Photo-Fries-type rearrangement of cyclic enamides. An efficient route to structurally diverse five-membered enaminones.

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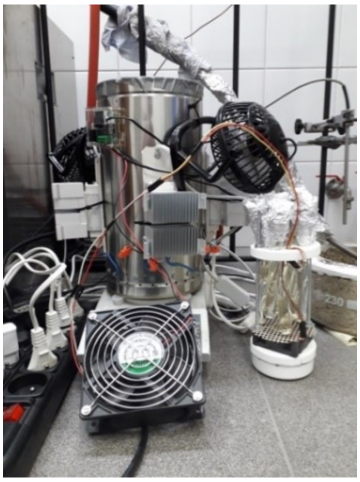
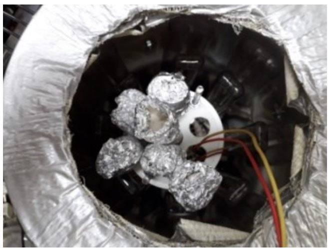
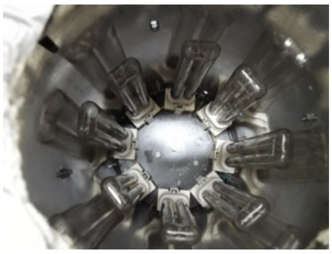
Table of Context:

General information:

^{1}H NMR and ^{13}C{^{1}H} NMR spectra were recorded on a Bruker 400 and Bruker 500 spectrometers. ^{1}H NMR spectra were referenced to: chloroform-*d* (δ = 7.26 ppm), benzene-d_6 (δ = 7.16 ppm), methanol-d_4 (δ = 3.31 ppm). ^{13}C{^{1}H} NMR spectra were referenced to: chloroform-*d* (δ = 77.00 ppm), benzene-d_6 (δ = 128.06 ppm), methanol-d_4 (δ = 49.00 ppm).[1] Chemical shifts (δ) were given in ppm and coupling constants (*J*) were given in Hertz (Hz). Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dd (doublet of doublet). Infrared spectra were recorded on a FT-IR Jasco 6200 and FT-IR Spectrum 2000 Perkin Elmer spectrophotometer. High-resolution mass spectra were recorded on ESI-TOF Mariner Spectrometer, SYNAPT G2-S HDMS or AMD 604 mass spectrometer. Thin layer chromatography was performed on Merck aluminium sheet Silica Gel 60 F254. Column chromatography was carried out using Merck silica gel (230-400 mesh). Photochemical reactions were performed in self-made photoreactor consisting of: eight sockets lamp, temperature control, mixing and cooling system. The electronic part was designed in such a way that each of the four lamp sets could be triggered individually or simultaneously *via* switches, modulating the intensity of the emitted light. The photoreactor can operate at three different wavelengths UV-A (320-400 nm), UV-B (290-320 nm), UV-C (100-290 nm).

Design of the lab-made photoreactor:

Elements included in the photoreactor:

- 1 x metal can e.g. for Sigma Aldrich reagents, Ø 15.6 cm, H 26 cm
- 8 x lamp holder, G23 (7 EUR)
- 8 x 9W UV-C lamp, Osram, Puritec, HNS, S 9W (59 EUR)
- 4 x magnetic ballast, LN36 2x18W 1x36W Schwabe VS (15 EUR)
- 4 x aluminum heat sink; thermal resistance 3.4K/W, L 7.2 cm, W 6.8 cm, H 4.0 cm (4 EUR)
- 1 x computer fan 120x120x38, 24Vdc, 322m^3/h, 54dBA (24 EUR)
- 1 x computer fun 40x40x10, 12Vdc, 13.5m^3/h, 27,3dBA (4 EUR)
- 2 x windmill desk fan; 2.5W, H 15 cm, W 14 cm (6 EUR)
- 1 x Thermostat W1209 with thermocouple, supply voltage 12V, temperature control -50 ° C to 110 ° C (3 EUR)
- 2 x switching power supply, 12V, 1.5A (2 EUR)
- 1 x tube rack (self-made)
- 8 x quartz tube Ø 14 mm, H 130 mm (25 EUR)

Totally cost: 149 EUR

Construction of the photoreactor:

1. In the bottom of the can, cut a hole with a diameter 10.5 cm. Sharp edges secured with self-adhesive tape.
2. Drill the holes in the can (see Figure 1 and 2): cooling air flow ● lamp holder ● electric wires ● magnetic ballast ● thermostat ● windmill desk fun ●
3. Fasten with screws: 8 x lamp holder, 4 x magnetic balast, thermostat (see figure 2)
4. Connect the power cable and the lamp holders to the magnetic ballast according to the scheme 1 (two lamps for one magnetic ballast)
5. Connect the switching power supply and computer fun to the thermostat as shown on scheme 2
6. Stick the aluminum heat sinks to the magnetic ballasts with thermal paste.
7. Fasten the windmill desk fans e.g. with the zip-tie.
8. Construction of the tube rack is shown on figure 3

Figure 1

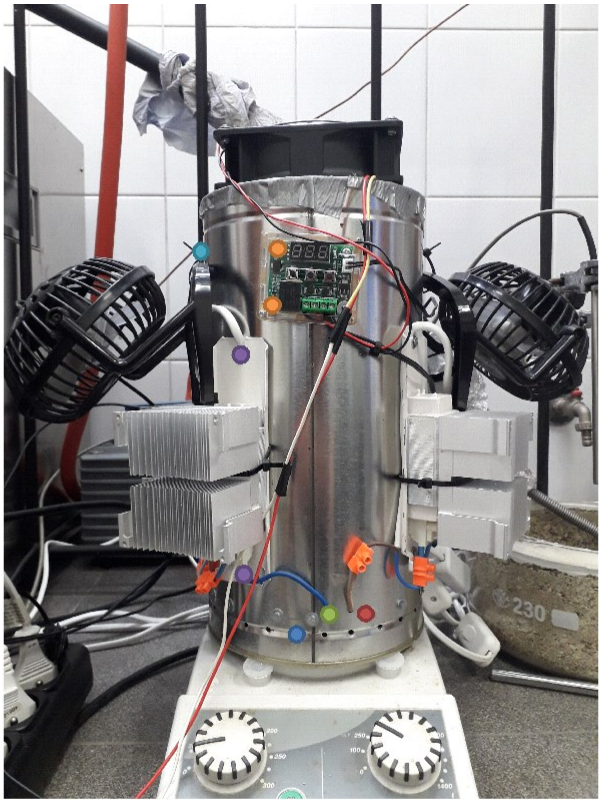
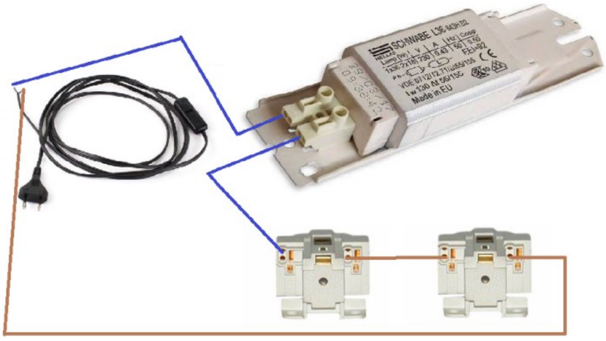


Figure 2



Scheme 1

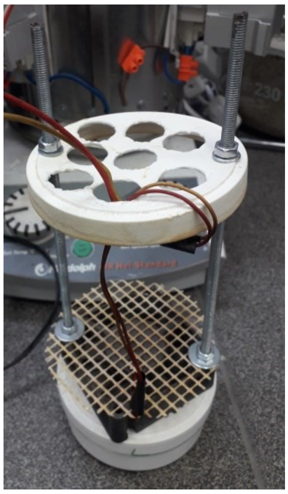
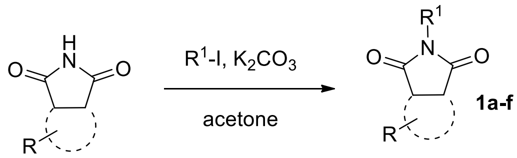


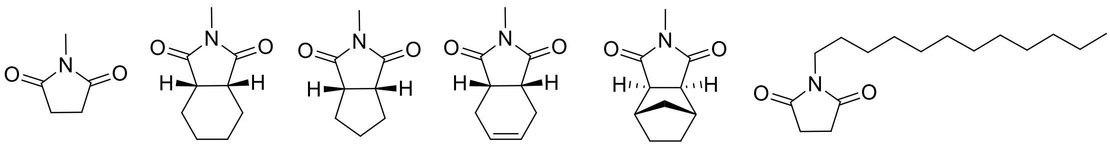
Figure 3

Scheme 2

General procedure for the *N*-alkylation of imides. Synthesis of 1a-f.

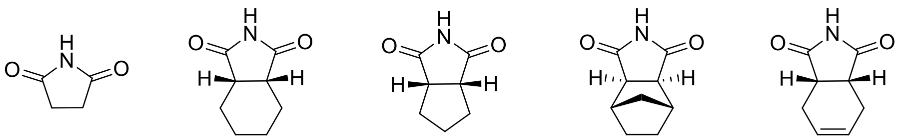
The *N*-alkylation reaction was performed according to the literature procedure with small modification.[2] Reactions were performed in sealed tube. To a solution of imide[a] (10.1 mmol) in dry acetone (18 mL) methyl iodide (691 µL, 11.1 mmol; 1.1 equiv.), anhydrous potassium carbonate (1.7 g, 12.1 mmol; 1.2 equiv.) were added under argon. The mixture was reflux until complete conversion of substrate (24-48 h). After cooling to room temperature the mixture was filtered and the acetone evaporated to give a residue, which was dissolved in CH_2Cl_2 (10 mL) and washed with H_2O (10 mL) and brine (10 mL). Organic layer was dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. Further evaporation under high vacuum gave pure product **1a-f**.



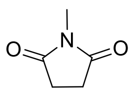


1a 95% **1b** 94% **1c** 91% **1d** 96% **1e** 94% **1f** 25%

[a]Imides were purchased from commercial supplier Fluorochem:

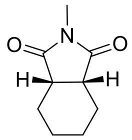


CAS: 123-56-8 CAS: 7506-66-3 CAS: 5763-44-0 CAS: 14805-29-9 CAS: 1469-48-3



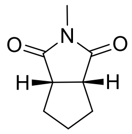
1a

1-Methylpyrrolidine-2,5-dione; 95% (4.34 g starting from 4.0 g of succinimide); white solid; m.p. 70-71 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 2.99 (s, 3H), 2.70 (s, 4H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 177.2, 28.2, 24.8 ppm; spectroscopic data are in agreement with literature data.[2]



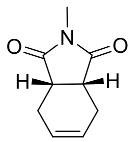
1b

***cis*-2-Methylhexahydro-1*H*-isoindole-1,3(2*H*)-dione**; 94% (513 mg; starting from 500 mg of cis-hexahydro-1*H*-isoindole-1,3(2*H*)-dione); yellow solid; m.p. 52-53 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 2.97 (s, 3H), 2.88 – 2.81 (m, 2H), 1.91 – 1.81 (m, 2H), 1.78 – 1.69 (m, 2H), 1.49 – 1.37 (m, 4H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 179.9, 39.8, 24.6, 23.6, 21.5 ppm; HRMS (ESI-TOF) *m/z* calc for $C_9H_{14}NO_2$ [M+H$^+$] 168.1025. Found 168.1029; IR (film, CH_2Cl_2) *v*: 3462, 2940, 2859, 1775, 1703, 1433, 1383, 1275, 1130, 1034, 943 cm^{-1}; spectroscopic data are in agreement with literature data.[3]



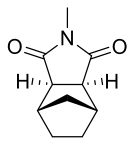
1c

***cis*-2-Methyltetrahydrocyclopenta[c]pyrrole-1,3(2*H*,3a*H*)-dione**; 91% (501 mg; starting from 500 mg of cyclopentane-1,2-dicarboximide); waxy solid; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 3.16 – 3.06 (m, 2H), 2.90 (s, 3H), 2.09 (dd, *J* = 6.1, 1.6 Hz, 1H), 2.06 (dd, *J* = 6.2, 1.7 Hz, 1H), 1.87 – 1.76 (m, 2H), 1.76 – 1.64 (m, 1H), 1.24 (tq, *J* = 12.3, 5.9 Hz, 1H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 180.4, 45.2, 30.3, 24.9, 24.7 ppm; HRMS (ESI-TOF) *m/z* calc for $C_8H_{12}NO_2$ [M+H$^+$] 154.0868. Found 154.0866; IR (film, CH_2Cl_2) *v*: 3455, 2959, 2874, 1773, 1697, 1433, 1383, 1281, 1086, 1028, 957, 820, 586 cm^{-1}.



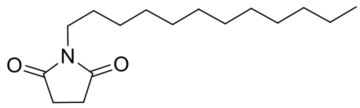
1d

***cis*-2-Methyl-3a,4,7,7a-tetrahydro-1H-isoindole-1,3(2*H*)-dione**; 96% (525 mg; starting from 500 mg of cis-3a,4,7,7a-tetrahydro-1H-isoindole-1,3(2*H*)-dione); yellow solid; m.p. 73-74 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 5.91 – 5.82 (m, 2H), 3.09 – 3.05 (m, 2H), 2.94 (s, 3H), 2.63 – 2.59 (m, 1H), 2.58 – 2.55 (m, 1H), 2.26 – 2.23 (m, 1H), 2.22 – 2.19 (m, 1H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 180.2, 127.7, 39.1, 24.9, 23.5 ppm; HRMS (ESI-TOF) *m/z* calc for $C_9H_{12}NO_2$ [M+H$^+$] 166.0868. Found 166.0869; IR (film, CH_2Cl_2) *v*: 3441, 3040, 2951, 1767, 1690, 1445, 1385, 1323, 1285, 1126, 1022, 941, 768, 698, 652, 592 cm^{-1}; spectroscopic data are in agreement with literature data.[4]



1e

(3a*R,4*S**,7*R**,7a*S**)-2-Methylhexahydro-1*H*-4,7-methanoisoindole-1,3(2*H*)-dione**; 94% (509 mg starting from 500 mg of *exo*-2,3-norbornanedicarboximide; yellow solid; m.p. 72-73 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 2.93 (s, 3H), 2.70 – 2.65 (m, 2H), 2.61 – 2.57 (m, 2H), 1.68 – 1.60 (m, 2H), 1.34 (dd, *J* = 6.3, 2.3 Hz, 1H), 1.32 – 1.29 (m, 1H), 1.19 (dt, *J* = 11.0, 1.5 Hz, 1H), 1.06 (dp, *J* = 11.0, 2.0 Hz, 1H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 179.0, 48.8, 39.7, 33.2, 28.0, 24.6 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{10}H_{14}NO_2$ [M+H$^+$] 180.1025. Found 180.1024; IR (film, CH_2Cl_2) *v*: 2961, 2876, 1770, 1696, 1432, 1382, 1283, 1137, 981, 800, 775, 648, 596 cm^{-1}.



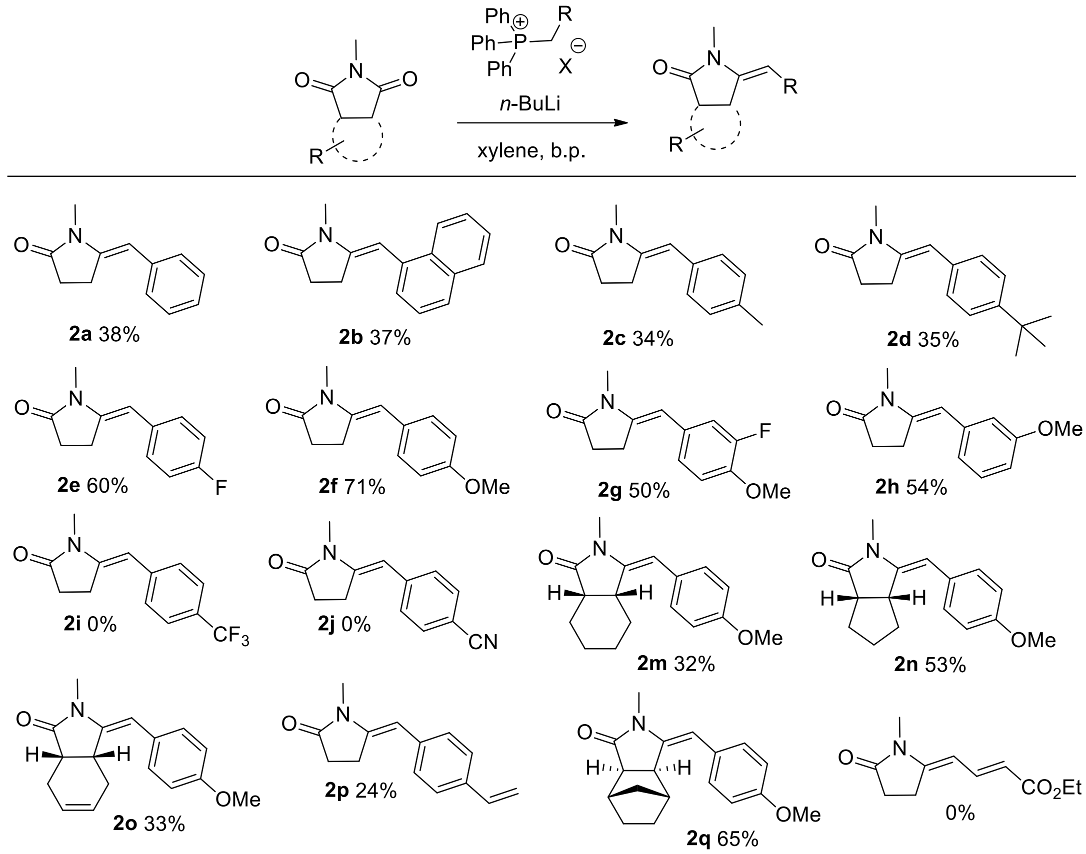
1f

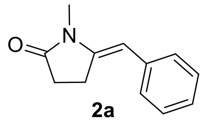
1-Dodecylpyrrolidine-2,5-dione; 25% (338 mg; starting from 500 mg of succinimide); white solid; m.p. 74-75 °C; column chromatography (1:4 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 3.48 (t, *J* = 7.5 Hz, 2H), 2.70 – 2.64 (m, 4H), 1.59 – 1.49 (m, 2H), 1.34 – 1.14 (m, 18H), 0.87 (t, *J* = 6.1 Hz, 3H) ppm; ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 177.20, 38.90, 31.88, 29.58, 29.52, 29.45, 29.31, 29.13, 28.14, 27.70, 26.85, 22.65, 14.07 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{30}NO_2$ [M+H$^+$] 268.2277. Found 268.2282; IR (film, CH_2C_{l2}) *v*: 2916, 2847, 1692, 1414, 1346, 1136, 820, 671 cm^{-1}.

General procedure for the synthesis of enamides 2a-h, 2m-q *via* Wittig olefination.

Compounds **2a-h**, **2m-q** were prepared according to the literature procedure with small modification.[5] Reactions were performed in sealed tube. To a solution of phosphonium salt (2.25 mmol, 1.5 equiv.) in dry xylenes (12 mL) *n*-BuLi solution (2.5M in hexanes)(2.25 mmol, 0.9 mL, 1.5 equiv.), wad added dropwise under argon at room temperature. The blood red solution was stirred for 30 min at the same temperature. Then, *N*-substituted imide (1.8 mmol) was added, and the mixture was reflux for 24-48 hours (TLC monitoring). After complete conversion of substrate, the reaction was cool down to room temperature, Et_2O (10 mL) was added and the precipitate formed (mainly triphenylphosphine oxide), was filtered. The filtrate cake was washed several time with Et_2O (5 mL). Combine filtrates were removed under diminished pressure. The residue was purified by column chromatography on silica gel to afford the corresponding adduct **2a-h**, **2m-q**. The configuration of alkenes **2a-h**, **2m-q** (E/Z) was establish by NOE experiment.

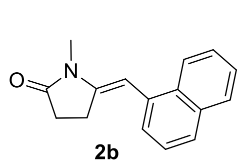
(The reaction proceeds well with aromatic phosphonium salts, especially containing EDG group, and does not undergo with aliphatic and aromatic EWG phosphonium salts.)





2a

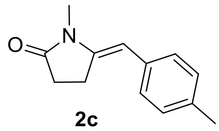
(5*E*)-5-Benzylidene-1-methylpyrrolidin-2-one; 38% (94 mg; starting from 150 mg of **1a** and 862 mg of benzyltriphenylphosphonium bromide); white solid; m.p. 99-100 °C; R*f* 0.47 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36 – 7.30 (m, 2H), 7.29 – 7.24 (m, 2H), 7.21 – 7.13 (m, 1H), 5.75 (s, 1H), 3.08 (s, 3H), 3.05 – 2.96 (m, 2H), 2.62 – 2.52 (m, 2H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.2, 143.2, 136.8, 128.5, 127.6, 125.5, 102.7, 29.1, 26.8, 23.8 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{12}H_{14}NO$ [M+H^{+}] 188.1075. Found 188.1080; IR (film, CH_2Cl_2) *v*: 3059, 3019, 2937, 1712, 1637, 1592, 1473, 1426, 1352, 1321, 1129, 939, 904, 846, 823, 748, 692, 601, 519, 501 cm^{-1}; spectroscopic data are in agreement with literature data.[5]



2b

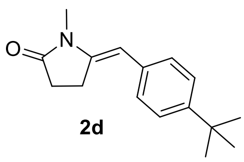
(5*E*)-1-Methyl-5-[(naphthalen-1-yl)methylidene]pyrrolidin-2-one; 37% (116 mg; starting from 150 mg of **1a** and 873 mg of 1-naphthylmethyltriphenylphosphonium chloride); white solid; m.p. 128-129 °C; R*f* 0.61 (2:1 AcOEt in hexanes); column chromatography (1:3 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07 – 8.00 (m, 1H), 7.89 – 7.84 (m, 1H), 7.77 – 7.72 (m, 1H), 7.55 – 7.48 (m, 2H), 7.48 – 7.43 (m, 1H), 7.41 – 7.37 (m, 1H), 6.21 (s, 1H), 3.18

(s, 3H), 2.83 – 2.76 (m, 2H), 2.53 – 2.46 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.6, 144.4, 133.8, 133.3, 132.1, 128.6, 126.8, 125.9, 125.9, 125.7, 125.4, 124.4, 99.2, 29.1, 26.9, 23.1 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{16}NO$ [M+H$^+$] 238.1232. Found 238.1236; IR (film, CH_2Cl_2) *v*: 3495, 3048, 2936, 1716, 1645, 1471, 1426, 1318, 1256, 1129, 933, 784, 673, 611 cm^{-1}.



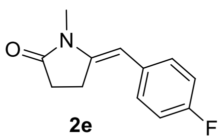
2c

(5*E*)-1-Methyl-5-[(4-methylphenyl)methylidene]pyrrolidin-2-one; 34% (91 mg; starting from 150 mg of **1a** and 890 mg of 4-methylbenzyl-triphenylphosphonium bromide); white solid; m.p. 83-84 °C; R*f* 0.45 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (500 MHz, Chloroform-*d*) δ 7.18 – 7.14 (m, 2H), 7.14 – 7.11 (m, 2H), 5.71 (s, 1H), 3.05 (s, 3H), 3.00 – 2.92 (m, 2H), 2.58 – 2.51 (m, 2H), 2.33 (s, 3H) ppm; $^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*) δ 175.1, 142.4, 135.0, 133.7, 129.1, 127.4, 102.5, 29.0, 26.7, 23.7, 20.9 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{16}NO$ [M+H$^+$] 202.1232. Found 202.1236; IR (film, CH_2Cl_2) *v*: 3020, 2922, 1711, 1646, 1470, 1424, 1317, 1129, 939, 844 cm^{-1}.



2d

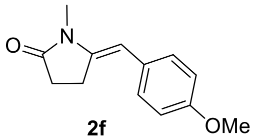
(5*E*)-5-[(4-tert-butylphenyl)methylidene]-1-methylpyrrolidin-2-one; 35% (112 mg; starting from 150 mg of **1a** and 974 mg of 4-(*t*-butyl)benzyl-triphenylphosphonium bromide); white solid; m.p. 133-135 °C; R*f* 0.63 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.38 – 7.32 (m, 2H), 7.24 – 7.18 (m, 2H), 5.73 (s, 1H), 3.07 (s, 3H), 3.04 – 2.98 (m, 2H), 2.65 – 2.52 (m, 2H), 1.32 (s, 9H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.2, 148.5, 142.6, 133.8, 127.3, 125.4, 102.5, 34.4, 31.3, 29.1, 26.8, 23.8 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{22}NO$ [M+H$^+$] 244.1701. Found 244.1702; IR (film, CH_2Cl_2) *v*: 3087, 3054, 2953, 2909, 2867, 1713, 1643, 1554, 1469, 1422, 1313, 1205, 1122, 1010, 939, 849, 812, 663, 557, 498 cm^{-1}.



2e

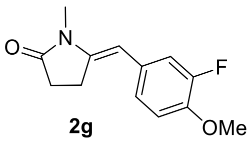
(5*E*)-5-[(4-Fluorophenyl)methylidene]-1-methylpyrrolidin-2-one; 60% (109 mg; starting from 100 mg of **1a** and 540 mg of 4-fluorobenzyl-triphenylphosphonium chloride); white solid; m.p. 102-103 °C; R*f* 0.43 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.23 – 7.18 (m, 2H), 7.04 – 6.97 (m, 2H), 5.70 (s, 1H), 3.06 (s, 3H), 3.00 – 2.91 (m, 2H), 2.64 – 2.52 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.1, 160.7 (d, *J* = 245.5 Hz), 143.0, 132.8 (d, *J* = 3.1 Hz), 129.0 (d, *J* = 7.7

Hz), 115.4 (d, J = 21.4 Hz), 101.6, 29.0, 26.8, 23.6 ppm; HRMS (ESI-TOF) m/z calc for $C_{12}H_{13}NOF$ [M+H$^+$] 206.0981. Found 206.0987; IR (film, CH_2Cl_2) v: 3038, 2942, 1709, 1646, 1508, 1470, 1422, 1319, 1226, 1129, 844 cm^{-1}.



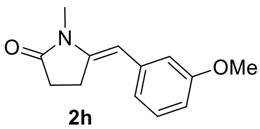
2f

(5*E*)-5-[(4-Methoxyphenyl)methylidene]-1-methylpyrrolidin-2-one; 71% (204 mg; starting from 150 mg of **1a** and 833 mg of 4-methoxybenzyl-triphenylphosphonium chloride); yellow solid; m.p. 72-73 °C; R*f* 0.39 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); NMR (400 MHz, Chloroform-*d*) δ 7.21 – 7.15 (m, 2H), 6.91 – 6.85 (m, 2H), 5.69 (s, 1H), 3.83 – 3.79 (m, 3H), 3.08 – 3.04 (m, 3H), 2.99 – 2.90 (m, 2H), 2.61 – 2.51 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.1, 157.5, 141.6, 129.3, 128.7, 114.0, 102.2, 55.3, 29.1, 26.8, 23.6 ppm; HRMS (ESI-TOF) m/z calc for $C_{13}H_{16}NO_2$ [M+H$^+$] 218.1181. Found 218.1182; IR (film, CH_2Cl_2) v: 3476, 2935, 2836, 1713, 1647, 1512, 1469, 1423, 1315, 1247, 1179, 1130, 1032, 938, 844 cm^{-1}.



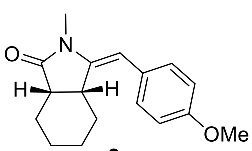
2g

(5*E*)-5-[(3-Fluoro-4-methoxyphenyl)methylidene]-1-methylpyrrolidin-2-one; 50% % (104 mg; starting from 100 mg of **1a** and 579 mg of 3-fluoro-4-methoxybenzyl-triphenylphosphonium chloride); yellow solid; m.p. 79-80 °C; R*f* 0.58 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.06 – 6.86 (m, 3H), 5.75 – 5.59 (m, 1H), 3.87 (s, 3H), 3.04 (s, 3H), 2.97 – 2.91 (m, 2H), 2.59 – 2.53 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.1, 152.3 (d, J = 244.9 Hz), 145.4 (d, J = 10.9 Hz), 142.7, 130.2 (d, J = 7.0 Hz), 123.5, 115.0 (d, J = 19.0 Hz), 113.7 (d, J = 2.5 Hz), 101.4, 56.4, 29.0, 26.8, 23.6 ppm; HRMS (ESI-TOF) m/z calc for $C_{13}H_{15}NO_2F$ [M+H$^+$] 236.1087. Found 236.1094; IR (film, CH_2Cl_2) v: 3488, 2938, 2841, 1717, 1648, 1517, 1469, 1424, 1316, 1281, 1222, 1124, 1026, 916 cm^{-1}.



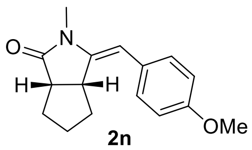
2h

(5*E*)-5-[(3-Methoxyphenyl)methylidene]-1-methylpyrrolidin-2-one; 54% (155 mg; starting from 150 mg of **1a** and 833 mg of 3-methoxybenzyl-triphenylphosphonium chloride); yellow solid; m.p. 136-137 °C; R*f* 0.41 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.29 (d, J = 7.4 Hz, 1H), 6.90 (d, J = 7.9 Hz, 0H), 6.85 (t, J = 2.1 Hz, 1H), 6.76 (dd, J = 7.5, 2.1 Hz, 1H), 5.76 (s, 1H), 3.85 (s, 3H), 3.11 (s, 3H), 3.05 (td, J = 7.6, 2.1 Hz, 2H), 2.66 – 2.57 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.3, 159.7, 143.6, 138.1, 129.4, 120.2, 113.5, 110.8, 102.6, 55.2, 29.1, 26.8, 23.9 ppm; HRMS (ESI-TOF) m/z calc for $C_{13}H_{16}NO_2$ [M+H$^+$] 218.1181. Found 218.1187; IR (film, CH_2Cl_2) v: 2983, 2935, 2829, 1709, 1636, 1598, 1467, 1426, 1327, 1289, 1160 ,1132, 1050, 957 cm^{-1}.



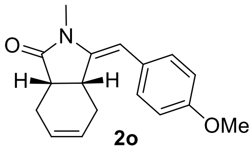
2m

(3a*S,7a*R**,*E*)-3-(4-Methoxybenzylidene)-2-methyloctahydro-1*H*-isoindol-1-one**; 32% (78 mg; starting from 150 mg of **1b** and 564 mg of 4-methoxybenzyl-triphenylphosphonium chloride); colorless oil; R*f* 0.58 (2:3 AcOEt in hexanes); column chromatography (1:4 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.24 – 7.19 (m, 2H), 6.88 – 6.85 (m, 2H), 5.66 (s, 1H), 3.80 (s, 3H), 3.36 – 3.26 (m, 1H), 3.04 (s, 3H), 2.69 – 2.61 (m, 1H), 2.31 – 2.24 (m, 1H), 2.01 – 1.95 (m, 1H), 1.63 – 1.56 (m, 2H), 1.55 – 1.46 (m, 1H), 1.21 – 1.12 (m, 2H), 1.09 – 0.98 (m, 1H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.6, 157.7, 146.1, 129.0, 128.8, 114.1, 102.3, 55.2, 40.9, 36.1, 28.6, 26.8, 23.4, 22.5, 22.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{17}H_{22}NO_2$ [M+H$^+$] 272.1651. Found 272.1652; IR (film, CH_2Cl_2) *v*: 3409, 2933, 2856, 1717, 1651, 1608, 1512, 1425, 1305, 1281, 1250, 1178, 1121, 1034, 940, 845, 563, 531 cm^{-1}.



2n

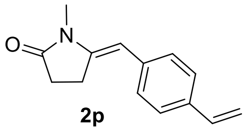
(3a*R,6a*S**,*E*)-3-(4-Methoxybenzylidene)-2-methylhexahydrocyclopenta[c]pyrrol-1(2*H*)-one**; 53% (134 mg; starting from 150 mg of **1c** and 615 mg of 4-methoxybenzyl-triphenylphosphonium chloride); waxy solid; R*f* 0.61 (2:3 AcOEt in hexanes); column chromatography (1:4 AcOEt in hexanes); ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.28 – 7.26 (m, 2H), 6.91 – 6.86 (m, 2H), 5.65 (d, *J* = 1.7 Hz, 1H), 3.82 (s, 3H), 3.72 – 3.68 (m, 1H), 3.07 (dd, *J* = 8.8, 2.2 Hz, 1H), 3.04 (s, 3H), 2.15 – 2.11 (m, 1H), 2.02 – 1.94 (m, 1H), 1.88 – 1.80 (m, 1H), 1.79 – 1.74 (m, 1H), 1.71 – 1.63 (m, 1H), 1.40 – 1.30 (m, 1H); ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 177.5, 157.5, 146.1, 129.1, 128.7, 114.0, 101.9, 55.3, 46.3, 40.0, 33.6, 30.6, 26.9, 25.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{20}NO_2$ [M+H$^+$] 258.1494. Found 258.1495; IR (film, CH_2Cl_2) *v*: 3454, 2958, 2871, 1772, 1699, 1644, 1603, 1511, 1432, 1383, 1281, 1250, 1168, 1087, 1029, 957, 844, 821, 773, 587 cm^{-1}.



2o

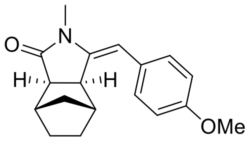
(3a*R,7a*S**,*E*)-3-(4-Methoxybenzylidene)-2-methyl-2,3,3a,4,7,7a-hexahydro-1*H*-isoindol-1-one**; 33% (109 mg; starting from 200 mg of **1e** and 761 mg of 4-methoxybenzyl-triphenylphosphonium chloride); yellow oil; R*f* 0.62 (1:1 AcOEt in hexanes); column chromatography (1:5 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.24 – 7.21 (m, 2H), 6.89 – 6.85 (m, 2H), 5.92 – 5.81 (m, 1H), 5.80 – 5.71 (m, 1H), 5.67 (s, 1H), 3.81 (s, 3H), 3.62 – 3.56 (m, 1H), 3.03 (s, 3H), 2.88 (td, *J* = 8.8, 8.4, 3.7 Hz, 1H), 2.61 – 2.53 (m, 1H), 2.33 –

2.22 (m, 2H), 1.98 – 1.89 (m, 1H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 176.6, 157.7, 146.3, 128.9, 128.8, 127.2, 126.7, 114.1, 102.0, 55.3, 39.5, 33.6, 26.9, 25.9, 22.5 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{17}H_{20}NO_2$ [M+H$^+$] 270.1494. Found 270.1497; IR (film, CH_2Cl_2) *v*: 3408, 3033, 2952, 2838, 1709, 1648, 1607, 1512, 1469, 1426, 1305, 1249, 1178, 1129, 1032, 848, 688, 580, 532 cm^{-1}.



2p

(5*E*)-5-[(4-Ethenylphenyl)methylidene]-1-methylpyrrolidin-2-one; 24% (45 mg; starting from 100 mg of **1a** and 550 mg of 4-vinylbenzyl-triphenylphosphonium chloride); yellow solid; m.p. 81-82 °C; R*f* 0.56 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.45 – 7.32 (m, 2H), 7.29 – 7.16 (m, 2H), 6.68 (dd, *J* = 17.6, 10.9 Hz, 1H), 5.80 – 5.66 (m, 2H), 5.21 (d, *J* = 10.9 Hz, 2H), 3.06 (s, 3H), 3.03 – 2.93 (m, 2H), 2.63 – 2.52 (m, 2H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 175.2, 143.4, 136.4, 134.7, 127.6, 126.4, 113.2, 102.5, 29.1, 26.8, 23.9 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{16}NO$ [M+H$^+$] 214.1232. Found 214.1238; IR (film, CH_2Cl_2) *v*: 3430, 2934, 1718, 1643, 1602, 1469, 1424, 1317, 1130, 938, 855, 671, 503 cm^{-1}.



2q

(3a*R,4*S**,7*R**,7a*S**,*E*)-3-(4-Methoxybenzylidene)-2-methyloctahydro-1*H*-4,7-methanoisoindol-1-one**; 65% (206 mg; starting from 200 mg of **1e** and 701 mg of 4-methoxybenzyl-triphenylphosphonium chloride); waxy solid; R*f* 0.48 (1:2 AcOEt in hexanes); column chromatography (1:4 AcOEt in hexanes); ^1H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.22 (m, 2H), 6.90 – 6.78 (m, 2H), 5.60 (s, 1H), 3.80 (s, 3H), 3.17 (d, *J* = 7.9 Hz, 1H), 2.99 (s, 3H), 2.64 (d, *J* = 4.1 Hz, 1H), 2.53 (d, *J* = 7.8 Hz, 1H), 2.40 (d, *J* = 4.1 Hz, 1H), 1.60 (dd, *J* = 7.4, 4.3 Hz, 0H), 1.54 (dd, *J* = 8.1, 4.2 Hz, 0H), 1.37 – 1.29 (m, 2H), 1.16 – 1.11 (m, 1H), 1.09 – 1.03 (m, 1H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 176.4, 157.4, 144.5, 129.1, 128.8, 114.0, 102.2, 55.2, 49.8, 44.1, 40.4, 40.3, 33.2, 28.1, 28.1, 26.6 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{18}H_{21}NNaO_2$ [M+Na$^+$] 306.1470. Found 306.1465; IR (film, CH_2Cl_2) *v*: 3450, 2958, 2876, 1769, 1695, 1642, 1603, 1512, 1432, 1383, 1284, 1250, 1170, 1135, 1028, 982, 930, 847, 799, 774, 648, 597 cm^{-1}.

General procedure for the synthesis of enamides 2i-l *via* samarium diiodide-mediated coupling of organic halides with *N*-substituted imides.

Compounds **2i-l** were prepared according to the literature procedure with small modification.[6] Reactions were performed in glove box under nitrogen. To a solution of SmI_2

(0.1M in THF)(22.1 mL, 2.5 equiv.) NiI_2 (2.8 mg; 1 mol%), organic halide (1.1 mmol, 1.25 equiv.) and *N*-substituted imide (0.89 mmol, 1.0 equiv.) were added sequentially in room temperature. The reaction was stirred until navy blue solution turn to yellow (ca. 15 min). After complete conversion of substrate (TLC monitoring) the reaction was quenched with HCl (0.5 M)(10 mL) and then diluted with Et_2O (20 mL). After phase separation, the aqua layer was washed with Et_2O (3x10 mL). Combined organic layers were dried over Na_2SO_4, filtered and solvent was removed under diminished pressure. The residue was purified by column chromatography on silica gel to give the corresponding product **2i-l**.

(*The reaction proceeds well with aromatic and aliphatic halides, however the reaction yield is highly dependent on the quality of the samarium diiodide solution. We strongly recommended using a freshly prepared samarium diiodide solution.*)

star reaction

after 15 min

Preparation of 0.1 M samarium diiodide solution.

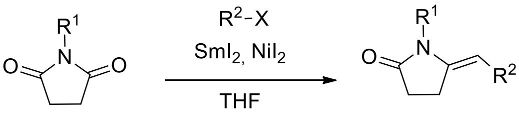
Reaction was performed in glove box under nitrogen. To the freshly grated samarium (samarium rod; Alfa Aesar 40298)(1.24 g) degassed THF (20 mL) and iodine (1.28 g) were added sequentially in room temperature, and the mixture was stirred until navy blue solution appears.

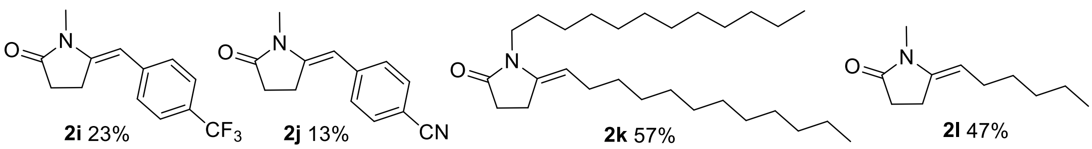
Samarium rod

start of the reaction

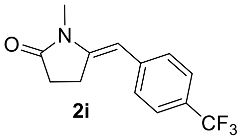
after 10 min

after 30 min
ready for use



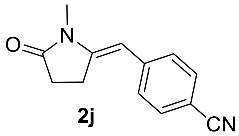


2i 23% **2j** 13% **2k** 57% **2l** 47%



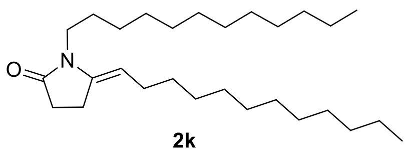
2i

(5*E*)-1-Methyl-5-{[4-(trifluoromethyl)phenyl]methylidene}pyrrolidin-2-one; 23% (78 mg; starting from 150 mg of **1a** and 396 mg of 4-(trifluoromethyl)benzyl bromide; yellow solid; m.p. 96-97 °C; R*f* 0.65 (2:1 AcOEt in hexanes); column chromatography (1:2 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.62 – 7.52 (m, 2H), 7.45 – 7.29 (m, 2H), 5.78 – 5.74 (m, 1H), 3.08 (s, 3H), 3.04 – 2.98 (m, 2H), 2.63 – 2.55 (m, 2H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.2, 145.5, 140.5, 127.5, 125.4 (q, *J* = 3.8 Hz), 101.5, 28.8, 26.9, 24.0 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{13}NOF_3$ [M+H$^+$] 256.0949. Found 256.0956; IR (film, CH_2Cl_2) *v*: 2963, 2939, 1715, 1642, 1610, 1472, 1424, 1323, 1196, 1157, 1117, 1067, 1011, 939, 857, 824, 672, 597, 513 cm^{-1}.



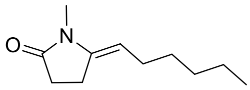
2j

4-[(*E*)-(1-Methyl-5-oxopyrrolidin-2-ylidene)methyl]benzonitrile; 13% (37 mg; starting from 150 mg of **1a** and 325 mg of 4-(bromomethyl)benzonitrile; yellow solid; m.p. 167-168 °C; R*f* 0.58 (2:1 AcOEt in hexanes); column chromatography (1:1 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.62 – 7.55 (m, 2H), 7.38 – 7.28 (m, 2H), 5.73 (s, 1H), 3.08 (s, 3H), 3.05 – 2.97 (m, 2H), 2.67 – 2.57 (m, 2H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.2, 146.7, 141.8, 132.3, 127.7, 119.1, 108.3, 101.4, 28.8, 26.9, 24.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{13}N_2O$ [M+H$^+$] 213.1028. Found 213.1031; IR (film, CH_2Cl_2) *v*: 2938, 2217, 1712, 1638, 1596, 1466, 1423, 1322, 1174, 1132, 939, 860, 688, 552 cm^{-1}.



2k

(*E*)-1-Dodecyl-5-dodecylidenepyrrolidin-2-one; 57% (135 mg; starting from 150 mg of **1f** and 173 µL of 1-iodododecane; waxy solid; R*f* 0.51 (1:3 AcOEt in hexanes); column chromatography (1:9 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 4.66 – 4.57 (m, 1H), 3.45 – 3.37 (m, 2H), 2.61 – 2.56 (m, 2H), 2.49 – 2.42 (m, 2H), 2.04 – 1.94 (m, 2H), 1.55 – 1.48 (m, 2H), 1.39 – 1.34 (m, 2H), 1.33 – 1.19 (m, 35H), 0.90 – 0.84 (m, 6H) ppm; ^{13}C{^{1}H} NMR (151 MHz, Chloroform-*d*) δ 175.4, 139.0, 100.9, 39.9, 32.0, 30.2, 29.64, 29.63, 29.61, 29.60, 29.58, 29.57, 29.52, 29.51, 29.32, 29.30, 29.21, 28.9, 27.0, 26.7, 26.5, 22.7, 21.3, 14.1 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{28}H_{54}NO$ [M+H$^+$] 420.4205. Found 420.4210; IR (film, CH_2Cl_2) *v*: 3324, 2924, 2853, 1703, 1670, 1465, 1414, 1357, 1176, 1128, 1082, 721, 666 cm^{-1}.

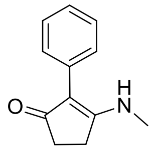


2l

(5*E*)-5-Hexylidene-1-methylpyrrolidin-2-one; 47% (112 mg; starting from 150 mg of **1a** and 245 µL of 1-iodohexane; colorless liquid; R*f* 0.75 (2:1 AcOEt in hexanes); column chromatography (1:2 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 4.64 – 4.57 (m, 1H), 2.89 (s, 3H), 2.64 – 2.57 (m, 2H), 2.50 – 2.43 (m, 2H), 2.06 – 1.94 (m, 2H), 1.41 – 1.23 (m, 9H), 0.88 (t, *J* = 6.8 Hz, 3H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.4, 140.4, 100.8, 31.4, 29.9, 29.0, 26.6, 26.4, 22.5, 21.2, 14.0 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{11}H_{20}NO$ [M+H$^+$] 182.1545. Found 182.1548; IR (film, CH_2Cl_2) *v*: 3348, 2953, 2929, 2858, 1674, 1457, 1423, 1399, 1307, 1282, 1177, 1119, 1074, 953, 797, 726, 671 cm^{-1}.

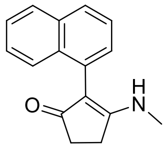
Photochemical Fries-type rearrangement of enamides 2a-r. General procedure for the synthesis of enaminones 3a-o.

The reaction was prepared in glove box. To the quartz vial containing substrate **2a-r** (0.11 mmol) degassed MeOH (8 mL) was added. The vial was sealed with a septum (wrapped with aluminum foil) and transferred to a photoreactor. The reaction was irradiated with eight UV-C lamps (9W, 254 nm) at internal temperature 25-35 °C until complete conversion of substrate (24-48 h). After evaporation of the solvent, in most cases pure product was resaved.



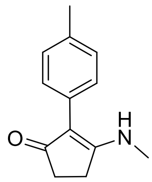
3a

3-(Methylamino)-2-phenylcyclopent-2-en-1-one; quant. yield (starting from 20 mg of **2a**, 21 h irradiation); without chromatography; white solid; m.p. 99-100 °C; ^{1}H NMR (500 MHz, Benzene-*d*$_6$) δ 7.59 (d, *J* = 7.8 Hz, 2H), 7.29 (t, *J* = 7.6 Hz, 2H), 7.09 (t, *J* = 7.4 Hz, 1H), 4.93 – 4.70 (m, 1H), 2.19 – 2.14 (m, 2H), 1.90 (d, *J* = 5.1 Hz, 3H), 1.70 – 1.64 (m, 2H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 175.2, 143.2, 136.8, 128.5, 127.6, 125.5, 102.7, 29.1, 26.8, 23.8 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{12}H_{14}NO$ [M+H$^+$] 188.1075. Found 188.1080; IR (film, CH_2Cl_2) *v*: 3059, 3019, 2937, 1712, 1637, 1592, 1473, 1426, 1352, 1321, 1129, 939, 904, 846, 823, 748, 692, 601, 519, 501 cm^{-1}.



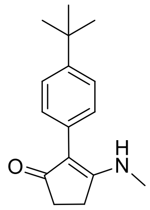
3b

3-(Methylamino)-2-(naphthalen-1-yl)cyclopent-2-en-1-one; quant. yield (starting from 22 mg of **2b**, 46 h irradiation); without chromatography; waxy solid; ^{1}H NMR (500 MHz, Benzene-*d*$_6$) δ 7.86 – 7.80 (m, 1H), 7.81 – 7.75 (m, 1H), 7.67 – 7.62 (m, 1H), 7.50 – 7.38 (m, 4H), 7.33 – 7.28 (m, 1H), 5.01 (s, 1H), 2.83 (s, 3H), 2.79 – 2.70 (m, 2H), 2.68 – 2.51 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 200.3, 174.8, 134.1, 131.5, 129.7, 128.4, 128.3, 127.7, 125.8, 125.7, 125.6, 112.2, 33.4, 30.0, 24.6 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{16}NO$ [M+H$^+$] 238.1232. Found 238.1237; IR (film, CH_2Cl_2) *v*: 3385, 3265, 3049, 2926, 1565, 1398, 1316, 1257, 1219, 1147, 1061, 1015, 916, 801, 779, 732, 695, 663, 612, 582, 533, 420 cm^{-1}.



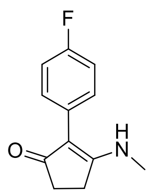
3c

3-(Methylamino)-2-(4-methylphenyl)cyclopent-2-en-1-one; quant. yield (starting from 20 mg of **2c**, 18 h irradiation); without chromatography; brown solid; m.p. 119-120 °C; ^{1}H NMR (500 MHz, Benzene-*d*$_6$) δ 7.56 – 7.50 (m, 2H), 7.16 – 7.11 (m, 2H), 5.19 – 5.06 (m, 1H), 2.17 (s, 3H), 2.18 – 2.12 (m, 2H), 2.01 (d, *J* = 5.1 Hz, 3H), 1.76 – 1.69 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Benzene-*d*$_6$) δ 193.9, 167.1, 130.5, 126.2, 124.5, 123.8, 107.7, 28.4, 24.4, 19.1, 16.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{15}NONa$ [M+Na$^+$] 22.1051. Found 224.1046; IR (film, CH_2Cl_2) *v*: 3272, 2923, 1577, 1519, 1389, 1327, 1303 cm^{-1}.



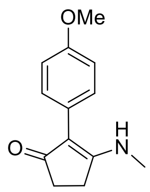
3d

2-(4-*tert*-Butylphenyl)-3-(methylamino)cyclopent-2-en-1-one; quant. yield (starting from 20 mg of **2d**, 24 h irradiation); without chromatography; yellow solid; m.p. 196-197 °C; ^{1}H NMR (500 MHz, Methanol-d_4) δ 7.46 – 7.40 (m, 2H), 7.25 – 7.17 (m, 2H), 2.97 (s, 3H), 2.81 – 2.74 (m, 2H), 2.52 – 2.45 (m, 2H), 1.32 (s, 9H) ppm; $^{13}C\{^{1}H\}$ NMR (126 MHz, Methanol-d_4) δ 202.6, 179.1, 150.5, 130.6, 129.8, 126.6, 113.4, 35.3, 34.1, 31.8, 30.5, 25.6 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{22}NO$ [M+H^{+}] 244.1701. Found 244.1702; IR (film, CH_2Cl_2) *v*: 3274, 2958, 2867, 1658, 1569, 1517, 1462, 1402, 1328, 1305, 1269, 1141, 1107, 836, 678 cm^{-1}.



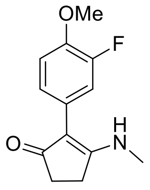
3e

2-(4-Fluorophenyl)-3-(methylamino)cyclopent-2-en-1-one; quant. yield (starting from 22 mg of **2e**, 23 h irradiation); without chromatography; Brown oil; ^{1}H NMR (500 MHz, Methanol-d_4) δ 7.34 – 7.25 (m, 2H), 7.14 – 7.06 (m, 2H), 2.99 (s, 3H), 2.81 – 2.77 (m, 2H), 2.51 – 2.45 (m, 2H) ppm; $^{13}C\{^{1}H\}$ NMR (126 MHz, Chloroform-*d*) δ 202.5, 179.1, 162.9 (d, *J* = 244.1 Hz), 132.0 (d, *J* = 8.0 Hz), 129.7, 116.33 (d, *J* = 21.6 Hz), 112.4, 34.0, 30.5, 25.7 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{12}H_{13}NOF$ [M+H^{+}] 206.0981. Found 206.0986; IR (film, CH_2Cl_2) *v*: 3270, 2927, 1573, 1516, 1389, 1324, 1295, 1218, 1158, 839, 811, 685, 638, 557, 512 cm^{-1}.



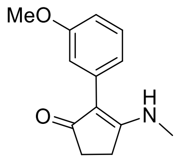
3f

2-(4-Methoxyphenyl)-3-(methylamino)cyclopent-2-en-1-one; quant. yield (starting from 20 mg of **2f**, 18 h irradiation); without chromatography; orange solid; m.p. 126-127 °C; ^{1}H NMR (500 MHz, Benzene-d_6) δ 7.56 – 7.51 (m, 2H), 6.96 – 6.90 (m, 2H), 5.25 – 5.15 (m, 1H), 3.38 (s, 3H), 2.20 – 2.14 (m, 2H), 2.07 (d, *J* = 5.0 Hz, 3H), 1.84 – 1.75 (m, 2H) ppm; $^{13}C\{^{1}H\}$ NMR (126 MHz, Benzene-d_6) δ 199.1, 172.1, 158.4, 130.1, 126.3, 114.4, 112.5, 54.8, 33.4, 29.5, 24.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{16}NO_2$ [M+H^{+}] 218.1181. Found 218.1189; IR (film, CH_2Cl_2) *v*: 3274, 2929, 1574, 1518, 1464, 1389, 1329, 1288, 1244, 1178, 1032 cm^{-1}.



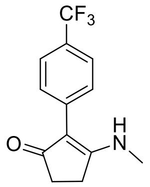
3g

2-(3-Fluoro-4-methoxyphenyl)-3-(methylamino)cyclopent-2-en-1-one; 97% (starting from 22 mg of **2g**, 23 h irradiation); without chromatography; brown oil; ^{1}H NMR (500 MHz, Methanol-d_4) δ 7.11 – 6.97 (m, 3H), 3.84 (s, 3H), 2.96 (s, 3H), 2.78 – 2.72 (m, 2H), 2.48 – 2.42 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 200.2, 173.9, 152.6 (d, *J* = 245.7 Hz), 146.1 (d, *J* = 10.8 Hz), 125.6 (d, *J* = 7.1 Hz), 124.4, 116.1 (d, *J* = 18.5 Hz), 114.0, 111.8 (d, *J* = 1.7 Hz), 56.4, 33.1, 30.3, 24.5 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{15}NO_2F$ [M+H$^+$] 236.1087. Found 236.1087; IR (film, CH_2Cl_2) *v*: 3277, 2934, 1651, 1577, 1520, 1464, 1386, 1328, 1301, 1268, 1247, 1115, 1026, 759, 688 cm^{-1}.



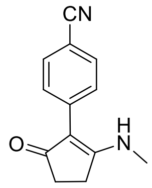
3h

2-(3-Methoxyphenyl)-3-(methylamino)cyclopent-2-en-1-one; quant. yield (starting from 20 mg of **2h**, 23 h irradiation); without chromatography; brown oil; ^{1}H NMR (500 MHz, Benzene-d_6) δ 7.40 – 7.36 (m, 1H), 7.26 – 7.20 (m, 1H), 7.19 – 7.16 (m, 1H), 6.80 – 6.70 (m, 1H), 5.27 – 5.11 (m, 1H), 3.45 (s, 3H), 2.18 – 2.12 (m, 2H), 1.97 (d, *J* = 5.2 Hz, 3H), 1.74 – 1.66 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Benzene-d_6) δ 198.7, 172.4, 160.6, 135.5, 129.7, 120.8, 114.5, 112.5, 112.1, 54.8, 33.4, 29.4, 24.0 ppm; HRMS (EI) *m/z* calc for $C_{13}H_{15}NO_2$ 217.1103. Found 217.1107; IR (film, CH_2Cl_2) *v*: 3276, 2926, 1578, 1499, 1466, 1391, 1327, 1282, 1237, 1043, 819, 785, 704 cm^{-1}.



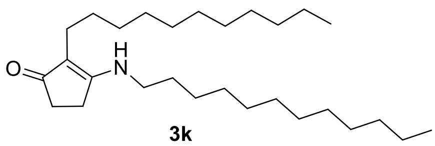
3i

3-(Methylamino)-2-[4-(trifluoromethyl)phenyl]cyclopent-2-en-1-one; 92% (starting from 25 mg of **2i**, 48 h irradiation, conversion 94% determined by ^{1}H-NMR); column chromatography (2,5 % MeOH in DCM); waxy solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.65 – 7.60 (m, 2H), 7.54 – 7.43 (m, 2H), 5.83 (s, 1H), 3.01 (s, 3H), 2.73 – 2.65 (m, 2H), 2.53 – 2.43 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 200.0, 174.2, 136.5, 130.6, 128.4, 128.1 (q, *J* = 32.4 Hz), 125.7, 111.6, 33.2, 30.3, 24.6 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{13}NOF_3$ [M+H$^+$] 256.0949. Found 256.0951; IR (film, CH_2Cl_2) *v*: 3272, 2930, 1576, 1522, 1392, 1324, 1162, 1113, 1066, 1017, 922, 845, 736, 703, 672, 615, 601 cm^{-1}.



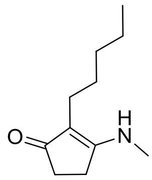
3j

4-[2-(Methylamino)-5-oxocyclopent-1-en-1-yl]benzonitrile; 87% (starting from 22 mg of **2j**, 48 h irradiation, conversion 90% determined by ^{1}H-NMR); column chromatography (2,5 % MeOH in DCM); Brown solid; 149-150 °C; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.65 – 7.60 (m, 2H), 7.54 – 7.49 (m, 2H), 5.97 (s, 1H), 3.05 (s, 3H), 2.74 – 2.68 (m, 2H), 2.54 – 2.46 (m, 2H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 199.7, 174.5, 137.9, 132.5, 128.5, 119.1, 111.0, 109.2, 33.2, 30.4, 24.7 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{13}H_{13}N_2O$ [M+H$^+$] 213.1028. Found 213.1033; IR (film, CH_2Cl_2) *v*: 3279, 2926, 2222, 1717, 1639, 1598, 1579, 1515, 1329, 1324, 1301, 1133, 735, 681, 552 cm^{-1}.



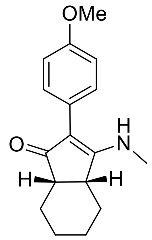
3k

3-(Dodecylamino)-2-undecylcyclopent-2-enone; quant. yield (starting from 20 mg of **2k**, 20 h irradiation); without chromatography; Waxy solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 4.82 (t, *J* = 6.0 Hz, 1H), 3.32 – 3.23 (m, 2H), 2.56 – 2.49 (m, 2H), 2.41 – 2.34 (m, 2H), 2.13 – 2.00 (m, 2H), 1.66 – 1.54 (m, 2H), 1.34 – 1.22 (m, 36H), 0.92 – 0.84 (m, 6H) ppm; ^{13}C{^{1}H} NMR (126 MHz Chloroform-*d*) δ 202.1, 172.7, 112.8, 43.7, 32.9, 31.88, 31.86, 30.8, 29.8, 29.65, 29.64, 29.62, 29.61, 29.59, 29.57, 29.52, 29.48, 29.31, 29.29, 29.25, 28.1, 26.7, 22.64, 22.63, 21.7, 14.1 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{28}H_{54}NO$ [M+H$^+$] 420.4205. Found 420.4209; IR (film, CH_2Cl_2) *v*: 3184, 3109, 2932, 2851, 1607, 1516, 1434, 1364, 1301, 1170, 1125, 1079, 807, 721, 664, 566 cm^{-1}.



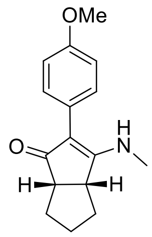
3l

3-(Methylamino)-2-pentylcyclopent-2-en-1-one; 85% (starting from 27 mg of **2l**, 22 h irradiation); column chromatography (2,5 % MeOH in DCM); waxy solid; ^{1}H NMR (500 MHz, Benzene-d_6) δ 5.37 – 5.27 (m, 1H), 2.38 – 2.28 (m, 5H), 2.23 – 2.16 (m, 2H), 1.88 – 1.81 (m, 2H), 1.61 (p, *J* = 7.3 Hz, 2H), 1.47 – 1.35 (m, 4H), 0.94 (t, *J* = 6.9 Hz, 3H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Benzene-d_6) δ 200.9, 172.5, 112.8, 33.2, 32.4, 29.7, 28.6, 24.5, 23.2, 22.3, 14.4 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{11}H_{20}NO$ [M+H$^+$] 182.1545. Found 182.1552; IR (film, CH_2Cl_2) *v*: 3267, 2927, 2856, 1566, 1470, 1395, 1281, 1198, 1173, 1116, 1070, 999, 830, 725, 661 cm^{-1}.



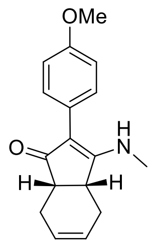
3m

(3a*S,7a*R**)-2-(4-Methoxyphenyl)-3-(methylamino)-3a,4,5,6,7,7a-hexahydro-1*H*-inden-1-one**; 65% (starting from 27 mg of **2m**, 69 h irradiation); column chromatography (6:1 AcOEt:hexanes); Yellow solid; m.p. 163-164 °C; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.28 – 7.23 (m, 2H), 6.94 – 6.89 (m, 2H), 5.43 (s, 1H), 3.79 (s, 3H), 2.97 (s, 4H), 2.67 – 2.58 (m, 1H), 2.25 – 2.10 (m, 2H), 1.72 – 1.51 (m, 3H), 1.41 – 1.23 (m, 3H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 201.6, 176.3, 158.0, 129.9, 125.2, 114.2, 110.3, 55.3, 44.3, 36.7, 30.7, 28.6, 22.3, 22.1, 21.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{17}H_{22}NO_2$ [M+H$^+$] 272.1651. Found 272.1654; IR (film, CH_2Cl_2) *v*: 3270, 2932, 2865, 1658, 1567, 1516, 1460, 1375, 1285, 1243, 1177, 1034, 817, 734, 577, 550, 524 cm^{-1}.



3n

(3a*R,6a*S**)-2-(4-Methoxyphenyl)-3-(methylamino)-4,5,6,6a-tetrahydropentalen-1(3a*H*)-one**; 68% (starting from 20 mg of **2n**, 120 h irradiation); column chromatography (6:1 AcOEt:hexanes); Colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.32 – 7.20 (m, 2H), 7.02 – 6.86 (m, 2H), 5.49 (s, 1H), 3.78 (s, 3H), 3.33 – 3.21 (m, 1H), 3.01 (s, 3H), 2.96 – 2.87 (m, 1H), 2.08 – 2.02 (m, 1H), 1.90 – 1.83 (m, 1H), 1.82 – 1.75 (m, 1H), 1.74 – 1.62 (m, 2H), 1.54 – 1.43 (m, 1H) ppm; ^{13}C{^{1}H} NMR (126 MHz, Chloroform-*d*) δ 202.3, 175.0, 158.1, 129.7, 124.9, 114.3, 113.0, 55.2, 50.3, 41.2, 30.8, 30.0, 29.4, 24.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{16}H_{20}NO_2$ [M+H$^+$] 258.1494. Found 258.1501; IR (film, CH_2Cl_2) *v*: 3271, 2951, 1570, 1516, 1462, 1389, 1339, 1287, 1244, 1177, 1034, 829, 806, 573 cm^{-1}.

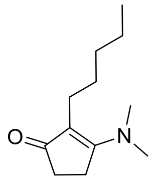


3o

(3a*R,7a*S**)-2-(4-Methoxyphenyl)-3-(methylamino)-3a,4,7,7a-tetrahydro-1*H*-inden-1-one**; 53% (starting from 20 mg of **2o**, 42 h irradiation); column chromatography (6:1 AcOEt:hexanes); white solid; m.p. 166-167 °C; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.26 –

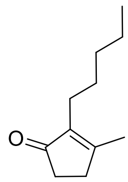
7.23 (m, 2H), 6.95 – 6.89 (m, 2H), 5.97 (dt, *J* = 9.9, 5.0 Hz, 1H), 5.82 (dt, *J* = 9.7, 5.0 Hz, 1H), 5.38 (s, 1H), 3.80 (s, 3H), 3.22 – 3.13 (m, 1H), 2.99 (s, 3H), 2.76 (td, *J* = 7.4, 4.7 Hz, 1H), 2.59 – 2.42 (m, 2H), 2.37 – 2.28 (m, 1H), 2.14 (dt, *J* = 15.4, 5.4 Hz, 1H) ppm; $^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*) δ 201.7, 174.8, 158.2, 130.0, 129.2, 125.7, 124.9, 114.2, 113.3, 55.3, 43.4, 36.4, 31.0, 26.2, 24.2 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{17}H_{20}NO_2$ [M+H$^+$] 270.1494. Found 270.1491; IR (film, CH_2Cl_2) *v*: 3271, 3036, 2937, 2836, 1565, 1515, 1461, 1373, 1286, 1244, 1176, 1138, 1107, 1033, 828, 686, 597 cm^{-1}.

Synthesis of Dihydrojasmone:



4

3-(Dimethylamino)-2-pentylcyclopent-2-en-1-one. To a solution of **3o** (94 mg; 0.52 mmol, crude product) in dry THF (2.5 mL), NaH (60% in mineral oil)(31 mg, 0.78 mmol; 1.5 eqiuv.) was added in portion under argon at room temperature. The mixture was stirred for 1 h at the same temperature, and then methyl iodide (65 µL, 1.04 mmol, 2.0 equiv.) was added dropwise. The reaction was stirred for overnight. After complete conversion of substrate (TLC monitoring) the reaction was quenched with H_2O (2 mL) and then diluted with Et_2O (2 mL). After phase separation, the aqua layer was washed with Et_2O (3x3 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4 and filtered. The filtrate was concentrated under reduced pressure to give the crude product, which was purified by silica gel column chromatography (100% AcOEt than 5:95 MeOH in DCM); to afford 79 mg (76%, after two steps) of **4** as a brown oil. Rf = 0.38 (5:95 MeOH in DCM); ^1H NMR (400 MHz, Chloroform-*d*) δ 3.12 (s, 6H), 2.52 – 2.48 (m, 2H), 2.36 – 2.31 (m, 4H), 1.38 – 1.27 (m, 6H), 0.91 – 0.83 (m, 3H) ppm; $^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*) δ 203.7, 172.0, 113.4, 40.8, 32.7, 31.9, 31.1, 27.8, 23.9, 22.6, 14.1 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{22}H_{22}NO$ [M+H$^+$] 196.1701. Found 196.1700; IR (film, CH_2Cl_2) *v*: 3435, 2954, 2926, 2858, 1659, 1571, 1397, 1339, 1120, 881, 671.



dihydrojasmone

3-Methyl-2-pentylcyclopent-2-en-1-one (dihydrojasmone). The Grignard reagent addition to cyclic enaminone was performed according to the literature procedure.[7] To a cooled to 0 °C solution of **4** (50 mg, 0.256 mmol) in dry THF (1 mL) MeMgBr (3.0 M in Et_2O)(256 µL, 0.769 mmol, 3.0 equiv.) was added dropwise under argon. The reaction was warmed to room temperature and stirred overnight. After complete conversion of substrate (TLC monitoring), the reaction was diluted with Et_2O (2 mL), quenched with 1M aq. solution of HCl (2 mL) and stirred for 15 min. Then, the mixture was neutralised with 2M solution of NaOH in 80% saturated aq. solution of brine. After phase separation, the aqua layer was washed with Et_2O (3x5 mL), dried over Na_2SO_4 and filtered. The filtrate was concentrated under reduced pressure to give the crude product, which was purified by silica gel column chromatography (1:4 AcOEt in hexanes); to afford 15 mg (35%) of dihydrolasmone as a coroless liquid. Rf = 0.67 (2:1 AcOEt in hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 2.51 – 2.45 (m, 2H), 2.38 – 2.32 (m, 2H), 2.16 (t, *J* = 7.7 Hz, 2H), 2.04 (s, 3H), 1.40 – 1.22 (m, 6H), 0.87 (t, *J* = 7.0 Hz, 3H) ppm; ^{13}C{^{1}H} NMR (101 MHz, Chloroform-*d*) δ 209.6, 169.8, 140.8, 34.3, 31.8, 31.5, 28.1, 23.0, 22.5, 17.2, 14.0 ppm; HRMS (ESI-TOF) *m/z* calc for $C_{11}H_{19}O$ [M+H$^+$] 167.1436. Found 167.1431; spectroscopic data are in agreement with literature data.[8]

Literature

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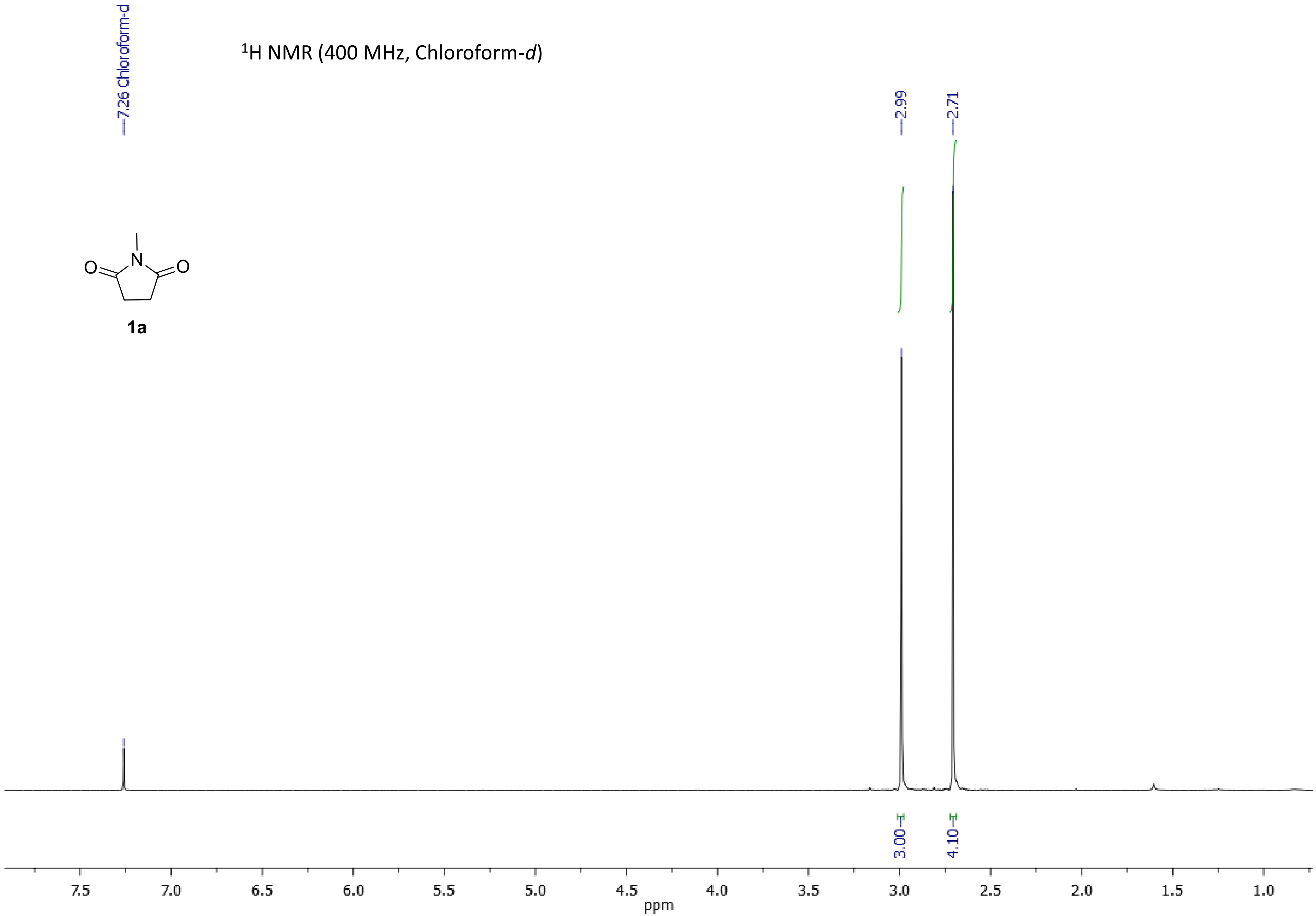
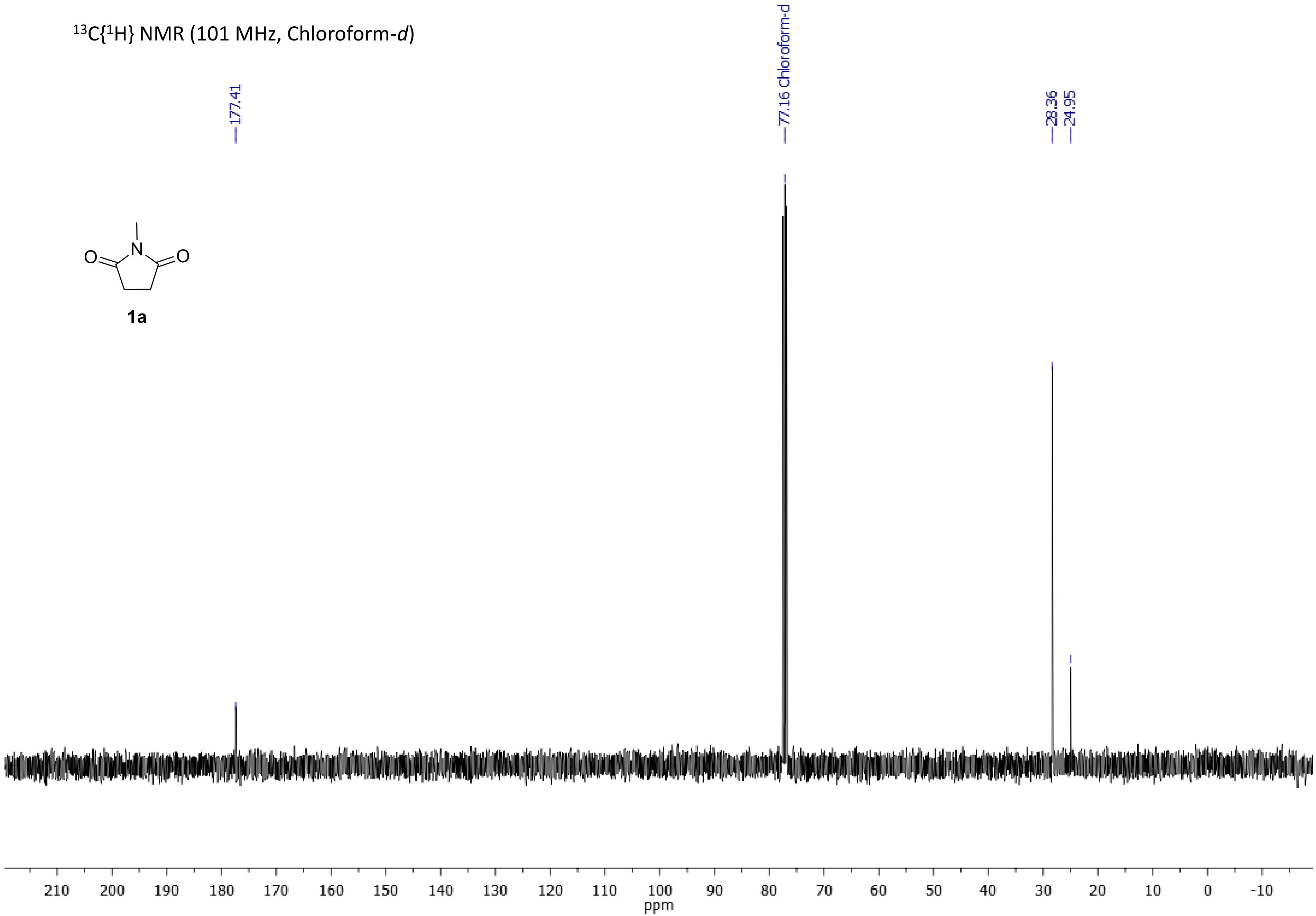
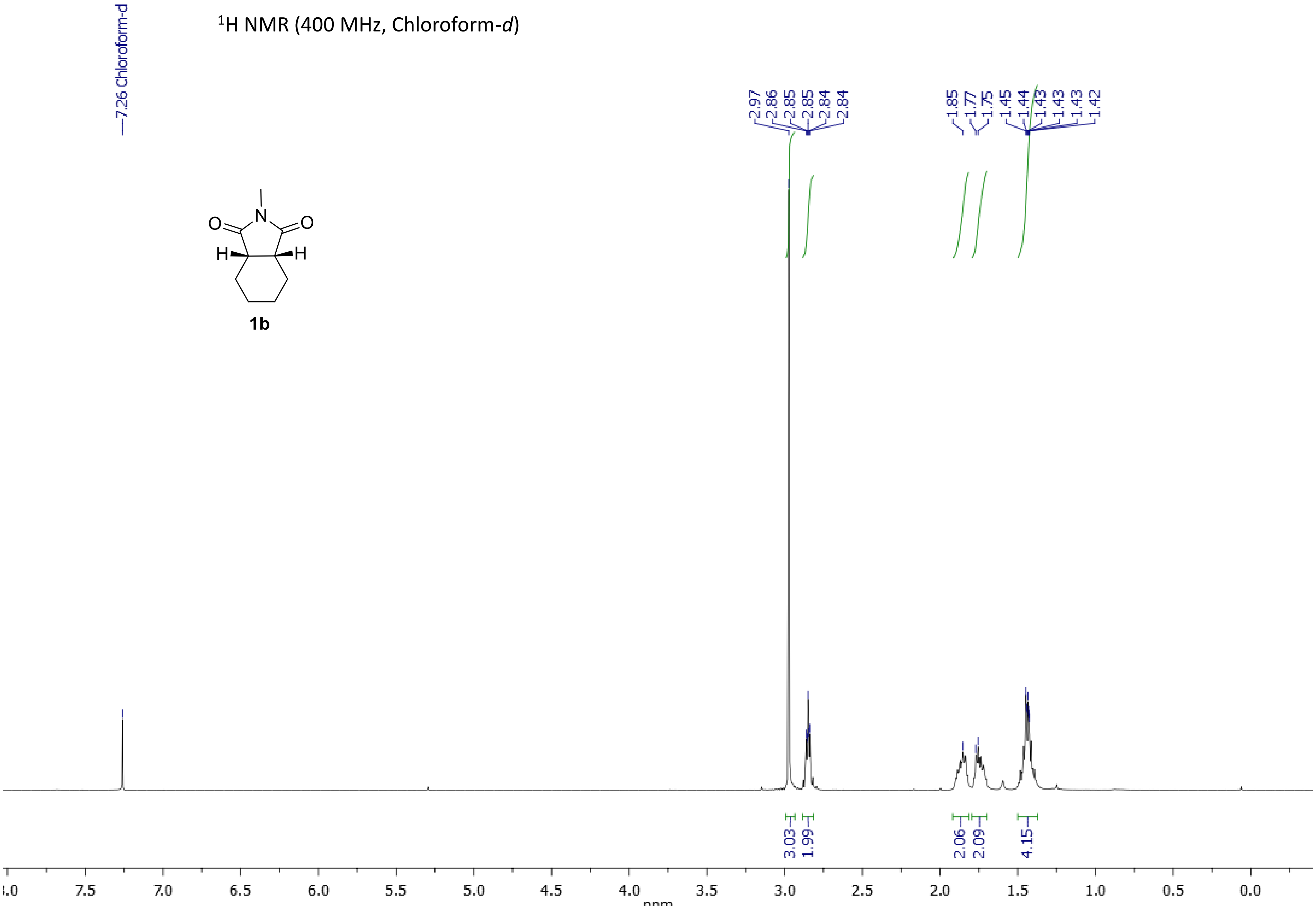
[1]H NMR (400 MHz, Chloroform-*d*)



$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

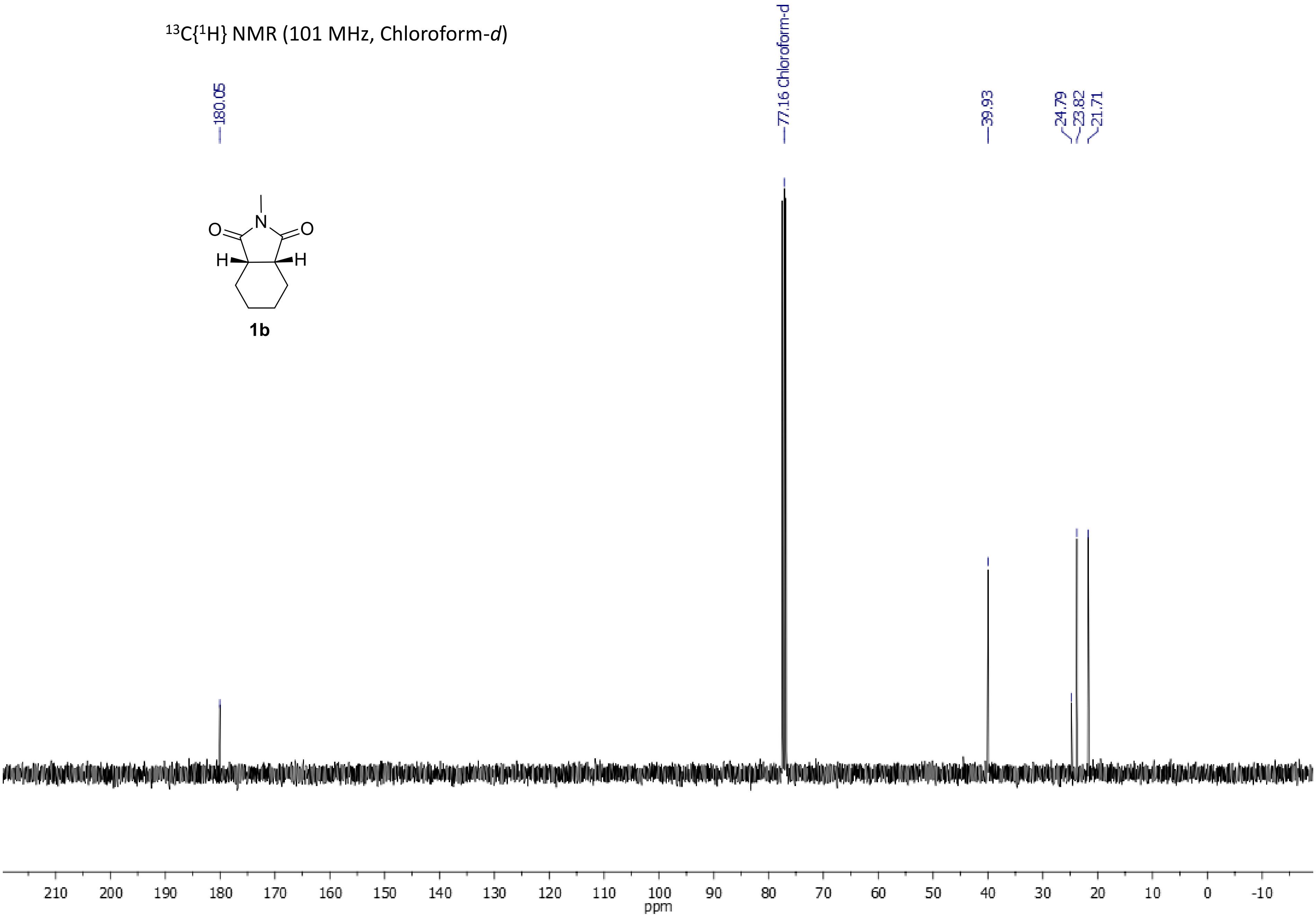


^{1}H NMR (400 MHz, Chloroform-d)

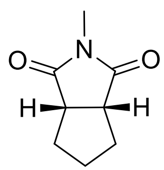


1b

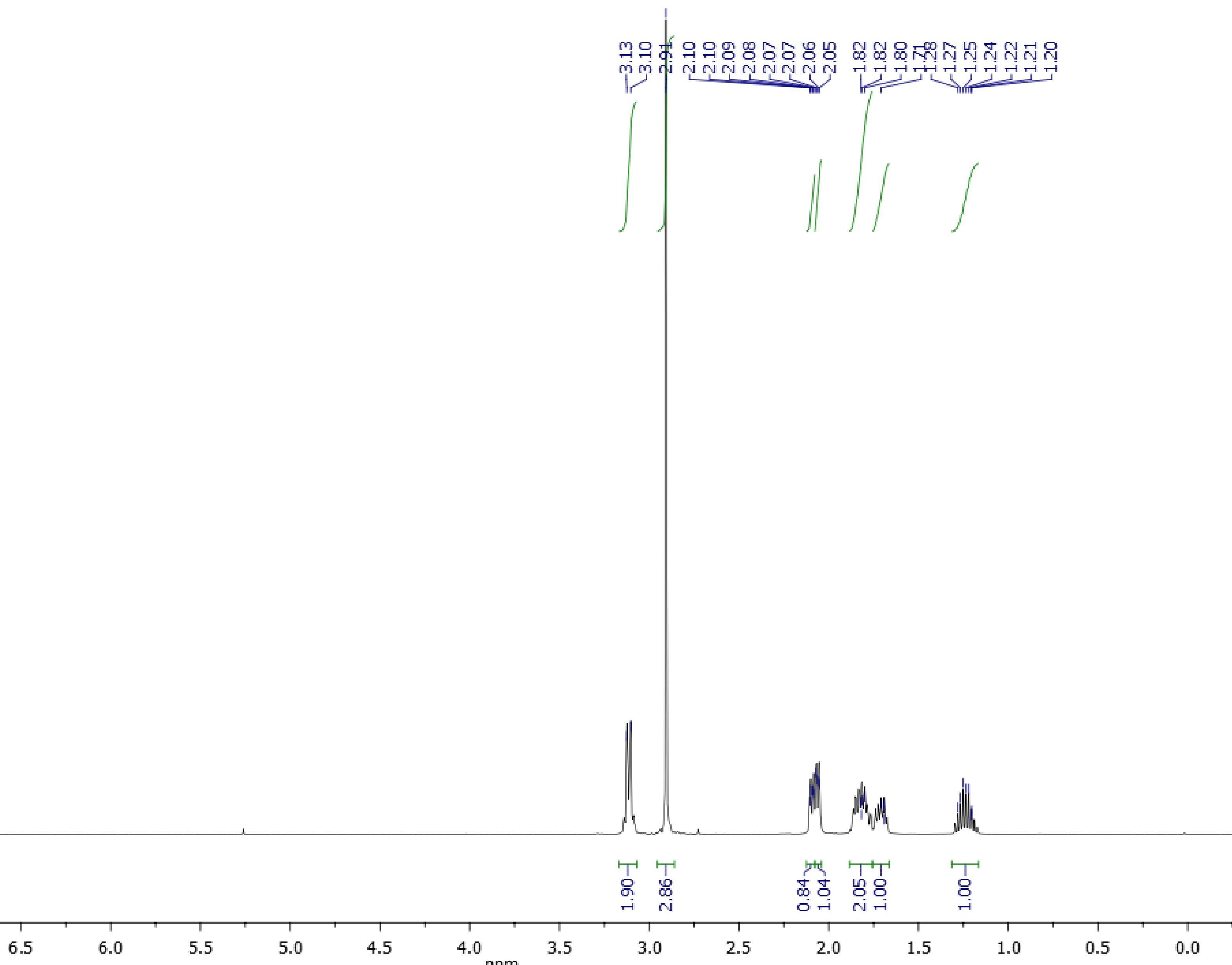
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



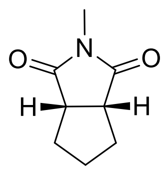
[1]H NMR (400 MHz, Chloroform-*d*)



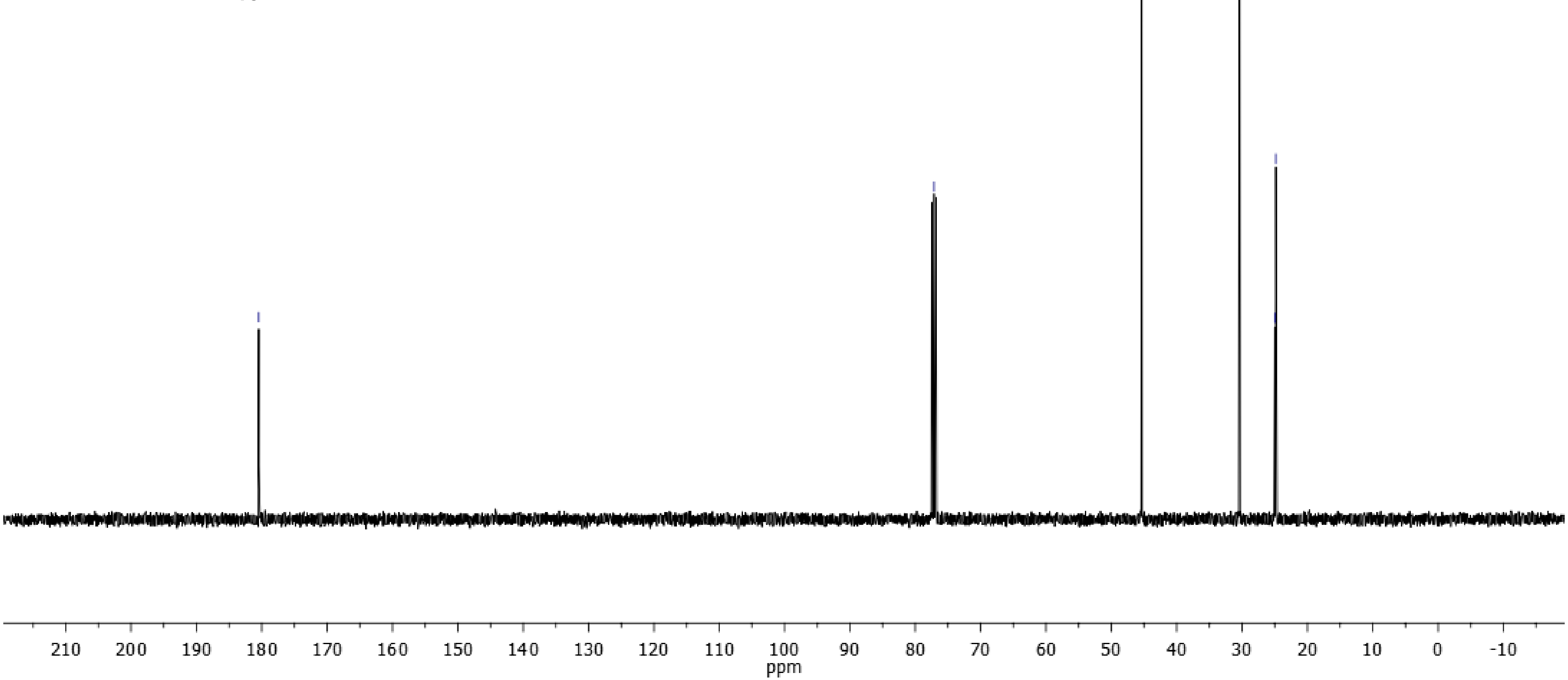
1c



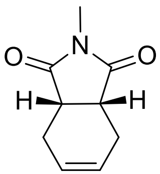
$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)



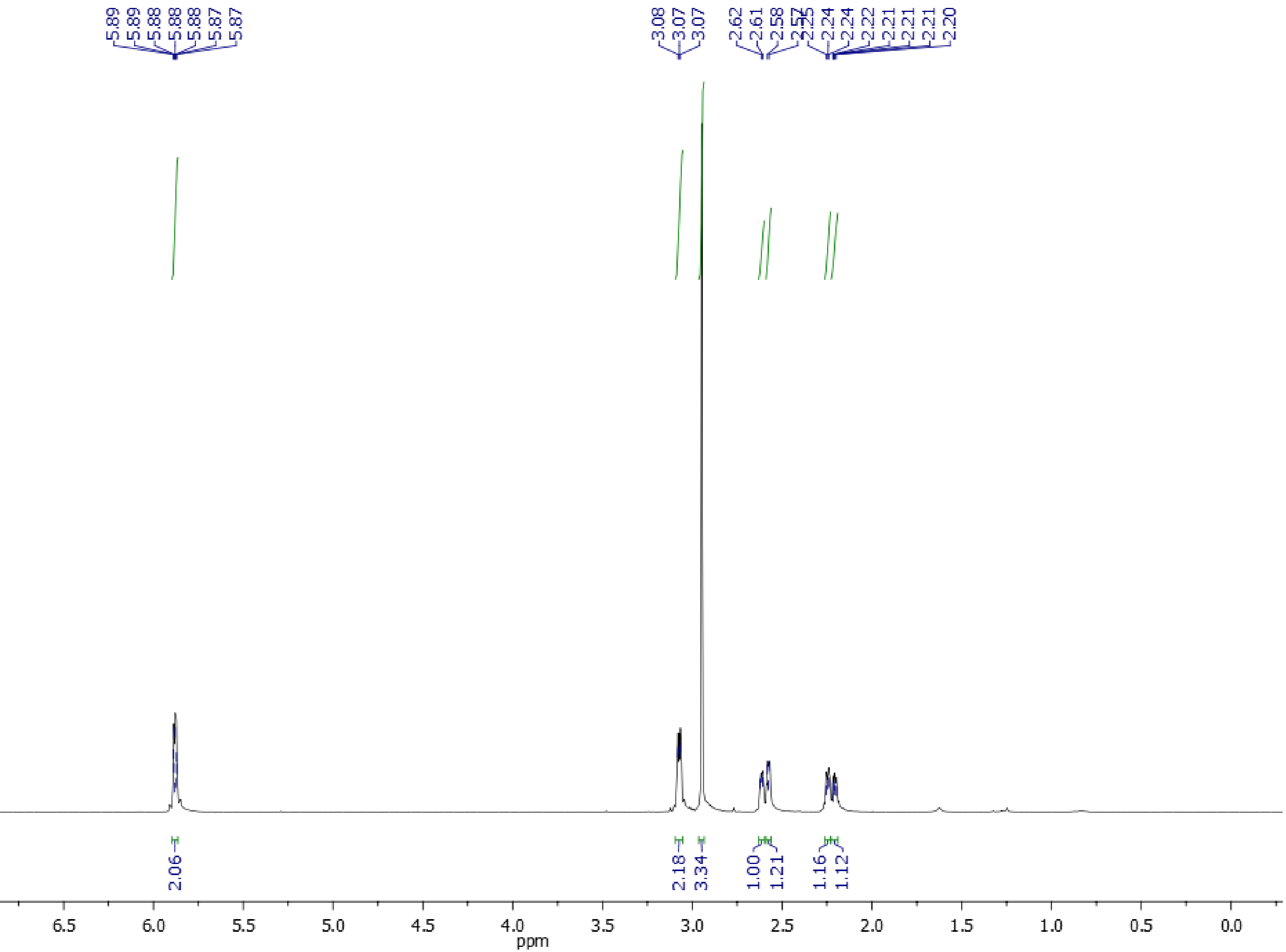
1c



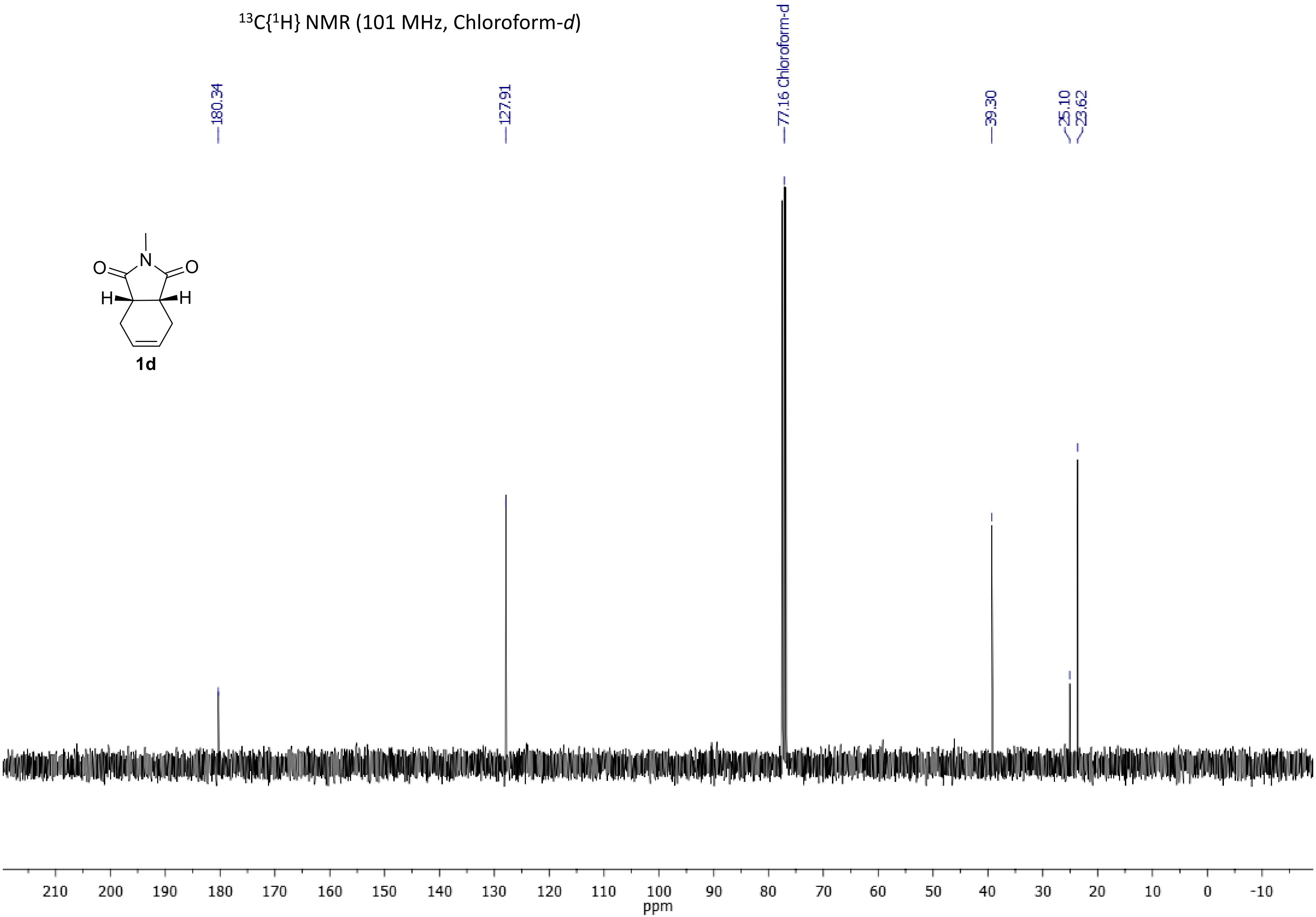
^{1}H NMR (400 MHz, Chloroform-*d*)



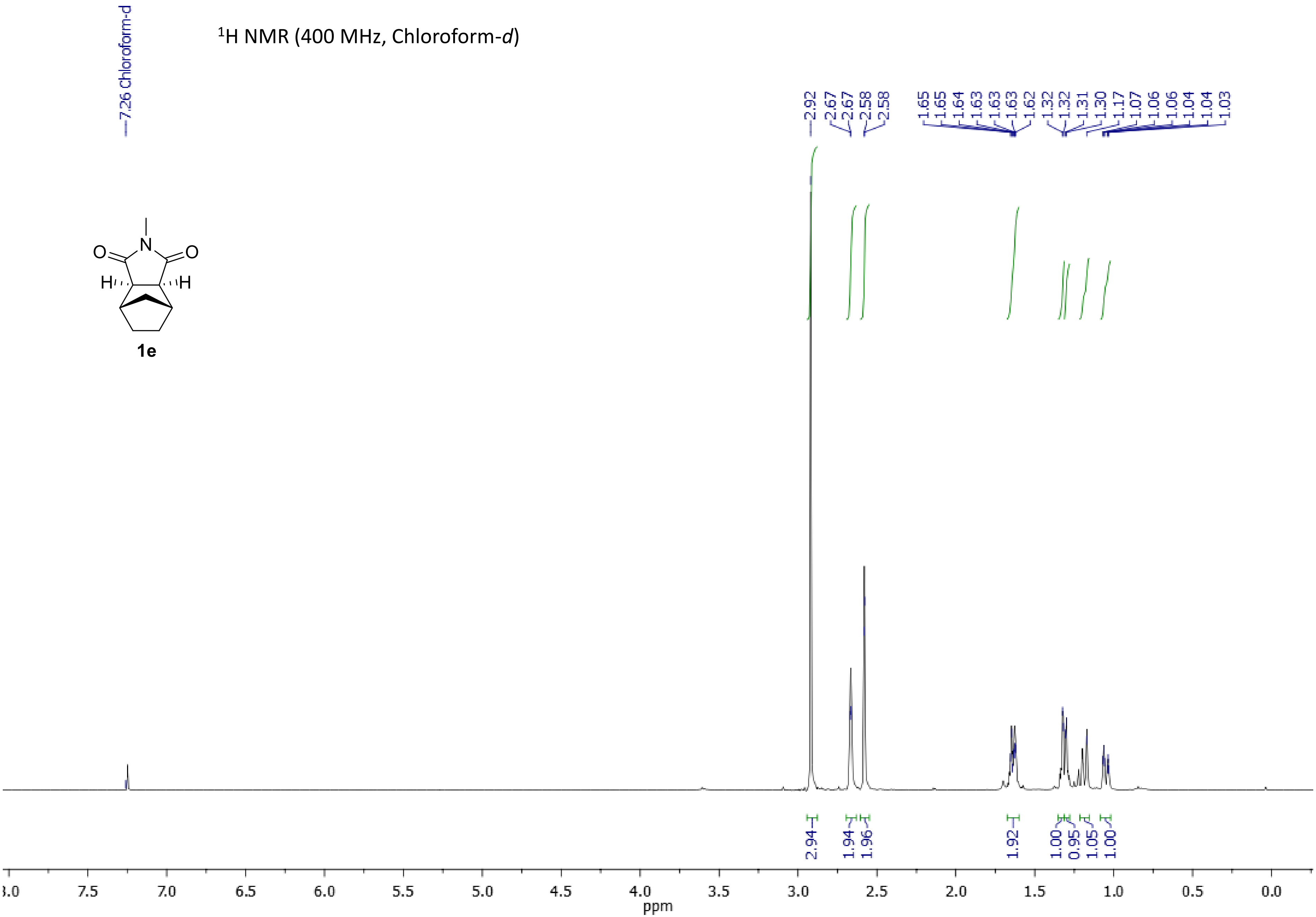
1d



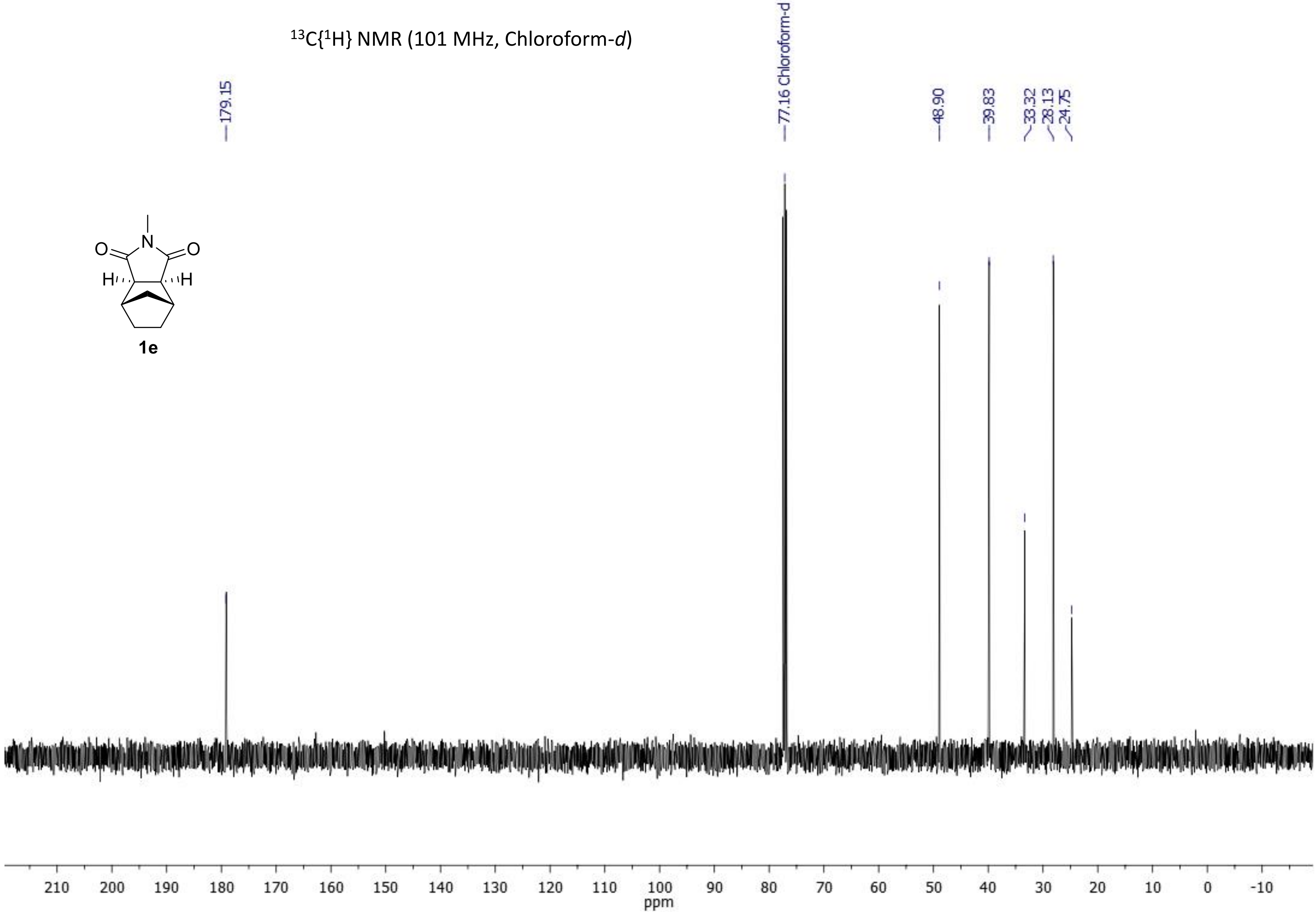
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



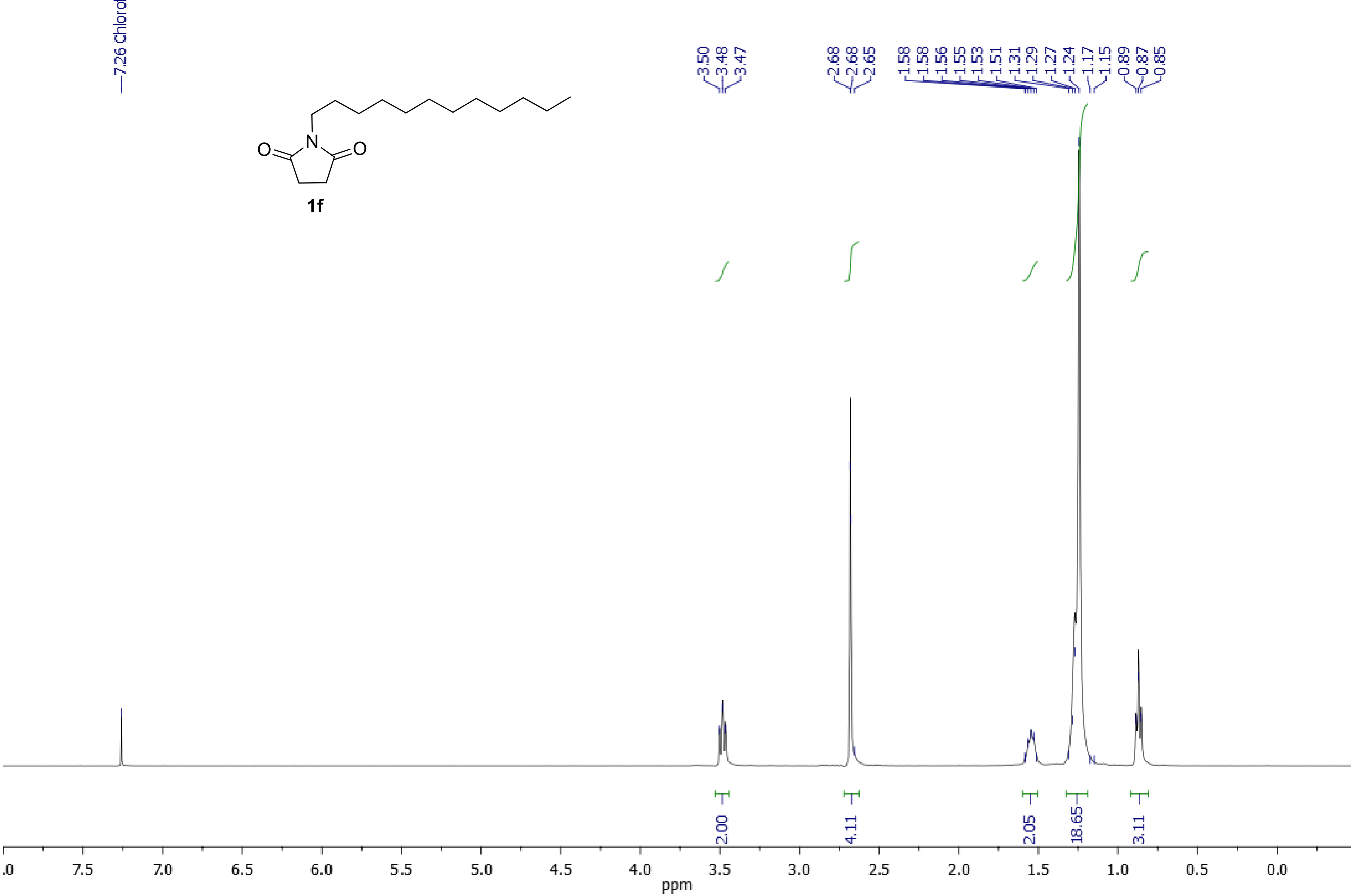
[1]H NMR (400 MHz, Chloroform-*d*)



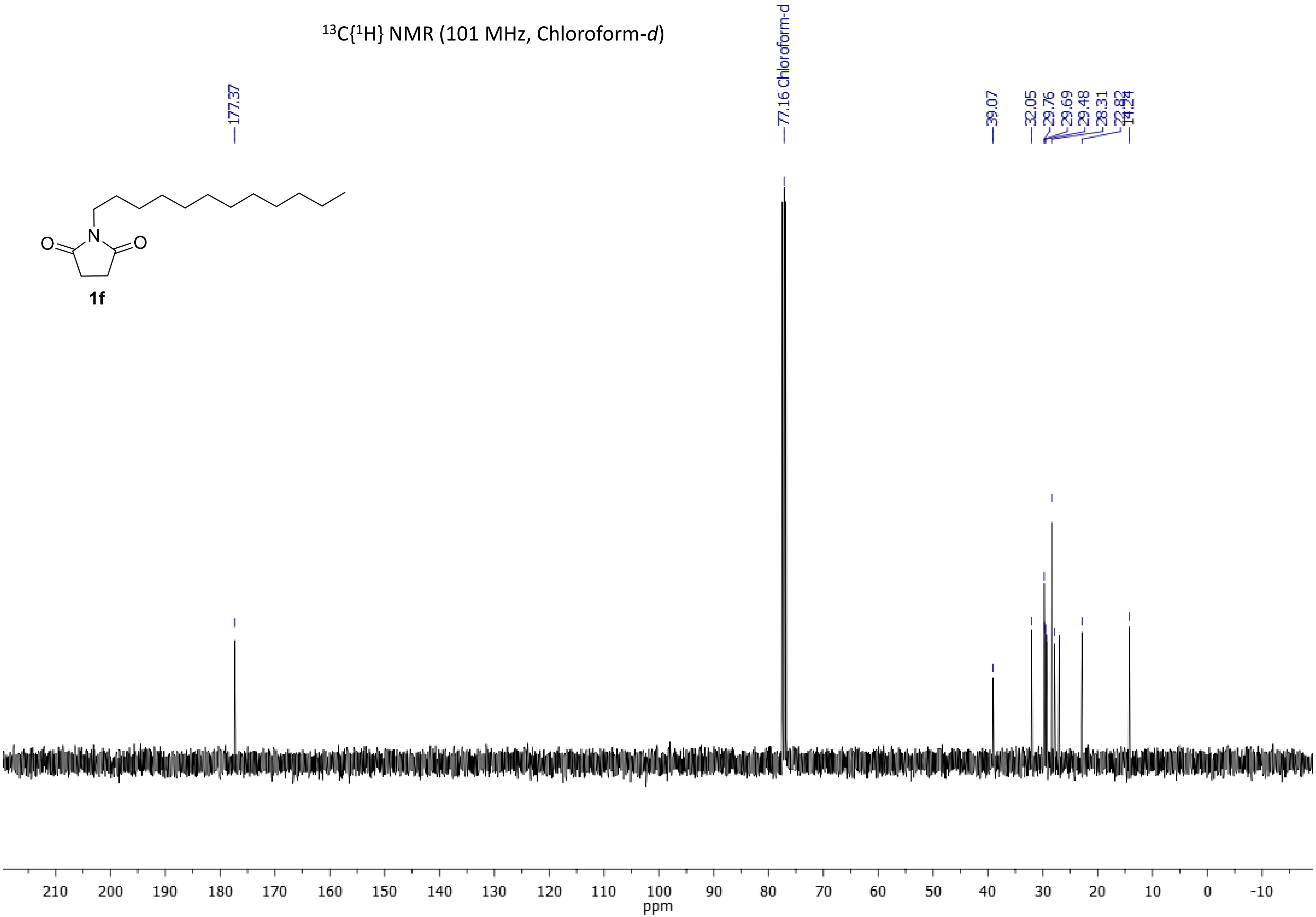
$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)



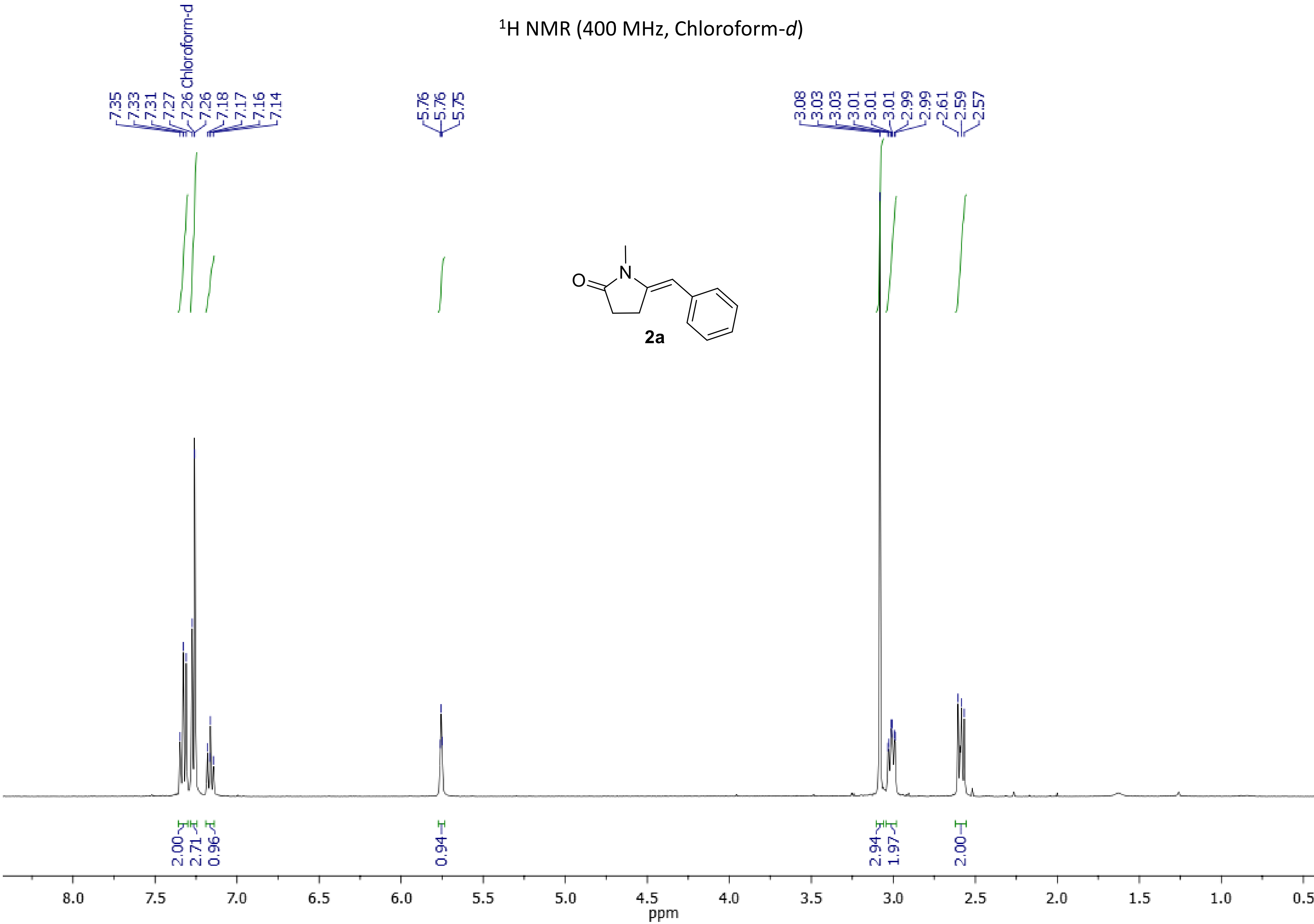
[1]H NMR (400 MHz, Chloroform-*d*)



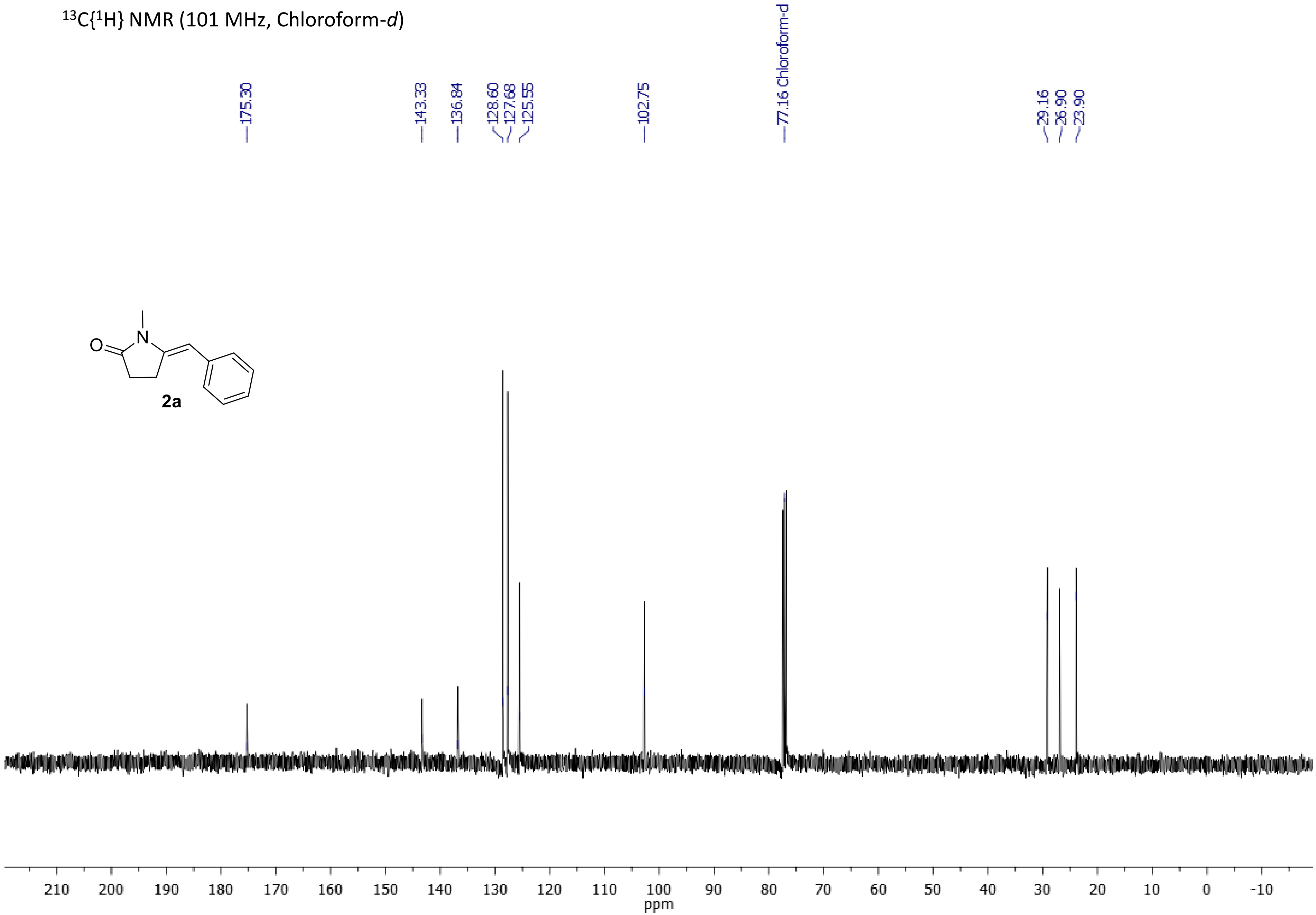
$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)

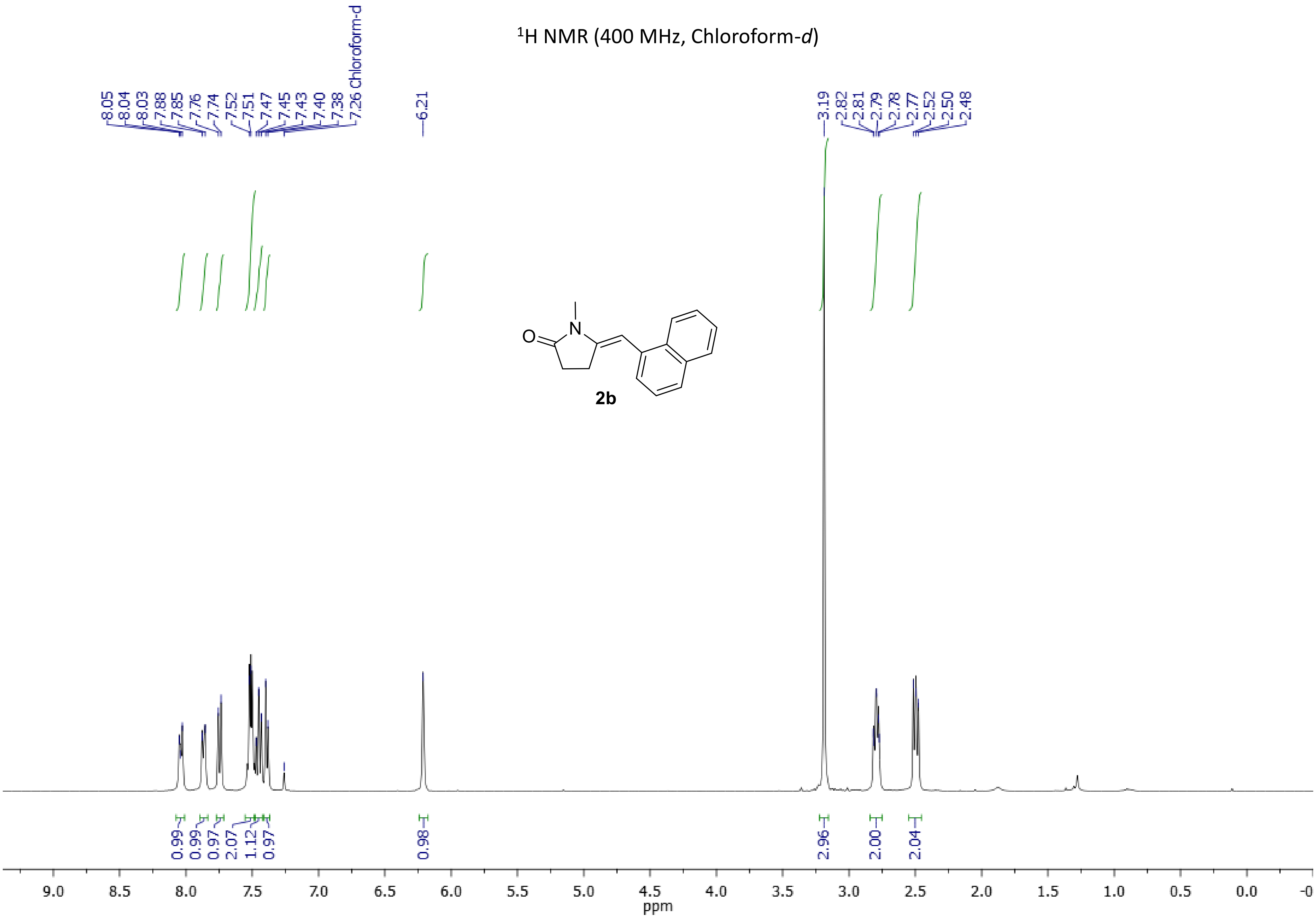


^{1}H NMR (400 MHz, Chloroform-*d*)



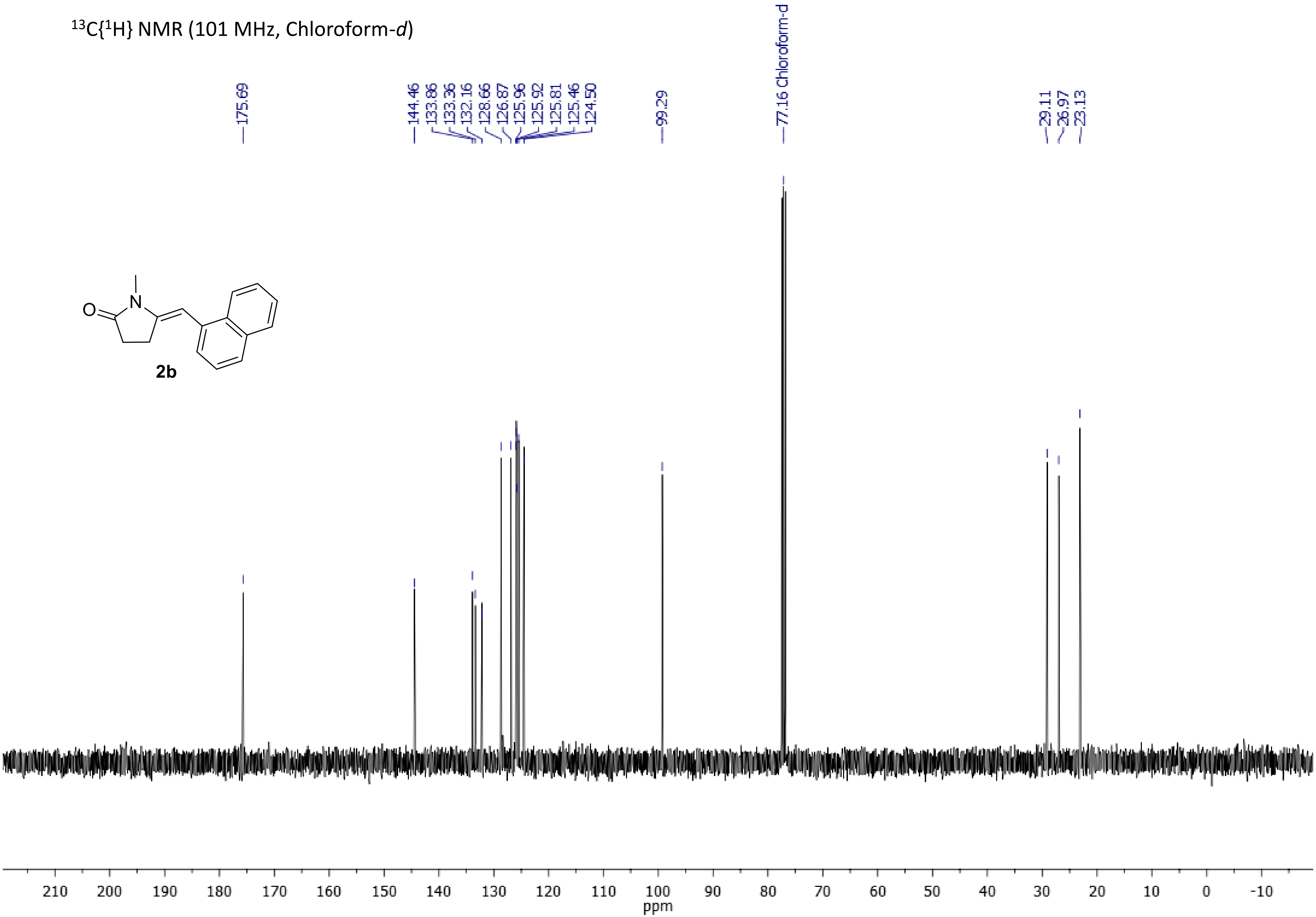
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

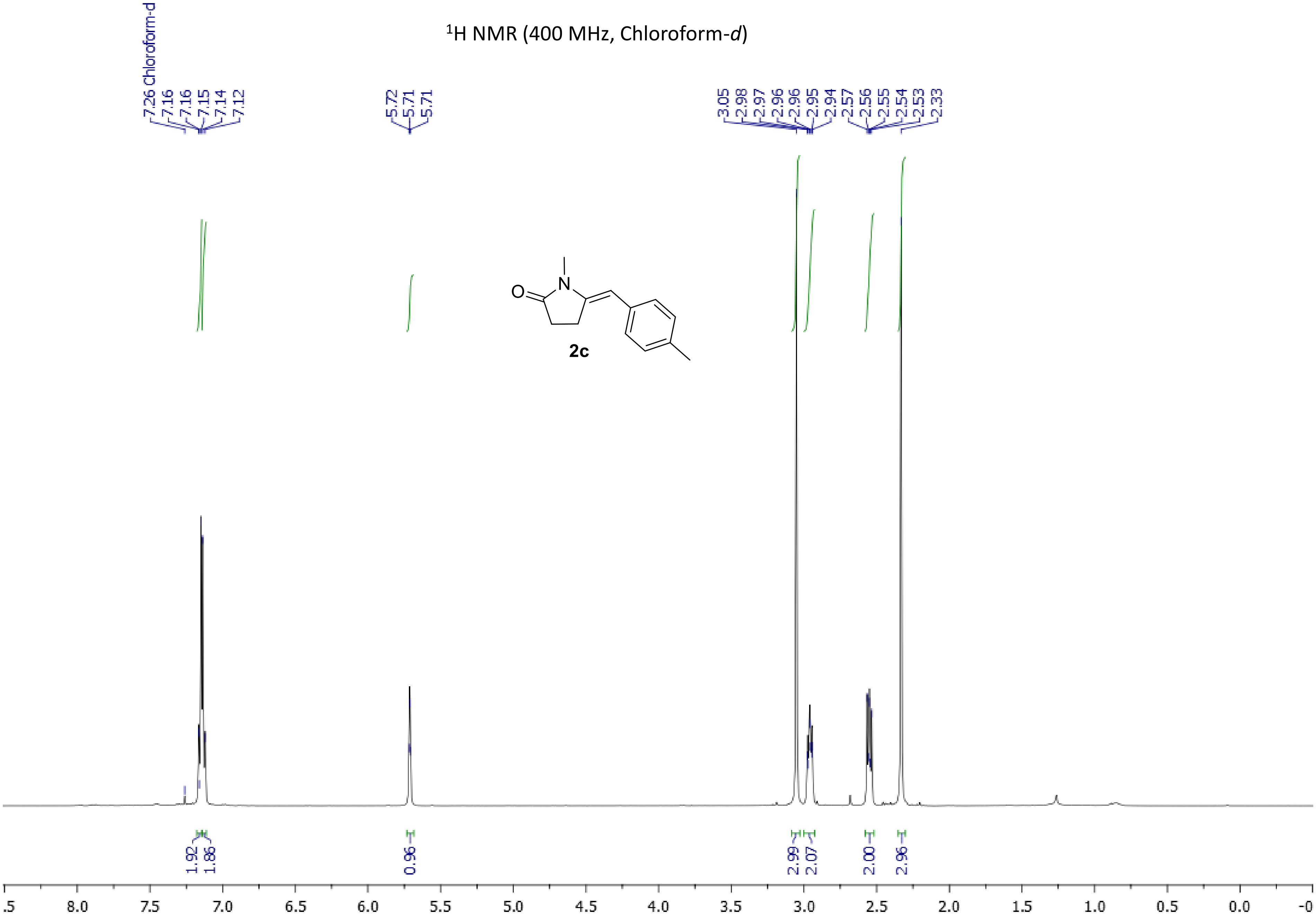




^{1}H NMR (400 MHz, Chloroform-d)
8.05 8.04 8.03 7.88 7.85 7.76 7.74 7.52 7.51 7.47 7.45 7.43 7.40 7.38 7.26 Chloroform-d
6.21
3.19 2.82 2.81 2.79 2.78 2.77 2.52 2.50 2.48
O
N
2b
0.99 0.99 0.97 2.07 1.12 0.97
0.98
2.96
2.00
2.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

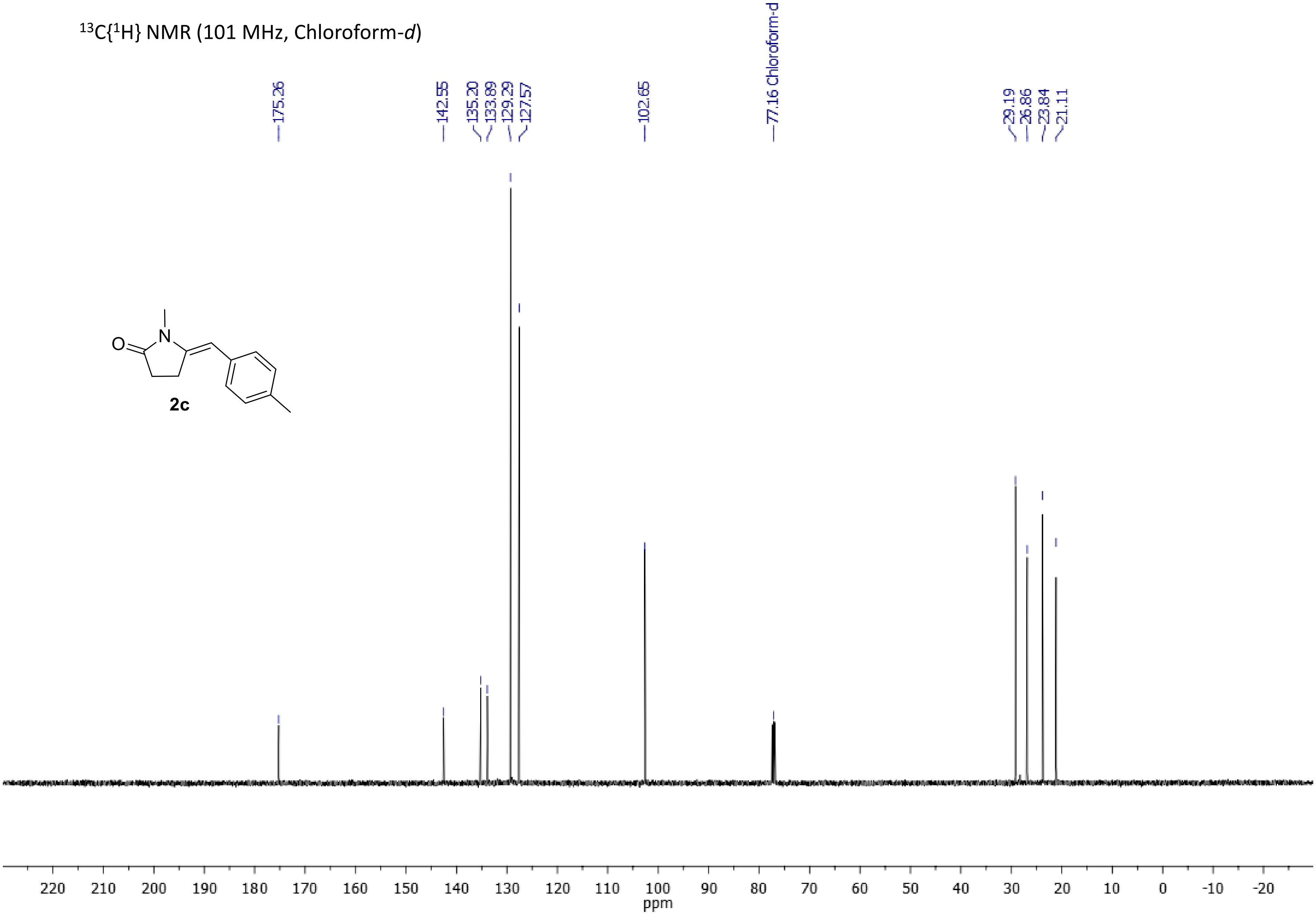
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



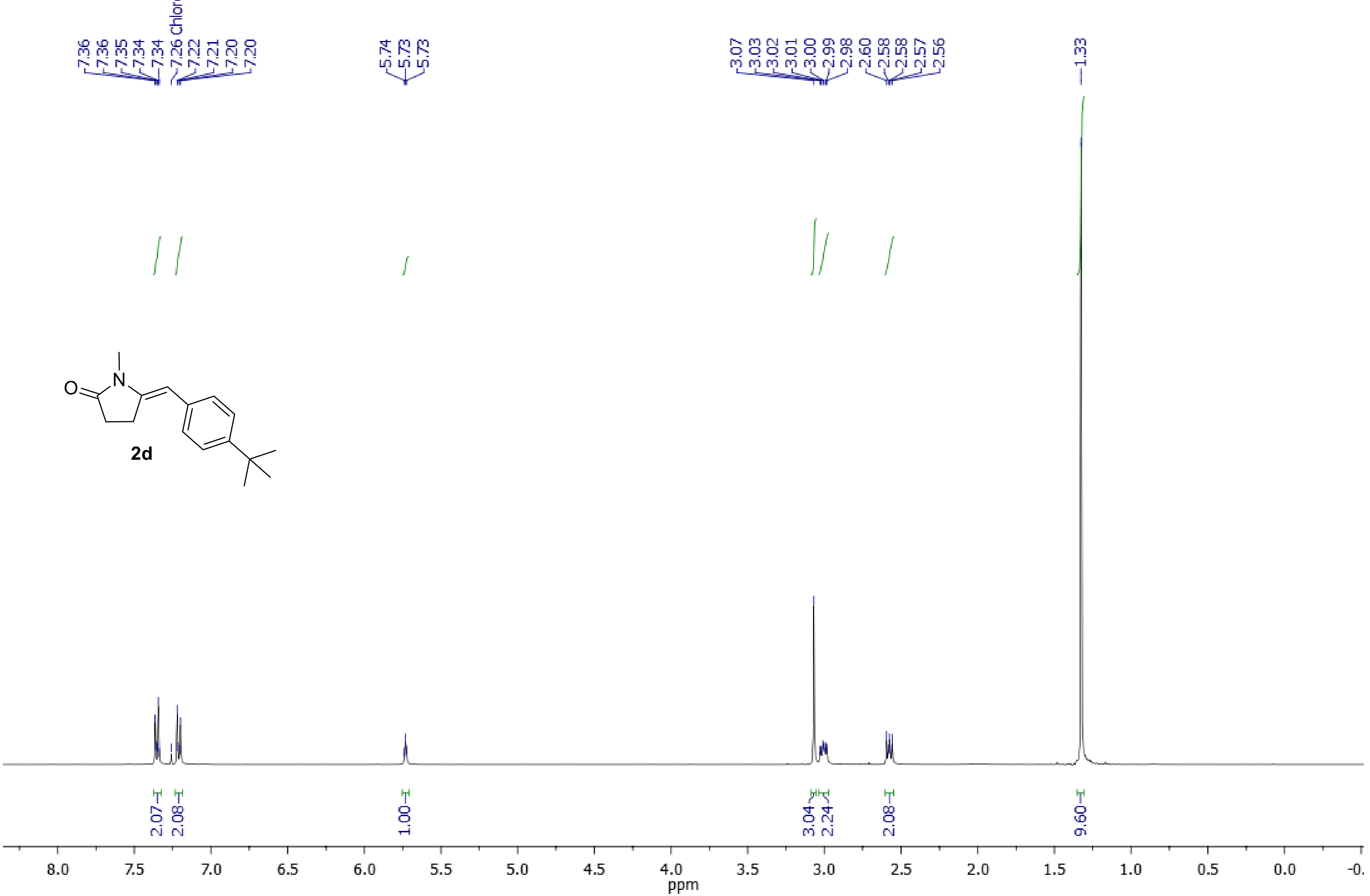


1H NMR (400 MHz, Chloroform-d)
7.26 Chloroform-d
7.16
7.16
7.15
7.14
7.12
5.72
5.71
5.71
3.05
2.98
2.97
2.96
2.96
2.95
2.94
2.57
2.56
2.55
2.54
2.53
2.33
O
N
2c
1.92
1.86
0.96
2.99
2.07
2.00
2.96
.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0

$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

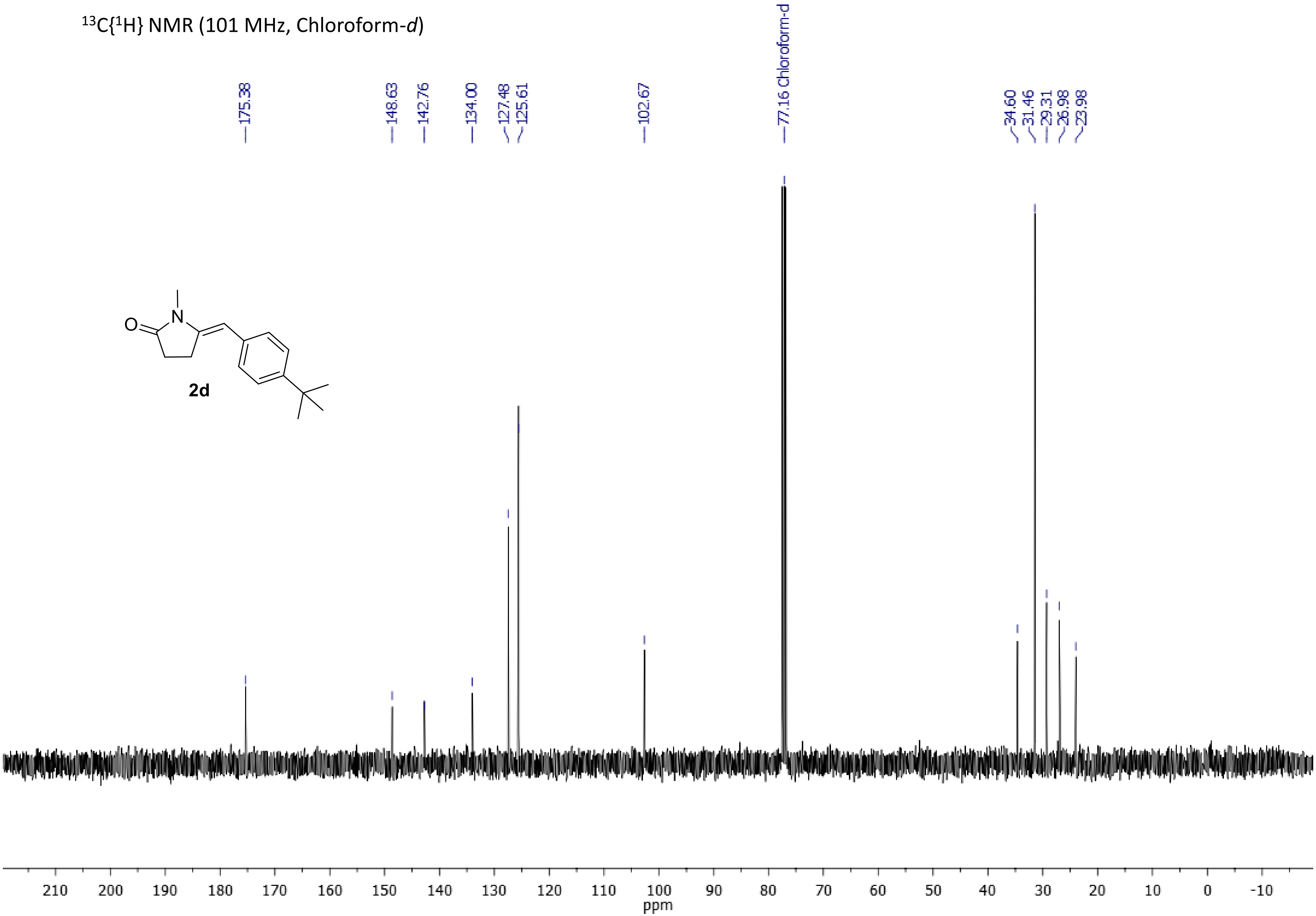


^1H NMR (400 MHz, Chloroform-*d*)

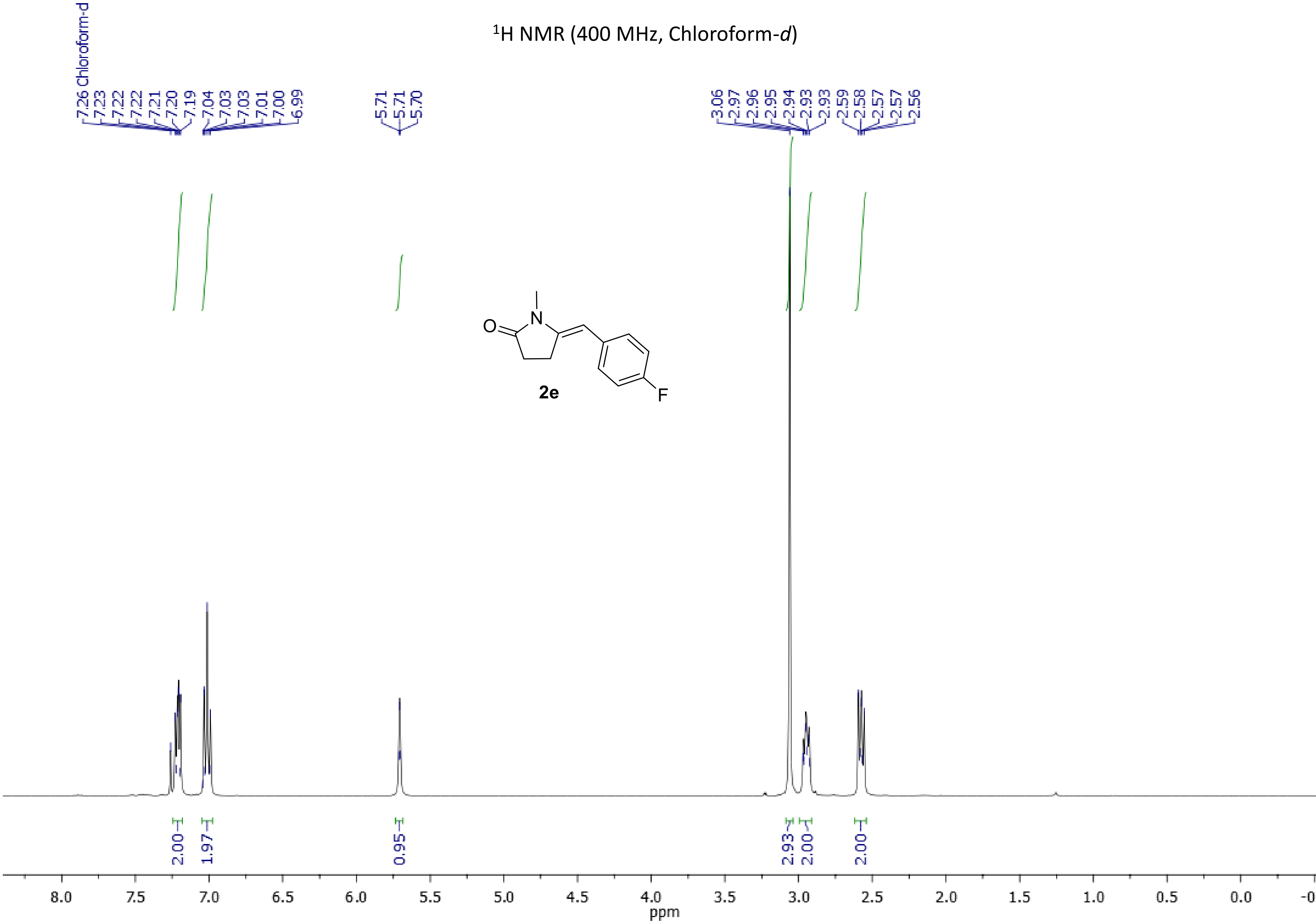


2d

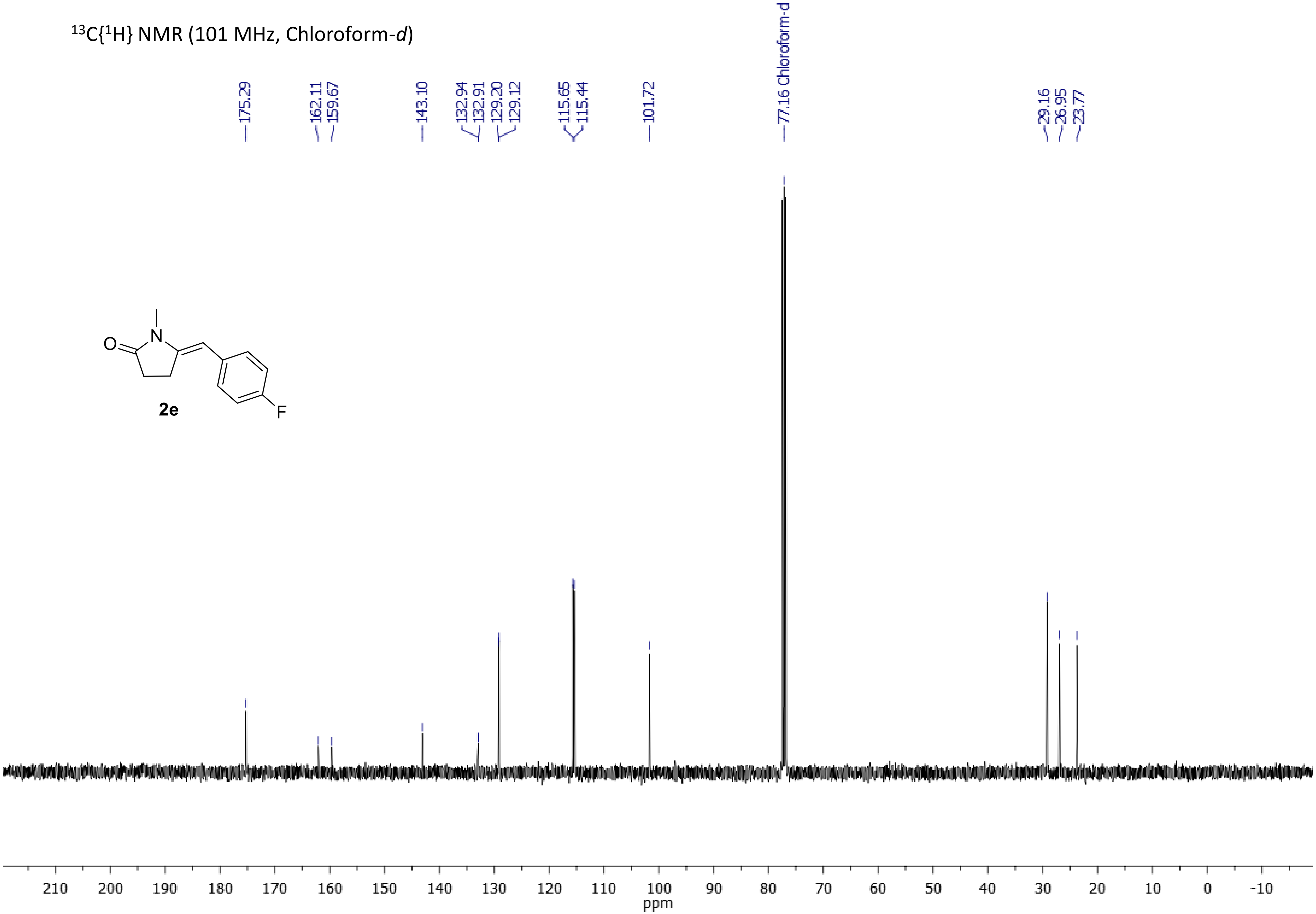
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



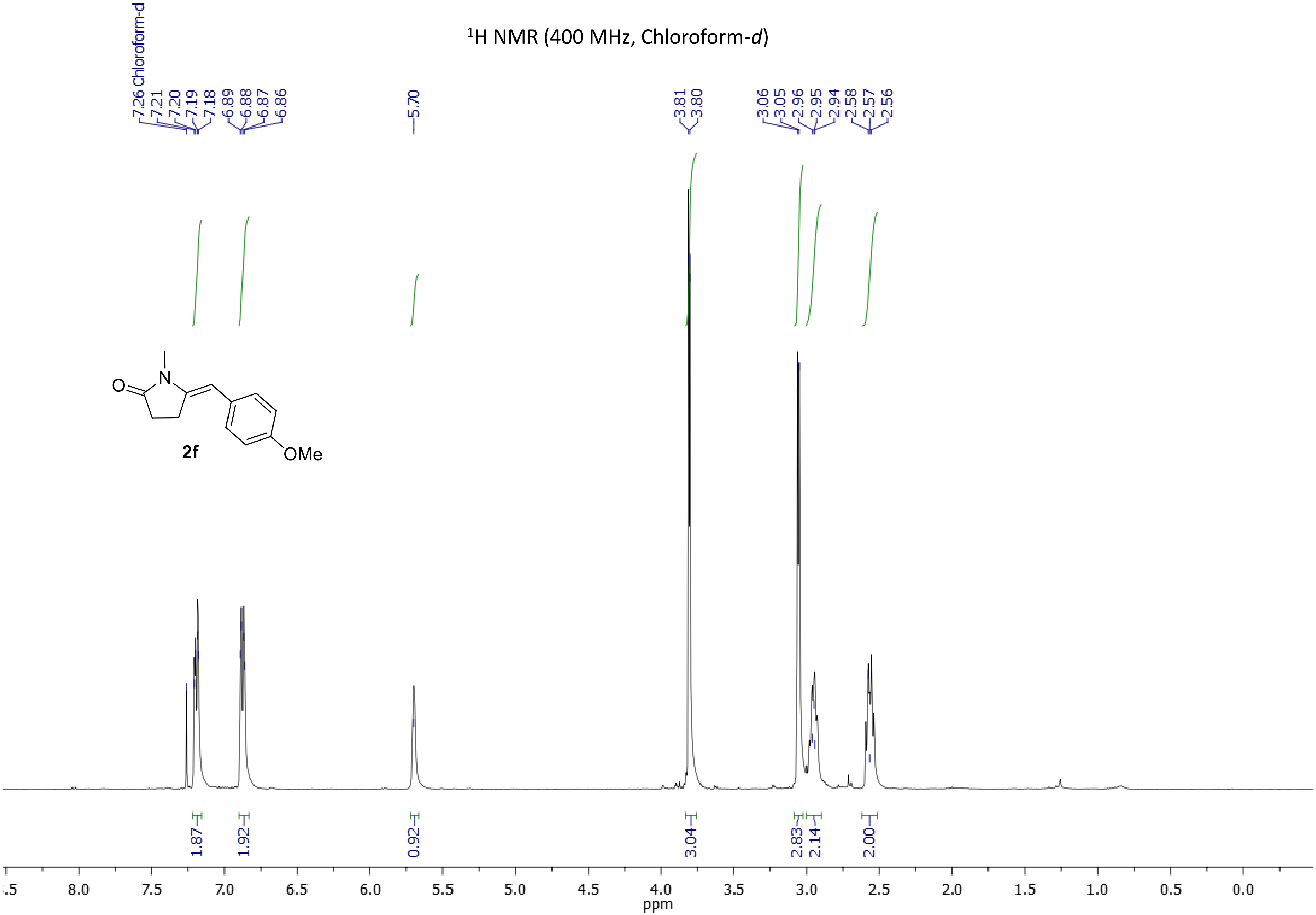
^{1}H NMR (400 MHz, Chloroform-d)



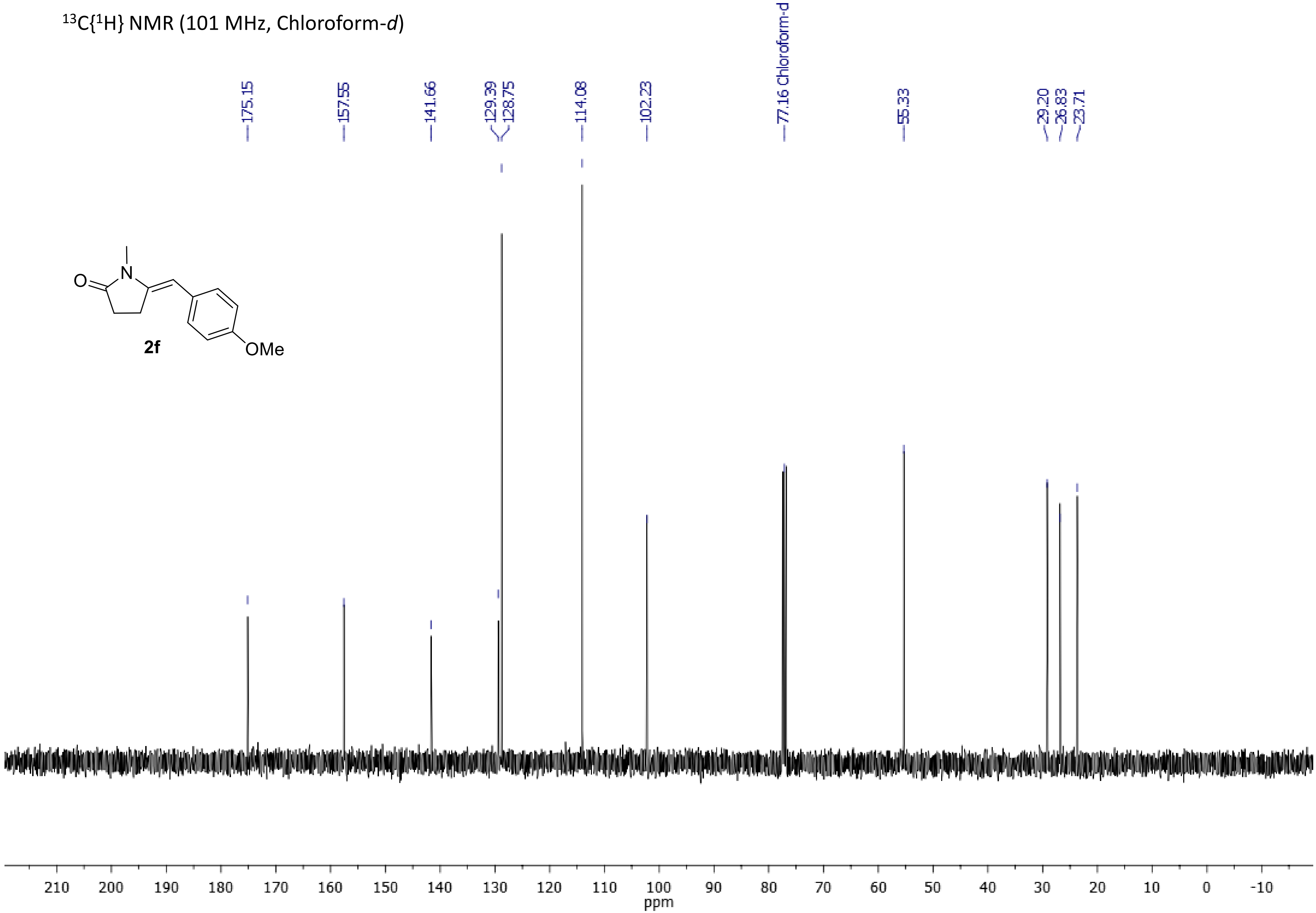
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



^{1}H NMR (400 MHz, Chloroform-*d*)

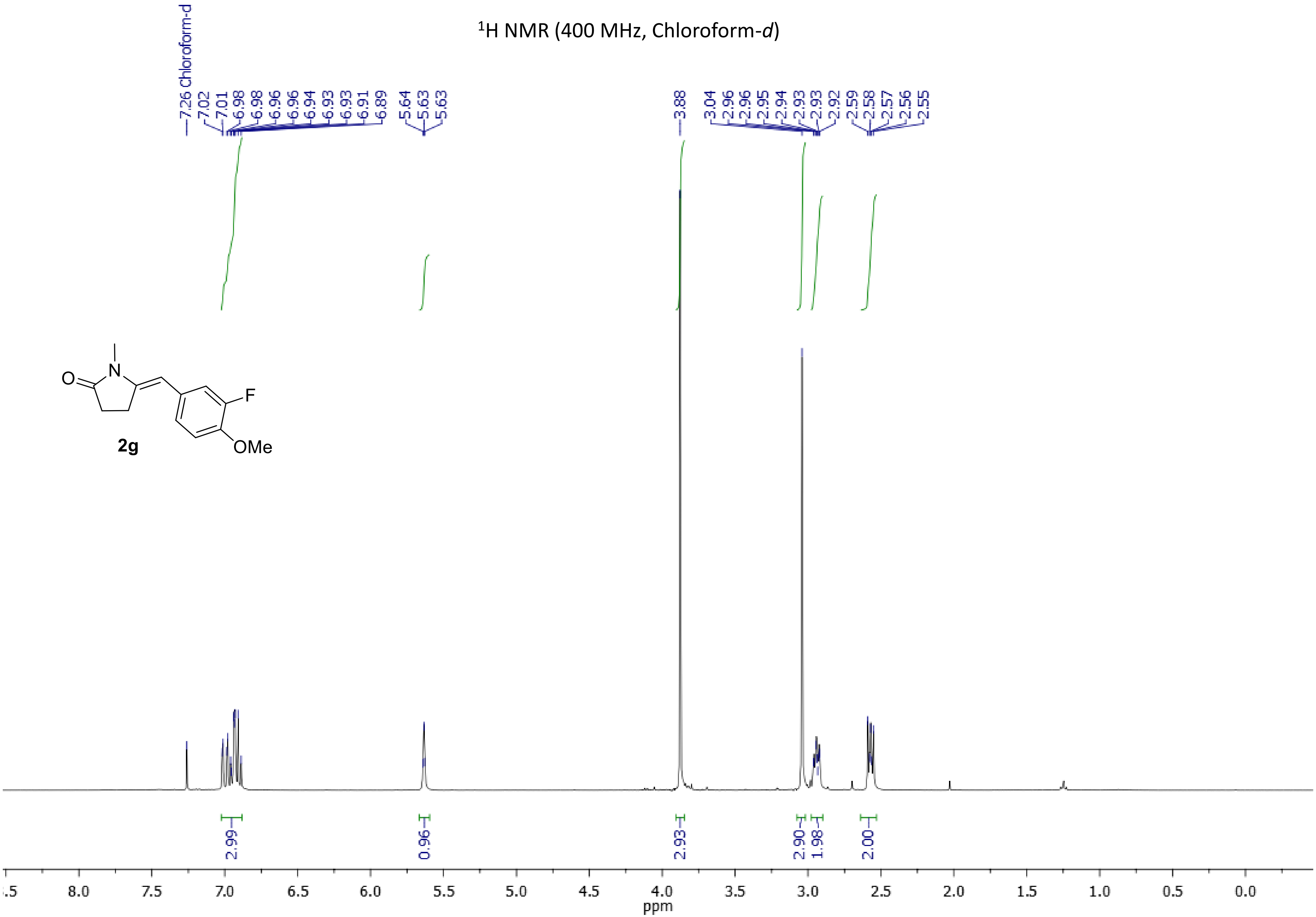


$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-d)

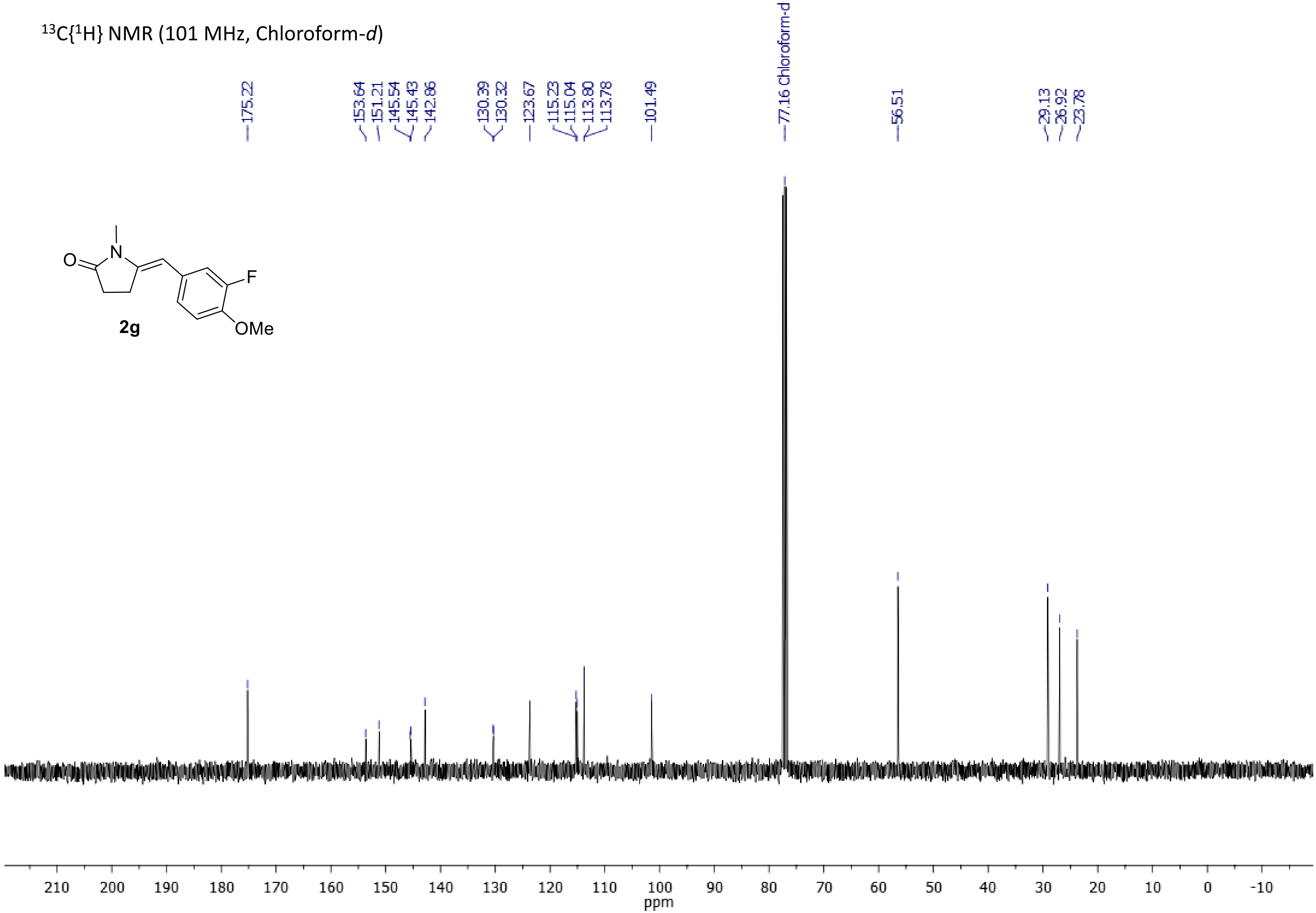


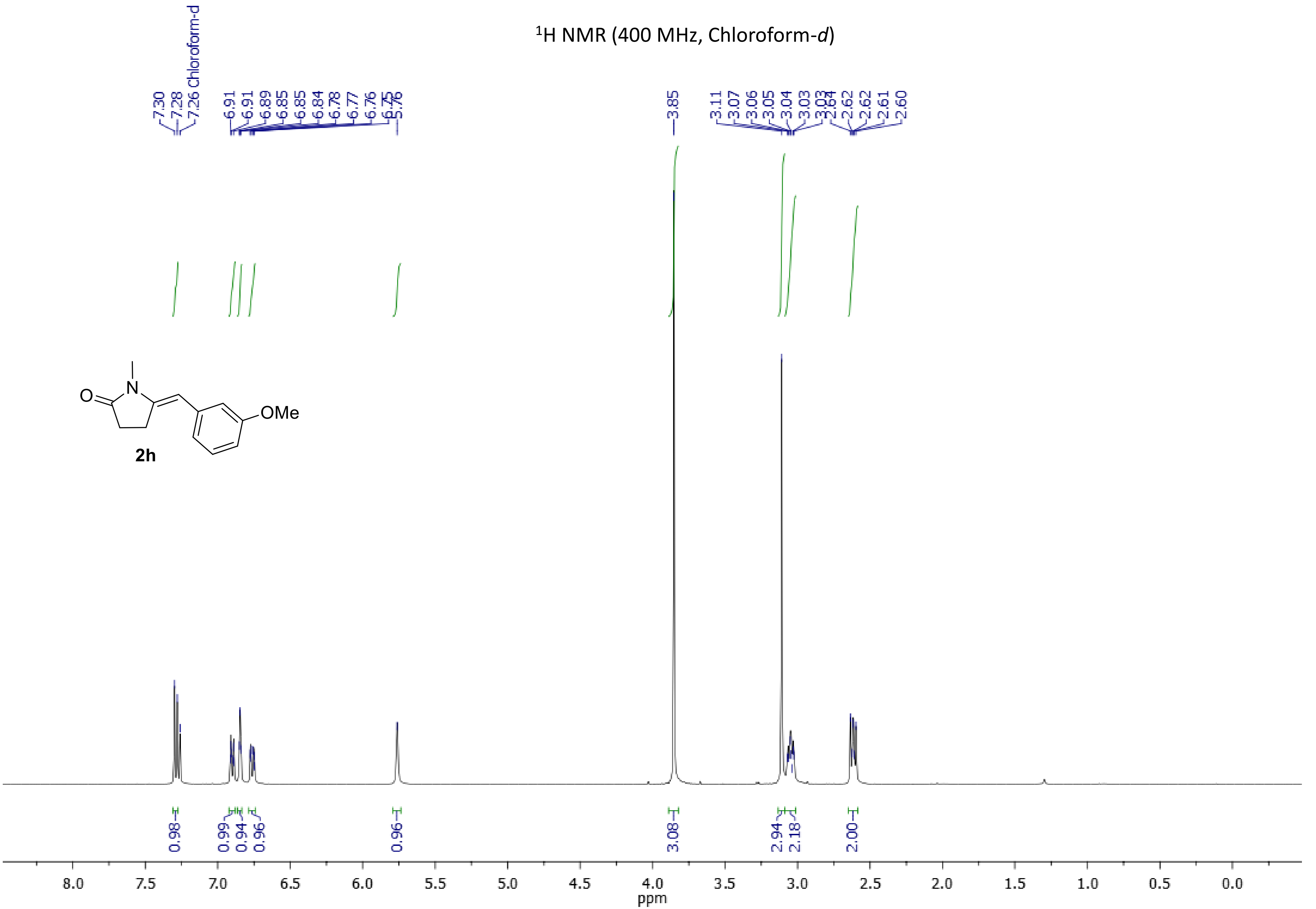
2f

^{1}H NMR (400 MHz, Chloroform-*d*)



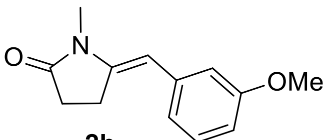
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



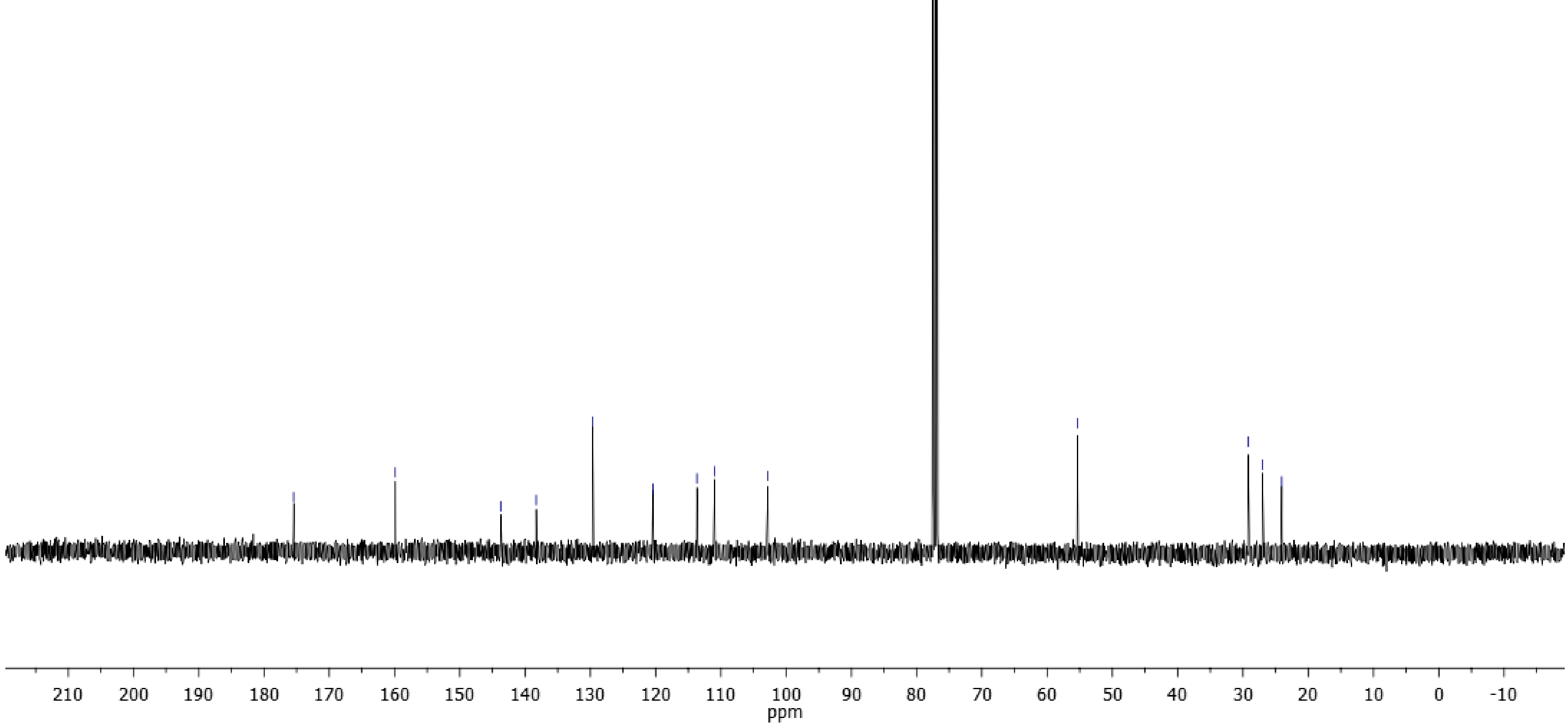


^{1}H NMR (400 MHz, Chloroform-d)
7.30
7.28
7.26 Chloroform-d
6.91
6.91
6.89
6.85
6.85
6.84
6.78
6.77
6.76
6.75
5.76
3.85
3.11
3.07
3.06
3.05
3.04
3.03
3.03
2.64
2.62
2.62
2.61
2.60
O
N
OMe
2h
0.98
0.99
0.94
0.96
0.96
3.08
2.94
2.18
2.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm

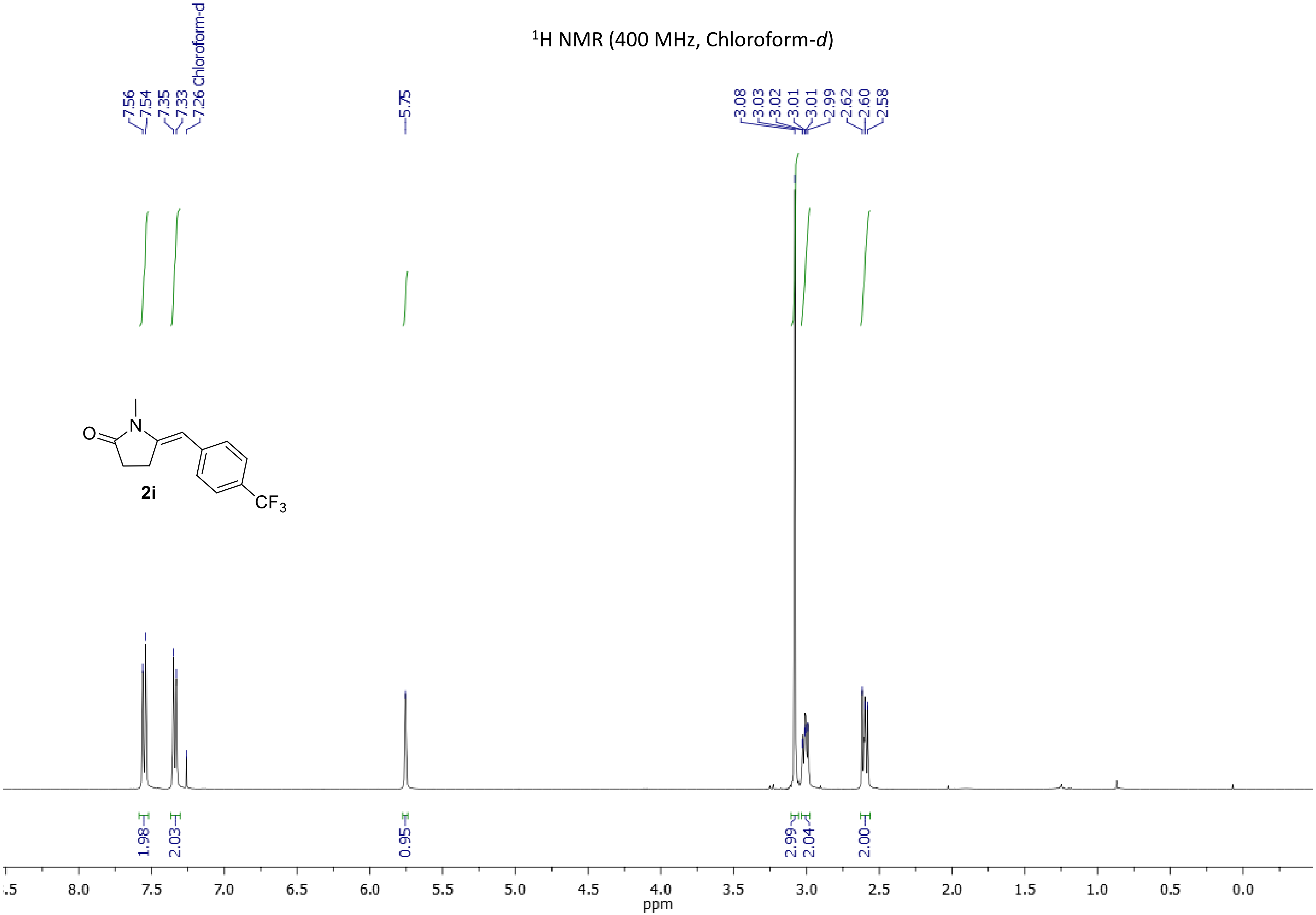
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

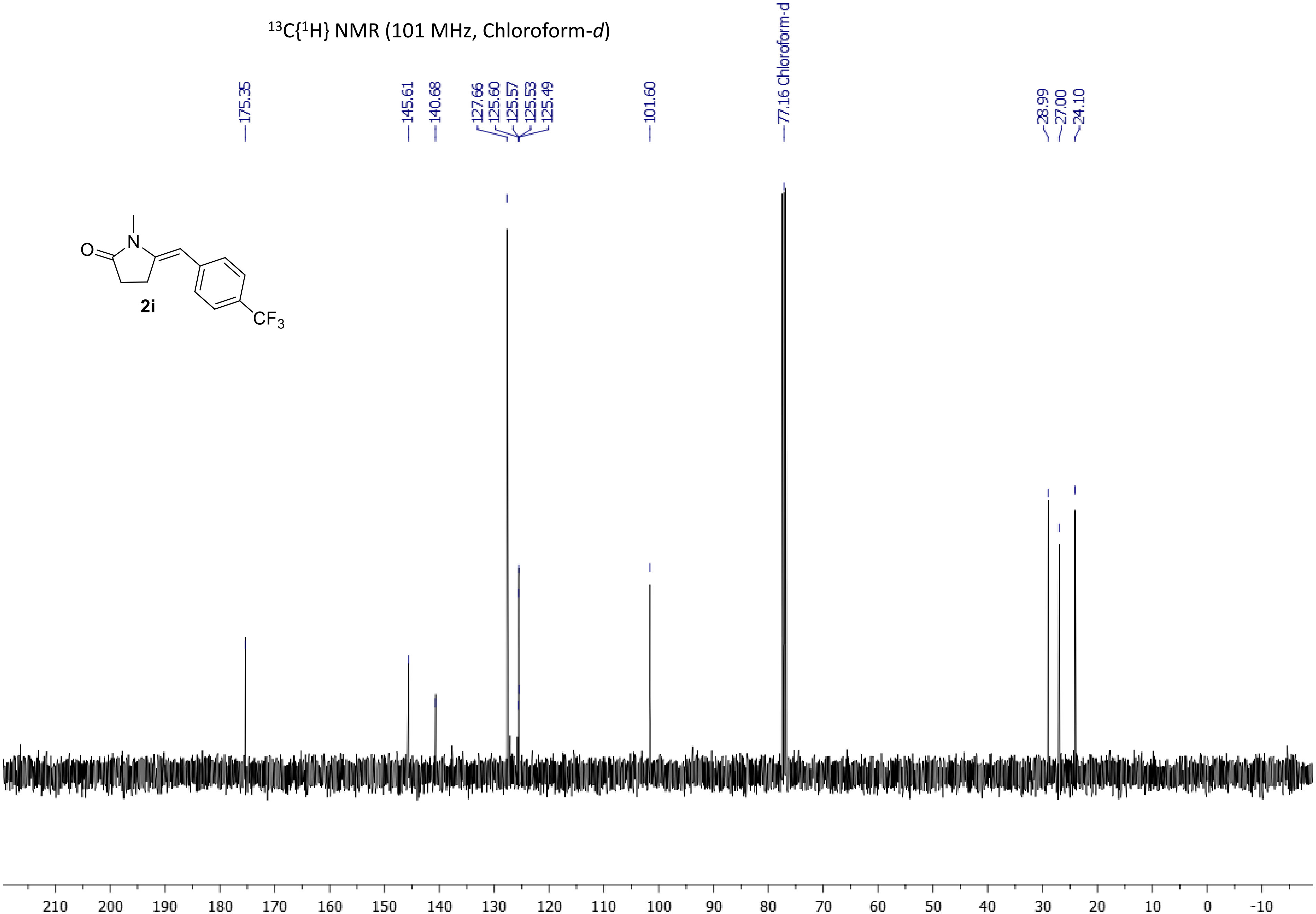


2h

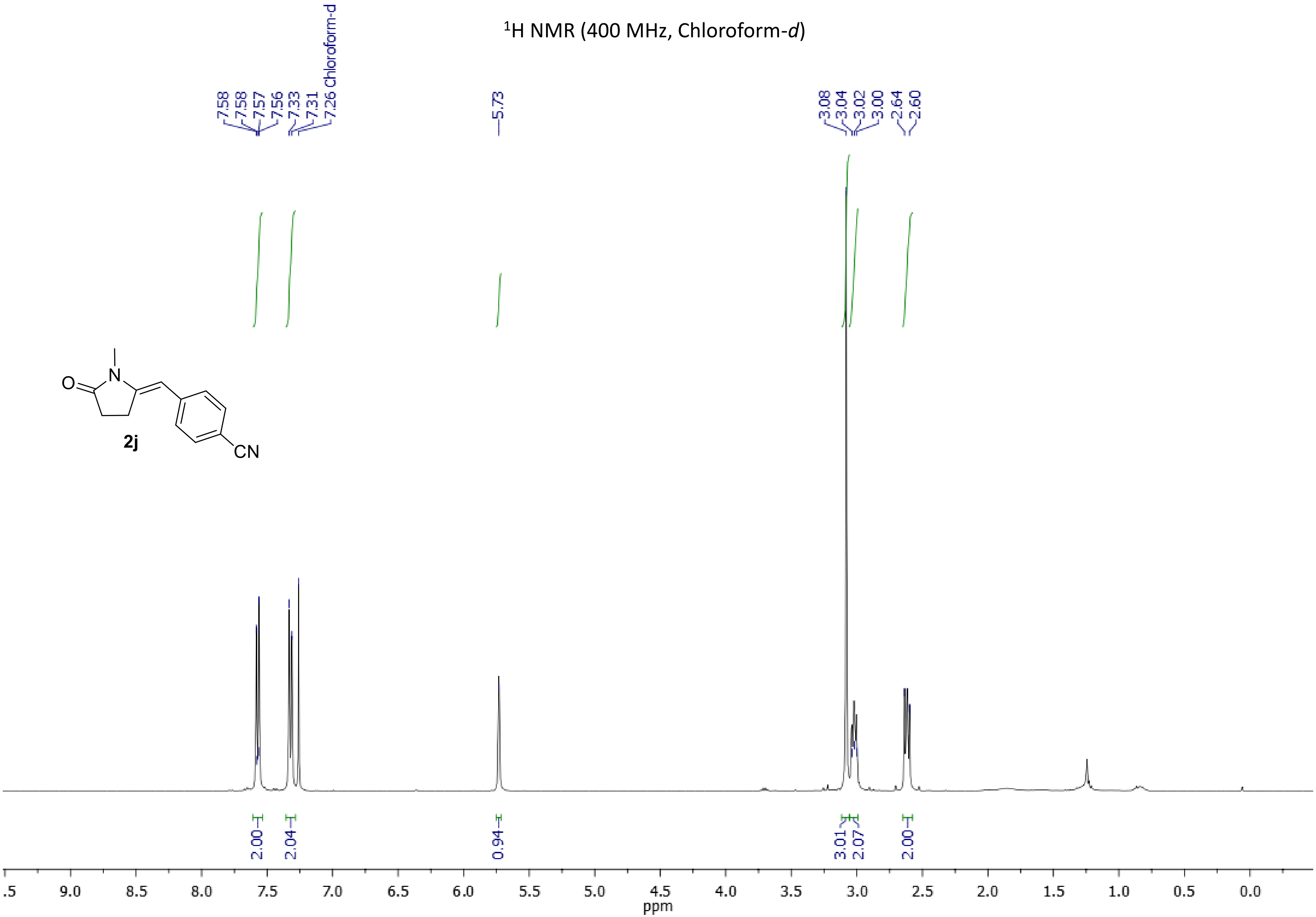


^{1}H NMR (400 MHz, Chloroform-*d*)

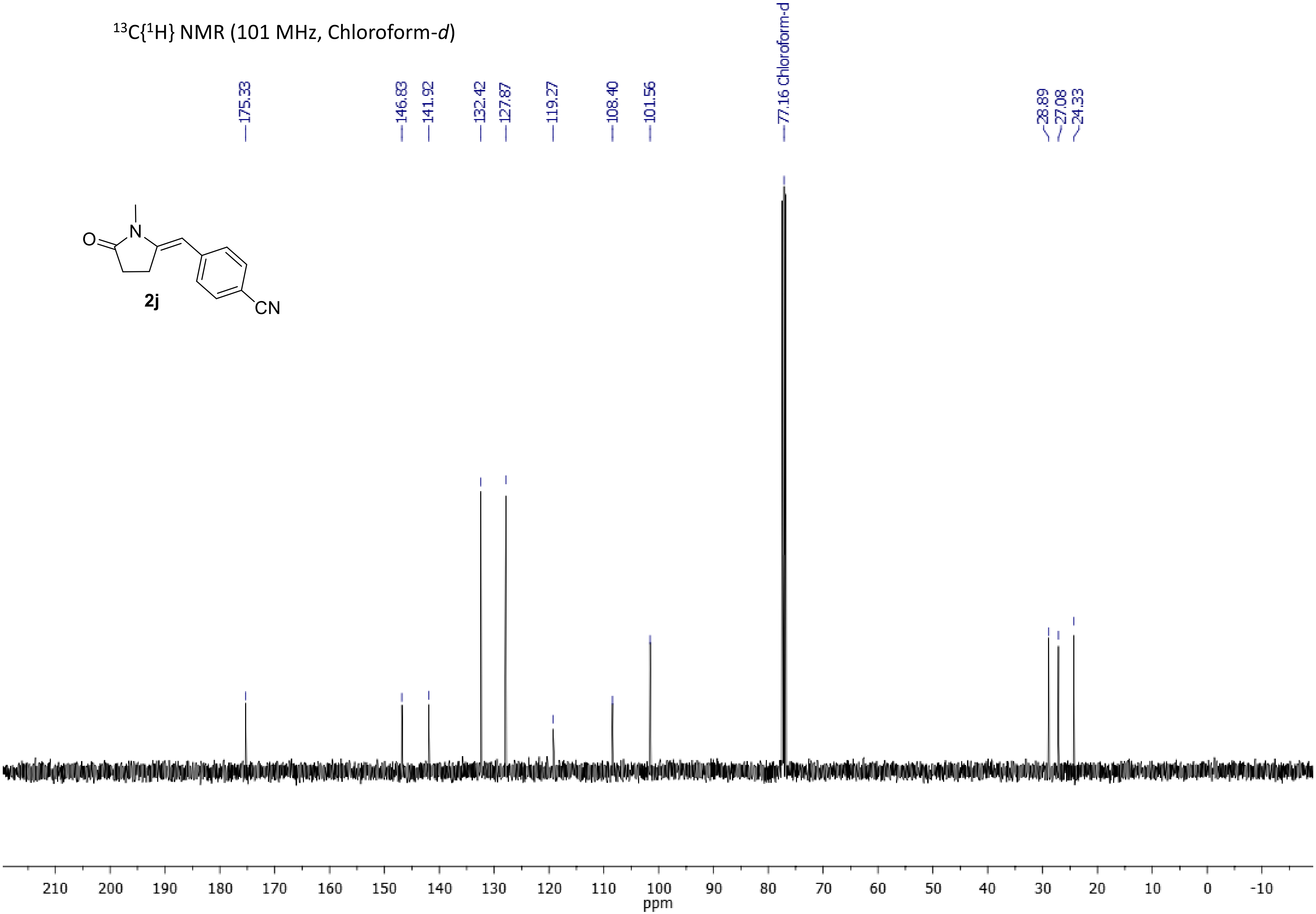



$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)
175.35
145.61
140.68
127.66
125.60
125.57
125.53
125.49
101.60
77.16 Chloroform-d
28.99
27.00
24.10
O
N
CF3
2i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

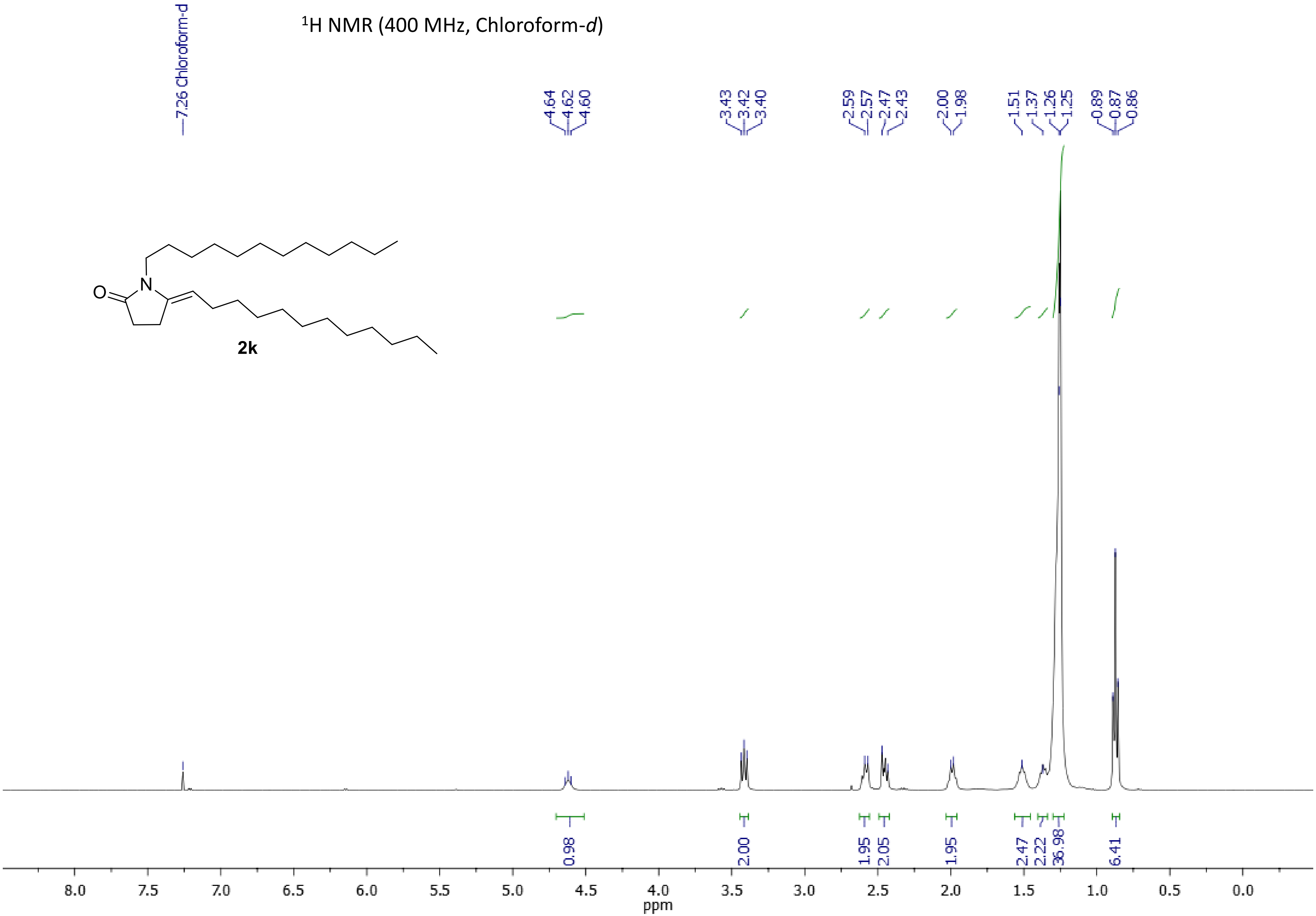
^{1}H NMR (400 MHz, Chloroform-d)



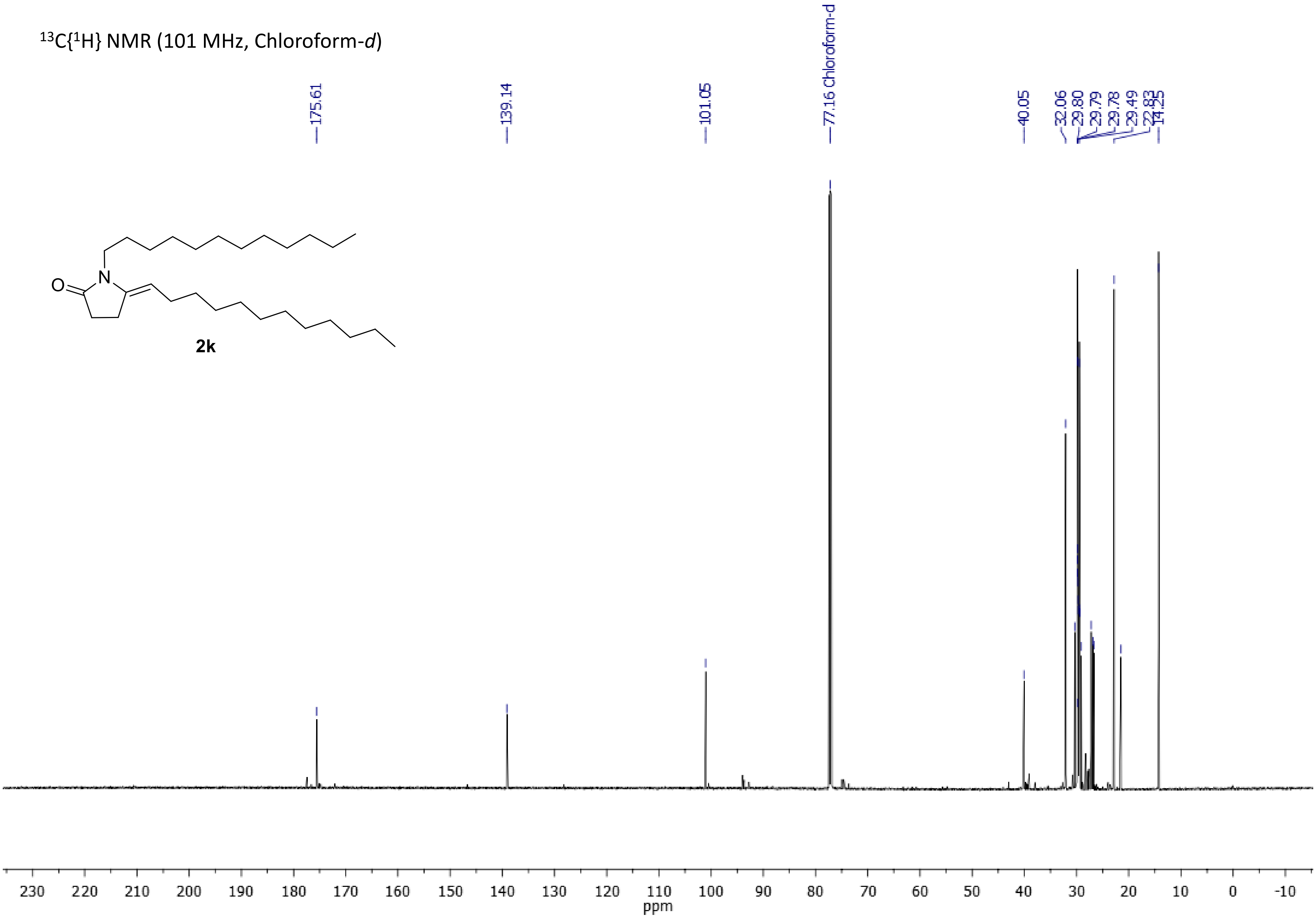
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



^{1}H NMR (400 MHz, Chloroform-*d*)

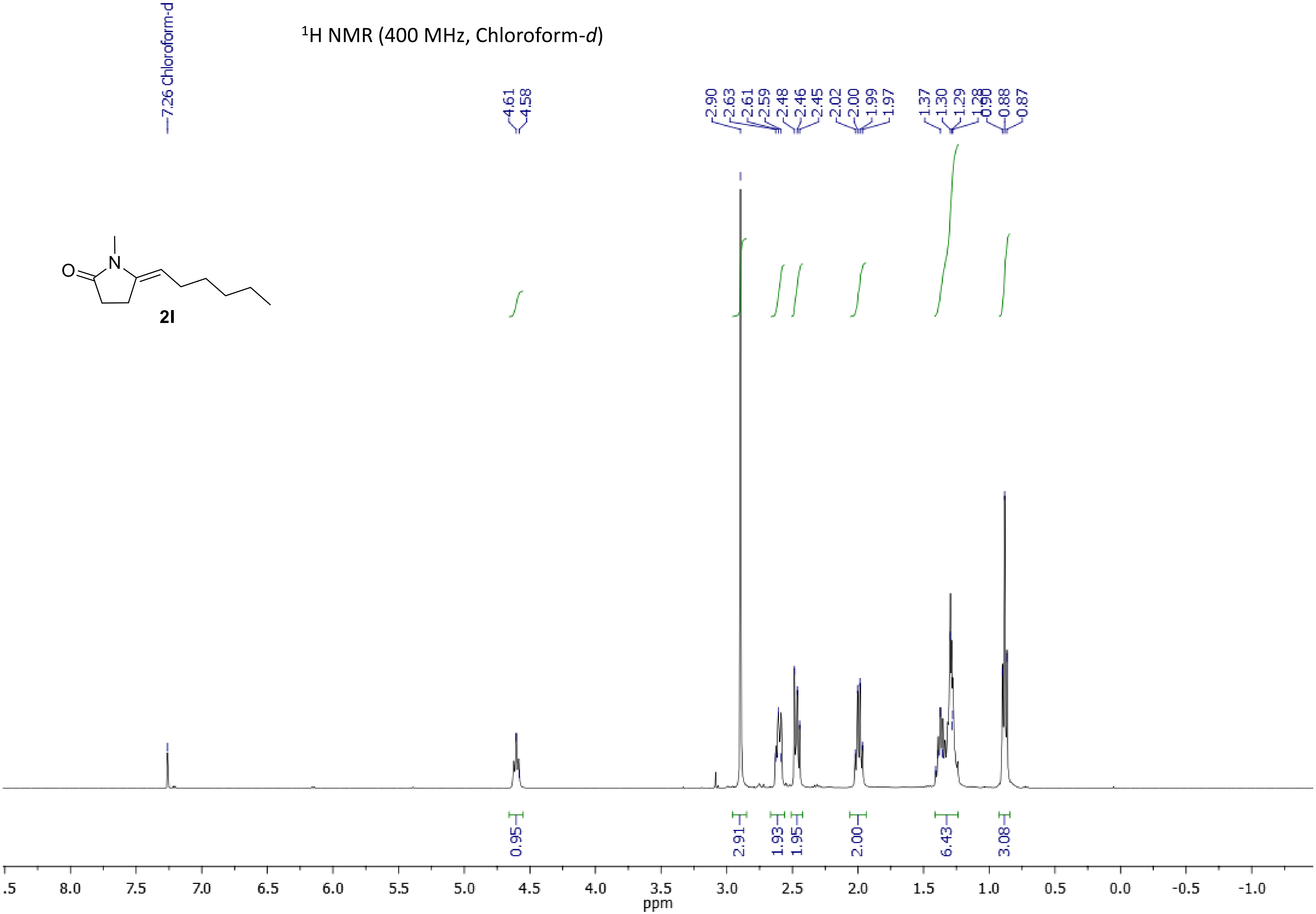


$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



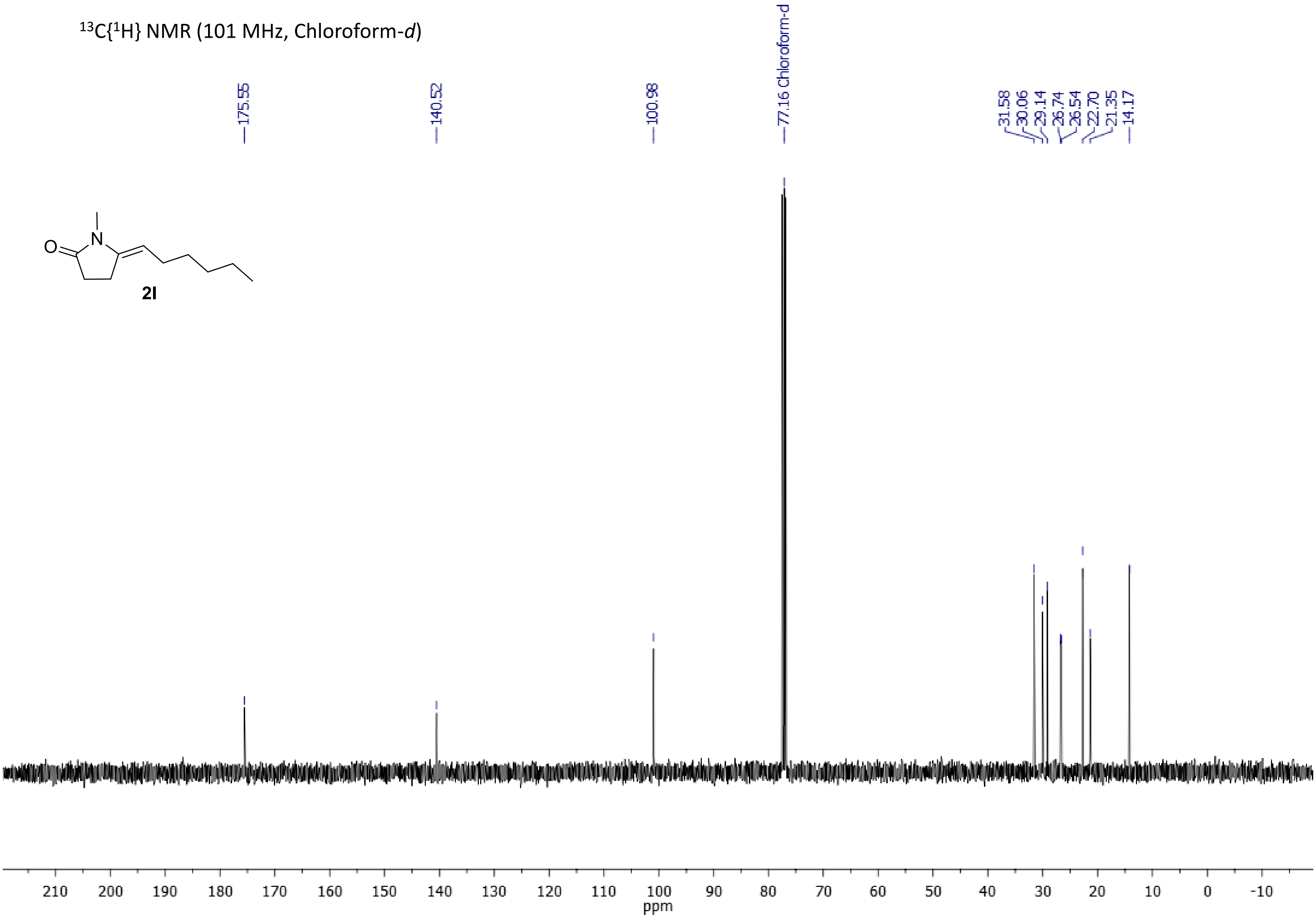
2k

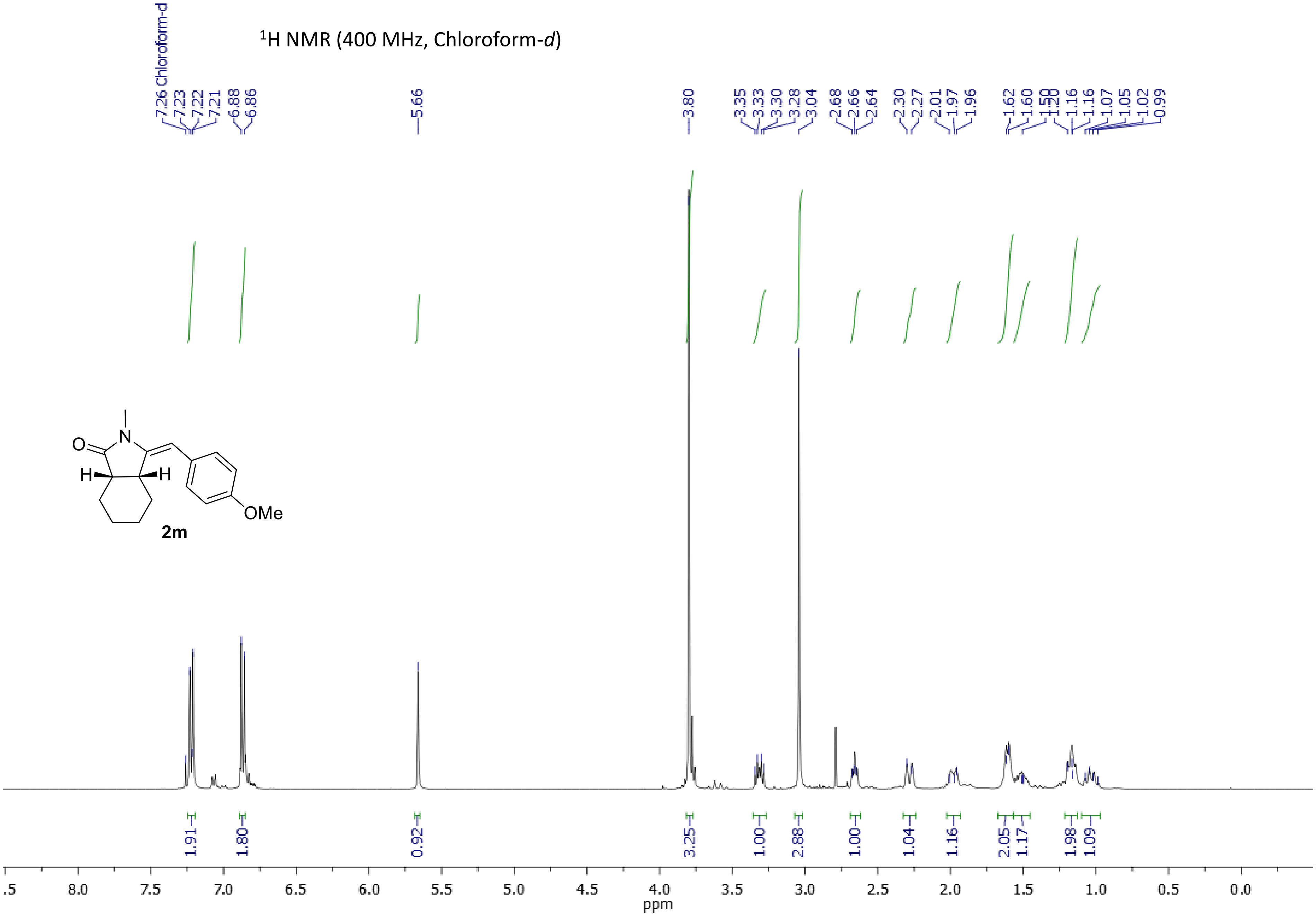
[1]H NMR (400 MHz, Chloroform-*d*)



2l

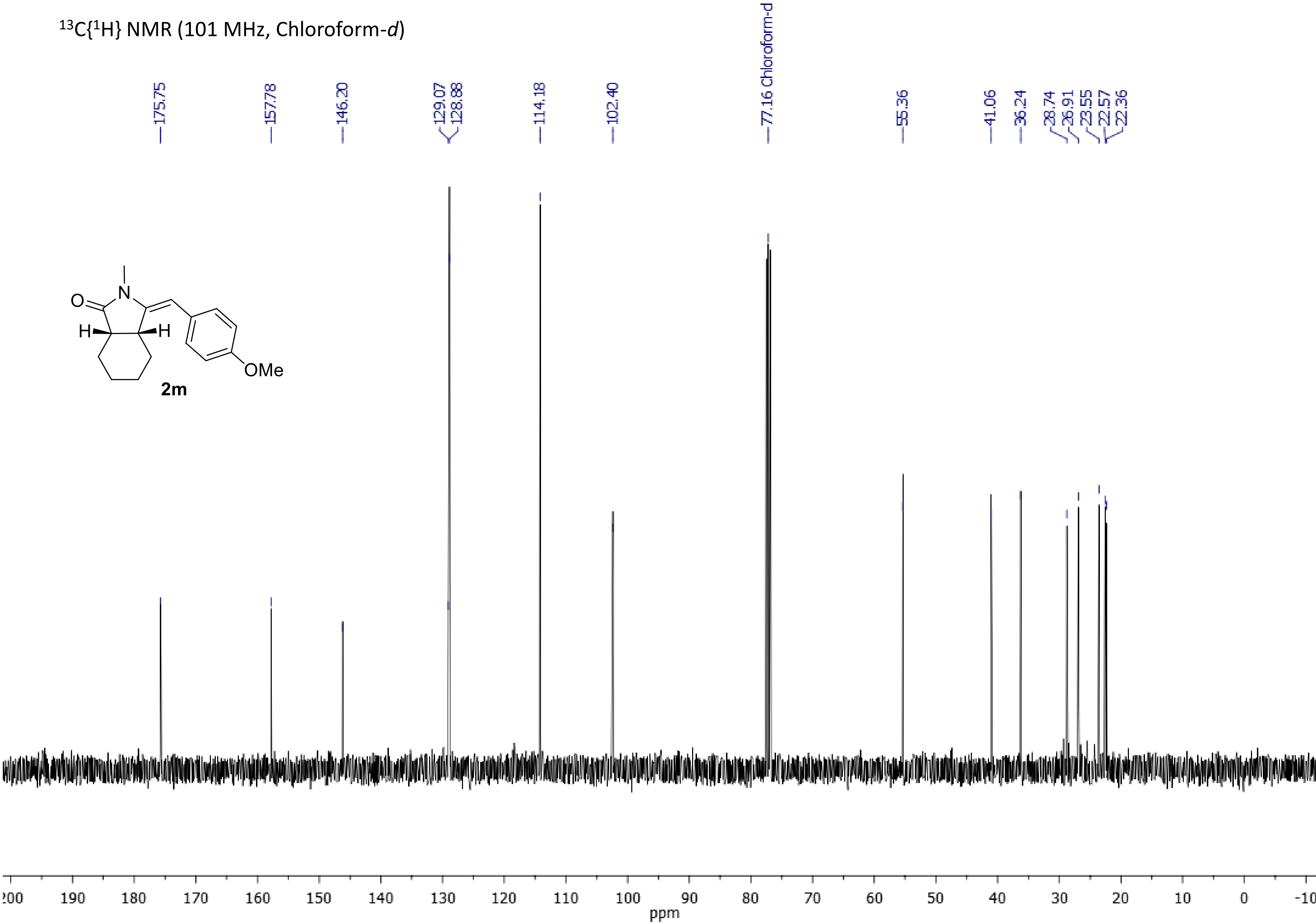
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

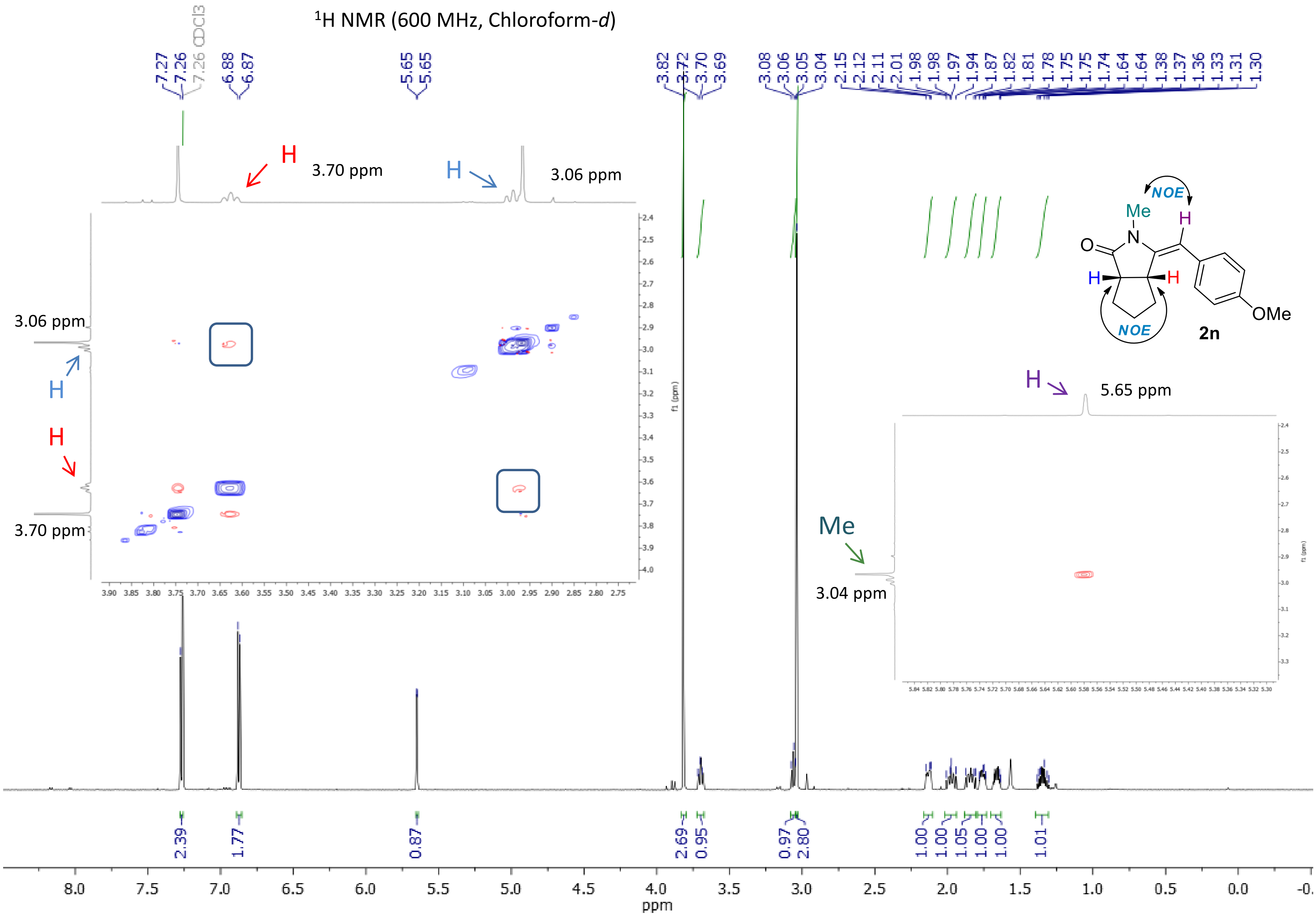




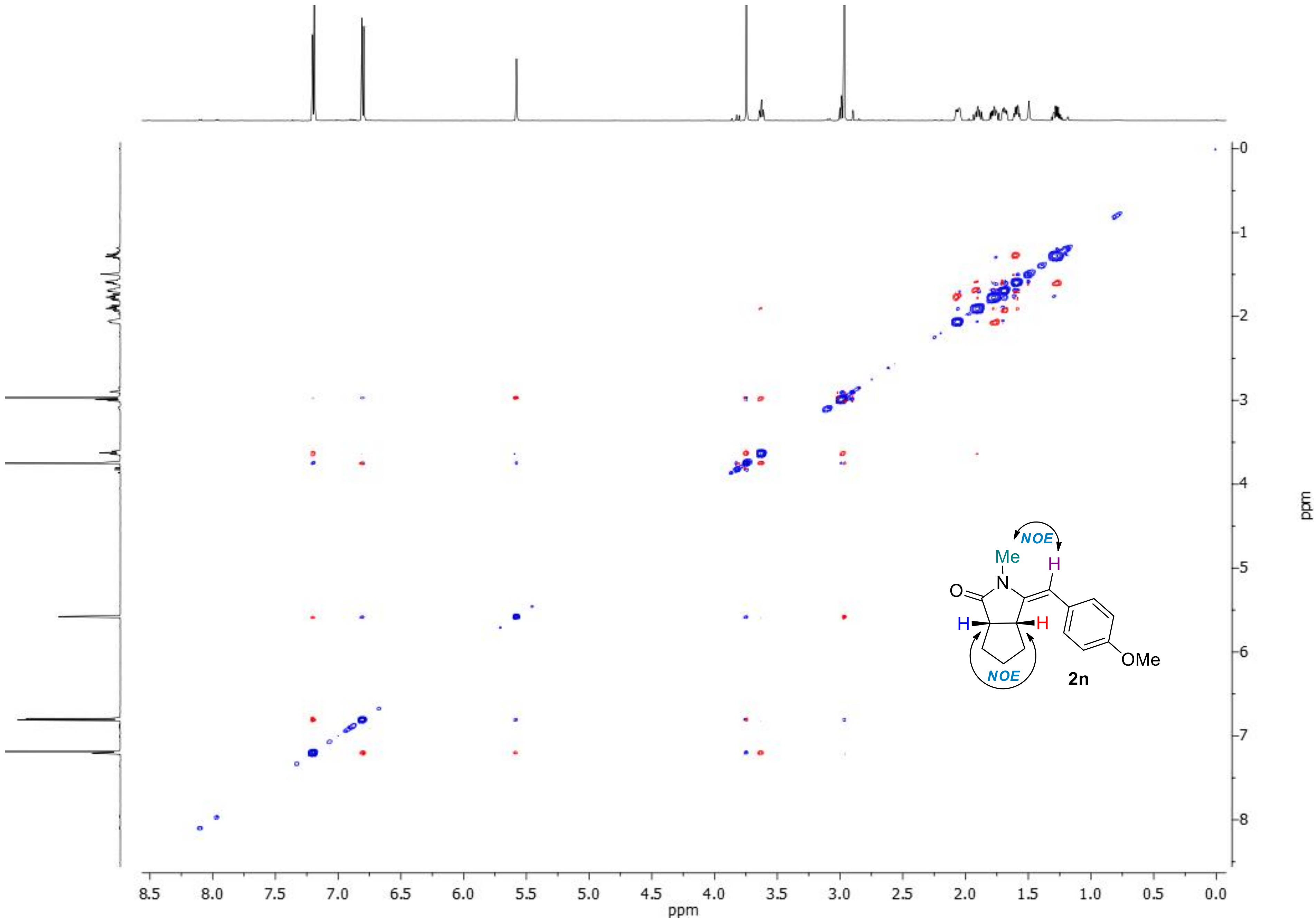
1H NMR (400 MHz, Chloroform-d)
7.26 Chloroform-d
7.23
7.22
7.21
6.88
6.86
5.66
3.80
3.35
3.33
3.30
3.28
3.04
2.68
2.66
2.64
2.30
2.27
2.01
1.97
1.96
1.62
1.60
1.16
1.16
1.07
1.05
1.02
0.99
O
N
H
H
OMe
2m
1.91
1.80
0.92
3.25
1.00
2.88
1.00
1.04
1.16
2.05
1.17
1.98
1.09
ppm

$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



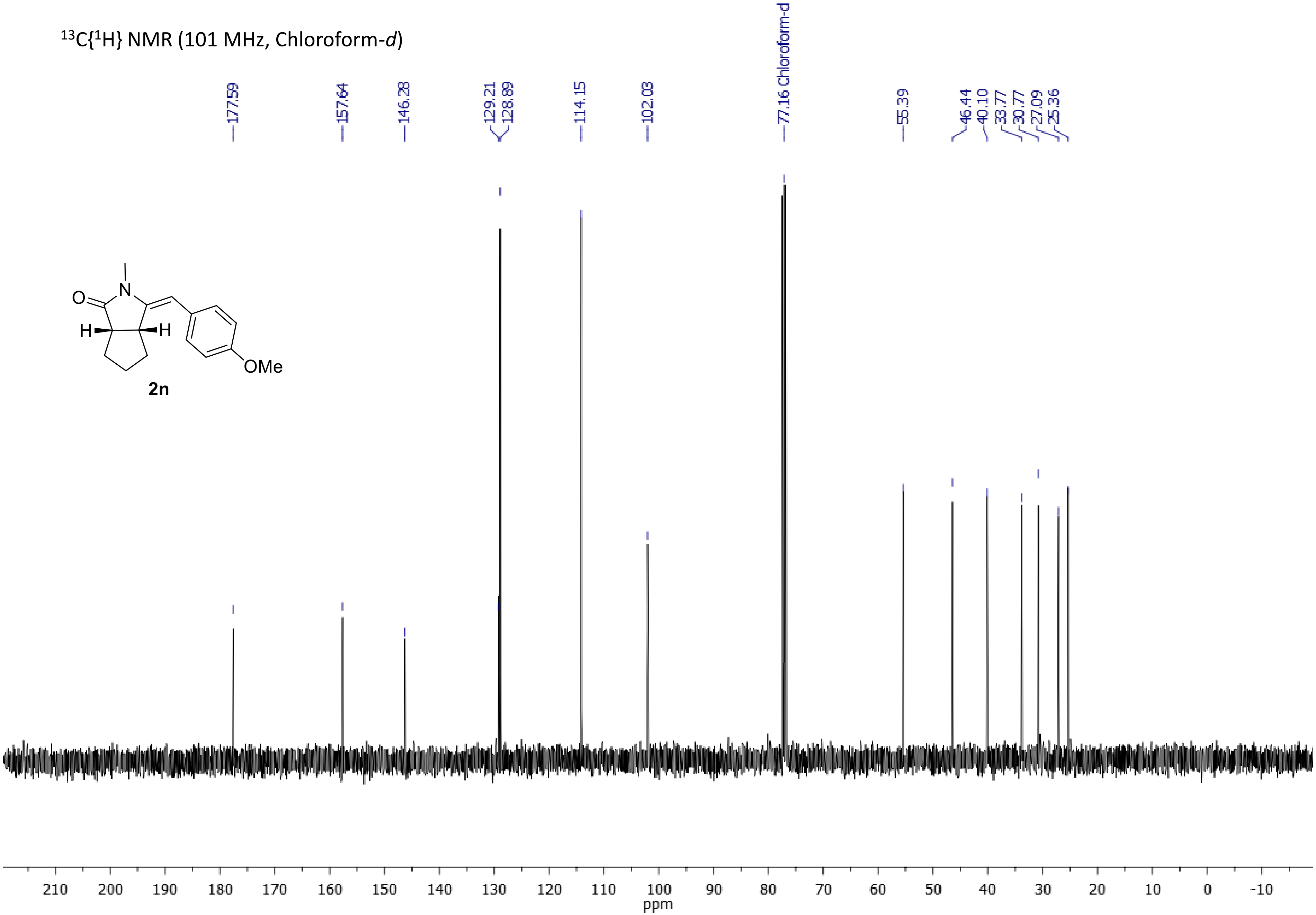


¹H NMR (600 MHz, Chloroform-d)
7.27
7.26
7.26 CDCl3
6.88
6.87
5.65
5.65
3.82
3.72
3.70
3.69
3.08
3.06
3.05
3.04
2.15
2.12
2.11
2.01
1.98
1.98
1.97
1.94
1.87
1.82
1.81
1.78
1.75
1.75
1.74
1.64
1.64
1.38
1.37
1.36
1.33
1.31
1.30
H
3.70 ppm
H
3.06 ppm
3.06 ppm
H
H
3.70 ppm
NOE
Me
N
O
H
H
H
NOE
OMe
2n
H
5.65 ppm
Me
3.04 ppm
2.39
1.77
0.87
2.69
0.95
0.97
2.80
1.00
1.00
1.05
1.00
1.00
1.01
ppm



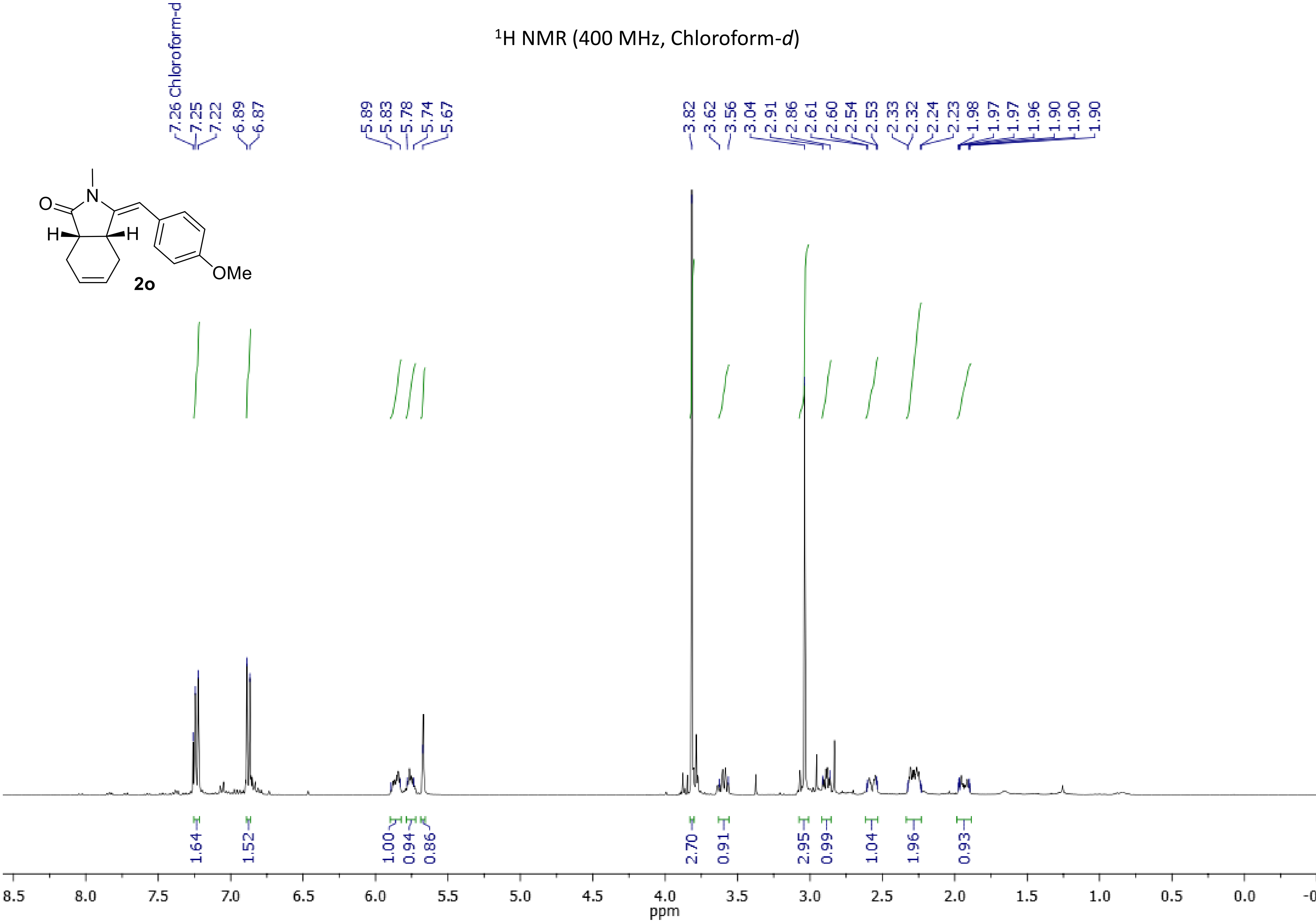
NOE
Me
N
H
O
H
H
OMe
NOE
2n
ppm
ppm

$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)

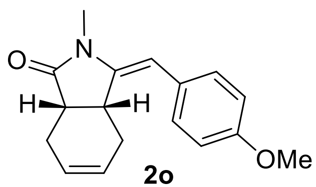


2n

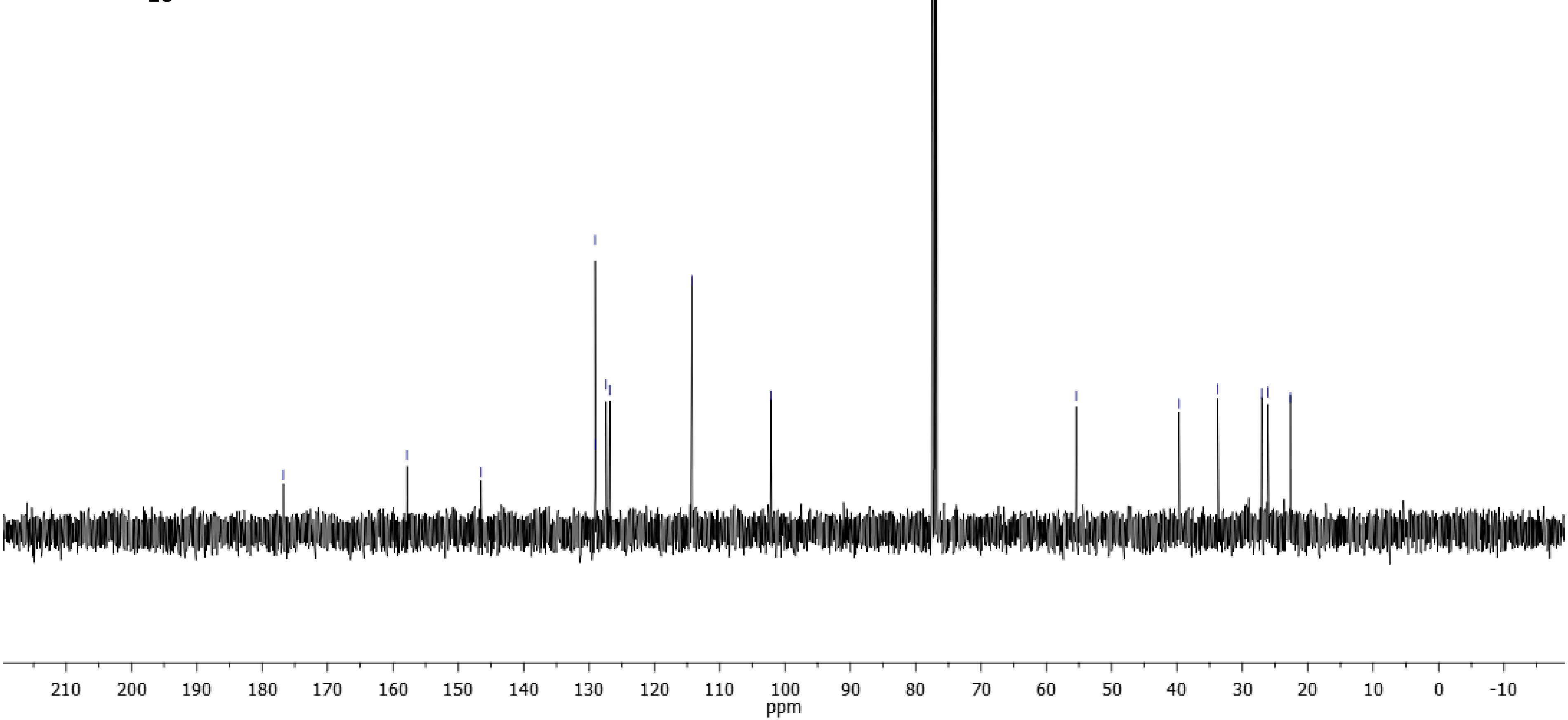
^{1}H NMR (400 MHz, Chloroform-*d*)



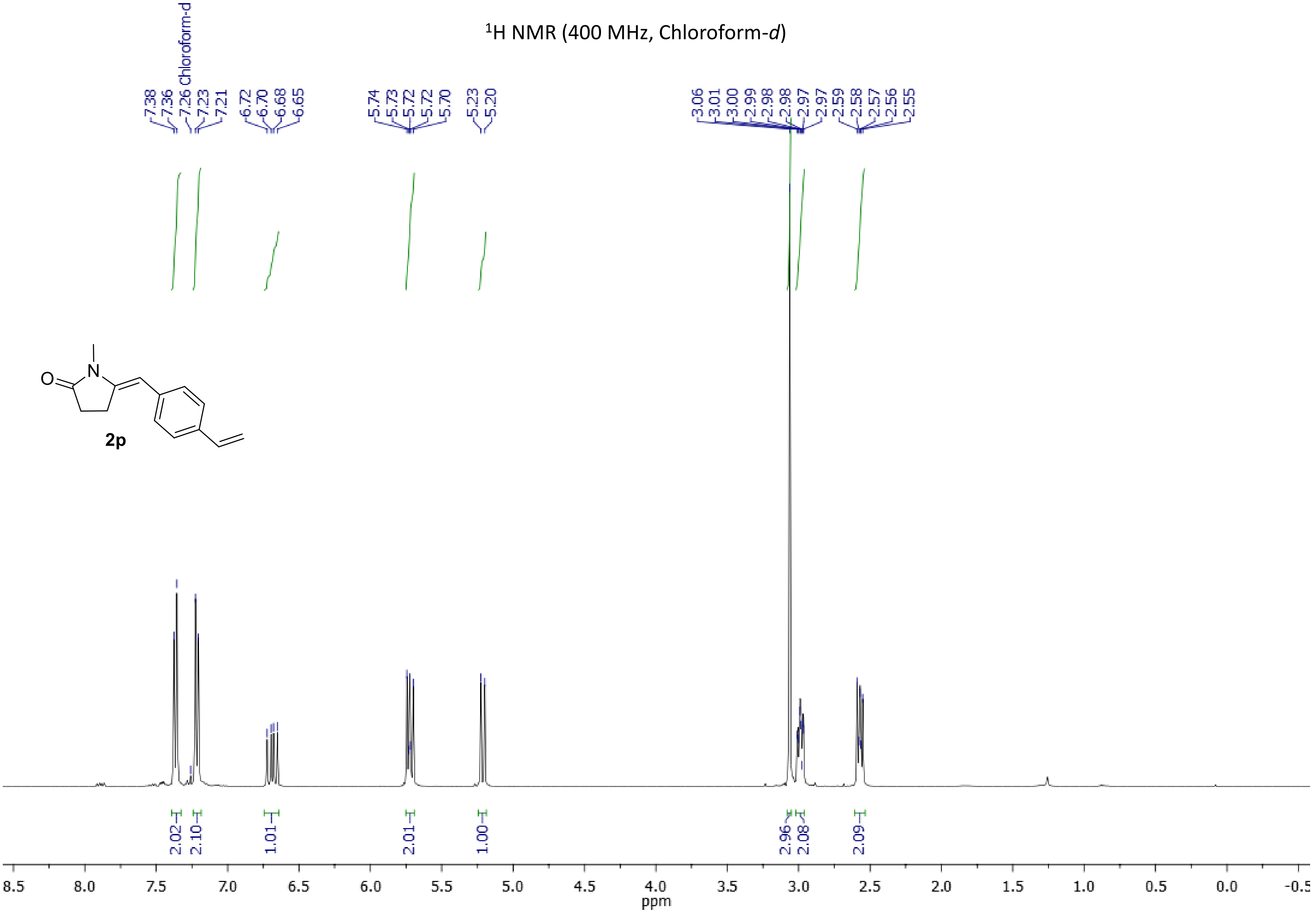
$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)



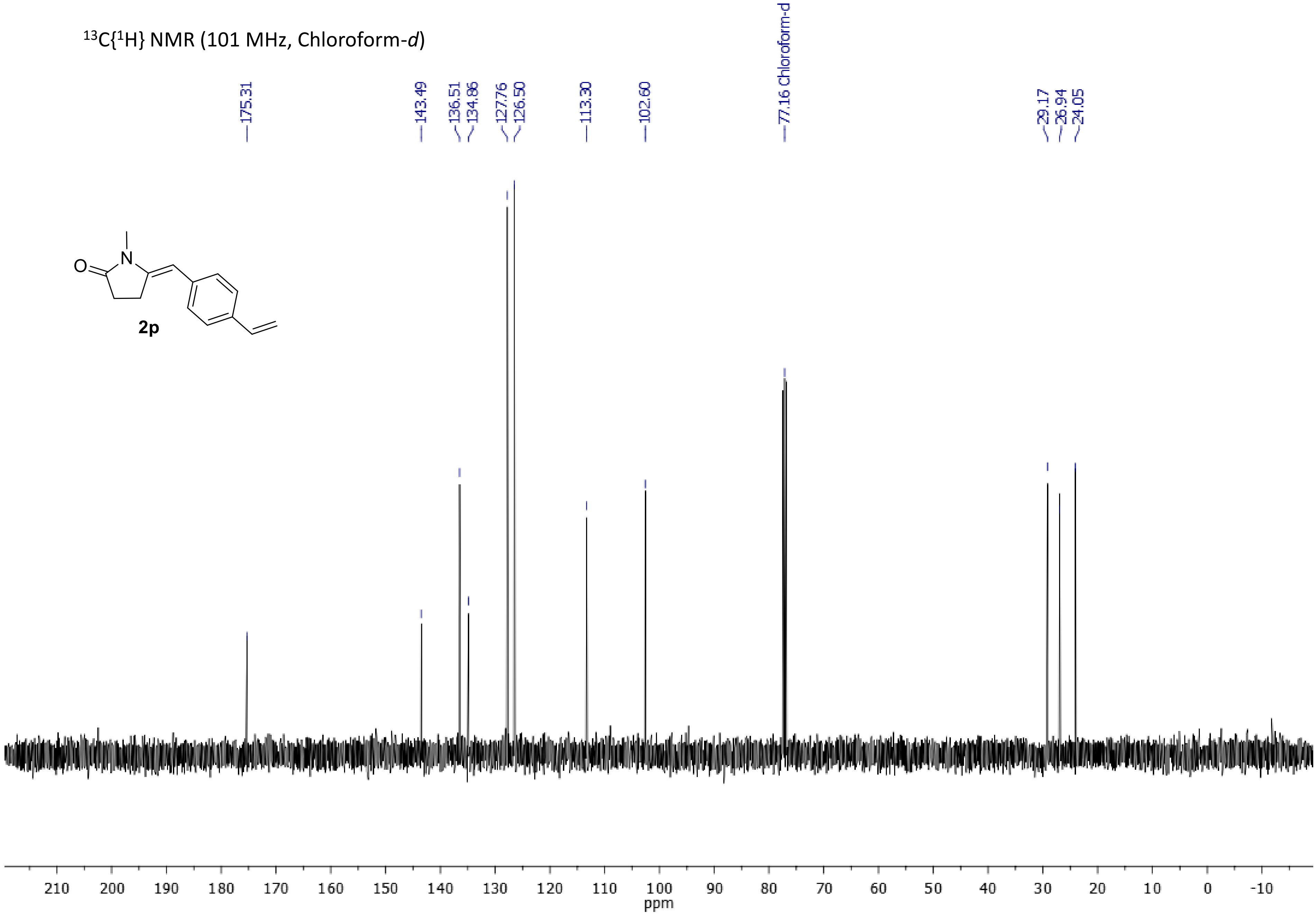
2o



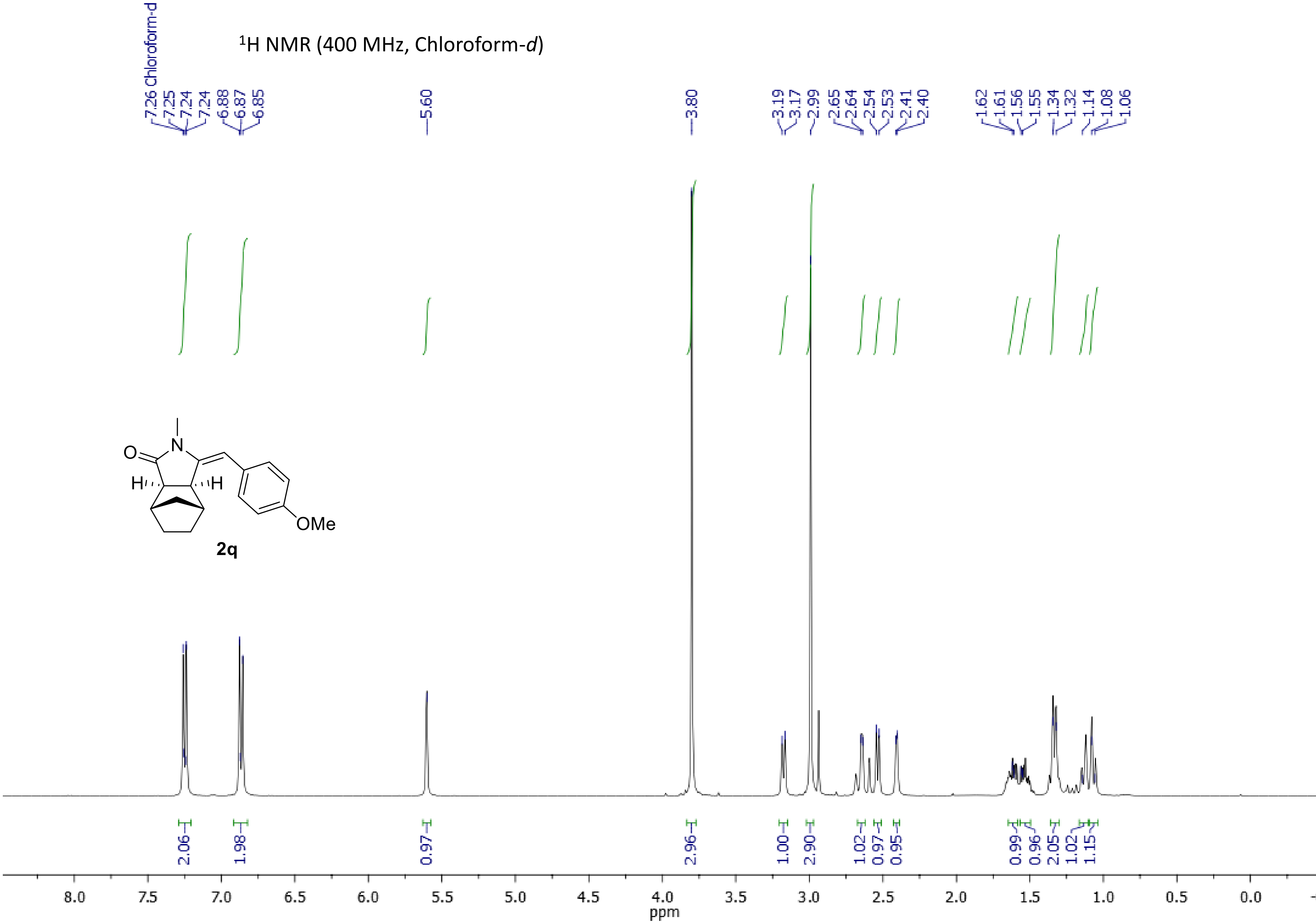
^{1}H NMR (400 MHz, Chloroform-*d*)



$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

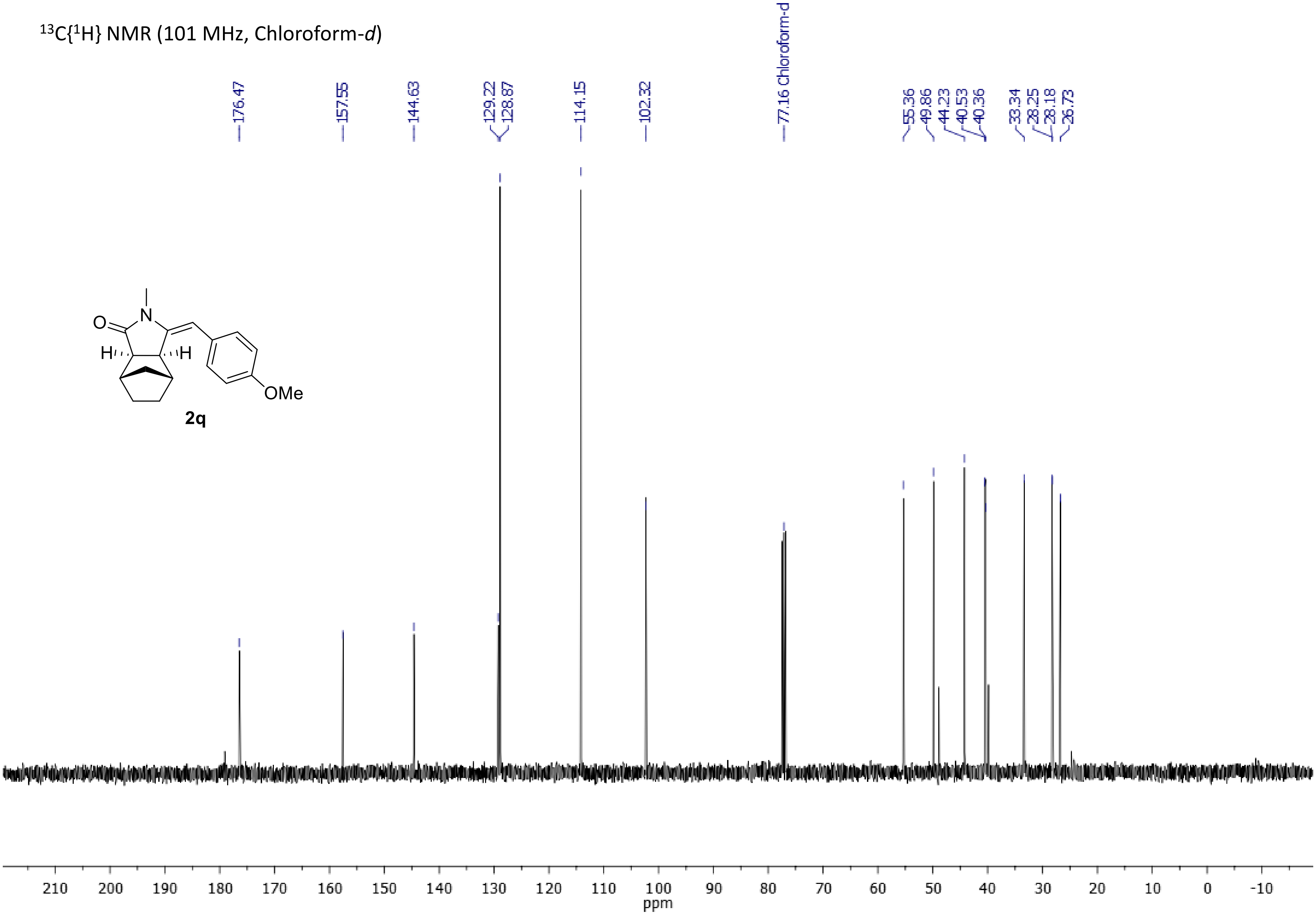


^{1}H NMR (400 MHz, Chloroform-d)

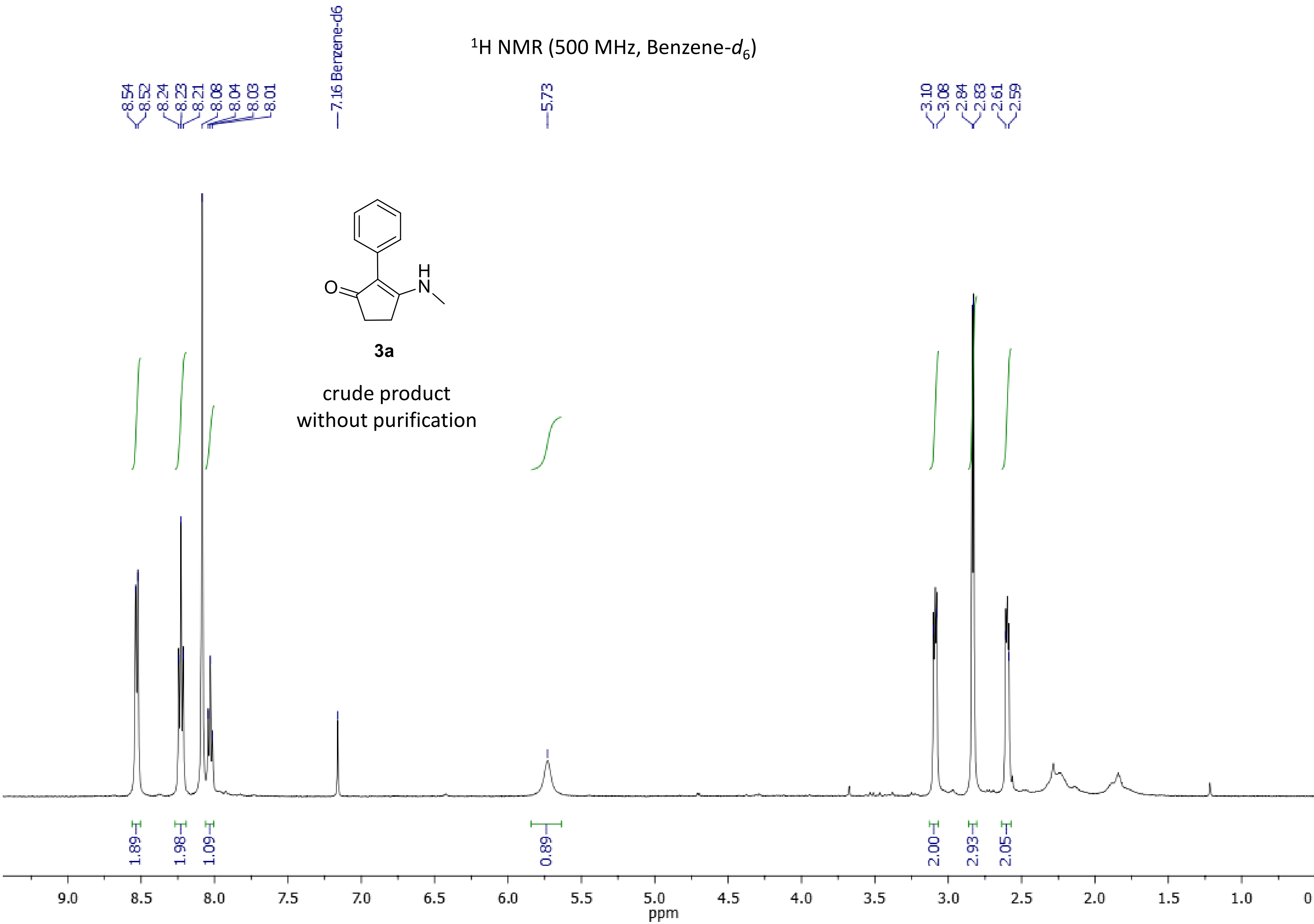


2q

$^{13}C\{^1H\}$ NMR (101 MHz, Chloroform-*d*)

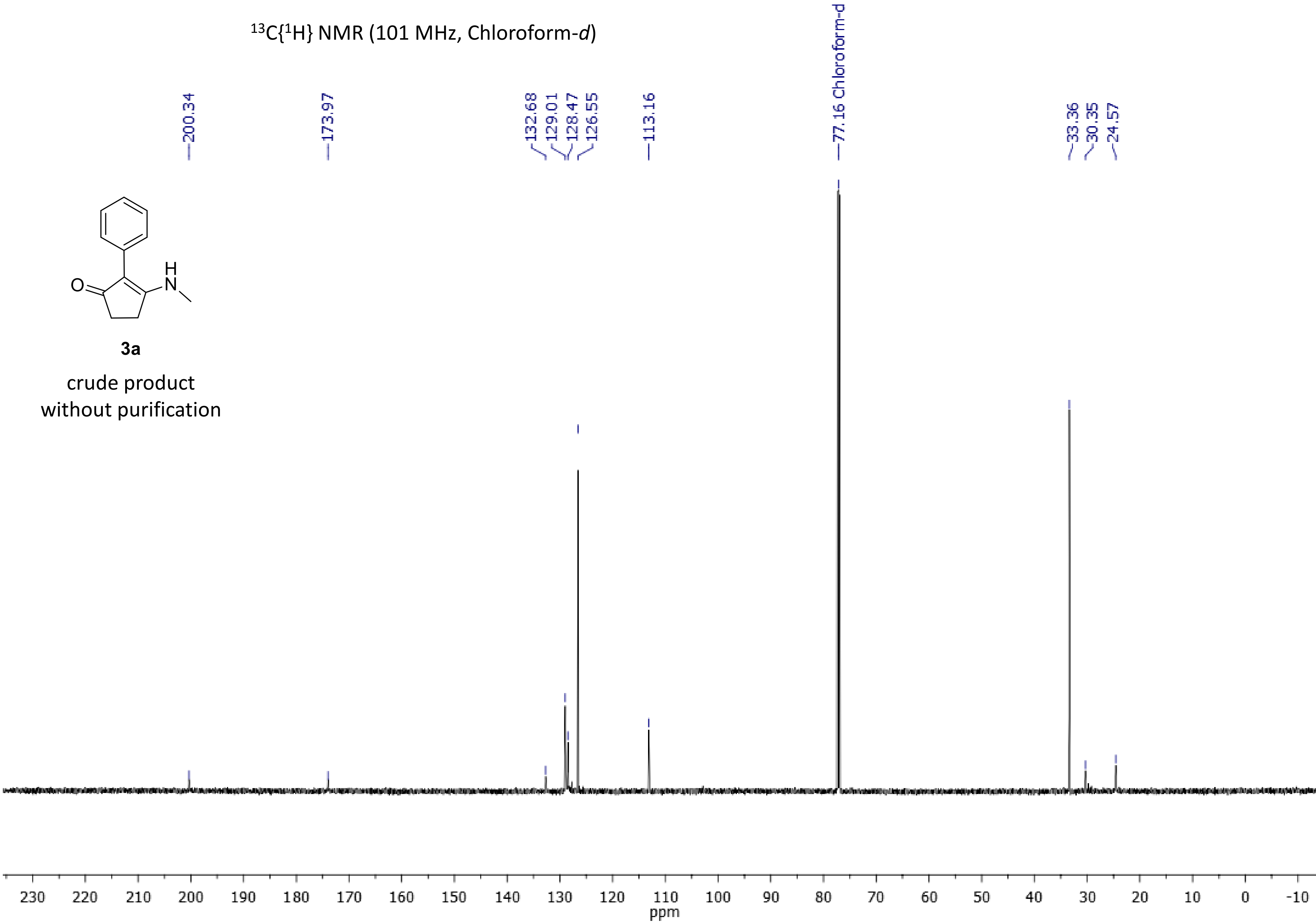


2q



1H NMR (500 MHz, Benzene-d6)
8.54
8.52
8.24
8.23
8.21
8.08
8.04
8.03
8.01
7.16 Benzene-d6
5.73
3.10
3.08
2.84
2.83
2.61
2.59
O
H
N
3a
crude product
without purification
1.89
1.98
1.09
0.89
2.00
2.93
2.05
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
ppm

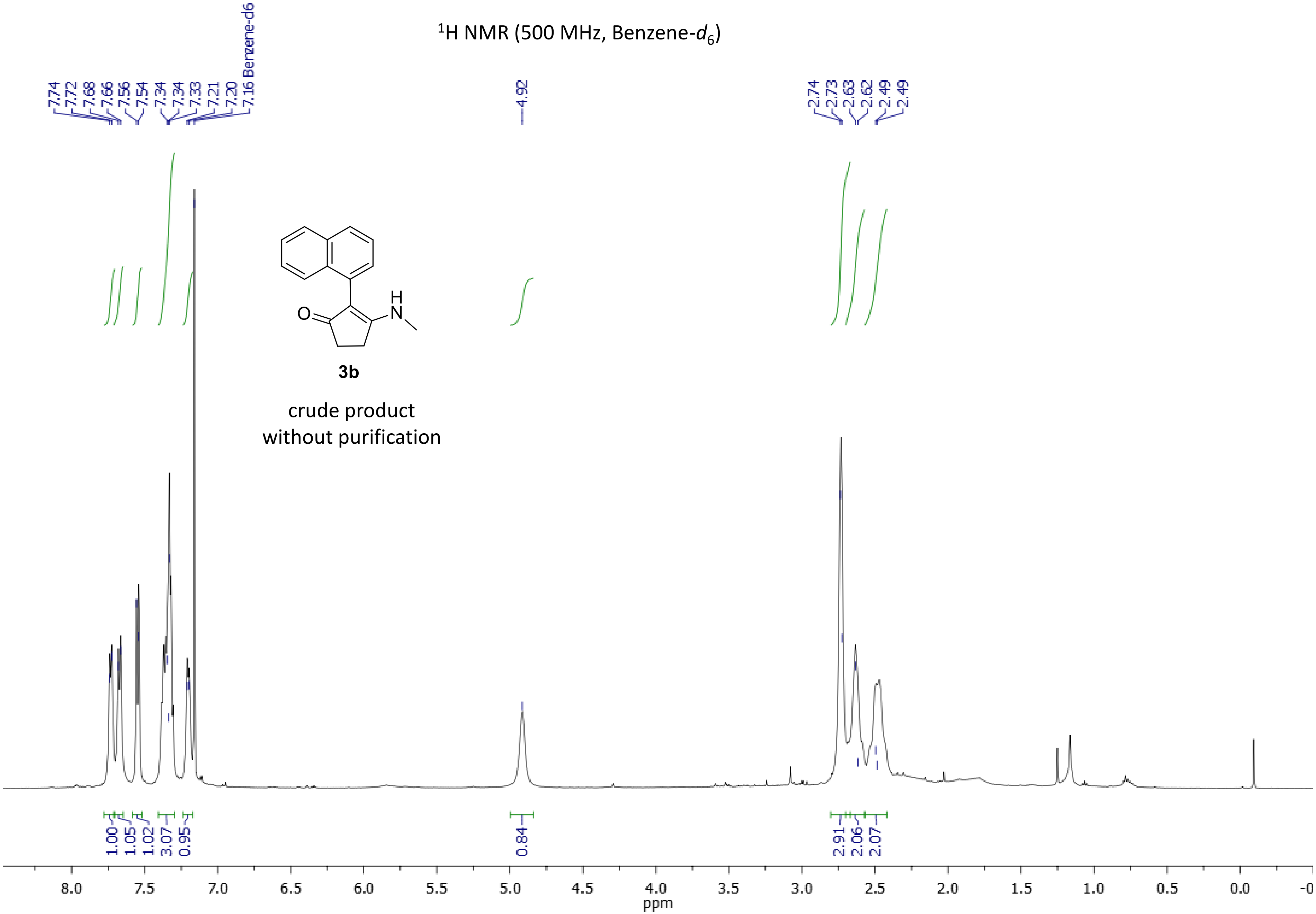
$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)

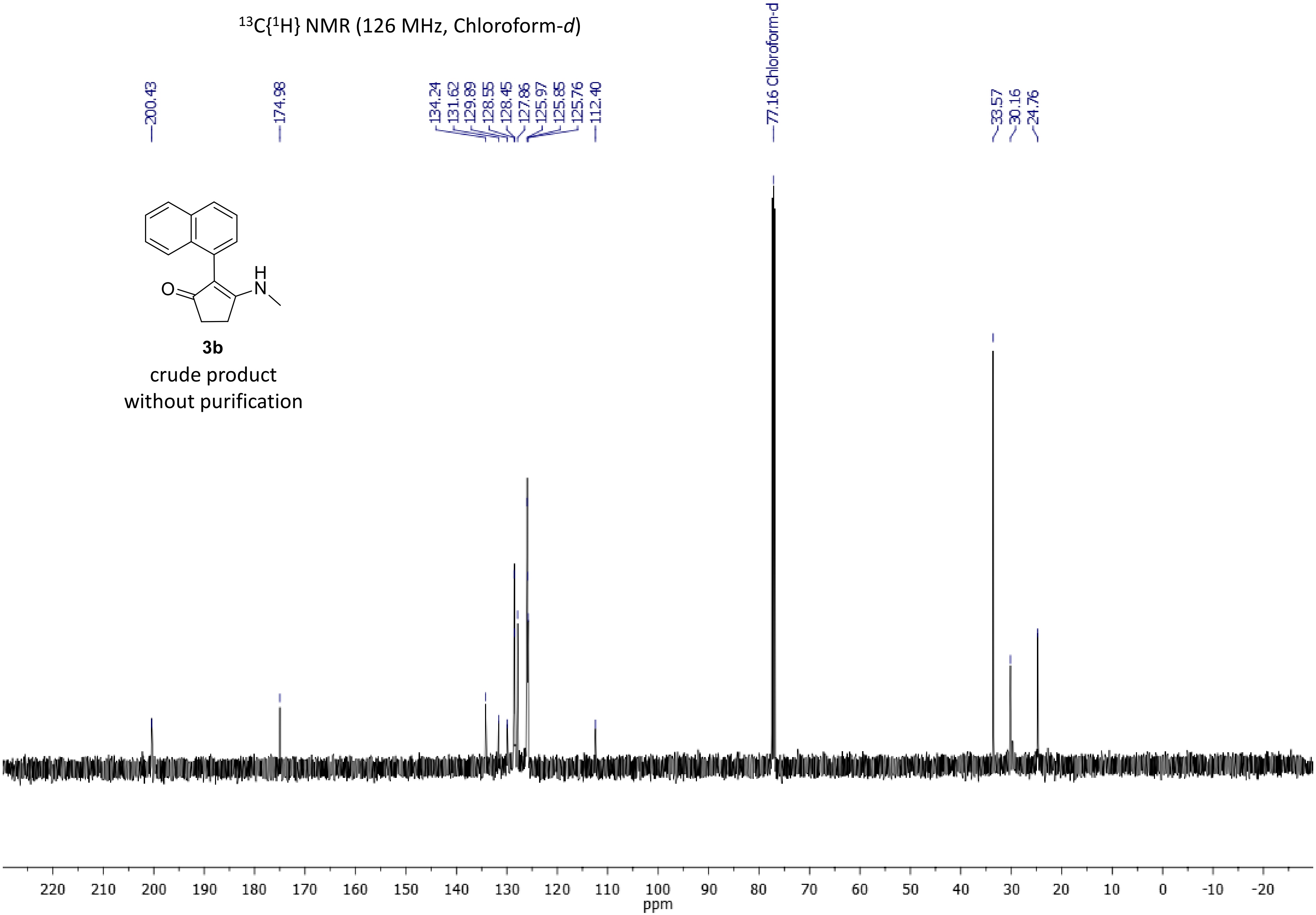


3a

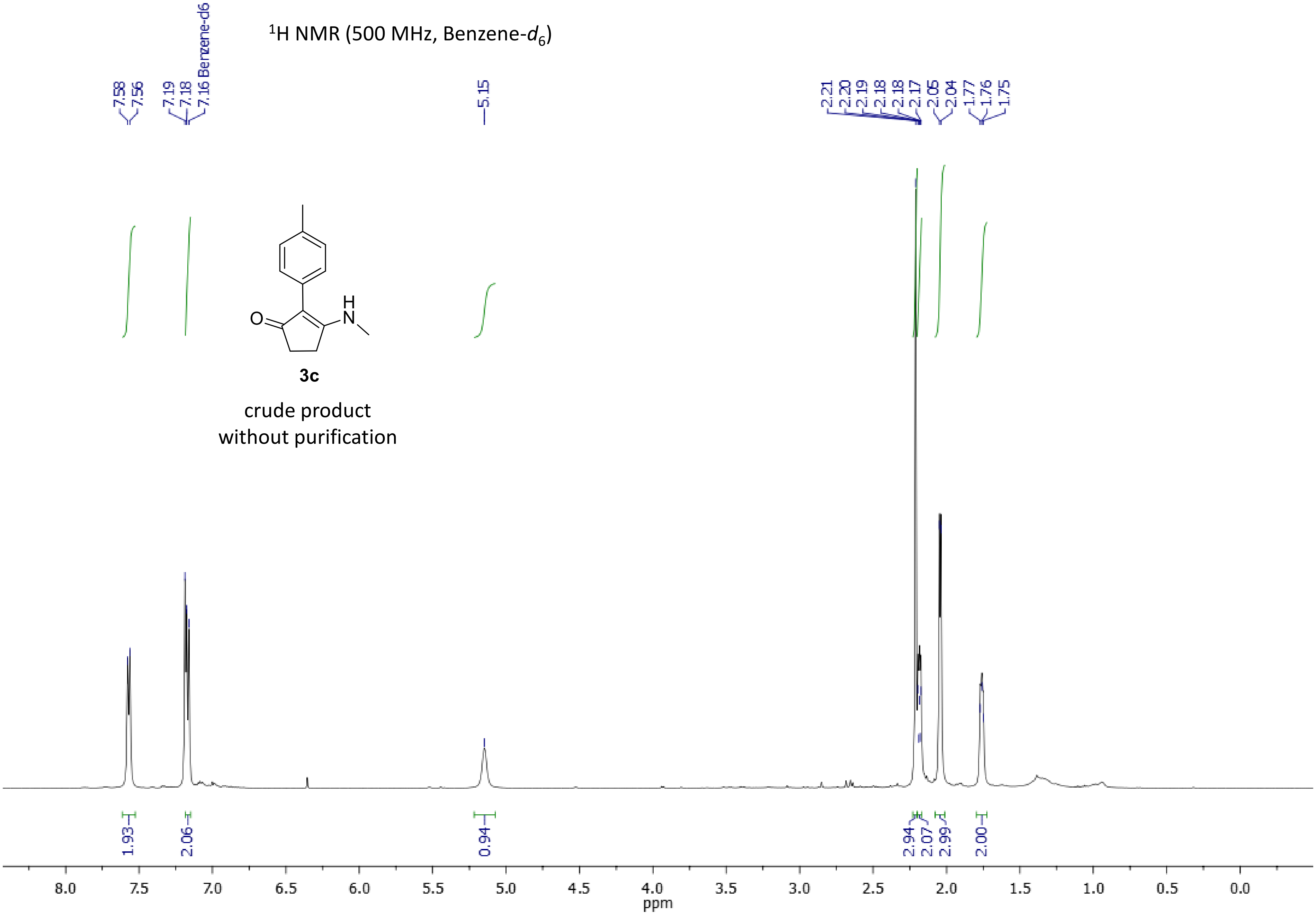
crude product
without purification

^{1}H NMR (500 MHz, Benzene-d_6)

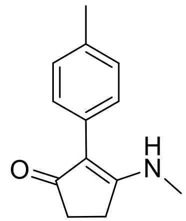



$^{13}C\{^{1}H\}$ NMR (126 MHz, Chloroform-*d*)
200.43
174.98
134.24
131.62
129.89
128.55
128.45
127.86
125.97
125.85
125.76
112.40
77.16 Chloroform-d
33.57
30.16
24.76
O
H
N
3b
crude product
without purification
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
ppm

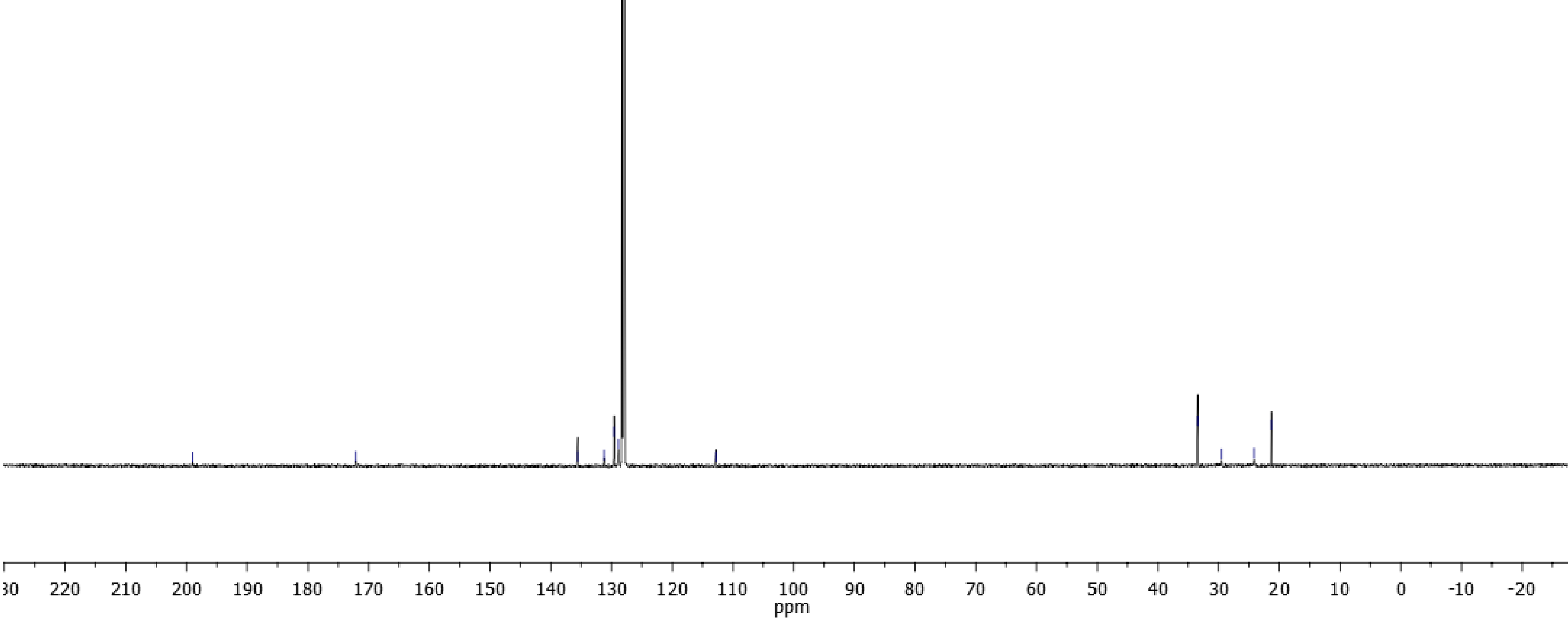
^{1}H NMR (500 MHz, Benzene-d_6)



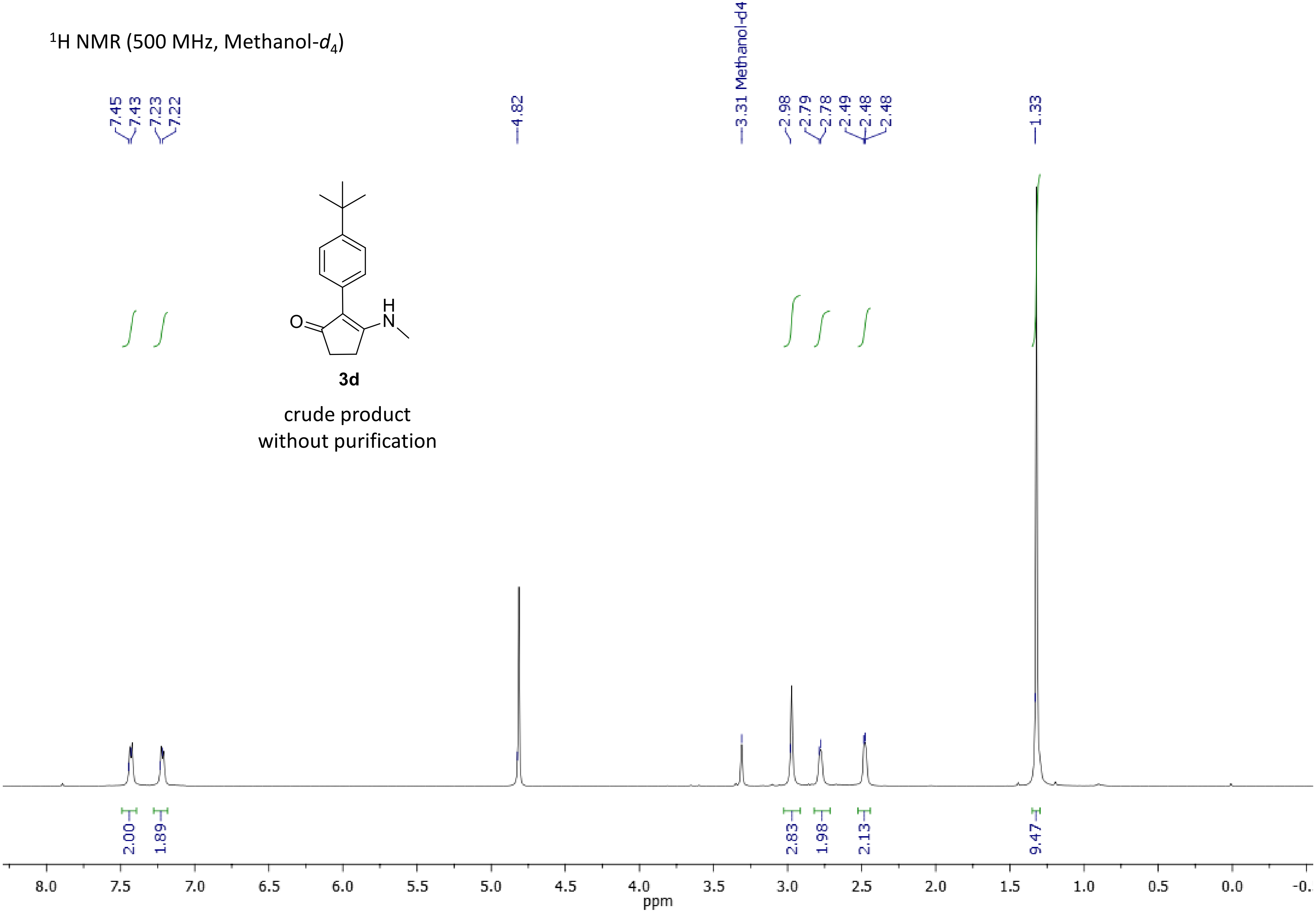
¹³C{¹H} NMR (126 MHz, Benzene-d_6)



3c
crude product
without purification

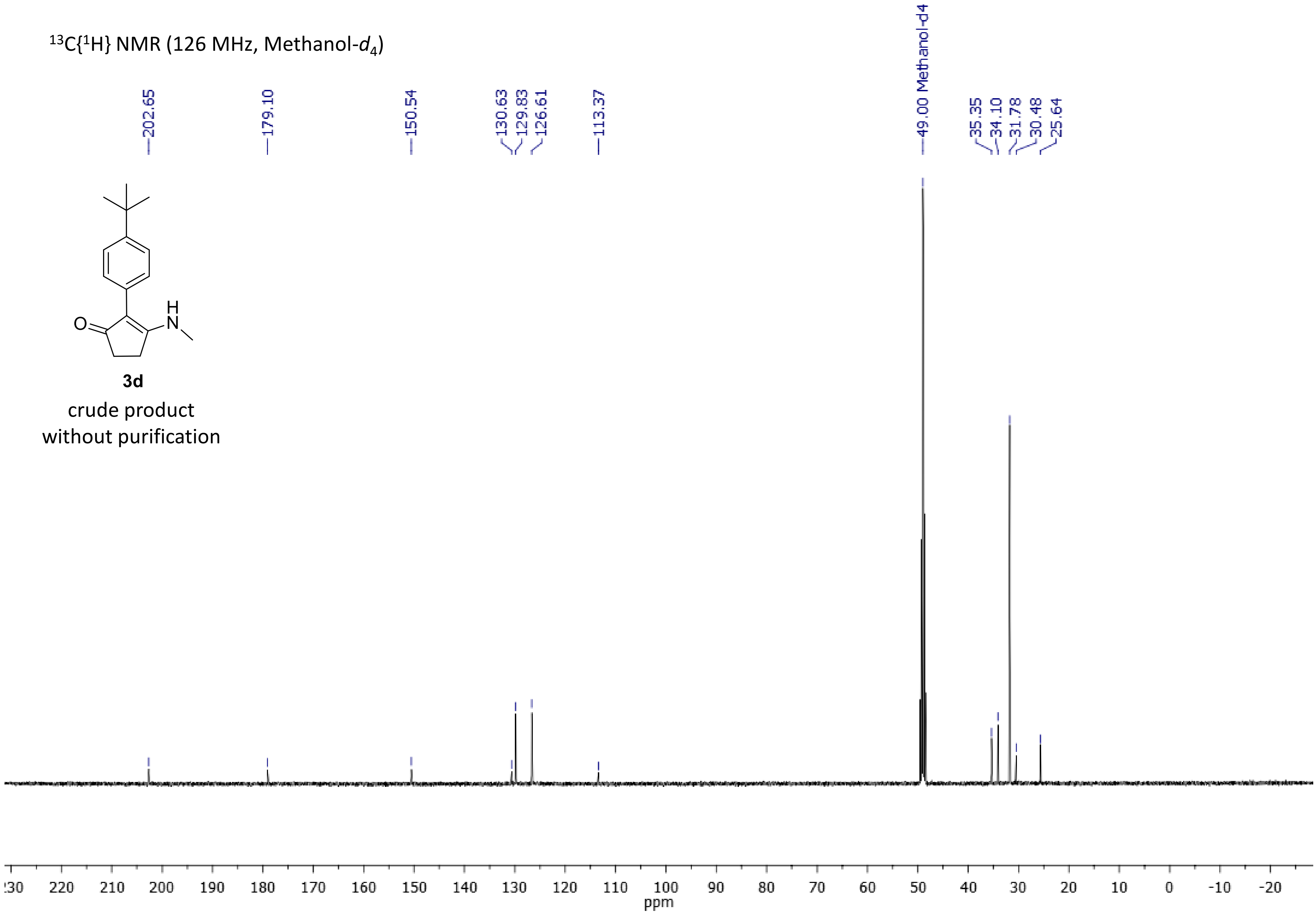


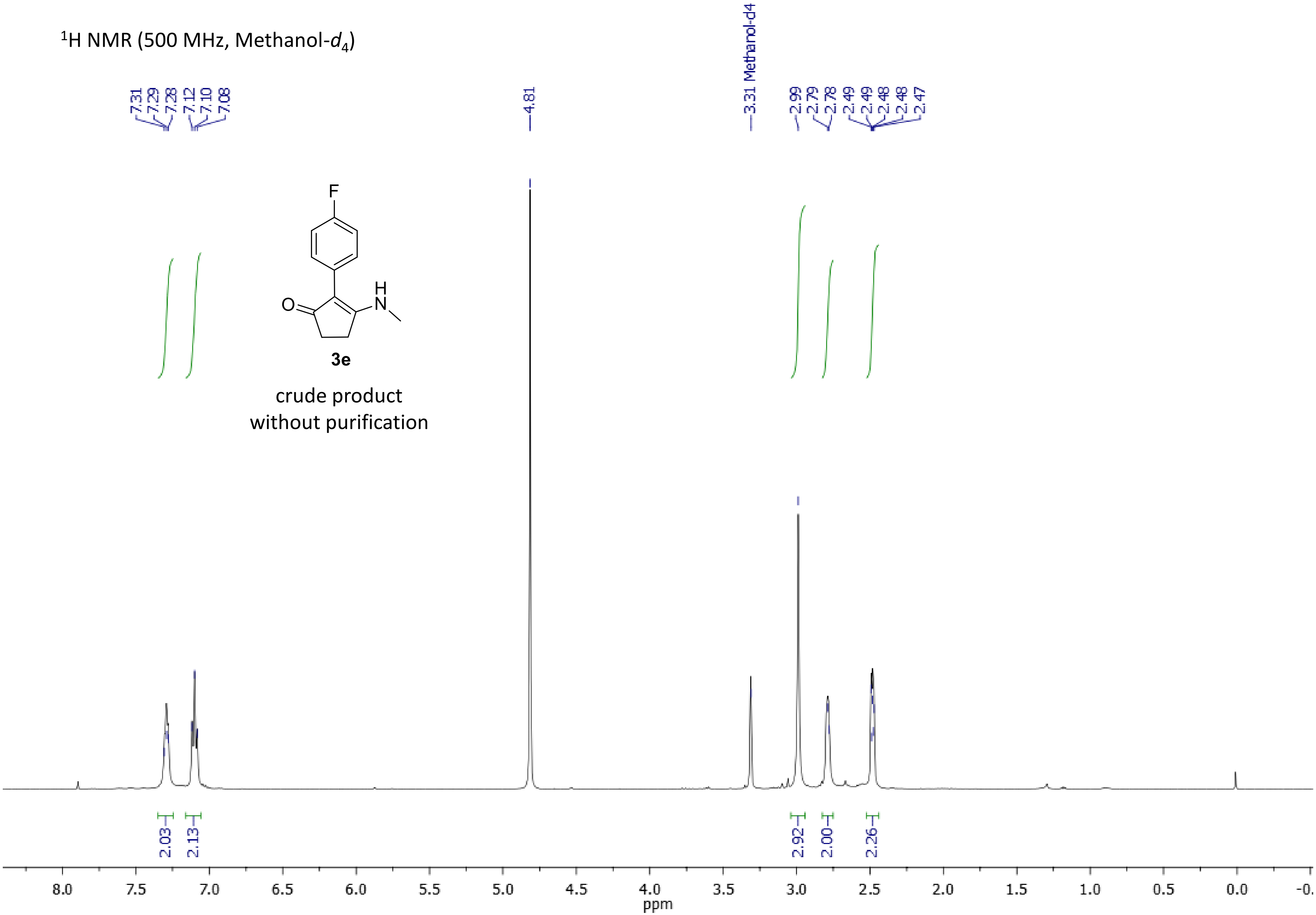
^{1}H NMR (500 MHz, Methanol-d_4)



$^{13}C\{^{1}H\}$ NMR (126 MHz, Methanol-d_4)

3d
crude product
without purification



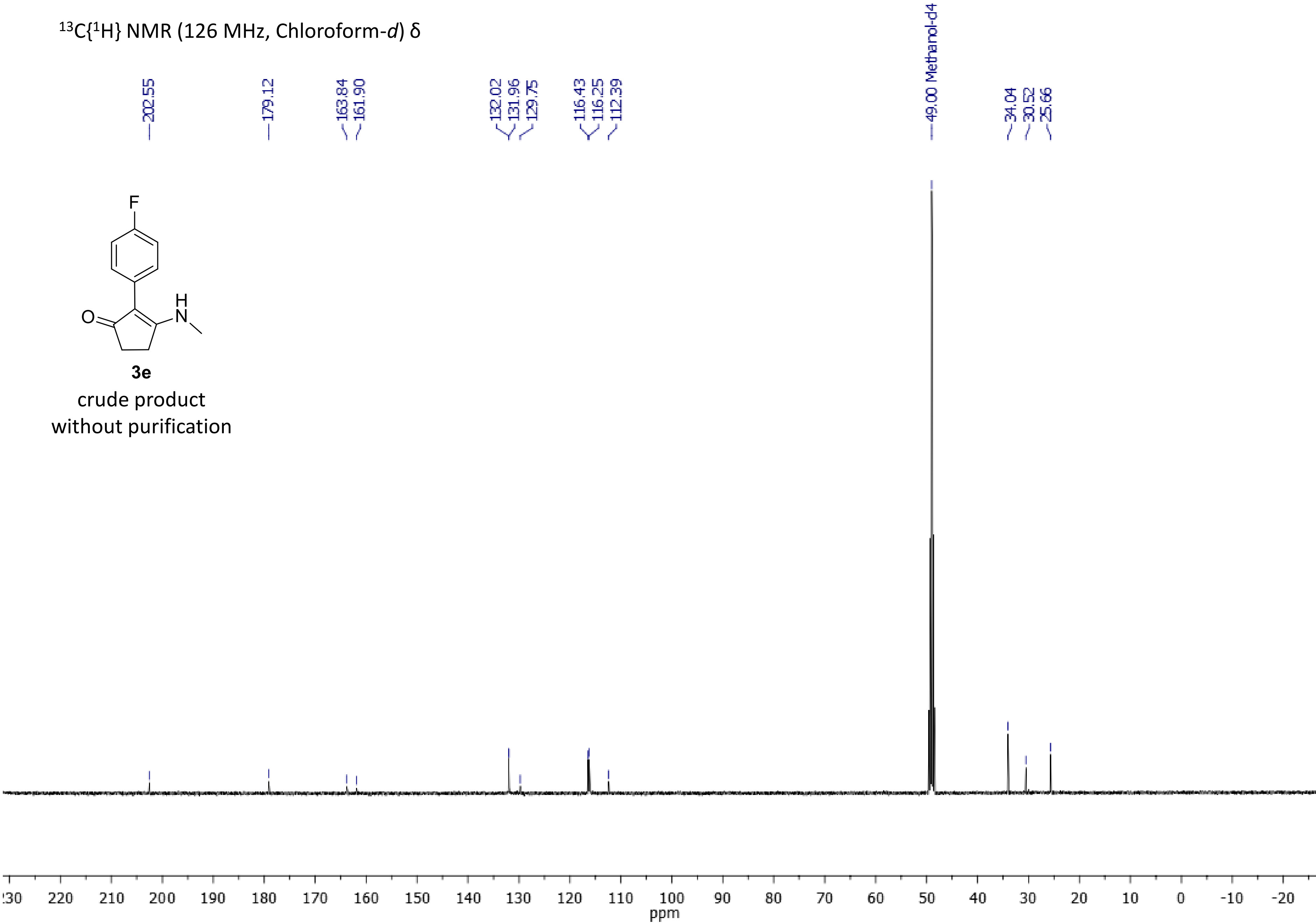


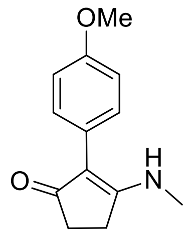
1H NMR (500 MHz, Methanol-d4)
7.31
7.29
7.28
7.12
7.10
7.08
4.81
3.31 Methanol-d4
2.99
2.79
2.78
2.49
2.49
2.48
2.48
2.47
F
H
N
O
3e
crude product
without purification
2.03
2.13
2.92
2.00
2.26
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm

$^{13}C\{^{1}H\}$ NMR (126 MHz, Chloroform-*d*) δ

3e

crude product
without purification

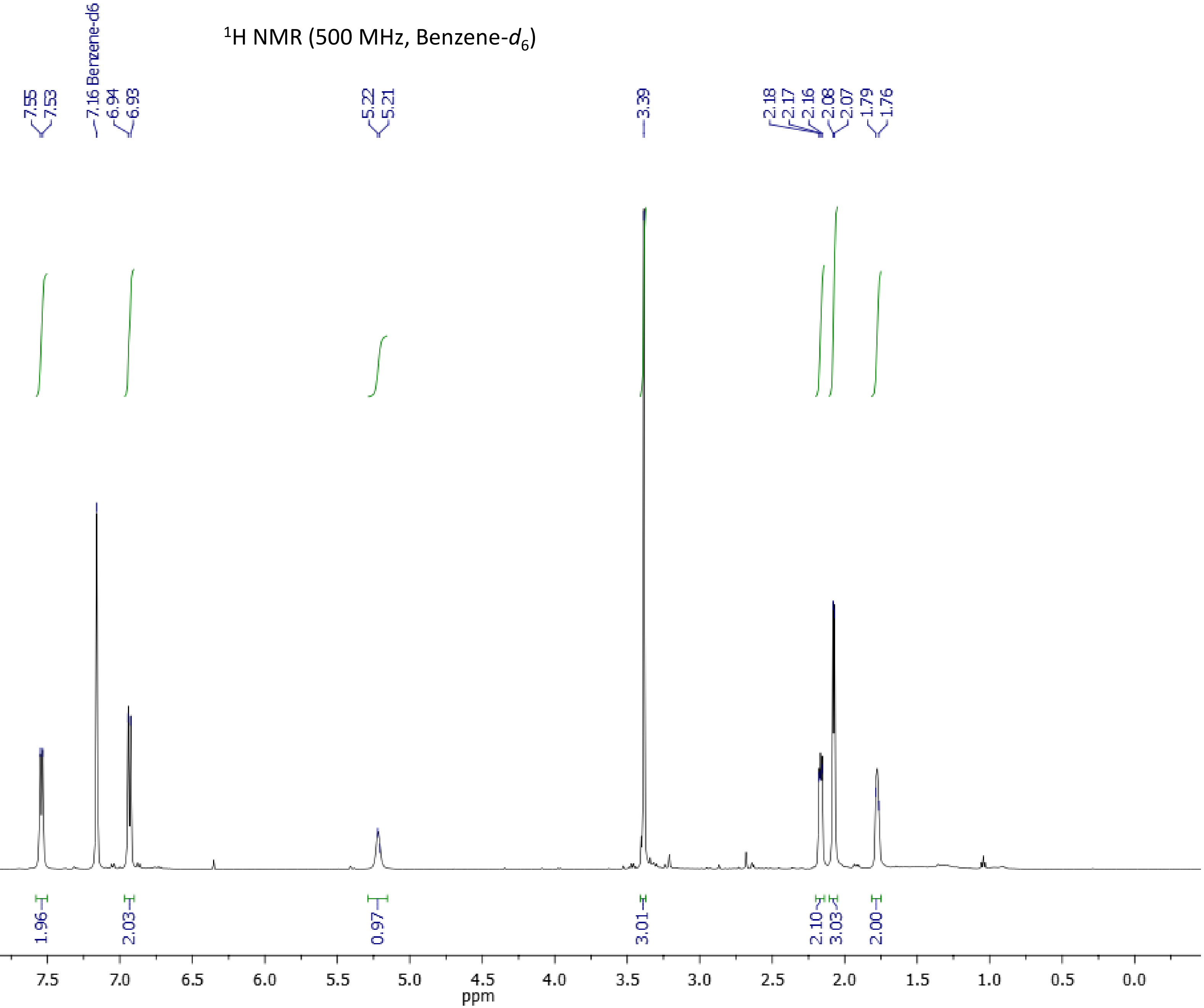




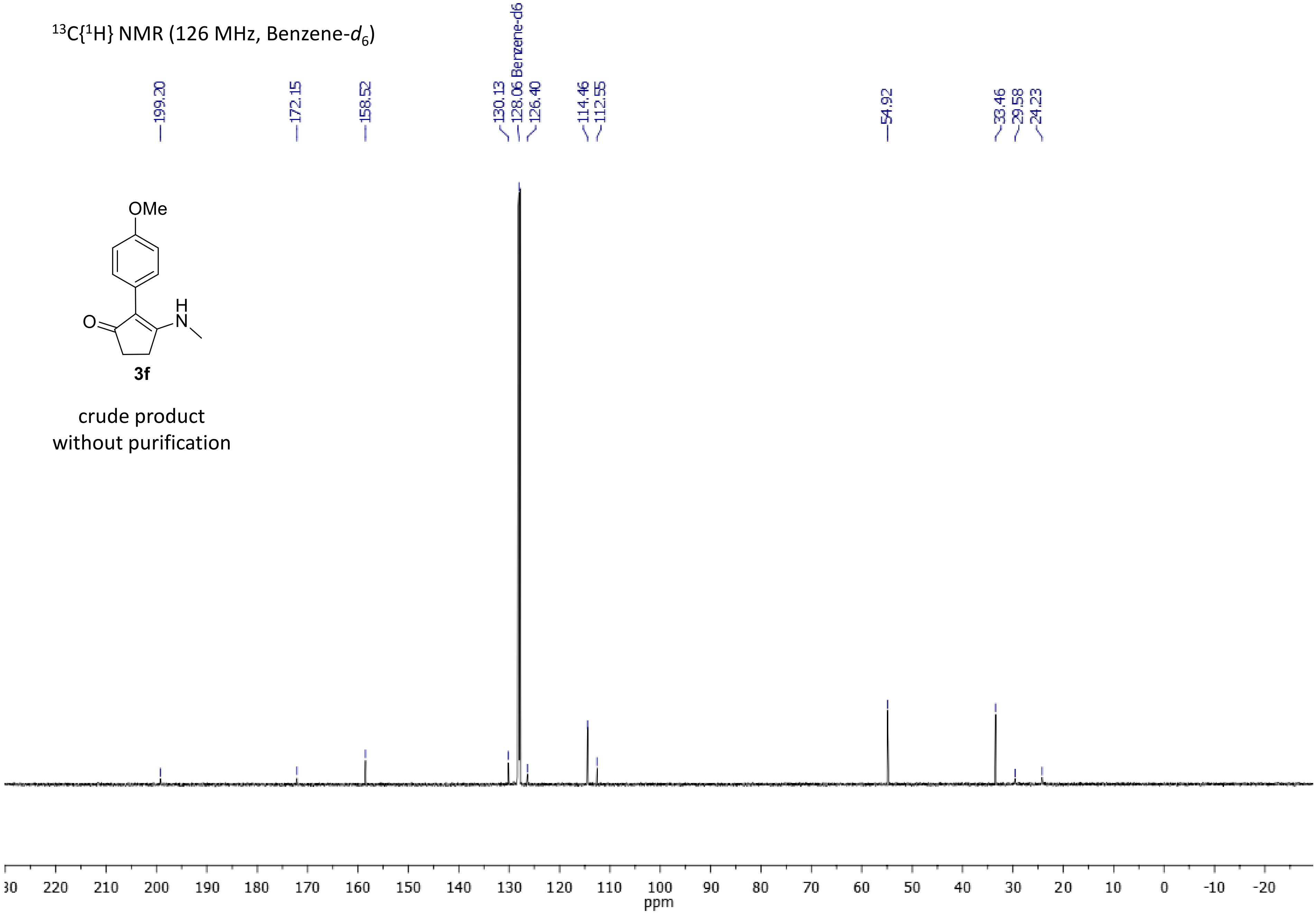
3f

crude product
without purification

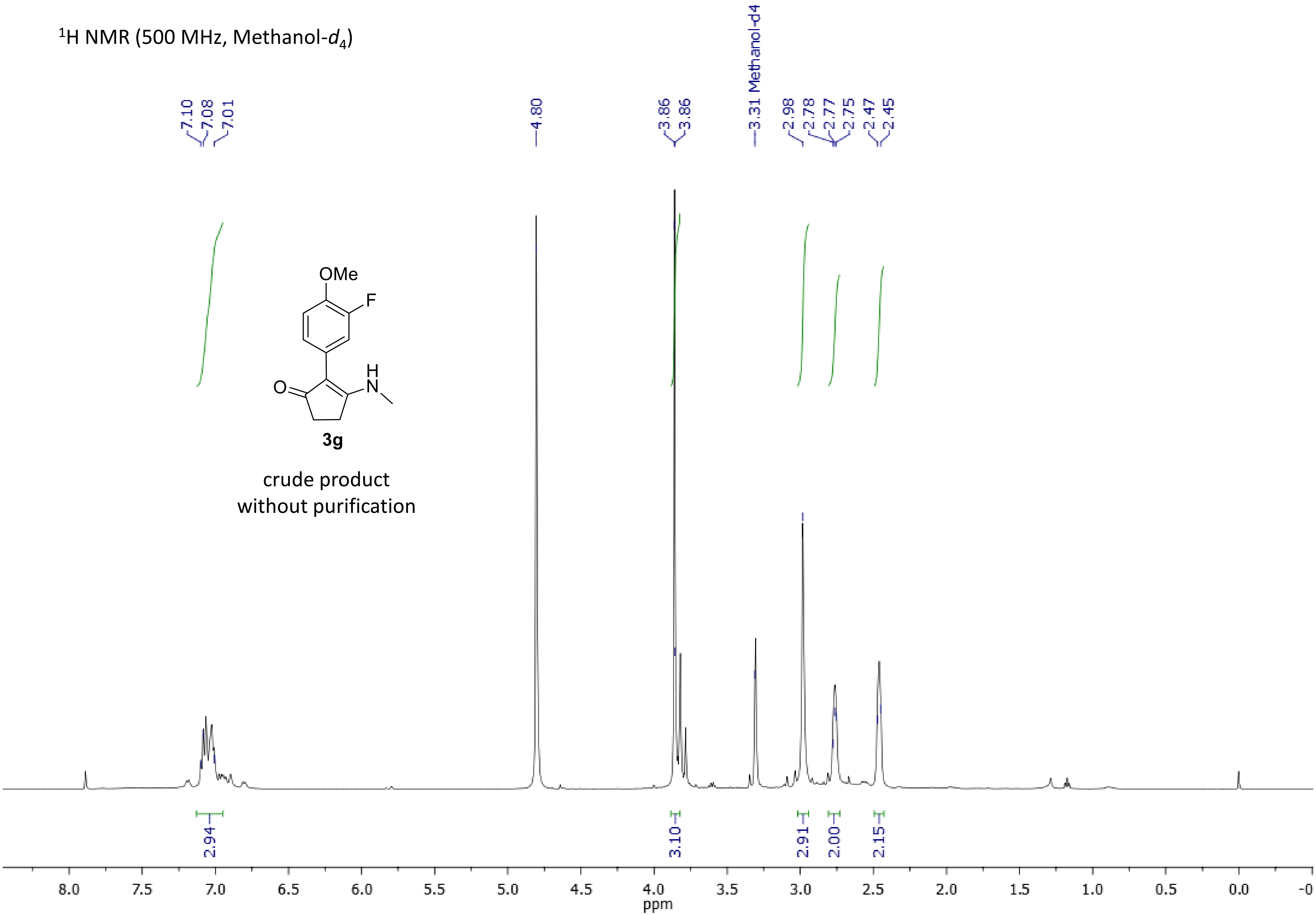
^{1}H NMR (500 MHz, Benzene-d_6)



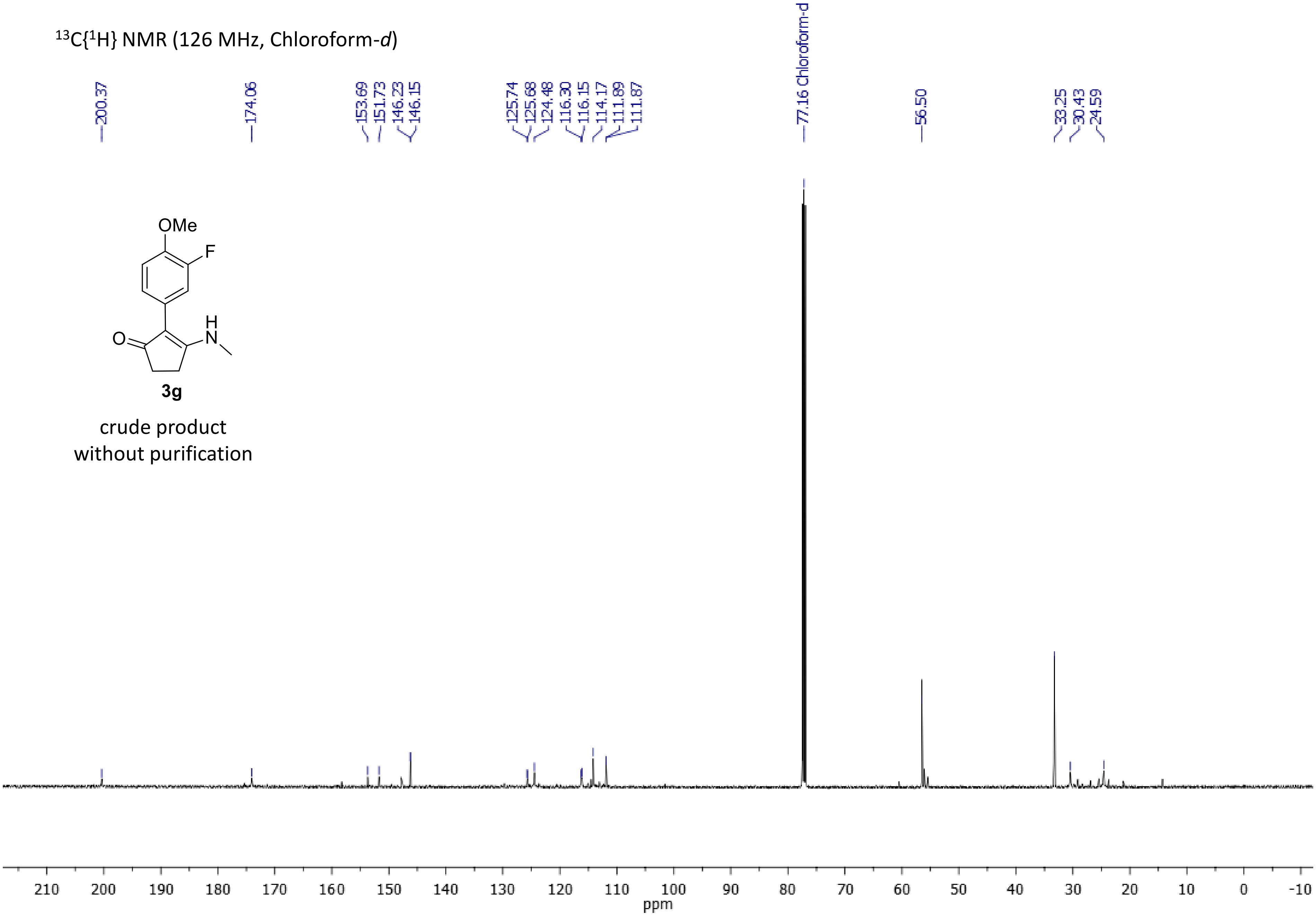
$^{13}C\{^1H\}$ NMR (126 MHz, Benzene-d_6)



^{1}H NMR (500 MHz, Methanol-d_4)

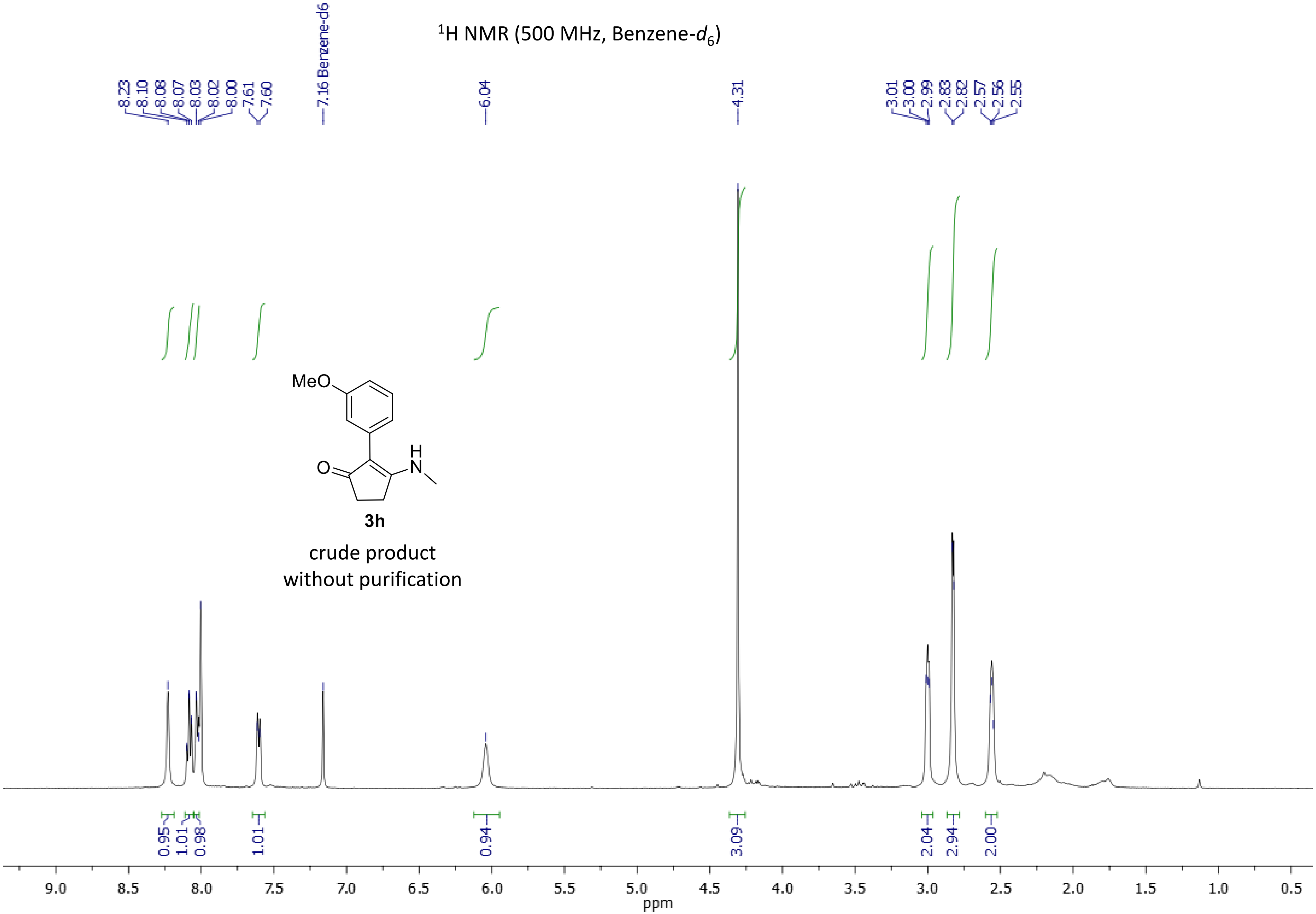


$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)

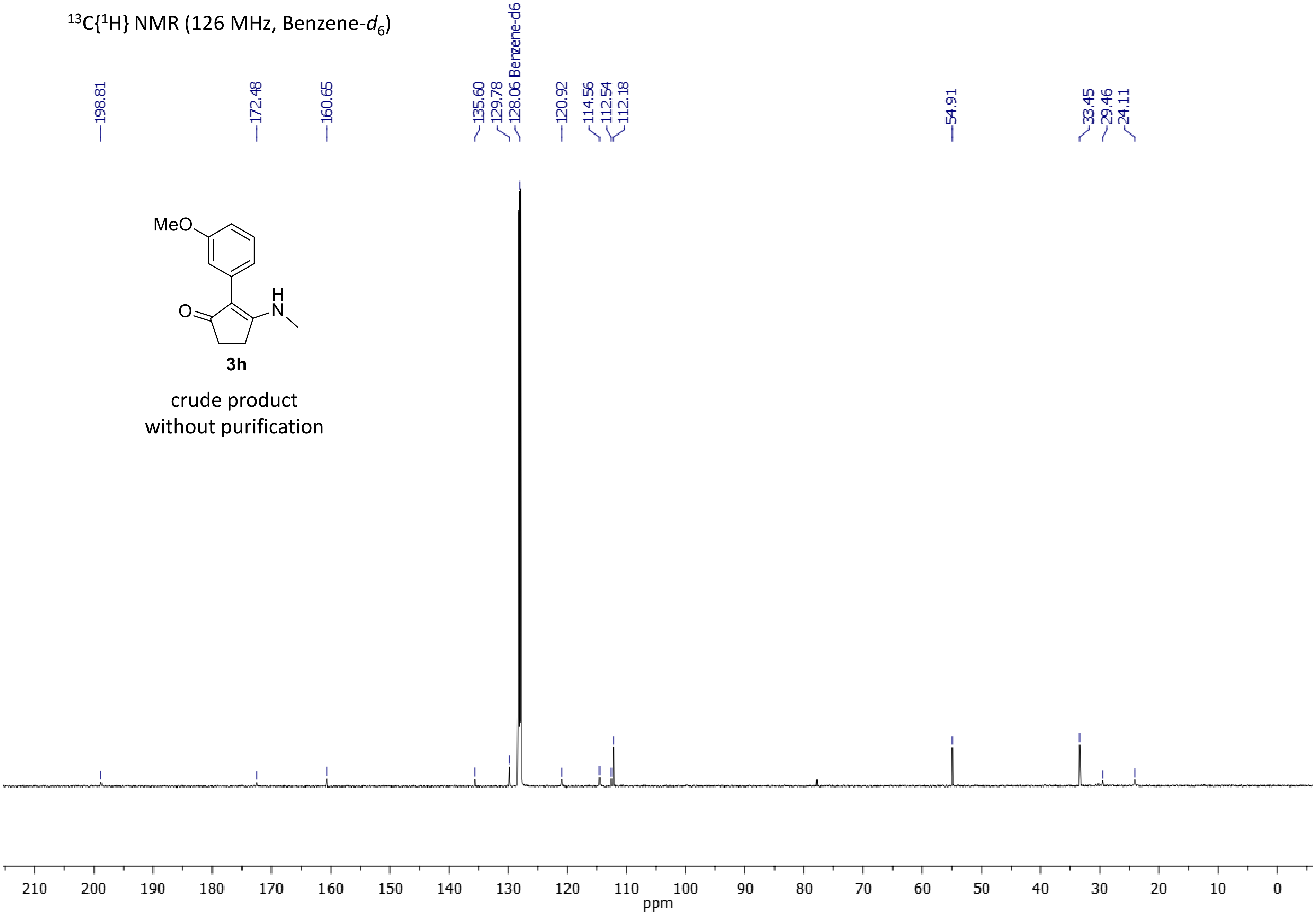


3g

crude product
without purification

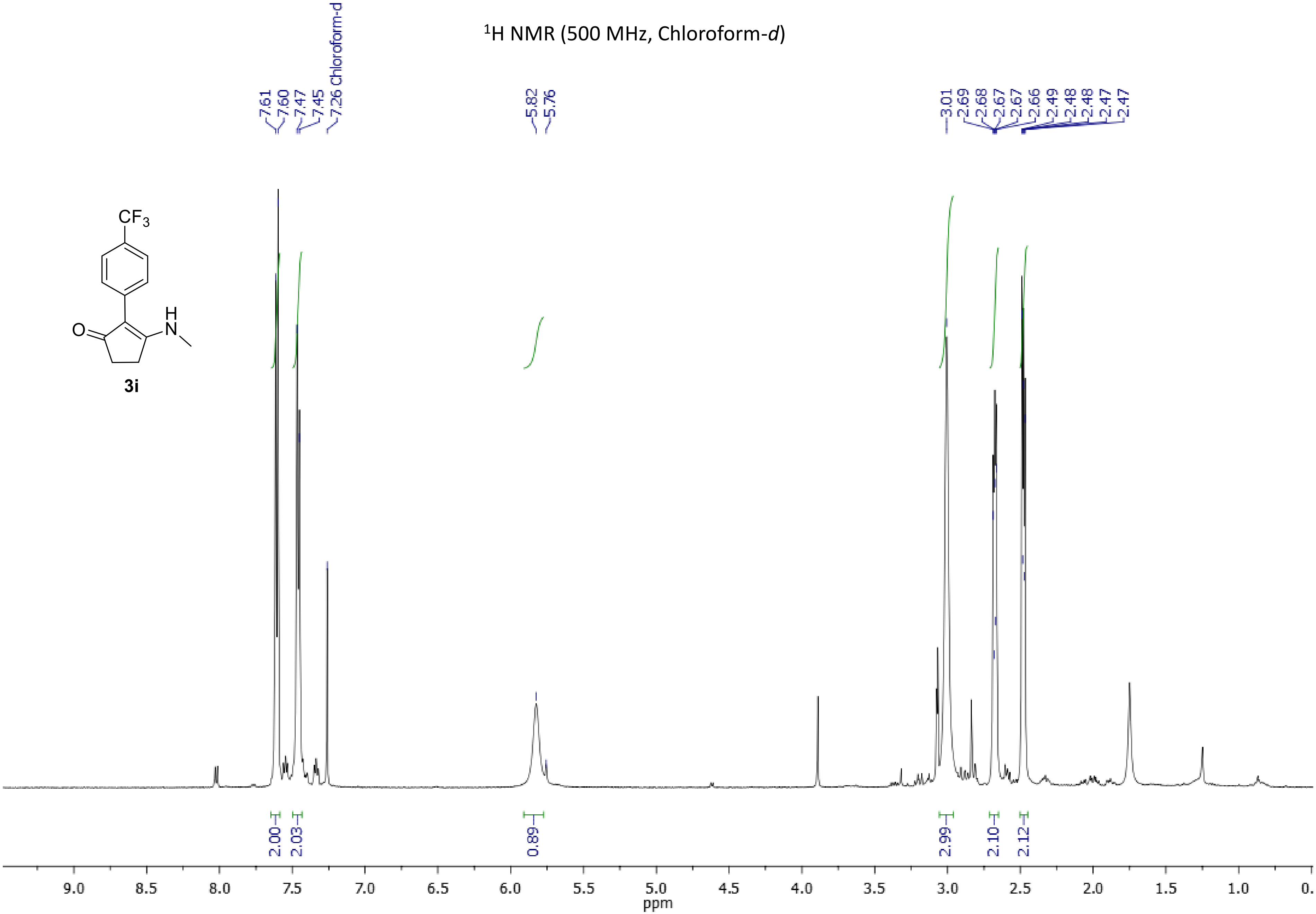

1H NMR (500 MHz, Benzene-d6)
8.23
8.10
8.08
8.07
8.03
8.02
8.00
7.61
7.60
7.16 Benzene-d6
6.04
4.31
3.01
3.00
2.99
2.83
2.82
2.57
2.56
2.55
MeO
H
N
O
3h
crude product
without purification
0.95
1.01
0.98
1.01
0.94
3.09
2.04
2.94
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm

$^{13}C\{^1H\}$ NMR (126 MHz, Benzene-d_6)



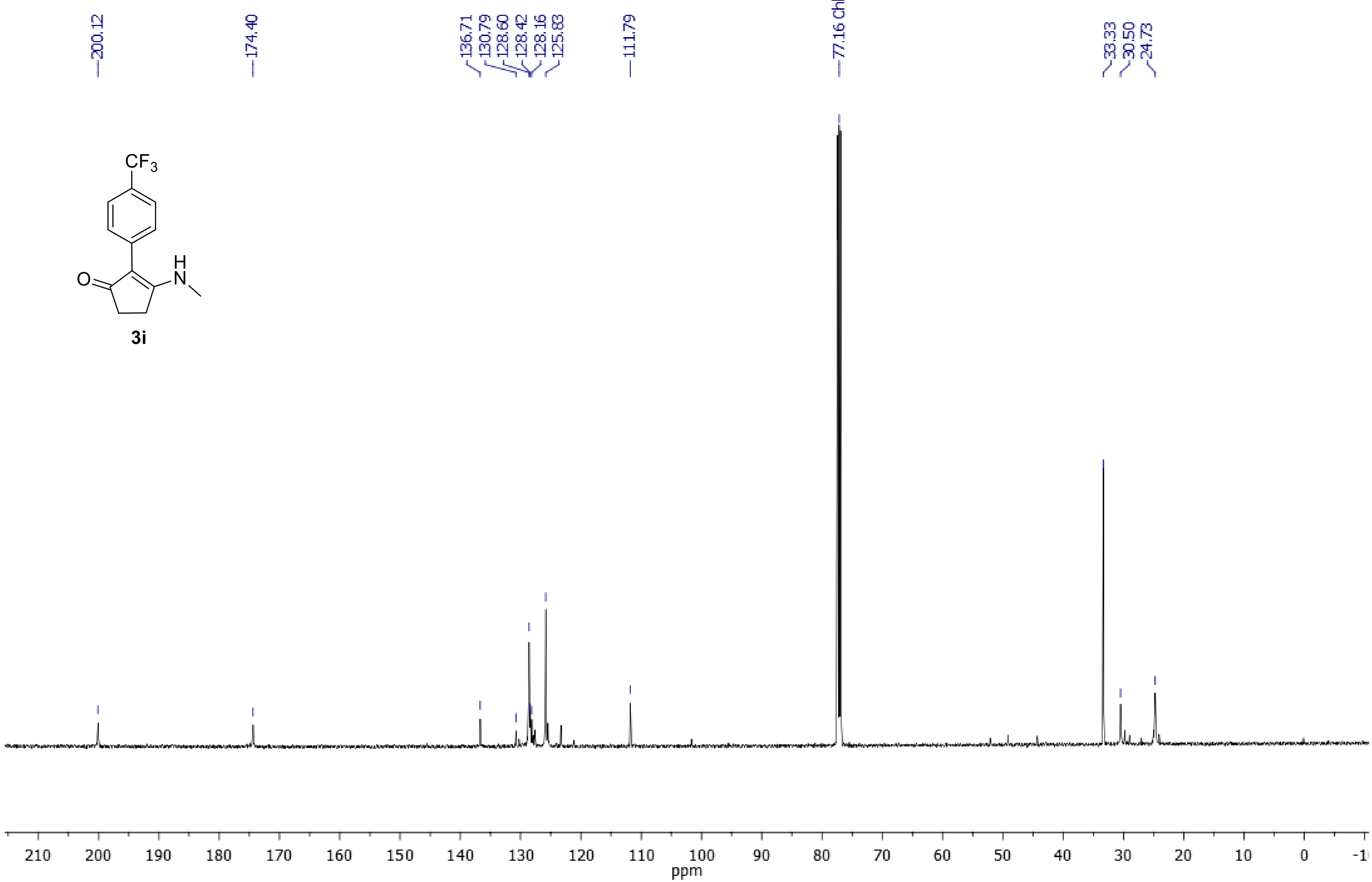
3h

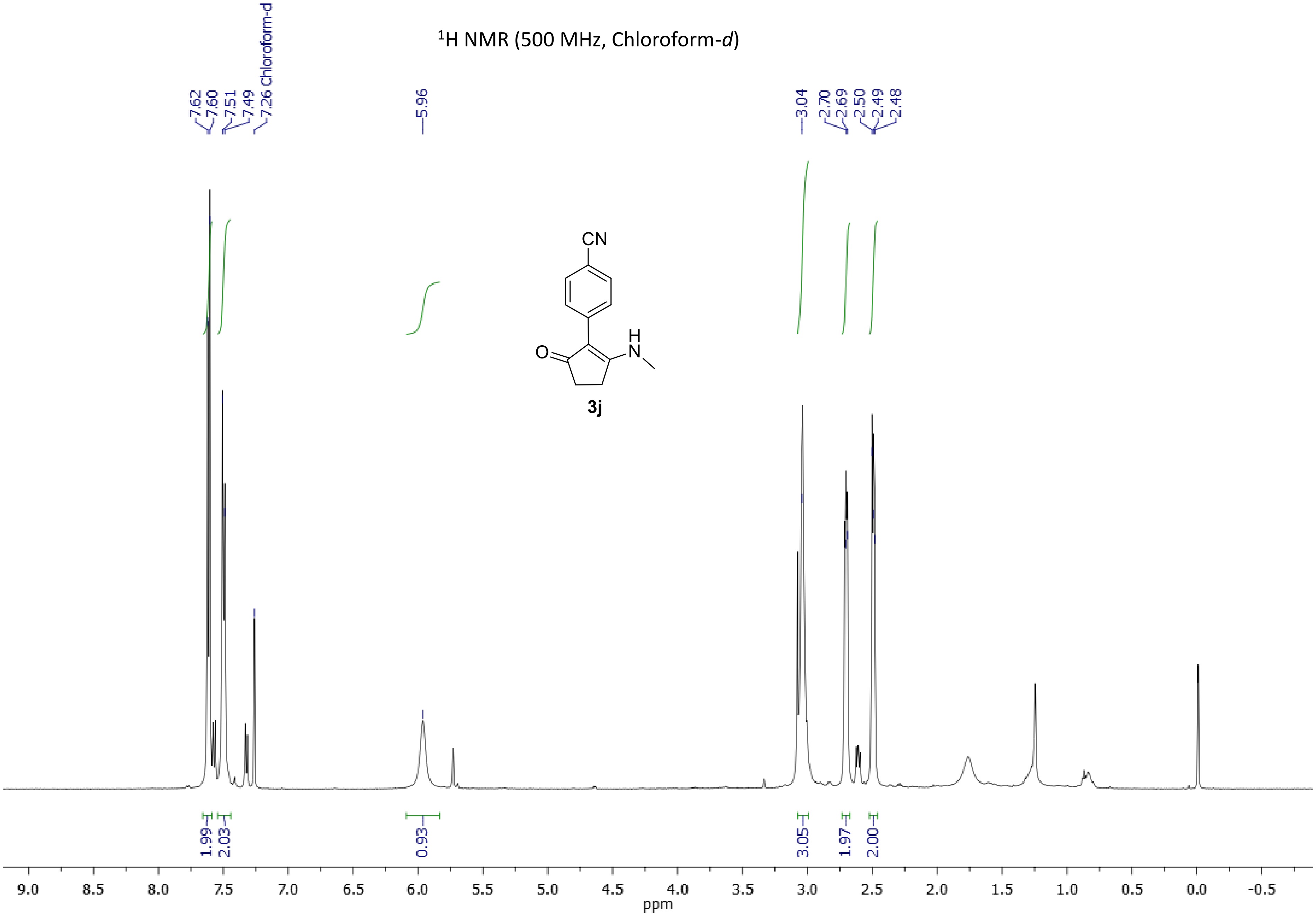
crude product
without purification



CF3
H
N
O
3i
1H NMR (500 MHz, Chloroform-d)
7.61
7.60
7.47
7.45
7.26 Chloroform-d
5.82
5.76
3.01
2.69
2.68
2.67
2.67
2.66
2.49
2.48
2.48
2.47
2.47
2.00
2.03
0.89
2.99
2.10
2.12
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
ppm
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0

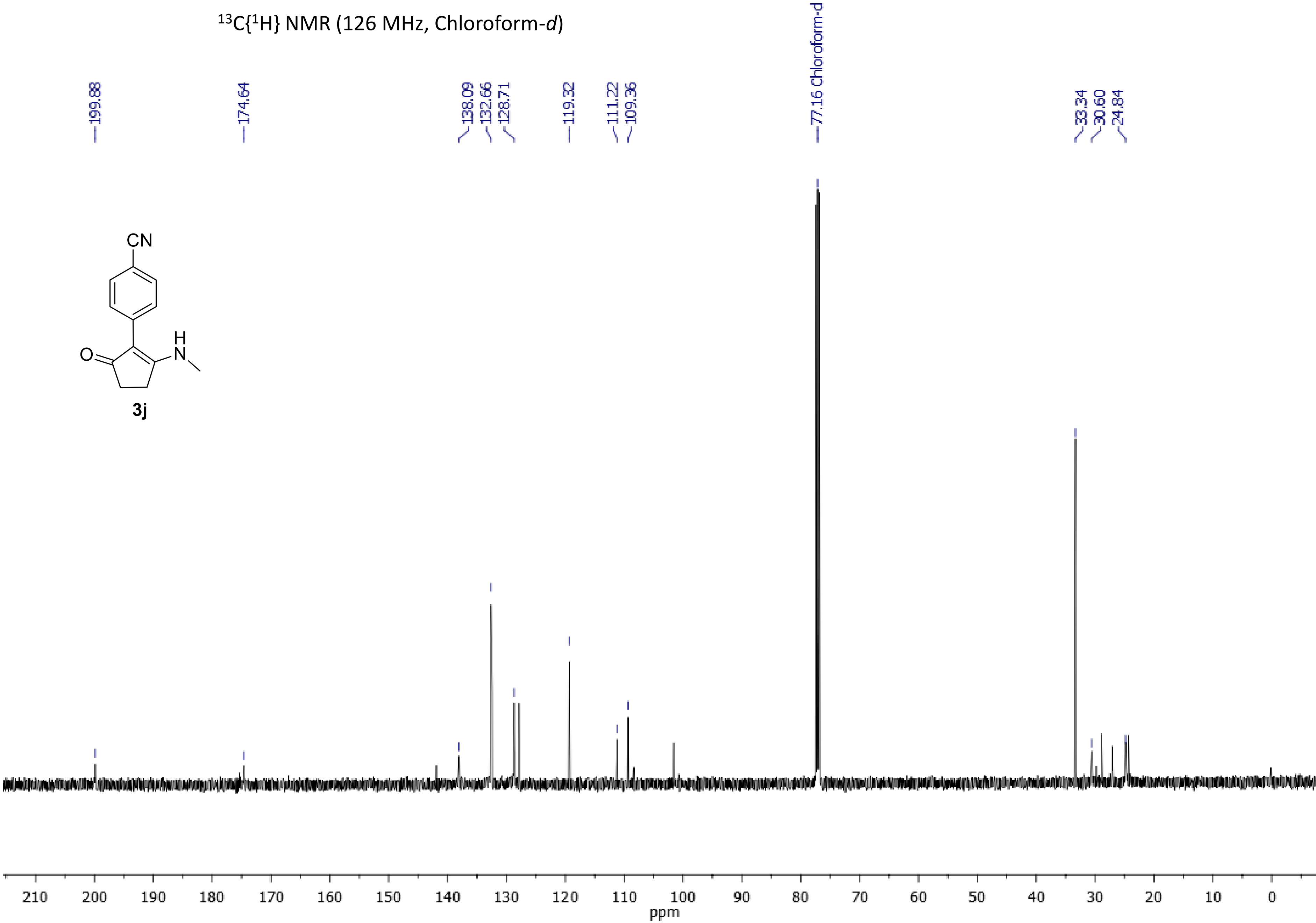
$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)

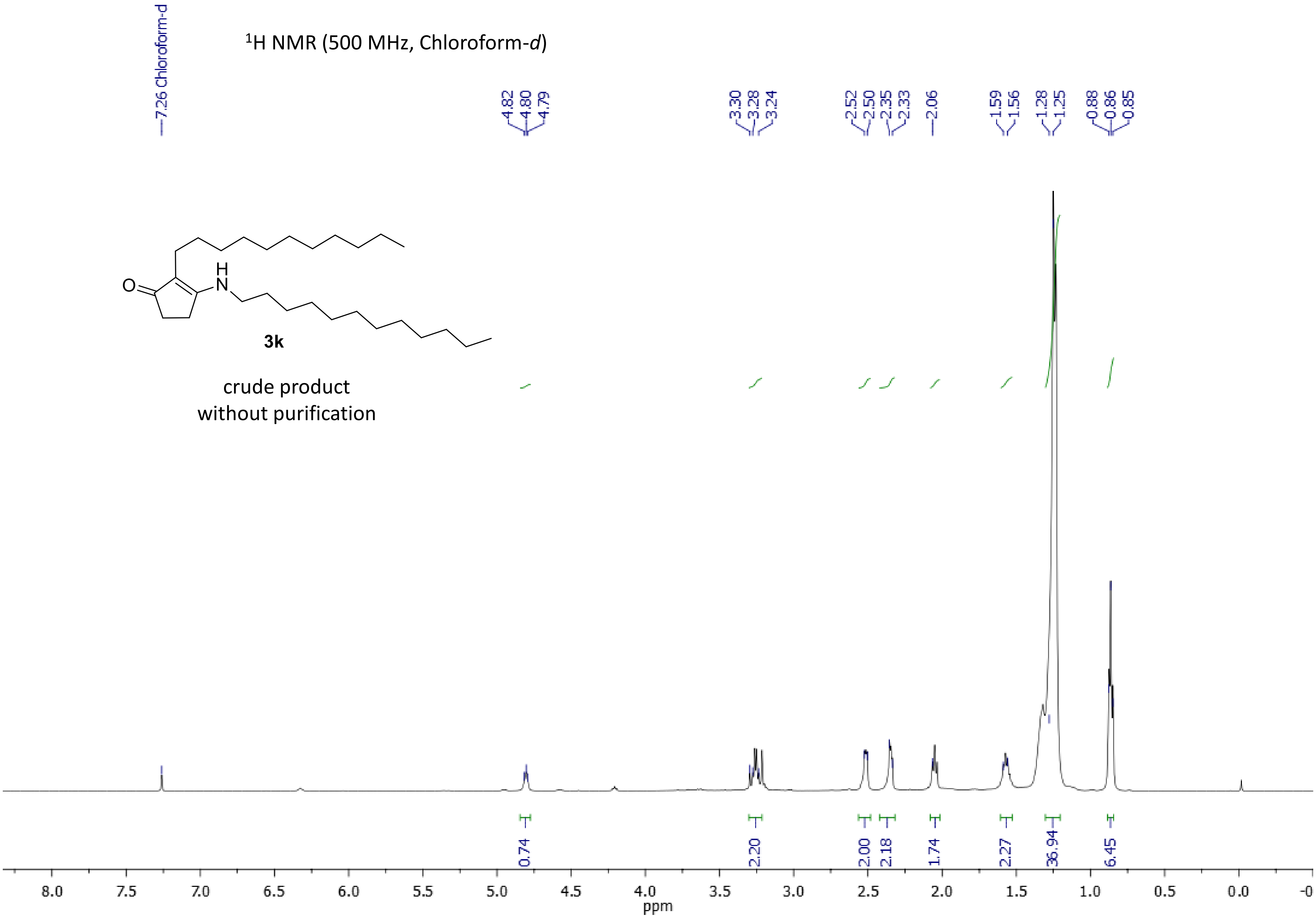




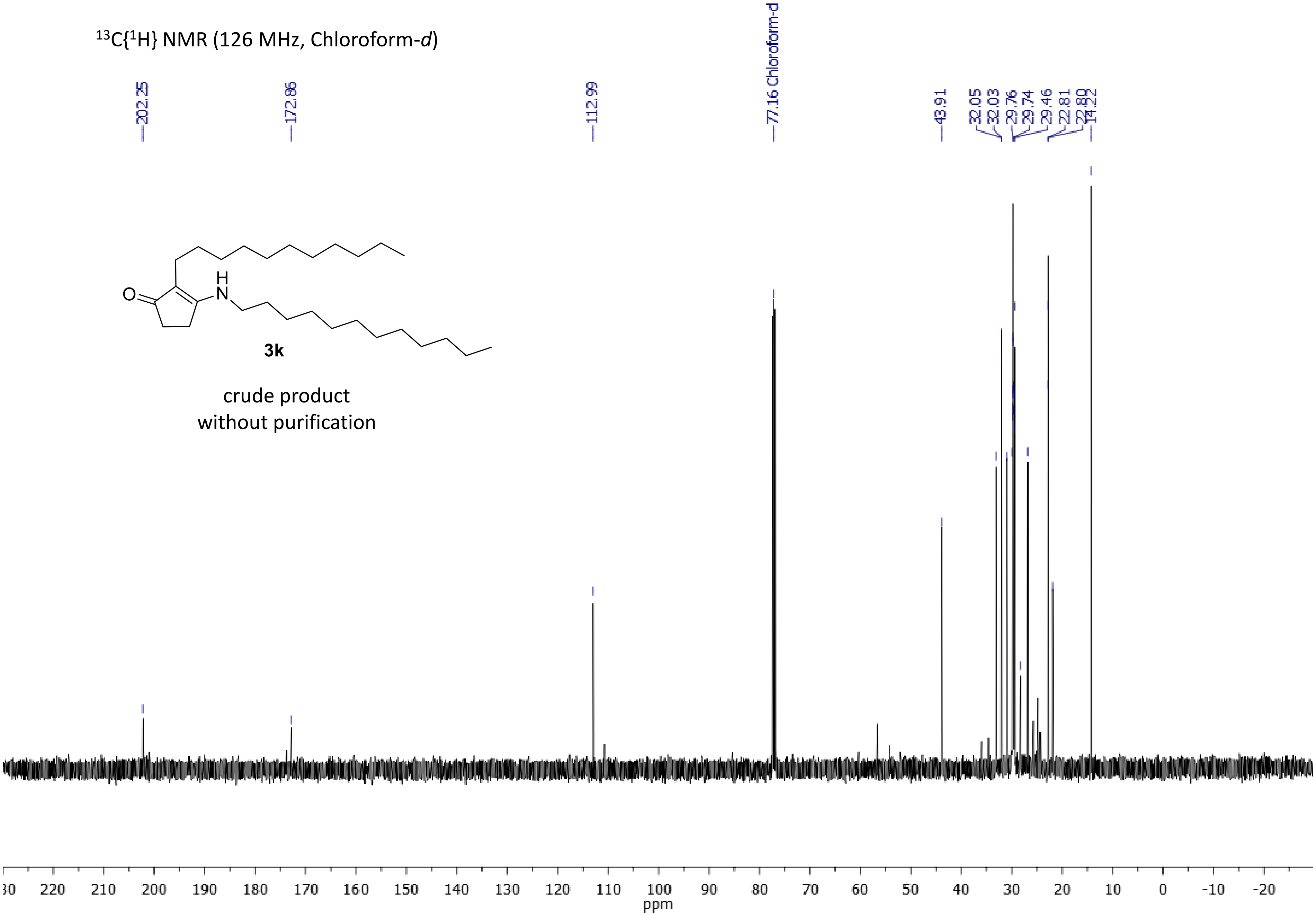
1H NMR (500 MHz, Chloroform-d)
7.62
7.60
7.51
7.49
7.26 Chloroform-d
5.96
3.04
2.70
2.69
2.50
2.49
2.48
CN
O
H
N
3j
1.99
2.03
0.93
3.05
1.97
2.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
ppm

$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)



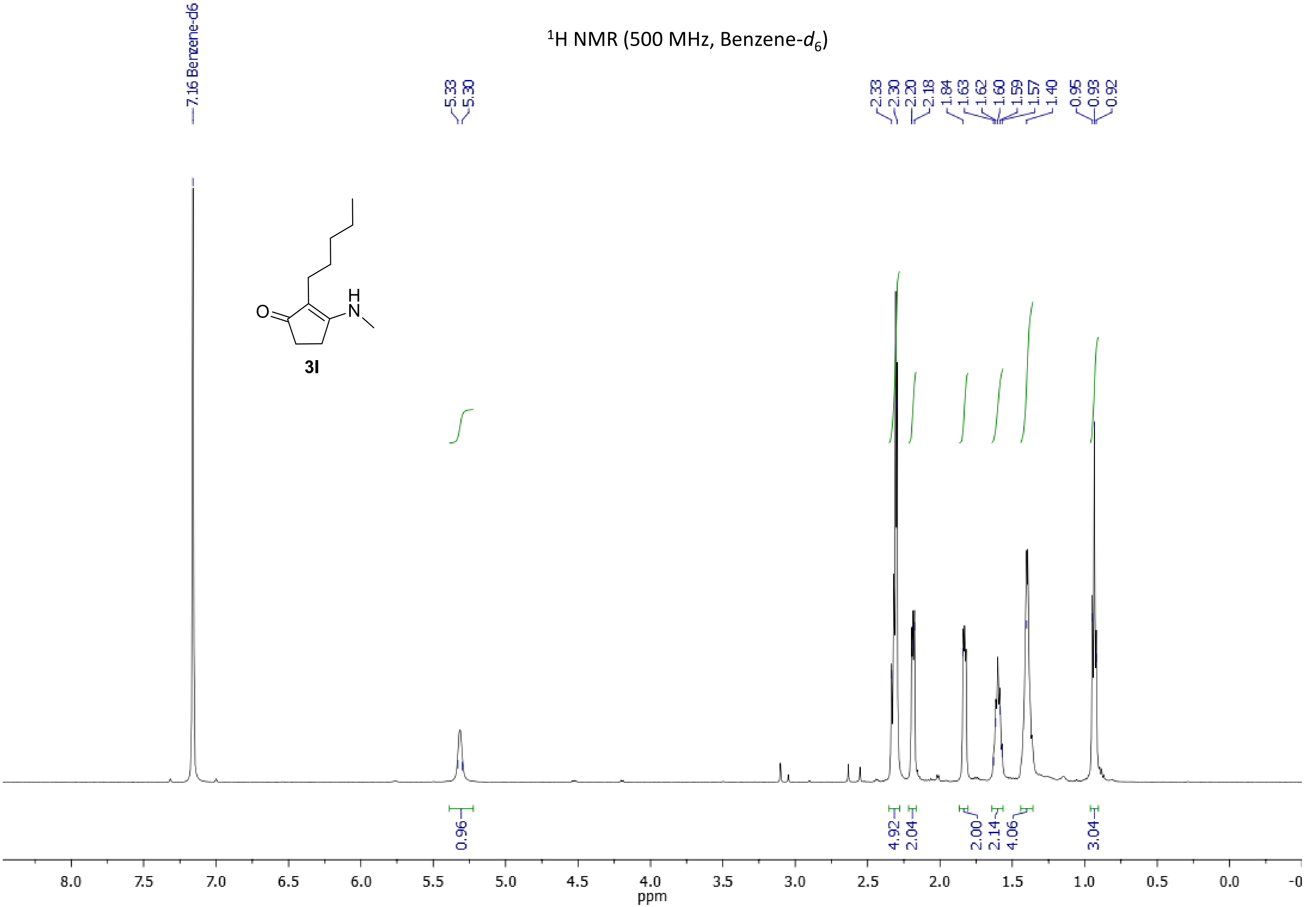

1H NMR (500 MHz, Chloroform-d)
7.26 Chloroform-d
4.82
4.80
4.79
3.30
3.28
3.24
2.52
2.50
2.35
2.33
2.06
1.59
1.56
1.28
1.25
0.88
0.86
0.85
O
H
N
3k
crude product
without purification
0.74
2.20
2.00
2.18
1.74
2.27
36.94
6.45
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm

$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)



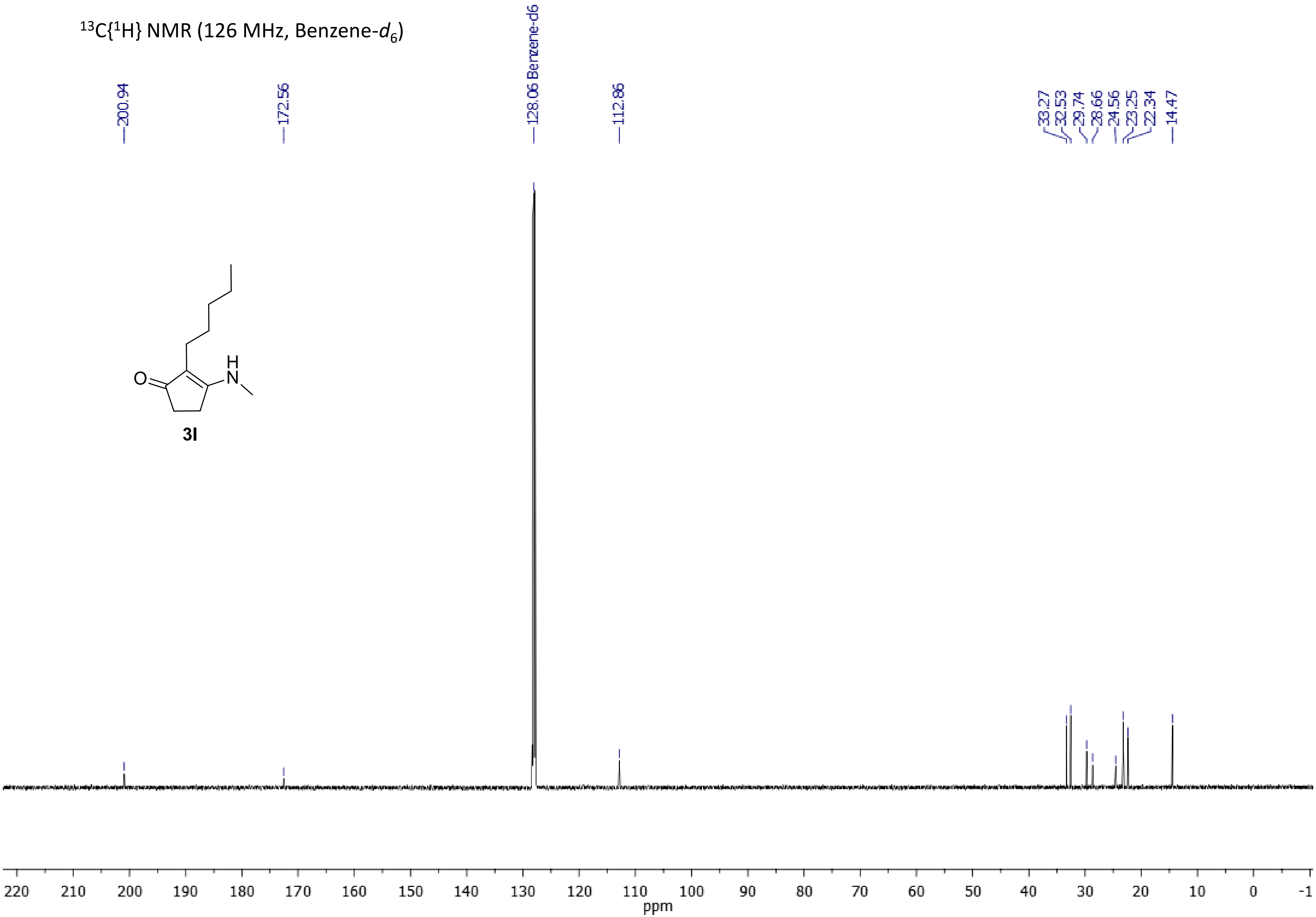
3k

crude product
without purification

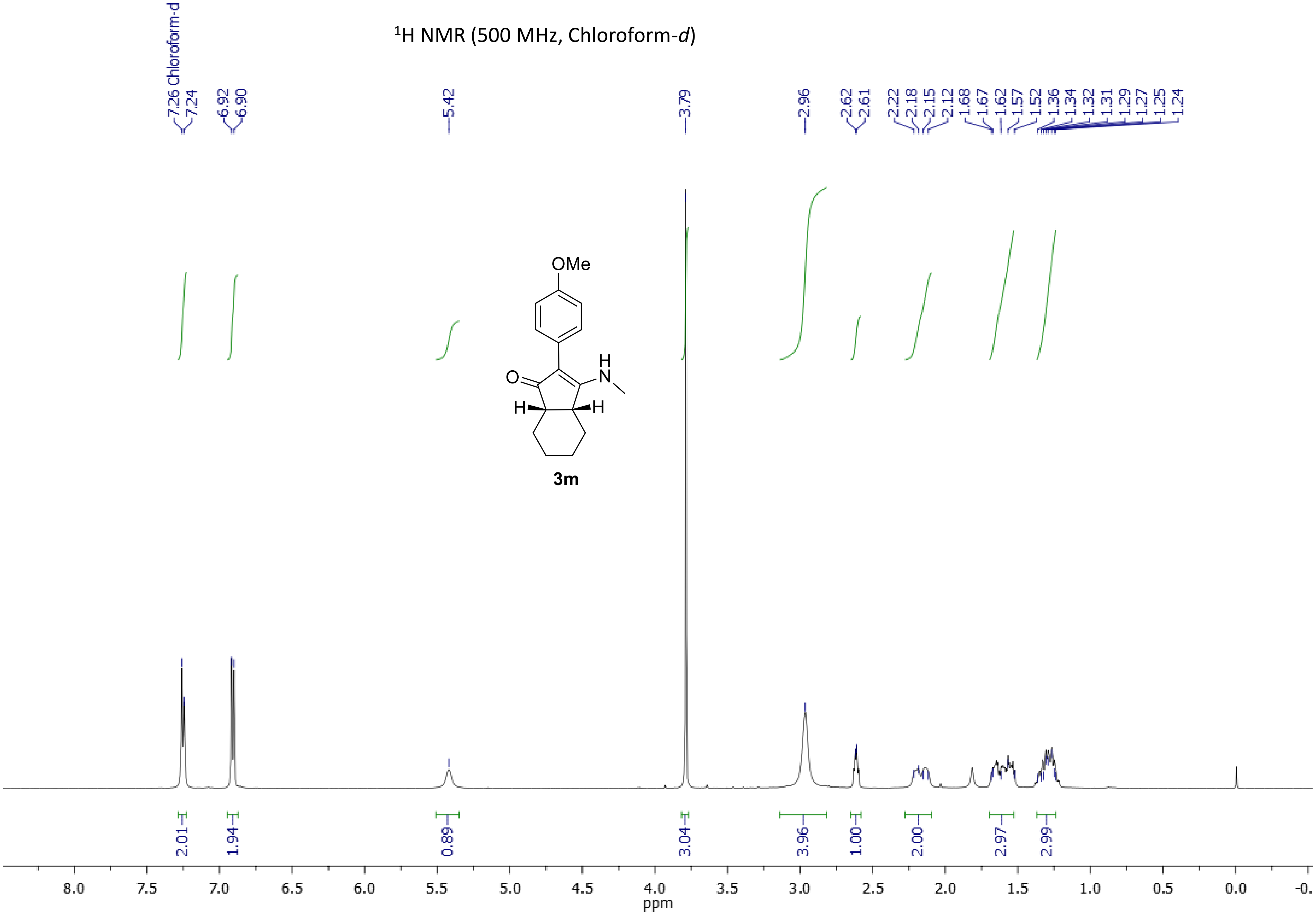


¹H NMR (500 MHz, Benzene-d6)
7.16 Benzene-d6
5.33
5.30
2.33
2.30
2.20
2.18
1.84
1.63
1.62
1.60
1.59
1.57
1.40
0.95
0.93
0.92
O
H
N
3l
0.96
4.92
2.04
2.00
2.14
4.06
3.04
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

$^{13}C\{^{1}H\}$ NMR (126 MHz, Benzene-d_6)

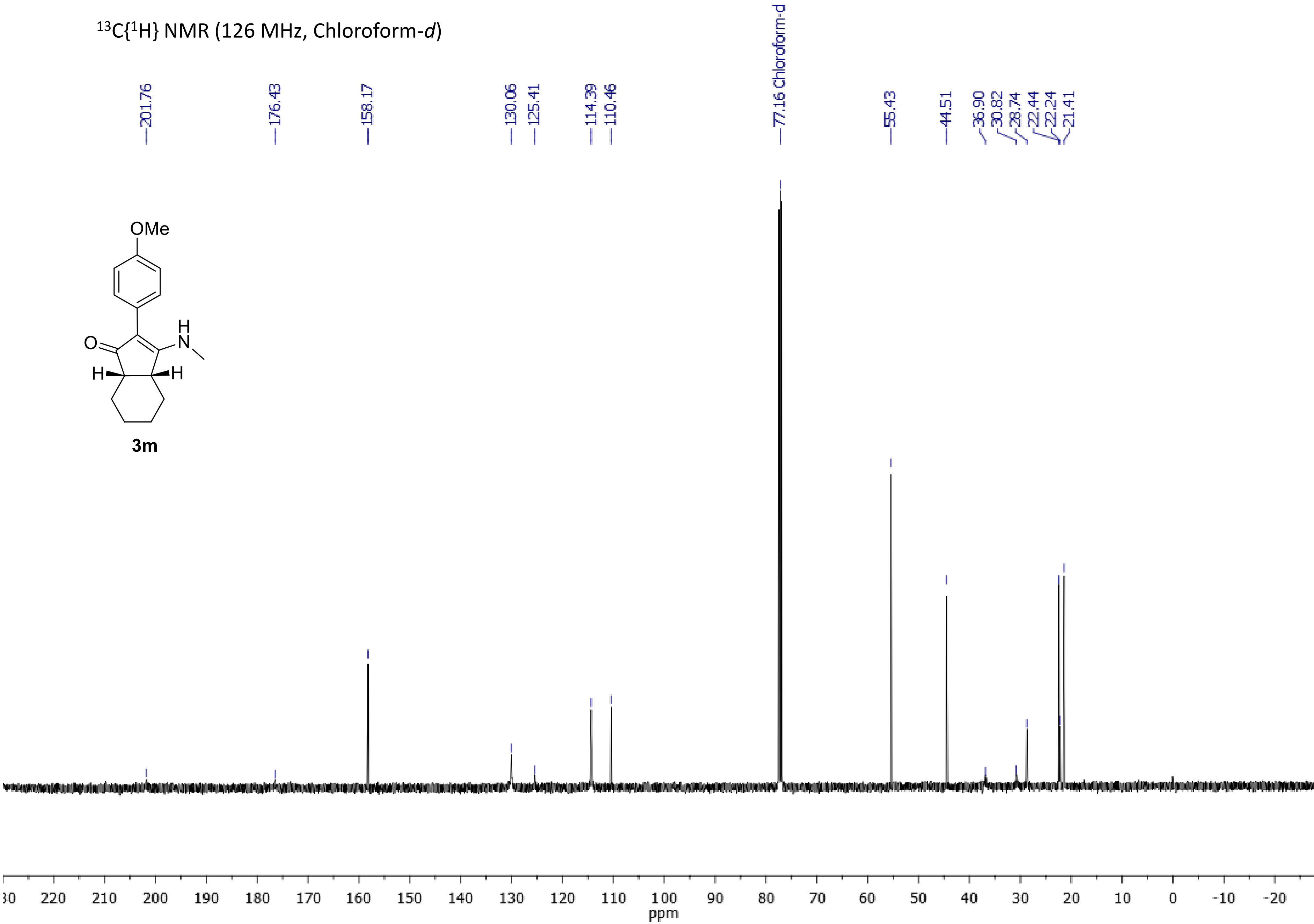


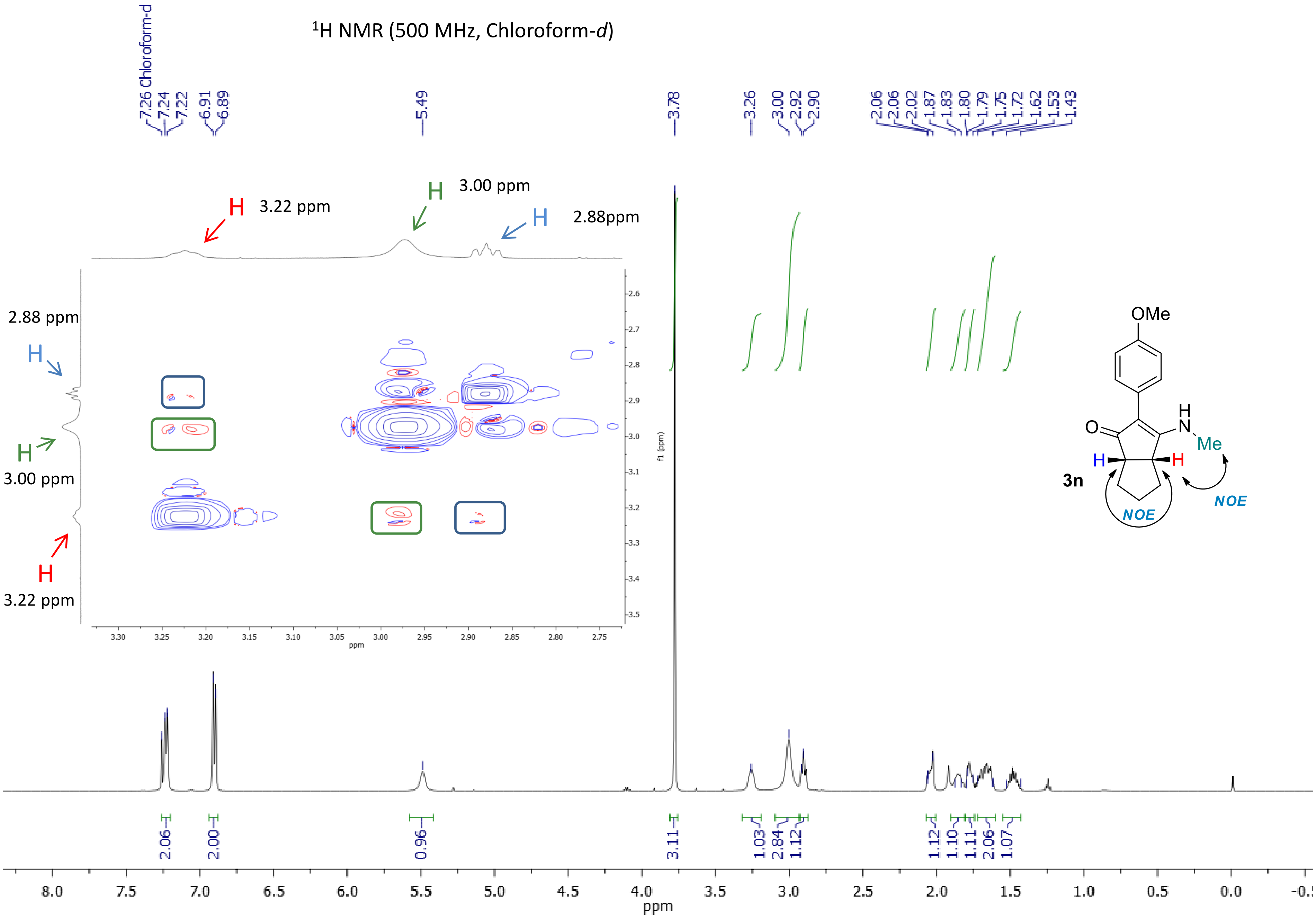
^1H NMR (500 MHz, Chloroform-*d*)

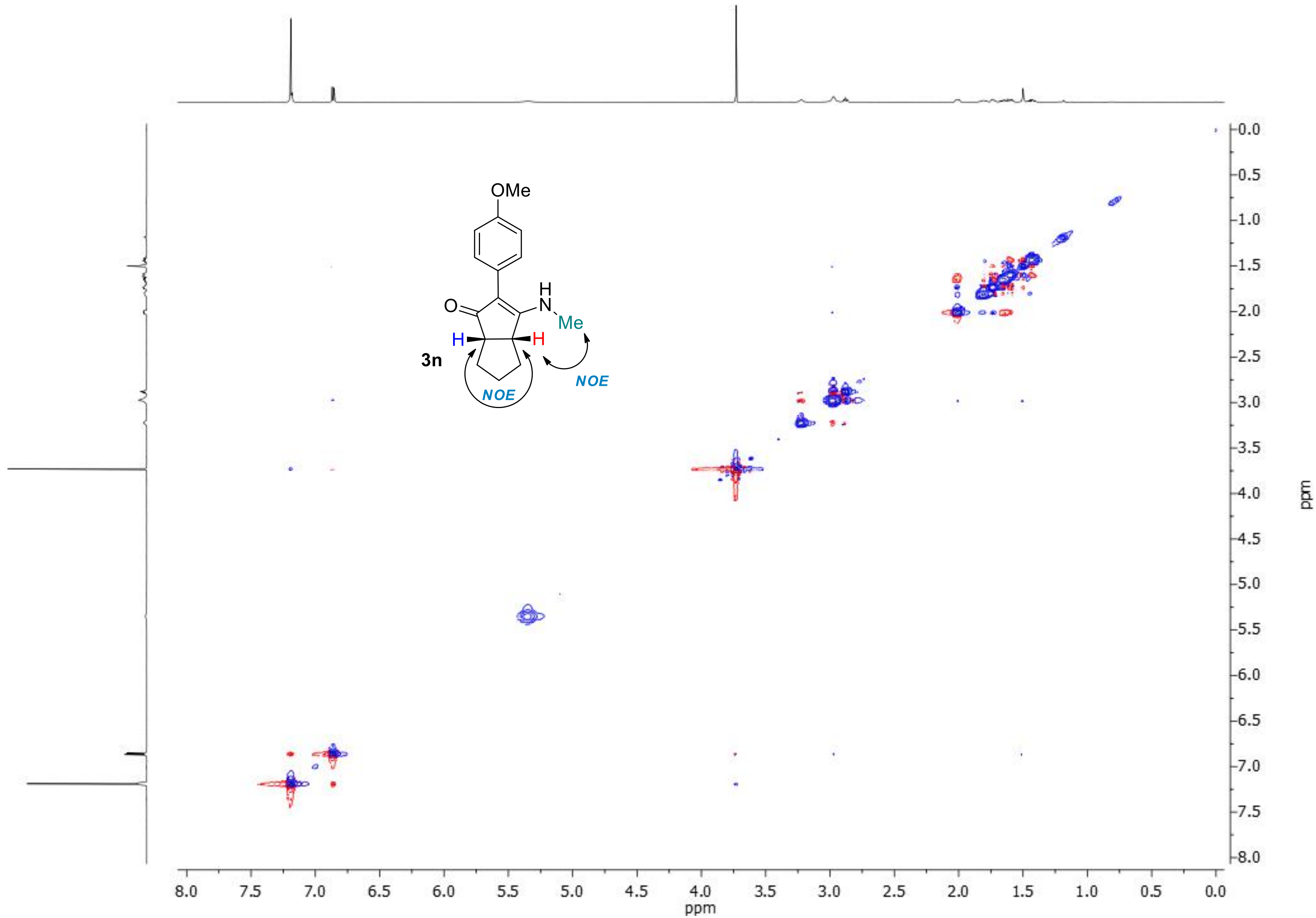


3m

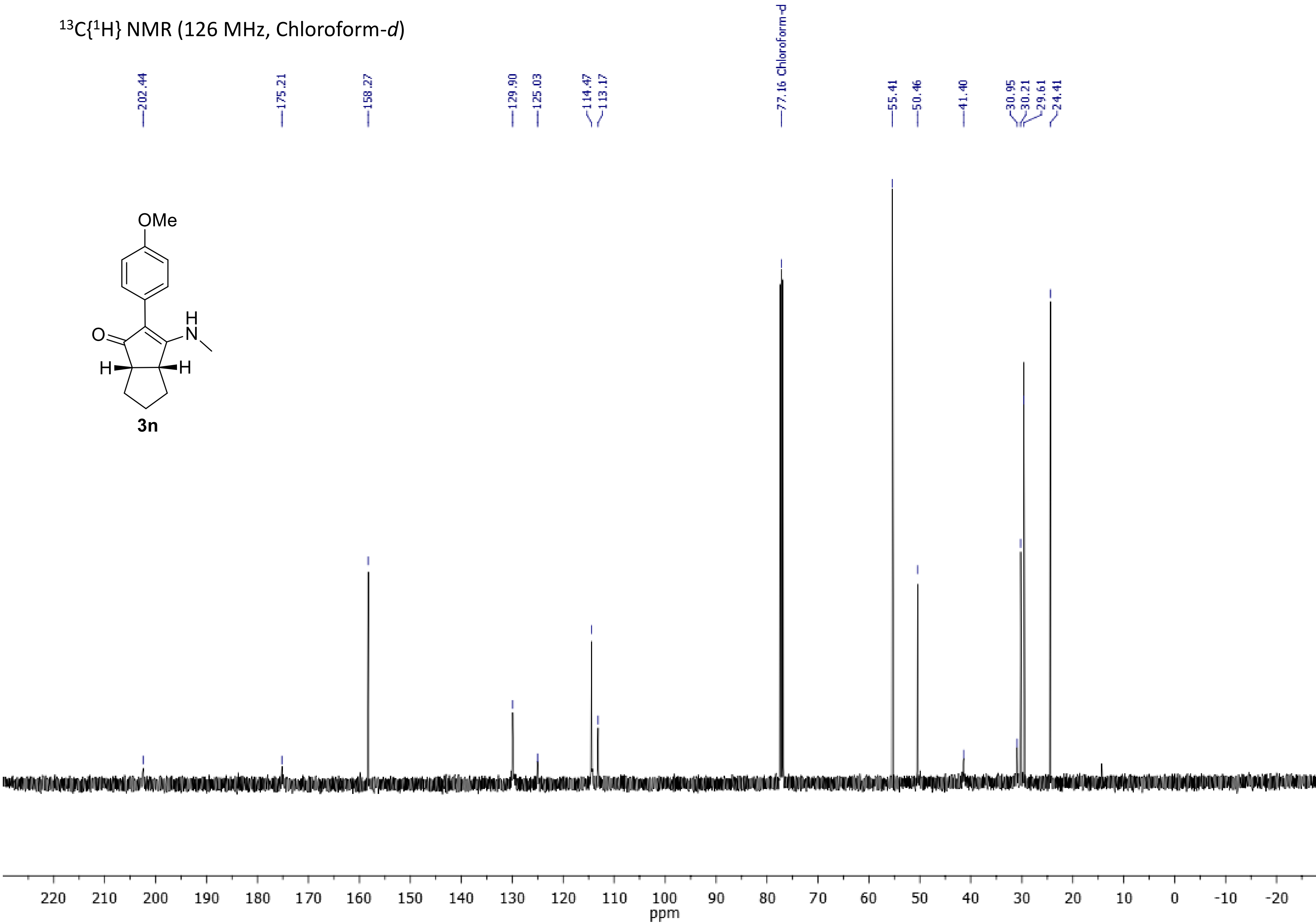
$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)

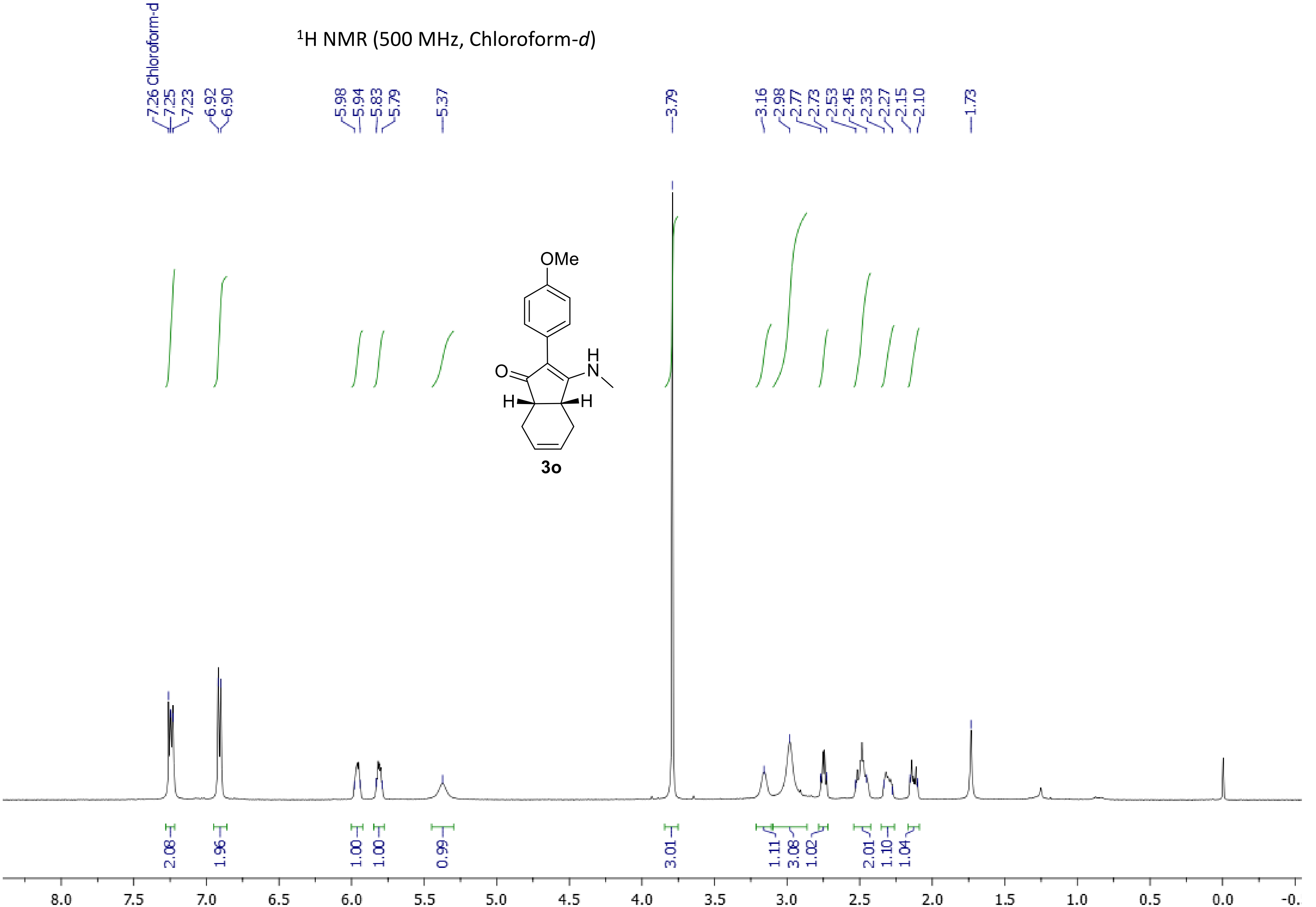



^{1}H NMR (500 MHz, Chloroform-d)
7.26 Chloroform-d
7.24
7.22
6.91
6.89
5.49
3.78
3.26
3.00
2.92
2.90
2.06
2.06
2.02
1.87
1.83
1.80
1.79
1.75
1.72
1.62
1.53
1.43
H 3.22 ppm
H 3.00 ppm
H 2.88ppm
2.88 ppm
3.00 ppm
3.22 ppm
f1 (ppm)
ppm
OMe
O
H
N
Me
H
H
3n
NOE
NOE
2.06
2.00
0.96
3.11
1.03
2.84
1.12
1.12
1.10
1.11
2.06
1.07
ppm


OMe
O
H
N
Me
H
H
3n
NOE
NOE
ppm
ppm

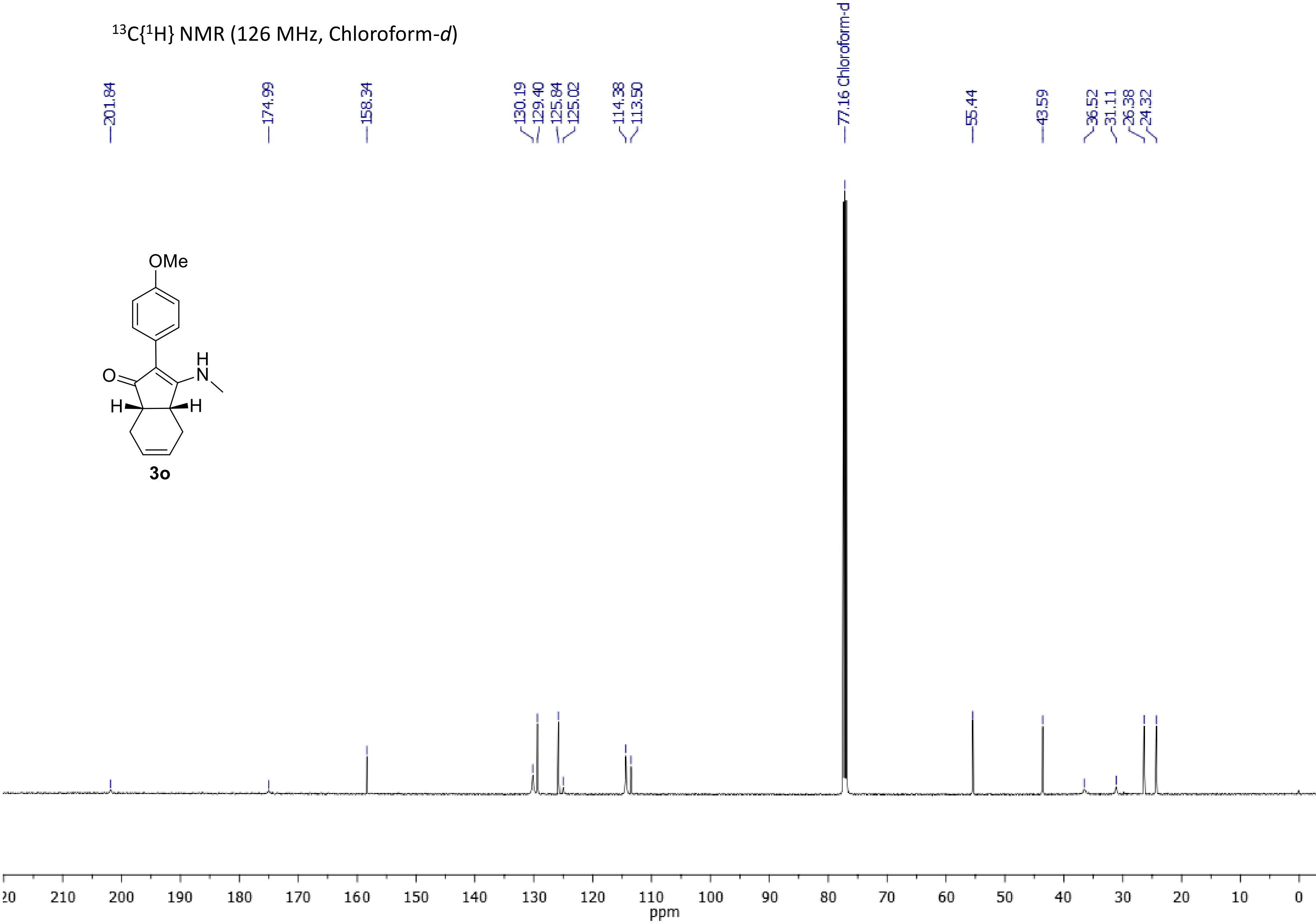
$^{13}C\{^1H\}$ NMR (126 MHz, Chloroform-*d*)



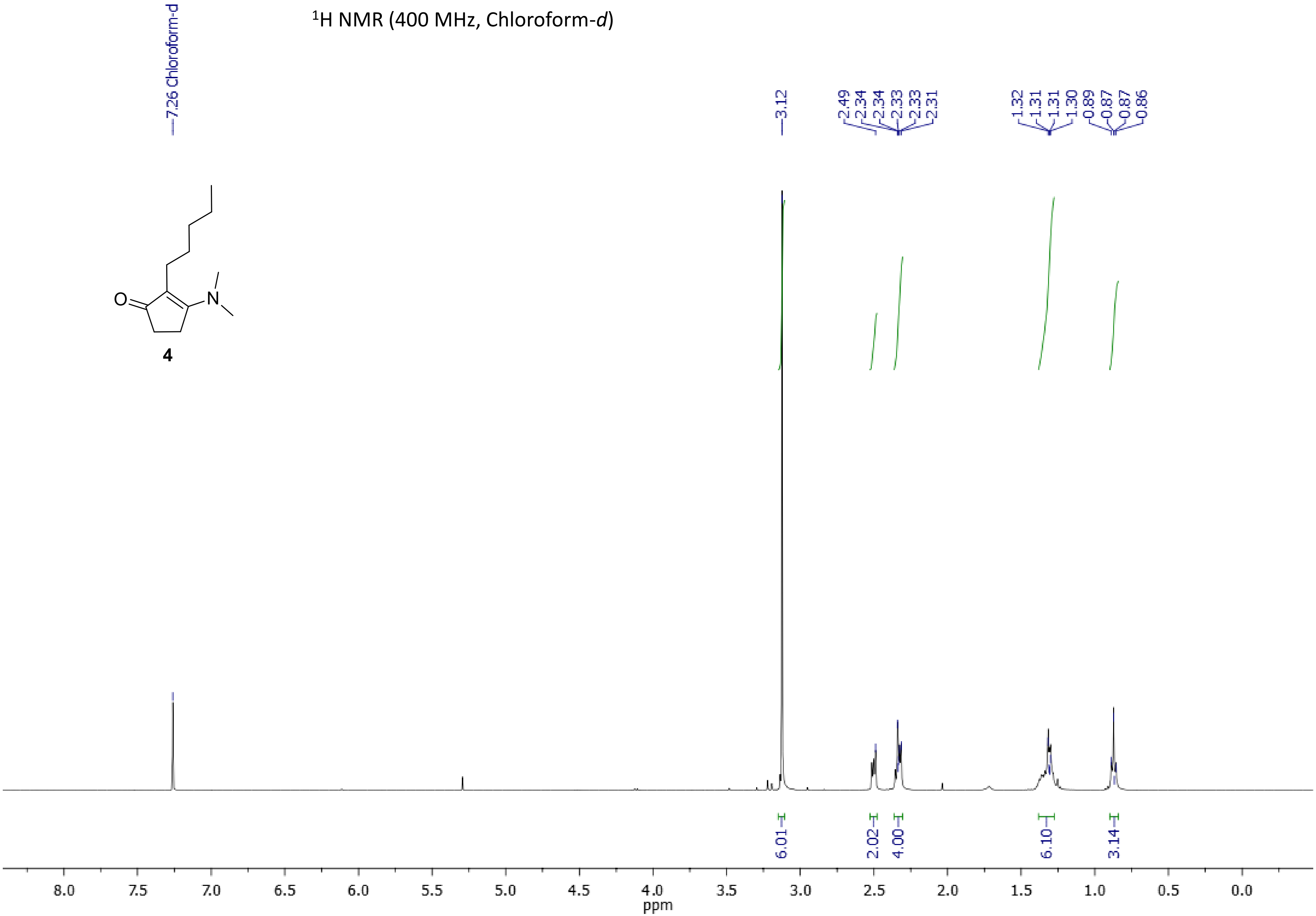


^{1}H NMR (500 MHz, Chloroform-d)
7.26 Chloroform-d
7.25
7.23
6.92
6.90
5.98
5.94
5.83
5.79
5.37
3.79
3.16
2.98
2.77
2.73
2.53
2.45
2.33
2.27
2.15
2.10
1.73
OMe
H
N
O
H
H
3o
2.08
1.96
1.00
1.00
0.99
3.01
1.11
3.08
1.02
2.01
1.10
1.04
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

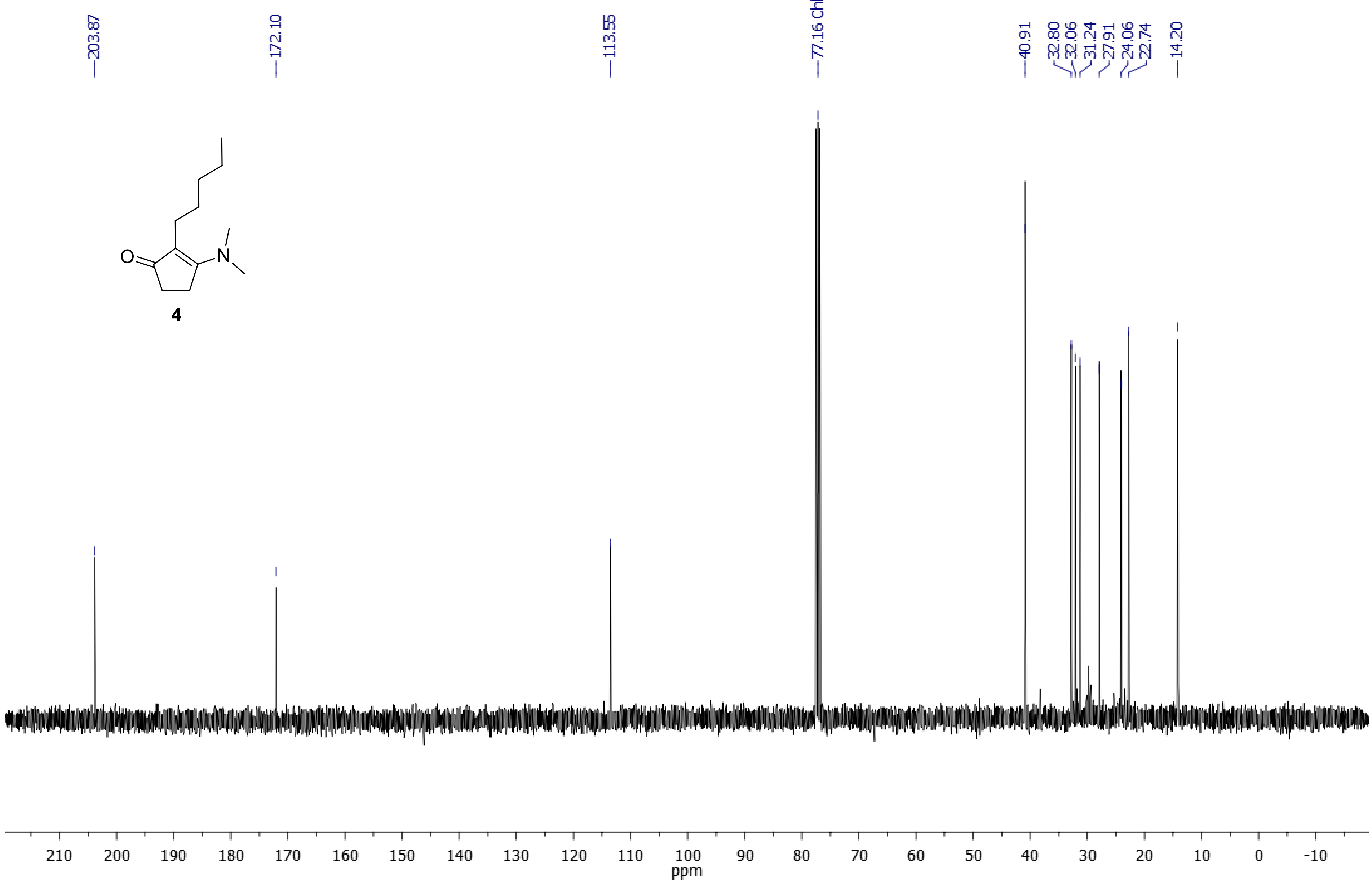
$^{13}C\{^{1}H\}$ NMR (126 MHz, Chloroform-*d*)



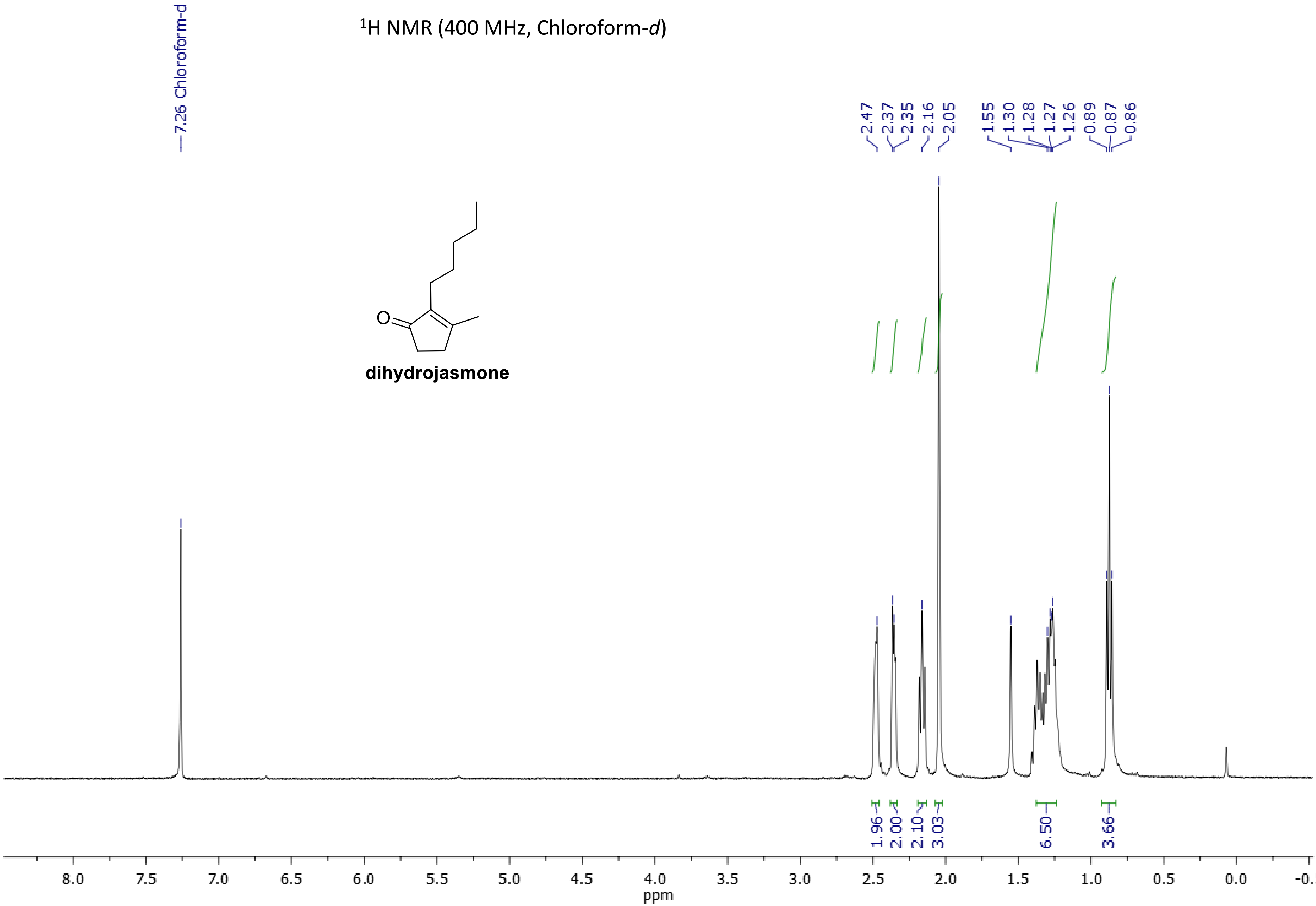
[1]H NMR (400 MHz, Chloroform-*d*)



$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)



^{1}H NMR (400 MHz, Chloroform-d)



$^{13}C\{^{1}H\}$ NMR (101 MHz, Chloroform-*d*)