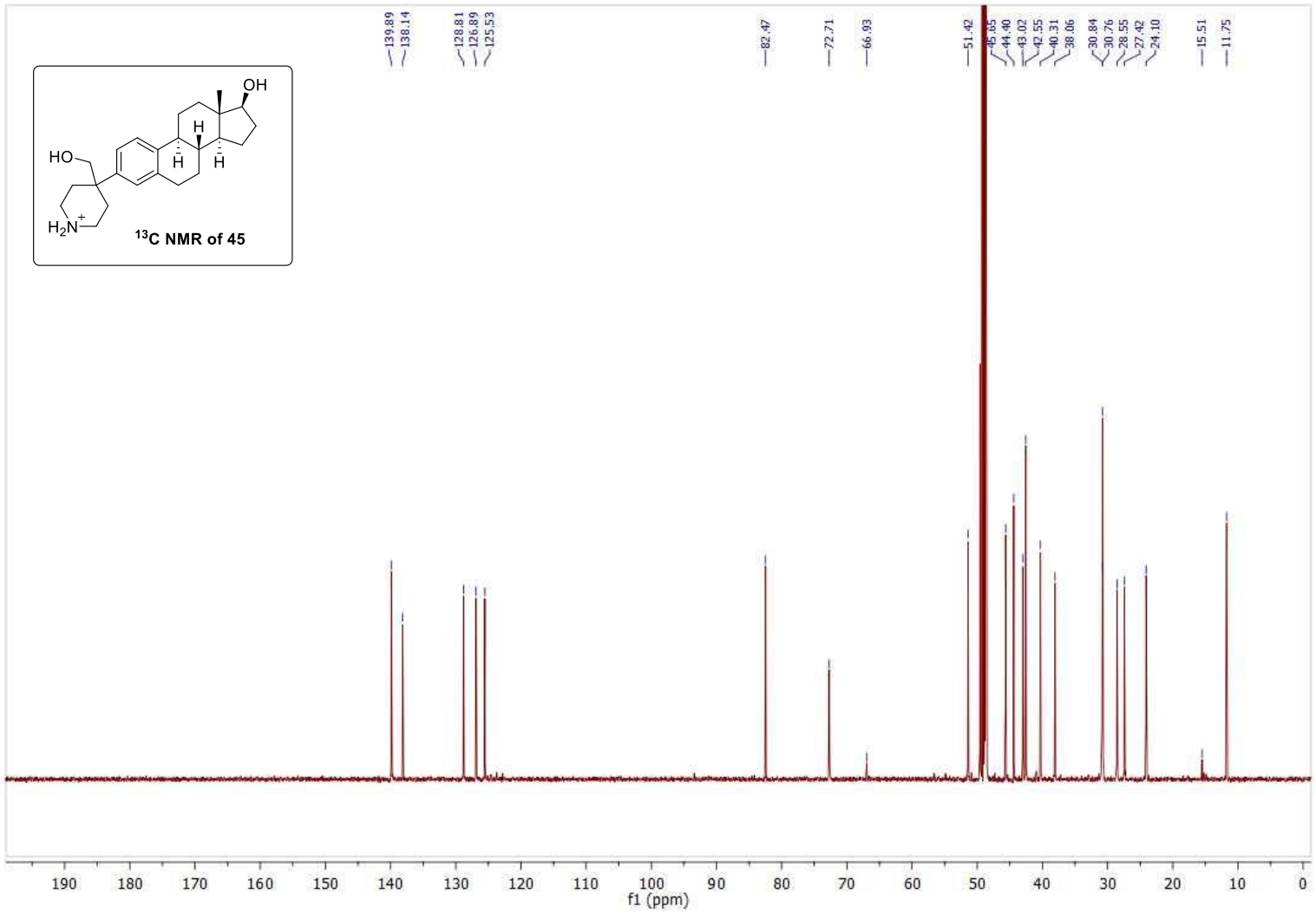

OH
N
H2
1H NMR of 34A
f1 (ppm)

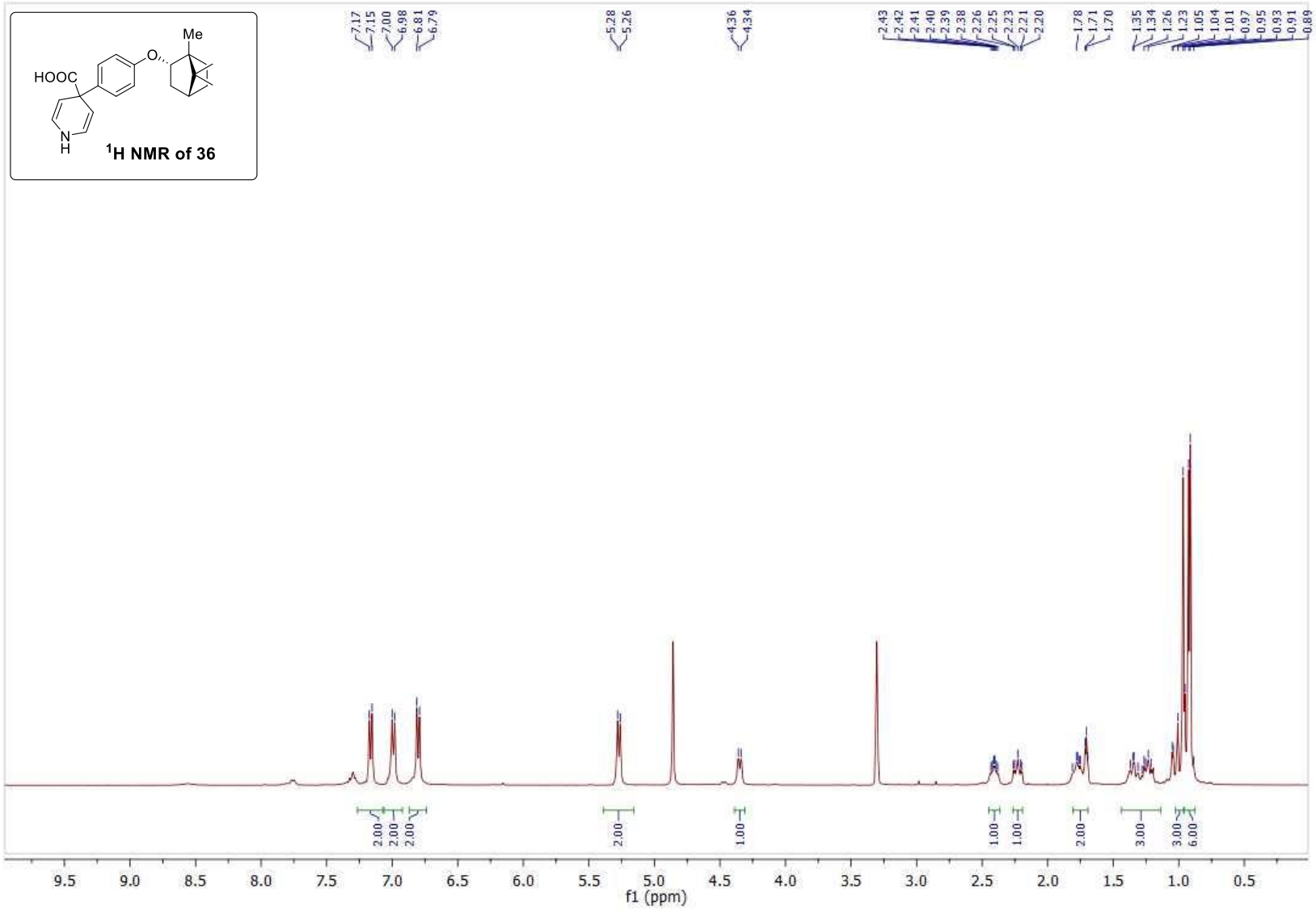


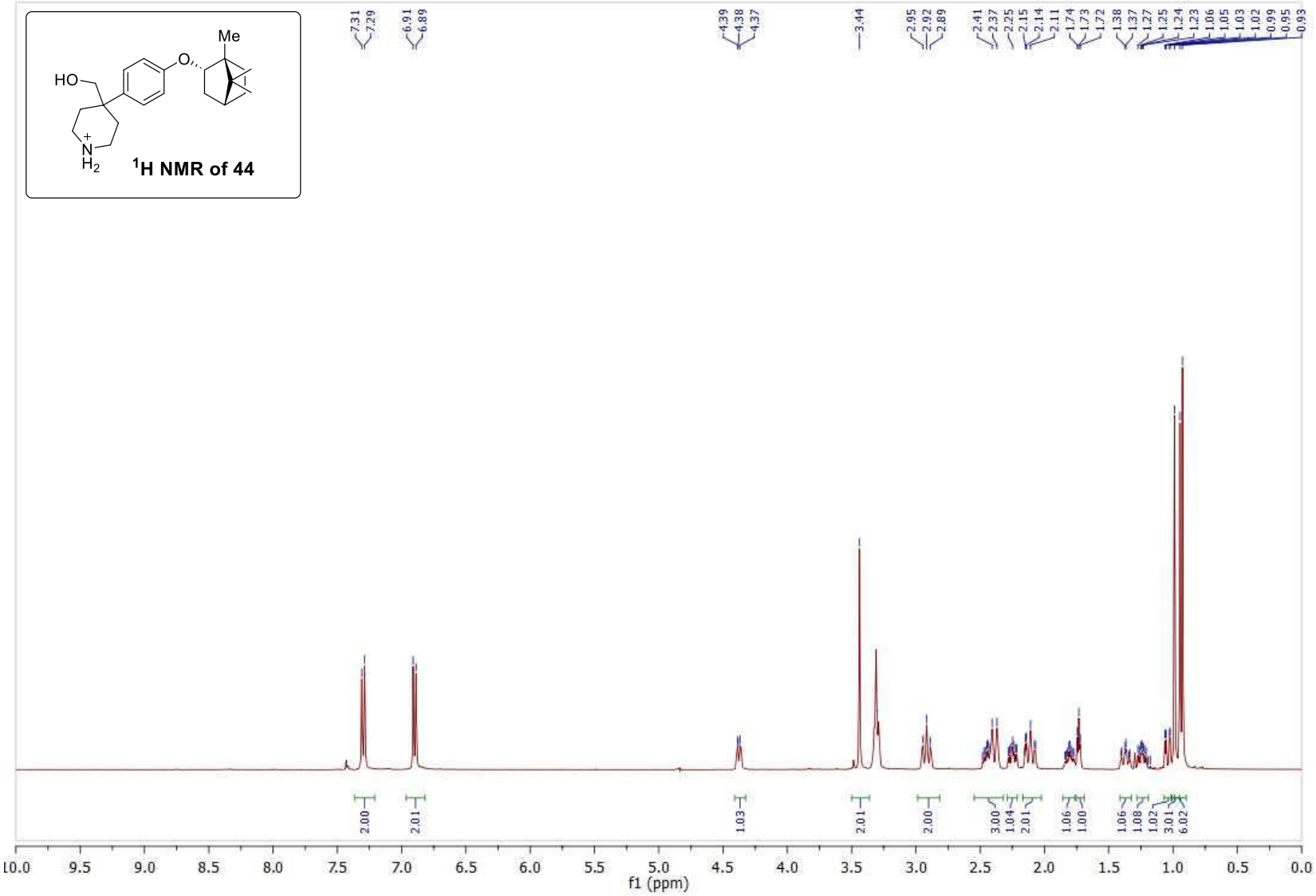
^{13}C NMR of 34A

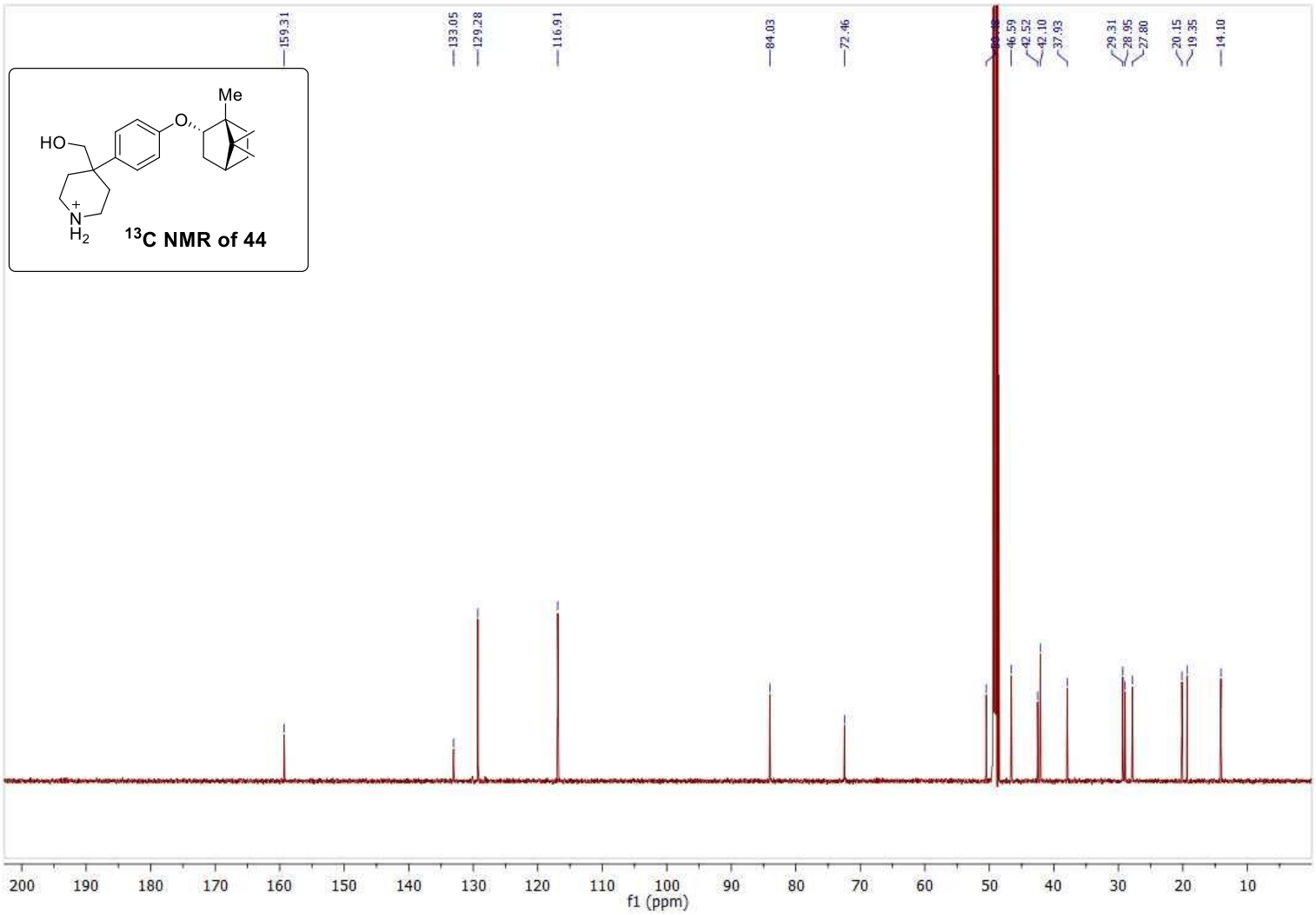

HOOC
HN
O
H
H
H
+
N
O
H
H
H
^{1}H NMR of 35 + S24 as mixture
f1 (ppm)

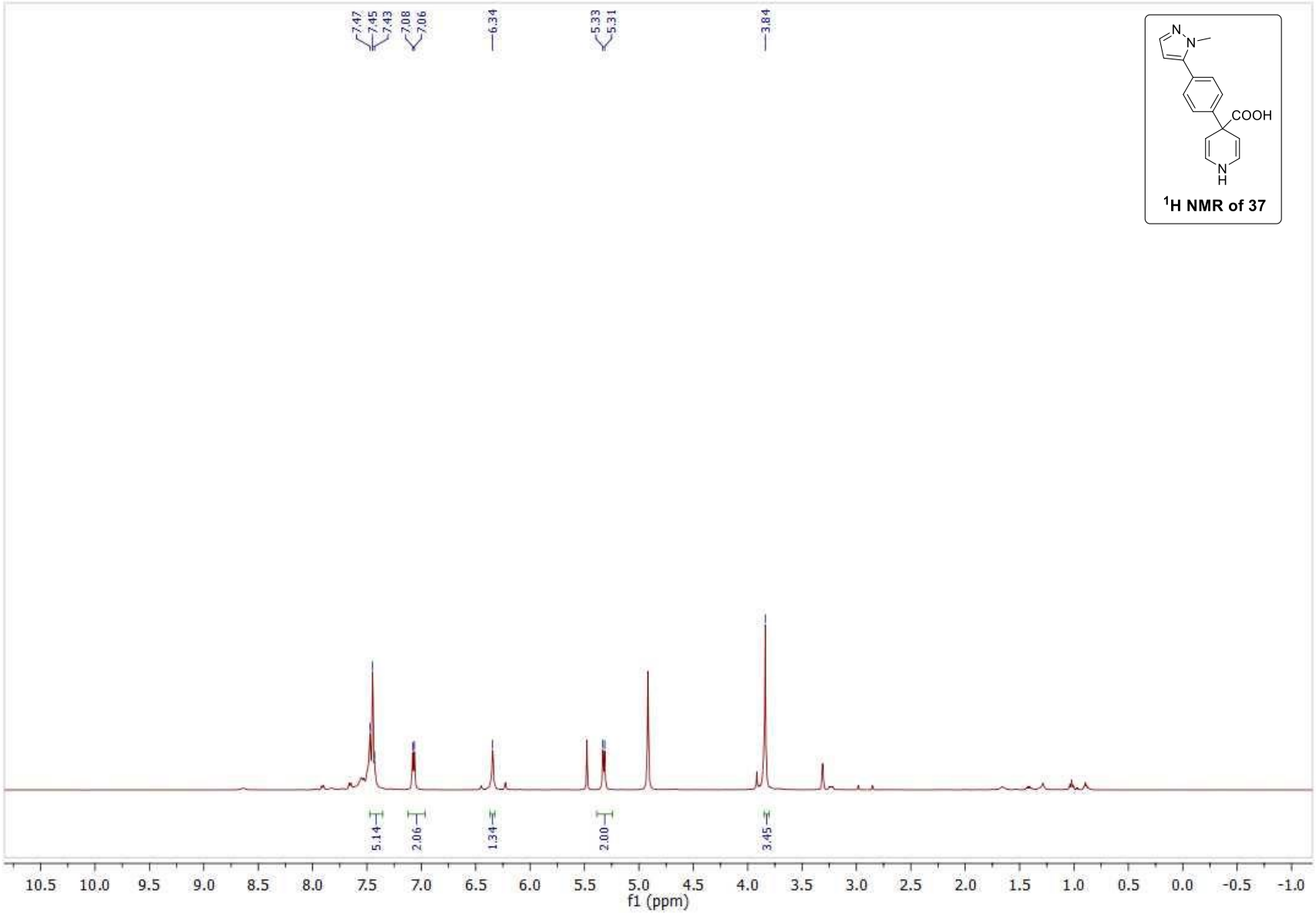

OH
HO
H
H
H
H_2N^+
^{1}H NMR of 45
f1 (ppm)


OH
HO
H
H
H
H_2N^+
^{13}C NMR of 45
139.89
138.14
128.81
126.89
125.53
82.47
72.71
66.93
51.42
45.05
44.40
43.02
42.55
40.31
38.06
30.84
30.76
28.55
27.42
24.10
15.51
11.75
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

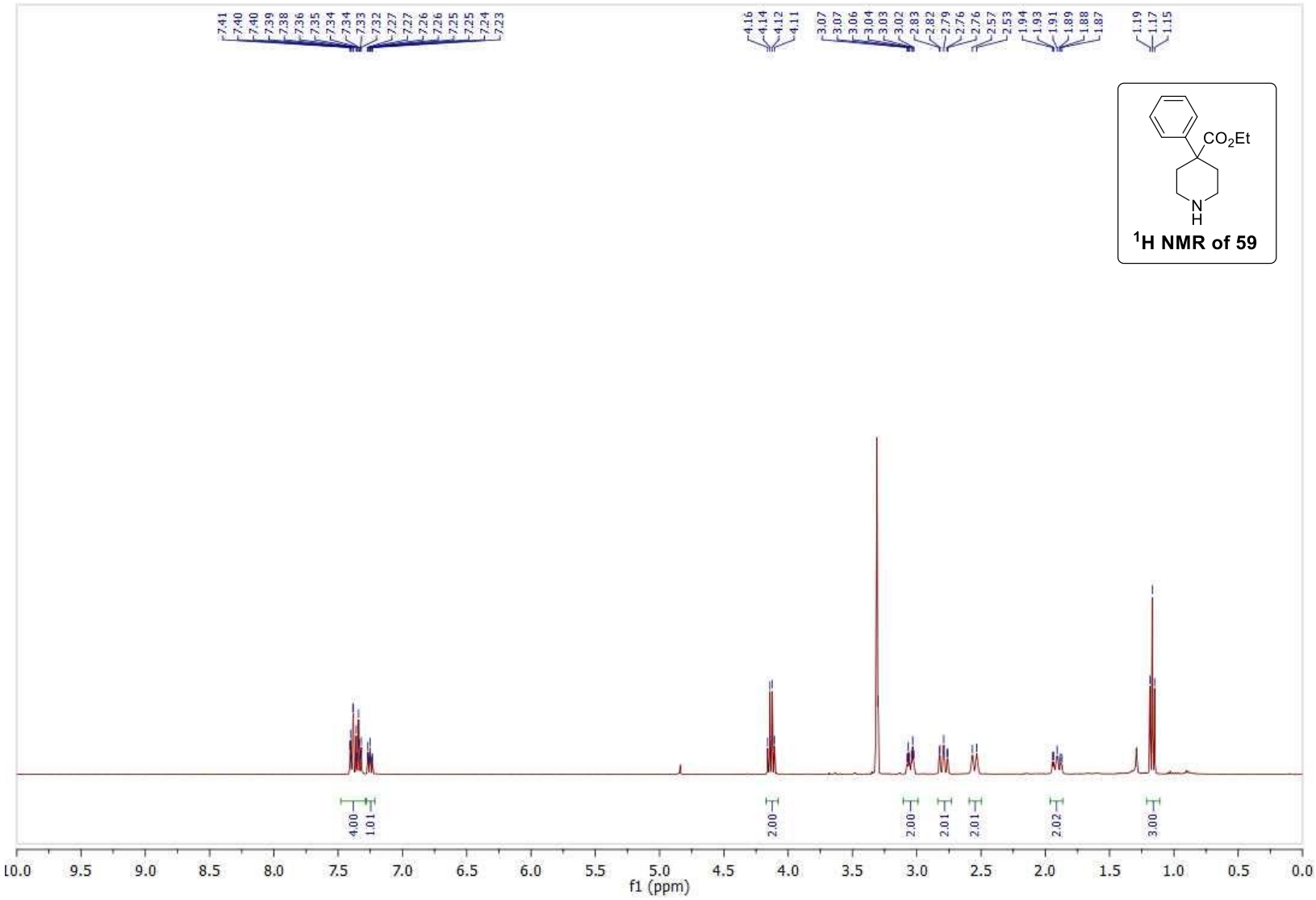

HOOC
Me
O
N
H
^{1}H NMR of 36
7.17
7.15
7.00
6.98
6.81
6.79
5.28
5.26
4.36
4.34
2.43
2.42
2.41
2.40
2.39
2.38
2.26
2.25
2.23
2.21
2.20
1.78
1.71
1.70
1.35
1.34
1.26
1.23
1.05
1.04
1.01
0.97
0.95
0.93
0.91
0.89
2.00
2.00
2.00
2.00
1.00
1.00
1.00
2.00
3.00
3.00
6.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

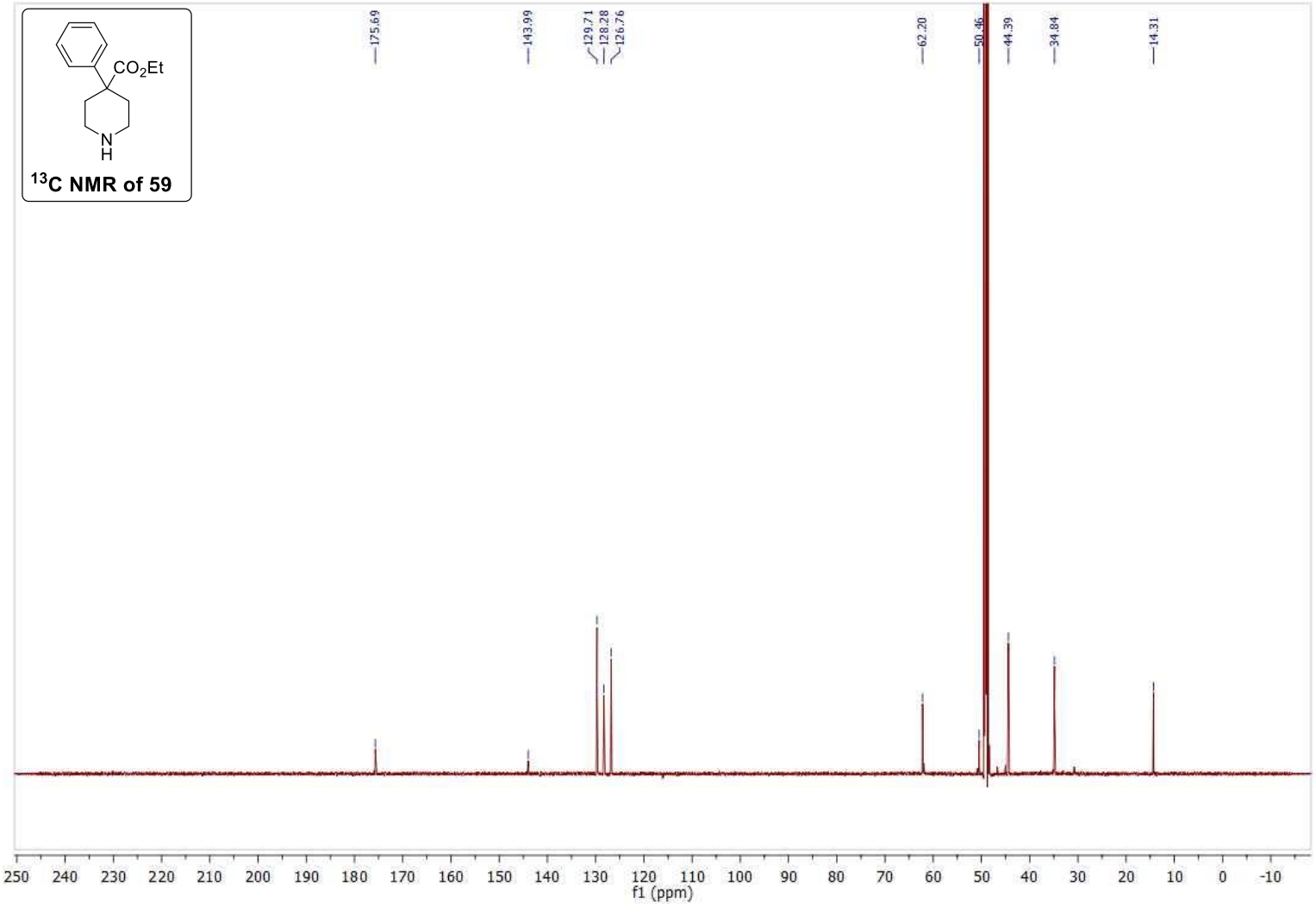

HO
Me
O
N
H2
1H NMR of 44
7.31
7.29
6.91
6.89
4.39
4.38
4.37
3.44
2.95
2.92
2.89
2.41
2.37
2.25
2.15
2.14
2.11
1.74
1.73
1.72
1.38
1.37
1.27
1.25
1.24
1.23
1.06
1.05
1.03
1.02
0.99
0.95
0.93
2.00
2.01
1.03
2.01
2.00
3.00
1.04
2.01
1.06
1.00
1.06
1.08
1.02
3.01
6.02
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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)

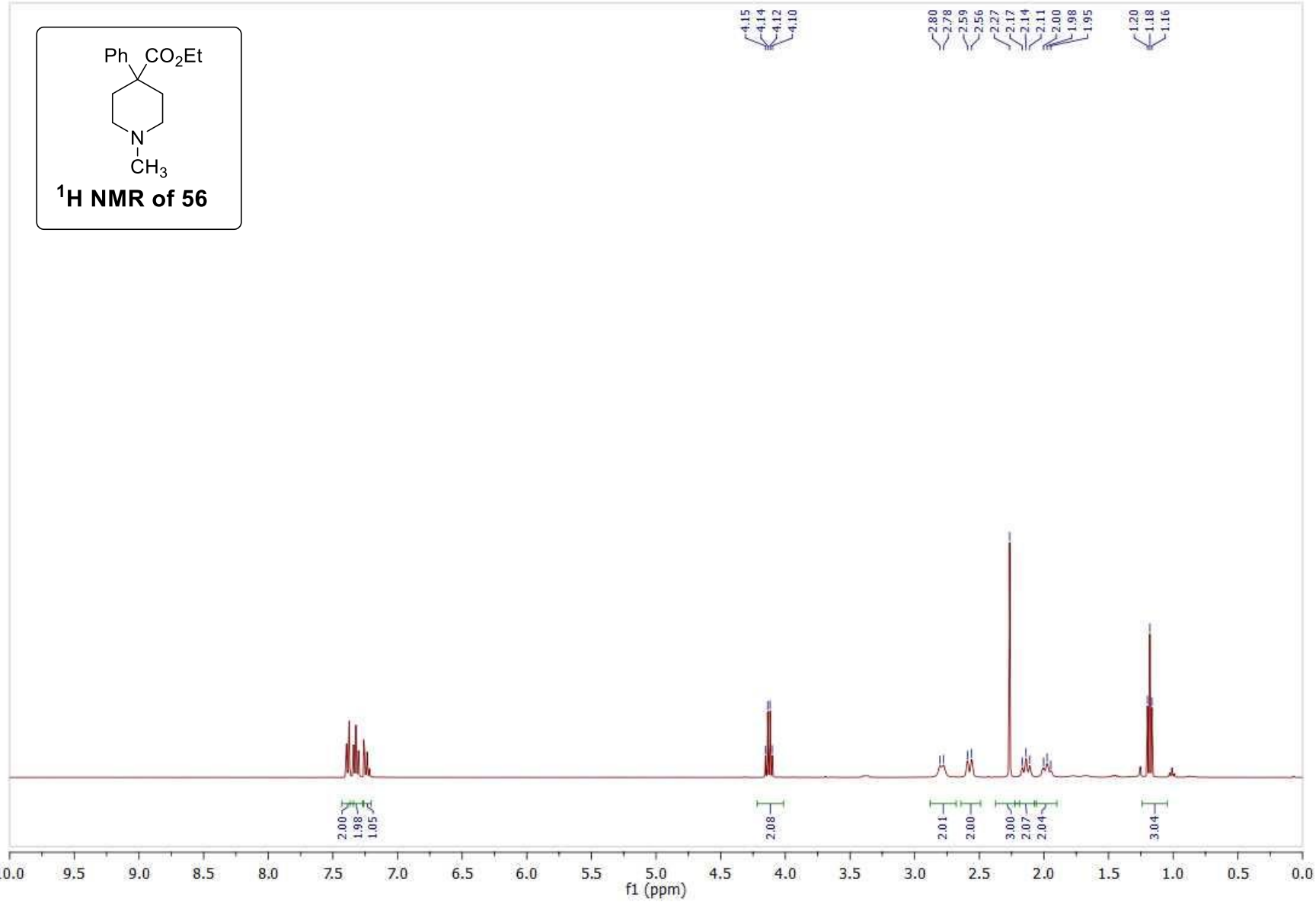

159.31
133.05
129.28
116.91
84.03
72.46
46.59
42.52
42.10
37.93
29.31
28.95
27.80
20.15
19.35
14.10
Me
O
HO
N
H2
13C NMR of 44
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

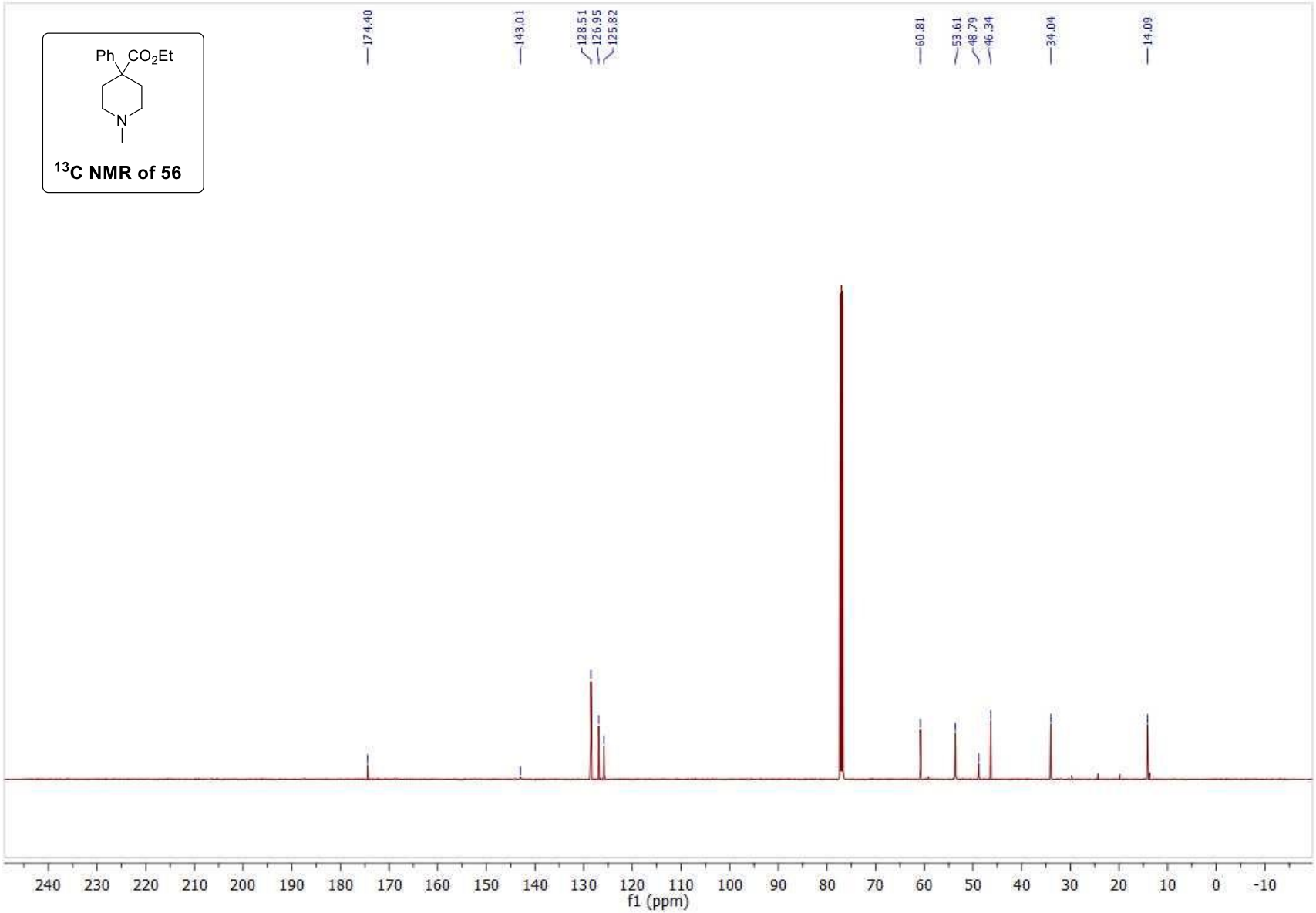

7.47
7.45
7.43
7.08
7.06
6.34
5.33
5.31
3.84
COOH
N
N
H
5.14
2.06
1.34
2.00
3.45
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

^{1}H NMR of 37


7.41
7.40
7.40
7.39
7.38
7.36
7.35
7.34
7.34
7.33
7.32
7.27
7.27
7.26
7.26
7.25
7.25
7.24
7.23
4.16
4.14
4.12
4.11
3.07
3.07
3.06
3.04
3.03
3.02
2.83
2.82
2.79
2.76
2.76
2.57
2.53
1.94
1.93
1.91
1.89
1.88
1.87
1.19
1.17
1.15
CO2Et
N
H
1H NMR of 59
4.00
1.01
2.00
2.00
2.01
2.01
2.02
3.00
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)


CO2Et
N
H
13C NMR of 59
175.69
143.99
129.71
128.28
126.76
62.20
50.46
44.39
34.84
14.31
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


Ph
CO2Et
N
CH3
1H NMR of 56
4.15
4.14
4.12
4.10
2.80
2.78
2.59
2.56
2.27
2.17
2.14
2.11
2.00
1.98
1.95
1.20
1.18
1.16
2.00
1.98
1.05
2.08
2.01
2.00
3.00
2.07
2.04
3.04
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)


Ph
CO2Et
N
13C NMR of 56
174.40
143.01
128.51
126.95
125.82
60.81
53.61
48.79
46.34
34.04
14.09
240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)