Supporting Information for

Synthesis of β-Fluoro-α,β-Unsaturated Amides from the Fragmentation of Morpholine 3,3,3-Trifluoropropanamide by Grignard Reagents

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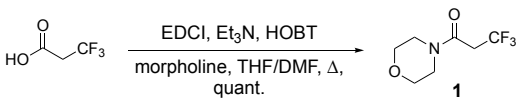
I. Experimental and Characterization Data

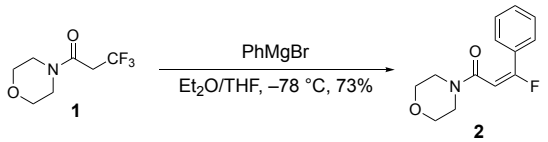
General Procedures. Experiments requiring anhydrous conditions were performed under argon atmosphere and organic solvents were dried over molecular sieves. All solvents and reagents were purchased from commercial sources unless otherwise noted. Thin-layer chromatography was conducted using MilliporeSigma TLC silica gel 60 F_{254} plates. Preparative thin-layer chromatography was performed using Sorbent Technologies silica G prep TLC plates with UV254. Flash chromatography was conducted using SiliCycle Siliaflash silica gel P60 (40–63 μm) 60Å. Melting points were taken on an OptiMelt apparatus from Stanford Research Systems and are not corrected. NMR spectra were recorded on a Bruker Topspin Avance III HD 500 MHz spectrometer equipped with prodigy cryoprobe or a Bruker Avance III HD 400 MHz spectrometer. The residual solvent peaks were used as an internal standard for ^{1}H and ^{13}C NMR spectra whereas trifluorotoluene was used as an added internal standard for ^{19}F NMR spectra. Mass spectrometry were acquired by the Department of Chemistry at the University of Mississippi using SYNAPT HD Mass Spectrometer from Waters. Infrared spectra were recorded on Agilent Technologies Cary 630 FTIR. X-ray crystallography was performed at the X-ray Facility at the Louisiana State University. Elemental analyses were carried out by Midwest Microlab.



1

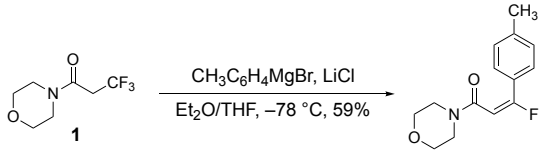
Morpholine 3,3,3-trifluoropropanamide (1). To a solution of 3,3,3-trifluoropropionic acid in THF/DMF (9:1, 150 mL) at rt was added morpholine (1.5 mL, 17 mmol), triethylamine (1.8 mL, 12 mmol), 1-hydroxybenzotriazole hydrate (1.76 g, 13.0 mmol), and *N*-(3-dimethylaminopropyl)-*N*-ethylcarbodiimide HCl (2.5 g, 13 mmol). The reaction mixture was heated for 24 h in an oil bath

at 65 °C. Next, the reaction mixture was cooled to rt, diluted with EtOAc (50 mL), quenched with a saturated aqueous NH_4Cl (30 mL), and extracted with EtOAc (3 × 25 mL). The organics were washed with 1.0 N HCl solution (30 mL), saturated aqueous $NaHCO_3$ (30 mL), saturated aqueous NaCl (50 mL), dried over Na_2SO_4, and concentrated under reduced pressure. The crude reaction mixture was purified by SiO_2 flash chromatography (10→30% EtOAc in hexanes) to yield the title compound **1** as a colorless solid (2.24 g, quant.). Recrystallization from a 1:1 solution of hexanes and cyclohexanes (by slow evaporation) provided a crystalline solid suitable for X-ray structure analysis: mp 76 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.68 (m, 6H), 3.47 (t, J = 4.8 Hz, 2H), 3.23 (q, J = 10.1 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.6 (q, J_{CF} = 3.3 Hz, 1C), 124.0 (q, J_{CF} = 275.3 Hz, 1C), 66.7, 66.4, 46.8, 42.3, 38.0 (q, J_{CF} = 29.0 Hz, 1C); ^{19}F NMR (376 MHz, $CDCl_3$) δ –62.41 (t, J_{HF} = 10.0 Hz, 3F); IR (film) ν_{max} 2862, 1653, 1439, 1094 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_7H_{10}F_3NO_2Cs$ $[M+Cs]^+$ 329.9718, found 329.9741; Anal. Calcd for $C_7H_{10}F_3NO_2 \cdot 0.2C_6H_6$: C, 46.29; H, 5.46; N, 6.58. Found: C, 46.62; H, 5.46; N, 6.79.



1 **2**

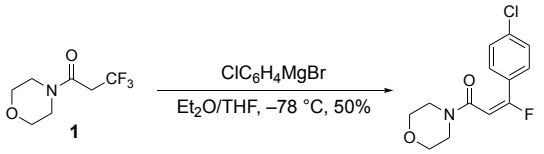
(*E*)-3-Fluoro-1-morpholino-3-phenylprop-2-en-1-one (2). A solution of **1** (100 mg, 0.51 mmol) in THF/Et_2O (1:1, 2 mL) was cooled to –78 °C, treated with a solution of phenylmagnesium bromide (1.0 mL, 1.0 M in THF), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (10→90% EtOAc in hexanes) afforded the title compound **2** as a pale yellow oil (88 mg, 73% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, J = 6.8 Hz, 2H), 7.41 (d, J = 7.5 Hz, 2H), 7.40 (m, 1H), 5.86 (d, J = 19.3 Hz, 1H), 3.61 (d, J = 5.3 Hz, 4H), 3.34 (d, J = 5.2 Hz, 2H), 3.30 (d, J = 5.0 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 164.4 (d, J_{CF} = 18.6 Hz, 1C), 161.7 (d, J_{CF} = 257.8 Hz, 1C), 130.7, 130.4 (d, J_{CF} = 28.2 Hz, 1C), 128.5 (2C), 127.2 (d, J_{CF} = 6.0 Hz, 2C), 101.7 (d, J_{CF} = 27.9 Hz, 1C), 66.3 (2C), 46.8, 41.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ –96.7 (d, J_{HF} = 19.3 Hz, 1F); IR (film) ν_{max} 2857, 1627, 1433, 1109 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{14}FNO_2Cs$ $[M+Cs]^+$ 368.0063, found 368.0076.



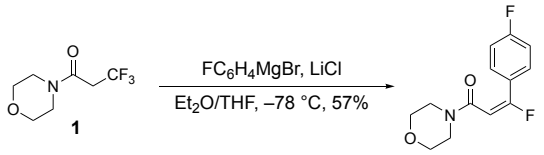
1 **3**

(*E*)-3-Fluoro-1-morpholino-3-(*p*-tolyl)prop-2-en-1-one (3). A solution of **1** (100 mg, 0.51 mmol) and LiCl (43.0 mg, 1.0 mmol) in THF/Et_2O (1:1, 8 mL) was cooled to –78 °C, treated with a solution of *p*-tolylmagnesium bromide (2.0 mL, 0.5 M in Et_2O), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **3** as a pale yellow oil (75 mg, 59%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, J = 8.3 Hz, 2H), 7.20 (d, J = 8.4 Hz, 2H), 5.81 (d, J = 19.3 Hz, 1H), 3.62 (app d, J = 2.6 Hz, 4H), 3.34 (app d, J = 4.0 Hz, 4H), 2.38 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6 (d, J_{CF}

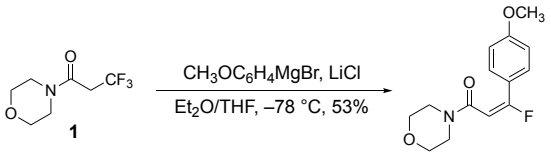
= 18.7 Hz, 1C), 162.0 (d, J_{CF} = 257.5 Hz, 1C), 141.1, 129.2 (2C), 127.5 (d, J_{CF} = 28.3 Hz, 1C), 127.1 (d, J_{CF} = 5.9 Hz, 2C), 100.9 (d, J_{CF} = 28.3 Hz, 1C), 66.3 (2C), 46.8, 41.8, 21.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ –96.3 (d, J_{HF} = 19.2 Hz, 1F); IR (film) ν_{max} 2855, 1627, 1431, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{14}H_{17}FNO_2$ $[M+H]^+$ 250.1243, found 250.1273.



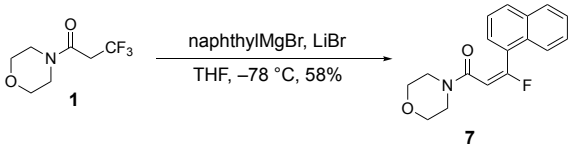
(*E*)-3-(4-chlorophenyl)-3-fluoro-1-morpholinoprop-2-en-1-one (4). A solution of **1** (100 mg, 0.51 mmol) in THF/Et_2O (1:1, 2 mL) was cooled to –78 °C, treated with a solution of 4-chlorophenylmagnesium bromide (1.0 mL, 1.0 M in Et_2O), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography in (5→70% EtOAc in hexanes) afforded the title compound **4** as a colorless oil (69 mg, 50%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.6 Hz, 2H), 7.36 (d, *J* = 8.4 Hz, 2H), 5.90 (d, *J* = 19.9 Hz, 1H), 3.61 (m, 4H), 3.39 (app d, *J* = 6.0 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9 (d, J_{CF} = 18.5 Hz, 1C), 161.1 (d, J_{CF} = 257.0 Hz, 1C), 136.8, 128.7 (d, J_{CF} = 28.7 Hz, 1C), 128.7 (2C), 128.6 (d, J_{CF} = 6.2 Hz, 2C), 102.1 (d, J_{CF} = 28.0 Hz, 1C), 66.4 (2C), 46.7, 41.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ –96.1 (d, J_{HF} = 19.9 Hz, 1F); IR (film) ν_{max} 2855, 1623, 1431, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{14}ClFNO_2$ $[M+H]^+$ 270.0697, found 270.0699.



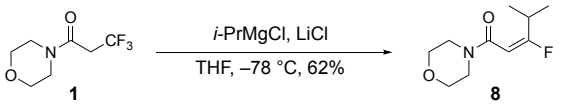
(*E*)-3-fluoro-3-(4-fluorophenyl)-1-morpholinoprop-2-en-1-one (5). A solution of **1** (100 mg, 0.51 mmol) and LiCl (43.0 mg, 1.0 mmol) in THF/Et_2O (1:1, 8 mL) was cooled to –78 °C, treated with a solution of 4-fluorophenylmagnesium bromide (0.5 mL, 2.0 M in Et_2O), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (8 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **5** as an orange-yellow oil (74 mg, 57%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 (dd, *J* = 8.7, 5.3 Hz, 2H), 7.08 (t, *J* = 8.6 Hz, 2H), 5.87 (d, *J* = 19.8 Hz, 1H), 3.62 (m, 4H), 3.39 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 164.1 (d, J_{CF} = 18.6 Hz, 1C), 163.9 (d, J_{CF} = 250.8 Hz, 1C), 161.2 (d, J_{CF} = 257.2 Hz, 1C), 129.6 (dd, J_{CF} = 8.7, 6.2 Hz, 2C), 126.5 (dd, J_{CF} = 28.8, 3.4 Hz, 1C), 115.7 (d, J_{CF} = 22.0 Hz, 2C), 101.5 (d, J_{CF} = 28.2 Hz, 1C), 66.4 (2C), 46.8, 41.9; ^{19}F NMR (471 MHz, $CDCl_3$) δ –95.7 (d, J_{HF} = 19.8 Hz, 1F), –108.3 (ddd, J_{HF} = 13.6, 8.5, 5.3 Hz, 1F); IR (film) ν_{max} 2855, 1625, 1508, 1228, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{14}F_2NO_2$ $[M+H]^+$ 254.0993, found 254.0978.



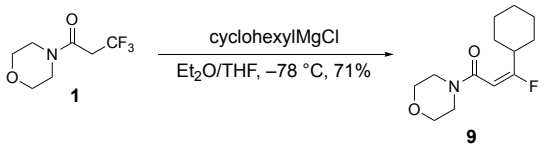
(*E*)-3-fluoro-3-(4-methoxyphenyl)-1-morpholinoprop-2-en-1-one (6). A solution of **1** (100 mg, 0.51 mmol) and LiCl (65 mg, 1.5 mmol) in THF/Et_2O (1:1, 6 mL) was cooled to –78 ºC, treated with a solution of 4-methoxyphenylmagnesium bromide (1.1 mL, 1.0 M in THF), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (6 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **6** as a yellow oil (72 mg, 53%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.51 (d, J = 8.7 Hz, 2H), 6.89 (d, J = 8.6 Hz, 2H), 5.76 (d, J = 19.5 Hz, 1H), 3.82 (s, 3H), 3.61 (m, 4H), 3.36 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 164.7 (d, J_{CF} = 19.0 Hz, 1C), 162.1 (d, J_{CF} = 255.1 Hz, 1C), 161.4, 128.9 (d, J_{CF} = 6.3 Hz, 2C), 122.7 (d, J_{CF} = 28.8 Hz, 1C), 113.8 (2C), 99.9 (d, J_{CF} = 29.0 Hz, 1C), 66.4 (2C), 55.3, 46.8, 41.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ –96.2 (d, J_{HF} = 19.5 Hz, 1F); IR (film) ν_{max} 2853, 1604, 1429, 1237, 1111 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{14}H_{16}FNO_3Cs$ $[M+Cs]^+$ 398.0169, found 398.0168.



(*E*)-3-fluoro-1-morpholino-3-(naphthalen-1-yl)prop-2-en-1-one (7). A solution of LiBr (310 mg, 3.57 mmol) in THF (24 mL) was treated with a solution of naphthylmagnesium bromide (21.4 mL, 0.5 M in MeTHF) and stirred for 1 h at rt. Next, the reaction mixture was cooled to –78 °C and a solution of **1** (352 mg, 1.79 mmol) in THF (10 mL) was added dropwise. The mixture was stirred for 4 h at –78 °C and then quenched with 1 N HCl solution (10 mL). The resultant mixture was diluted with EtOAc (15 mL) and extracted with EtOAc (3 × 25 mL). The combined organics were dried over Na_2SO_4 and concentrated under reduced pressure. Recrystallization from a solution of hexanes/EtOAc (8:2, by slow evaporation) followed by SiO_2 flash chromatography (8:2→7:3 hexanes/EtOAc) afforded the title compound **7** as a colorless solid (297 mg, 58%): mp 139–141 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (dd, J = 8.0, 2.8 Hz, 1H), 7.97 (d, J = 8.7 Hz, 1H), 7.90 (d, J = 8.5 Hz, 1H), 7.65 (d, J = 7.1 Hz, 1H), 7.56 (m, 2H), 7.49 (t, J = 7.7 Hz, 1H), 6.18 (d, J = 16.7 Hz, 1H), 3.42 (m, 2H), 3.33 (m, 2H), 3.23 (m, 2H), 2.83 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.9 (d, J_{CF} = 17.4 Hz, 1C), 163.5 (d, J_{CF} = 263.0 Hz, 1C), 133.4 (d, J_{CF} = 1.3 Hz, 1C), 131.4 (d, J_{CF} = 2.0 Hz, 1C), 130.3 (d, J_{CF} = 1.1 Hz, 1C), 128.8 (d, J_{CF} = 4.7 Hz, 1C), 128.7, 128.0 (d, J_{CF} = 24.9 Hz, 1C), 127.3 (d, J_{CF} = 1.2 Hz, 1C), 126.5, 124.9, 124.6 (d, J_{CF} = 3.3 Hz, 1C), 104.9 (d, J_{CF} = 26.9 Hz, 1C), 66.5 (d, J_{CF} = 30.4 Hz, 1C), 66.1 (d, J_{CF} = 38.7 Hz, 1C), 46.9, 41.8; ^{19}F NMR (471 MHz, $CDCl_3$) δ –82.9 (d, J_{HF} = 16.9 Hz, 1F); IR (film) ν_{max} 3010, 1670, 1618, 1437, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{17}H_{17}FNO_2$ $[M+H]^+$ 286.1243, found 286.1244.

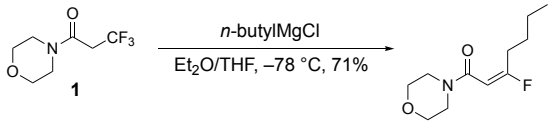


(*E*)-3-fluoro-4-methyl-1-morpholinopent-2-en-1-one (8). A solution of isopropylmagnesium chloride (2.2 mL, 2.0 M in THF) and LiCl (184 mg, 4.34 mmol) in THF (36 mL) was stirred at rt for 1 h, cooled to −78 °C, treated with a solution of **1** (428 mg, 2.17 mmol) in THF (7 mL), and stirred for 4 h. The reaction mixture was quenched with 1.0 N HCl solution (20 mL) and extracted with CH_2Cl_2 (3 × 25 mL). The combined organics were washed with saturated aqueous NaCl (30 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→60% EtOAc in hexanes) afforded the title compound **8** as a colorless oil (272.4 mg, 62%): ^{1}H NMR (500 MHz, $CDCl_3$); δ 5.67 (d, J = 20.9 Hz, 1H), 3.70–3.58 (m, 6H), 3.55 (m, 1H), 3.48 (m, 2H), 1.15 (d, J = 6.9 Hz, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 177.0 (d, J_{CF} = 272.9 Hz, 1C), 164.6 (d, J_{CF} = 21.5 Hz, 1C), 98.1 (d, J_{CF} = 27.5 Hz, 1C), 66.8, 66.6, 46.6, 41.9, 28.7 (d, J_{CF} = 23.1 Hz, 1C), 18.8 (2C); ^{19}F NMR (471 MHz, $CDCl_3$) δ –98.2 (dd, J_{HF} = 34.0, 21.0 Hz, 1F); IR (film) ν_{max} 2857, 1675, 1618, 1429, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{10}H_{16}FNO_2Cs$ $[M+Cs]^+$ 334.0220, found 334.0236.



1 **9**

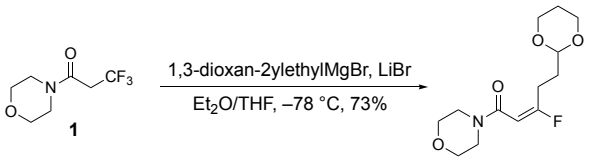
(*E*)-3-cyclohexyl-3-fluoro-1-morpholinoprop-2-en-1-one (9). A solution of **1** (100 mg, 0.51 mmol) in THF/Et_2O (1:1, 3 mL) was cooled to –78 °C, treated with a solution of cyclohexylmagnesium chloride (0.92 mL, 1.3 M in 1:1 THF/toluene), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (3 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **9** as a colorless oil (87 mg, 71%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.65 (d, J = 21.2 Hz, 1H), 3.77–3.55 (m, 8H), 3.20 (dt, J = 33.2, 11.9 Hz, 1H), 1.76–1.63 (m, 5H), 1.43 (q, J = 12.4 Hz, 2H), 1.31 (q, J = 12.9 Hz, 2H), 1.17 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.6 (d, J_{CF} = 272.0 Hz, 1C), 164.5 (d, J_{CF} = 21.7 Hz, 1C), 98.1 (d, J_{CF} = 27.9 Hz, 1C), 66.6, 66.5, 46.4, 41.7, 38.3 (d, J_{CF} = 22.0 Hz, 1C), 31.5, 28.5 (2C), 25.5 (2C); ^{19}F NMR (471 MHz, $CDCl_3$) δ –93.4 (dd, J_{HF} = 33.0, 21.2 Hz, 1F); IR (film) ν_{max} 2928, 2853, 1631, 1433, 1114 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{20}FNO_2Cs$ $[M+Cs]^+$ 374.0533, found 374.0541.



1 **10**

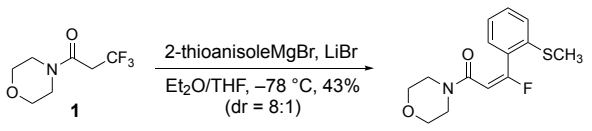
(*E*)-3-fluoro-1-morpholinohept-2-en-1-one (10). A solution of **1** (100 mg, 0.51 mmol) in THF/Et_2O (1:1, 3 mL) was cooled to –78 °C, treated with a solution of *n*-butylmagnesium chloride (1.0 mL, 2.0 M in Et_2O), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (3 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **10** as a colorless oil (78 mg, 71%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.78 (d, J = 20.8 Hz, 1H), 3.68–3.45 (m, 8H), 2.68 (dt, J = 25.2, 7.6 Hz, 2H), 1.57 (p, J = 7.6 Hz, 2H), 1.38 (q, J = 7.5 Hz, 2H), 0.91 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.9 (d, J_{CF} = 269.0 Hz, 1C), 164.6 (d, J_{CF} = 21.5 Hz, 1C), 99.7 (d, J_{CF} = 27.1 Hz, 1C), 66.8, 66.6, 46.5, 41.8, 29.5 (d, J_{CF} = 23.4 Hz, 1C), 28.0,

22.2, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ –81.7 (td, J_{HF} = 25.2, 21.0 Hz, 1F); IR (film) ν_{max} 2859, 1675, 1619, 1426, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{11}H_{18}FNO_2Cs$ $[M+Cs]^+$ 348.0376, found 348.0348.



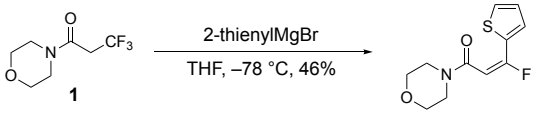
1 11

(*E*)-5-(1,3-dioxan-2-yl)-3-fluoro-1-morpholinopent-2-en-1-one (11). A solution of **1** (212 mg, 1.07 mmol) and LiBr (186 mg, 2.2 mmol) in THF/Et_2O (1:1, 2 mL) was cooled to –78 ºC, treated with a solution of 1,3-dioxan-2-ylethylmagnesium bromide (4.0 mL, 0.5 M in THF), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (20→80% EtOAc in hexanes) afforded the title compound **11** as a solid (213 mg, 73%). Recrystallization from toluene (by slow evaporation) provided a crystalline solid suitable for X-ray structure analysis: mp 55–56 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.79 (d, *J* = 20.4 Hz, 1H), 4.58 (t, *J* = 5.1 Hz, 1H), 4.09 (dd, *J* = 10.7, 5.0 Hz, 2H), 3.74 (td, *J* = 12.4, 2.5 Hz, 2H), 3.69–3.60 (m, 6H), 3.50–3.44 (m, 2H), 2.81 (t, *J* = 8.0 Hz, 1H), 2.76 (t, *J* = 8.0 Hz, 1H), 2.06 (dtt, *J* = 13.4, 12.5, 5.0 Hz, 1H), 1.90–1.84 (m, 2H), 1.32 (dt, *J* = 13.5, 1.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.9 (d, J_{CF} = 269.4 Hz, 1C), 164.4 (d, J_{CF} = 20.7 Hz, 1C), 101.1, 100.1 (d, J_{CF} = 26.5 Hz, 1C), 66.8 (2C), 66.6 (2C), 46.5, 41.9, 31.3, 25.7, 24.7 (d, J_{CF} = 23.9 Hz, 1C); ^{19}F NMR (376 MHz, $CDCl_3$) δ –82.6 (td, J_{HF} = 24.3, 20.9 Hz, 1F); IR (film) ν_{max} 2851, 1677, 1619, 1429, 1113 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{20}FNO_4Cs$ $[M+Cs]^+$ 406.0431, found 406.0439.



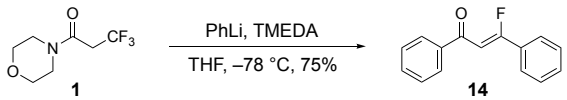
1 12

(*E*)-3-fluoro-3-(2-(methylthio)phenyl)-1-morpholinoprop-2-en-1-one (12). A solution of 2-thioanisolemagnesium bromide (2.0 mL, 0.5 M in THF) and LiBr (88.6 mg, 1.0 mmol) in 1:1 THF/Et_2O (10 mL) was stirred at rt for 1 h, cooled to –78 ºC, treated with a solution of **1** (100 mg, 0.5 mmol) in THF (7 mL), and then stirred for 8 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (5→80% EtOAc in hexanes) then preparative TLC (25% Et_2O in CH_2Cl_2) afforded the title compound **12** as a pale yellow oil (62 mg, 43%) as a 8:1 mixture of *E*/*Z*-isomers: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43–7.37 (m, 2H), 7.31 (d, *J* = 8.0 Hz, 1H), 7.19 (t, *J* = 7.5 Hz, 1H), 6.05 (d, *J* = 16.5, 1H), 5.84 (d, *J* = 37.5 Hz, 1H)*, 3.48 (m, 4H), 3.41 (m, 2H), 3.26 (m, 2H), 2.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.7 (d, J_{CF} = 17.4 Hz, 1C), 163.3 (d, J_{CF} = 263.3 Hz, 1C), 138.3, 131.1 (d, J_{CF} = 2.2 Hz, 1C), 130.6 (d, J_{CF} = 3.4 Hz, 1C), 129.9 (d, J_{CF} = 24.8 Hz, 1C), 126.2, 124.9, 104.5 (d, J_{CF} = 26.8 Hz, 1C), 66.5 (2C), 46.9, 41.9, 16.2; ^{19}F NMR (376 MHz, $CDCl_3$) δ –83.1 (d, *J* = 16.4 Hz), –87.8 (d, *J* = 37.7 Hz)*; IR (film) ν_{max} 2920, 2855, 1675, 1627, 1435, 1112 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{14}H_{17}FNO_2S$ $[M+H]^+$ 282.0964, found 282.0944. *denotes the minor (*Z*)-isomer.



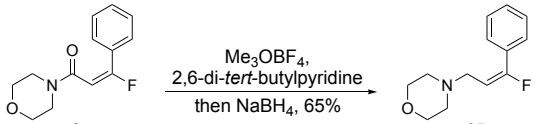
1 13

(*E*)-3-fluoro-1-morpholino-3-(thiophen-2-yl)prop-2-en-1-one (13). A solution of **1** (100 mg, 0.51 mmol) in THF (17 mL) was cooled to –78 °C, treated with a solution of 2-thienylmagnesium bromide (1.0 mL, 1.0 M in THF), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (3 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (5→60% EtOAc in hexanes) afforded the title compound **13** as a colorless oil (57 mg, 46%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (dd, J = 3.8, 1.2 Hz, 1H), 7.47 (ddd, J = 5.6, 2.8, 1.4 Hz, 1H), 7.05 (ddd, J = 5.1, 3.9, 1.6 Hz, 1H), 5.84 (d, J = 21.4 Hz, 1H), 3.67 (m, 4H), 3.55 (m, 2H), 3.48 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8 (d, J_{CF} = 19.1 Hz), 158.7 (d, J_{CF} = 249.4 Hz), 131.5 (d, J_{CF} = 33.3 Hz), 130.0, 129.9 (d, J_{CF} = 6.9 Hz), 127.0, 99.1 (d, J_{CF} = 29.8 Hz), 66.5 (2C), 46.7, 41.8; ^{19}F NMR (471 MHz, $CDCl_3$) δ –92.1 (d, J = 21.0 Hz); IR (film) ν_{max} 2853, 2201, 1620, 1415, 1111 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{11}H_{13}FNO_2S$ $[M+H]^+$ 242.0651, found 242.0670.



1 14

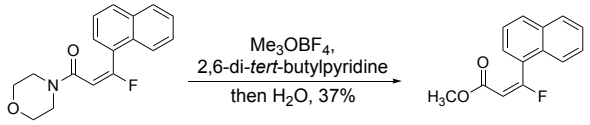
(*Z*)-3-fluoro-1,3-diphenylprop-2-en-1-one (14). A solution of **1** (100 mg, 0.51 mmol) and TMEDA (0.15 ml, 1.02 mmol) in THF (2 mL) was cooled to −78 °C, treated with a solution of phenyllithium (1.0 mL, 1.9 M in dibutylether), and stirred for 4 h. The reaction mixture was quenched with 0.2 N HCl solution (2 mL) and extracted with CH_2Cl_2 (3 × 5 mL). The combined organics were washed with saturated aqueous NaCl (10 mL), dried over Na_2SO_4, and concentrated under reduced pressure. SiO_2 flash chromatography (5→80% EtOAc in hexanes) afforded the title compound **14** as yellow oil (105 mg, 75%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 7.4 Hz, 2H), 7.75 (d, J = 6.8 Hz, 2H), 7.75 (d, J = 6.8 Hz, 1H), 7.52–7.44 (m, 5H), 6.80 (d, J = 34.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.9, 165.2 (d, J_{CF} = 276.5 Hz, 1C), 138.6, 132.9, 131.6, 130.9 (d, J_{CF} = 26.2 Hz, 1C), 128.9 (d, J_{CF} = 2.1 Hz, 2C), 128.6 (2C), 128.3 (2C), 125.8 (d, J_{CF} = 8.0 Hz, 2C), 101.7 (d, J_{CF} = 6.9 Hz, 1C); ^{19}F NMR (376 MHz, $CDCl_3$) δ –97.6 (d, J_{HF} = 34.2 Hz, 1F); IR (film) ν_{max} 3058, 1636, 1284, 1208 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{15}H_{11}FOCs$ $[M+Cs]^+$ 358.9848, found 358.9846. All data matched the reported data.[1]



2 15

(*E*)-4-(3-fluoro-3-phenylallyl)morpholine (15). A solution of amide **2** (341 mg, 1.45 mmol) in CH_2Cl_2 (24 mL) was treated with trimethyloxonium tetrafluoroborate (578 mg, 3.91 mmol) and 2,6-di-*tert*-butylpyridine (0.94 mL, 4.22 mmol), and the reaction mixture was stirred for 24 h at rt. Next, the reaction mixture was cooled to 0 °C, diluted with methanol (15 mL), and stirred for 20 min at 0 °C. $NaBH_4$ (564 mg, 14.9 mmol) was added and the resultant mixture was stirred for 30 min at 0 °C. The reaction mixture was quenched with saturated aqueous $NaHCO_3$ (20 mL) and diluted with CH_2Cl_2 (15 mL). The aqueous layer was extracted with CH_2Cl_2 (3 × 20 mL). The

combined organics were dried over Na_2SO_4 and concentrated under reduced pressure. SiO_2 flash chromatography (7:3 hexanes/EtOAc with 0.5% AcOH→7:3 hexanes/EtOAc with 0.5% Et_3N) afforded the title compound **15** as colorless oil (27 mg, 65%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49–7.45 (m, 2H), 7.43–7.38 (m, 3H), 5.53 (dt, J = 21.4, 7.5 Hz, 1H), 3.72 (t, J = 4.7 Hz, 4H), 3.15 (d, J = 7.5 Hz, 2H), 2.47 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3 (d, J_{CF} = 246.0 Hz, 1C), 131.4 (d, J_{CF} = 29.4 Hz, 1C), 129.4 (d, J_{CF} = 1.4 Hz, 1C), 128.3 (2C), 128.0 (d, J_{CF} = 4.8 Hz, 2C), 104.5 (d, J_{CF} = 26.7 Hz, 1C), 66.8 (2C), 54.4 (d, J_{CF} = 10.1 Hz, 1C), 53.3 (2C); ^{19}F NMR (376 MHz, $CDCl_3$) δ –95.0 (d, J_{HF} = 21.1 Hz, 1F); IR (film) ν_{max} 2959, 2918, 2853, 2808, 1677, 1115, 1060 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{13}H_{17}FNO$ $[M+H]^+$ 222.1294 found 222.1296.



7 **16**

Methyl (*E*)-3-fluoro-3-(naphthalen-1-yl)acrylate (16). A solution of amide **7** (38 mg, 0.13 mmol) in CH_2Cl_2 (5 mL) was treated with trimethyloxonium tetrafluoroborate (97 mg, 0.66 mmol) and stirred for 24 h at rt. The resultant mixture was concentrated under reduced pressure, diluted with THF (3 mL), treated with H_2O (2 mL), and stirred for 1 h at rt. Next, the mixture was added to H_2O (4 mL) and acidified to pH 2. Then, the mixture was extracted with Et_2O (3 × 10 mL). The combined organics were dried over Na_2SO_4 and concentrated under reduced pressure. SiO_2 flash chromatography (8:2 hexanes/EtOAc) afforded the title compound **16** as a colorless oil (11.1 mg, 37%): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99–7.89 (m, 3H), 7.64 (m, 1H), 7.57–7.49 (m, 3H), 6.18 (d, J = 16.8 Hz, 1H), 3.55 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.8 (d, J_{CF} = 271.0 Hz, 1C), 165.2 (d, J_{CF} = 23.5 Hz, 1C), 133.2 (d, J_{CF} = 1.7 Hz, 1C), 131.2 (d, J_{CF} = 3.0 Hz, 1C), 130.6, 128.8, 128.8, 128.5, 128.0 (d, J_{CF} = 24.0 Hz, 1C), 127.1 (d, J_{CF} = 1.2 Hz, 1C), 126.3, 124.6, 104.3 (d, J_{CF} = 32.0 Hz, 1C), 51.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ –66.2 (d, J_{HF} = 16.8 Hz, 1F); IR (film) ν_{max} 2952, 1731, 1666, 1202, 1101 cm^{-1}; HRMS (ESI–TOF) *m/z* calcd for $C_{14}H_{10}FO_2$ $[M–H]^–$ 229.0665, found 229.0663.

II. Mechanistic Experiments

Observation of diagnostic peaks the β,β-difluoroacrylamide by ^{19}F NMR. A solution of isopropylmagnesium chloride in THF-d_8 was cooled to –78 ºC, treated with a solution of **1** (one equiv.) in THF-d_8, and then stirred for 18 h at rt. The mixture was analyzed by ^{19}F NMR (471 MHz, THF-d_8) at rt. The diagnostic peaks are observed at –71.2 and –76.0 ppm (Figure S1, see below) and they are similar to the β,β-difluoroacrylamide intermediate reported by Shimada, Konno, and Ishihara.[2]

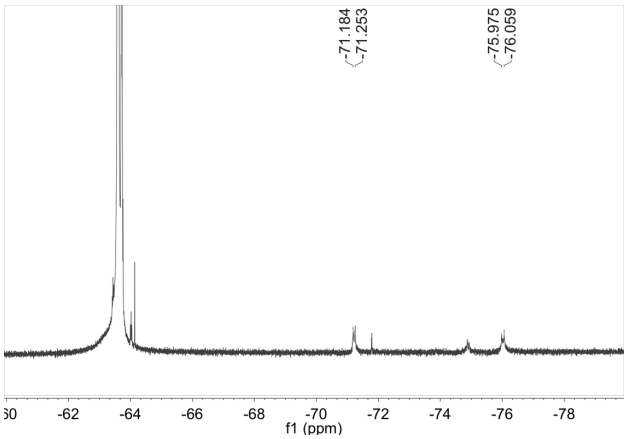


Figure S1. ^{19}F NMR data for the β,β-difluoroacrylamide intermediate was obtained from **1** and isopropylmagnesium chloride in THF-d_8 at 471 Hz at rt with trifluorotoluene as an internal standard.

III. References

1. Zhang, J.; Liu, L.; Duan, J.; Gu, L.; Chen, B.; Sun, T.; Gong, Y. Stereoselective One-Pot Sequential Dehydrochlorination/*trans*-Hydrofluorination Reaction of β-Chloro-α,β-unsaturated Aldehydes or Ketones: Facile Access to (*Z*)-β-Fluoro-β-arylenals/β-Fluoro-β-arylenones. *Adv. Synth. Catal.* **2017**, *359*, 4348–4358.
2. Shimada, T.; Konno, T.; Ishihara, T. A New Access to 3-Halo-3,3-difluoropropanoic Acid Derivatives via Fluorine-Halogen Exchange Reaction of Silyl Enolates of 3,3,3-Trifluoropropanoic Acid Derivatives. *Chem. Lett.* **2007**, *36*, 636–637.

IV. X-ray Experimental and Crystallographic Data

The X-ray crystal structures of **1** and **11** were determined at T=90K from data collected with Mo Kα radiation on a Bruker Kappa Apex-II DUO diffractometer equipped with a Triumph curved monochromator. Refinement was by SHELXL using all data, with H atoms in idealized positions. **1**: Recrystallization from a 1:1 solution of hexanes and cyclohexanes (by slow evaporation) provided a crystalline solid suitable for X-ray structure analysis. $C_7H_{10}F_3NO_2$, FW=197.16, monoclinic space group $P2_1/n$, a=12.5889(4), b=10.7958(3), c=12.6859(4) Å, β=96.670(2)°, V=1712.44(9) Å^3, Z=8. 14,586 data measured to θ_{max}=33.2° yielded 6524 unique data (R_{int}=0.039), of which 3902 had I>2σ(I), R=0.048. There are two independent (unrelated by symmetry) molecules, one of which exhibits disorder of the morpholine ring, the two conformations being present in 0.927/0.073 ratio. The CIF has been deposited at the Cambridge Crystallographic Data Centre, CCDC 1948771.
11: Recrystallization from toluene (by slow evaporation) provided a crystalline solid suitable for X-ray structure analysis. $C_{13}H_{20}FNO_4$, FW=273.30, orthorhombic space group $P2_12_12_1$, a=4.2875(5), b=10.9693(12), c=27.265(4) Å, V=1282.3(3) Å^3, Z=4. 4579 data measured to θ_{max}=26.4° yielded 2501 unique data (R_{int}=0.048), of which 1750 had I>2σ(I), R=0.066. The

morpholine ring has disorder similar to that seen in **1**, the two conformations being present in 0.888/0.112 ratio. CCDC 1948772.

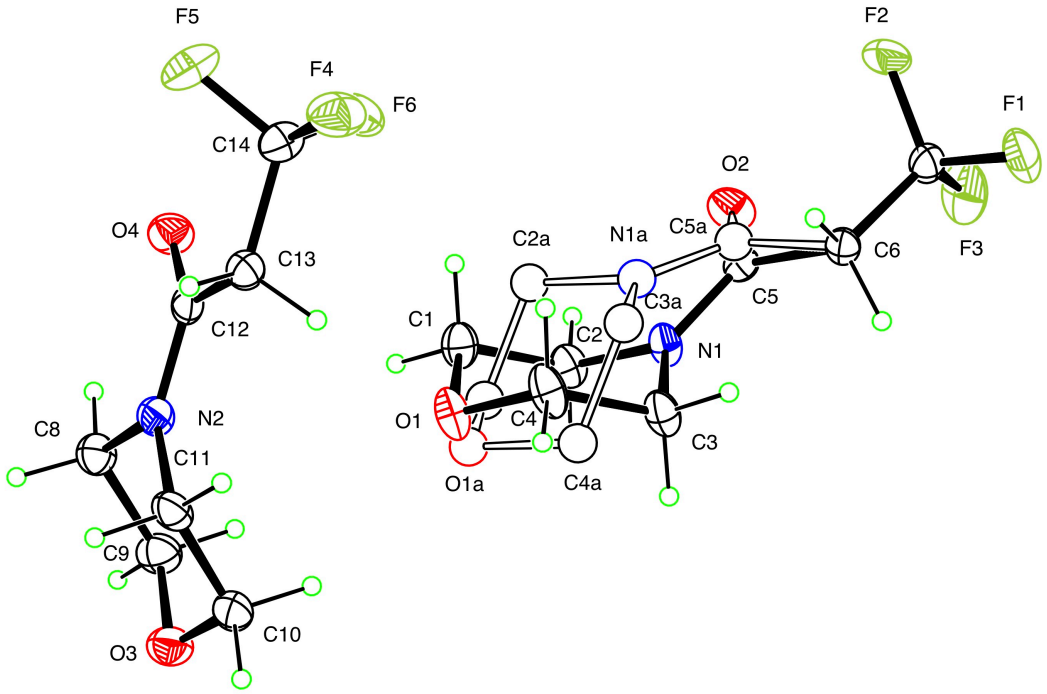


Figure S2. ORTEP diagram of **1** with 50% ellipsoids, showing disorder of the morpholine ring.

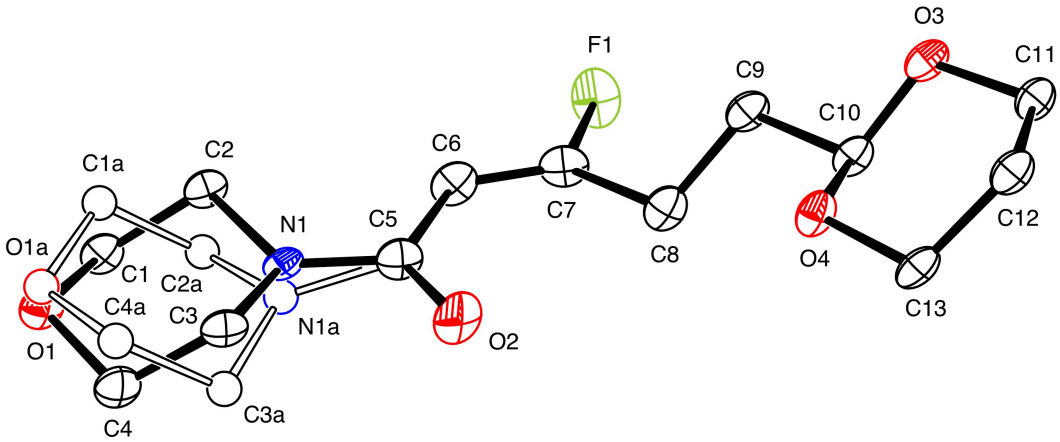
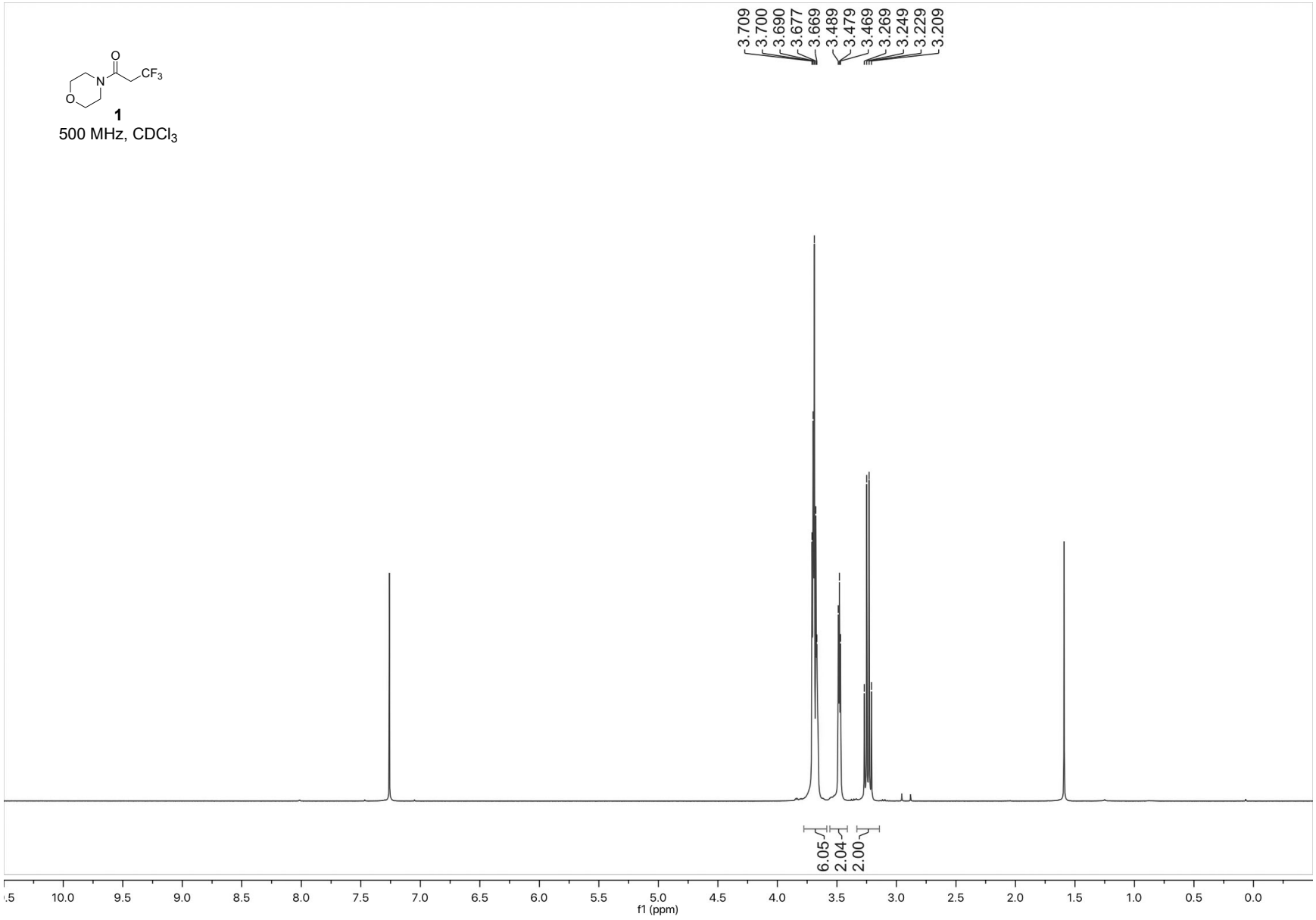


Figure S3. ORTEP diagram of **11** with 50% ellipsoids, showing disorder of the morpholine ring. H atoms are not shown.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N
O
CF3
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2.04
2.00
10.0
9.5
9.0
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6.5
6.0
5.5
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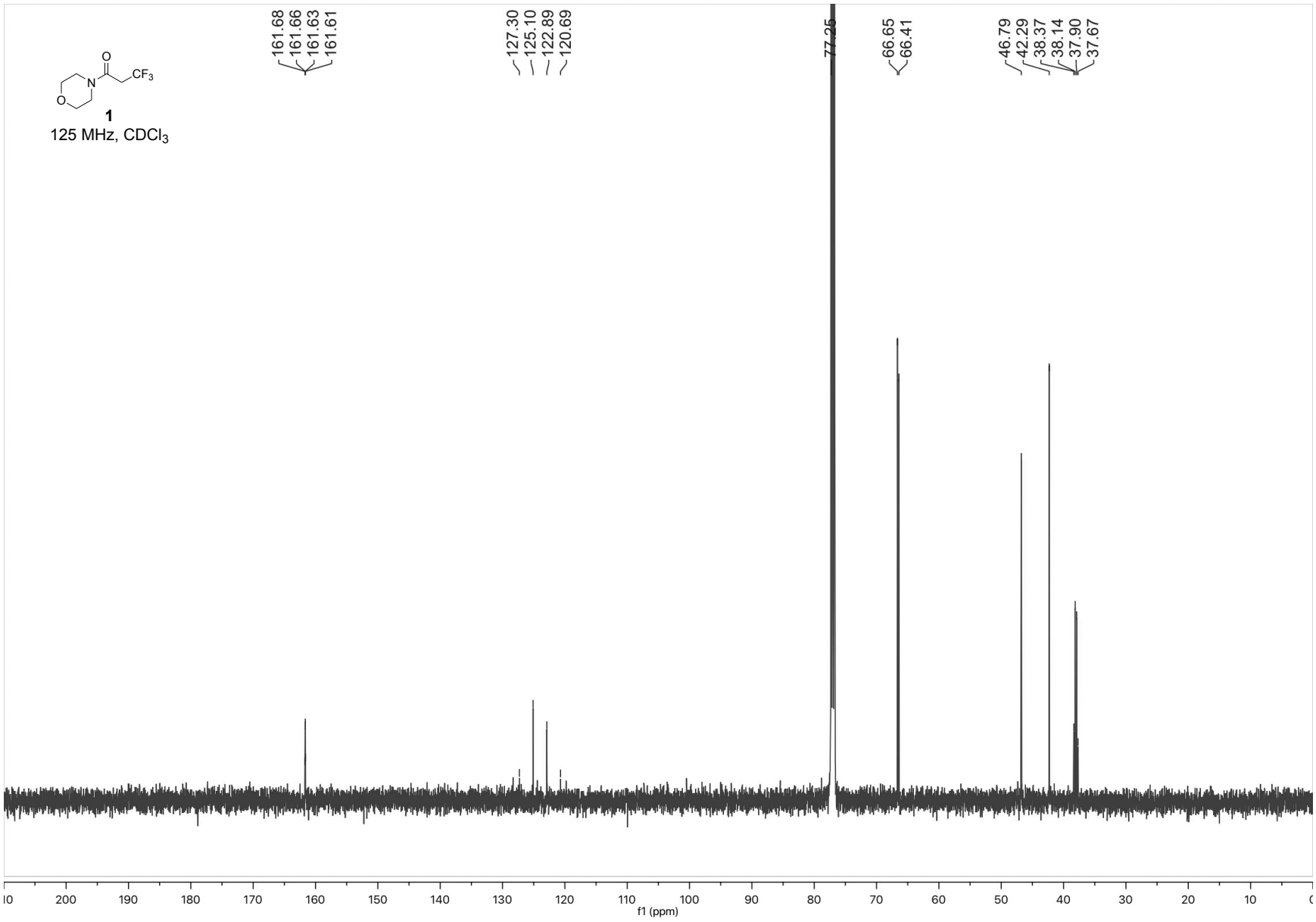
f1 (ppm)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37.67
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CF3
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60
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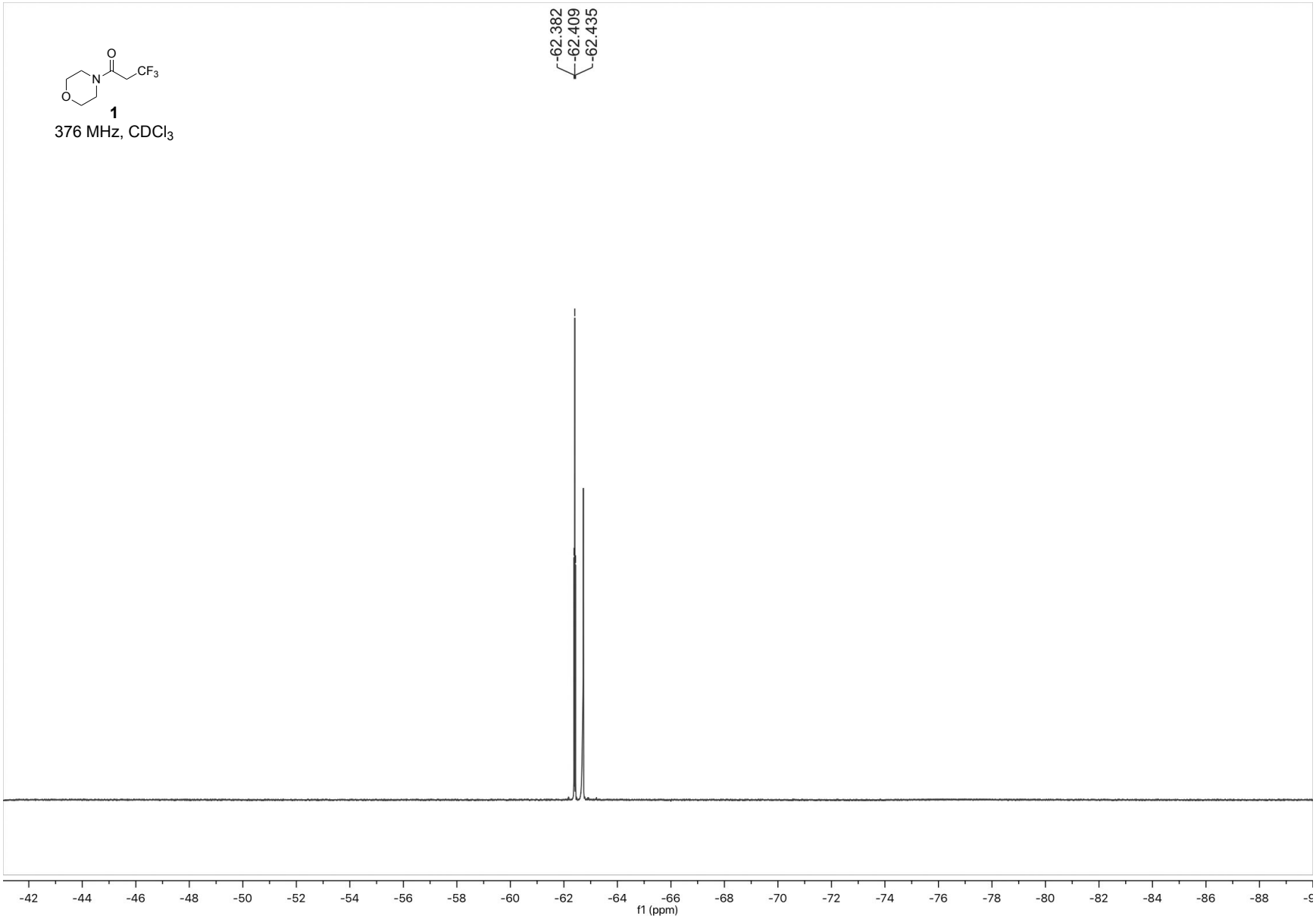
30
20
10
f1 (ppm)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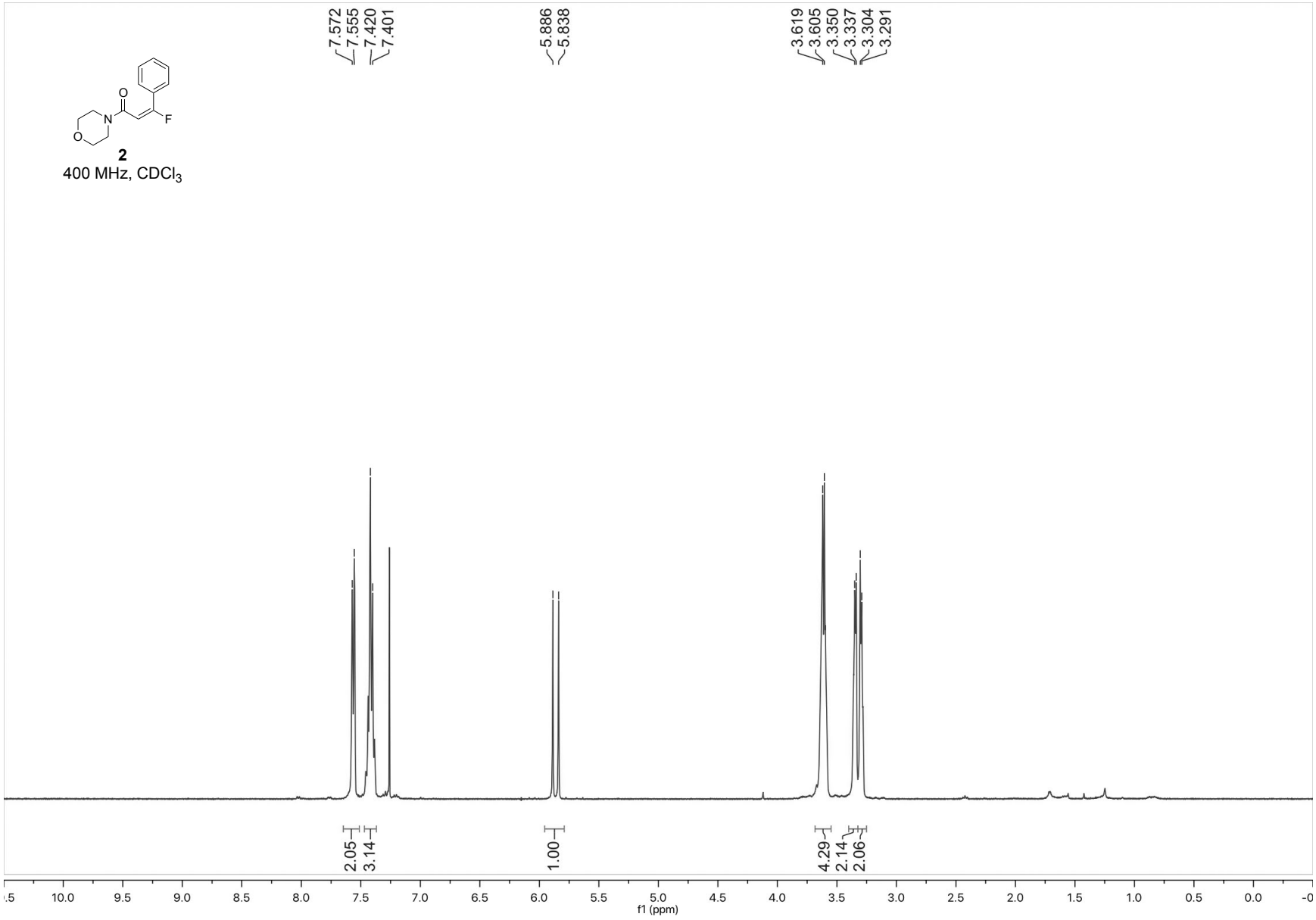
f1 (ppm)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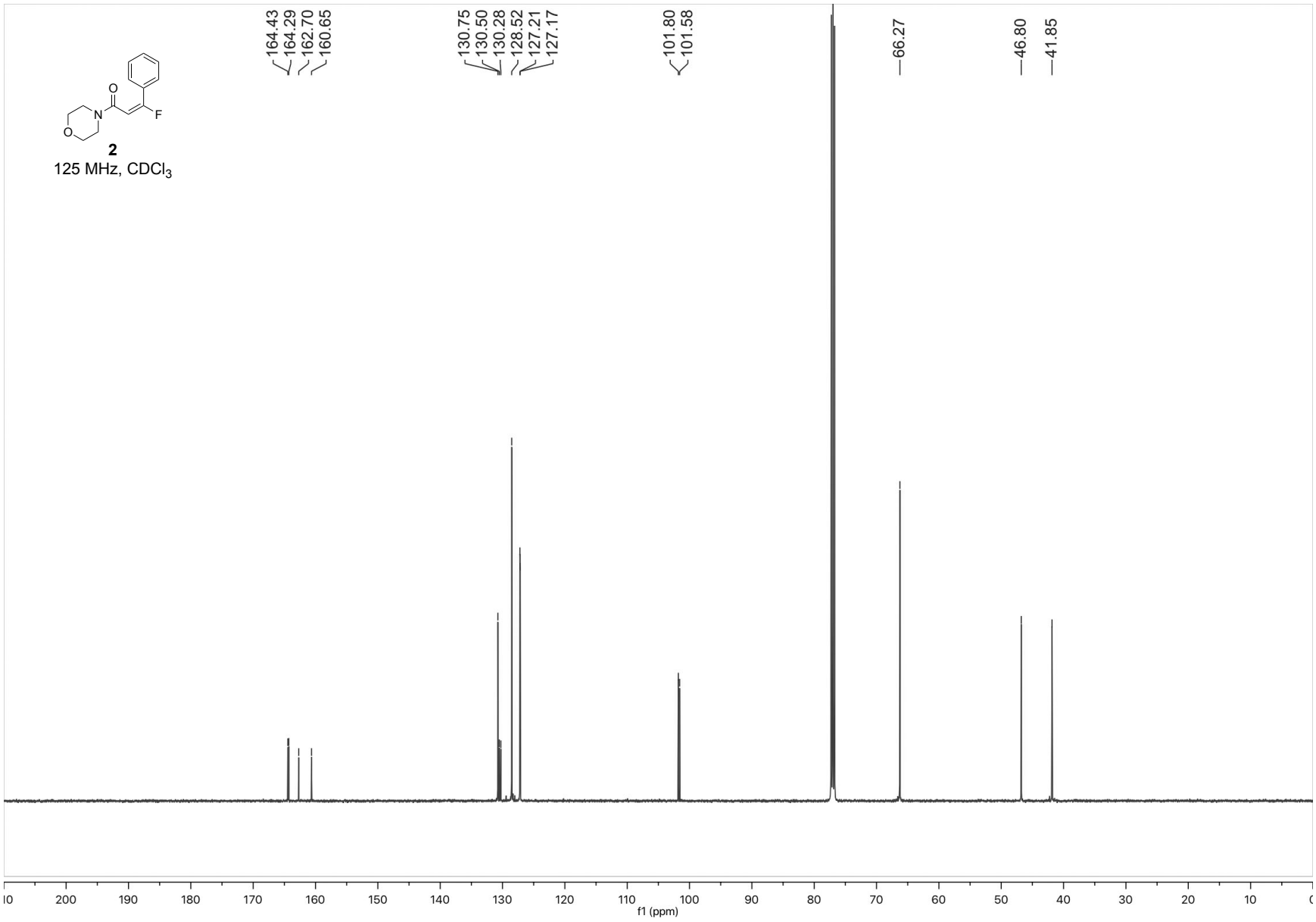
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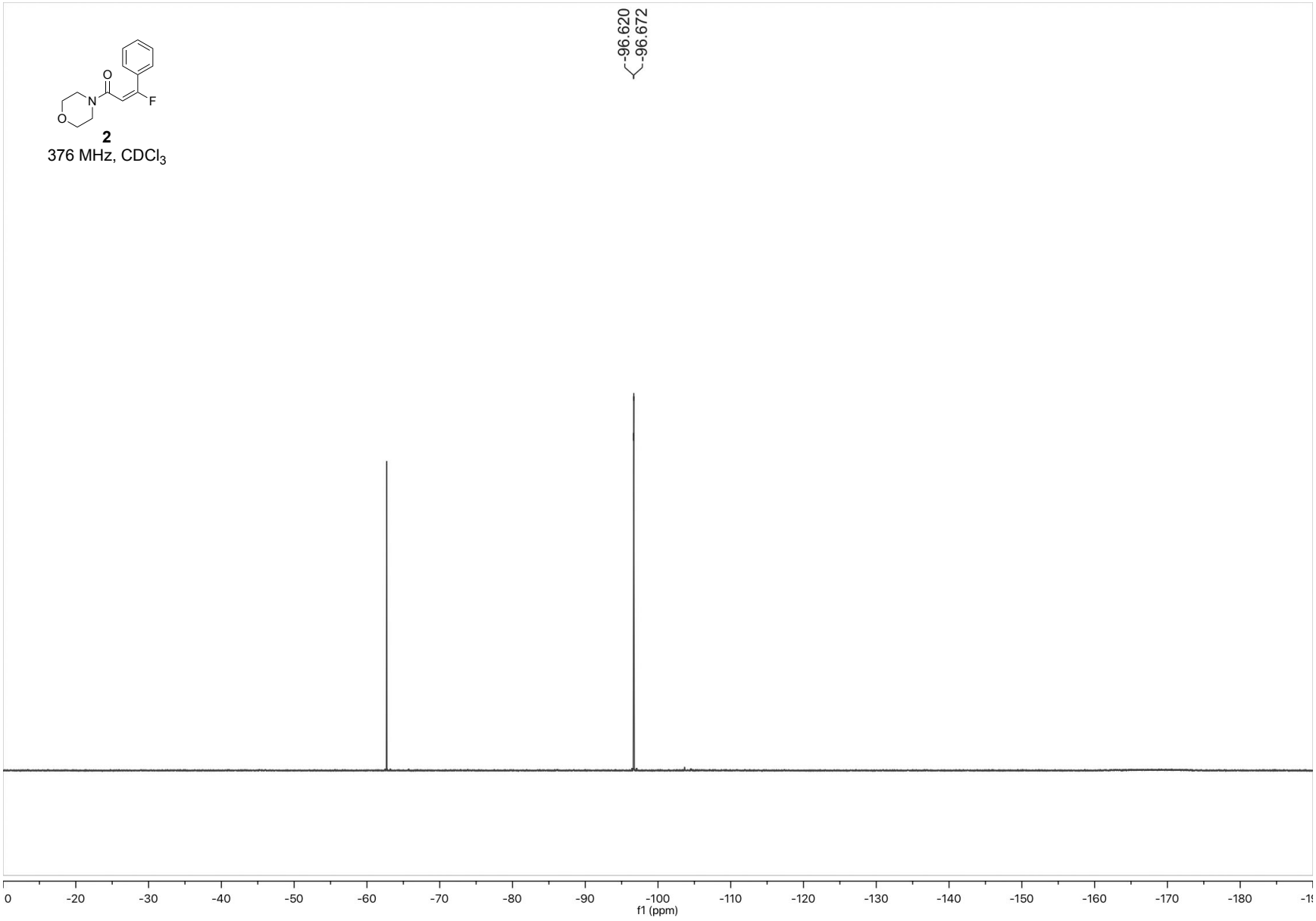
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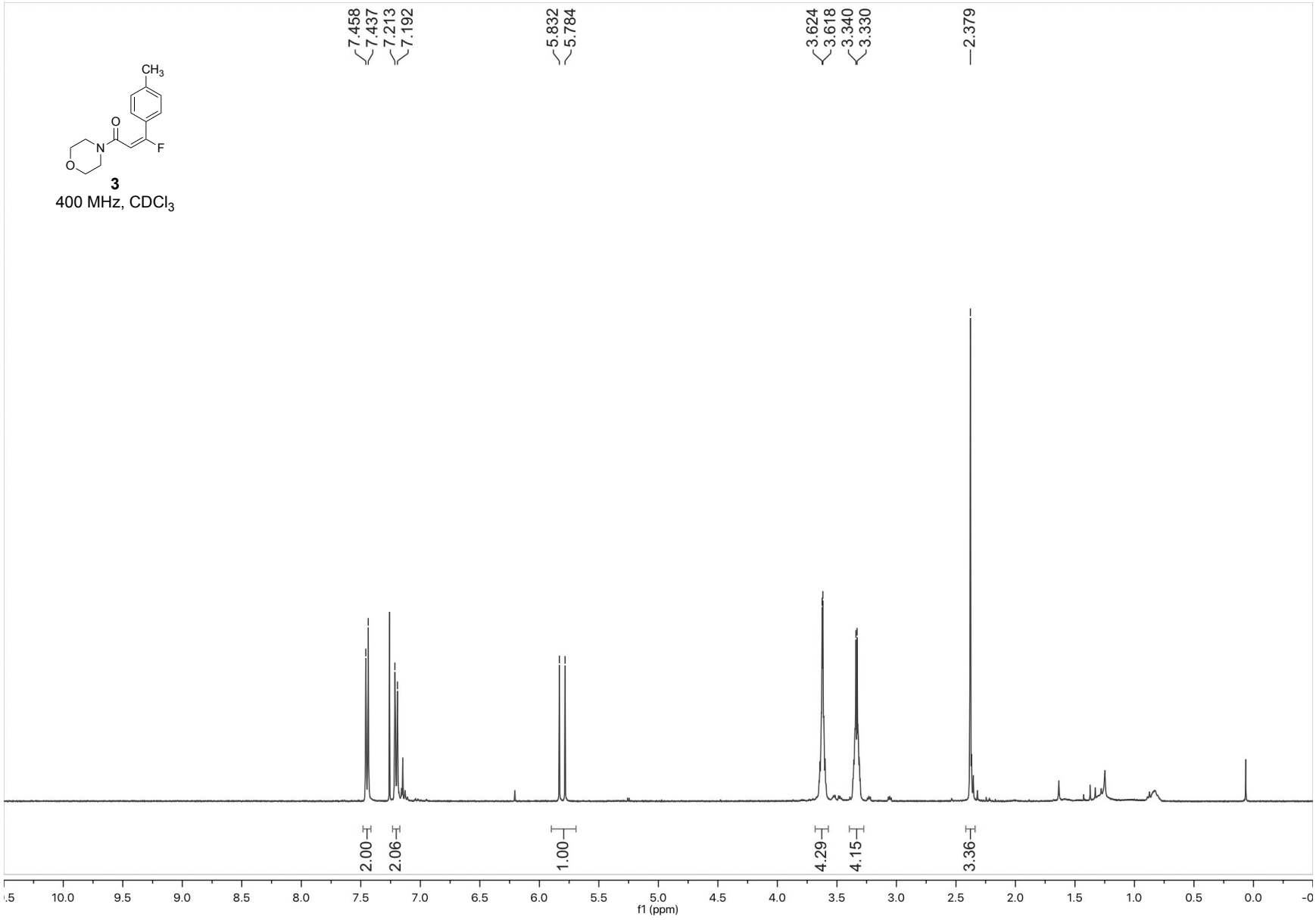
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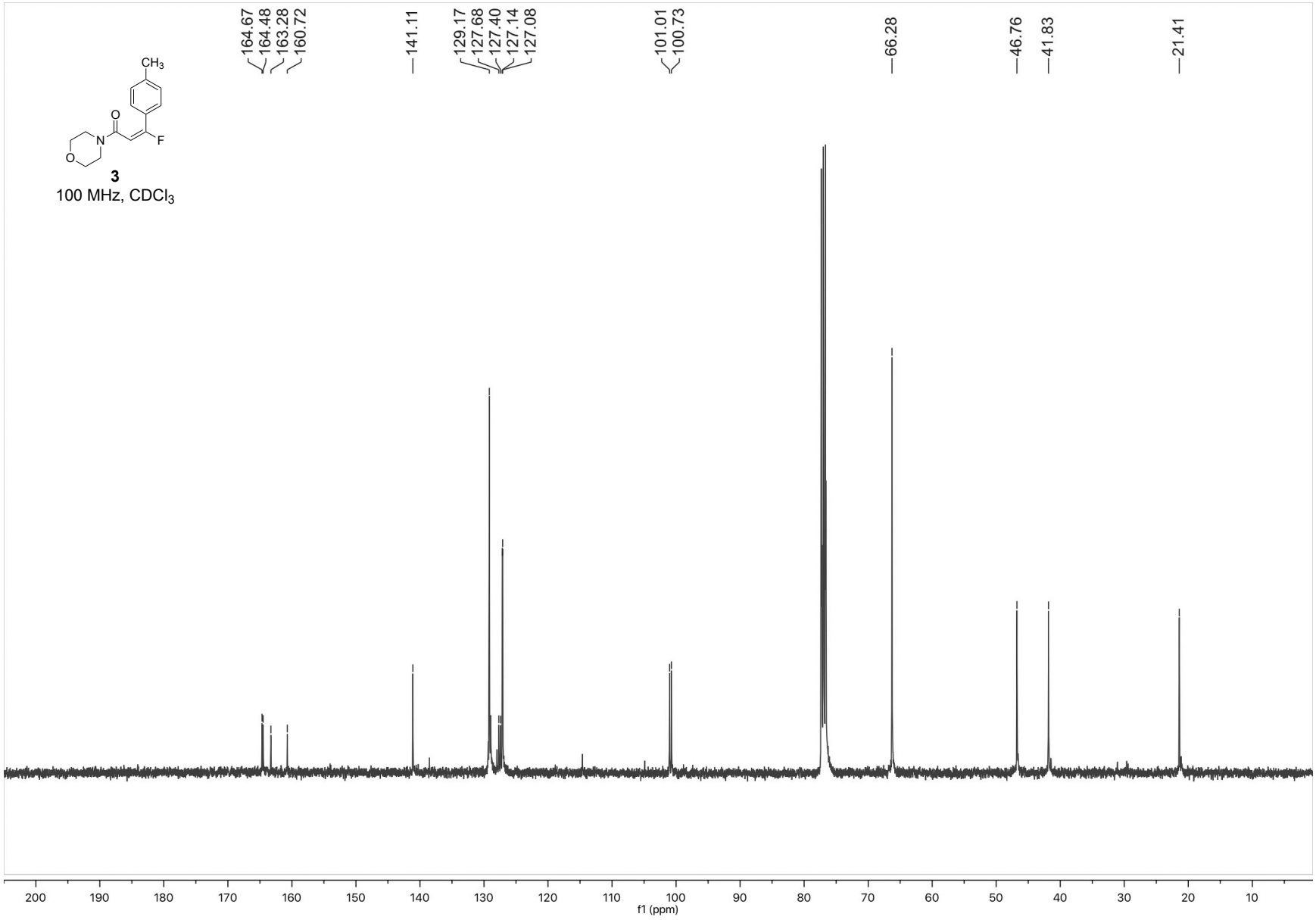
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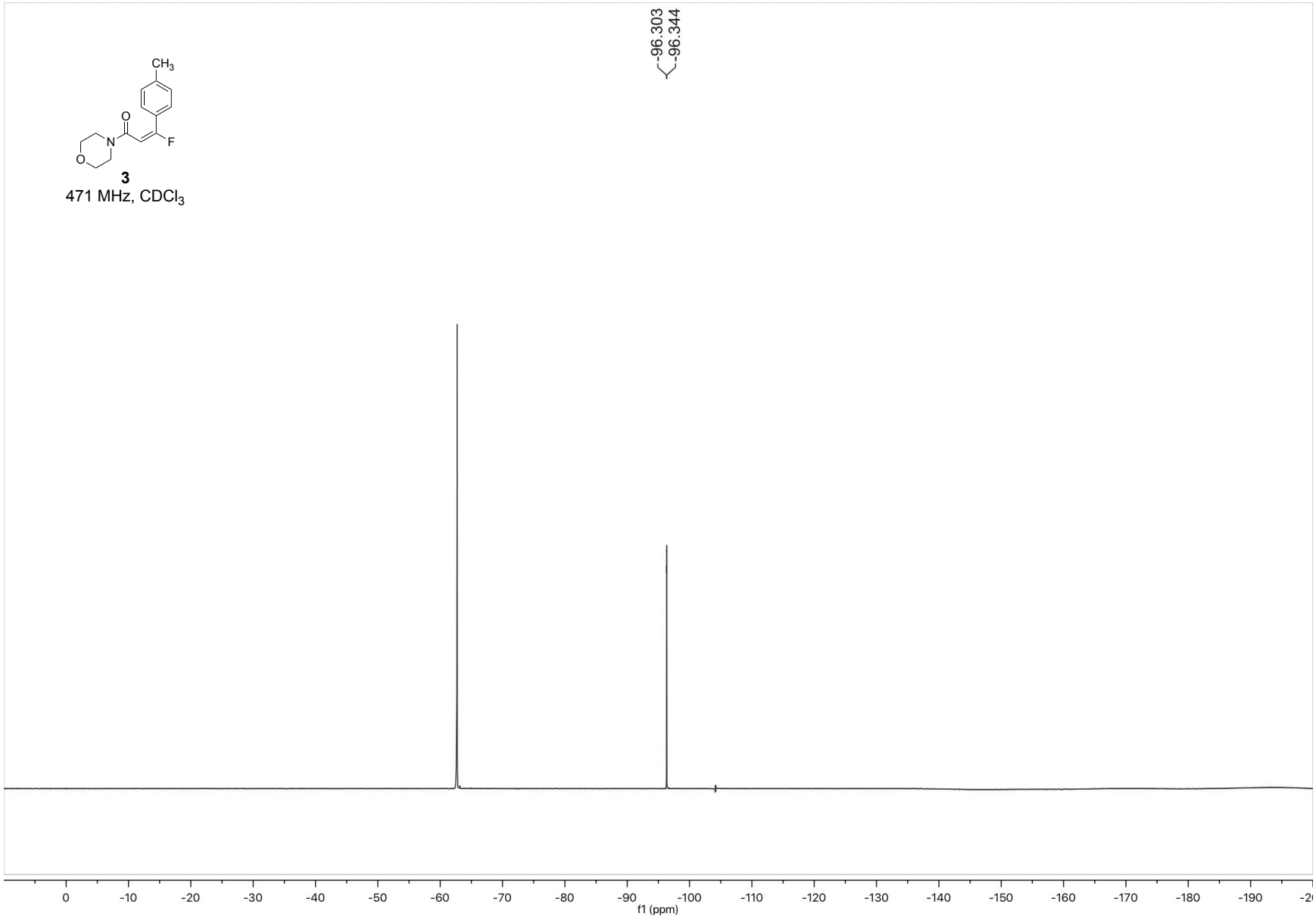
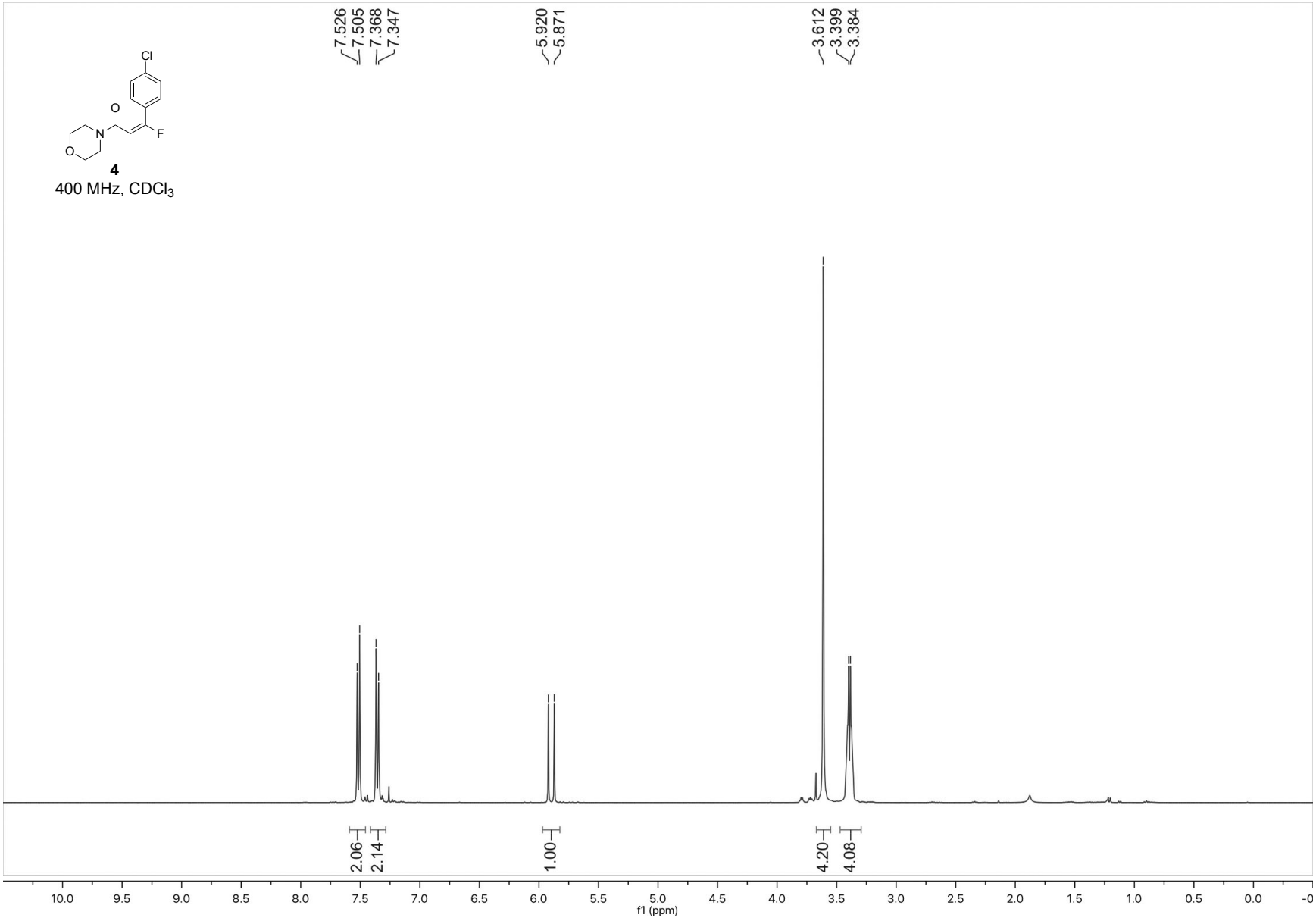
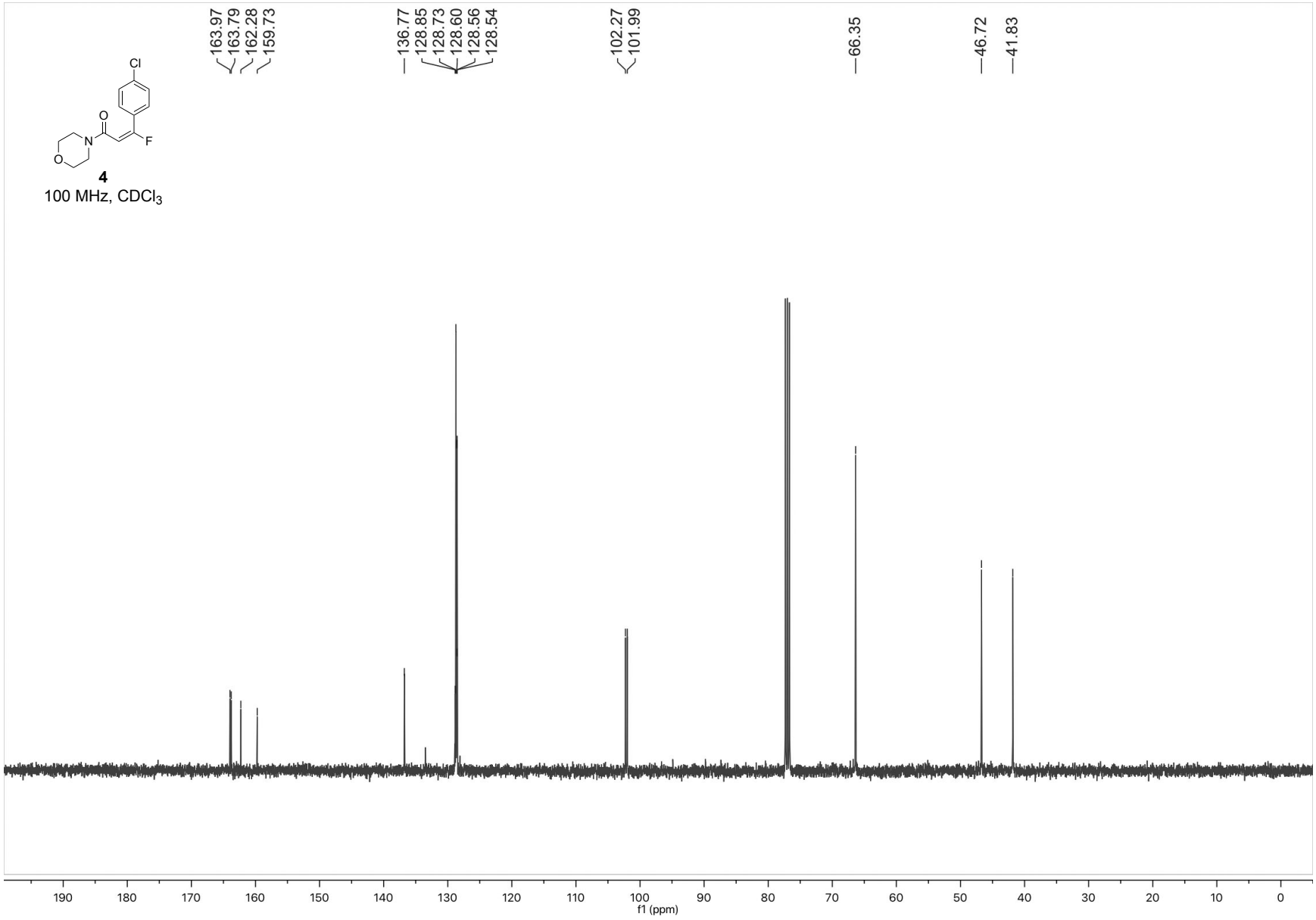
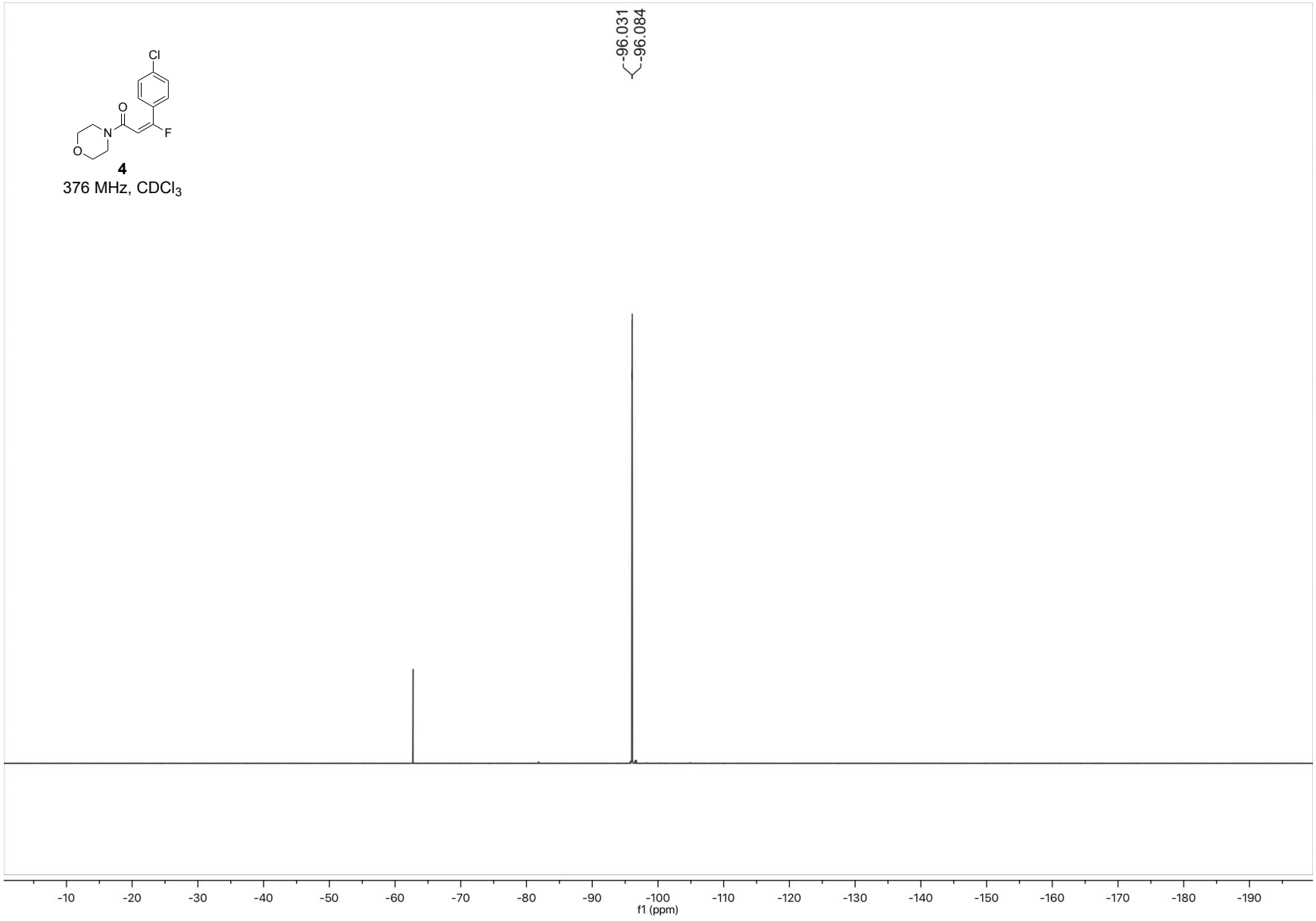
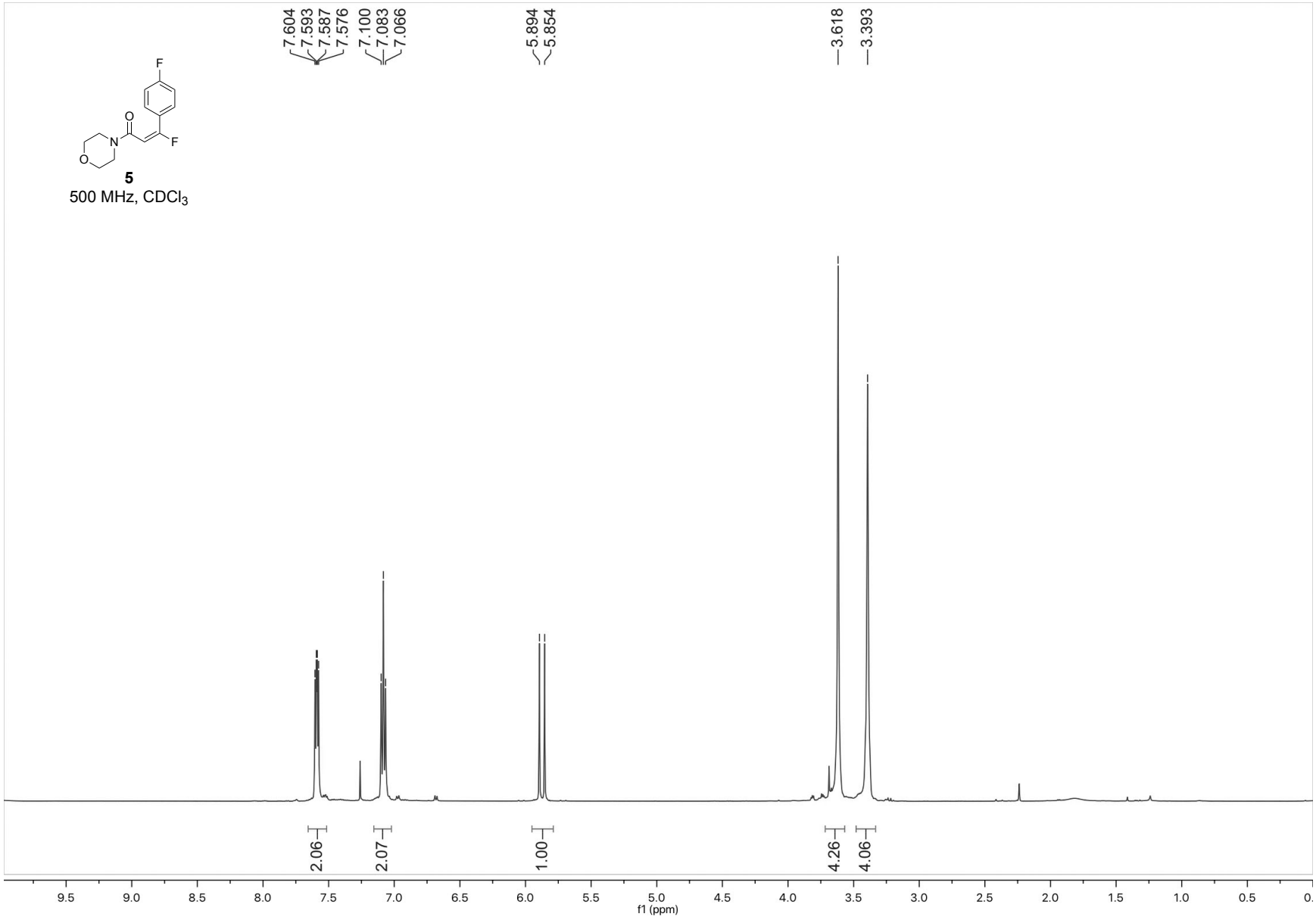
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

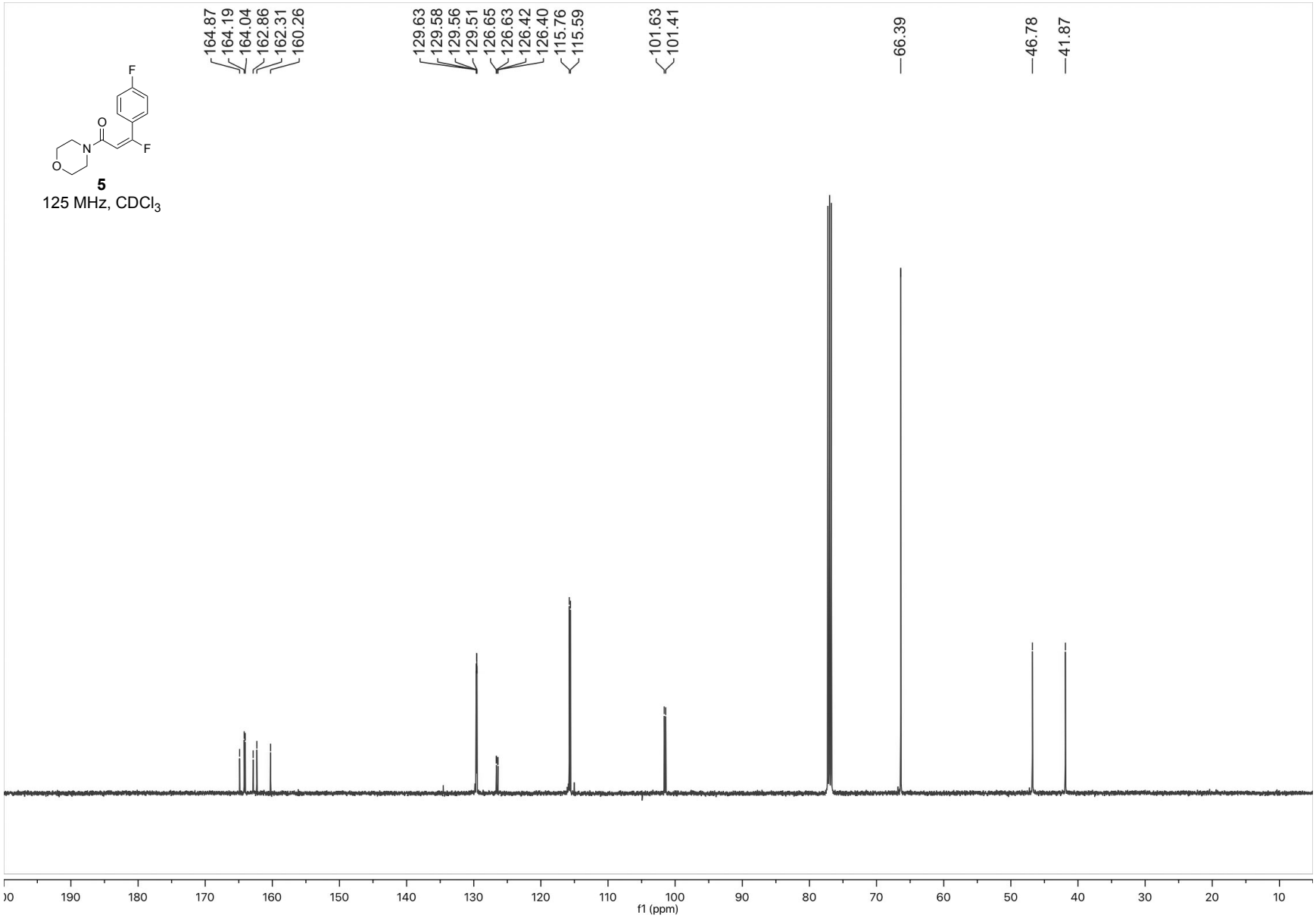

-96.303
-96.344
CH3
O
N
O
F
3
471 MHz, CDCl3
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)

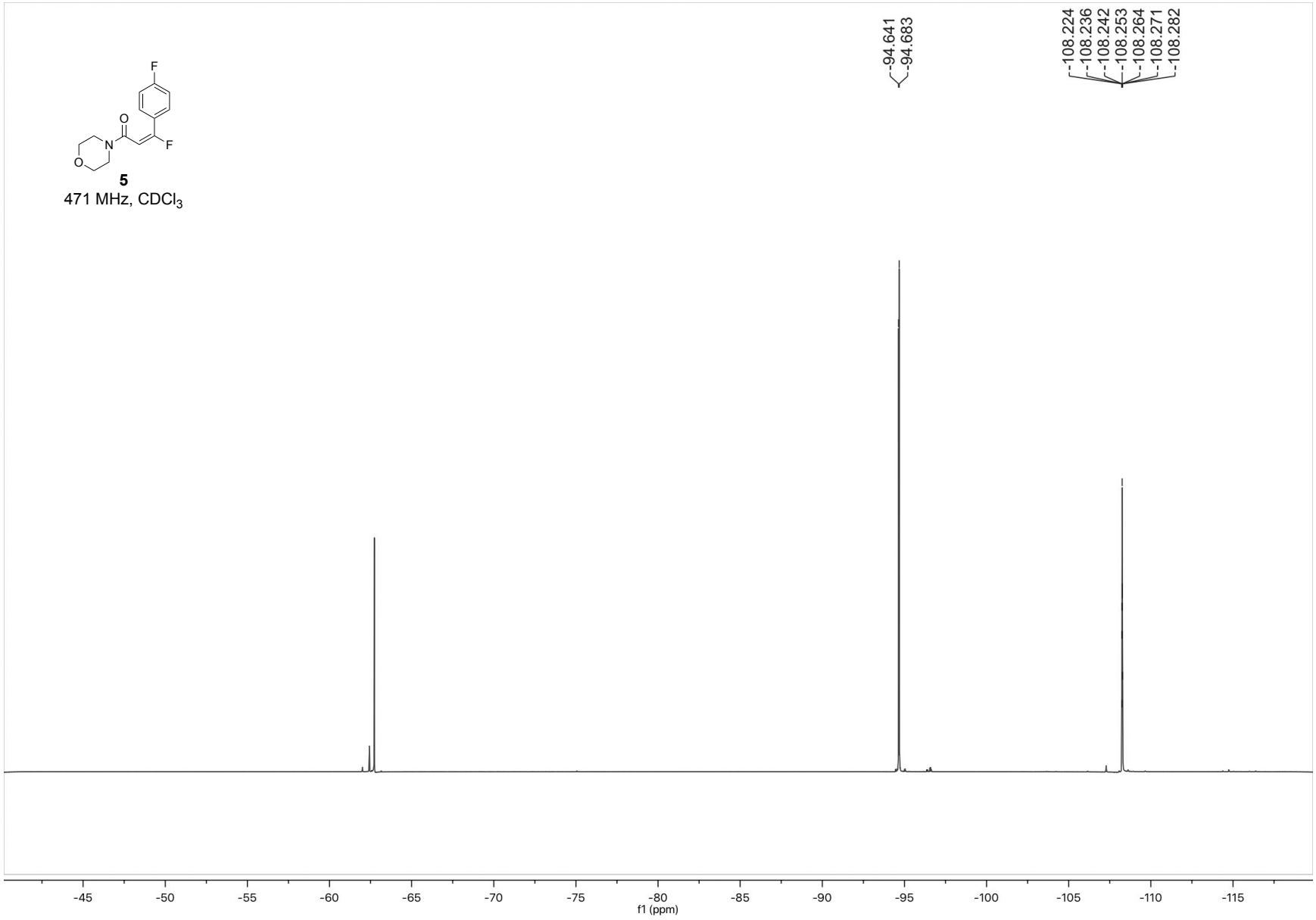

Cl
O
N
O
F
4
400 MHz, CDCl3
7.526
7.505
7.368
7.347
5.920
5.871
3.612
3.399
3.384
2.06
2.14
1.00
4.20
4.08
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

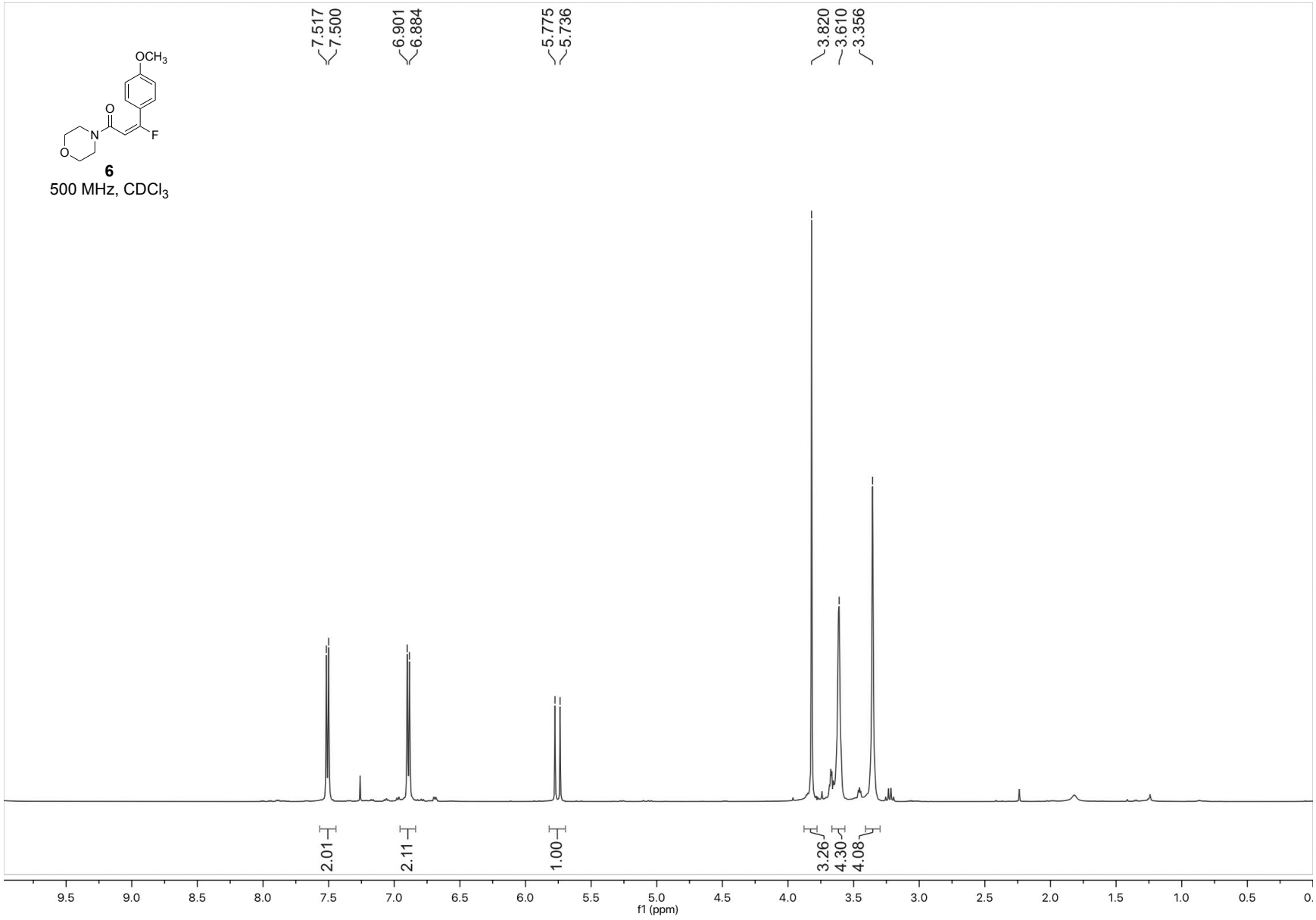

163.97
163.79
162.28
159.73
136.77
128.85
128.73
128.60
128.56
128.54
102.27
101.99
66.35
46.72
41.83
Cl
O
N
O
F
4
100 MHz, CDCl3
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

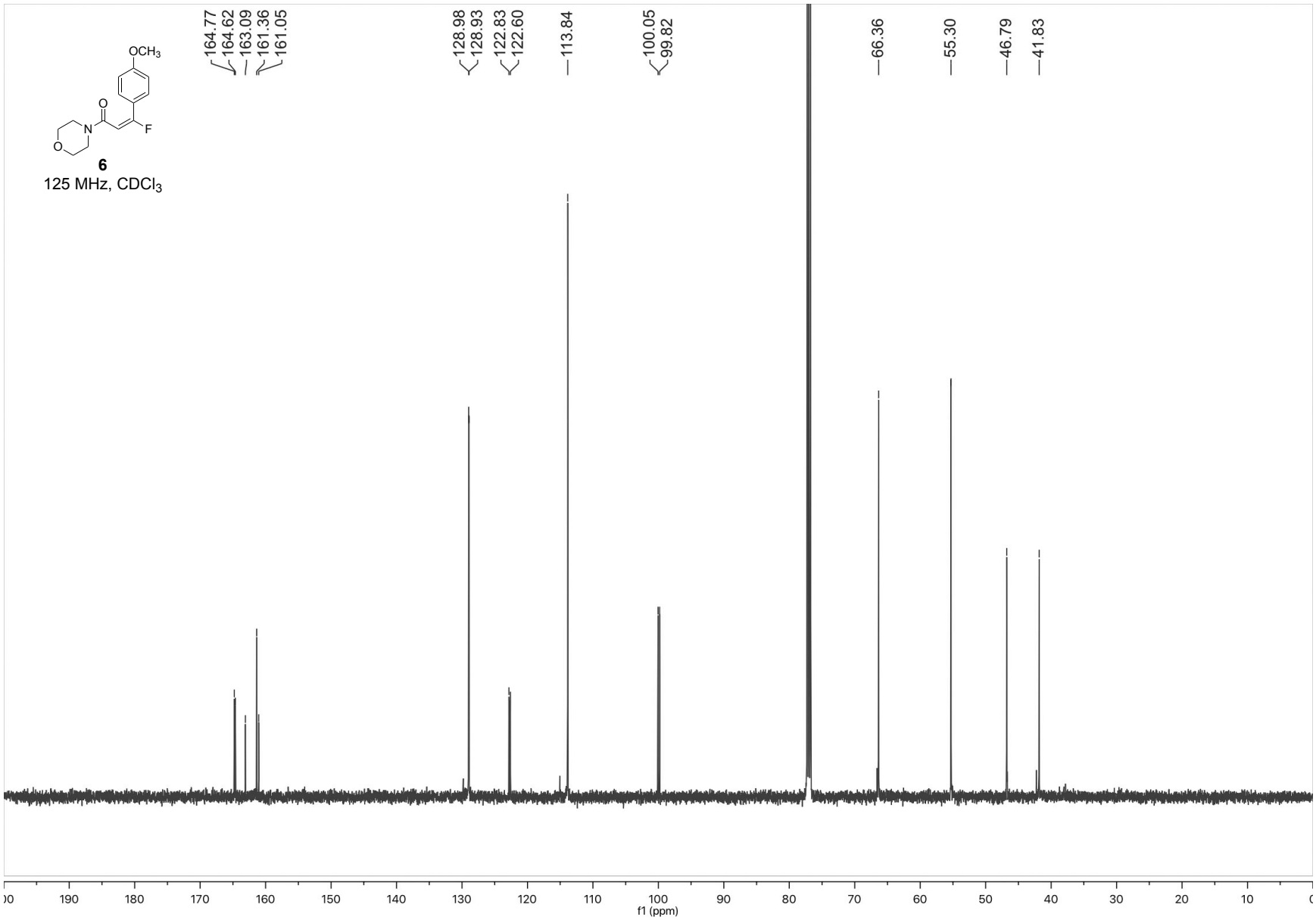

Cl
O
N
O
F
4
376 MHz, CDCl3
-96.031
-96.084
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)

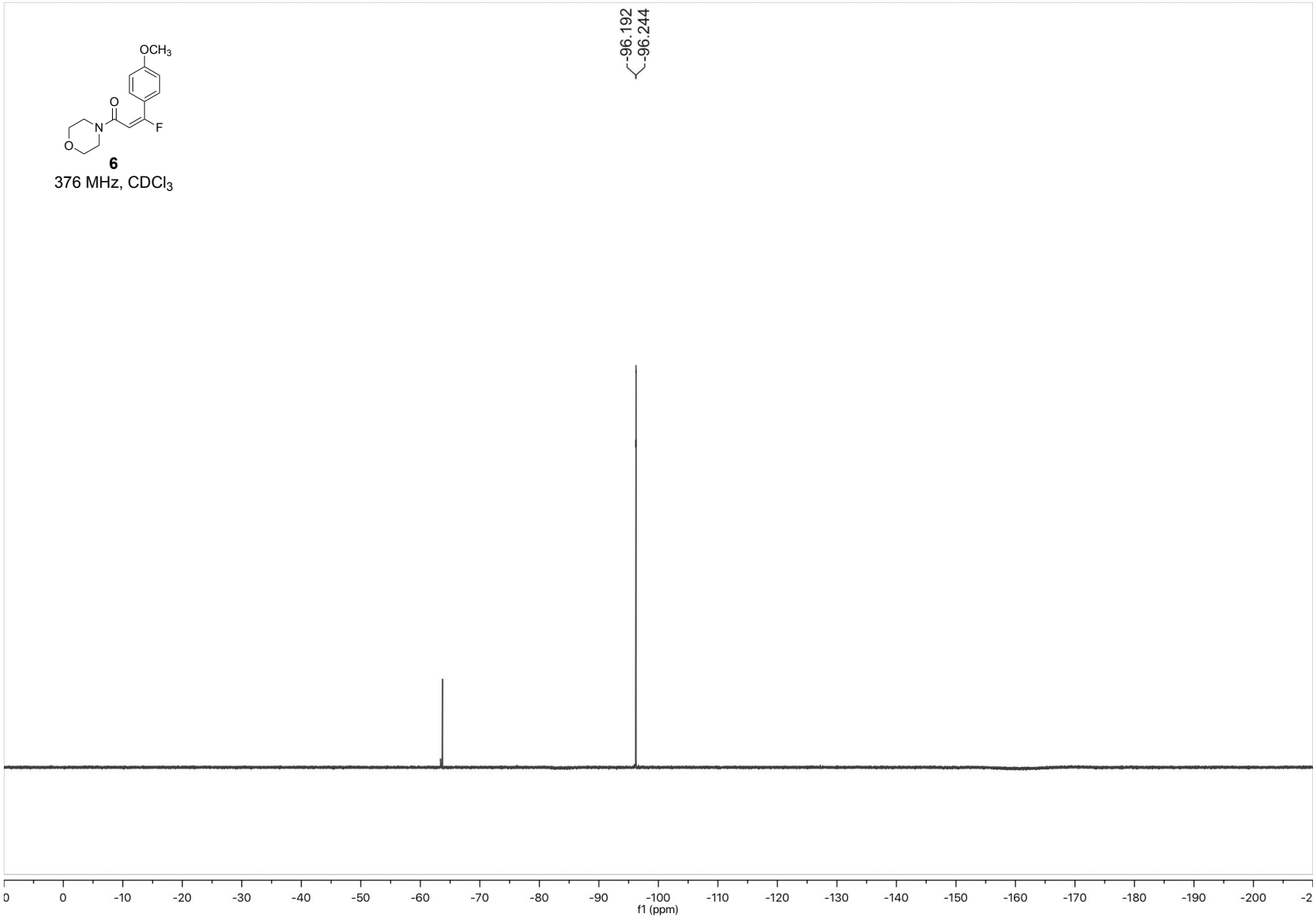

7.604
7.593
7.587
7.576
7.100
7.083
7.066
5.894
5.854
3.618
3.393
F
O
N
O
F
5
500 MHz, CDCl3
2.06
2.07
1.00
4.26
4.06
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

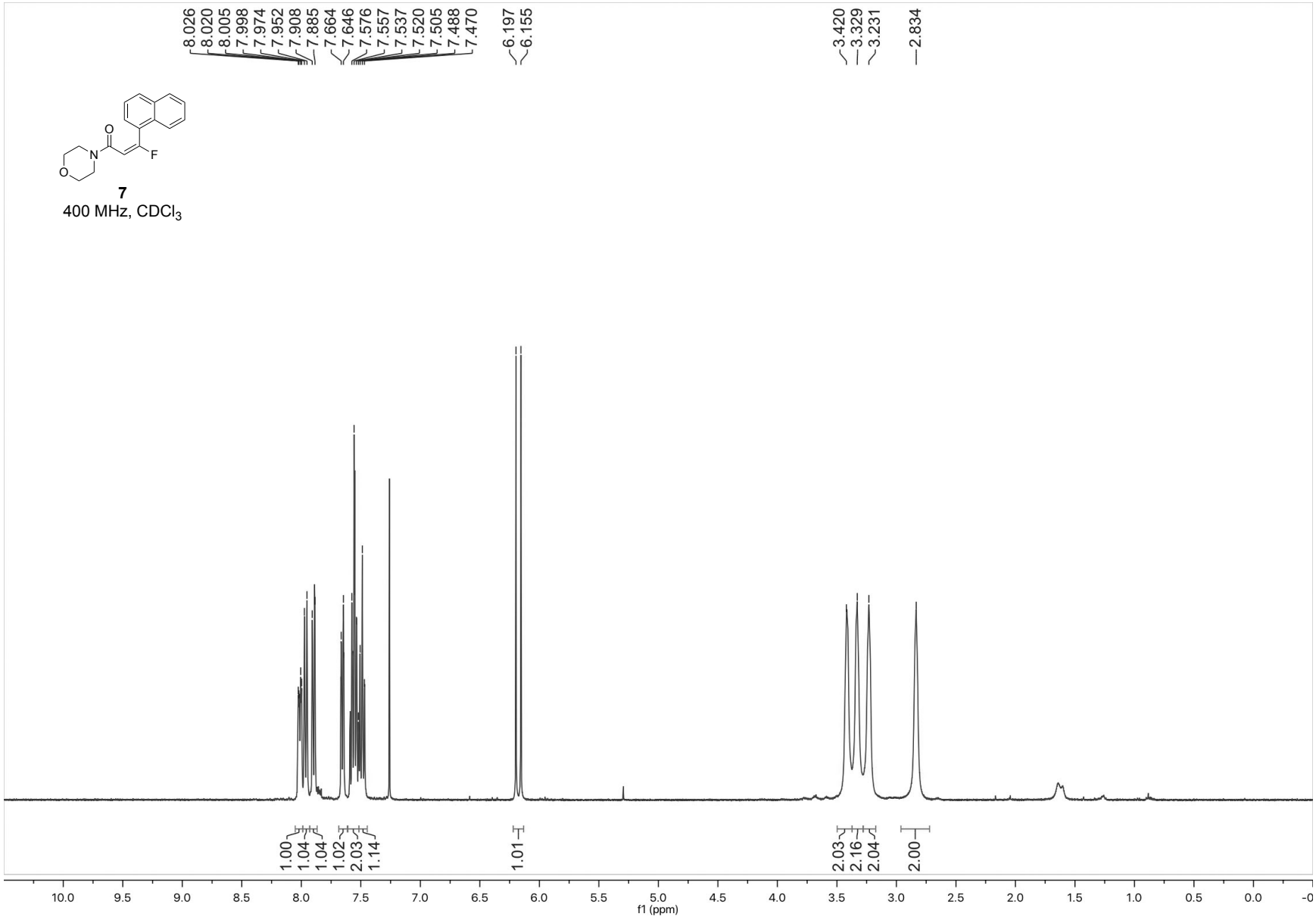

164.87
164.19
164.04
162.86
162.31
160.26
129.63
129.58
129.56
129.51
126.65
126.63
126.42
126.40
115.76
115.59
101.63
101.41
66.39
46.78
41.87
F
O
N
O
F
5
125 MHz, CDCl3
f1 (ppm)

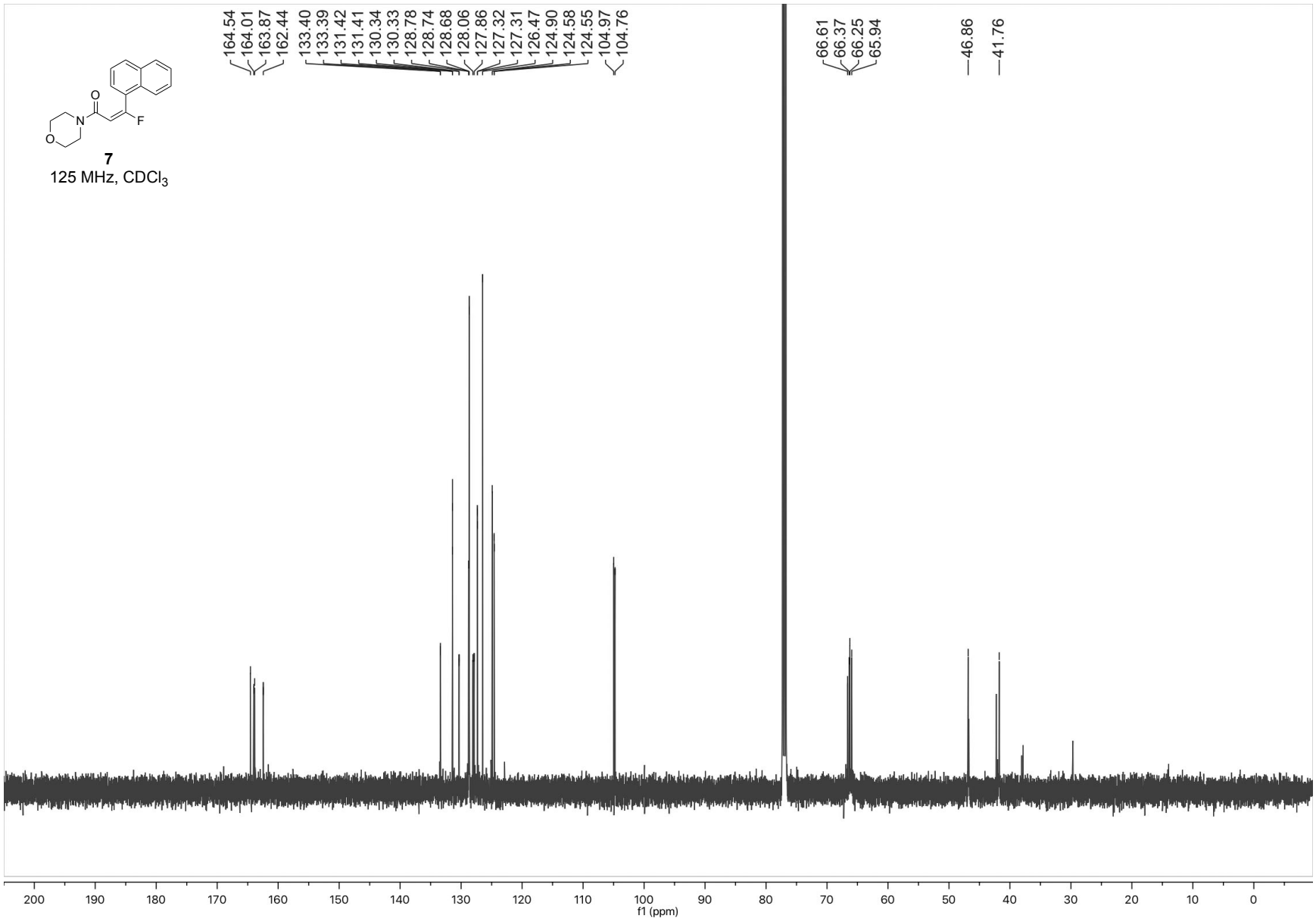

F
O
N
O
F
5
471 MHz, CDCl3
-94.641
-94.683
-108.224
-108.236
-108.242
-108.253
-108.264
-108.271
-108.282
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
-110
-115
f1 (ppm)

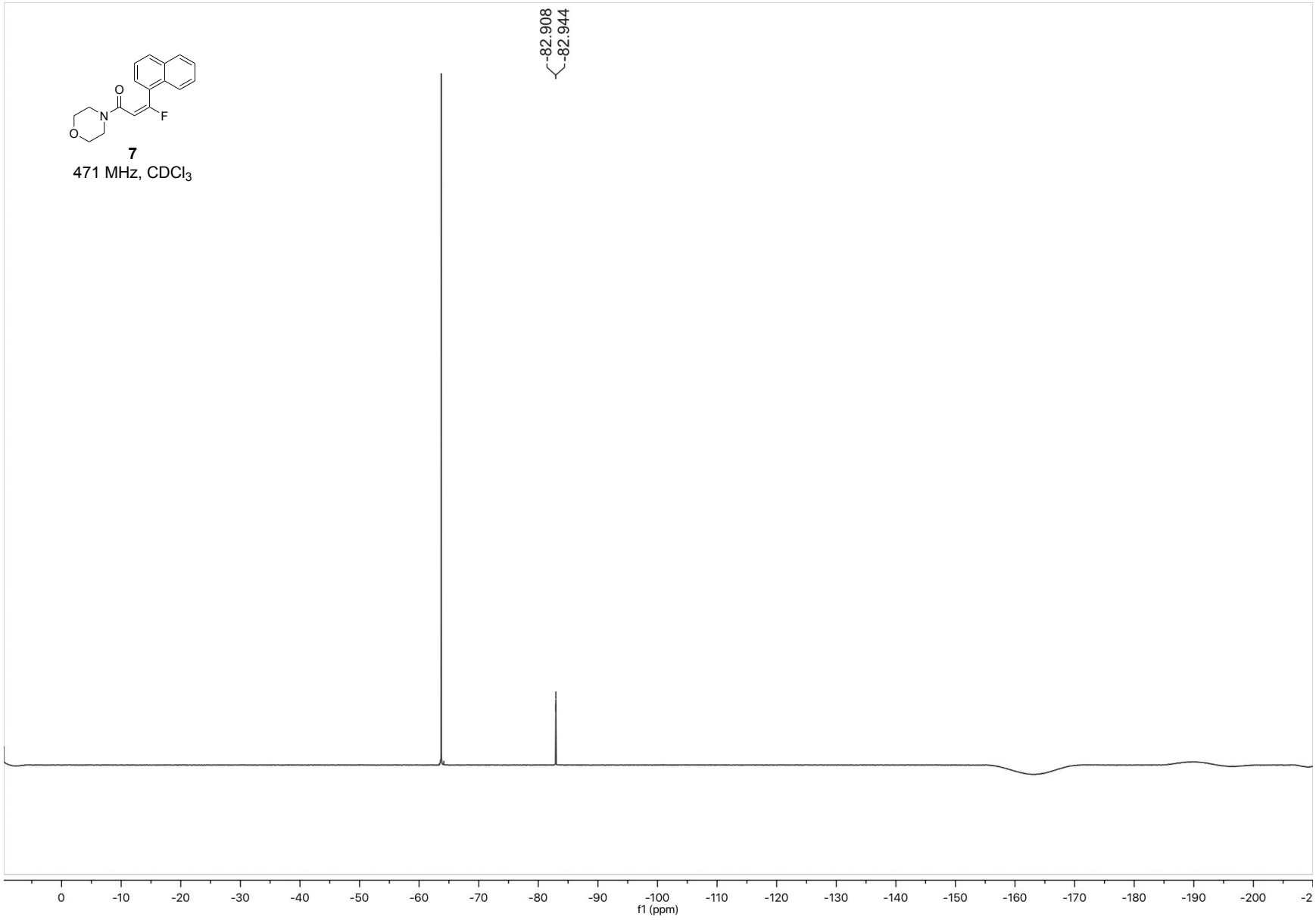

7.517
7.500
6.901
6.884
5.775
5.736
3.820
3.610
3.356
OCH3
O
N
O
F
6
500 MHz, CDCl3
2.01
2.11
1.00
3.26
4.30
4.08
f1 (ppm)

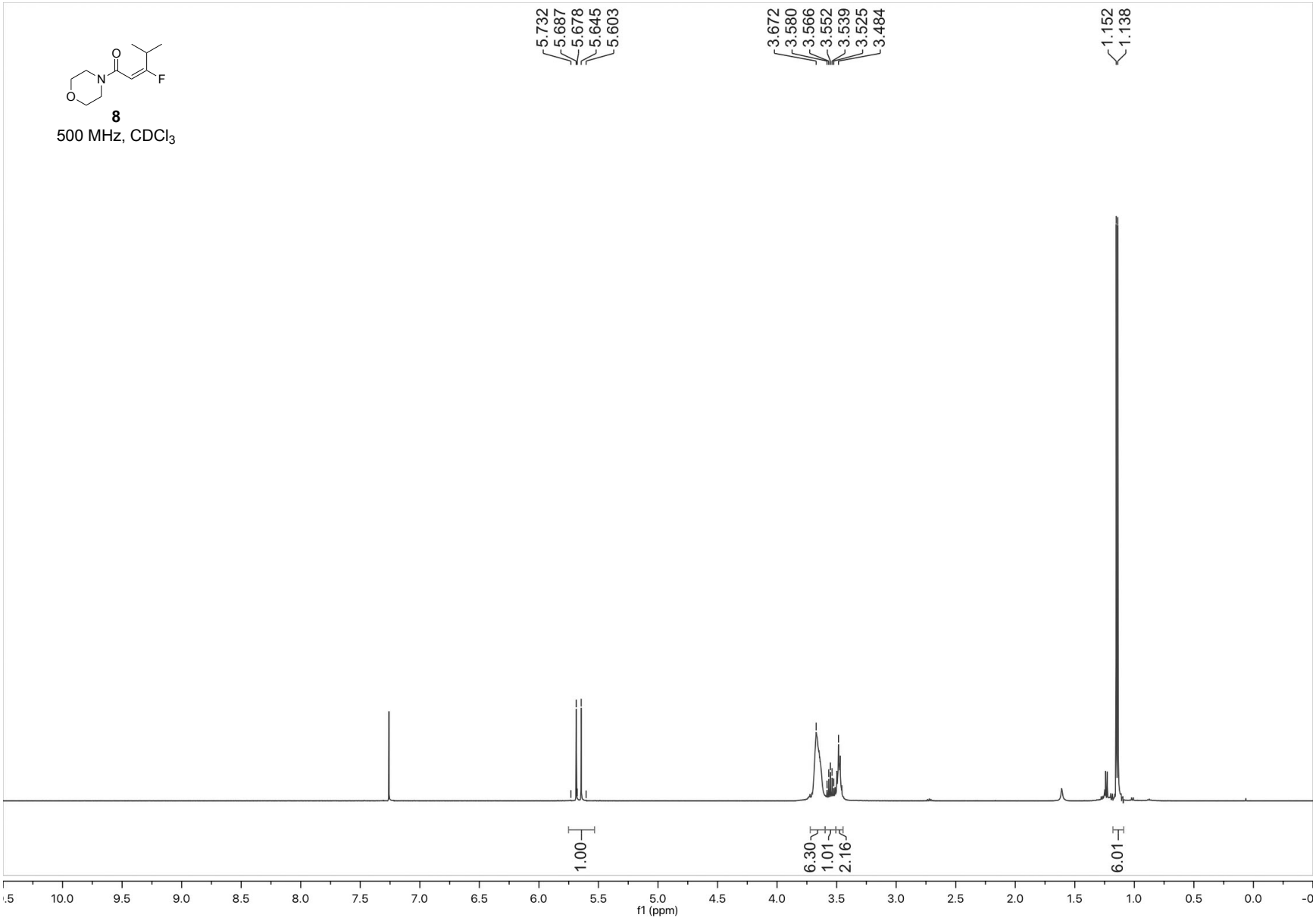

OCH3
O
N
O
F
6
125 MHz, CDCl3
164.77
164.62
163.09
161.36
161.05
128.98
128.93
122.83
122.60
113.84
100.05
99.82
66.36
55.30
46.79
41.83
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

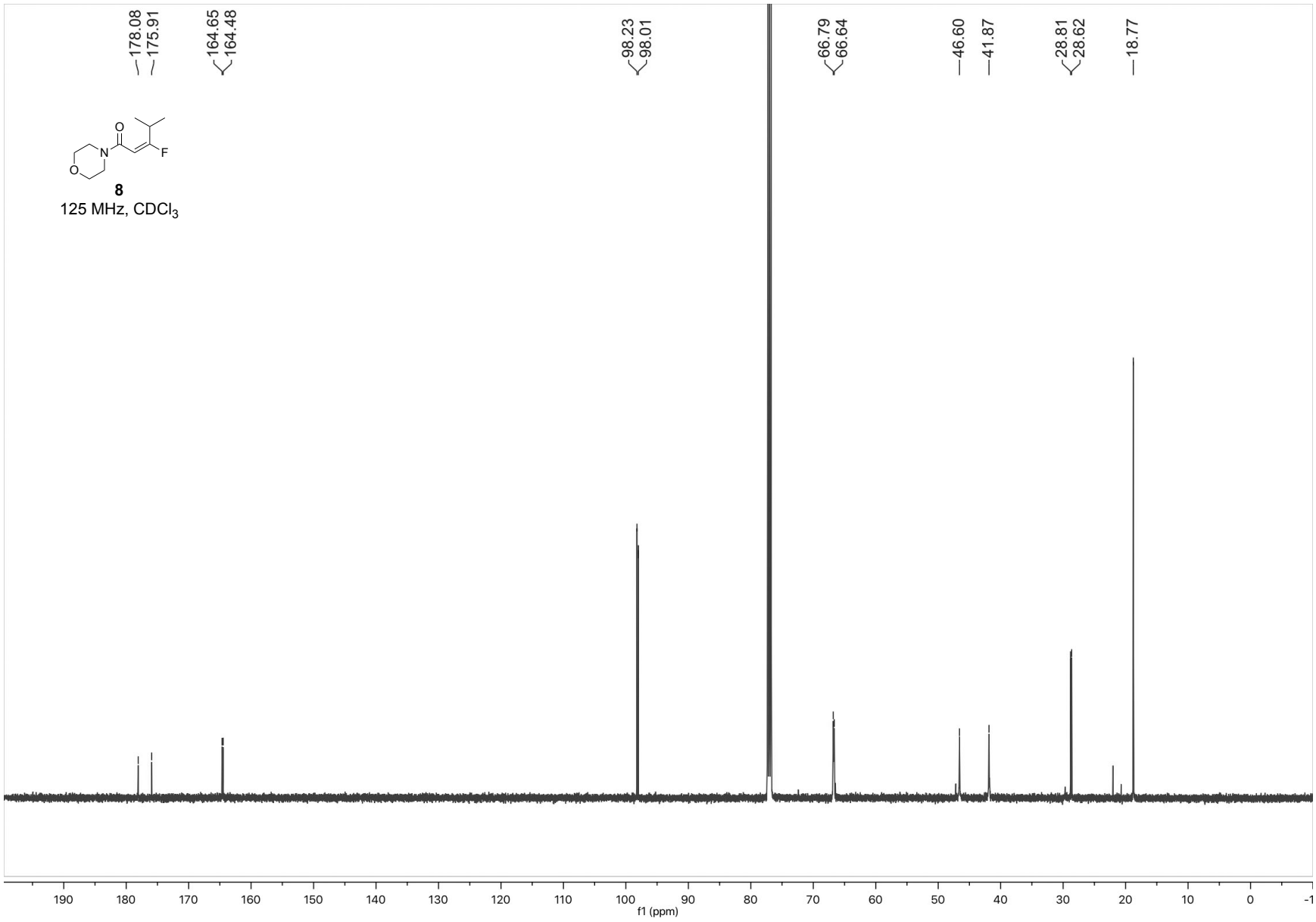

OCH3
O
N
O
F
6
376 MHz, CDCl3
-96.192
-96.244
0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-2
f1 (ppm)

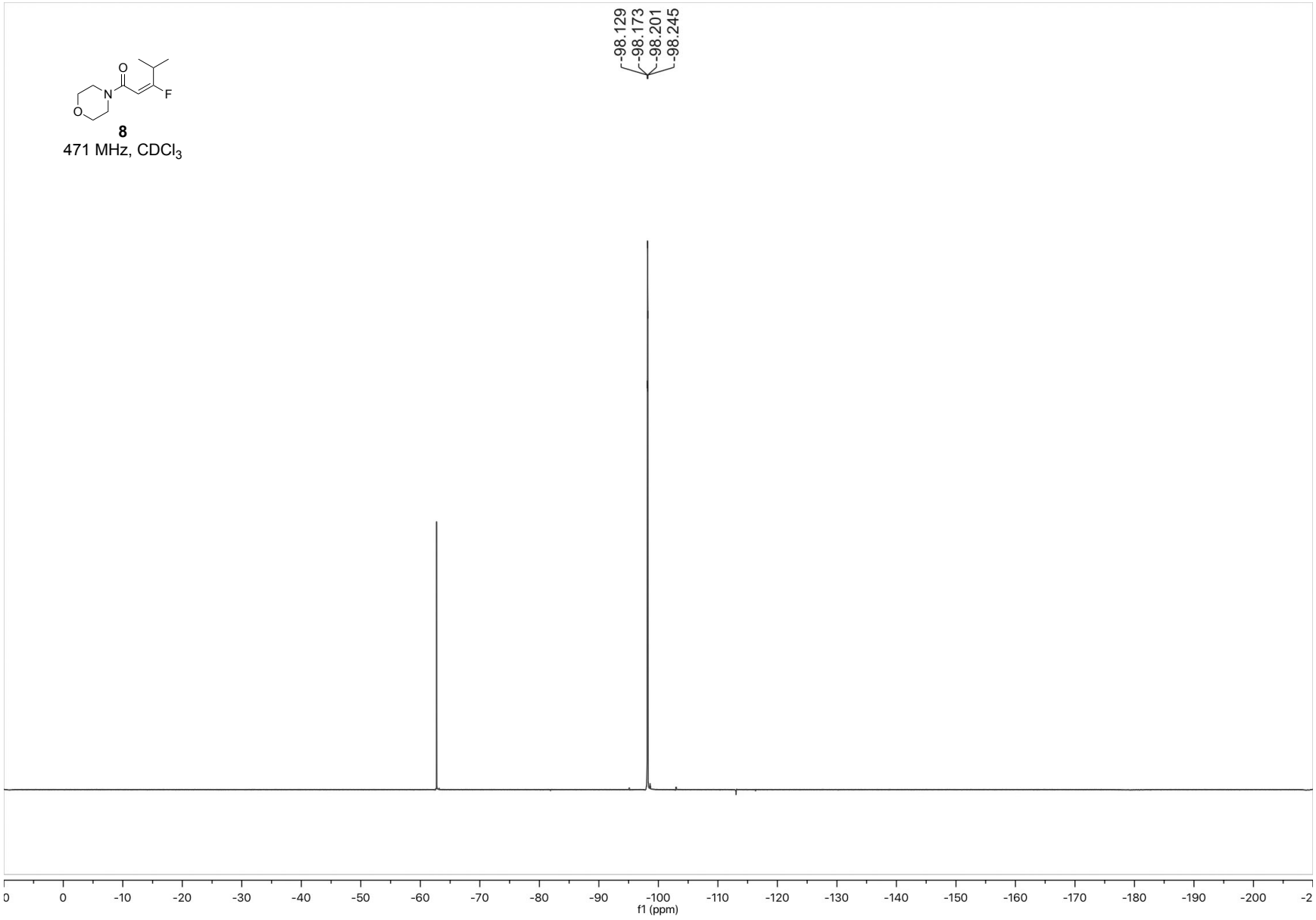

8.026
8.020
8.005
7.998
7.974
7.952
7.908
7.885
7.664
7.646
7.576
7.557
7.537
7.520
7.505
7.488
7.470
6.197
6.155
3.420
3.329
3.231
2.834
O
N
O
F
7
400 MHz, CDCl3
1.00
1.04
1.04
1.02
2.03
1.14
1.01
2.03
2.16
2.04
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

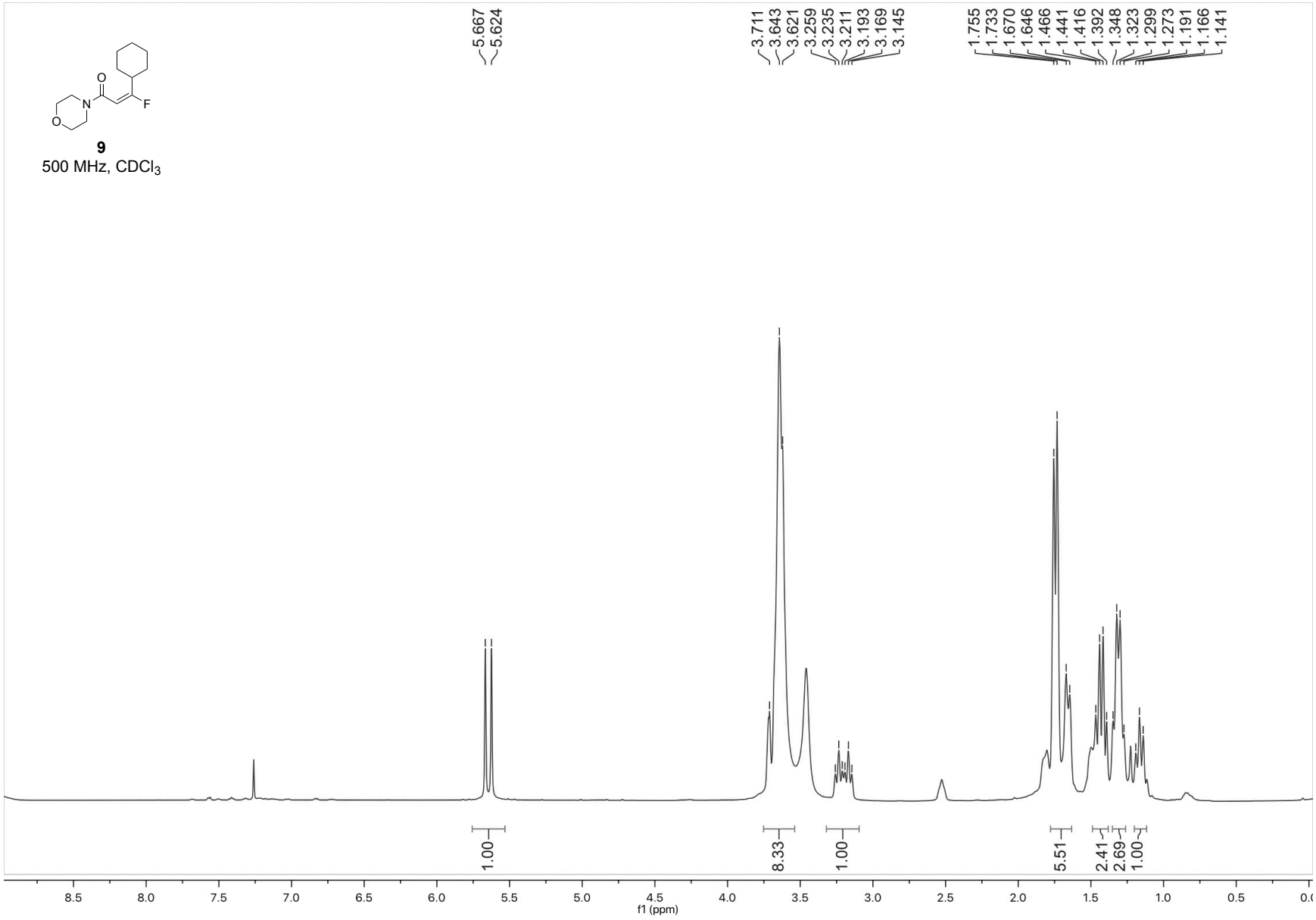

164.54
164.01
163.87
162.44
133.40
133.39
131.42
131.41
130.34
130.33
128.78
128.74
128.68
128.06
127.86
127.32
127.31
126.47
124.90
124.58
124.55
104.97
104.76
66.61
66.37
66.25
65.94
46.86
41.76
O
N
O
F
7
125 MHz, CDCl3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

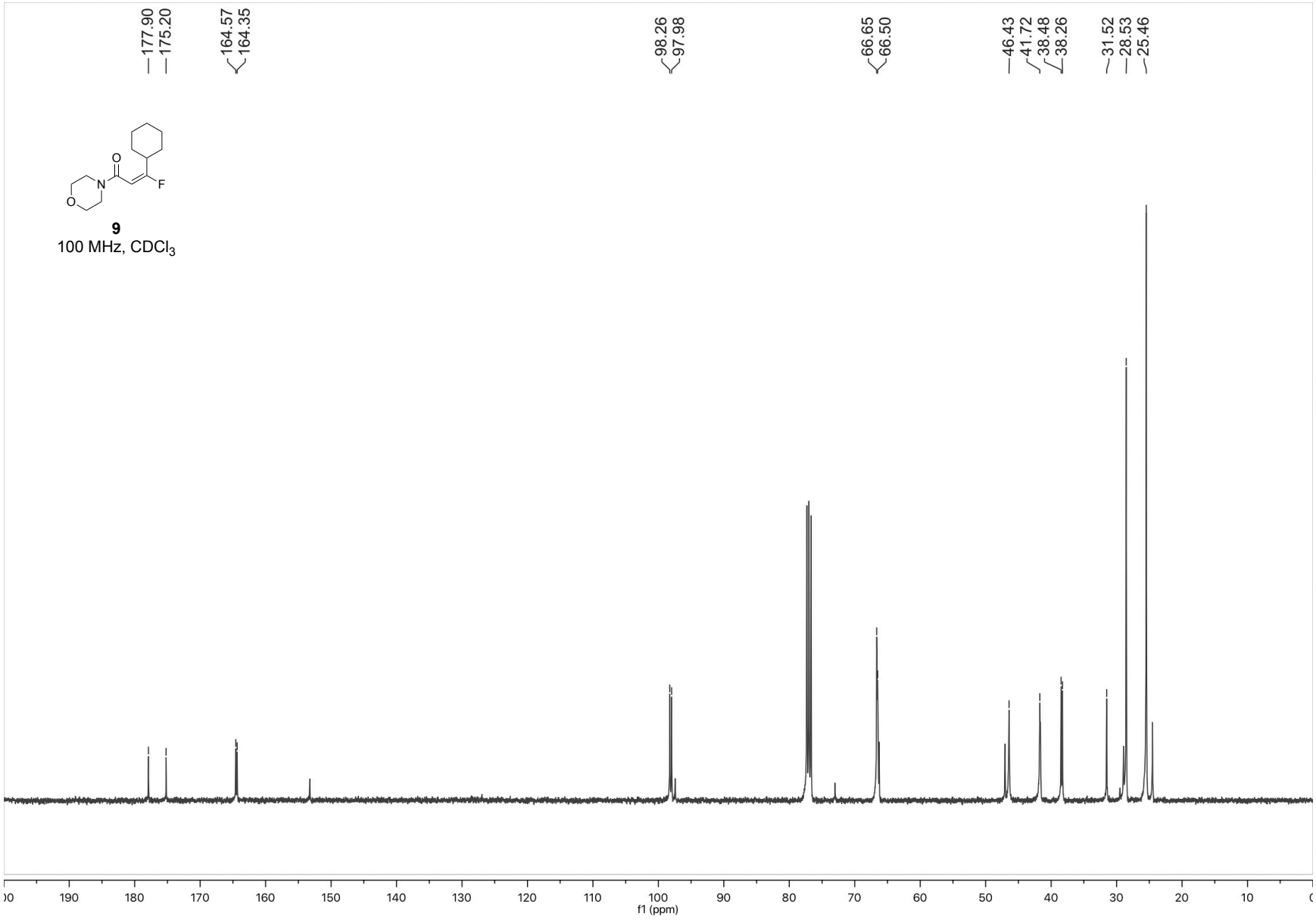

-82.908
-82.944
O
N
O
F
7
471 MHz, CDCl3
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
f1 (ppm)

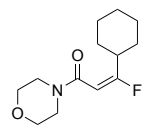

5.732
5.687
5.678
5.645
5.603
3.672
3.580
3.566
3.552
3.539
3.525
3.484
1.152
1.138
O
N
O
F
8
500 MHz, CDCl3
1.00
6.30
1.01
2.16
6.01
f1 (ppm)


178.08
175.91
164.65
164.48
98.23
98.01
66.79
66.64
46.60
41.87
28.81
28.62
18.77
O
N
O
F
8
125 MHz, CDCl3
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)


-98.129
-98.173
-98.201
-98.245
O
N
O
F
8
471 MHz, CDCl3
0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-2
f1 (ppm)

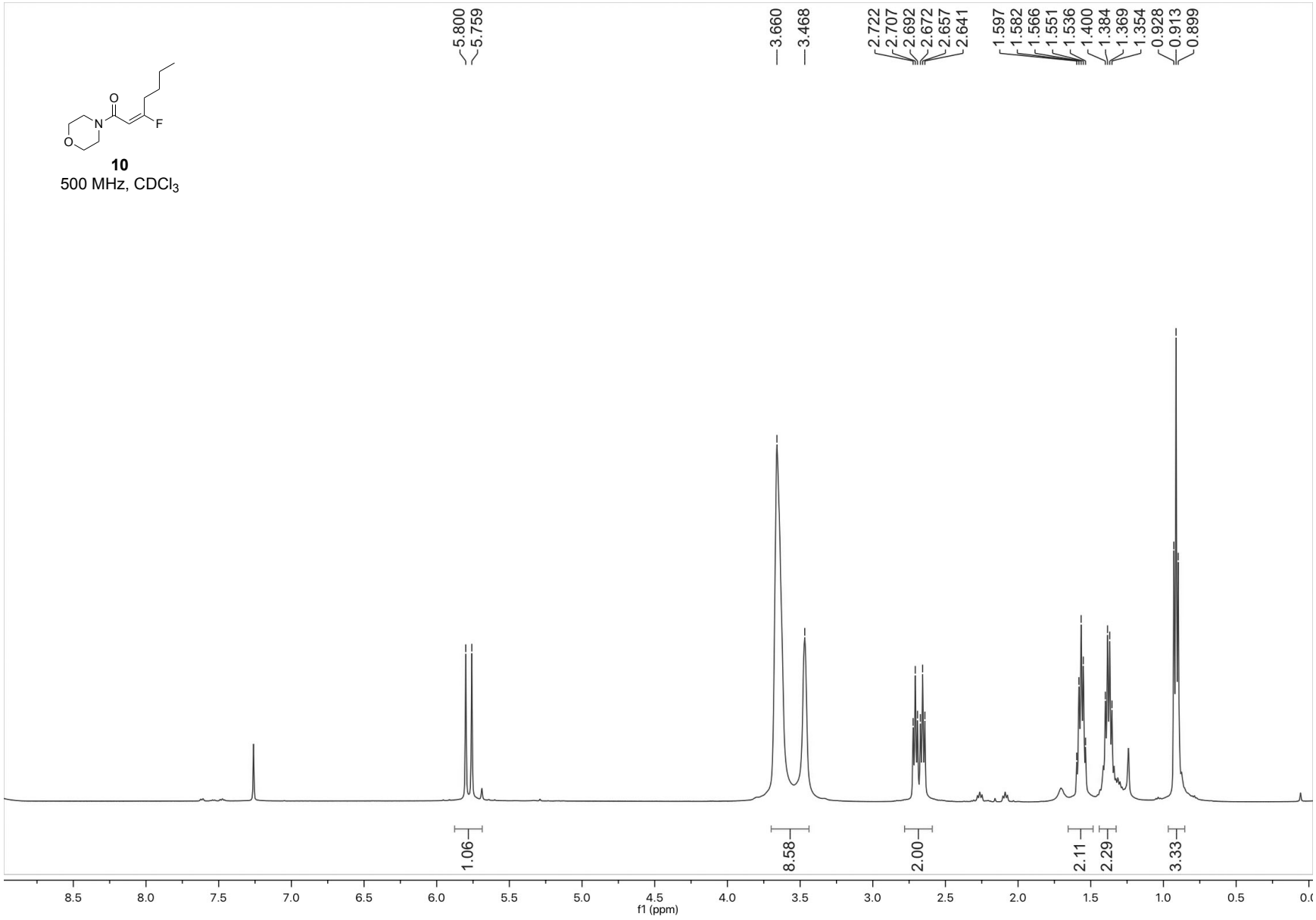

5.667
5.624
3.711
3.643
3.621
3.259
3.235
3.211
3.193
3.169
3.145
1.755
1.733
1.670
1.646
1.466
1.441
1.416
1.392
1.348
1.323
1.299
1.273
1.191
1.166
1.141
O
N
O
F
9
500 MHz, CDCl3
1.00
8.33
1.00
5.51
2.41
2.69
1.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

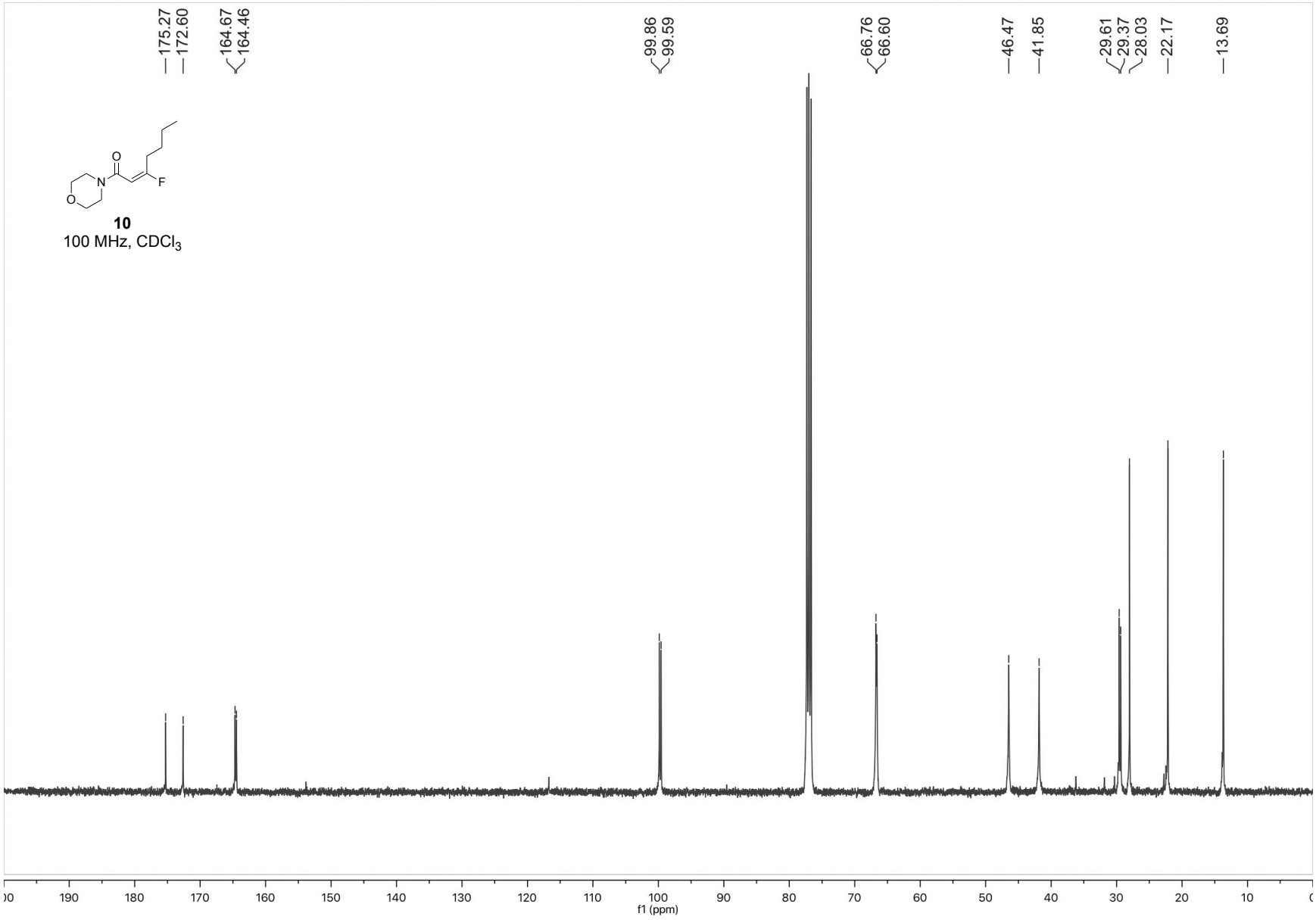

177.90
175.20
164.57
164.35
98.26
97.98
66.65
66.50
46.43
41.72
38.48
38.26
31.52
28.53
25.46
O
N
O
F
9
100 MHz, CDCl3
f1 (ppm)

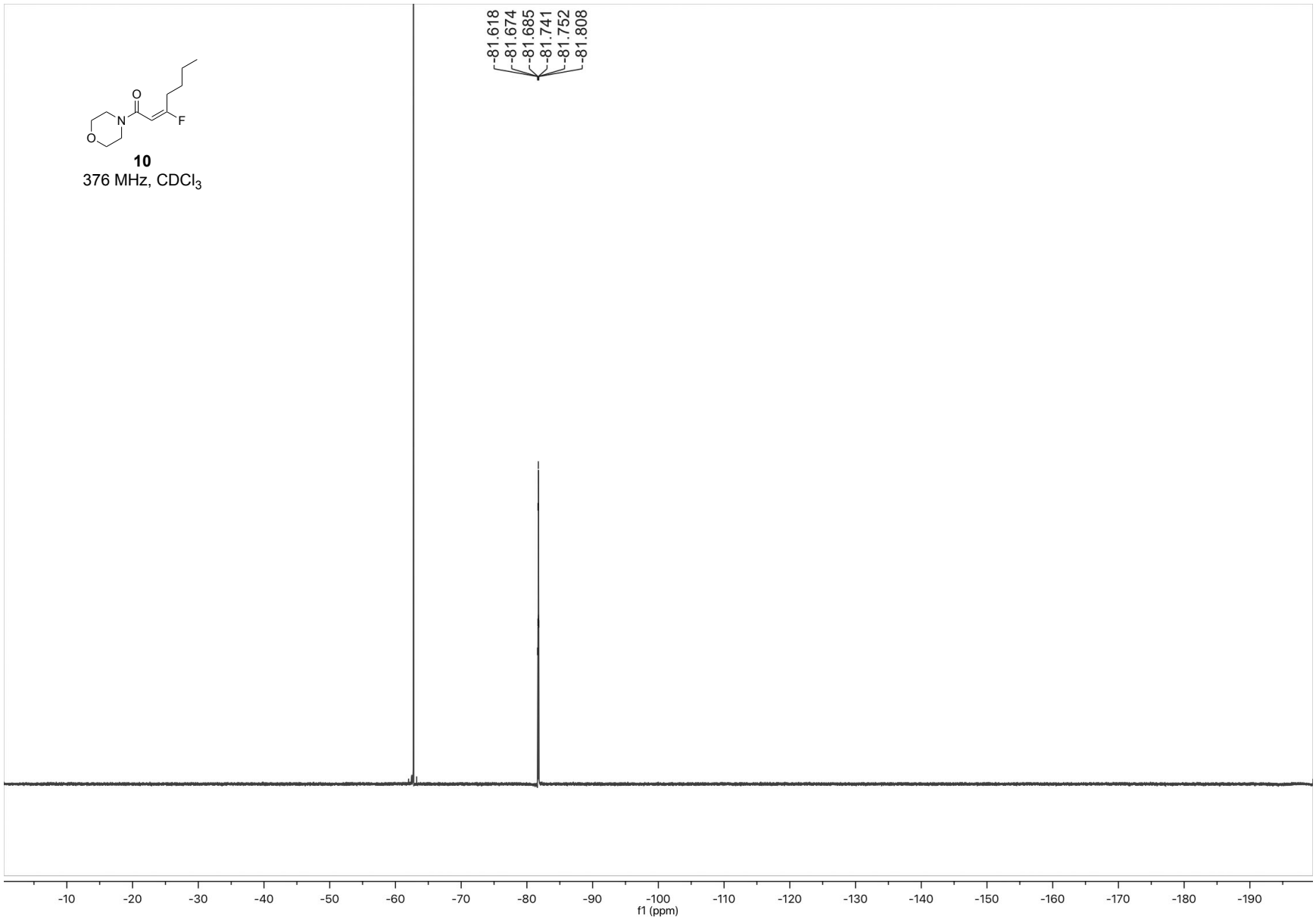


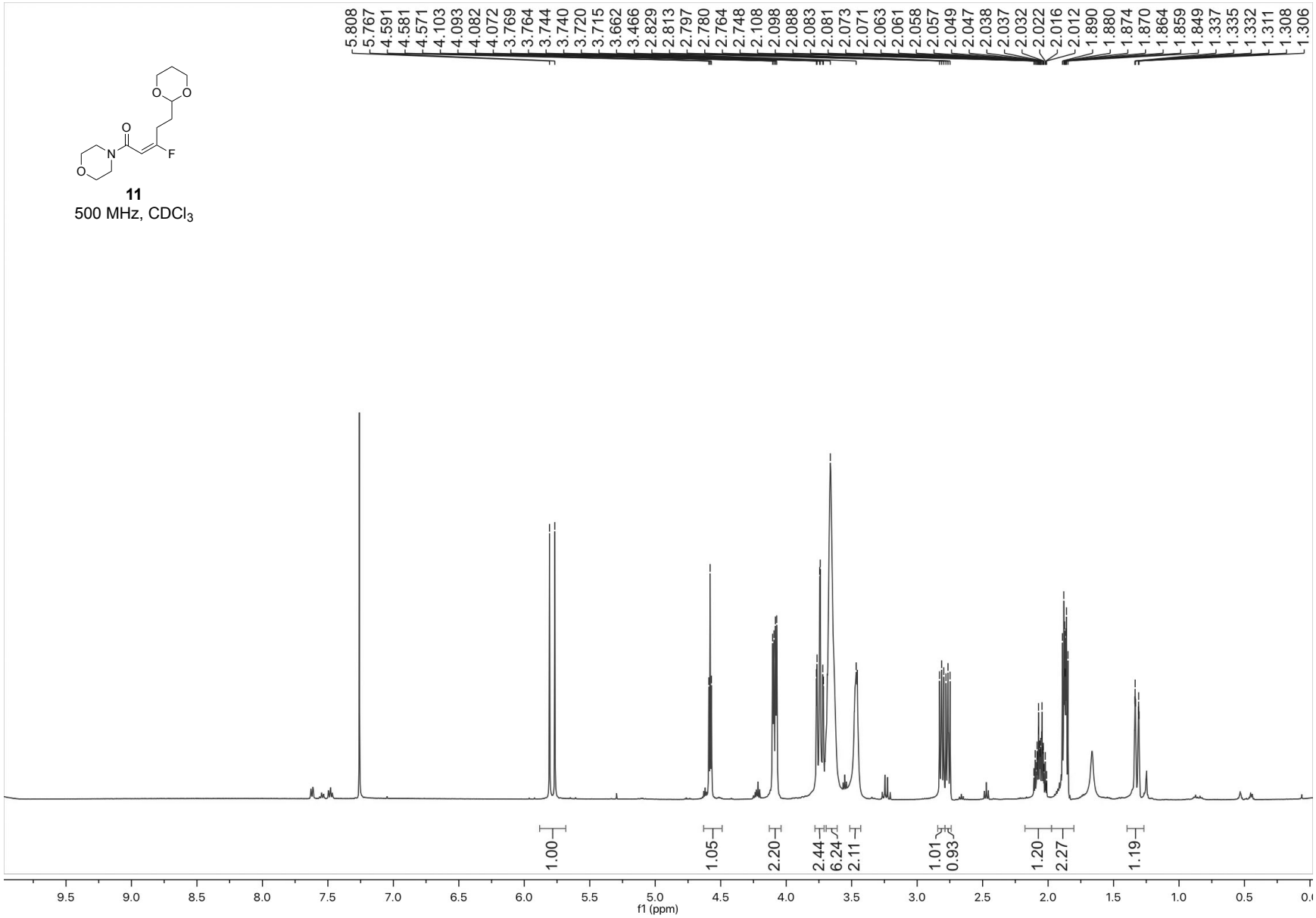
9

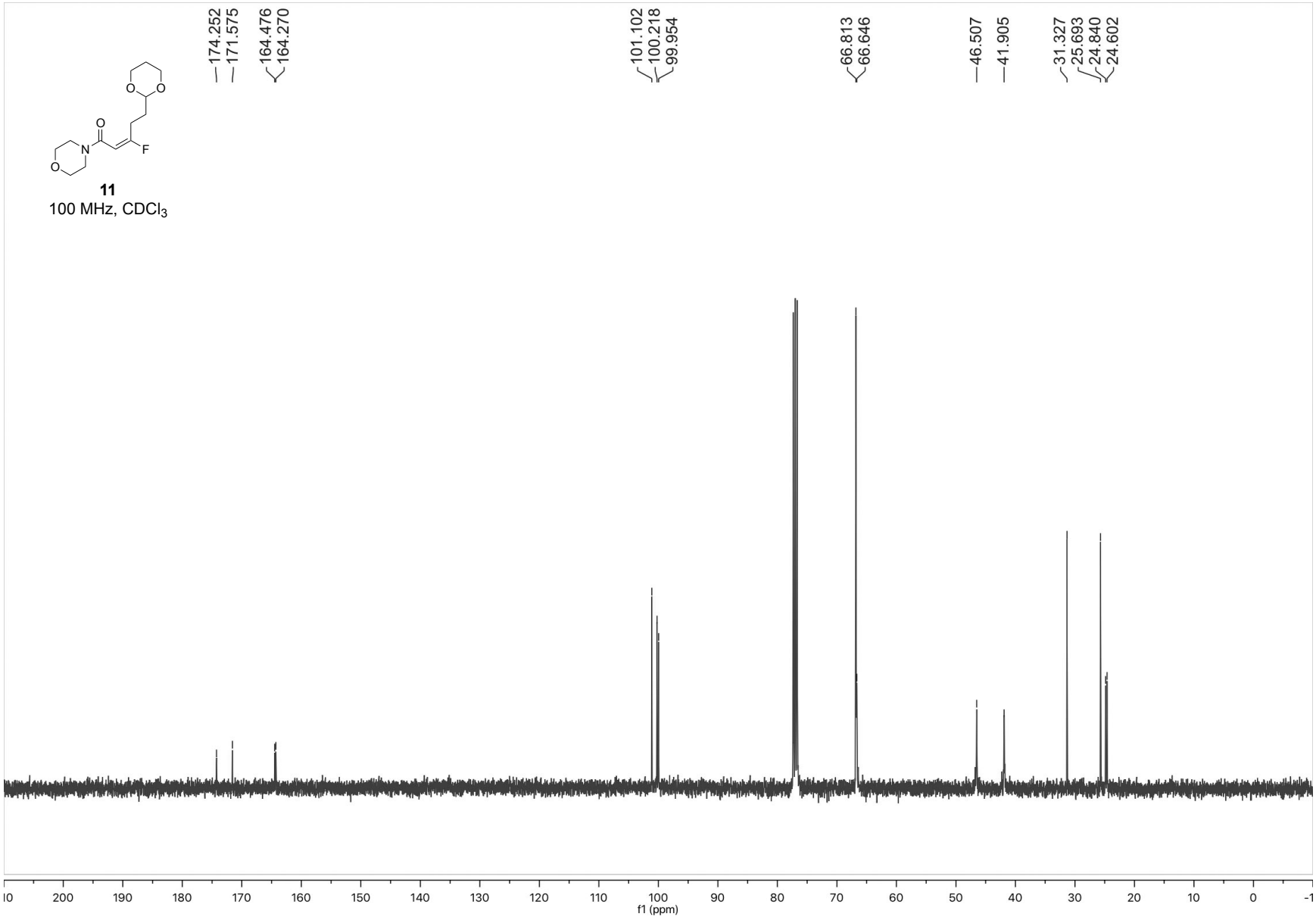
471 MHz, $CDCl_3$

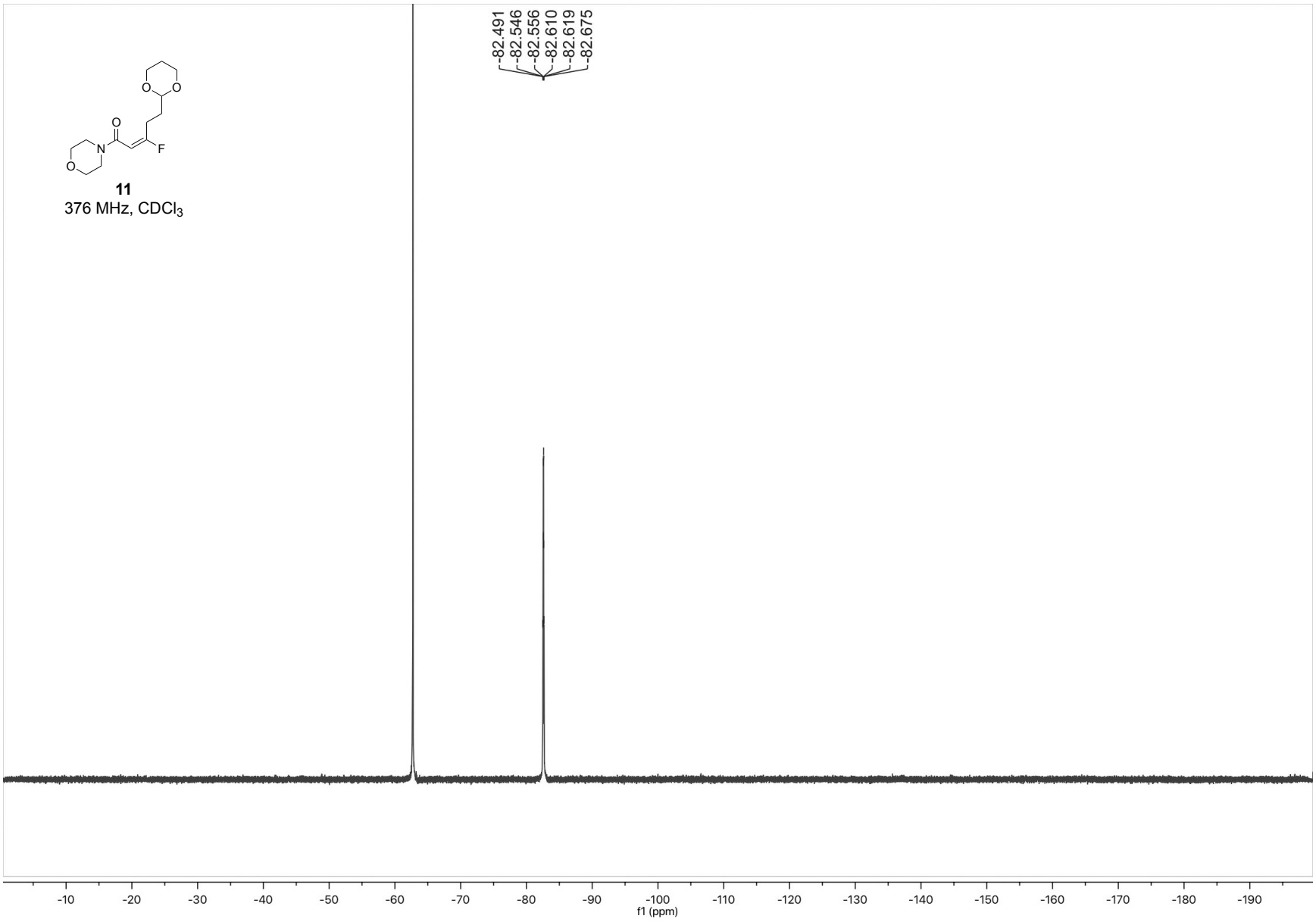

5.800
5.759
3.660
3.468
2.722
2.707
2.692
2.672
2.657
2.641
1.597
1.582
1.566
1.551
1.536
1.400
1.384
1.369
1.354
0.928
0.913
0.899
O
N
O
F
10
500 MHz, CDCl3
1.06
8.58
2.00
2.11
2.29
3.33
f1 (ppm)

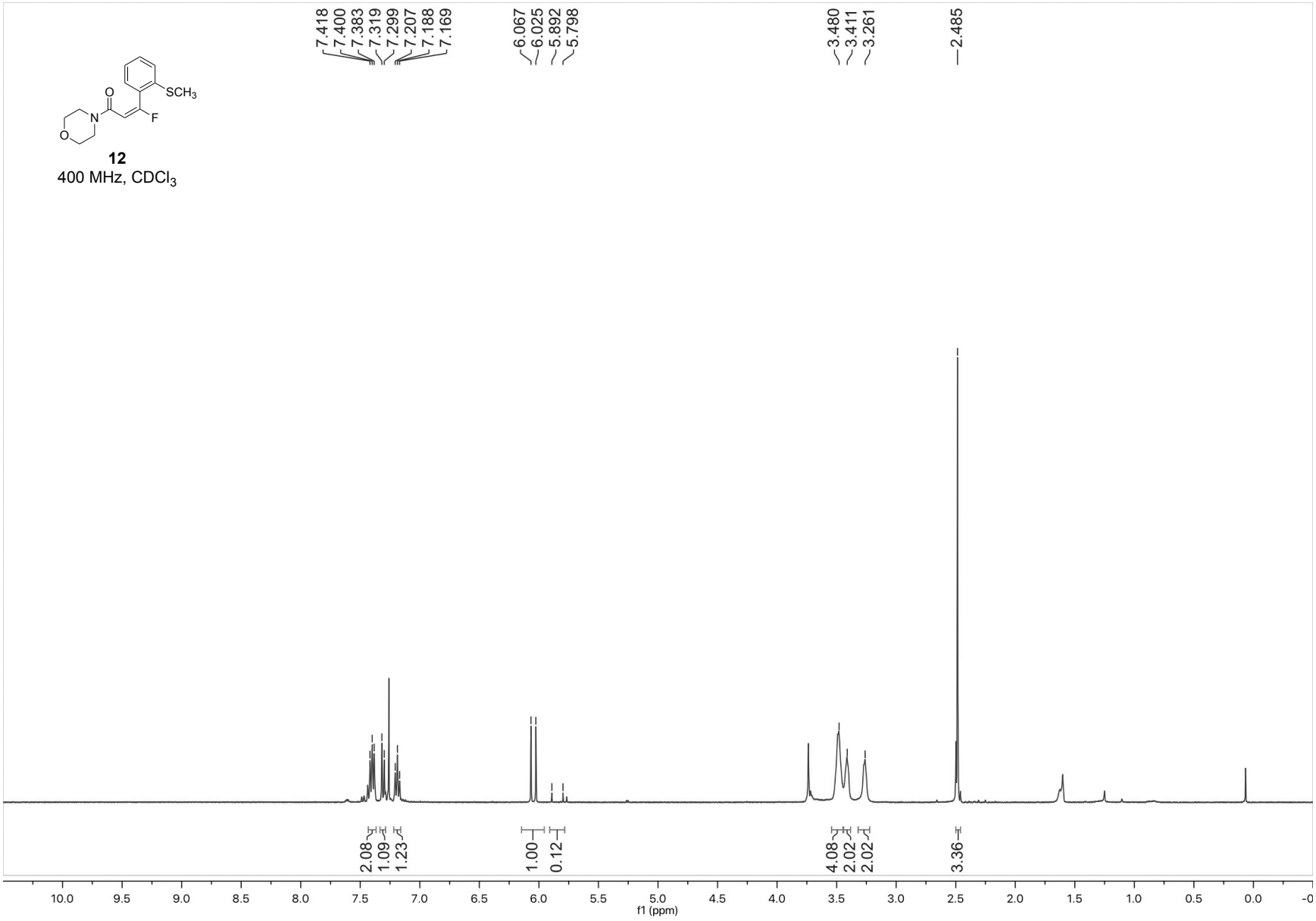

175.27
172.60
164.67
164.46
99.86
99.59
66.76
66.60
46.47
41.85
29.61
29.37
28.03
22.17
13.69
O
N
O
F
10
100 MHz, CDCl3
f1 (ppm)

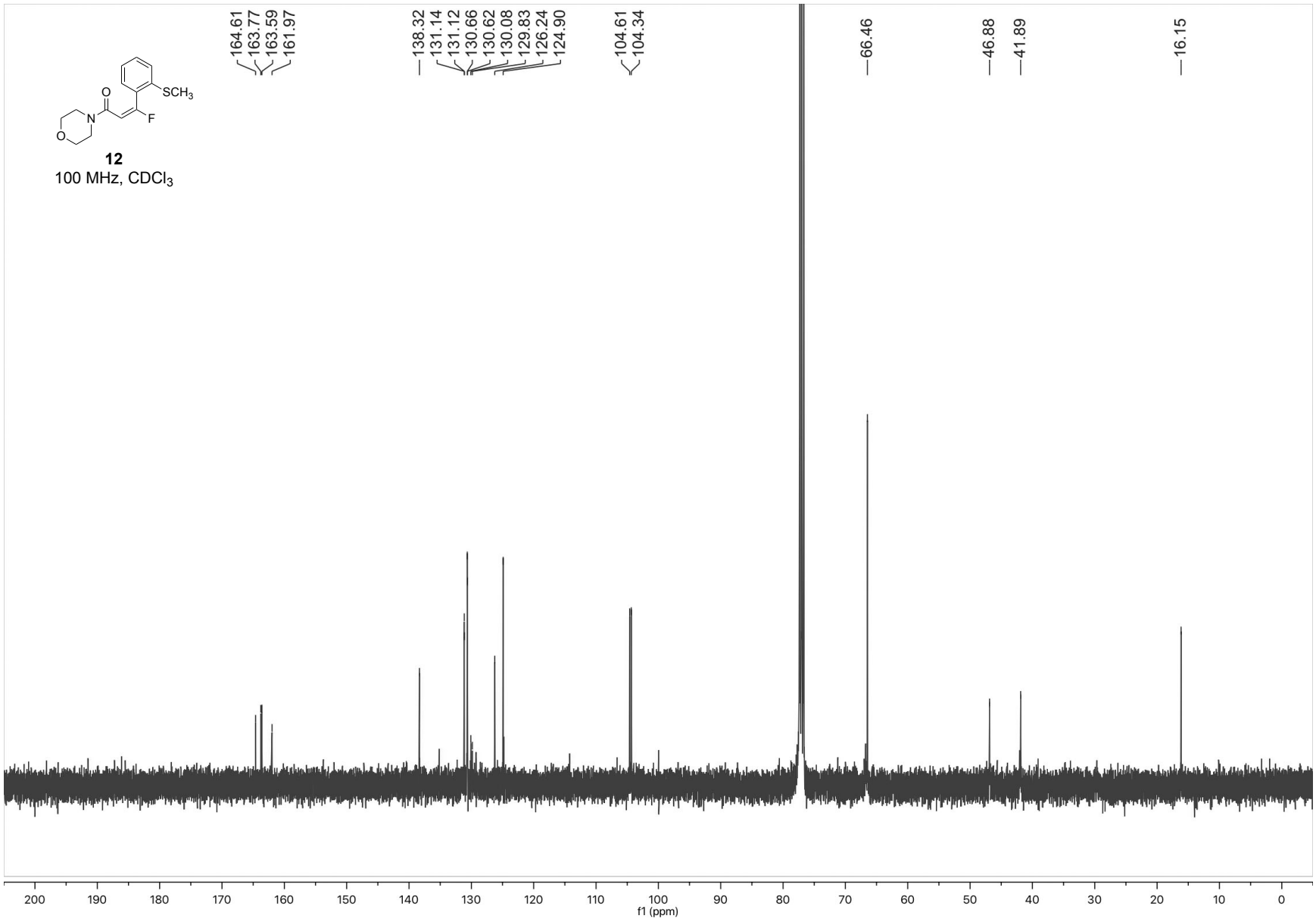

-81.618
-81.674
-81.685
-81.741
-81.752
-81.808
O
N
O
F
10
376 MHz, CDCl3
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)

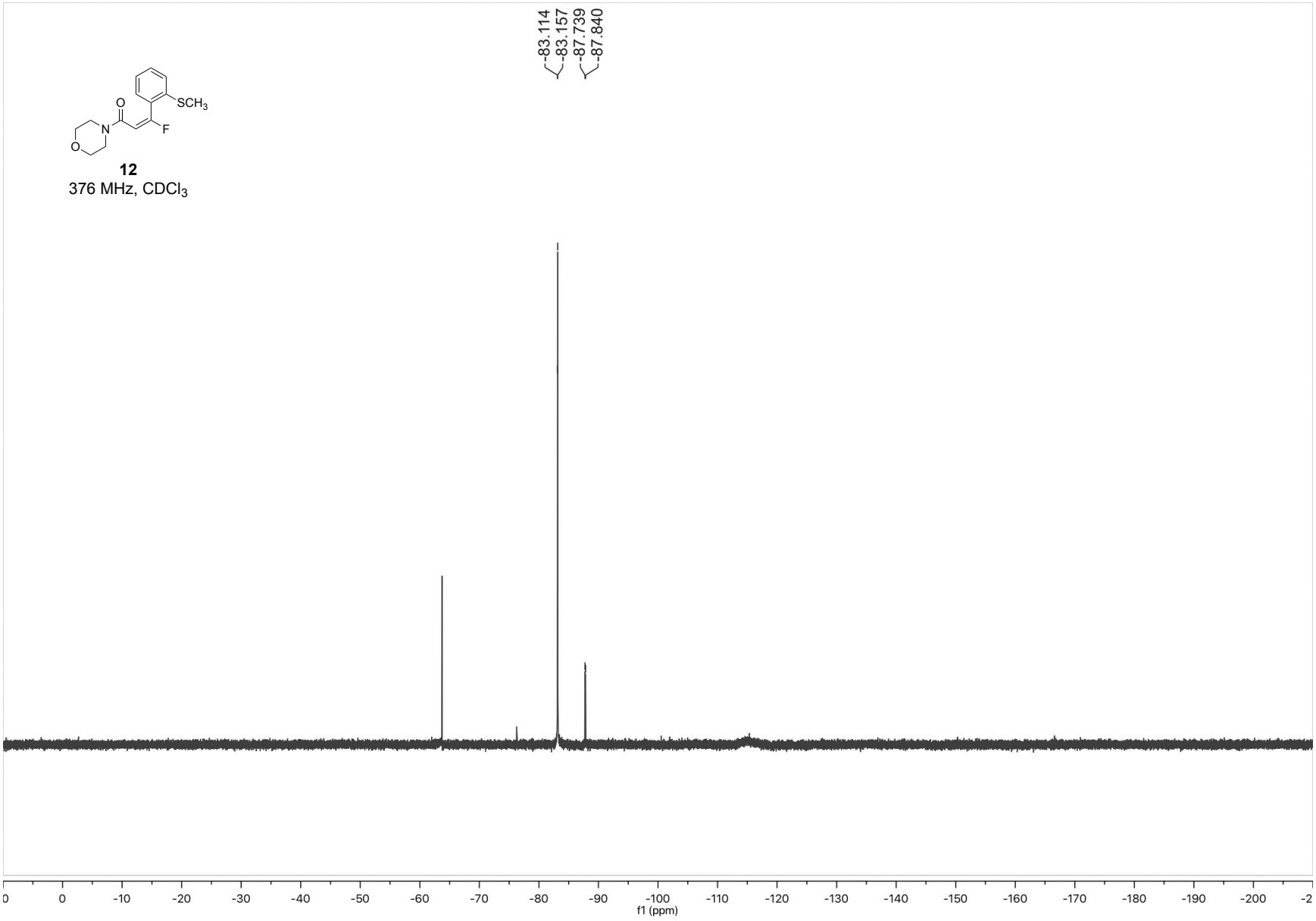

5.808
5.767
4.591
4.581
4.571
4.103
4.093
4.082
4.072
3.769
3.764
3.744
3.740
3.720
3.715
3.662
3.466
2.829
2.813
2.797
2.780
2.764
2.748
2.108
2.098
2.088
2.083
2.081
2.073
2.071
2.063
2.061
2.058
2.057
2.049
2.047
2.038
2.037
2.032
2.022
2.016
2.012
1.890
1.880
1.874
1.870
1.864
1.859
1.849
1.337
1.335
1.332
1.311
1.308
1.306
O
O
O
N
O
F
11
500 MHz, CDCl3
1.00
1.05
2.20
2.44
6.24
2.11
1.01
0.93
1.20
2.27
1.19
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

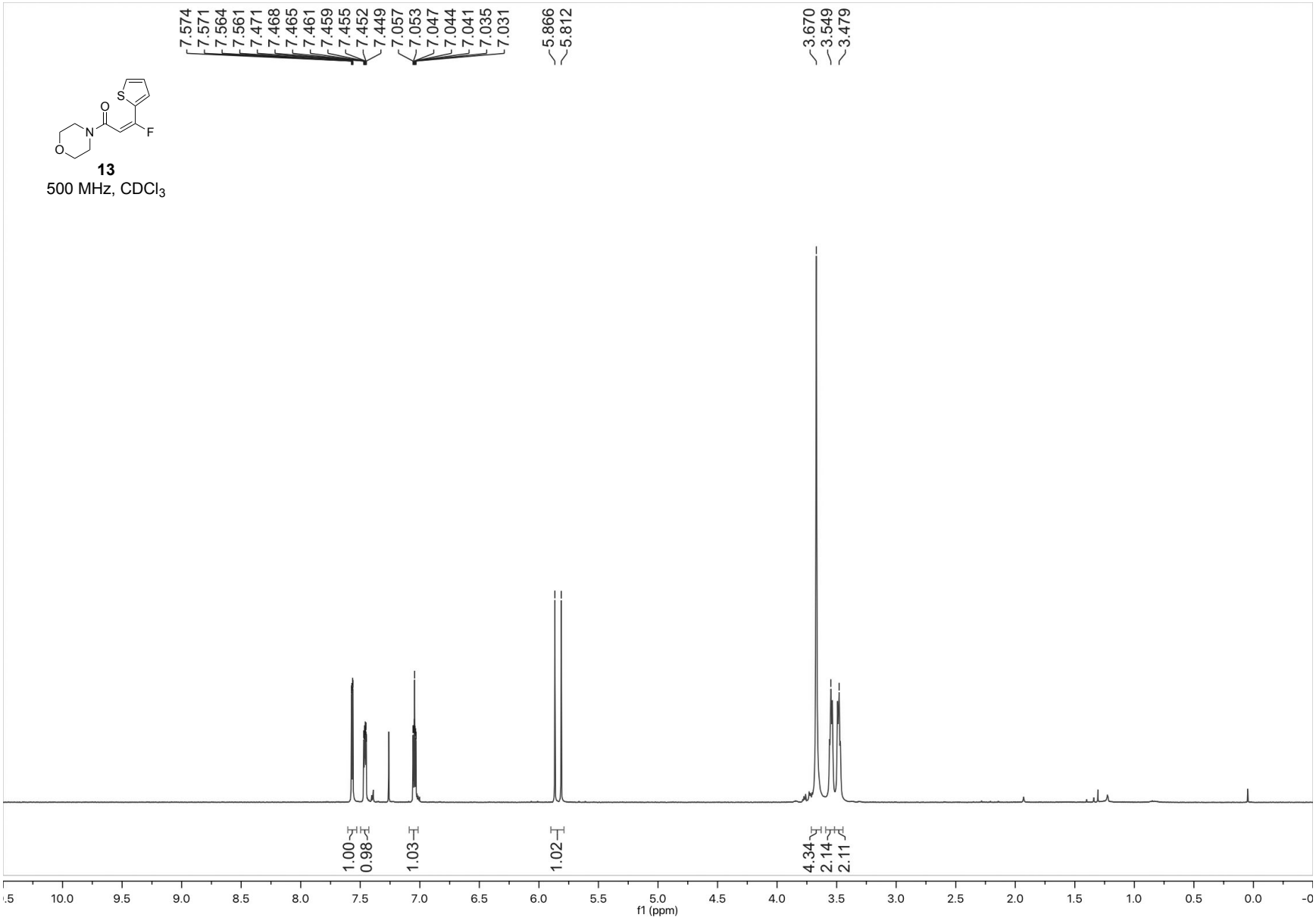

174.252
171.575
164.476
164.270
101.102
100.218
99.954
66.813
66.646
46.507
41.905
31.327
25.693
24.840
24.602
O
O
O
N
O
F
11
100 MHz, CDCl3
f1 (ppm)

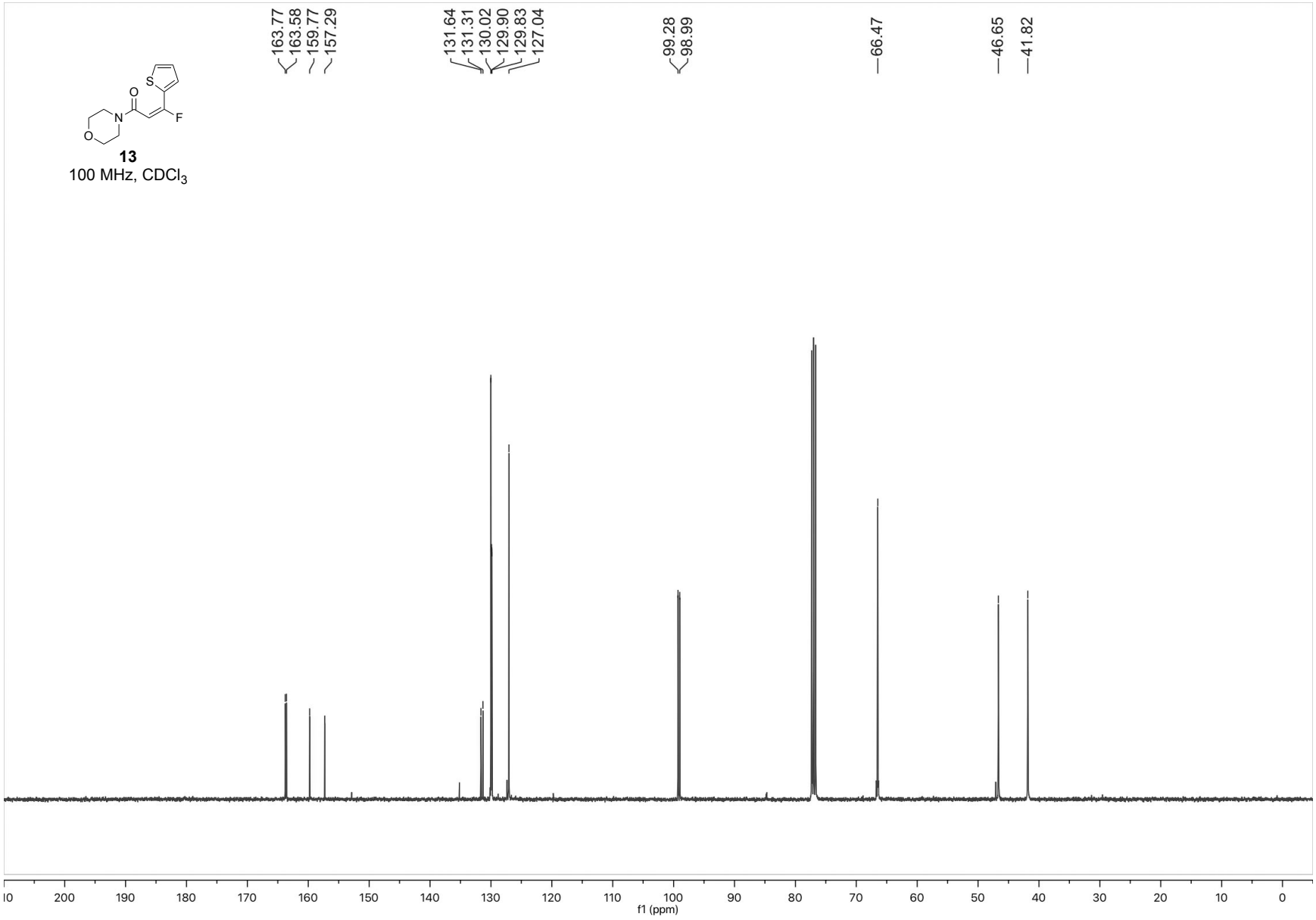

-82.491
-82.546
-82.556
-82.610
-82.619
-82.675
O
O
O
N
O
F
11
376 MHz, CDCl3
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
f1 (ppm)
-110
-120
-130
-140
-150
-160
-170
-180
-190

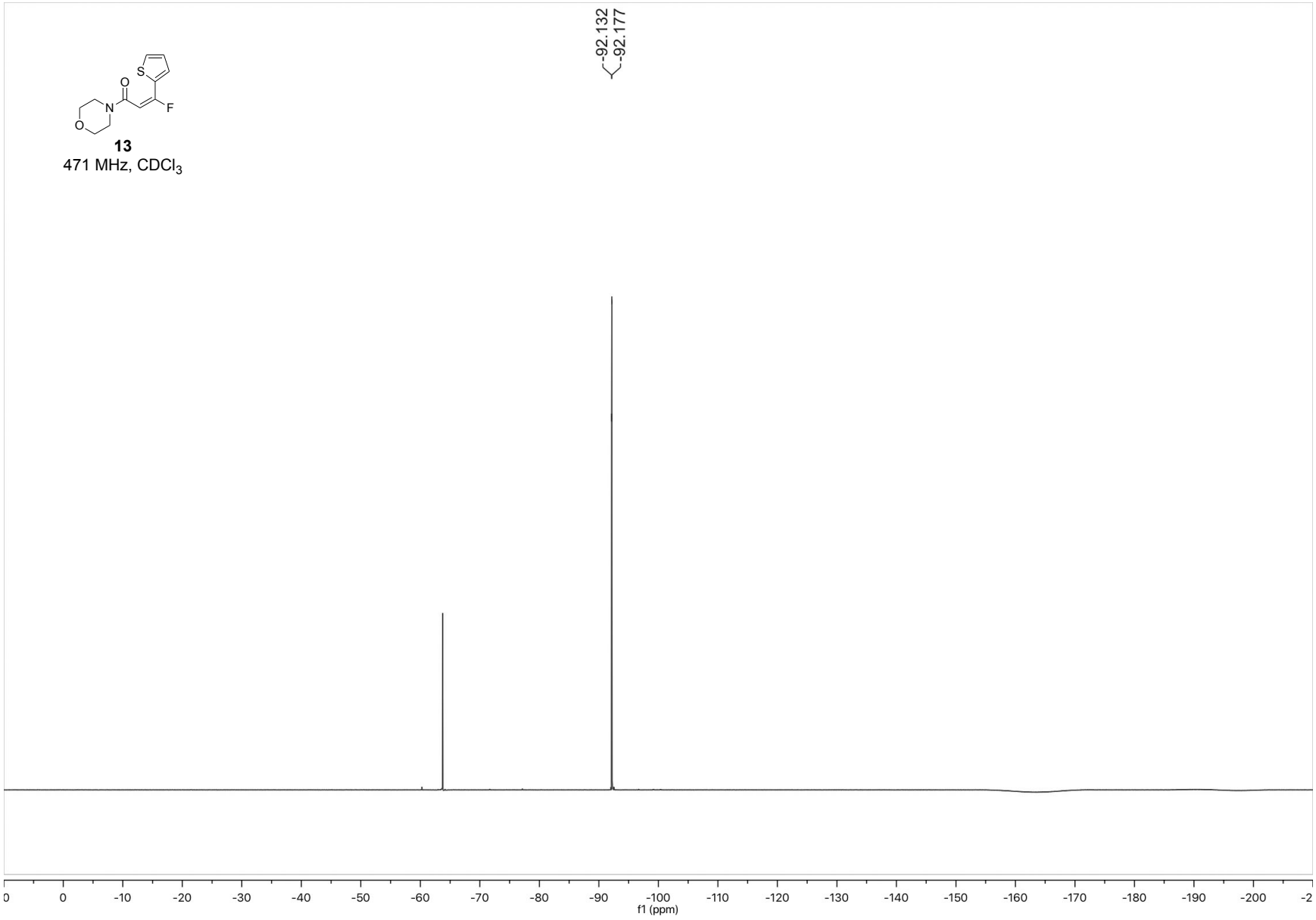

7.418
7.400
7.383
7.319
7.299
7.207
7.188
7.169
6.067
6.025
5.892
5.798
3.480
3.411
3.261
2.485
SCH3
O
N
O
F
12
400 MHz, CDCl3
2.08
1.09
1.23
1.00
0.12
4.08
2.02
2.02
3.36
f1 (ppm)

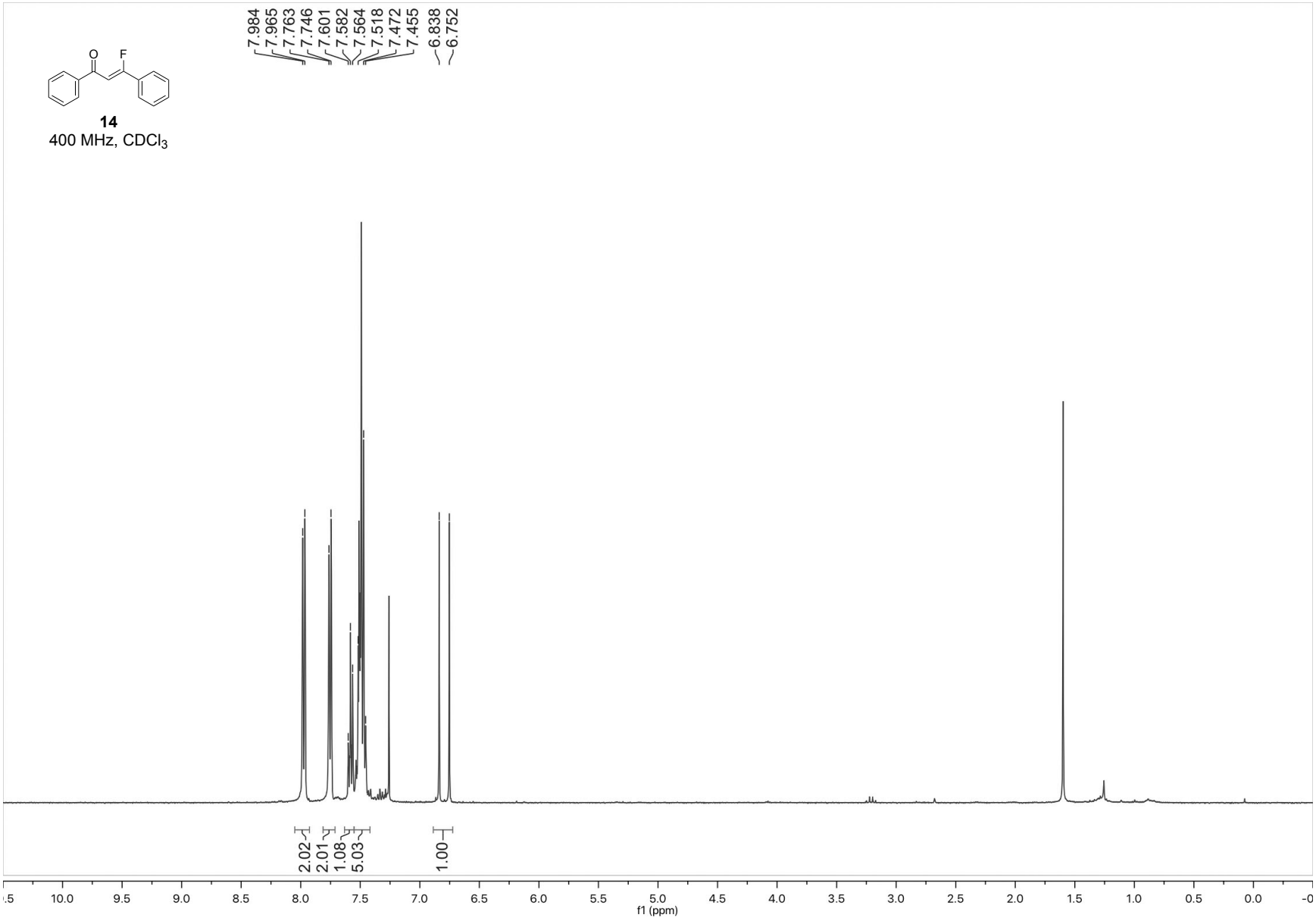

164.61
163.77
163.59
161.97
138.32
131.14
131.12
130.66
130.62
130.08
129.83
126.24
124.90
104.61
104.34
66.46
46.88
41.89
16.15
SCH3
O
N
O
F
12
100 MHz, CDCl3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

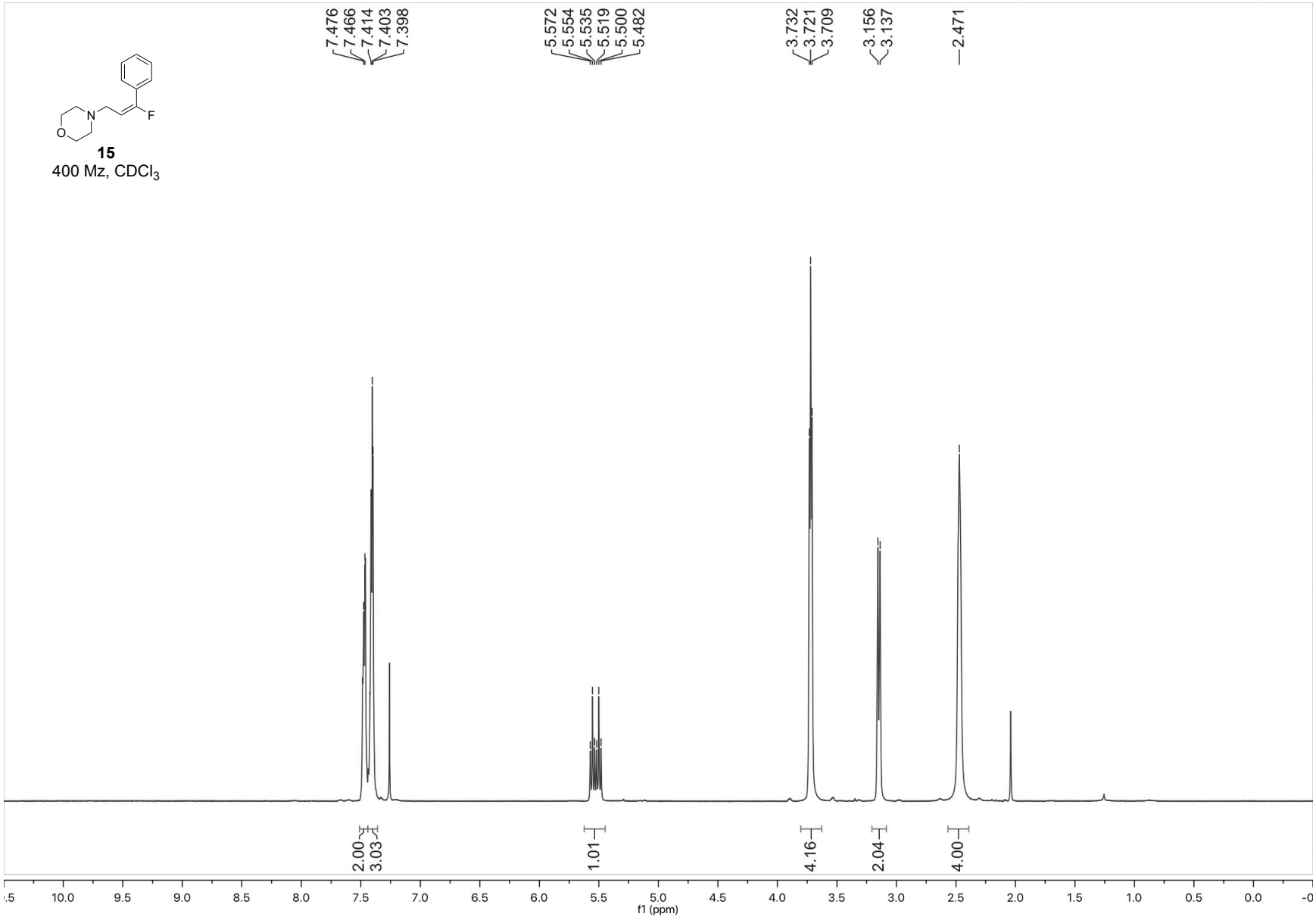

-83.114
-83.157
-87.739
-87.840
O
SCH3
N
F
O
12
376 MHz, CDCl3
0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-2
f1 (ppm)

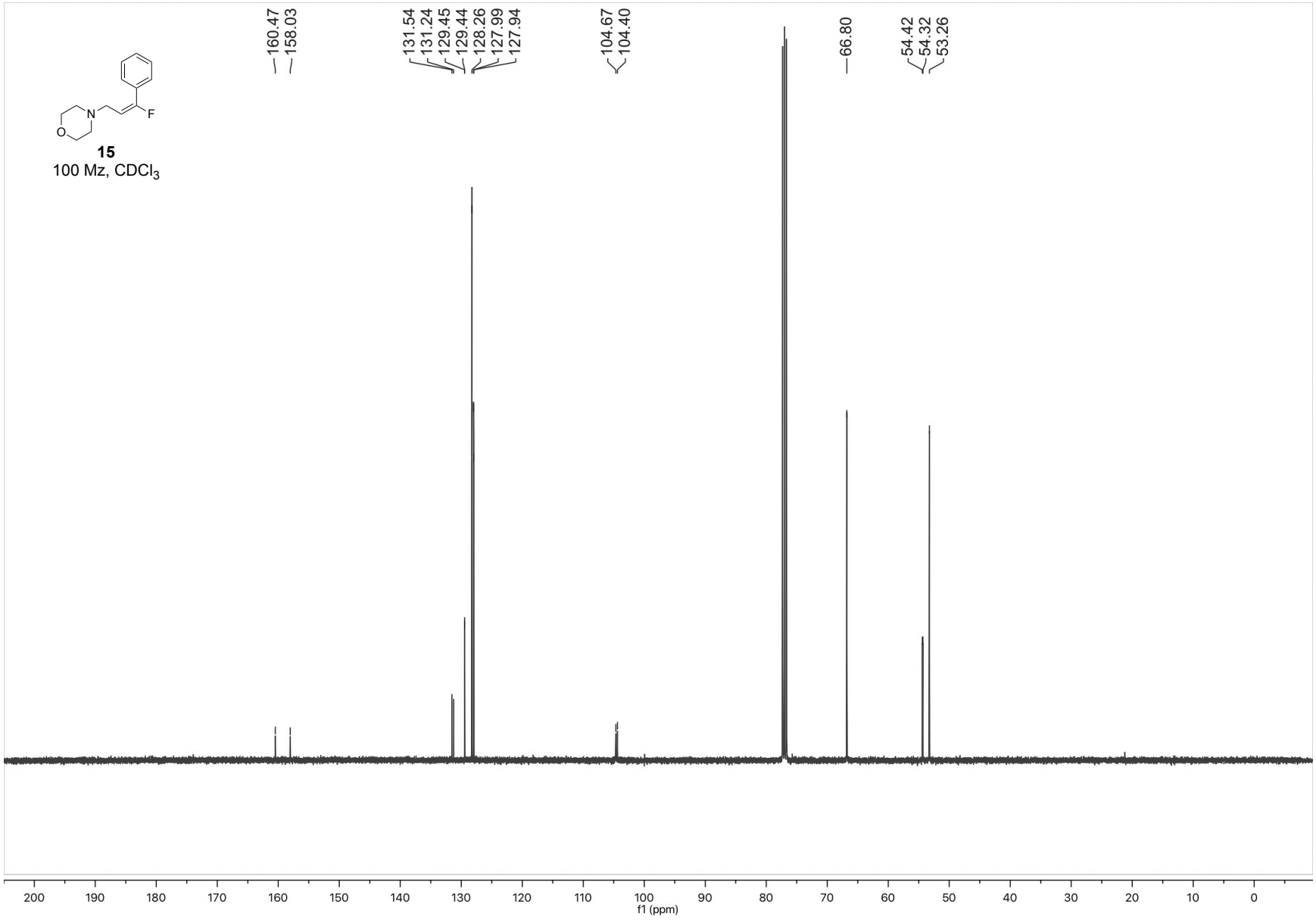

7.574
7.571
7.564
7.561
7.471
7.468
7.465
7.461
7.459
7.455
7.452
7.449
7.057
7.053
7.047
7.044
7.041
7.035
7.031
5.866
5.812
3.670
3.549
3.479
O
S
N
O
F
13
500 MHz, CDCl3
1.00
0.98
1.03
1.02
4.34
2.14
2.11
f1 (ppm)

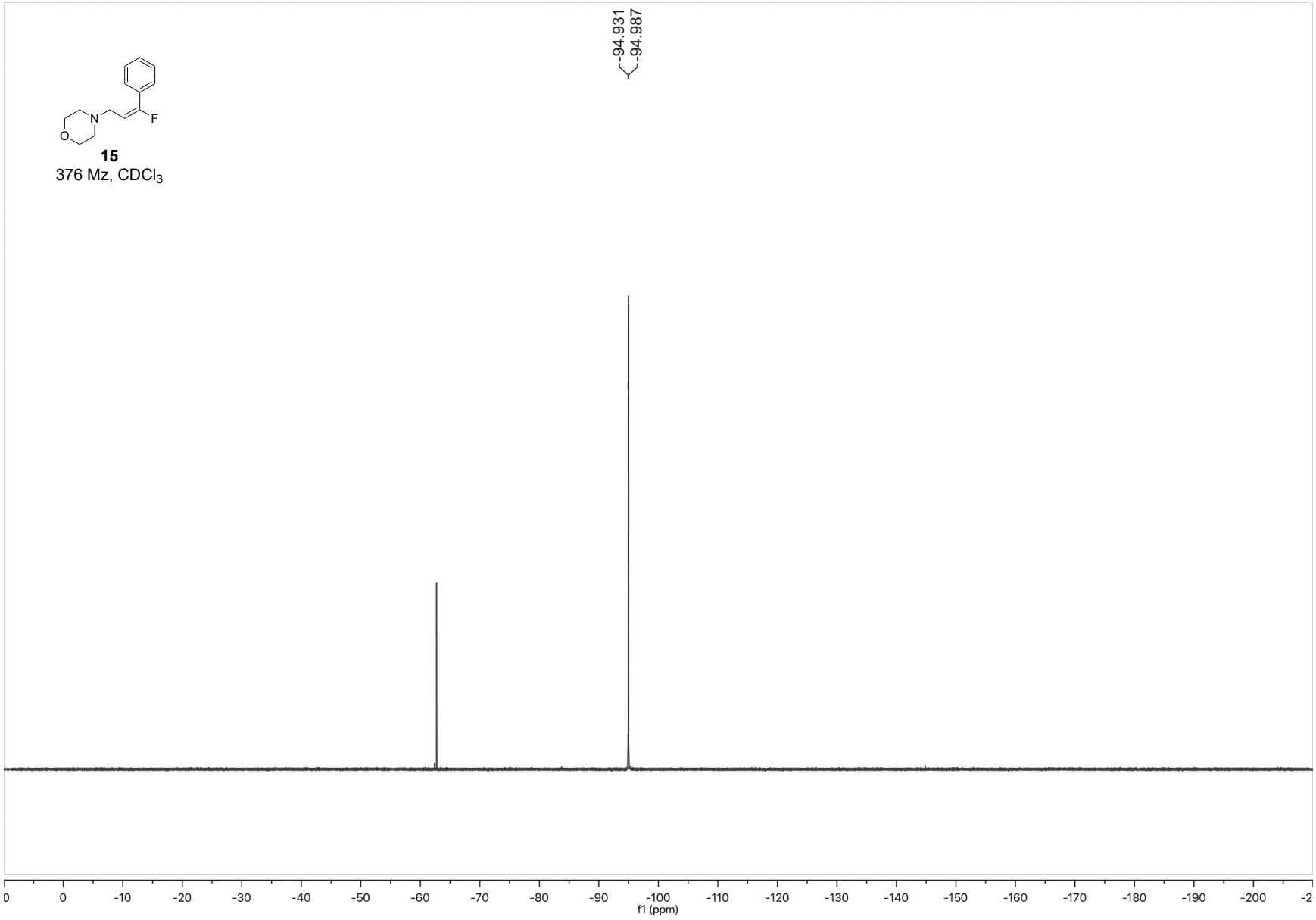

163.77
163.58
159.77
157.29
131.64
131.31
130.02
129.90
129.83
127.04
99.28
98.99
66.47
46.65
41.82
S
O
N
O
F
13
100 MHz, CDCl3
f1 (ppm)

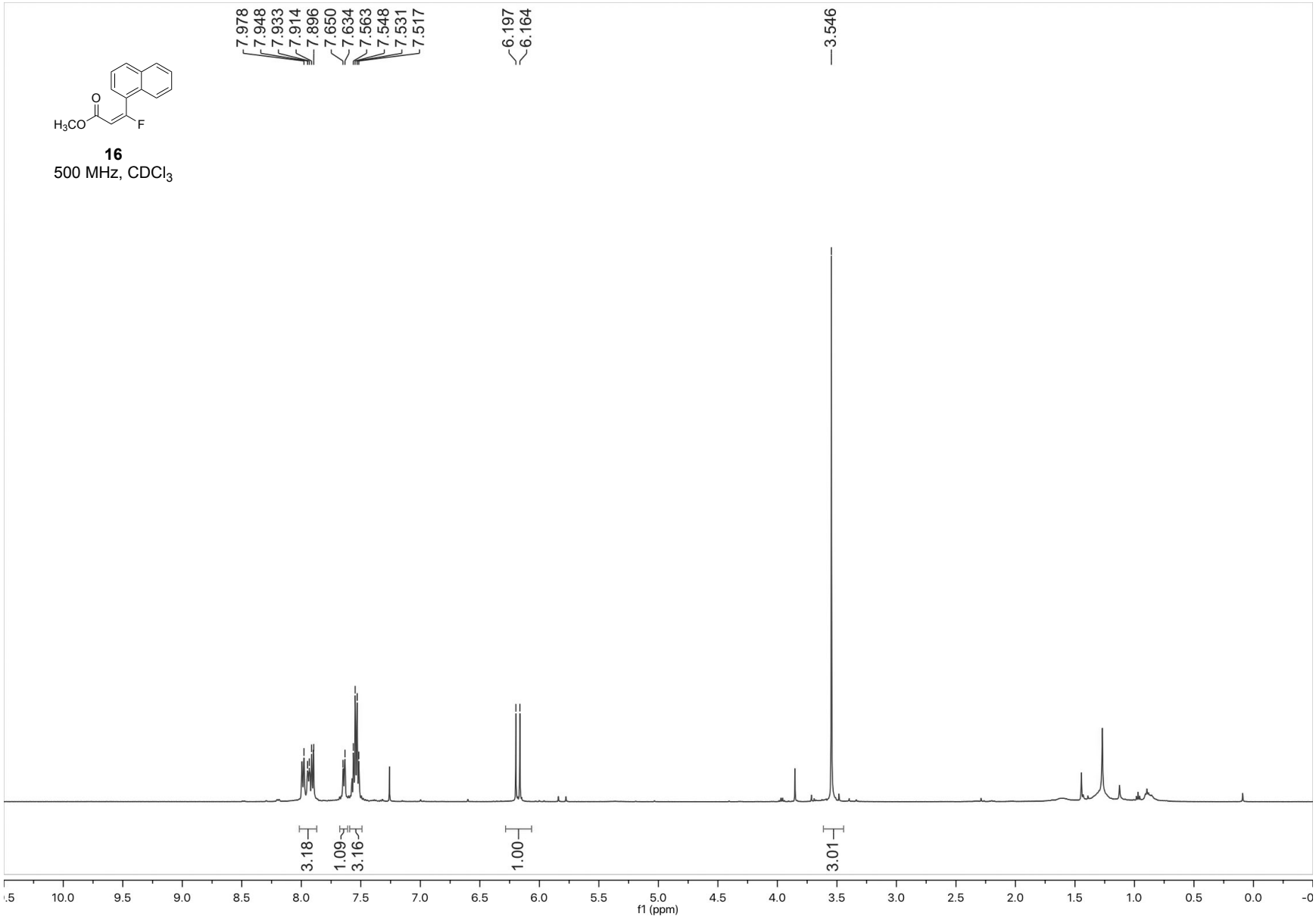

-92.132
-92.177
O
S
N
O
F
13
471 MHz, CDCl3
0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-2
f1 (ppm)

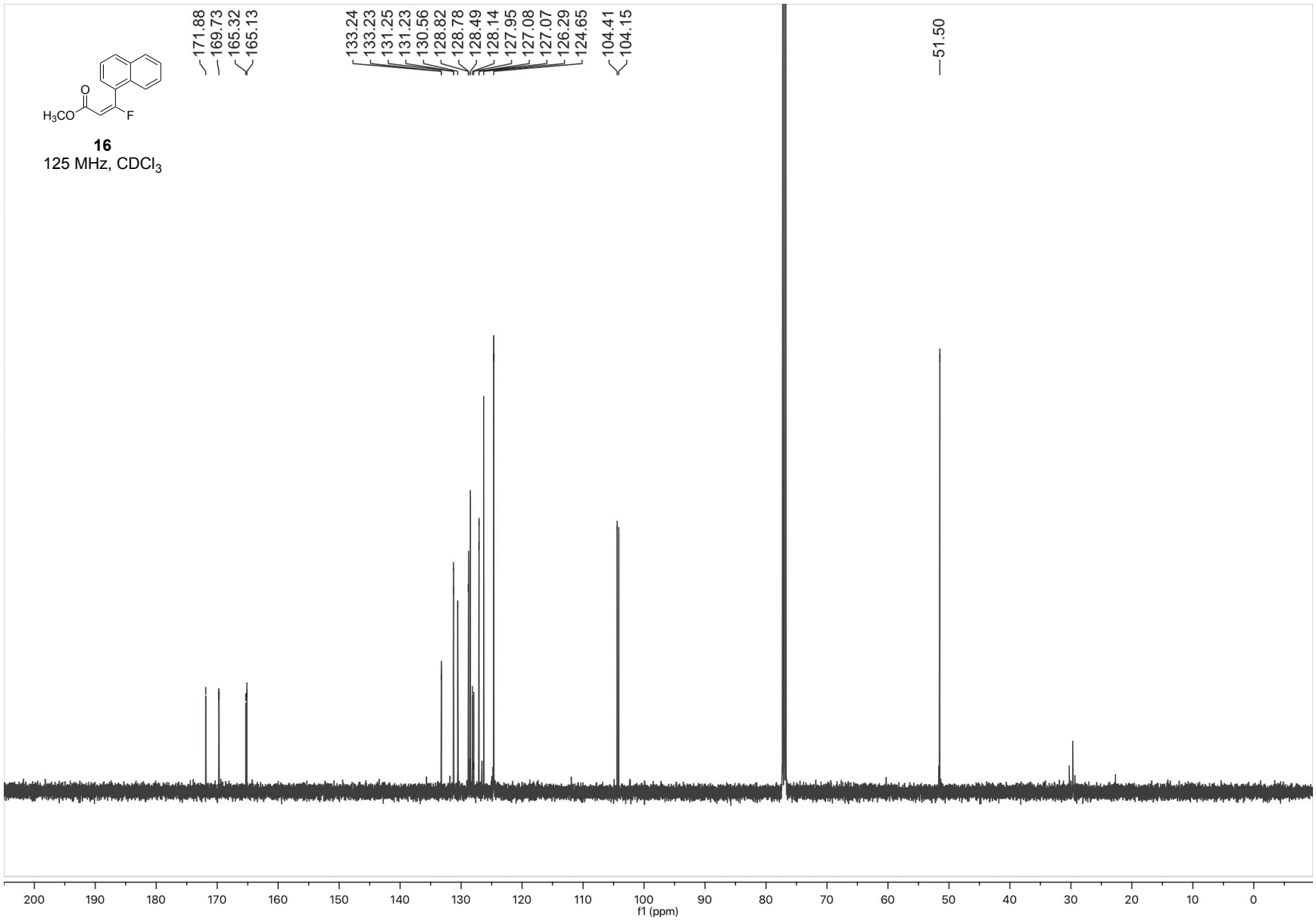

7.984
7.965
7.763
7.746
7.601
7.582
7.564
7.518
7.472
7.455
6.838
6.752
O
F
14
400 MHz, CDCl3
2.02
2.01
1.08
5.03
1.00
f1 (ppm)

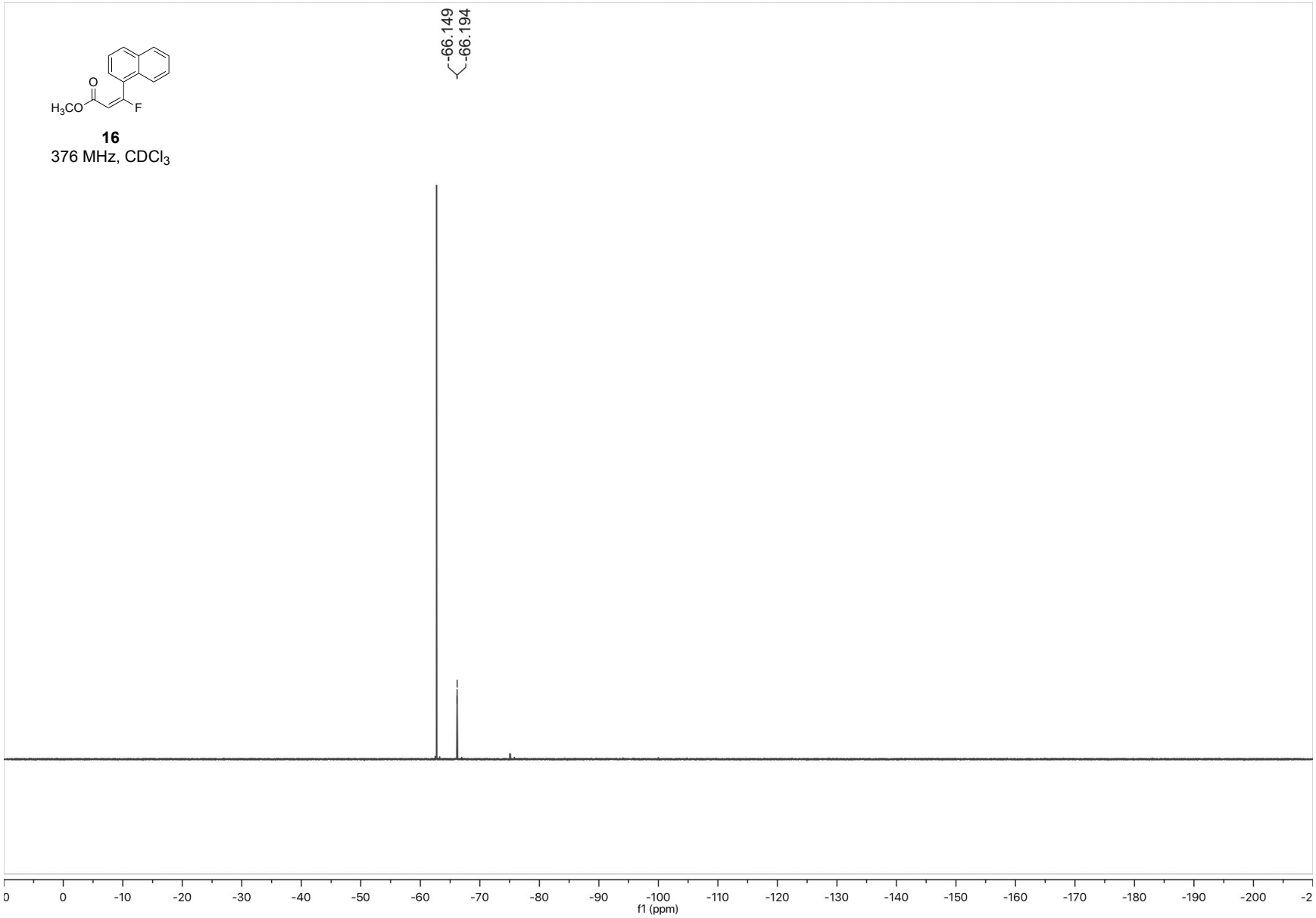

7.476
7.466
7.414
7.403
7.398
5.572
5.554
5.535
5.519
5.500
5.482
3.732
3.721
3.709
3.156
3.137
2.471
N
O
F
15
400 Mz, CDCl3
2.00
3.03
1.01
4.16
2.04
4.00
f1 (ppm)


160.47
158.03
131.54
131.24
129.45
129.44
128.26
127.99
127.94
104.67
104.40
66.80
54.42
54.32
53.26
N
O
F
15
100 Mz, CDCl3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-94.931
-94.987
N
O
F
15
376 Mz, CDCl3
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
f1 (ppm)


7.978
7.948
7.933
7.914
7.896
7.650
7.634
7.563
7.548
7.531
7.517
6.197
6.164
3.546
O
H3CO
F
16
500 MHz, CDCl3
3.18
1.09
3.16
1.00
3.01
f1 (ppm)


171.88
169.73
165.32
165.13
133.24
133.23
131.25
131.23
130.56
128.82
128.78
128.49
128.14
127.95
127.08
127.07
126.29
124.65
104.41
104.15
51.50
O
H3CO
F
16
125 MHz, CDCl3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-66.149
-66.194
O
H3CO
F
16
376 MHz, CDCl3
0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-2
f1 (ppm)