Acetamido-TEMPO mediated electrochemical oxidation of alcohols to aldehydes and ketones

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SUPPORTING INFORMATION

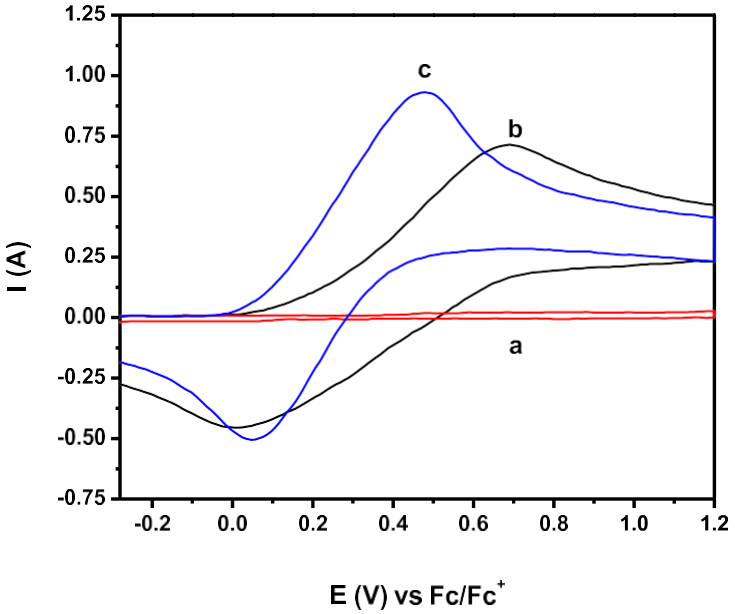
General Considerations

NMR spectra (^{1}H-, ^{13}C-, and ^{19}F-) were performed at 300 K using either a Brüker Avance Ultra Shield 300 MHz, or Brüker DRX-400 400 MHz spectrometer. ^{1}H-NMR spectra were referenced to residual $CHCl_3$ (7.26 ppm) in $CDCl_3$. ^{13}C-NMR spectra were referenced to $CDCl_3$ (77.16 ppm). ^{19}F-NMR spectra were referenced to hexafluorobenzene (-161.64 ppm).[1] Reactions were monitored by 1H, 19F-NMR, and/or by TLC on silica gel plates (60 Å porosity, 250 µm thickness). TLC analysis was performed using UV light. Electrochemistry reactions were performed using an IKA ElectraSyn 2.0 unit equipped with either a single-vial holder or a carousel.

Chemicals

Deuterated chloroform ($CDCl_3$) was purchased from Cambridge Isotope Laboratories. Hexafluorobenzene was purchased from Oakwood Chemicals. 4-Acetamido-TEMPO (ACT, **1**) was prepared and recrystallized using a previously reported protocol.[2] All the alcohols used were purchased from Oakwood Chemicals, Sigma-Aldrich, or Alfa Aesar.

Cyclic Voltammetry

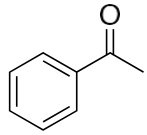


*Cyclic voltammograms in 0.1 M $LiClO_4$ in MeCN solution of (a) 1-phenylethanol (2.0 mmol), (b) ACT (**1**, 0.4 mmol) and (c) 1-phenylethanol (2.0 mmol) + ACT (**1**, 0.4 mmol), at a scan rate of 200 mV s^{-1}. Working electrode: glassy carbon. Pseudo reference electrode: Ag/Ag^+ (ferrocene as internal reference). Counter electrode: Pt plated electrode.*

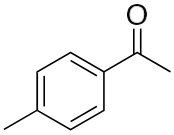
General Procedure for the preparation of Ketones and Aldehydes

Without precautions to exclude air or moisture; alcohol (2 mmol, 1 eq.), ACT (0.4 mmol, 0.2 eq.), lithium perchlorate in acetonitrile (4 mL, 0.1 M), and a stir bar were placed in an ElectraSyn 2.0 vial (5 mL capacity). The ElectraSyn vial cap was equipped with a graphite anode (working electrode) and a Ni cathode (counter electrode) and then secured onto the vial. The reaction mixture was electrolyzed at a constant current of 5 mA until the oxidation was deemed complete by 1H-NMR spectroscopy monitoring (24 - 48 h). Upon completion, the product mixture was filtered through a pad of silica. The silica was washed with diethyl ether to elute the product. The solvent was then removed from the filtrate under vacuum, affording the pure product.

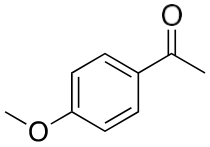
Product characterization



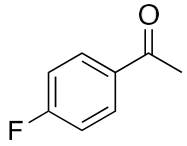
Acetophenone (3a). With a reaction time of 24 hours the product was obtained as a yellow oil (0.23 g, 90%). **^{1}H-NMR** (400 MHz, Chloroform-*d*) δ 8.02 – 7.90 (m, 2H), 7.63 – 7.52 (m, 1H), 7.47 (ddt, *J* = 8.2, 6.7, 1.1 Hz, 2H), 2.61 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 198.17, 137.19, 133.15, 128.62, 128.35, 26.63.[3]



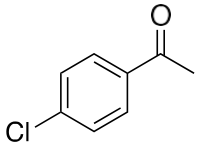
***para*-Methylacetophenone (3b).** With a reaction time of 24 hours the product was obtained as a yellow oil (0.18 g, 66%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.3 Hz, 2H), 7.45 – 6.91 (m, 2H), 2.59 (s, 3H), 2.42 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 197.81, 143.86, 134.75, 129.24, 128.44, 26.51, 21.62.[3]



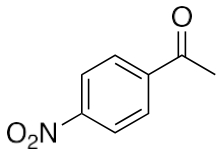
1-(4-Methoxyphenyl)ethanone (3c). With a reaction time of 24 hours the product was obtained as a yellow oil (0.21 g, 71%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.95 – 7.86 (m, 2H), 6.95 – 6.84 (m, 2H), 3.84 (s, 3H), 2.53 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 196.77, 163.55, 130.63, 130.41, 113.74, 55.50, 26.36.[3]



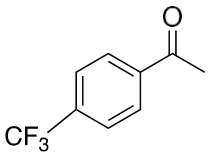
1-(4-Fluorophenyl)ethanone (3d). With a reaction time of 48 hours the product was obtained as a yellow oil (0.24 g, 88%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.02 – 7.92 (m, 2H), 7.17 – 7.06 (m, 2H), 2.58 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 196.44, 165.77 (d, *J* = 254.7 Hz), 133.62 (d, *J* = 3.2 Hz), 130.93 (d, *J* = 9.4 Hz), 115.64 (d, *J* = 22.0 Hz), 26.50. **^{19}F-NMR** (376 MHz, $CDCl_3$) δ -105.26 (ddd, *J* = 13.7, 8.7, 5.4 Hz).[4]



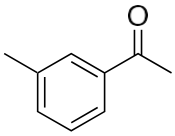
4-Chloroacetophenone (3e). With a reaction time of 24 hours the product was obtained as a yellow oil (0.29 g, 94%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.91 – 7.84 (m, 2H), 7.46 – 7.37 (m, 2H), 2.57 (q, *J* = 1.2 Hz, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 196.89, 139.67, 135.57, 129.83, 129.00, 26.64.[3]



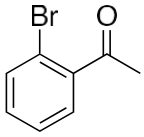
4-Nitroacetophenone (3f). With a reaction time of 48 hours the product was obtained as a yellow solid (0.26 g, 79%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.33 – 8.25 (m, 2H), 8.21 – 8.06 (m, 2H), 2.67 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 196.40, 150.46, 141.50, 129.40, 123.94, 27.06.[5]



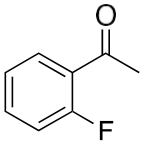
1-(4-Trifluoromethylphenyl)ethanone (3g). With a reaction time of 48 hours the product was obtained as a yellow solid (0.32 g, 84%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.04 (d, J = 8.0 Hz, 2H), 7.71 (d, J = 8.8 Hz, 2H), 2.63 (s, 3H). **^{13}C-NMR** (101 MHz, Chloroform-d) δ 196.96, 139.78, 134.42 (q, J = 32.5 Hz), 128.67, 125.69 (q, J = 3.8 Hz), 123.69 (q, J = 272.5 Hz), 26.71. **^{19}F-NMR** (376 MHz, $CDCl_3$) δ -62.89. [4] **^{19}F-NMR** (376 MHz, $CDCl_3$) δ -105.26 (ddd, *J* = 13.7, 8.7, 5.4 Hz).[4]



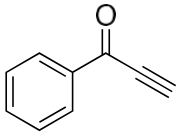
3-Methylacetophenone (3h). With a reaction time of 24 hours the product was obtained as a yellow oil (0.22 g, 84%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.80 – 7.69 (m, 2H), 7.41 – 7.30 (m, 2H), 2.59 (s, 3H), 2.41 (d, *J* = 0.8 Hz, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 198.37, 138.36, 137.20, 133.85, 128.79, 128.45, 125.59, 26.66, 21.33.[3]



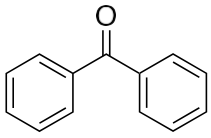
2-Bromoacetophenone (3i). With a reaction time of 24 hours the product was obtained as a yellow oil (0.32 g, 81%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.62 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.46 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.37 (td, *J* = 7.5, 1.2 Hz, 1H), 7.29 (ddd, *J* = 7.9, 7.4, 1.8 Hz, 1H), 2.63 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 201.38, 141.53, 133.86, 131.79, 128.92, 127.45, 118.93, 30.33.[3]



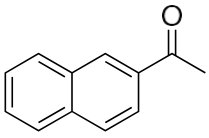
2'-Fluoroacetophenone (3j). With a reaction time of 48 hours the product was obtained as a yellow oil (0.21 g, 76%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.86 (td, *J* = 7.6, 1.9 Hz, 1H), 7.50 (dddd, *J* = 8.6, 7.1, 5.0, 1.9 Hz, 1H), 7.28 – 7.16 (m, 1H), 7.12 (ddd, *J* = 11.2, 8.3, 1.1 Hz, 1H), 2.63 (d, *J* = 5.0 Hz, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 195.99 (d, *J* = 3.5 Hz), 162.34 (d, *J* = 254.8 Hz), 134.76 (d, *J* = 9.1 Hz), 130.69 (d, *J* = 2.5 Hz), 125.84 (d, *J* = 12.8 Hz), 124.46 (d, *J* = 3.6 Hz), 116.75 (d, *J* = 23.8 Hz), 31.51 (d, *J* = 7.3 Hz). **^{19}F-NMR** (376 MHz, $CDCl_3$) δ -109.34 (ddq, *J* = 13.9, 9.8, 4.9 Hz).[6]



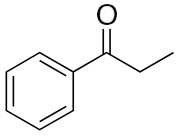
Benzoylacetylene (3k). With a reaction time of 36 hours the product was obtained as a yellow solid (0.18 g, 69%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.20 – 8.13 (m, 2H), 7.68 – 7.59 (m, 1H), 7.50 (t, *J* = 7.7 Hz, 2H), 3.44 (s, 1H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 177.50, 136.27, 134.63, 129.81, 128.80, 80.90, 80.39.[7]



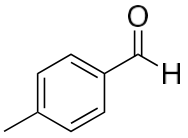
Benzophenone (3l). With a reaction time of 24 hours the product was obtained as a yellow solid (0.34 g, 92%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.85 – 7.78 (m, 4H), 7.64 – 7.53 (m, 2H), 7.49 (dd, *J* = 8.4, 7.0 Hz, 4H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 196.86, 137.75, 132.53, 130.18, 128.40.[3]



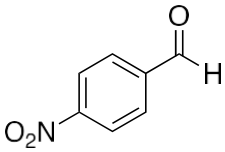
2-Acetonapthone (3m). With a reaction time of 24 hours the product was obtained as a yellow solid (0.33 g, 97%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.44 (d, *J* = 1.8 Hz, 1H), 8.02 (dd, *J* = 8.7, 1.8 Hz, 1H), 7.94 (d, *J* = 8.0 Hz, 1H), 7.86 (dd, *J* = 8.4, 4.4 Hz, 2H), 7.63 – 7.49 (m, 2H), 2.71 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 198.09, 135.64, 134.55, 132.57, 130.23, 129.60, 128.51, 128.46, 127.83, 126.82, 123.94, 26.71.[7]



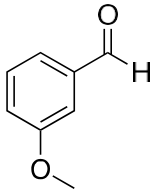
1-Phenylpropan-1-one (3n). With a reaction time of 24 hours the product was obtained as a yellow oil (0.20 g, 74%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.00 – 7.92 (m, 2H), 7.58 – 7.50 (m, 1H), 7.45 (dd, *J* = 8.3, 6.9 Hz, 2H), 2.99 (q, *J* = 7.2 Hz, 2H), 1.22 (t, *J* = 7.2 Hz, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 200.88, 137.04, 132.95, 128.64, 128.06, 31.86, 8.33.[4]



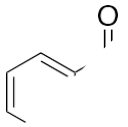
4-Methylbenzaldehyde (3o). With a reaction time of 36 hours the product was obtained as a yellow oil (0.14 g, 58%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 9.95 (s, 1H), 7.79 – 7.73 (m, 2H), 7.31 (d, *J* = 7.8 Hz, 2H), 2.42 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 192.03, 145.61, 134.30, 129.91, 129.78, 21.93.[8]



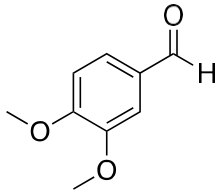
4-Nitrobenzaldehyde (3p). With a reaction time of 48 hours the product was obtained as a yellow solid (0.18 g, 60%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 10.14 (s, 1H), 8.40 – 8.33 (m, 2H), 8.10 – 8.02 (m, 2H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 190.42, 151.20, 140.16, 130.56, 124.37.'[8]



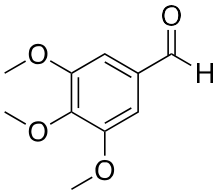
3-Methoxybenzaldehyde (3q). With a reaction time of 24 hours the product was obtained as a yellow oil (0.25 g, 92%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 9.95 (s, 1H), 7.47 – 7.39 (m, 2H), 7.37 (dd, *J* = 2.8, 1.1 Hz, 1H), 7.15 (dt, *J* = 6.4, 2.7 Hz, 1H), 3.84 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 192.17, 160.24, 137.91, 130.10, 123.56, 121.55, 112.18, 55.52.[8]



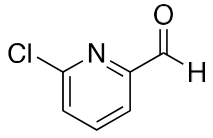
2-Bromobenzaldehyde (3r). With a reaction time of 48 hours the product was obtained as a yellow solid (0.28 g, 75%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 10.35 (s, 1H), 7.93 – 7.82 (m, 1H), 7.77 – 7.58 (m, 1H), 7.44 (tt, *J* = 6.1, 3.1 Hz, 2H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 191.94, 135.43, 134.00, 133.64, 129.97, 128.02, 127.21.[8]



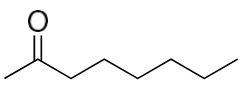
3,4-Dimethoxybenzaldehyde (3s). With a reaction time of 24 hours the product was obtained as a yellow oil (0.29 g, 87%). **^{1}H-NMR** (300 MHz, $CDCl_3$) δ 9.84 (s, 1H), 7.50 – 7.37 (m, 2H), 6.97 (d, *J* = 8.2 Hz, 1H), 3.95 (d, *J* = 7.6 Hz, 6H). **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 191.03, 154.58, 149.71, 130.23, 127.02, 110.47, 108.98, 56.30, 56.12.[9]



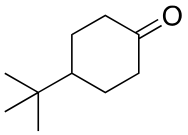
3,4,5-Trimethoxybenzaldehyde (3t). With a reaction time of 24 hours the product was obtained as a yellow solid (0.35 g, 88%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 9.83 (s, 1H), 7.10 (s, 2H), 3.91 (s, 3H), 3.90 (s, 7H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 191.08, 153.72, 143.70, 131.80, 106.80, 61.04, 56.34.[10]



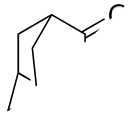
6-Chloropicolinaldehyde (3u). With a reaction time of 48 hours the product was obtained as a yellow solid (0.22 g, 77%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 9.96 (s, 1H), 7.90 – 7.80 (m, 2H), 7.55 (dd, *J* = 7.1, 1.8 Hz, 1H).[11] **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 191.77, 153.00, 152.16, 139.83, 129.05, 120.12. **HRMS (ESI)** *m/z* calculated for C_6H_4ClNO $[M+H]^+$ 142.0060, found 142.0060; and 144.0030, found 144.0035.[11]



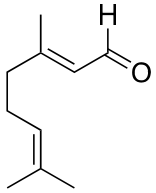
2-Octanone (3v). With a reaction time of 24 hours the product was obtained as a yellow oil (0.14 g, 55%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 2.40 (t, *J* = 7.4 Hz, 2H), 2.11 (s, 3H), 1.61 – 1.49 (m, 2H), 1.29 – 1.23 (m, 6H), 0.91 – 0.79 (m, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 209.42, 43.92, 31.70, 29.92, 28.96, 23.95, 22.60, 14.11.[12]



4-*tert*-Butylcyclohexanone (3w). With a reaction time of 24 hours the product was obtained as a yellow solid (0.25 g, 79%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 2.42 – 2.32 (m, 2H), 2.34 – 2.20 (m, 2H), 2.11 – 2.01 (m, 2H), 1.50 – 1.34 (m, 3H), 0.89 (s, 9H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 212.58, 46.81, 41.40, 32.56, 27.70.[13]



2-Adamantanone (3x). With a reaction time of 24 hours the product was obtained as a yellow solid (0.24 g, 80%). **^{1}H-NMR** (300 MHz, $CDCl_3$) δ 2.51 (s, 2H), 2.14 – 1.84 (m, 12H). **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 218.62, 47.05, 39.33, 36.37, 27.52.[14]

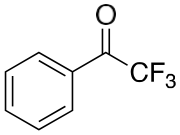


Geranial (3y). With a reaction time of 24 hours the product was obtained as a yellow oil (0.18 g, 59%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 9.98 (d, J = 8.1 Hz, 1H), 5.90 – 5.82 (m, 1H), 5.06 (td, J = 6.1, 3.4 Hz, 1H), 2.26 – 2.17 (m, 4H), 2.16 (d, J = 1.3 Hz, 3H), 1.68 (s, 3H), 1.60 (s, 3H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 191.41, 163.92, 133.05, 127.55, 122.70, 40.73, 25.87, 25.76, 17.83, 17.70.[15]

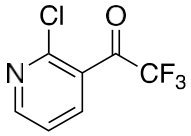
General Procedure for the preparation of Trifluoromethyl Ketones

Without precautions to exclude air or moisture; alcohol (2 mmol, 1 eq.), ACT (0.4 mmol, 0.2 eq.), lithium perchlorate in acetonitrile (4 mL, 0.1 M), and a stir bar were placed in an ElectraSyn vial (5 mL). The ElectraSyn vial cap was equipped with a graphite anode (working electrode) and a Ni cathode (counter electrode) and then secured onto the vial. The reaction mixture was electrolyzed at a constant current of 5 mA for 48 h. The product mixture was quenched with deionized water (50 mL), transferred to a separatory funnel, and extracted with Et2O (3 x 30 mL). The combined organics were washed with 1 M HCl (30 mL) and brine (30 mL), then dried over sodium sulfate and the solvent removed in vacuo to afford the pure trifluoromethyl ketone.

Product characterization



1,1,1-Trifluoroacetophenone (3z). With a reaction time of 48 hours the product was obtained as a yellow oil (0.21 g, 61%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 7.6 Hz, 2H), 7.76 (t, *J* = 7.4 Hz, 1H), 7.59 (t, *J* = 7.6 Hz, 2H). **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 179.73 (q, *J* = 35.0 Hz), 134.79, 129.34, 129.17, 128.37, 115.91 (q, *J* = 291.1 Hz). **^{19}F-NMR** (376 MHz, $CDCl_3$) δ -71.20.[12]



2-Chloro-3-trifluoroacetyl-pyridine (3aa). With a reaction time of 48 hours the product was obtained with a 83% conversion via ^{1}H NMR .

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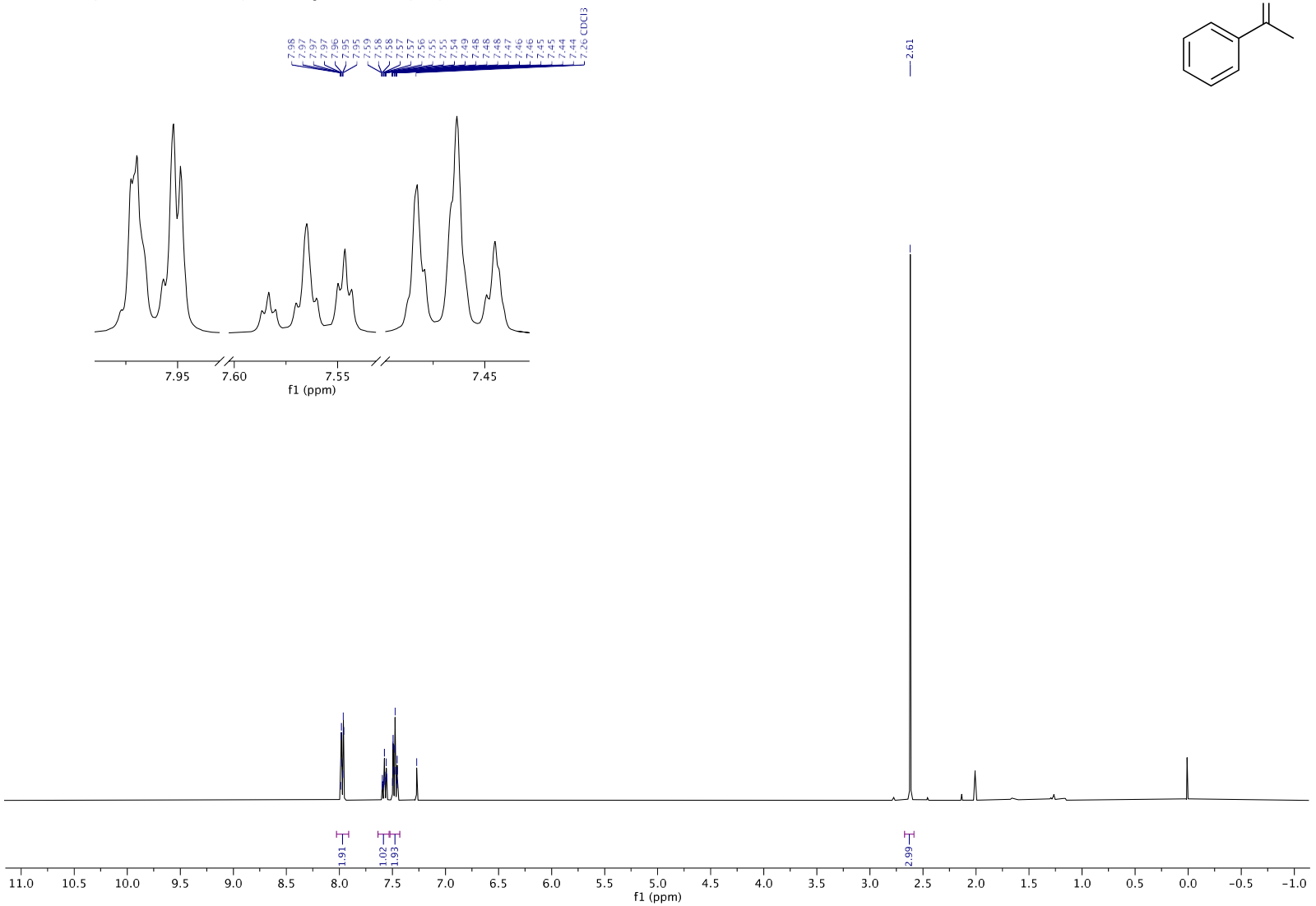
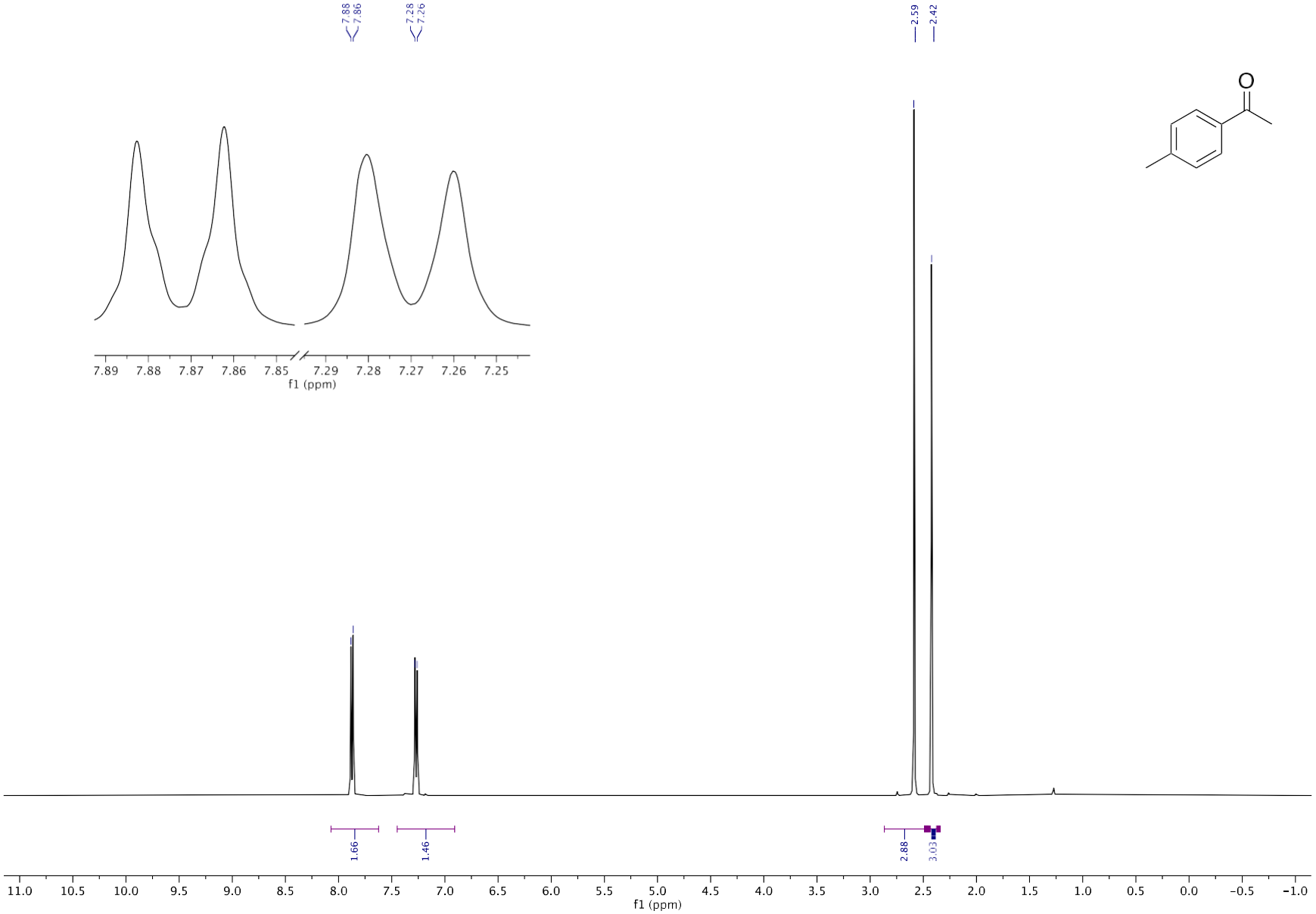
^{1}H-, ^{13}C-, and ^{19}F-NMR spectra of synthesized compounds

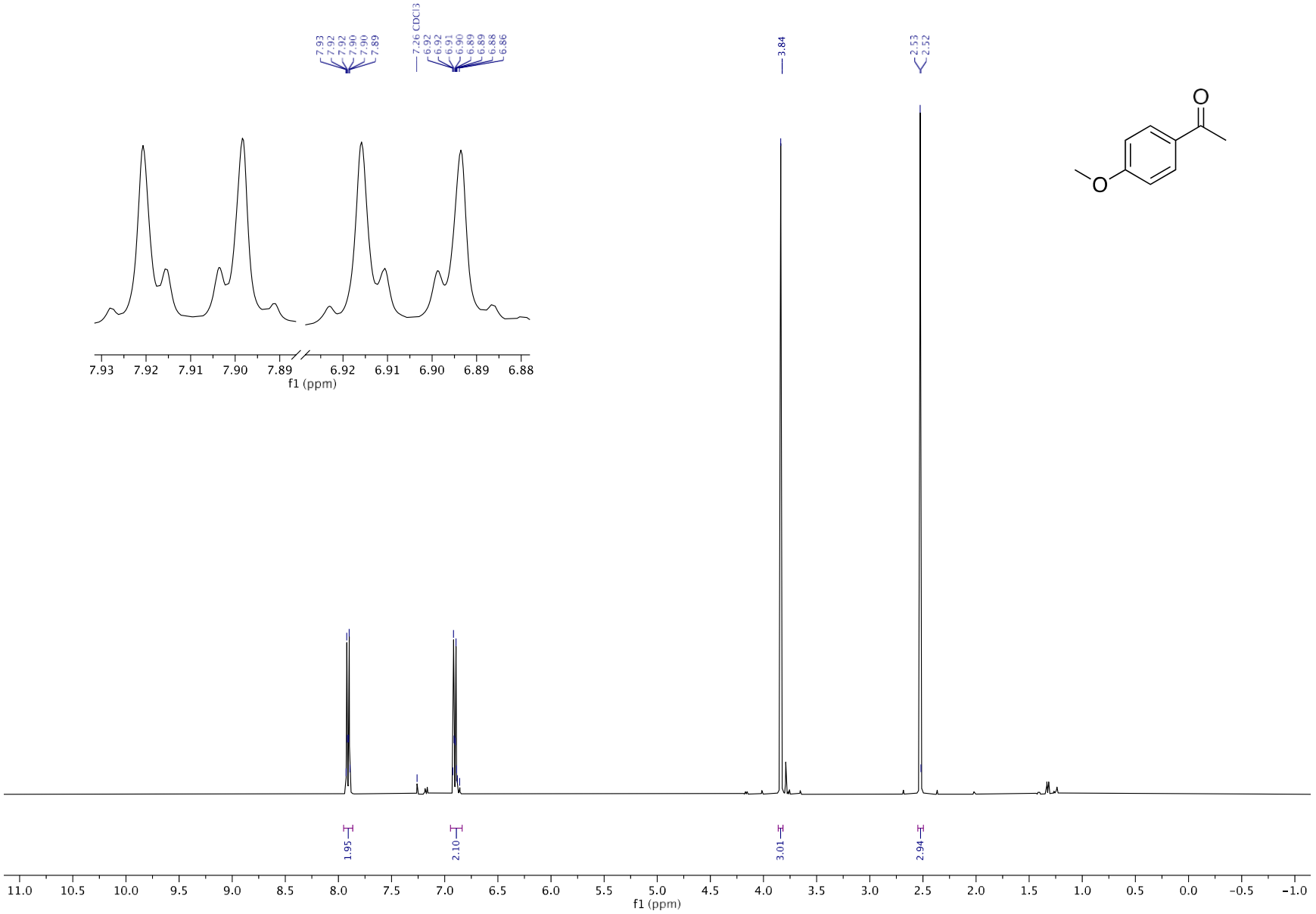
^{1}H-NMR (400MHz $CDCl_3$) Acetophenone (3a)



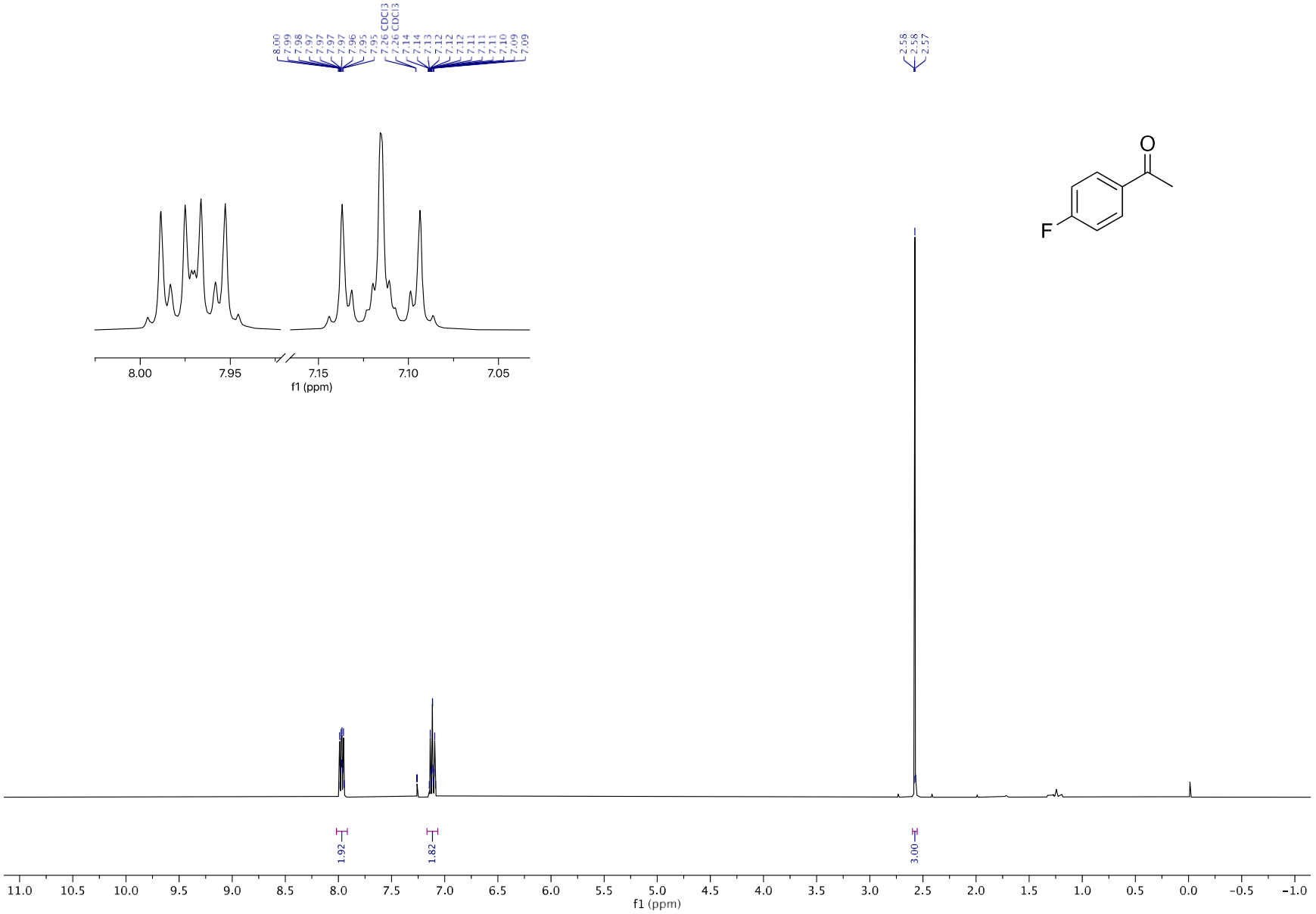
^{1}H-NMR (400 MHz $CDCl_3$) 4-Methylacetophenone (3b)



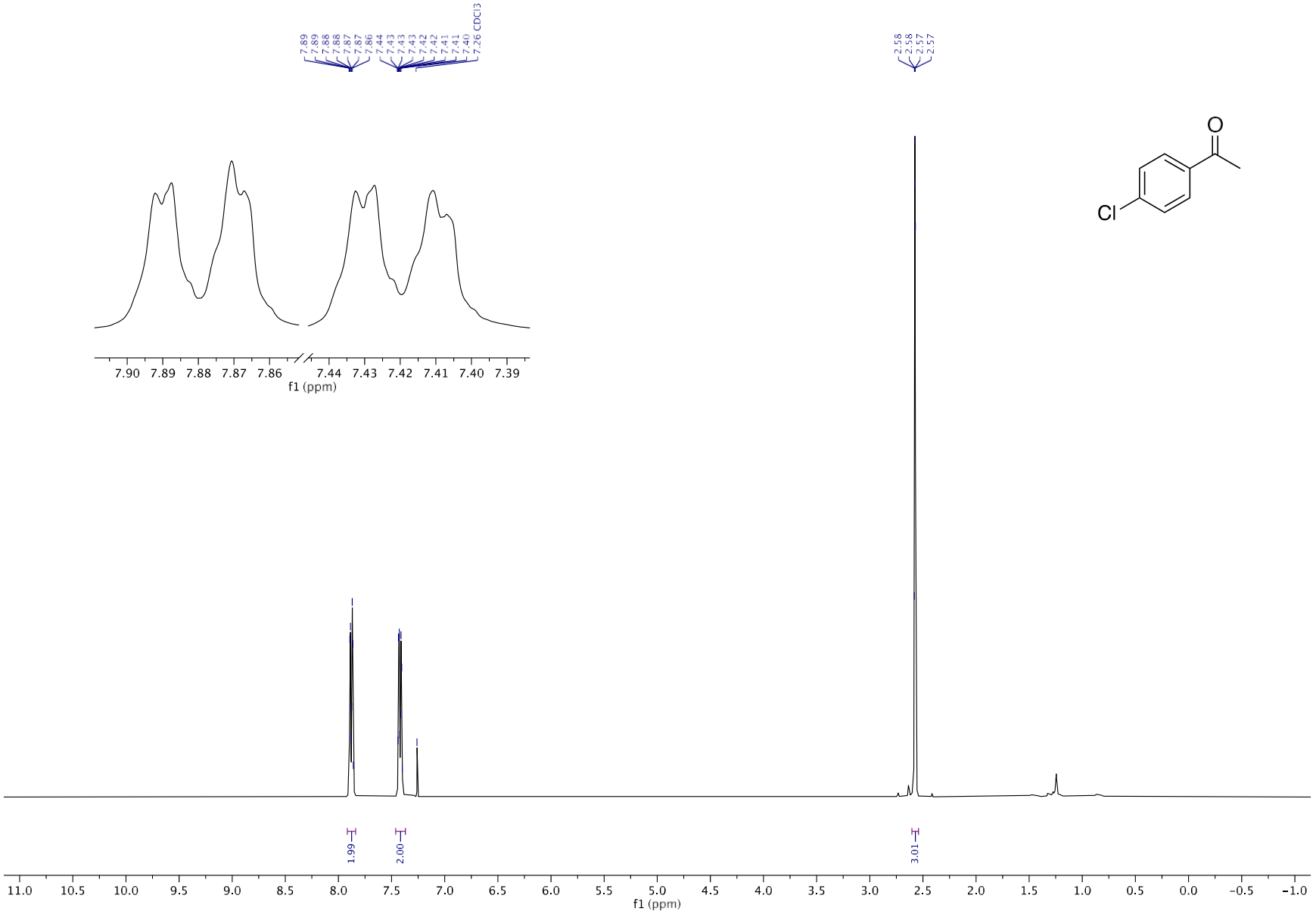
^{1}H-NMR (400 MHz $CDCl_3$) 1-(4-Methoxyphenyl)ethanone (3c)



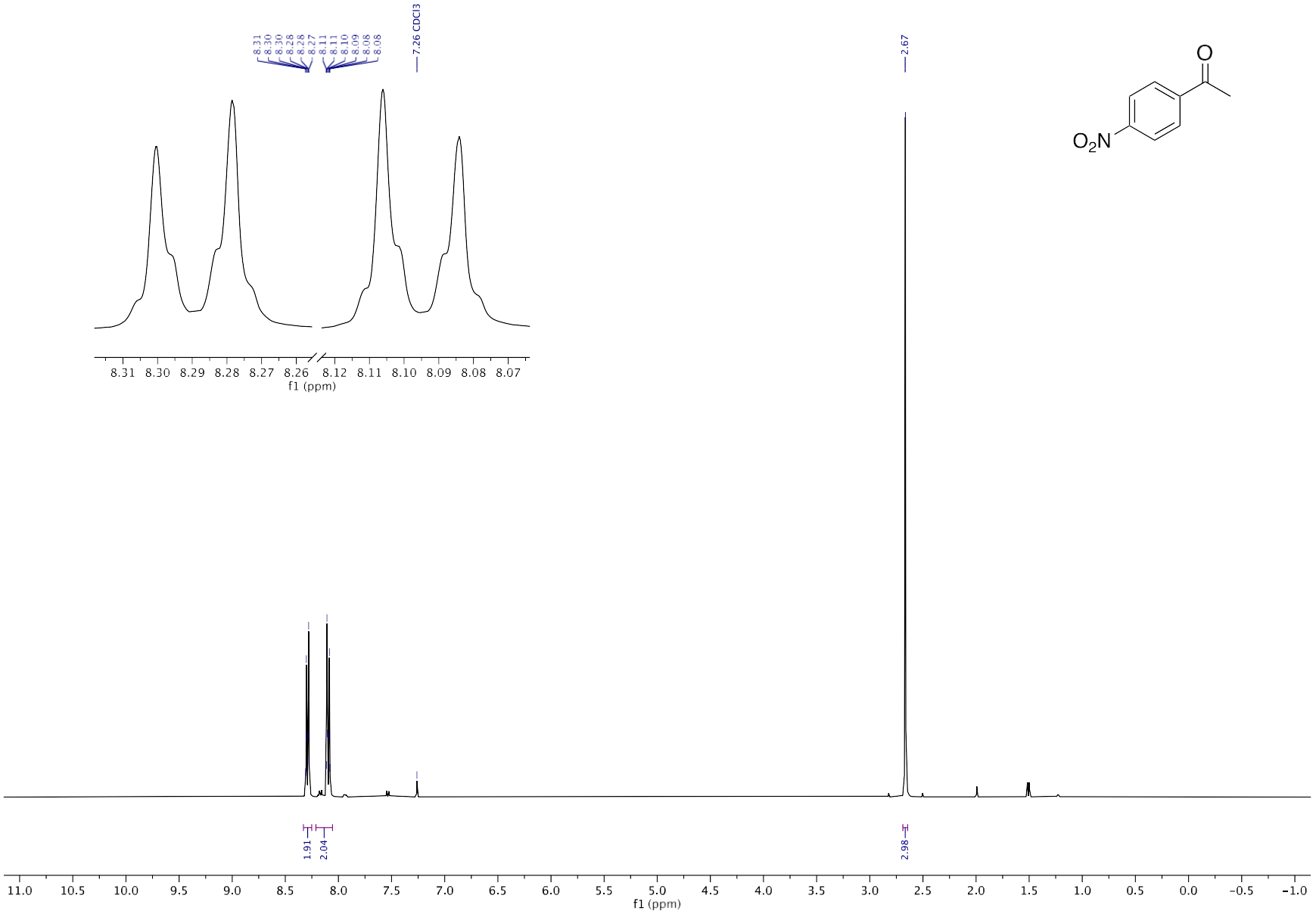
^{1}H-NMR (400 MHz $CDCl_3$) 1-(4-Fluorophenyl)ethanone (3d)



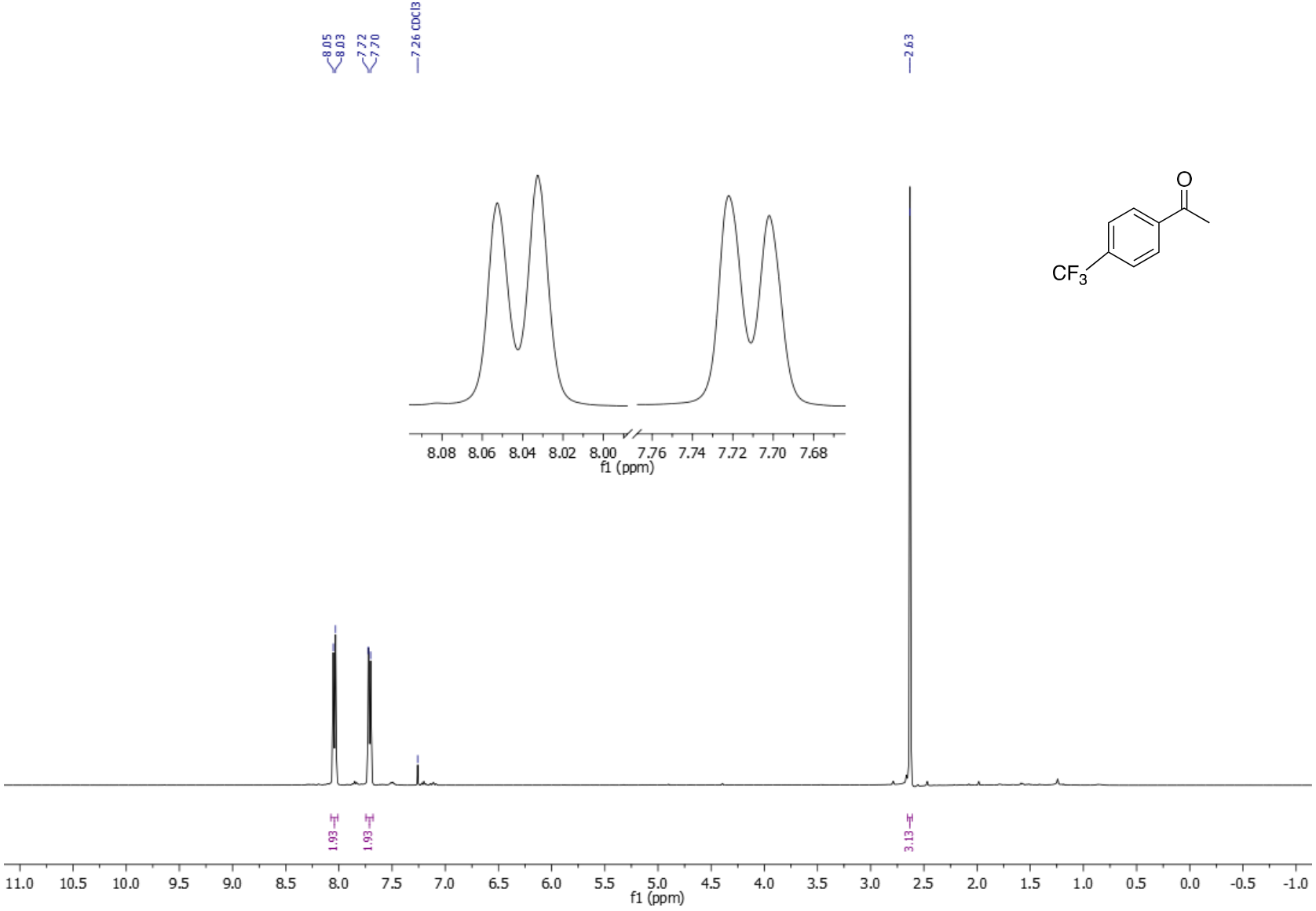
^{1}H-NMR (400 MHz $CDCl_3$) 4-Chloroacetophenone (3e)



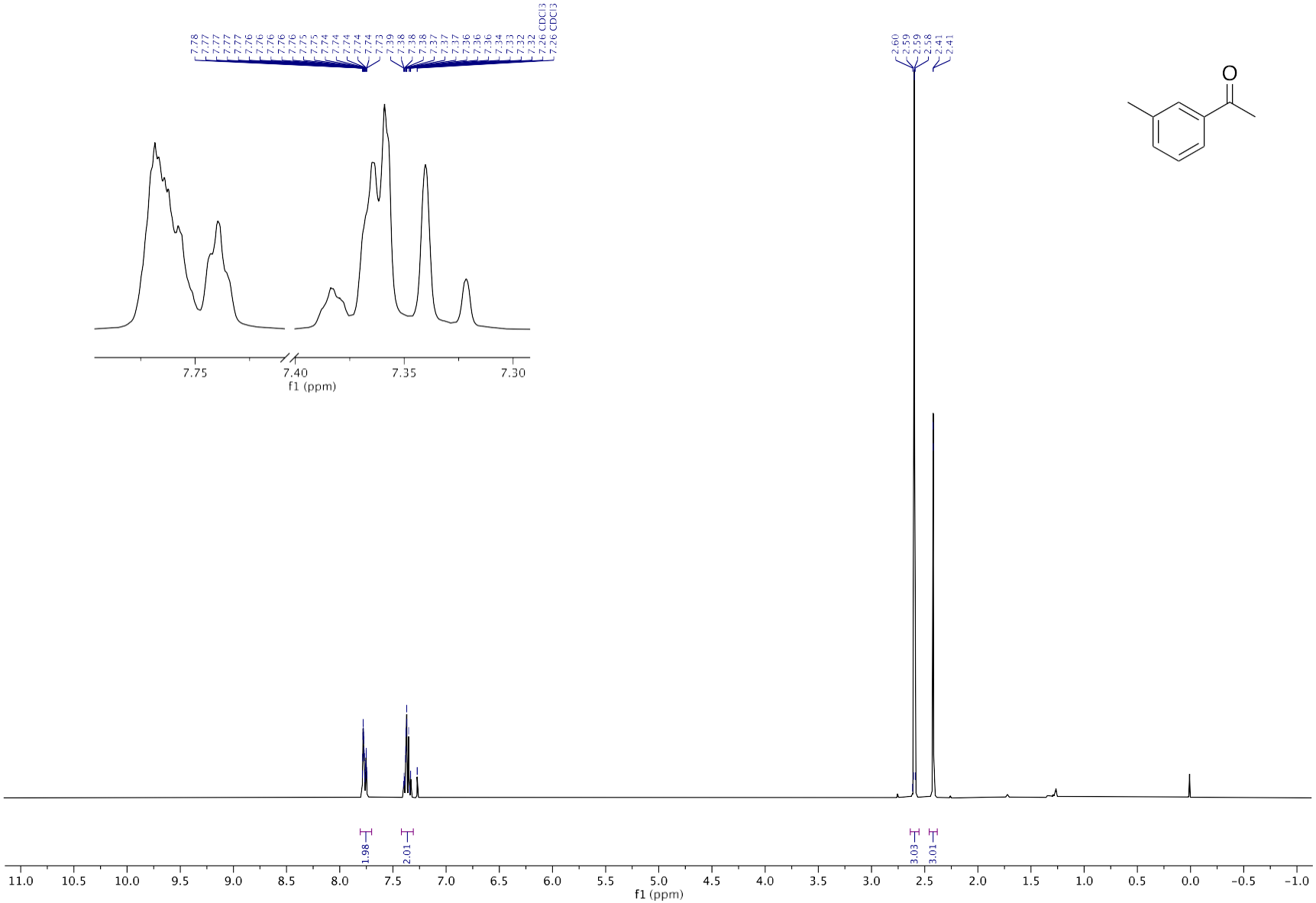
^{1}H-NMR (400 MHz $CDCl_3$) 4-Nitroacetophenone (3f)



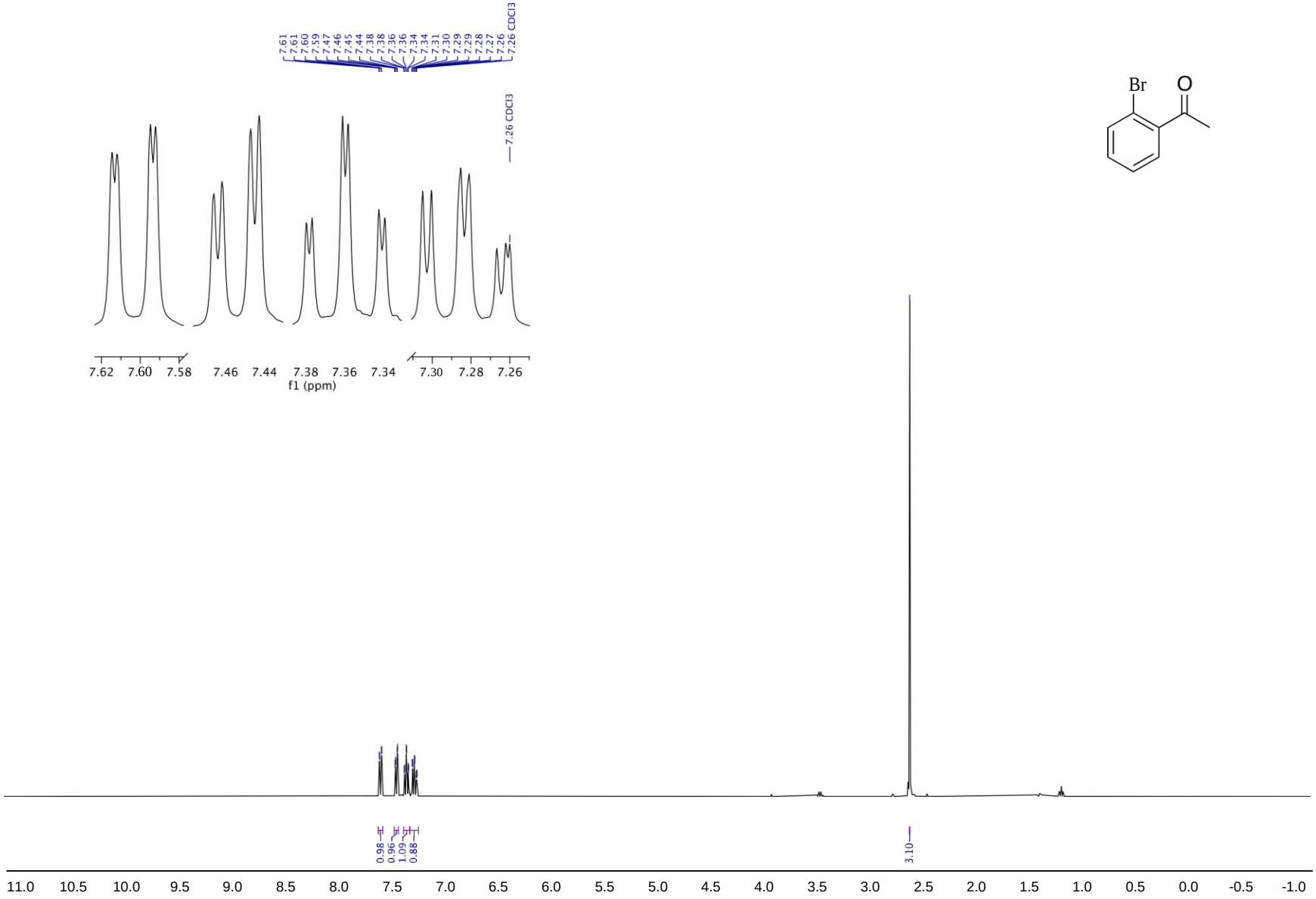
^{1}H-NMR (400 MHz $CDCl_3$) 1-(4-Trifluoromethylphenyl)ethanone (3g)



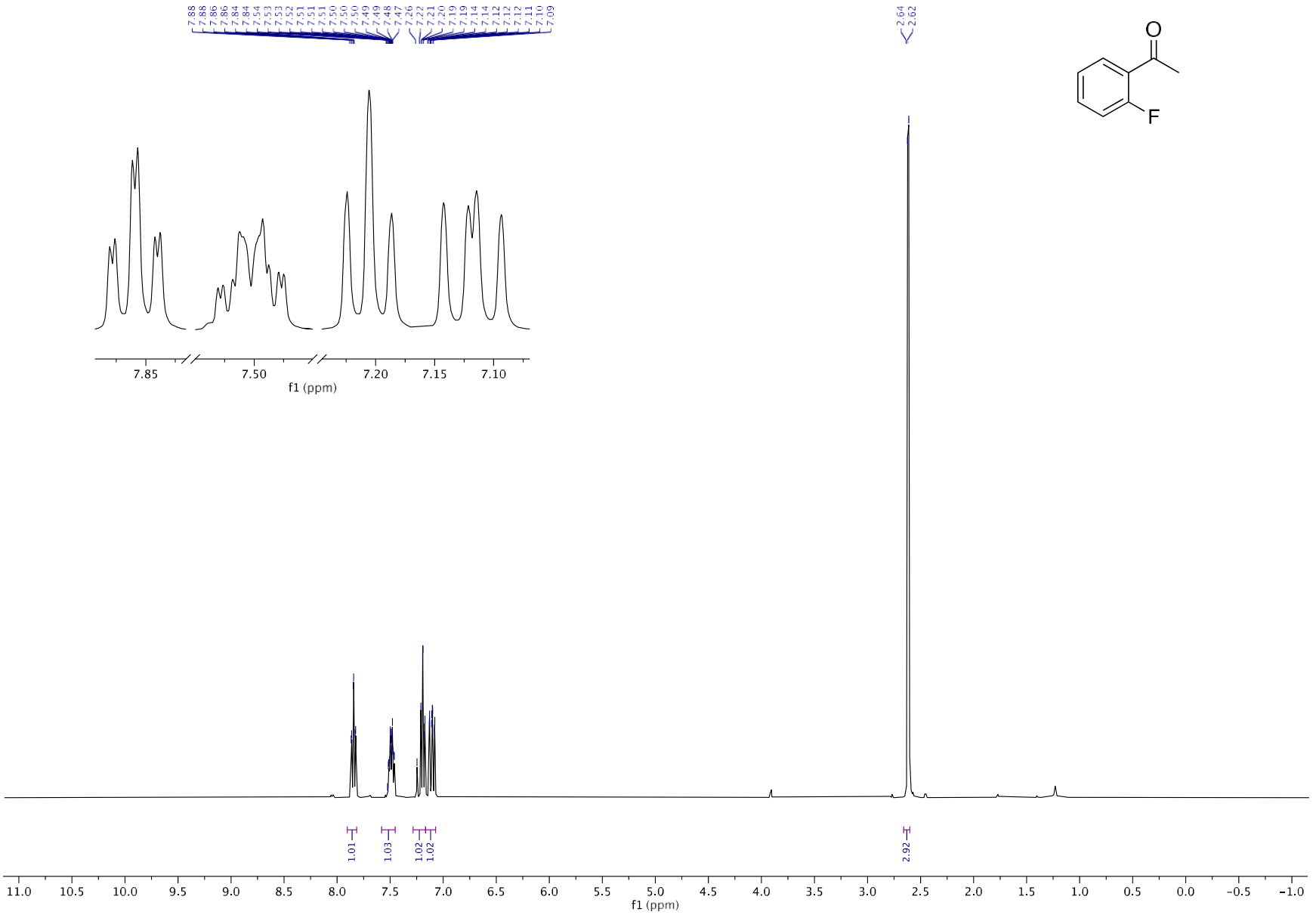
^{1}H-NMR (400 MHz $CDCl_3$) 3-Methylacetophenone (3h)



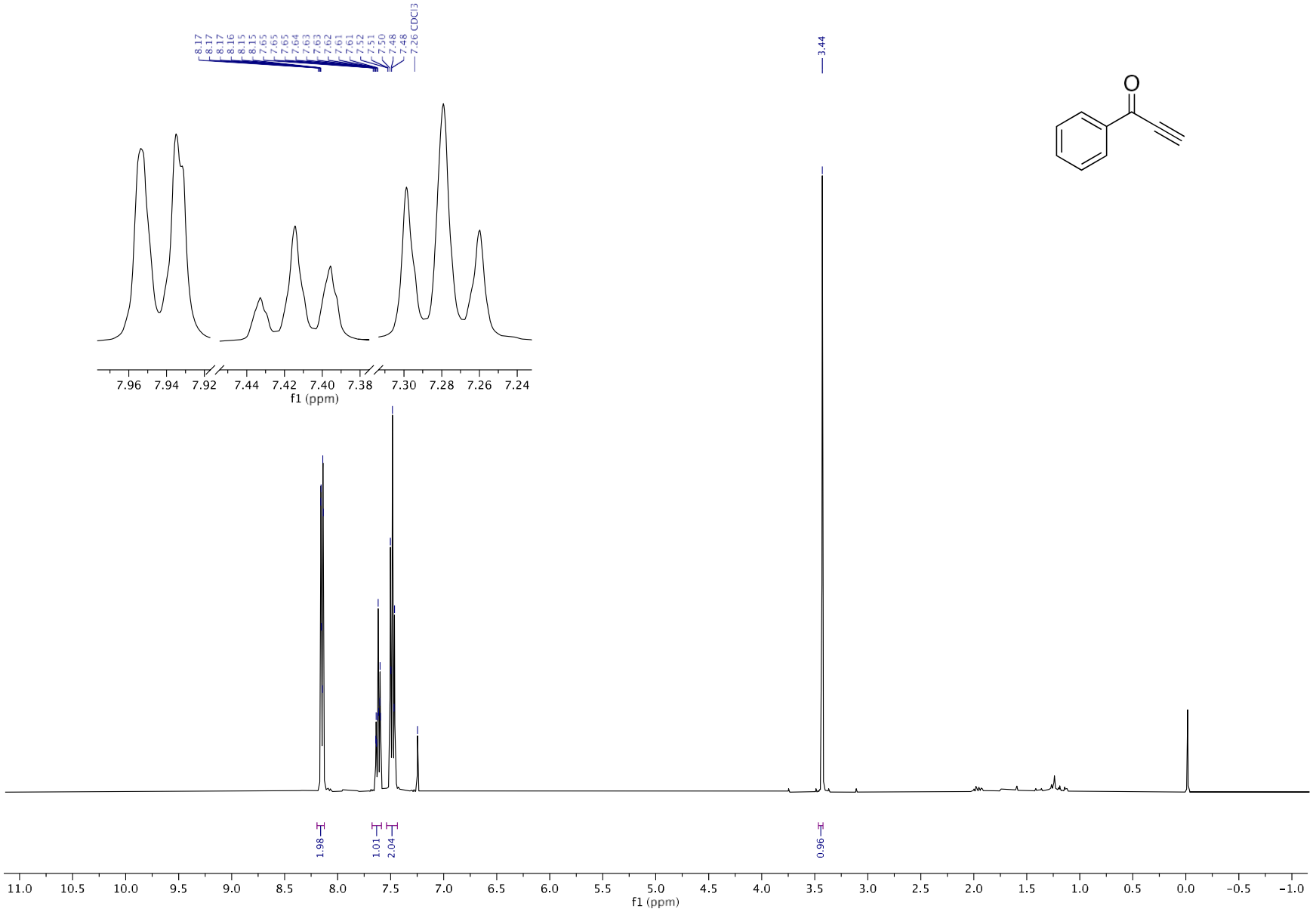
^{1}H-NMR (400 MHz $CDCl_3$) 2-Bromoacetophenone (3i)



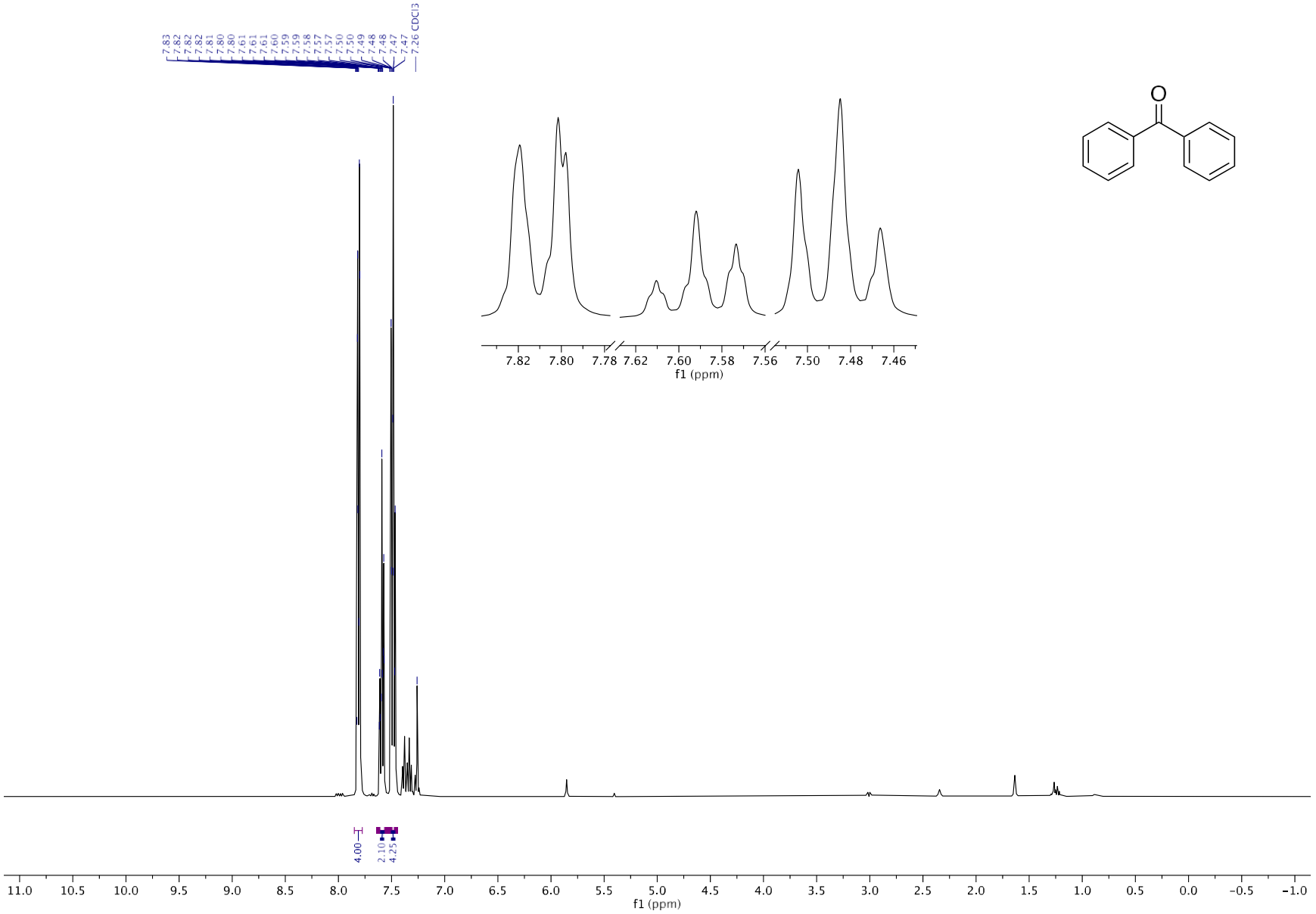
^{1}H-NMR (400 MHz $CDCl_3$) 2'-Fluoroacetophenone (3j)



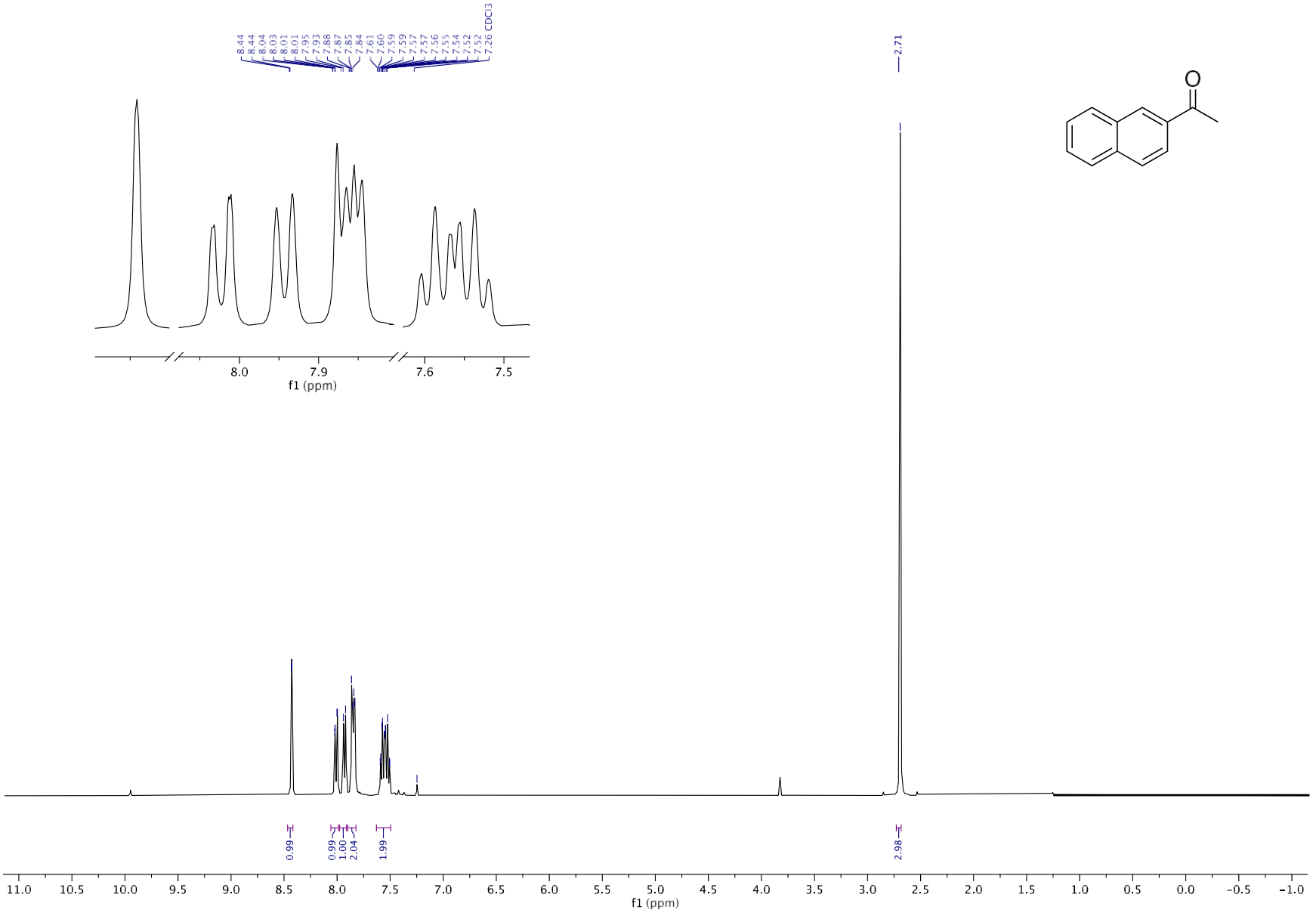
^{1}H-NMR (400 MHz $CDCl_3$) Benzoylacetylene (3k)



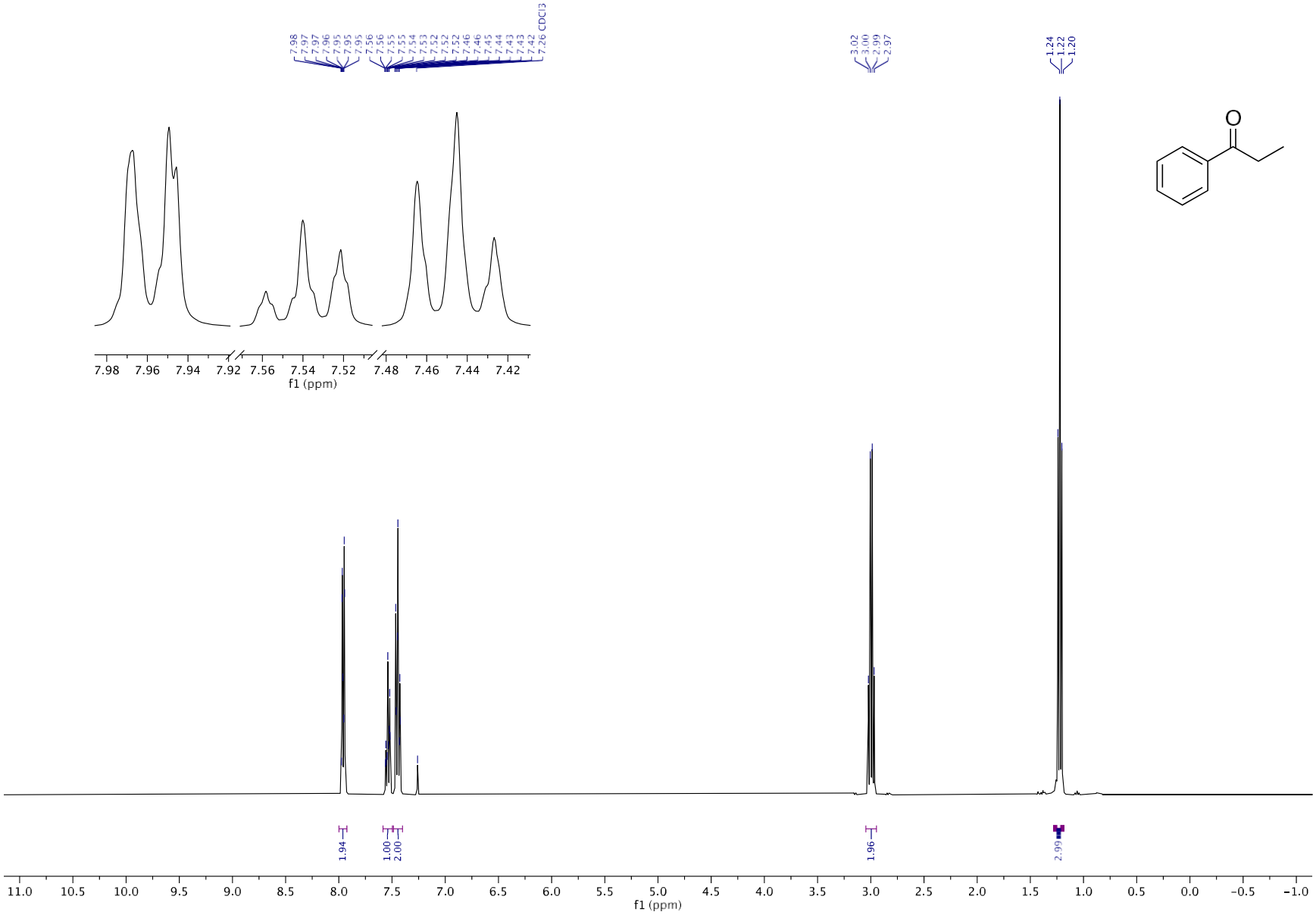
^{1}H-NMR (400 MHz $CDCl_3$) Benzophenone (3l)



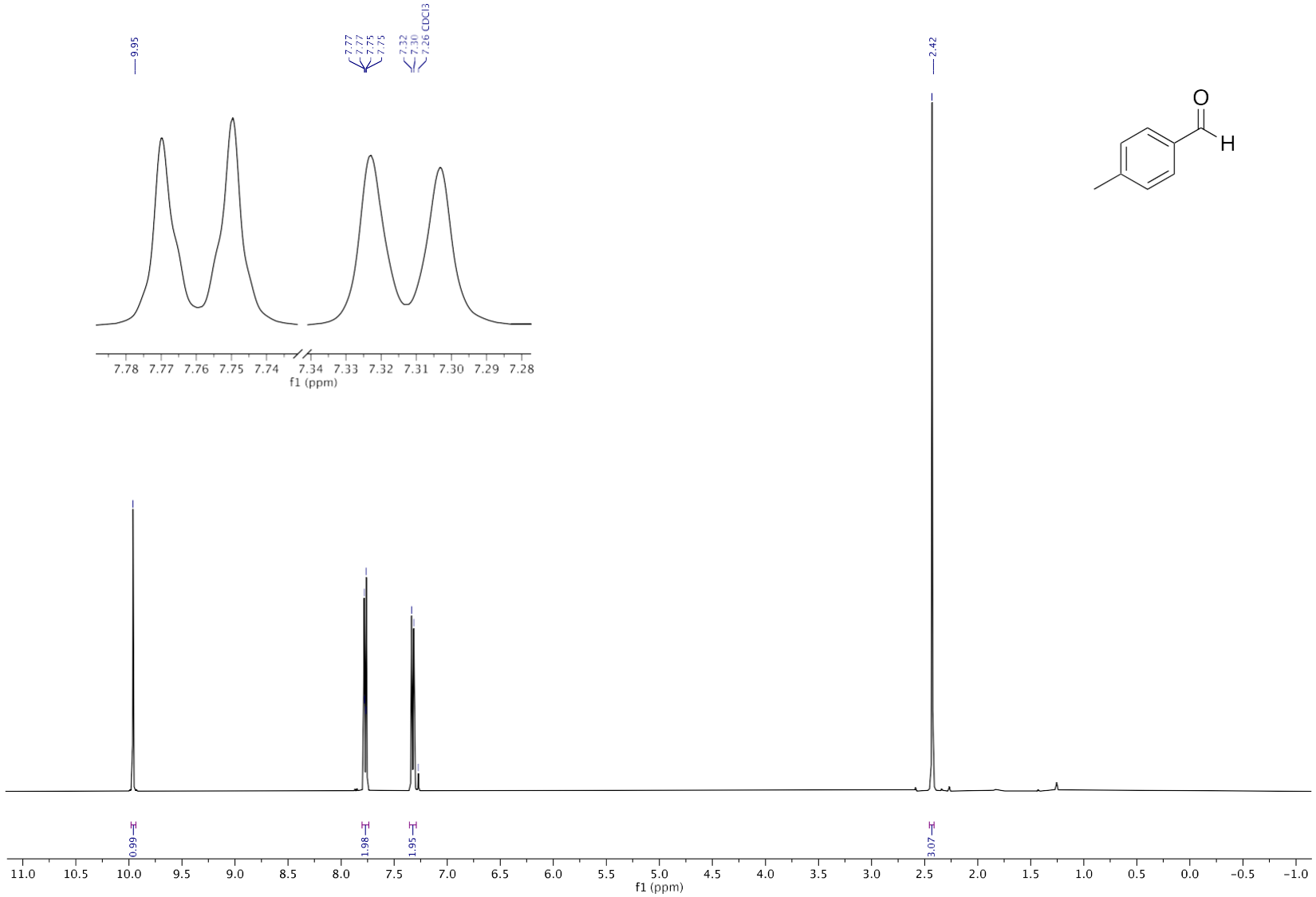
^{1}H-NMR (400 MHz $CDCl_3$) 2-Acetonapthone (3m)



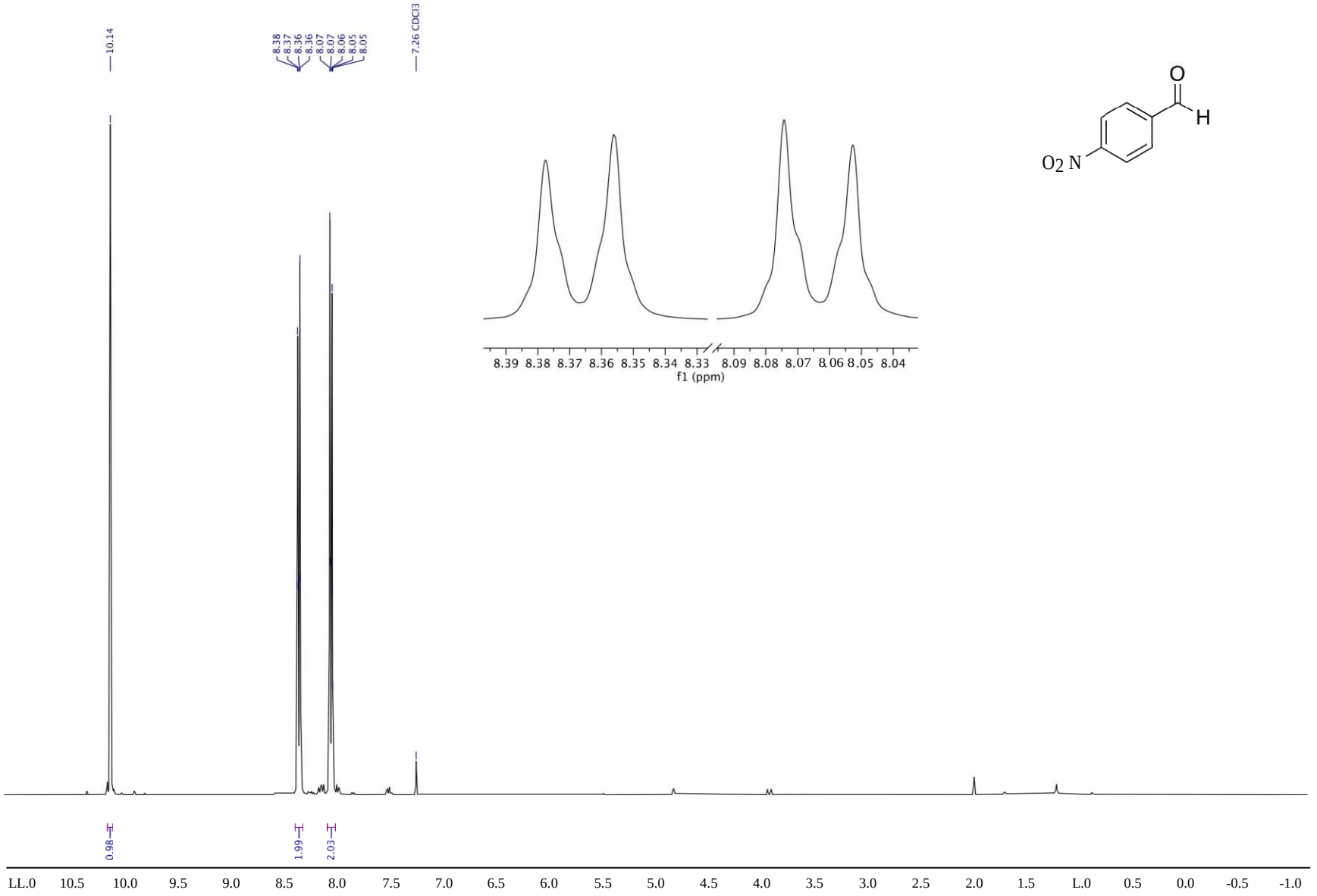
^{1}H-NMR (400 MHz $CDCl_3$) 1-Phenylpropan-1-one (3n)



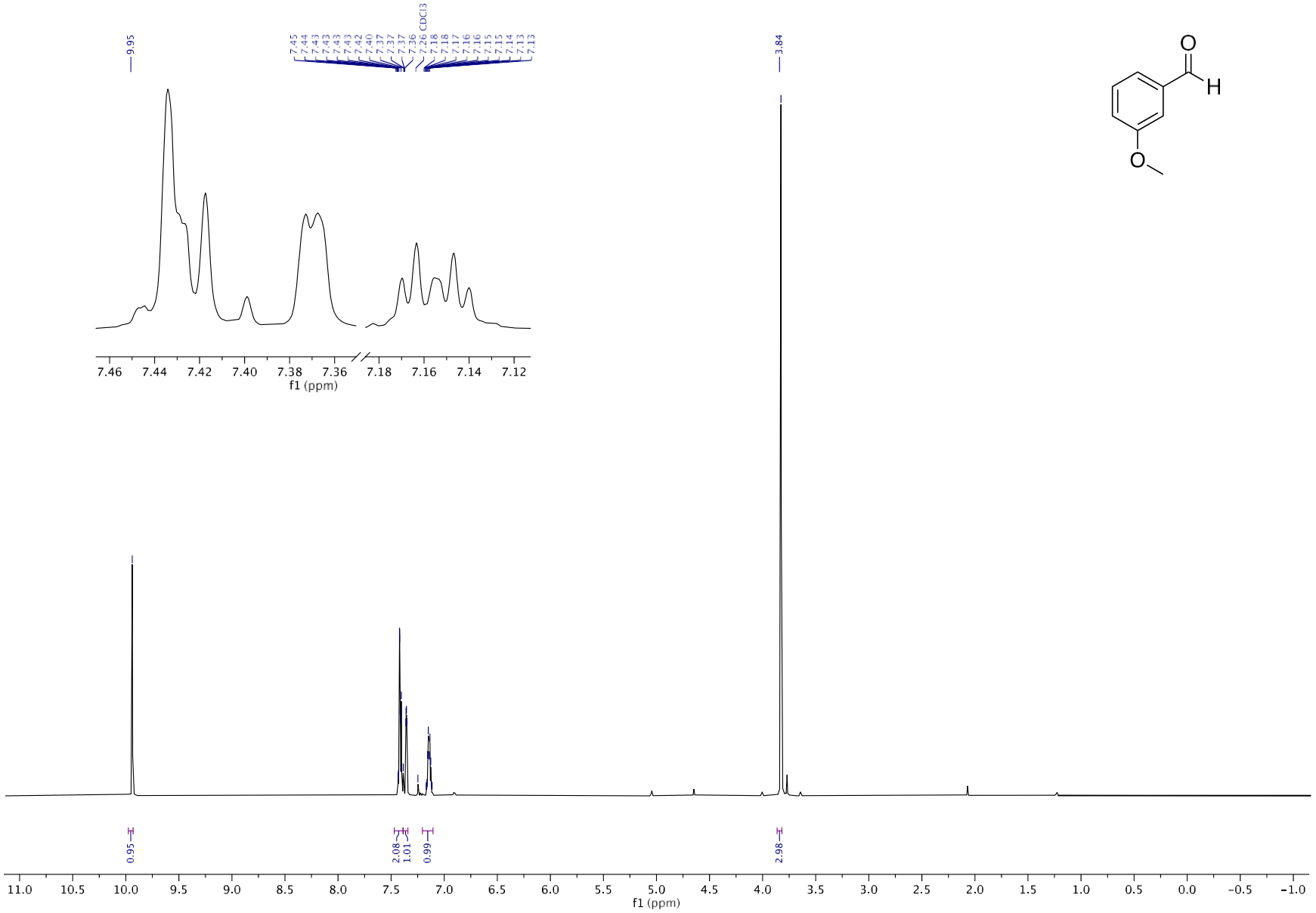
^{1}H-NMR (400 MHz $CDCl_3$) 4-Methylbenzaldehyde (3o)



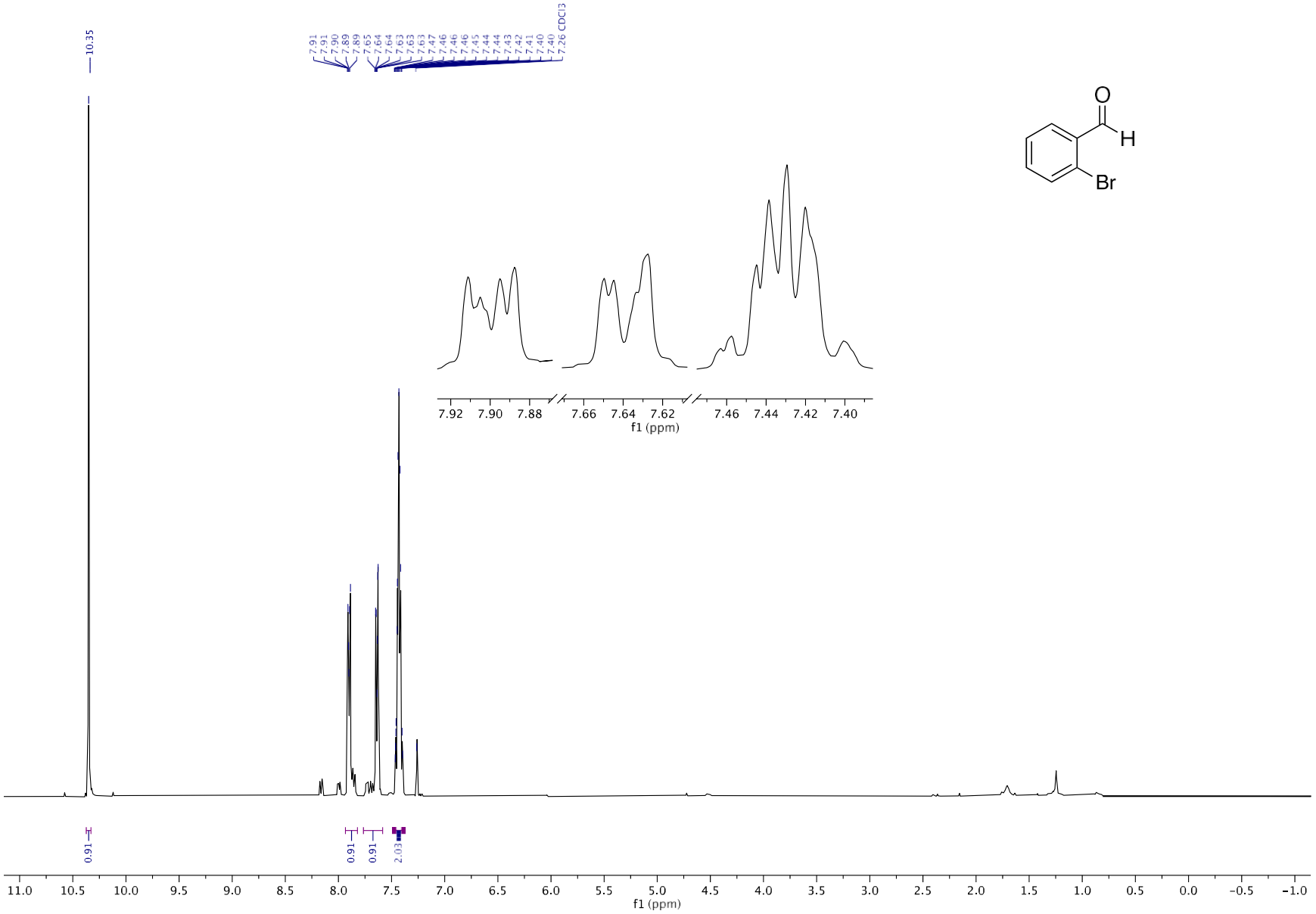
^{1}H-NMR (400 MHz $CDCl_3$) 4-Nitrobenzaldehyde (3p)



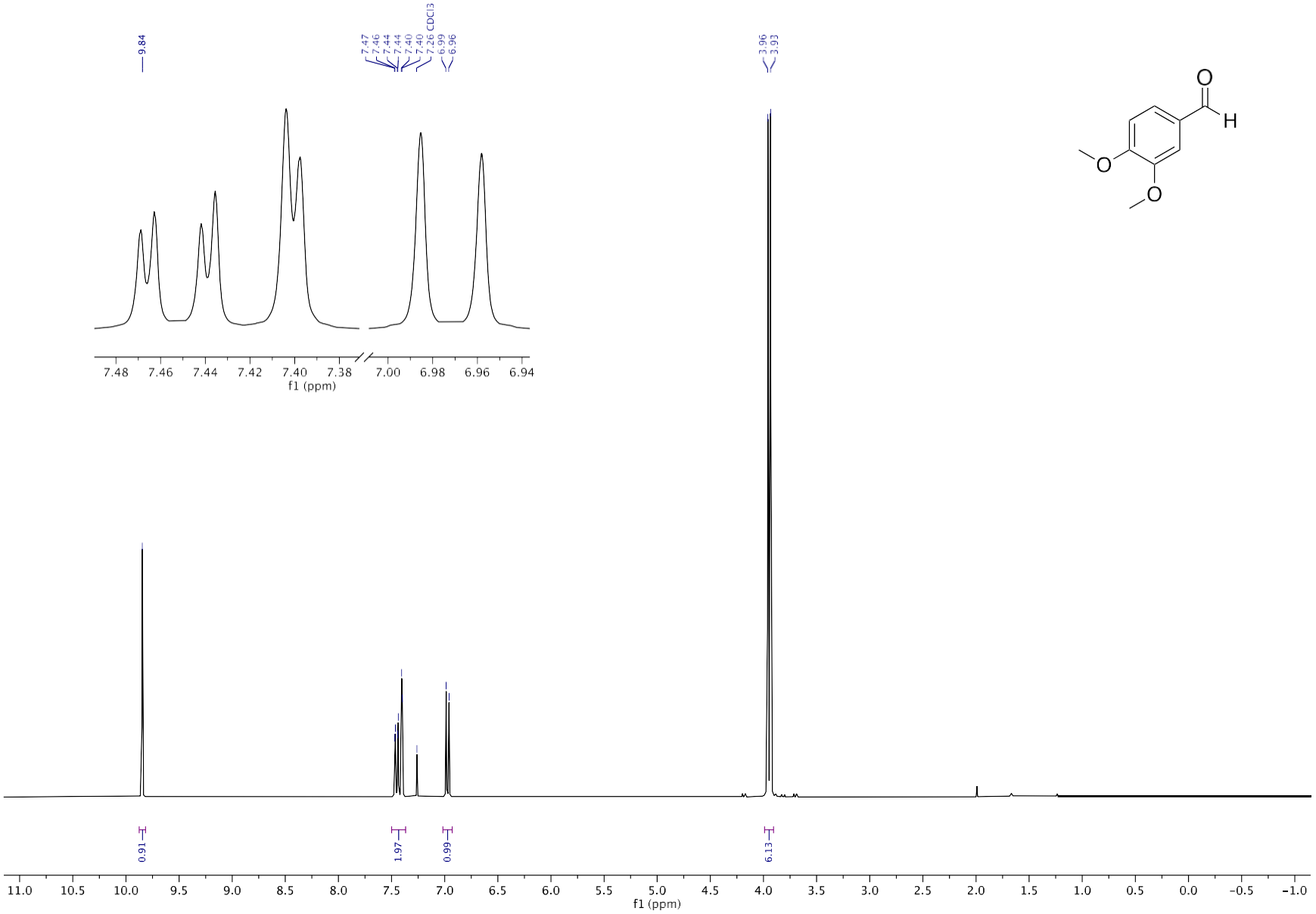
^{1}H-NMR (400 MHz $CDCl_3$) 3-Methoxybenzaldehyde (3q)



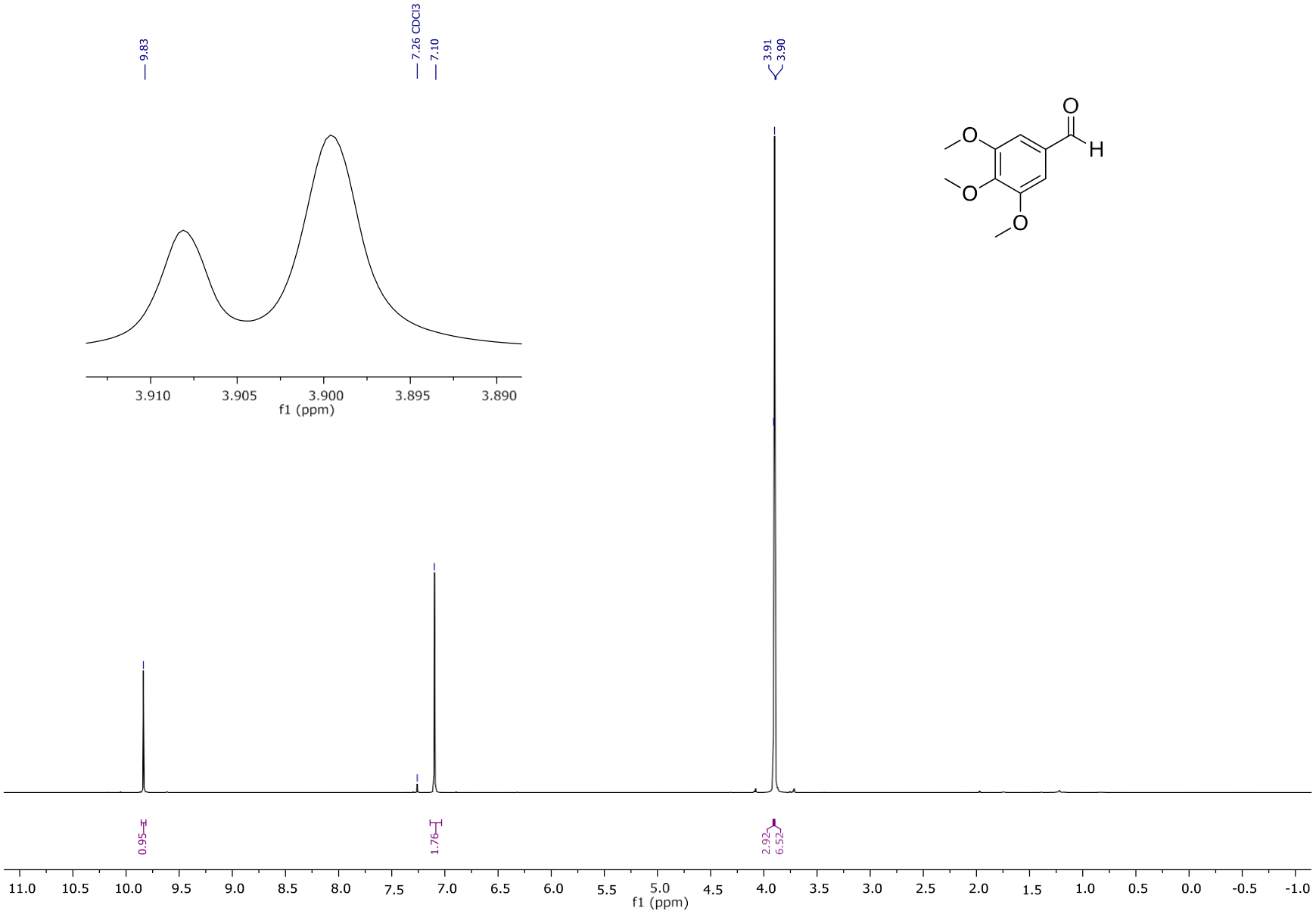
^{1}H-NMR (400 MHz $CDCl_3$) 2-Bromobenzaldehyde (3r)



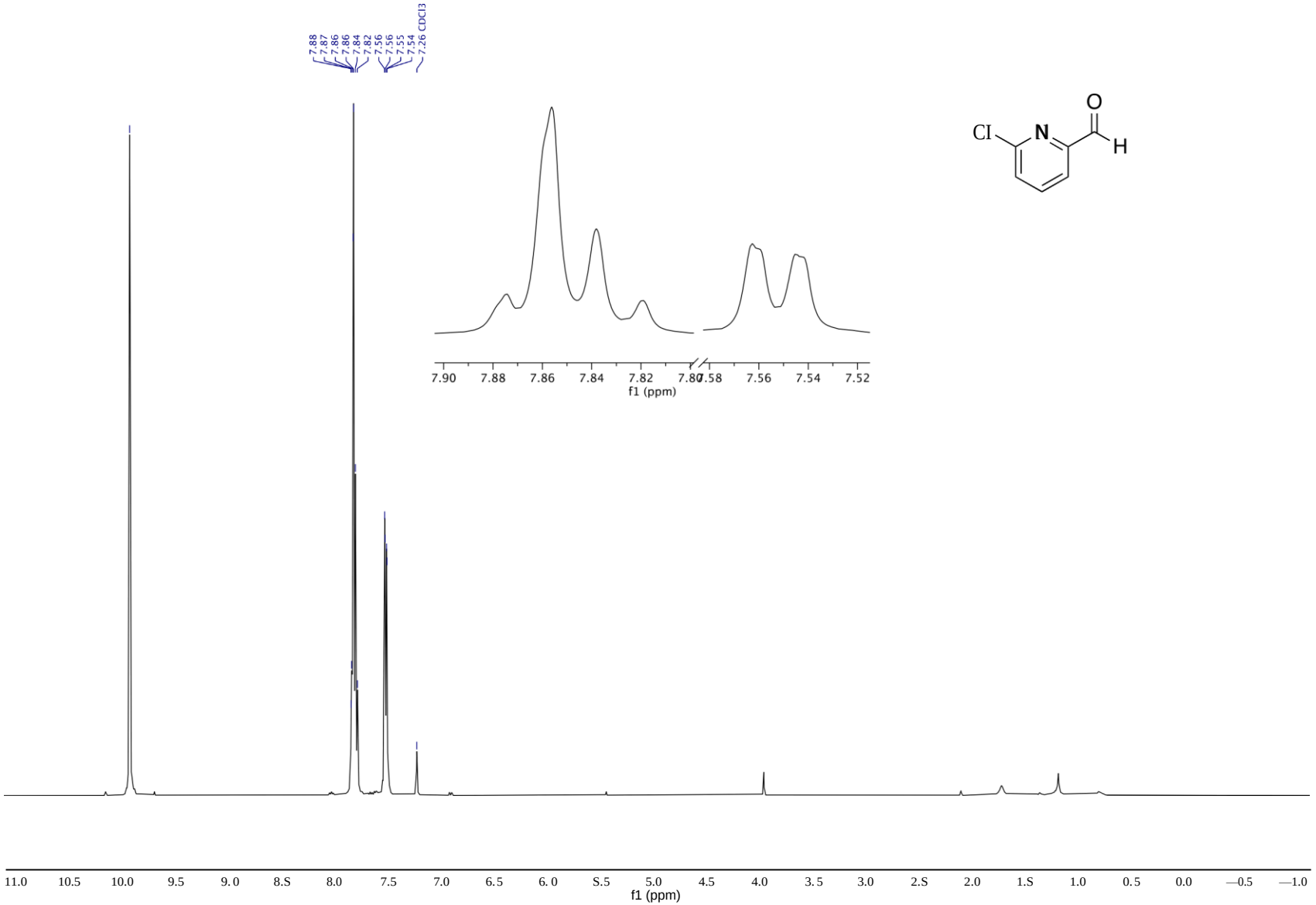
^{1}H-NMR (300 MHz $CDCl_3$) 3,4-Dimethoxybenzaldehyde (3s)



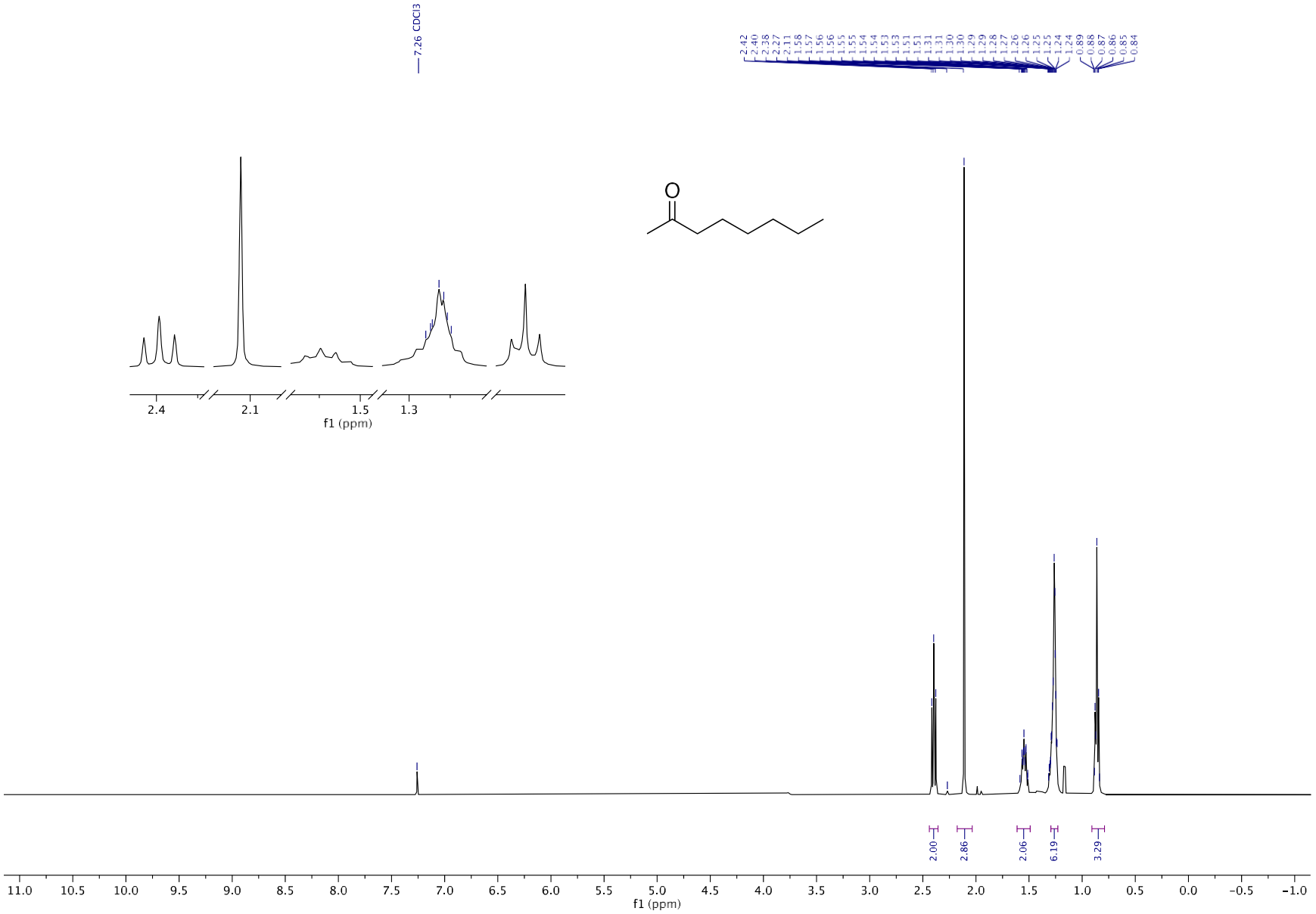
^{1}H-NMR (400 MHz $CDCl_3$) 3,4,5-Trimethoxybenzaldehyde (3t)



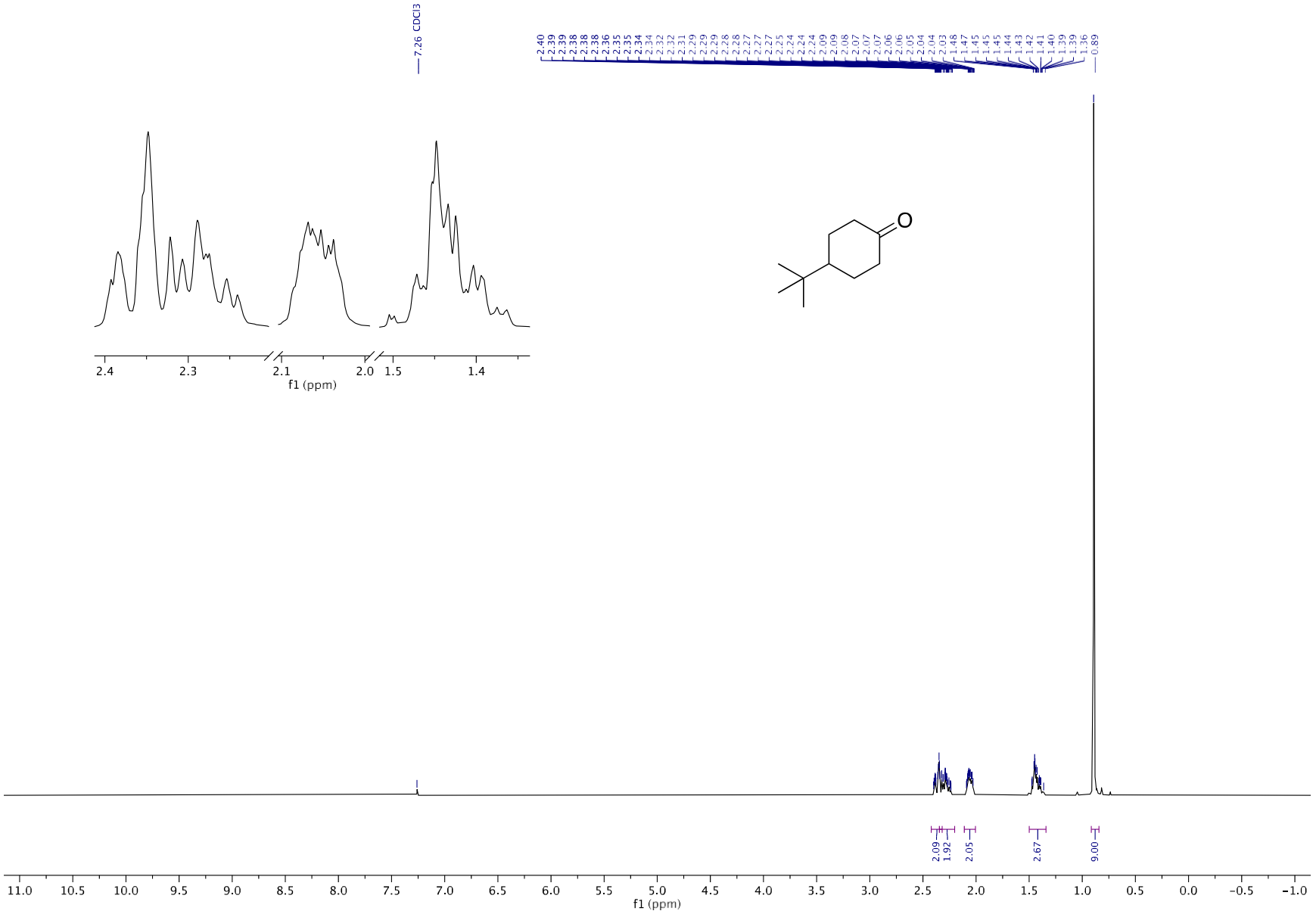
^{1}H-NMR (400 MHz $CDCl_3$) 6-Chloropicolinaldehyde (3u)



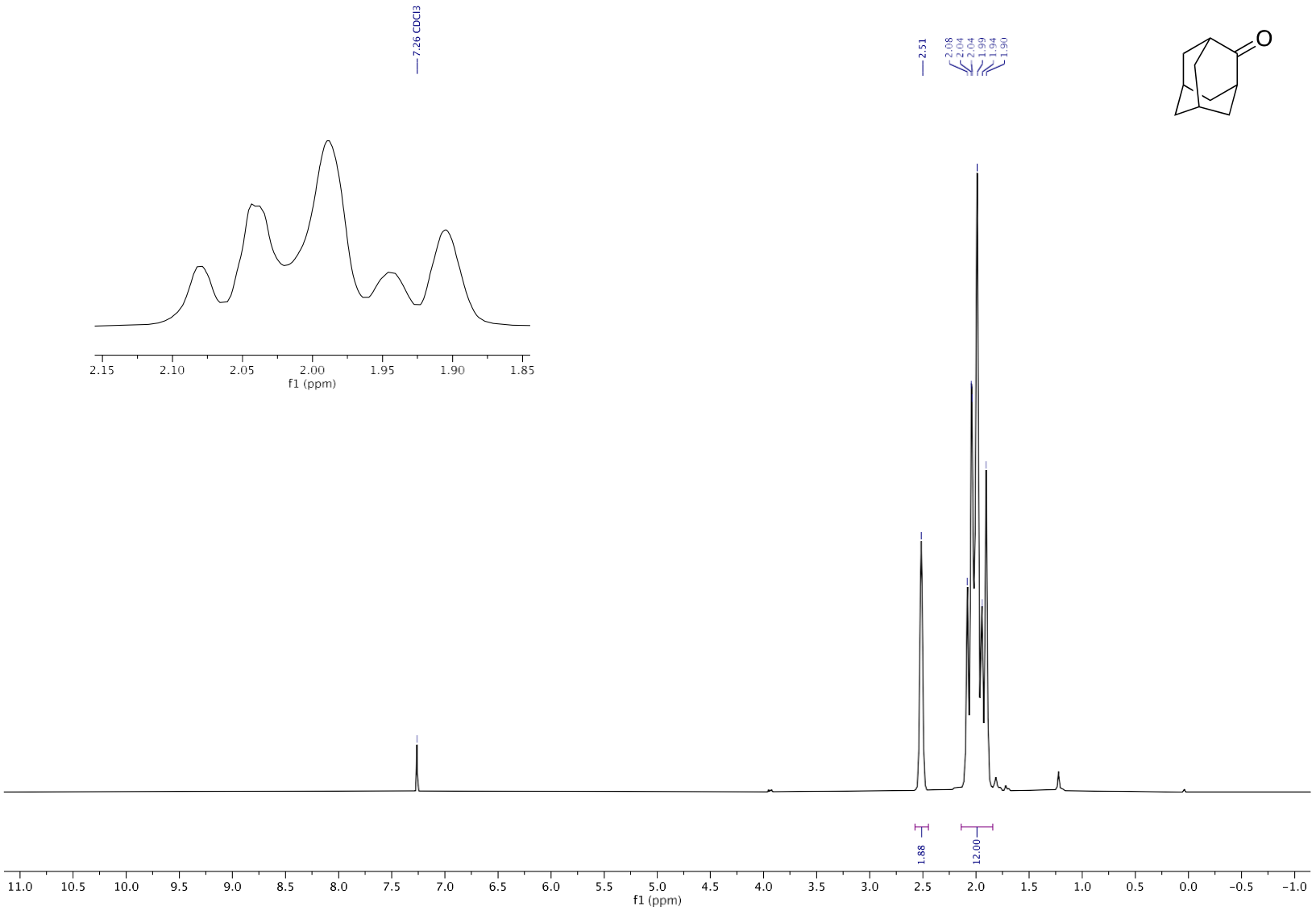
^{1}H-NMR (400 MHz $CDCl_3$) 2-Octanone (3v)



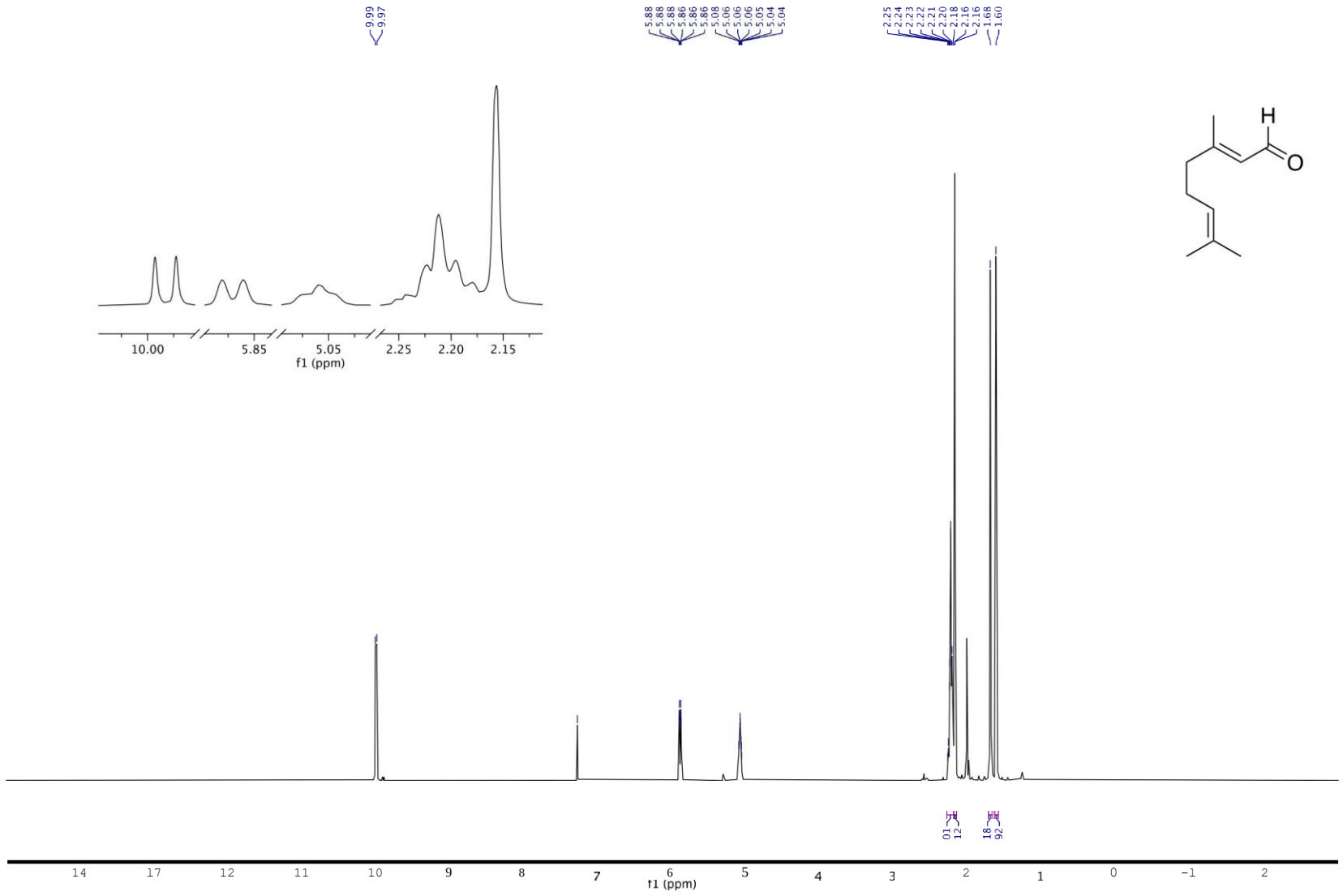
^{1}H-NMR (400 MHz $CDCl_3$) 4-*tert*-Butylcyclohexanone (3w)



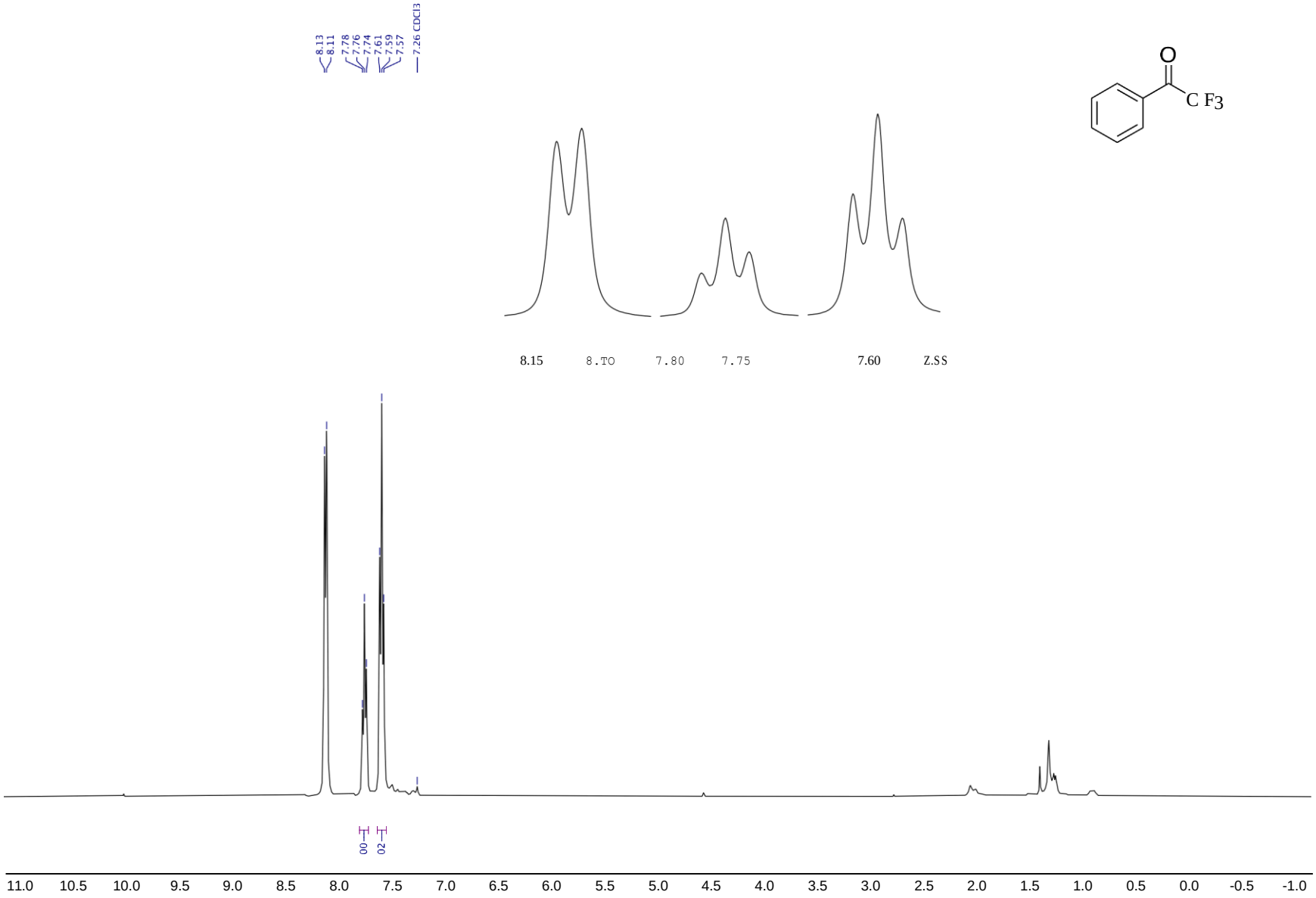
^{1}H-NMR (300 MHz $CDCl_3$) 2-Adamantanone (3x)



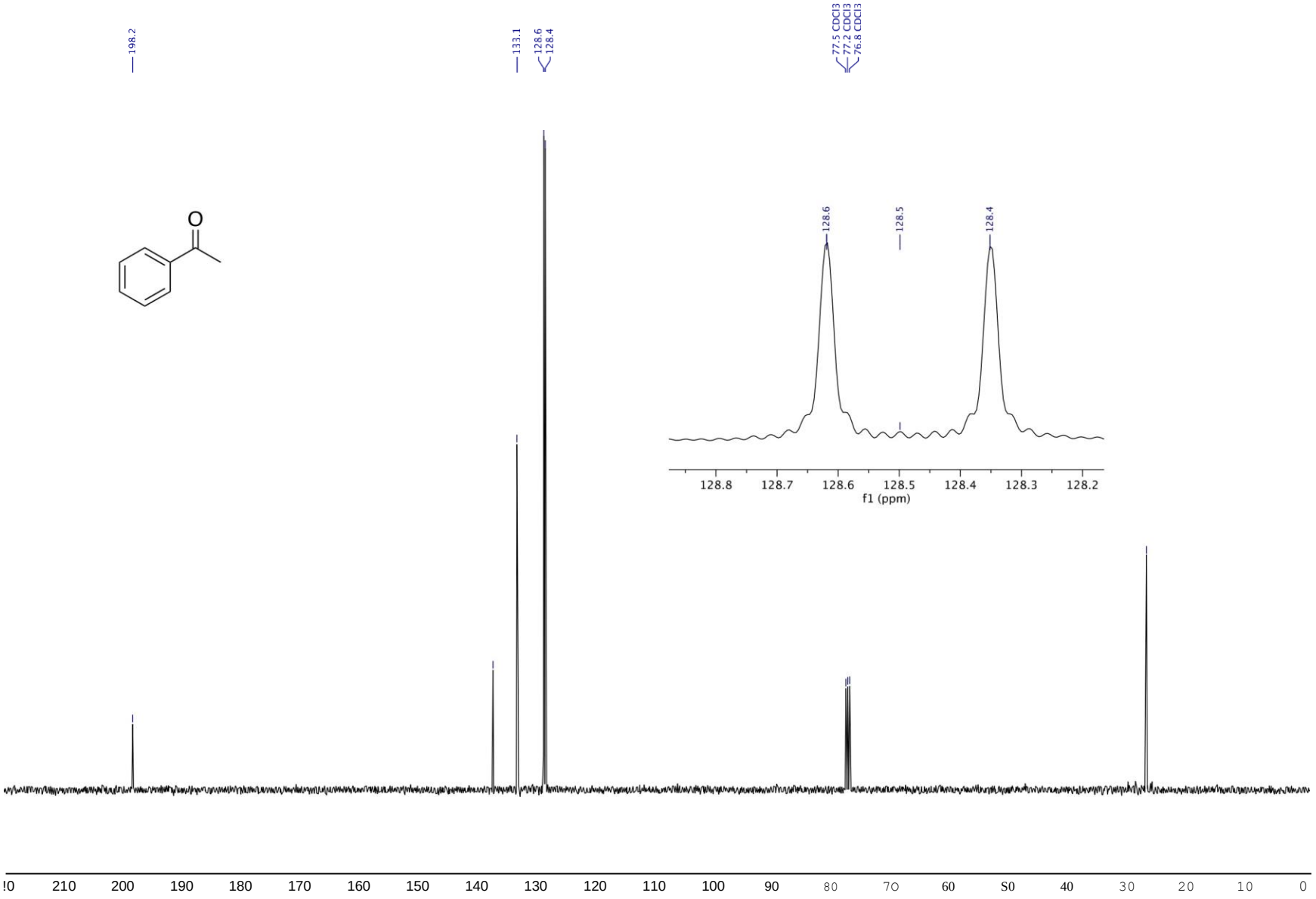
^{1}H-NMR (400 MHz $CDCl_3$) Geranial (3y)



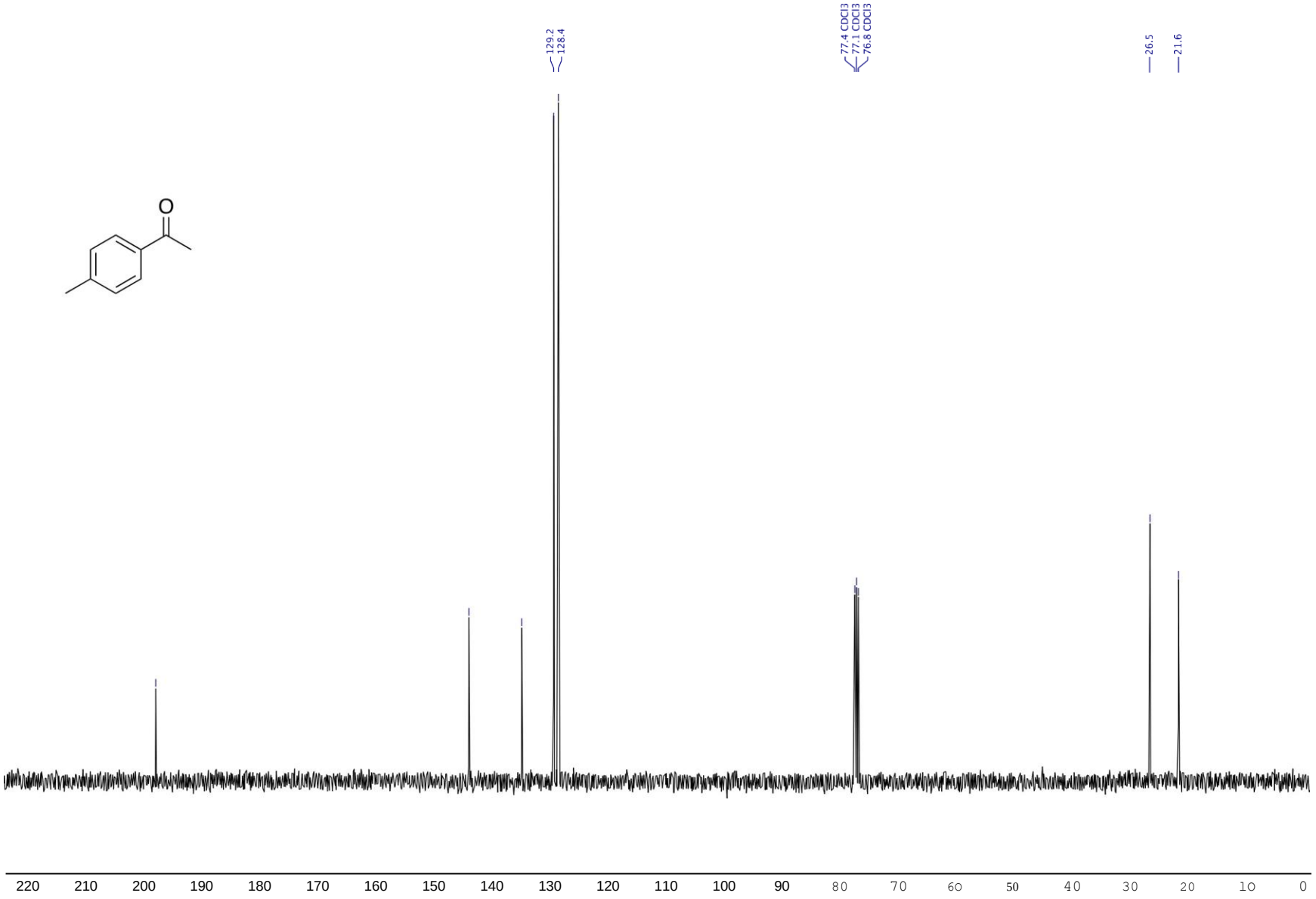
^{1}H-NMR (400 MHz $CDCl_3$) 1,1,1-Trifluoroacetophenone (3z)



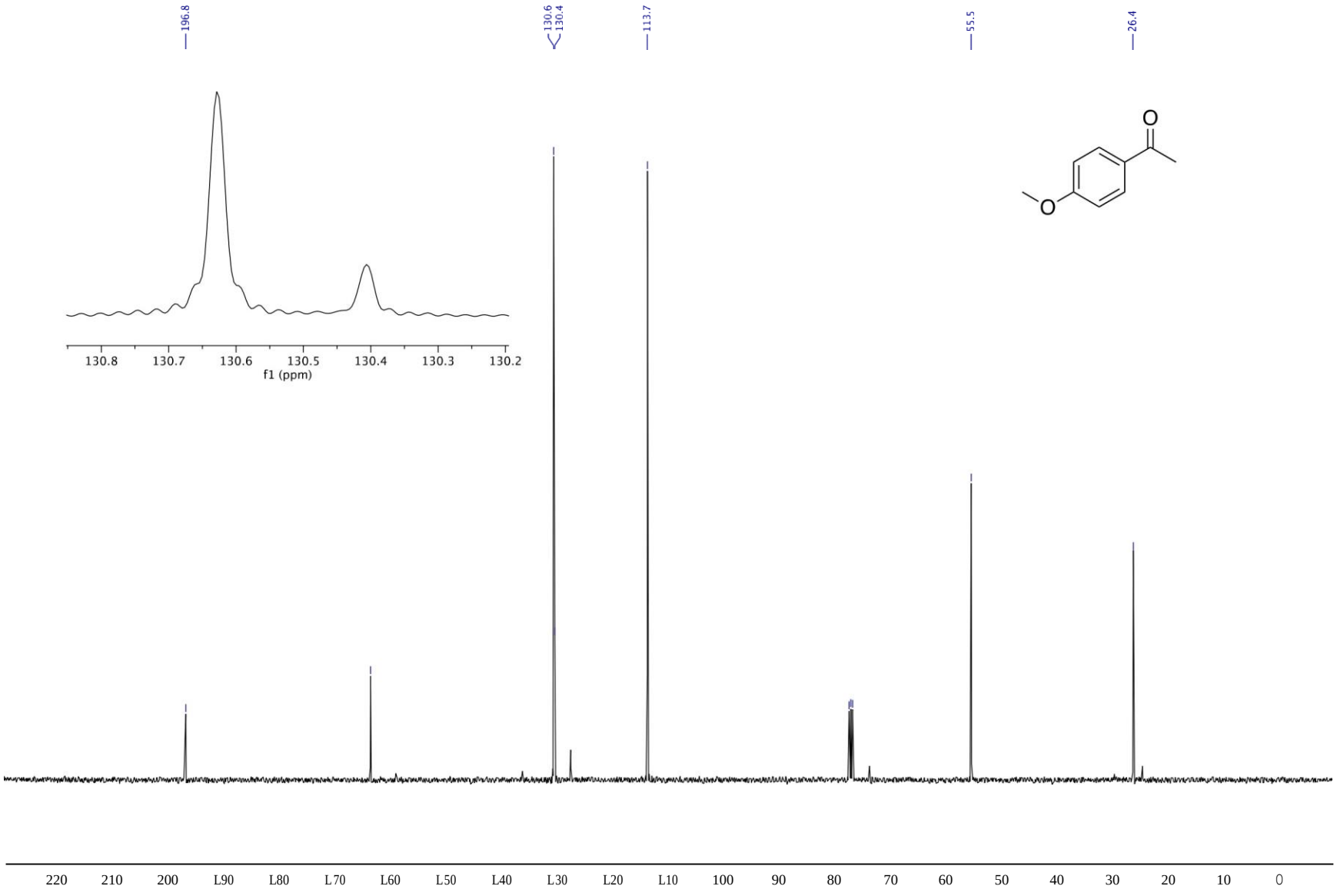
^{13}C-NMR (101 MHz $CDCl_3$) Acetophenone (3a)



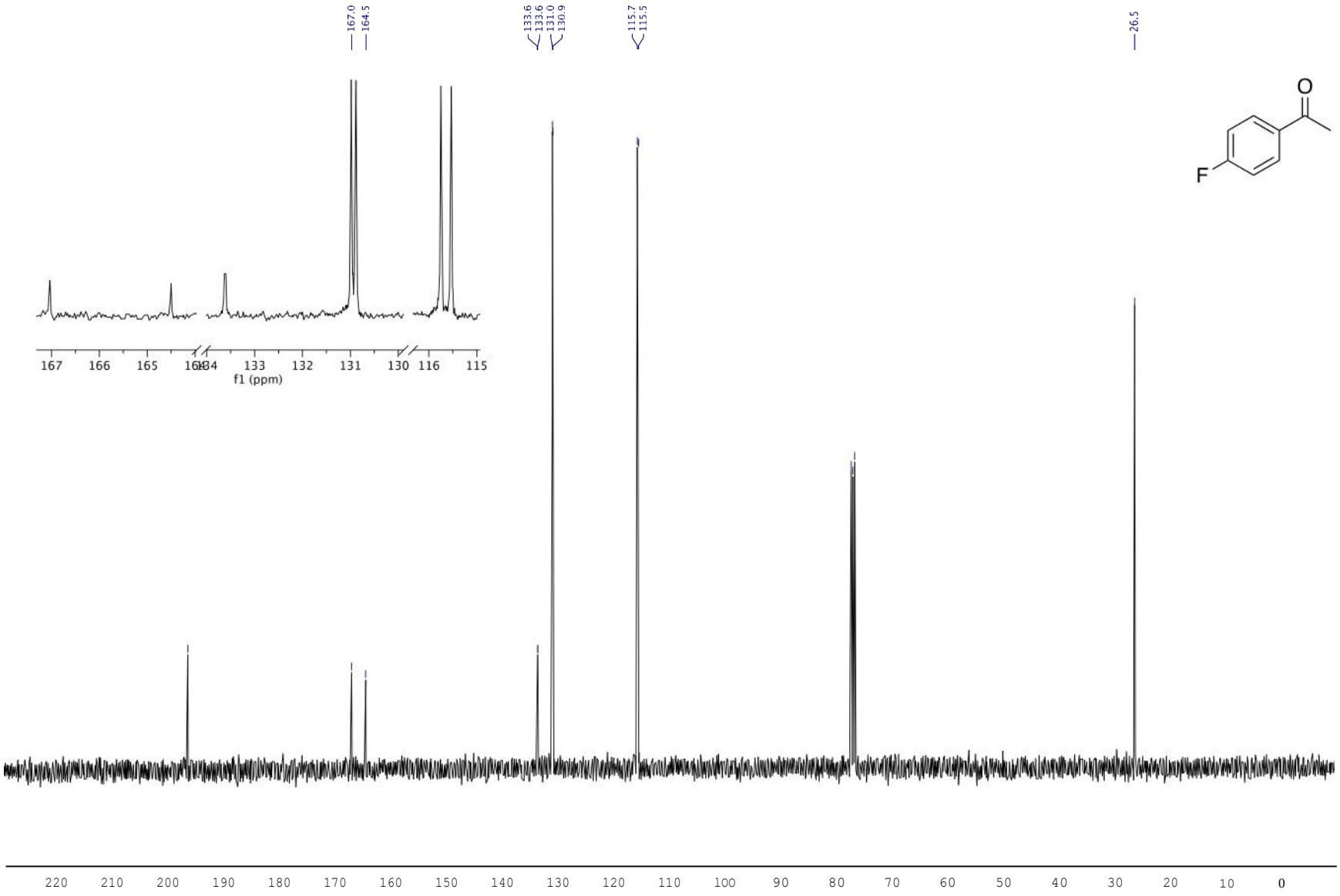
^{13}C-NMR (101 MHz $CDCl_3$) 4-Methylacetophenone (3b)



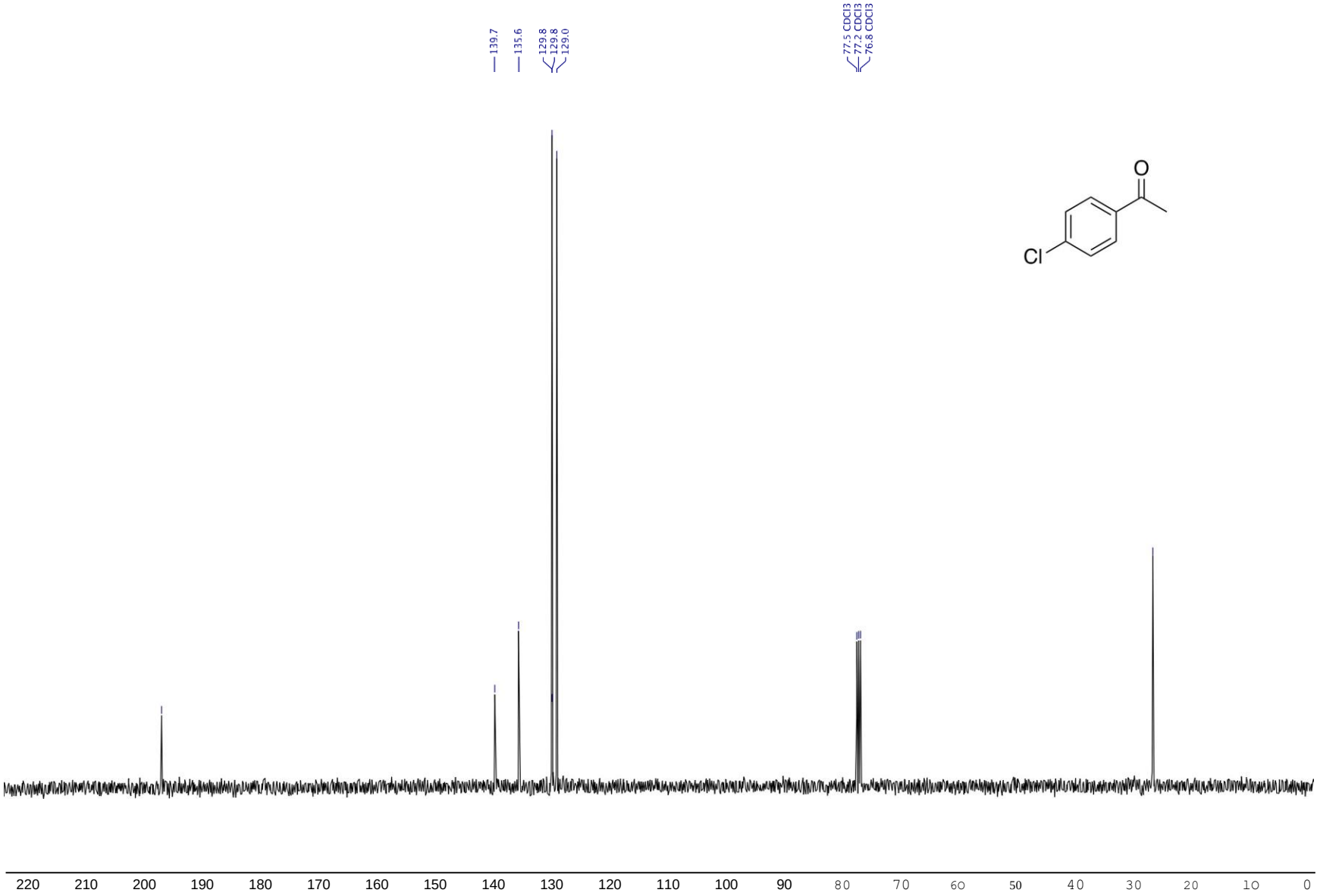
^{13}C-NMR (101 MHz $CDCl_3$) 1-(4-Methoxyphenyl)ethanone (3c)



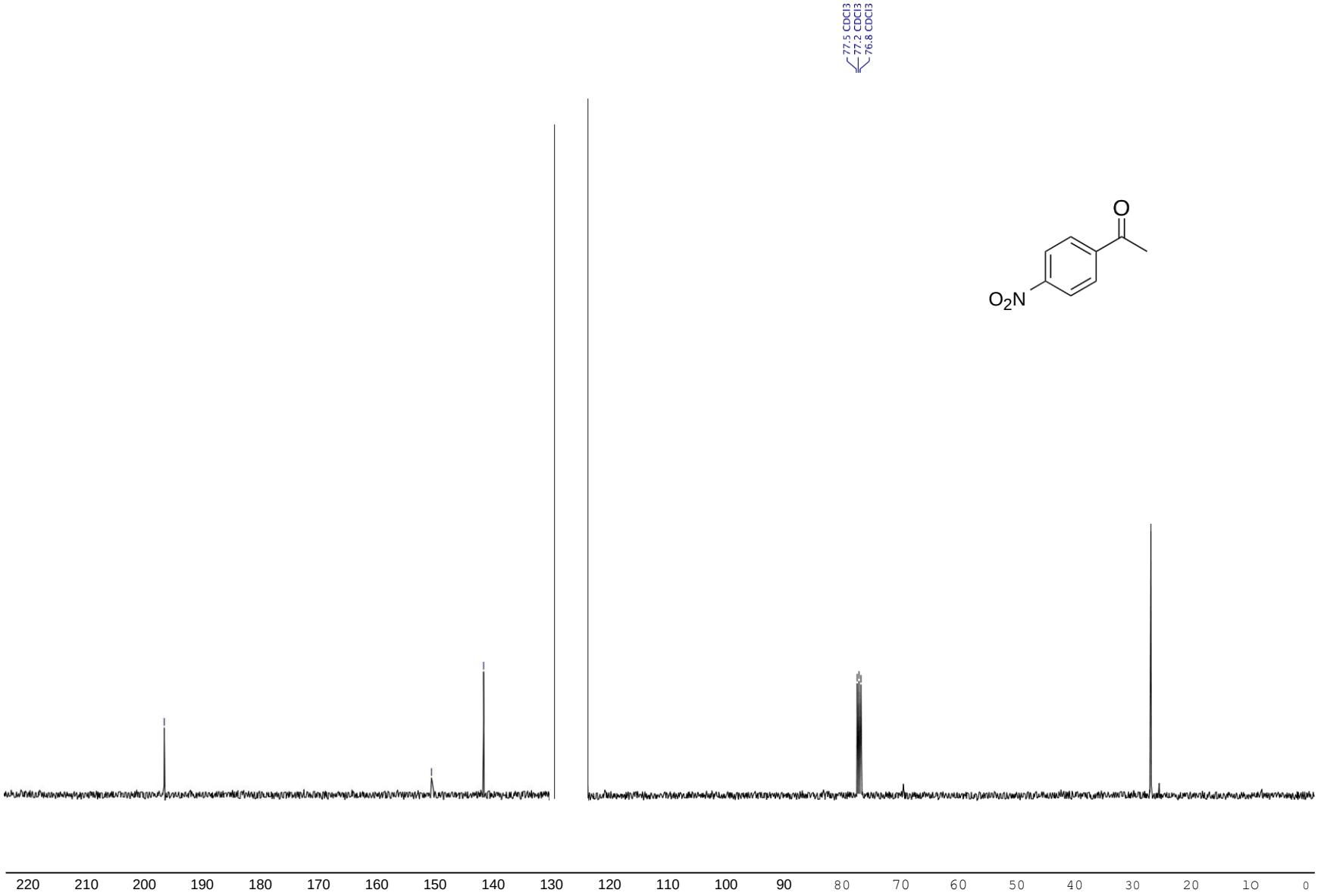
^{13}C-NMR (101 MHz $CDCl_3$) 1-(4-Fluorophenyl)ethanone (3d)



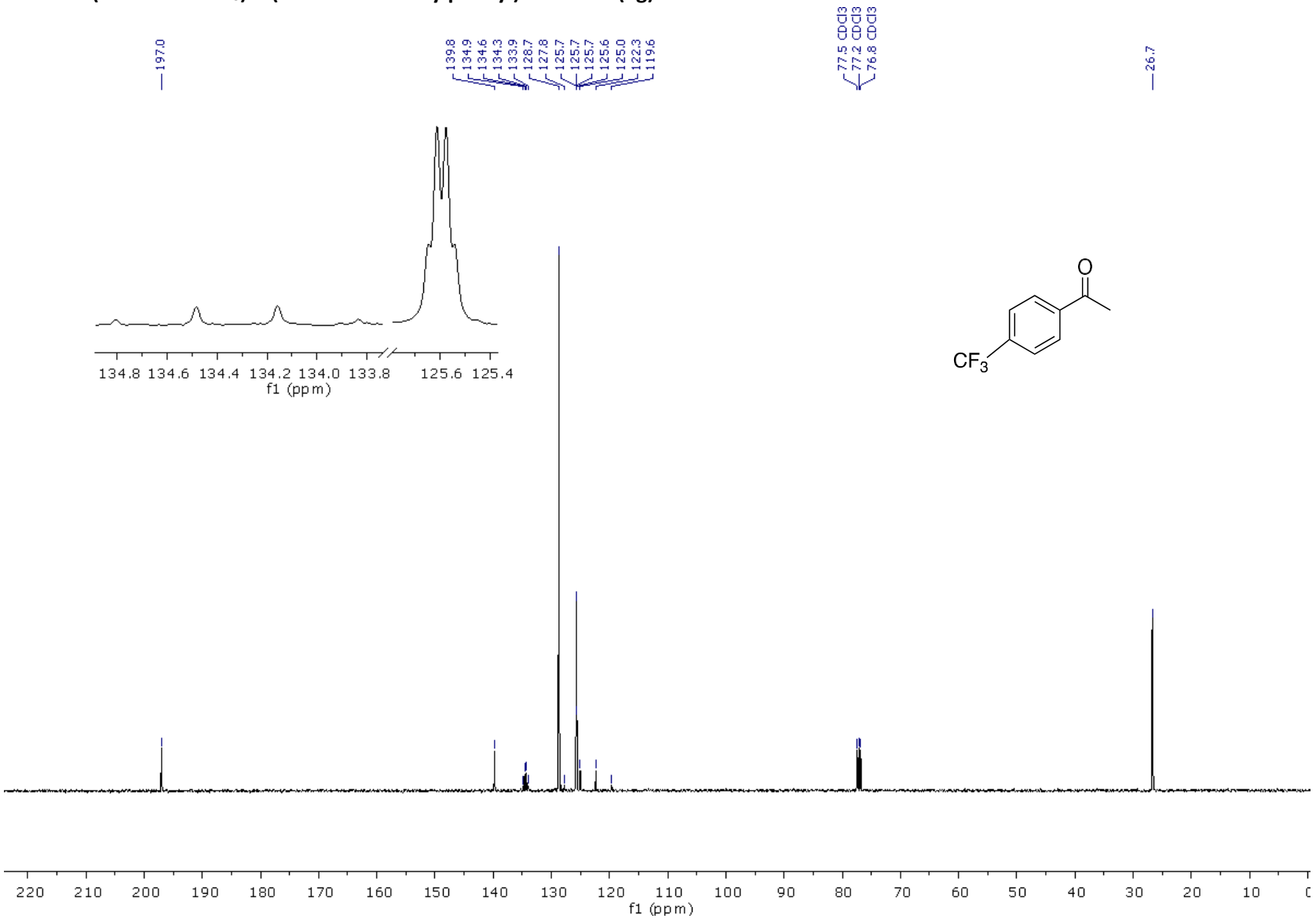
^{13}C-NMR (101 MHz $CDCl_3$) 4-Chloroacetophenone (3e)



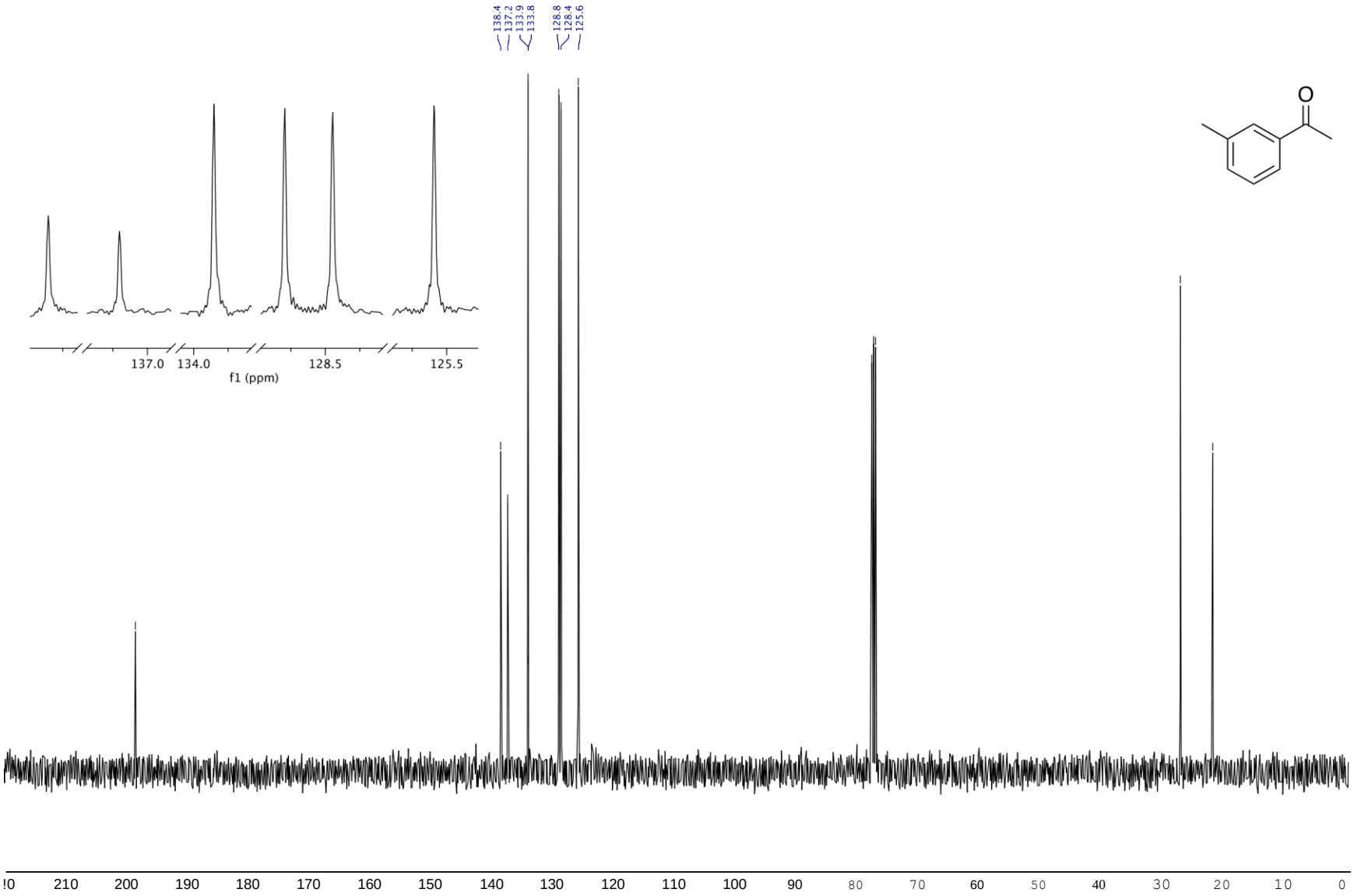
^{13}C-NMR (101 MHz $CDCl_3$) 4-Nitroacetophenone (3f)



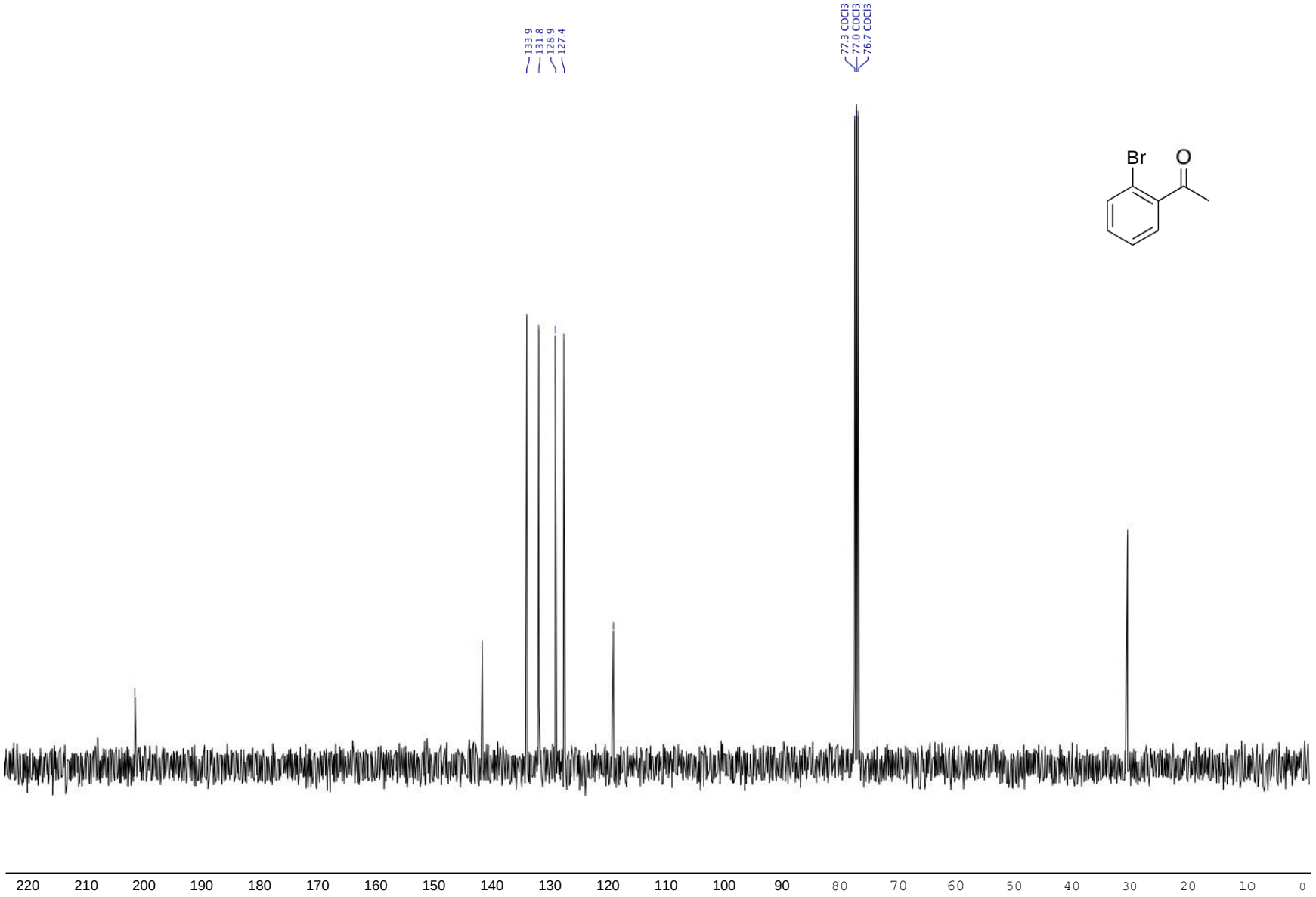
^{13}C-NMR (101 MHz $CDCl_3$) 1-(4-Trifluoromethylphenyl)ethenone (3g)



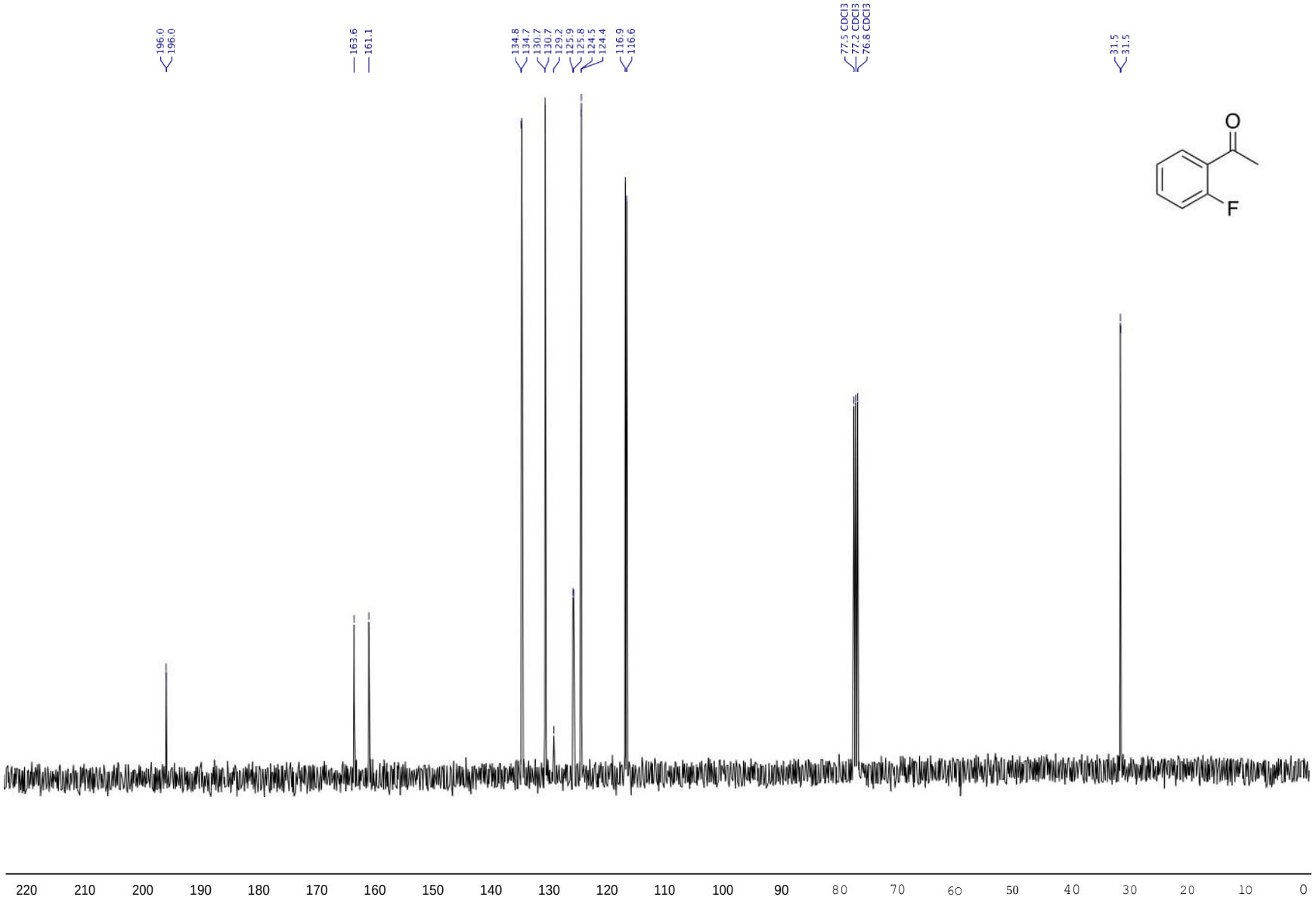
^{13}C-NMR (101 MHz $CDCl_3$) 3-Methylacetophenone (3h)



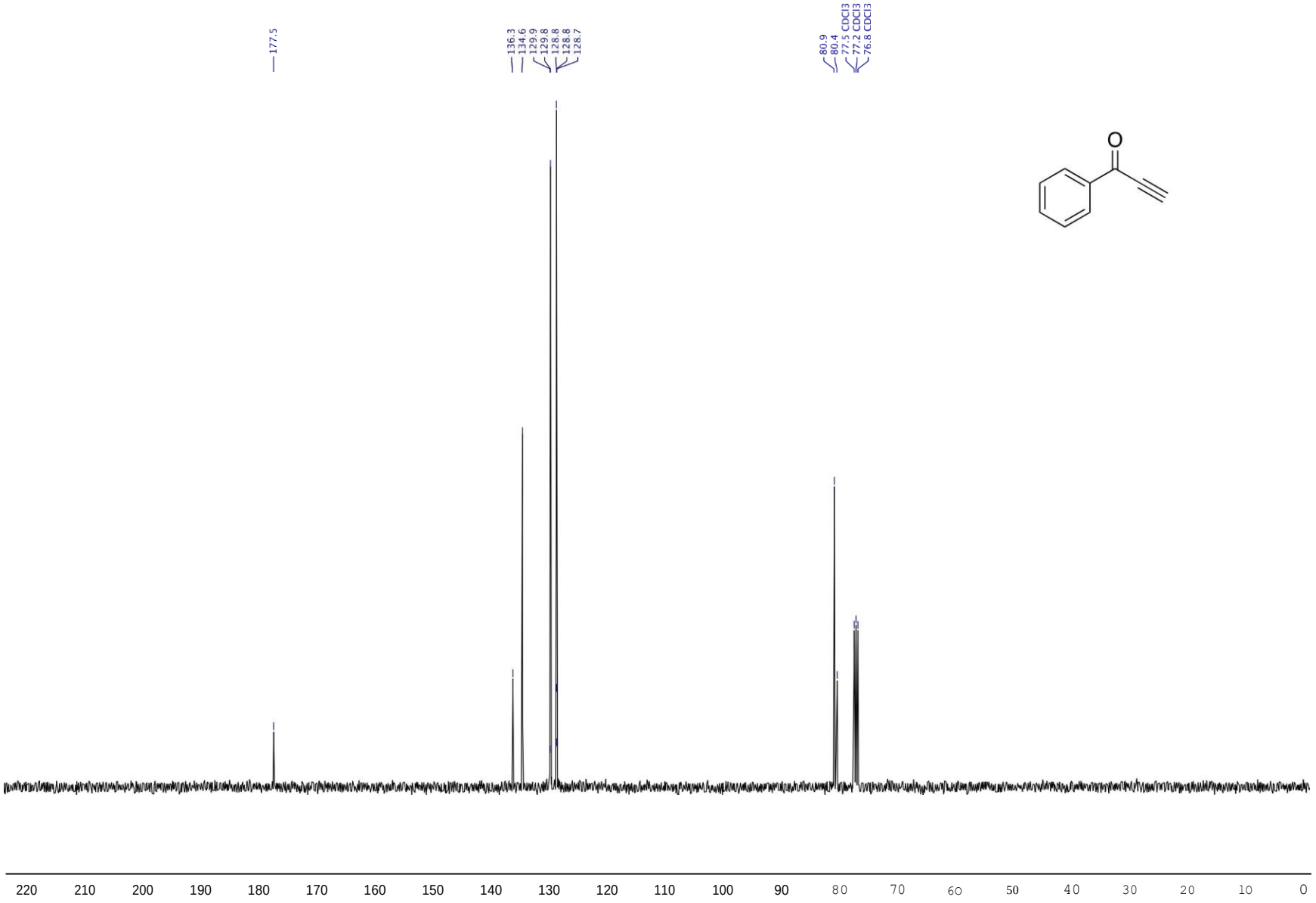
^{13}C-NMR (101 MHz $CDCl_3$) 2-Bromoacetophenone (3i)



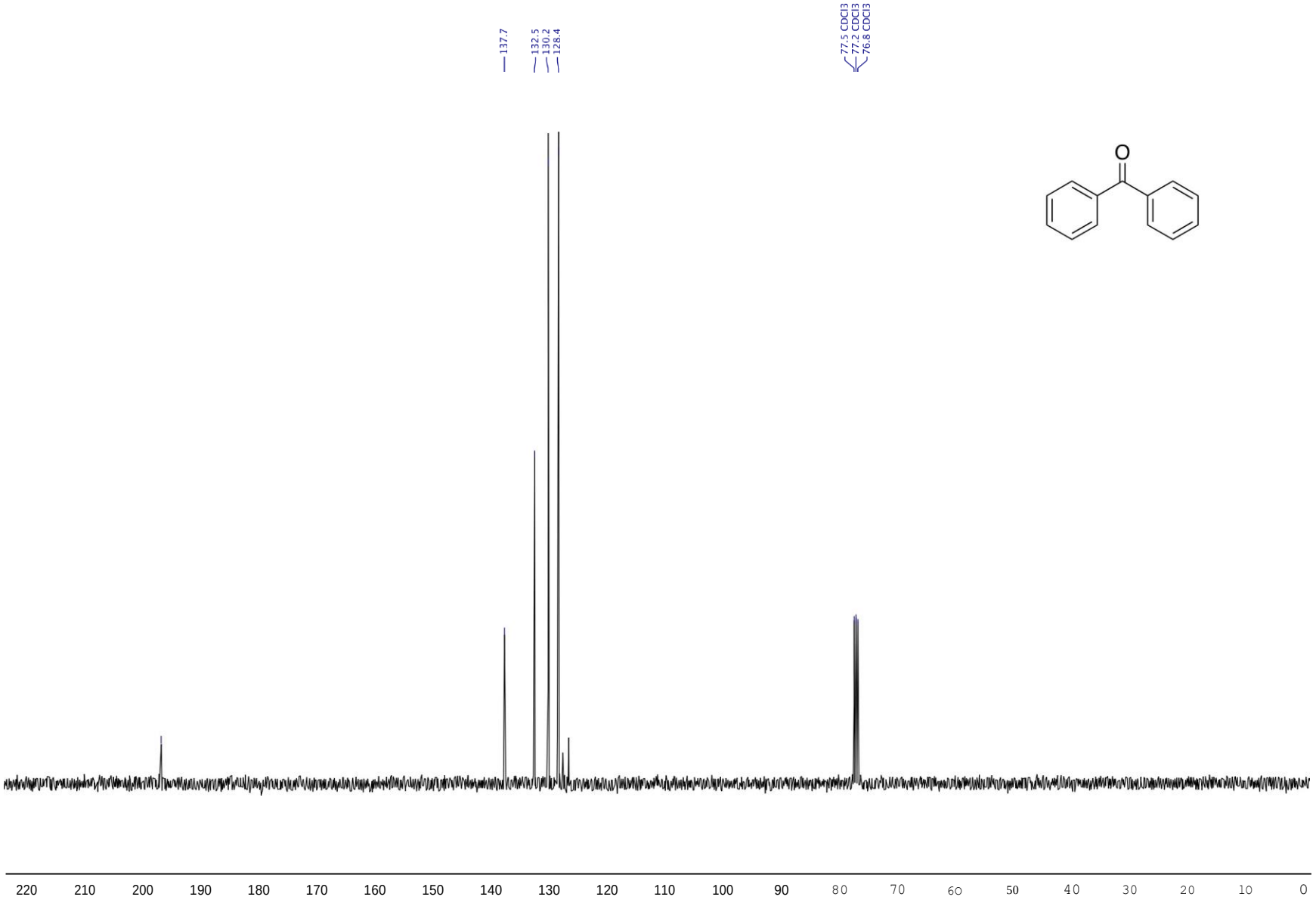
^{13}C-NMR (101 MHz $CDCl_3$) 2'-Fluoroacetophenone (3j)



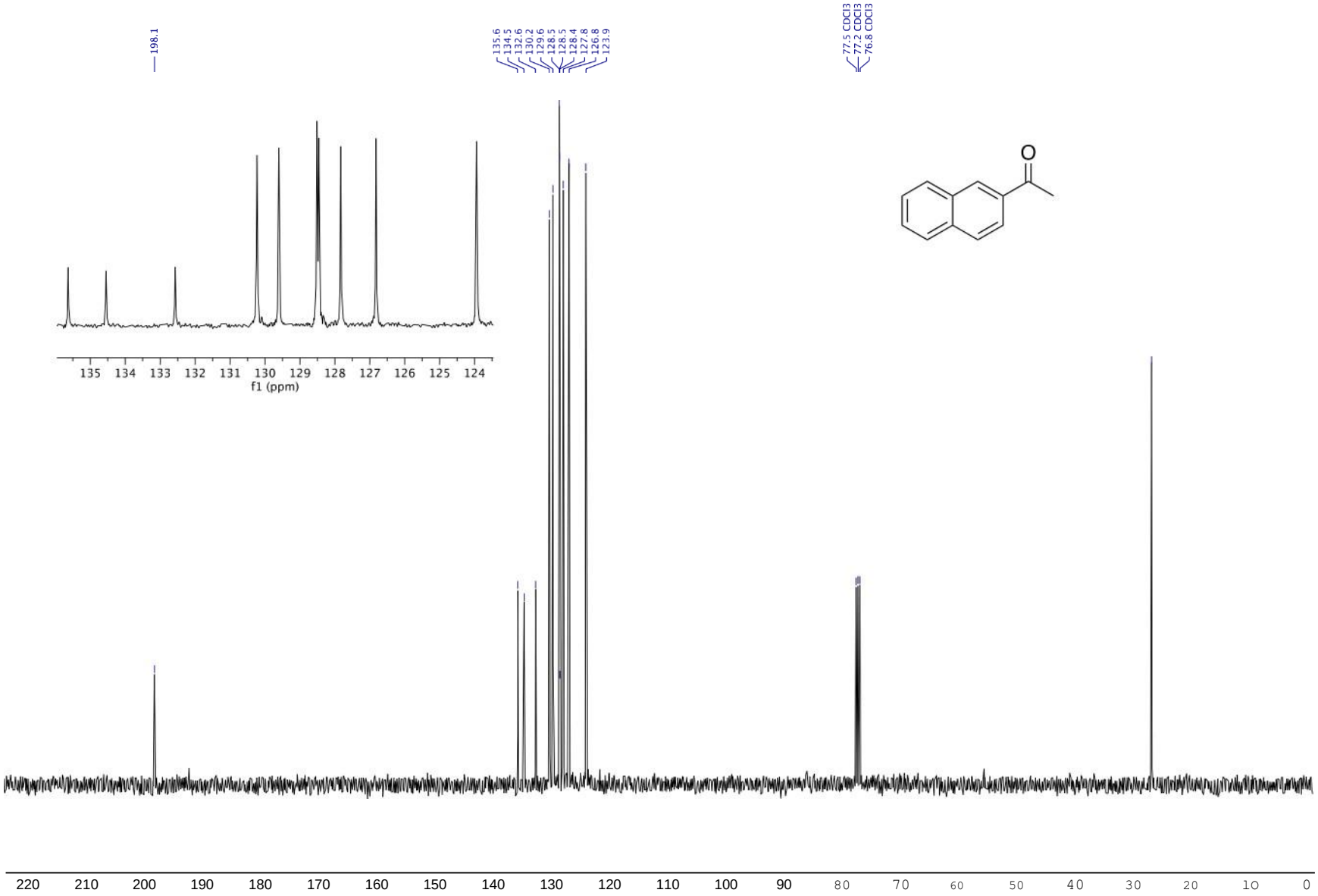
^{13}C-NMR (101 MHz $CDCl_3$) Benzoylacetylene (3k)



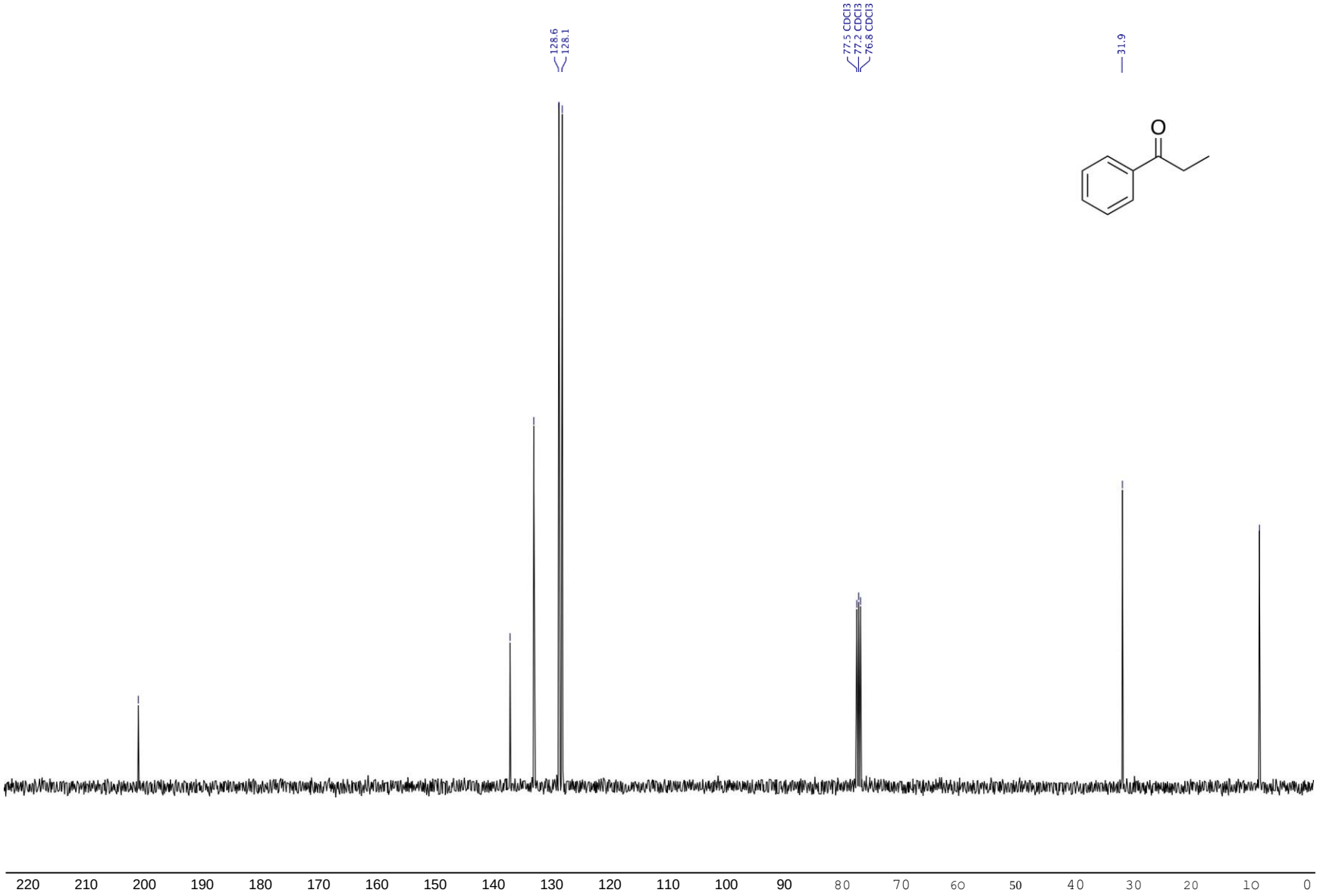
^{13}C-NMR (101 MHz $CDCl_3$) Benzophenone (3l)



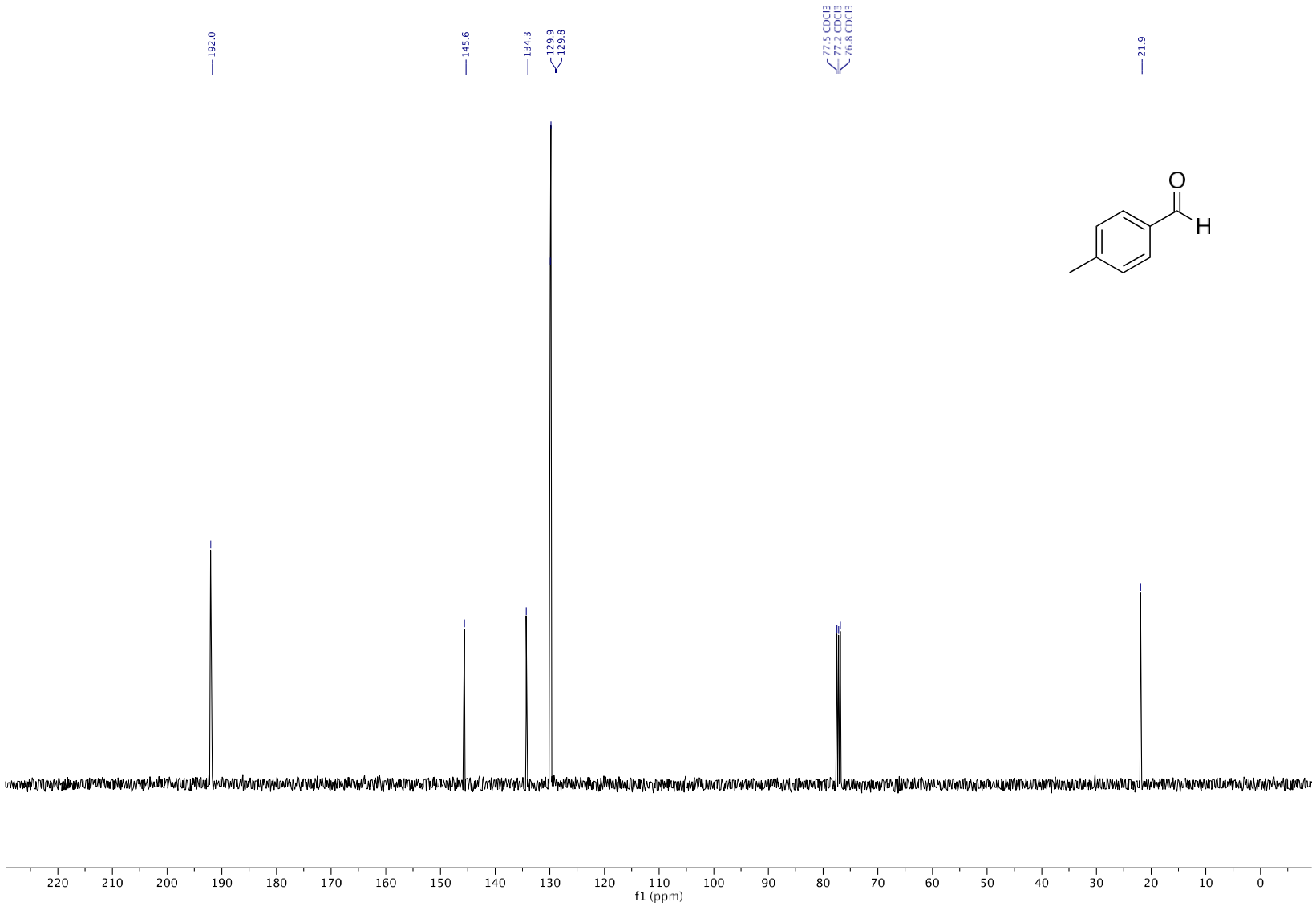
^{13}C-NMR (101 MHz $CDCl_3$) 2-Acetonapthone (3m)



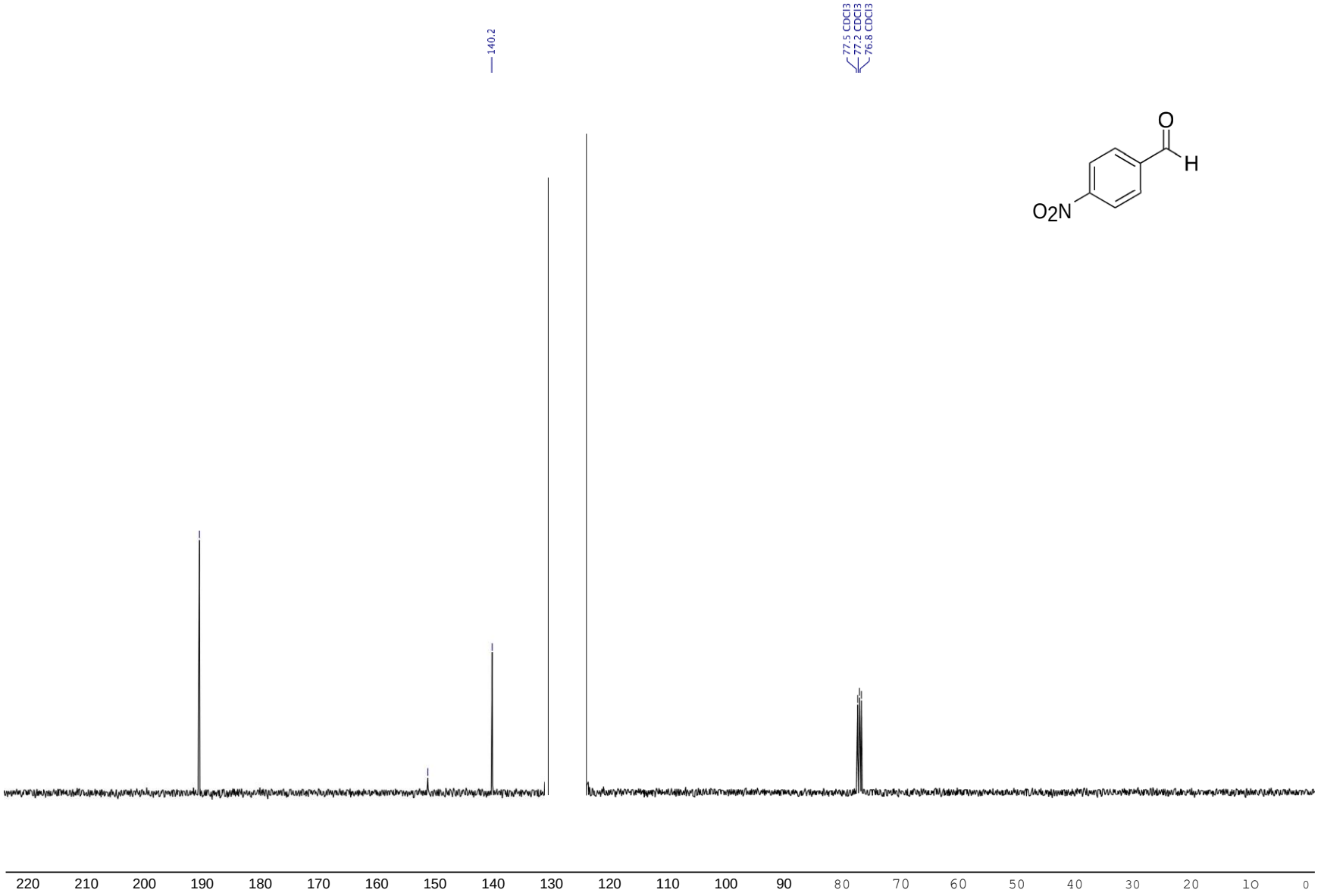
^{13}C-NMR (101 MHz $CDCl_3$) 1-Phenylpropan-1-one (3n)



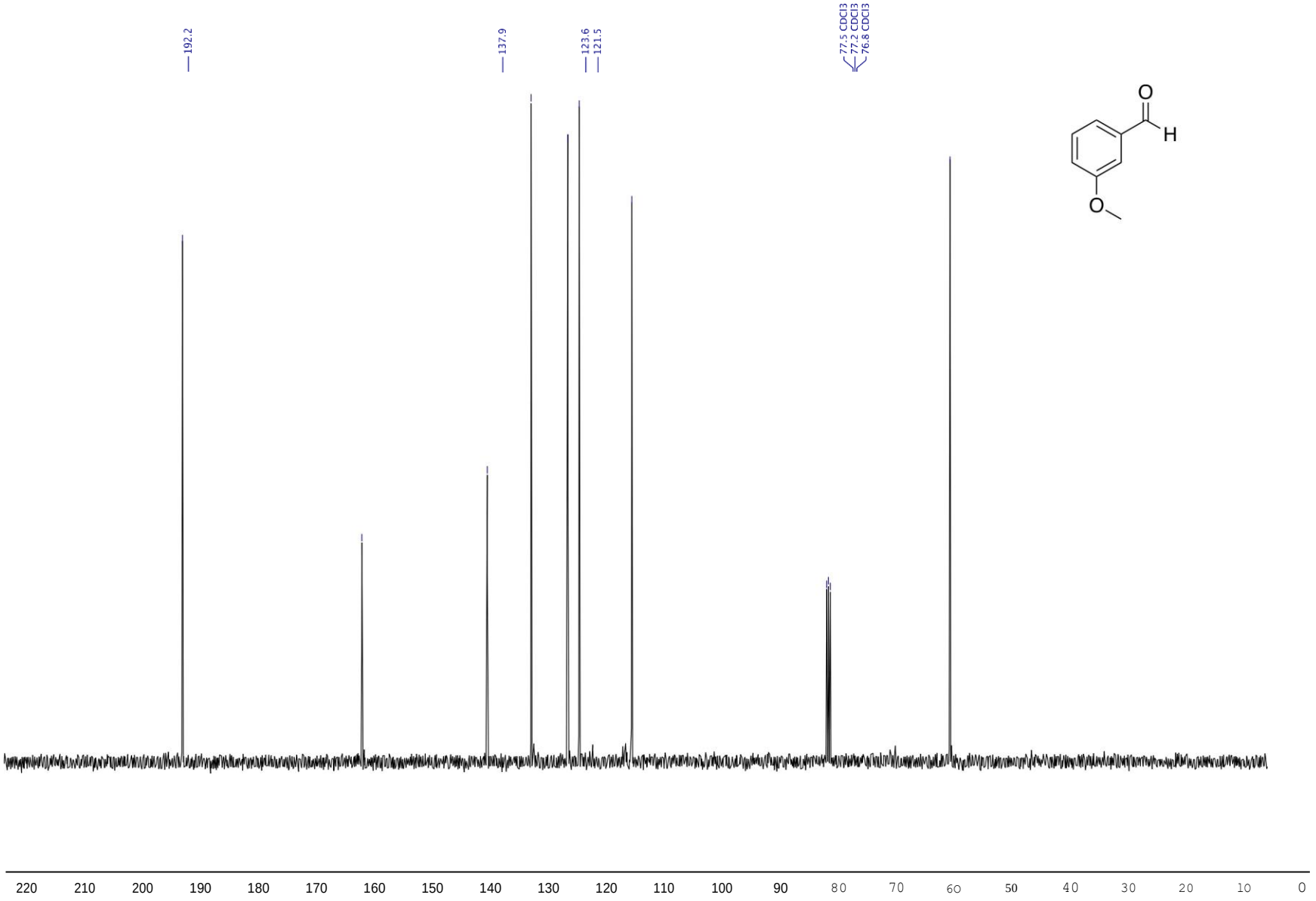
^{13}C-NMR (101 MHz $CDCl_3$) 4-Methylbenzaldehyde (3o)



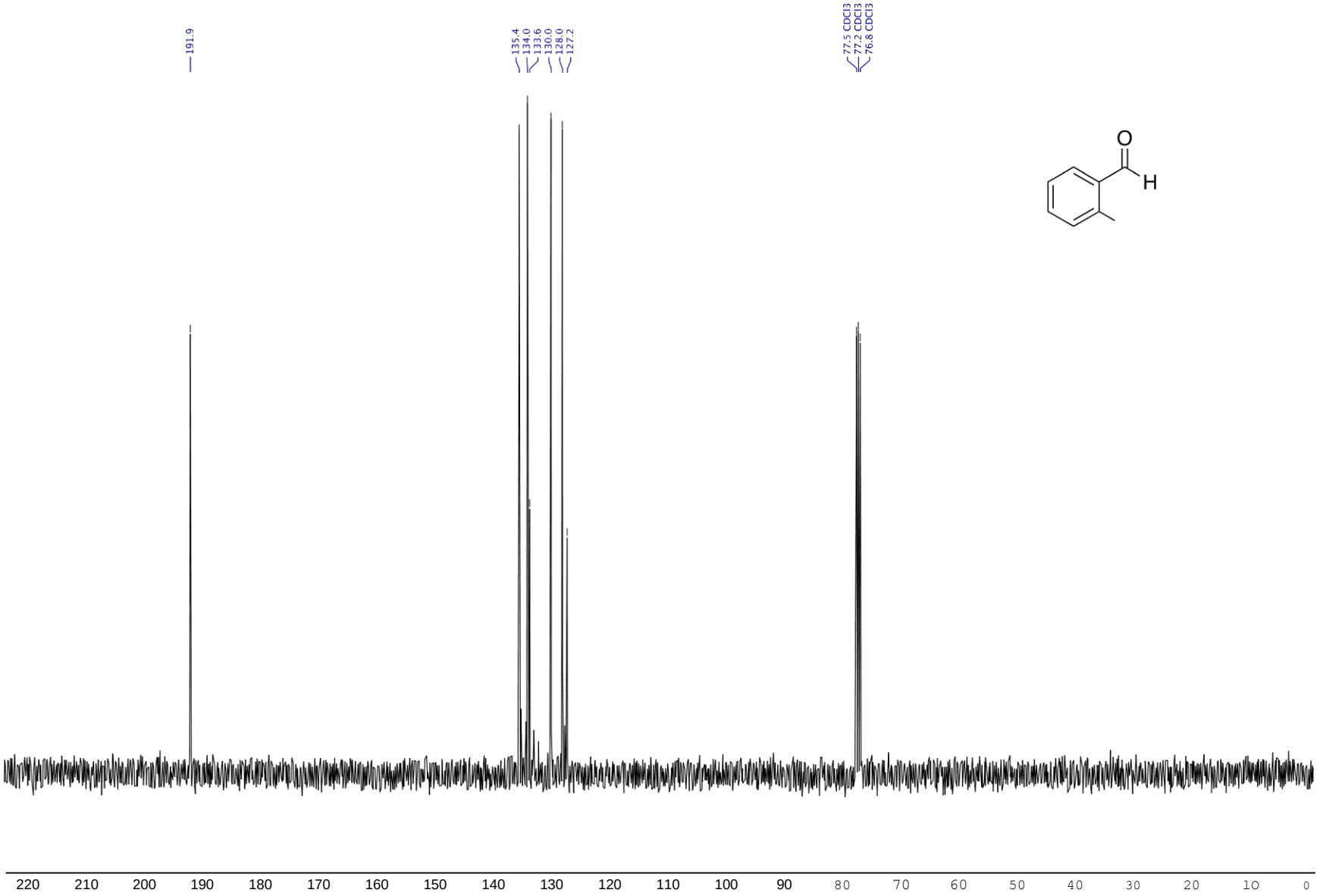
^{13}C-NMR (101 MHz $CDCl_3$) 4-Nitrobenzaldehdye (3p)



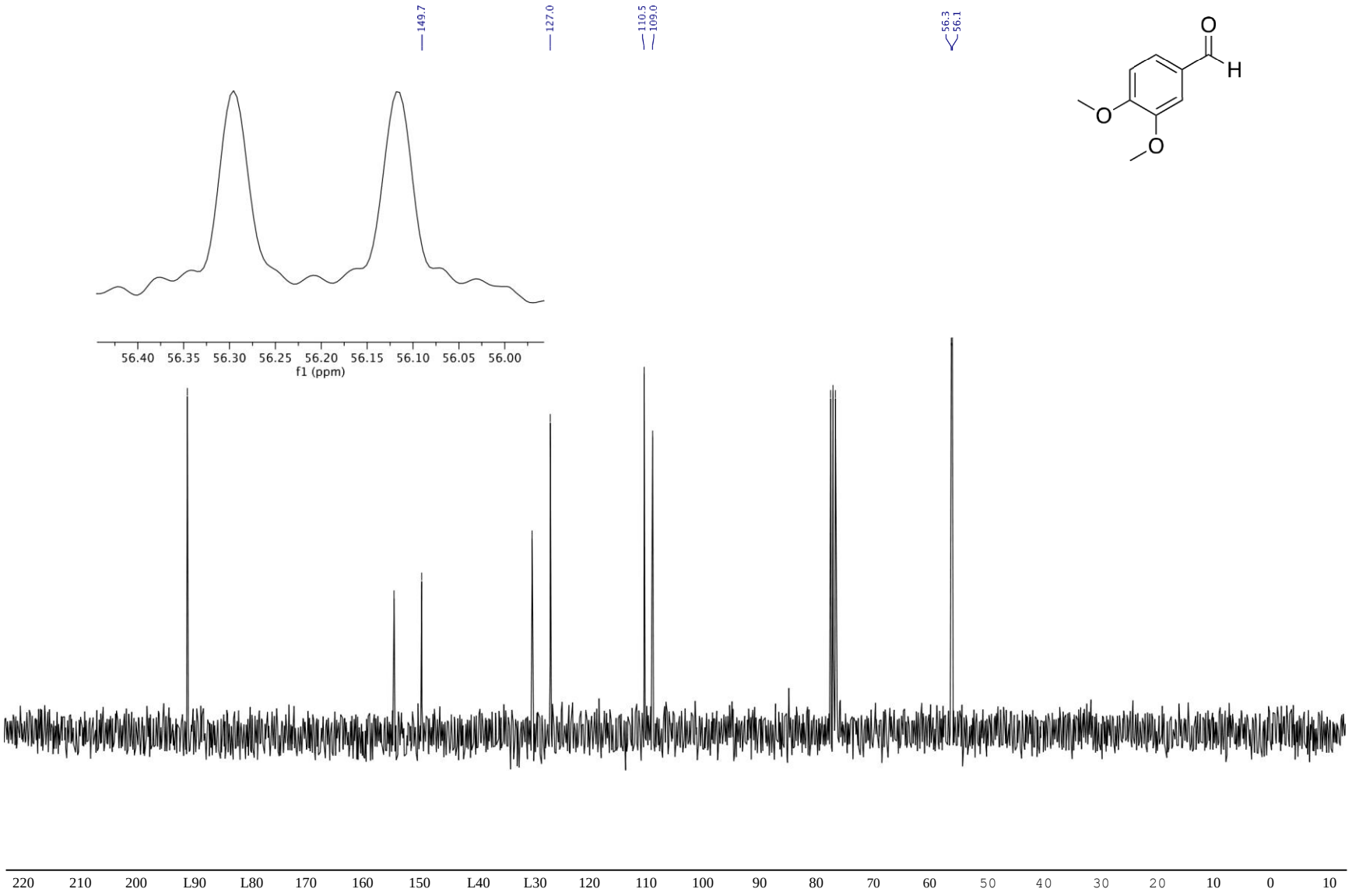
^{13}C-NMR (101 MHz $CDCl_3$) 3-Methoxybenzaldehyde (3q)



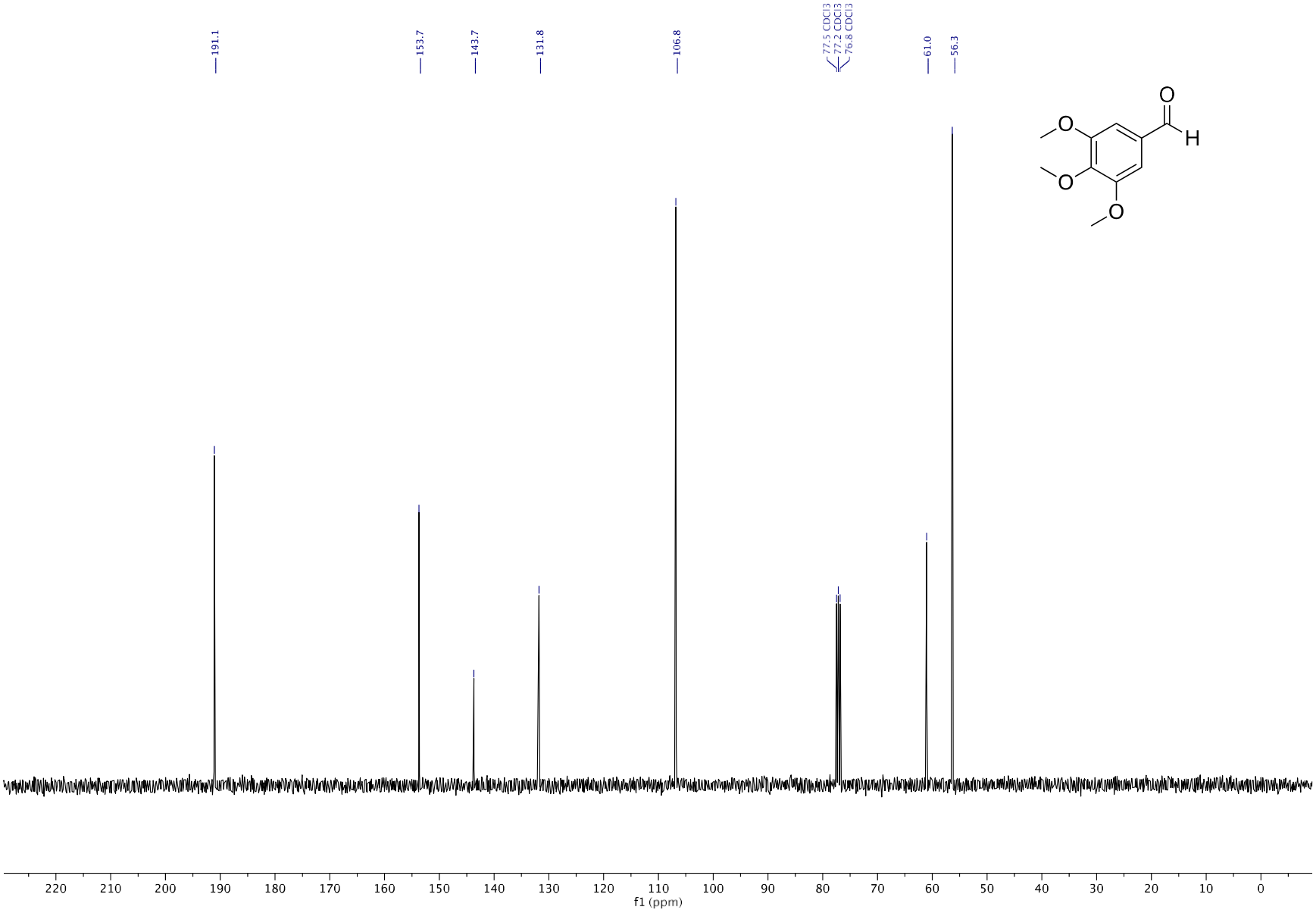
^{13}C-NMR (101 MHz $CDCl_3$) 2-Bromobenzaldehyde (3r)



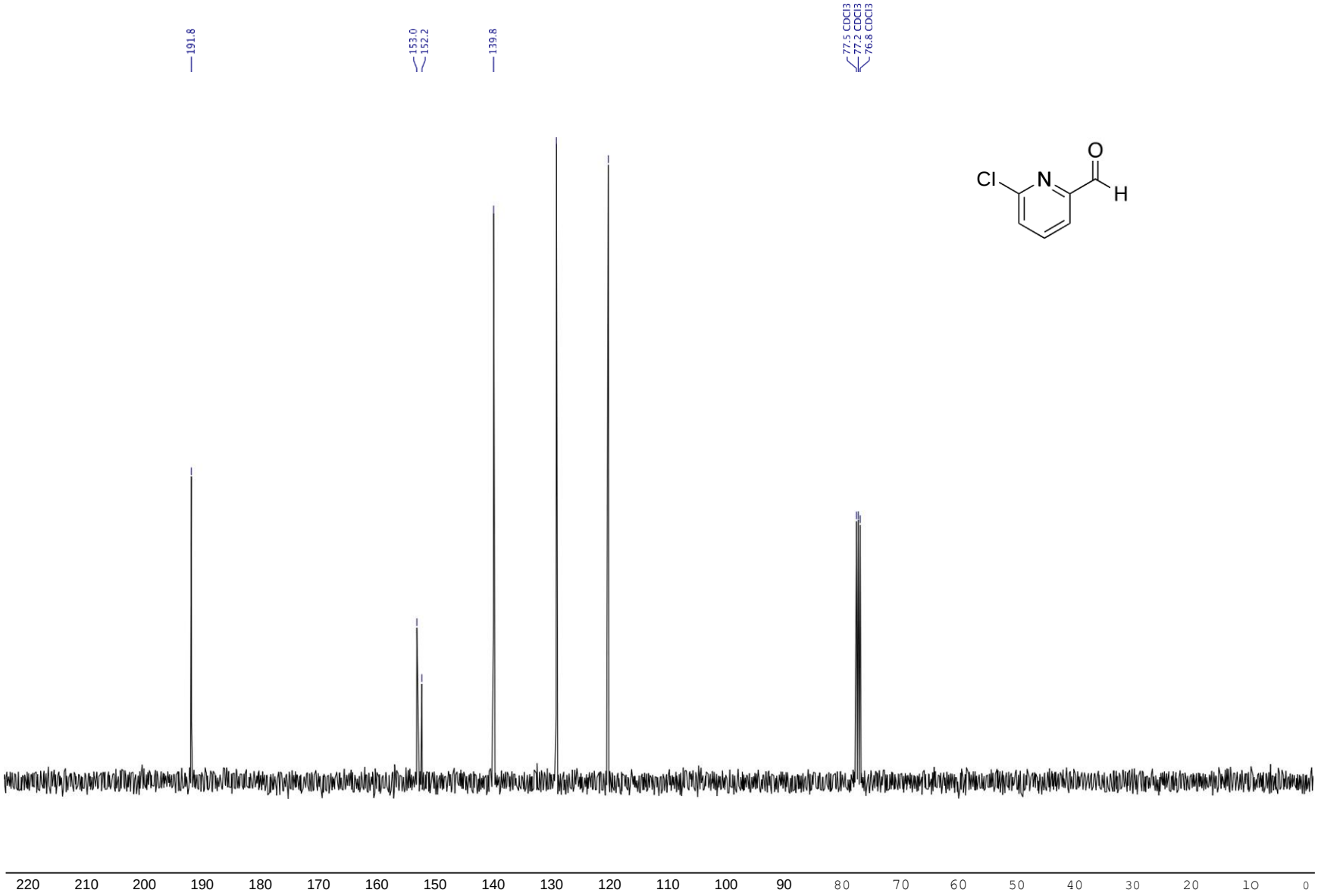
^{13}C-NMR (101 MHz $CDCl_3$) 3,4-Dimethoxybenzaldehyde (3s)



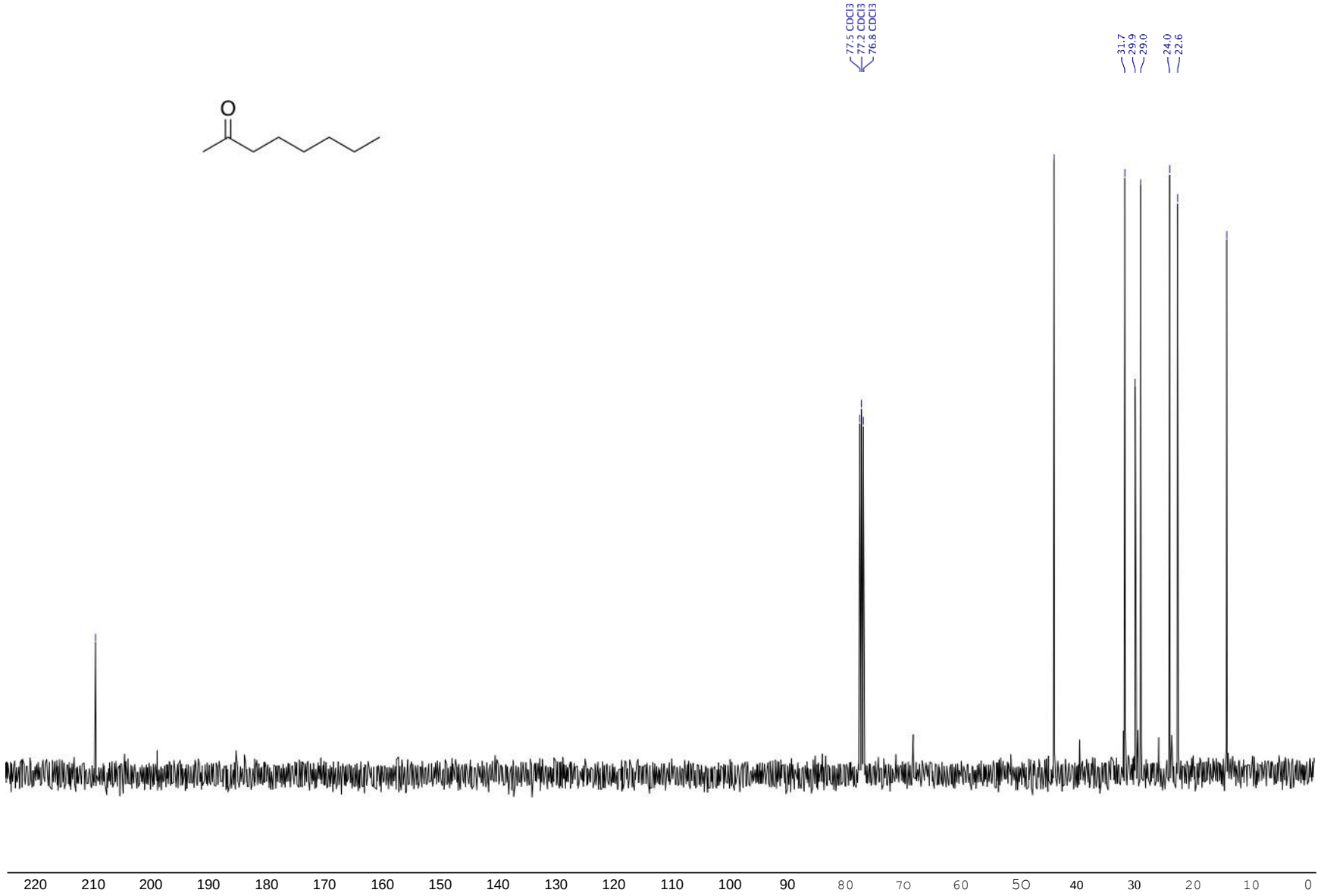
^{13}C-NMR (101 MHz $CDCl_3$) 3,4,5-Trimethoxybenzaldehyde (3t)



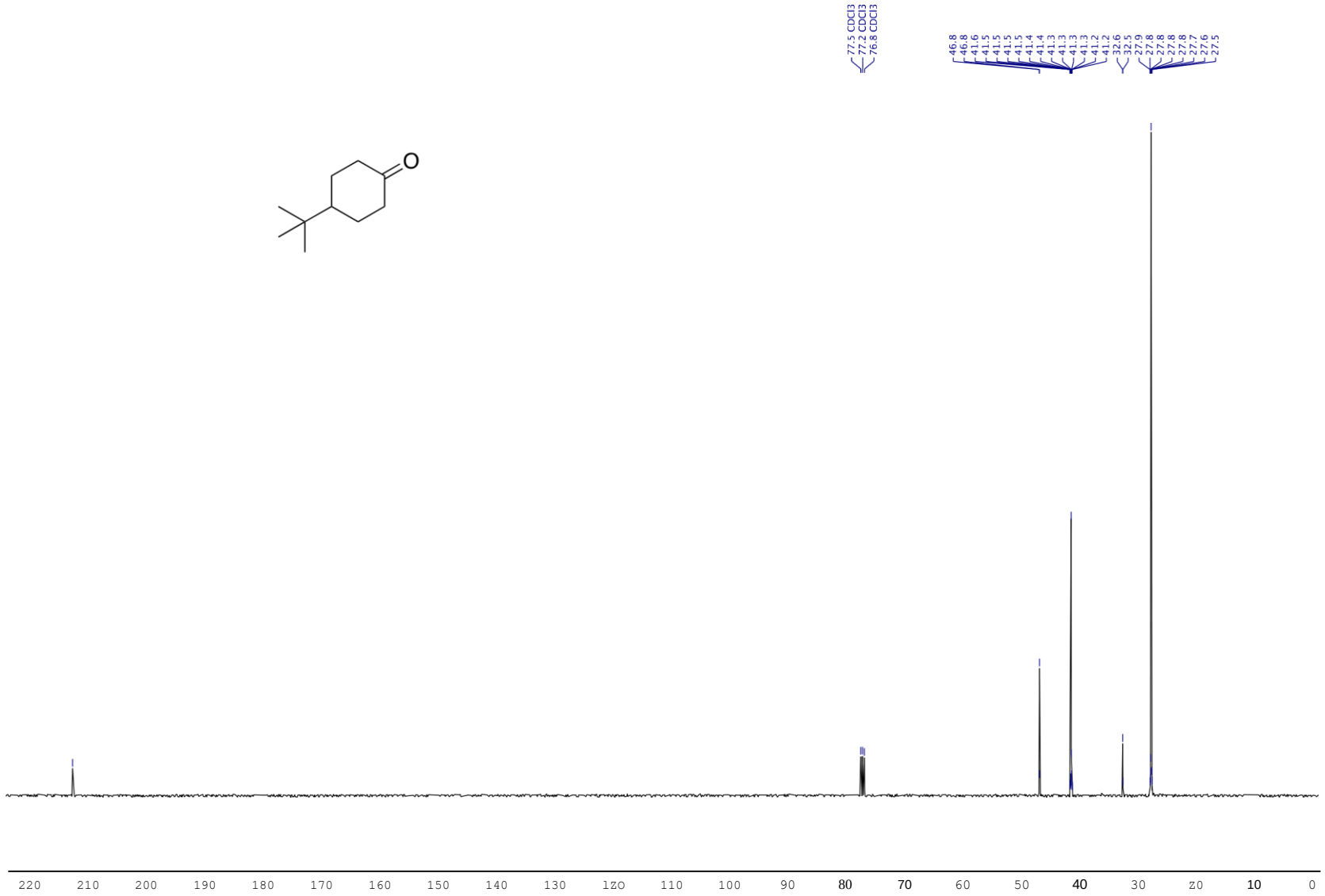
^{13}C-NMR (101 MHz $CDCl_3$) 6-Chloropicolinaldehyde (3u)



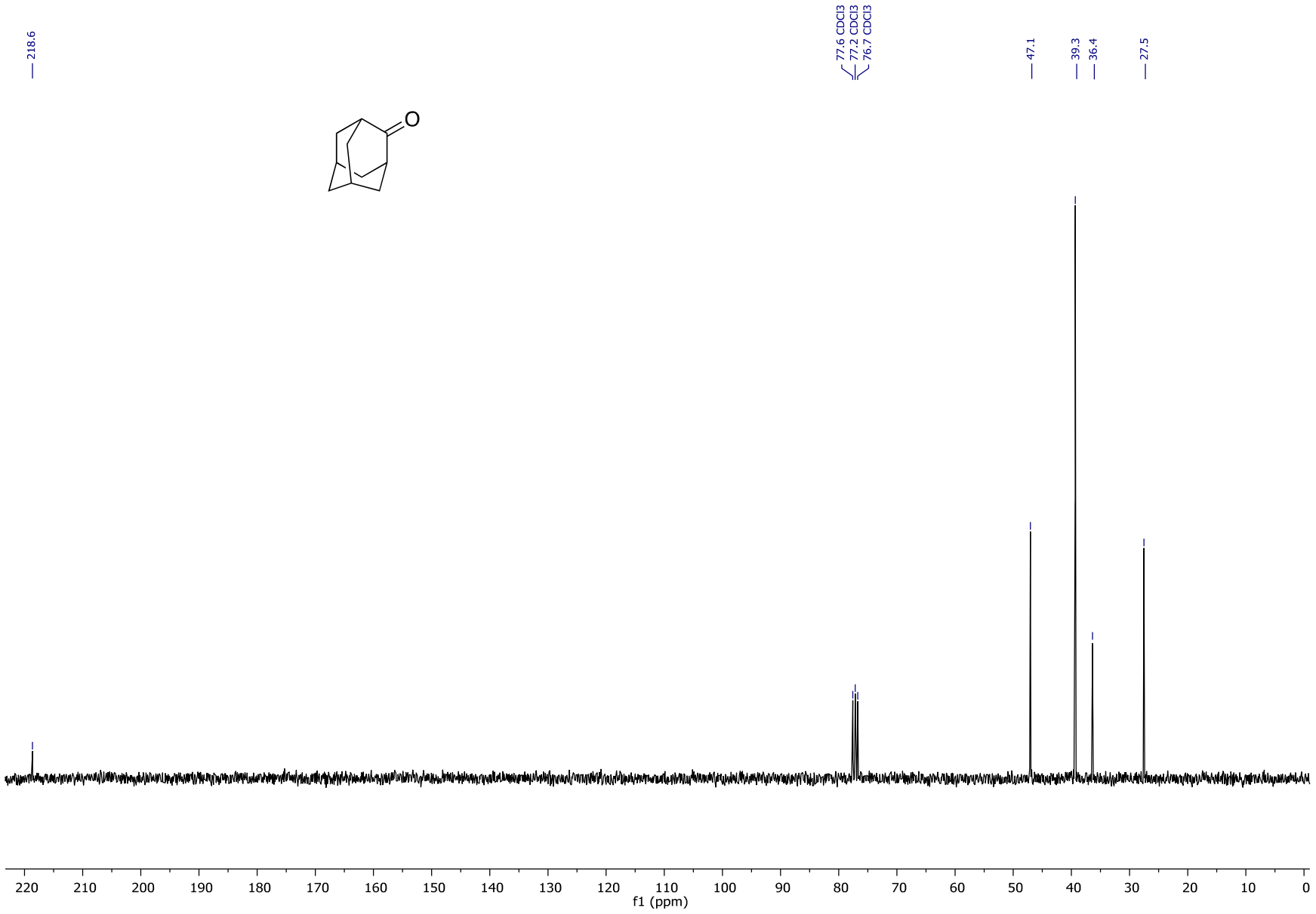
^{13}C-NMR (101 MHz $CDCl_3$) 2-Octanone (3v)



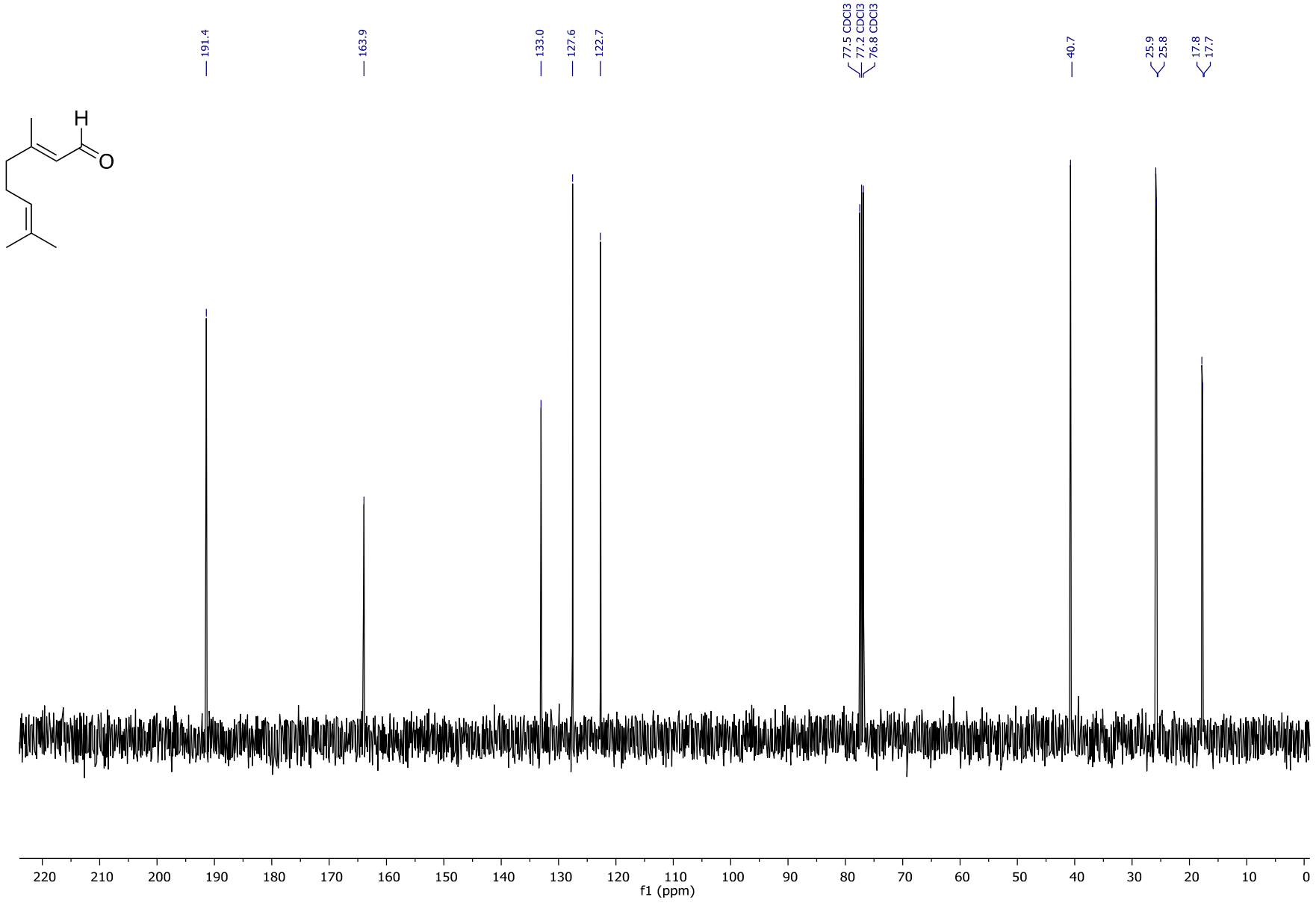
^{13}C-NMR (101 MHz $CDCl_3$) 4-*tert*-Butylcyclohexanone (3w)



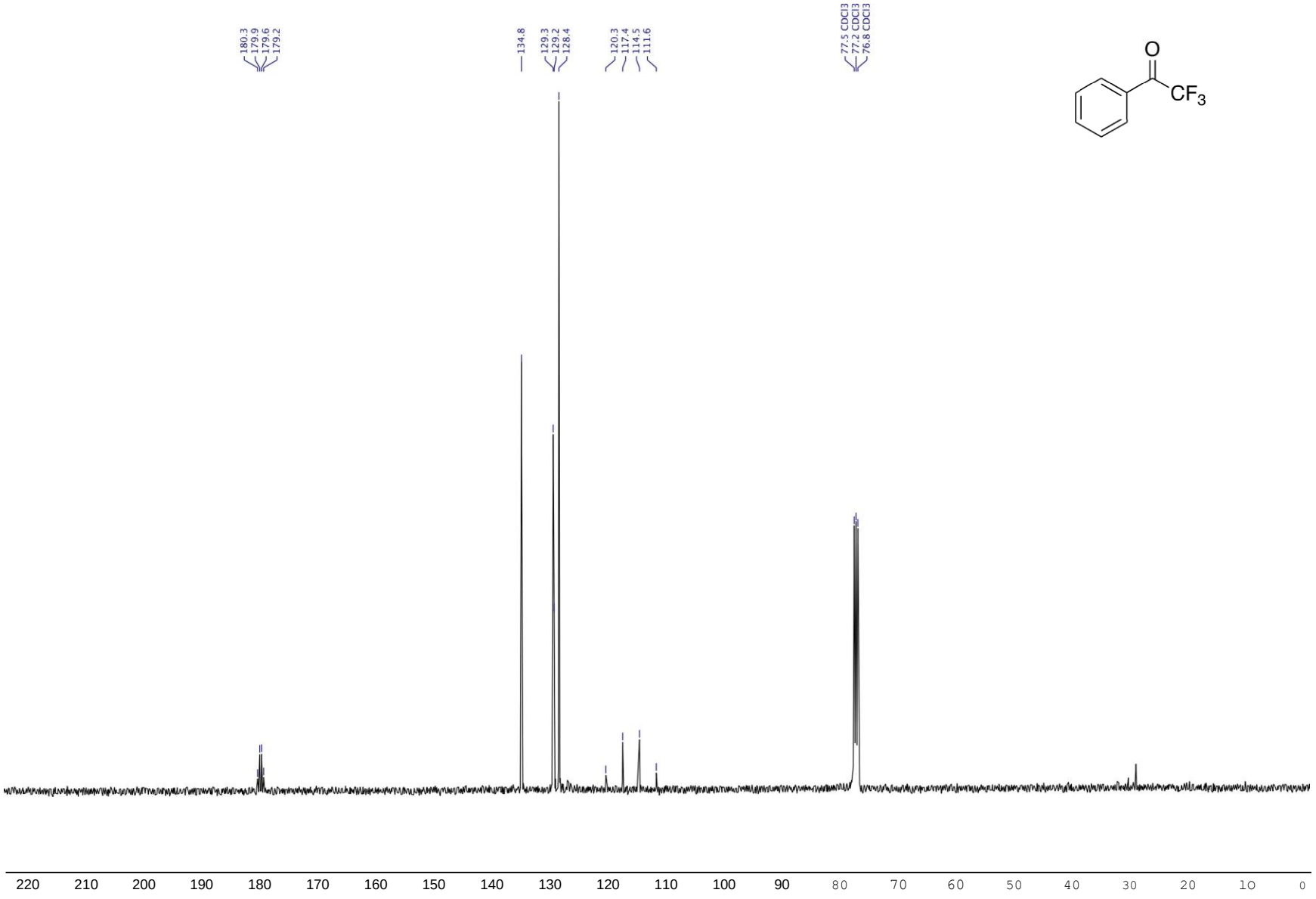
^{13}C-NMR (75 MHz $CDCl_3$) 2-Adamantanone (3x)



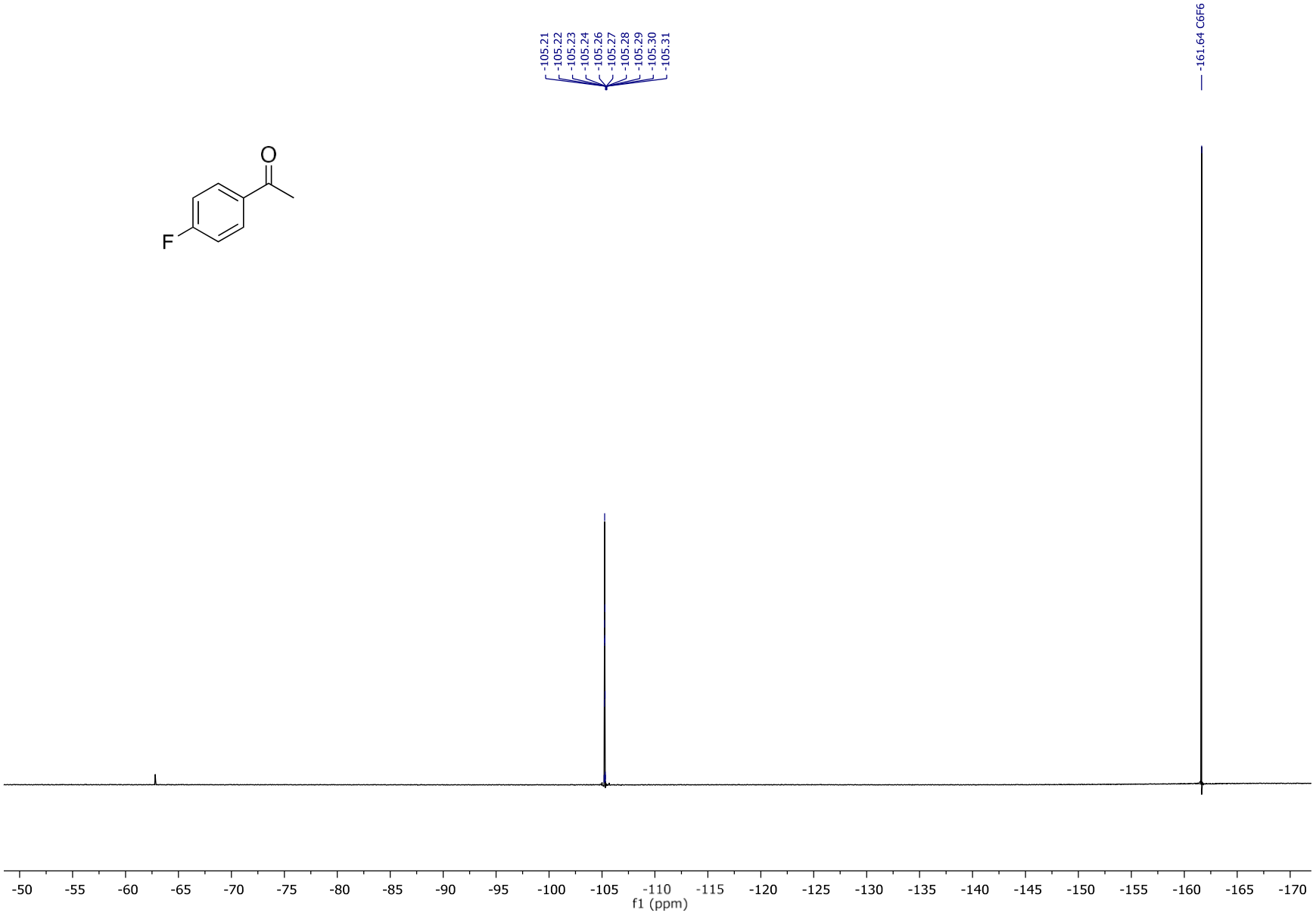
^{13}C-NMR (101 MHz $CDCl_3$) Geranial (3y)



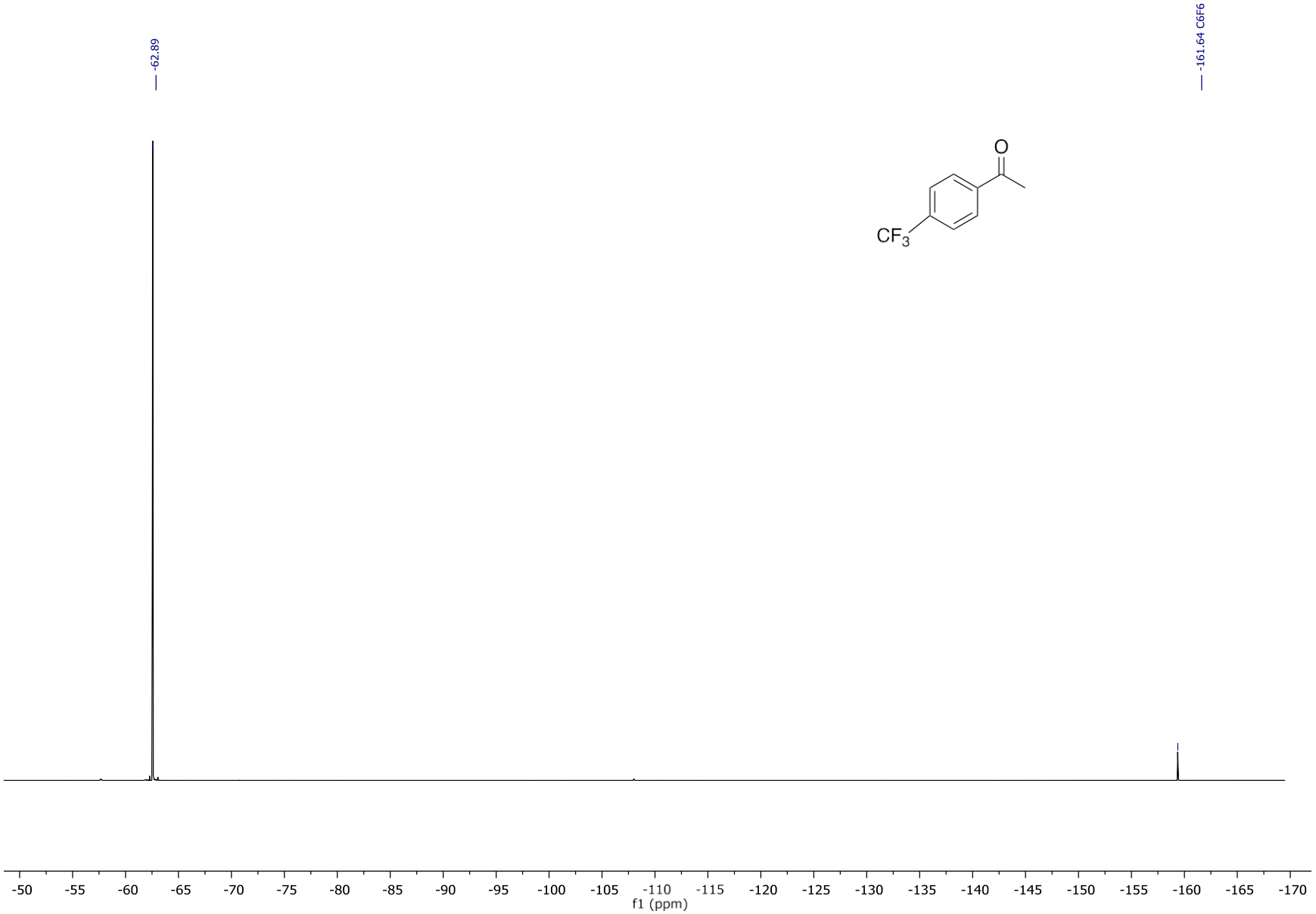
^{13}C-NMR (101 MHz $CDCl_3$) 1,1,1-Trifluoroacetophenone (3z)



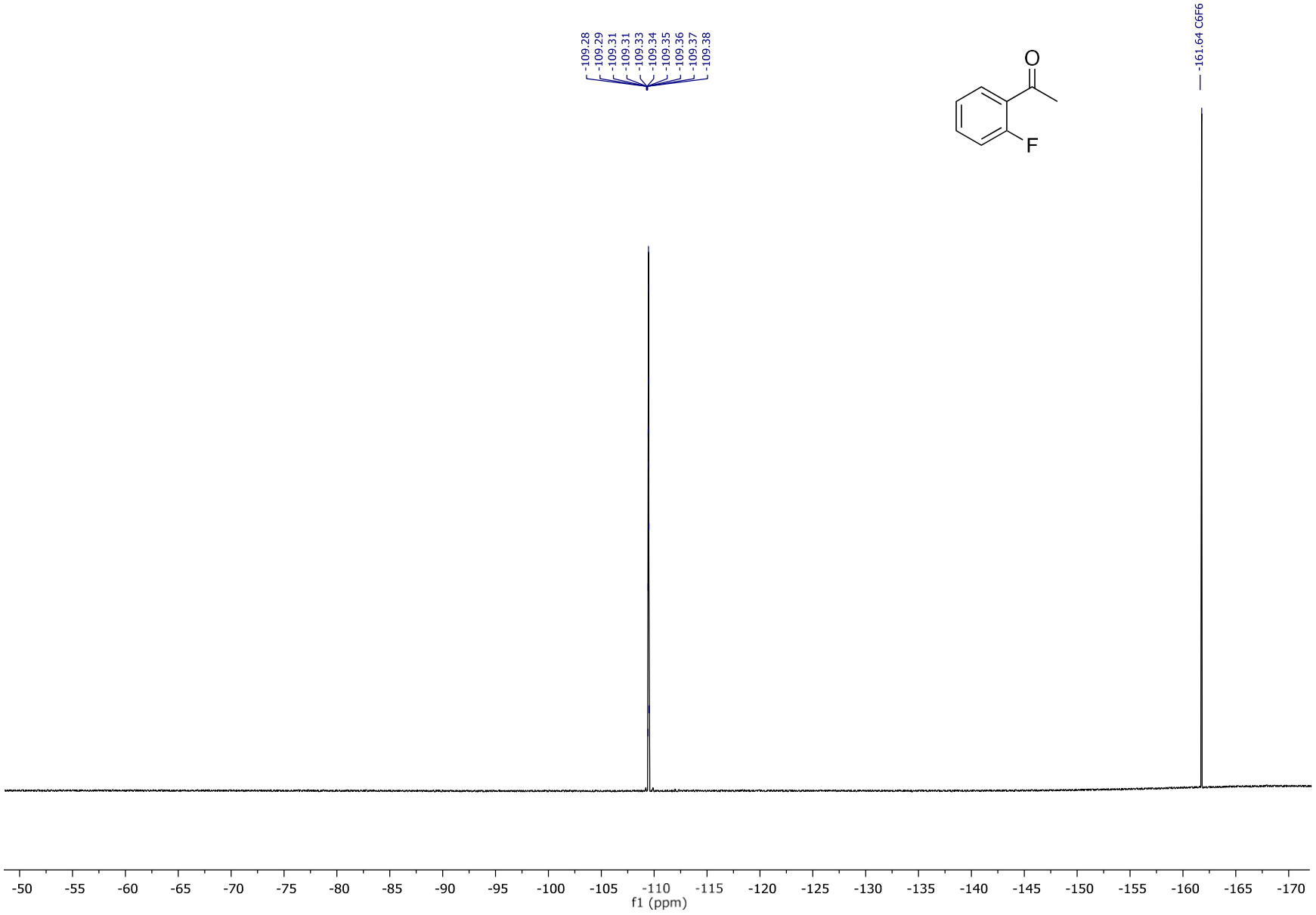
^{19}F-NMR (376 MHz $CDCl_3$) 1-(4-Fluorophenyl)ethenone (3d)



^{19}F-NMR (376 MHz $CDCl_3$)1-(4-Trifluoromethylphenyl)ethanone (3g)



^{19}F-NMR (376 MHz $CDCl_3$) 2'-Fluoroacetophenone (3j)



^{19}F-NMR (376 MHz $CDCl_3$) 1,1,1-Trifluoroacetophenone (3z)