

The Supplementary Information for the paper:

Total Syntheses of Conformationally-locked Difluorinated Pentopyranose and a Pentopyranosyl Phosphate Mimetic

Jonathan A. L. Miles,^a Lisa Mitchell,^b Jonathan M. Percy^{b,*} and Kuldip Singh^a

^aDepartment of Chemistry, University of Leicester, University Road, Leicester LE1 7RH (UK),.

^bDepartment of Pure and Applied Chemistry, WestCHEM, University of Strathclyde,

Thomas Graham Building, 295 Cathedral Street, Glasgow G1 1XL (UK)

jonathan.percy@strath.ac.uk

Table of contents	S1
General synthetic procedures	S2
Preparation of compounds 11a , 11b , 13 , 14 , 26a-27b , 30 , 44 and 45	S3-S14
Cartesian coordinates and energies for RHF 6-31G* optimised structures for lowest energy conformers of 39-41 , calculated energies (RHF 6-31+G**) for 39-41 .	S15-S19
NMR spectra (¹ H, ¹³ C, ¹⁹ F, ³¹ P) for 11a , 11b , 13 , 14 , 16-19a , 26a-27b , 33 , 34 , 44 , 45 and 47	S20-S92

General Experimental Procedures:

NMR spectra were recorded on 300 or 400MHz spectrometers. ^1H and ^{13}C NMR spectra were recorded using the deuterated solvent as the lock and the residual solvent as the internal reference. ^{19}F NMR spectra were recorded relative to chlorotrifluoromethane as the external standard. The multiplicities of the spectroscopic data are presented in the following manner: app. = apparent, s = singlet, d = doublet, t = triplet, pent. = pentet, q = quartet, m = multiplet and br = broad. The appearance of complex signals is indicated by app.. Homocouplings (H-H, F-F) are given in Hertz and specified by J ; the nuclei involved in heteronuclear couplings are defined with the observed nucleus given first. Unless stated otherwise, all refer to 3J couplings. Chemical ionisation were recorded using ammonia as the reagent gas. GC-MS was carried out on a 30 m x 0.25 μm column running a 20-350 $^{\circ}\text{C}$ ramp over 27 minutes. High resolution mass spectrometry measurements were carried out using peak matching to suitable reference peaks, depending on the technique used. Thin Layer Chromatography (TLC) was performed on precoated aluminium silica gel plates. Visualisation was achieved by UV light and/or potassium permanganate stain. THF was dried by refluxing with benzophenone over sodium wire until a deep purple colour developed and persisted, then distilled and collected by dry syringe as required.

1,1,1-Trifluoro-hept-6-en-2-one 11a

A solution of 5-bromopropene (50.7 mmol, 6 mL) in diethyl ether (30 mL) was added to magnesium turnings (49 mmol, 1.2 g) in diethyl ether (20 mL) dropwise with sonication so as to maintain a steady reflux. The black Grignard solution was sonicated at rt for 150 min. further, then cannulated cautiously dropwise to a stirred solution of ethyl trifluoroacetate (75 mmol, 9 mL) in diethyl ether (30 mL) at -78°C under N₂. The solution was warmed to -30°C and stirred for 90 min, then warmed to -10°C and stirred for a further 90 min, upon which a white precipitate was deposited. The reaction was quenched with HCl (20 mL of a 20% aqueous solution), the aqueous phase saturated with NaCl, and then extracted with diethyl ether (1 x 100 mL, 2 x 50 mL). The combined ether extracts were washed with NaHCO₃ (2 x 20 mL), brine (20 mL), dried (MgSO₄), and concentrated *in vacuo* to give a yellow oil, which was purified by distillation (95-100 °C/760 mm Hg) to afford known ketone **11a** (2.94 g, 36%, 92% by GC) as a clear oil. R_f (50 % ethyl acetate/hexane) 0.45; δ_H (300 MHz, CDCl₃) 5.85-5.65 (m, 1H), 5.12-5.01 (m, 2H), 2.72 (t, *J* 7.2, 2H), 2.12 (q, *J* 7.2, 2H), 1.79 (quintet, ³*J* 7.2, 2H); δ_C (75MHz, CDCl₃) 191.3 (q, ²*J*_{C-F} 34.7), 137.0, 116.2, 115.7 (q, ¹*J*_{C-F} 292.0, CF₃), 35.5, 32.6, 21.4; δ_F (282MHz, CDCl₃) -79.4 (s); ν_{max}(film)/cm⁻¹ 2940w, 1764s, 1643w, 1204s, 1145s; *m/z* (EI⁺) 166 (8%, M⁺), 165 (100), 145 (33), 124 (15), 113 (96), 95 (38), 59 (29). HRMS (EI⁺, [M]⁺) Calcd for C₇H₉F₃O 166.06055: found: 166.06047. The NMR data were in agreement with those of Felix and Laurent¹⁹ reported previously at a lower level of characterisation. The impurities in the product appear to arise from Wurtz coupling of the Grignard reagent.

1-Chloro-1,1-difluoro-hept-6-en-2-one 11b

The Grignard was prepared as for **11a** from 5-bromopropene (134 mmol, 15.8 mL) in diethyl ether (25 mL) and magnesium turnings (160 mmol, 3.84 g) in diethyl ether (15 mL). The black Grignard solution was then cannulated cautiously dropwise to a stirred solution of methyl chlorodifluoroacetate (145 mmol, 15.3 mL) in diethyl ether (140 mL) at -70°C under an atmosphere of N₂, then allowed to warm to rt and stirred for 48 h. Quenching and extractive work up as for **11a** afforded a yellow oil, which was distilled (32 °C/10 mmHg) to afford **11b** (8.12 g, 33%, 88% by GC); R_f. (30% ethyl acetate/hexane) 0.58; δ_H (300 MHz, CDCl₃) 5.76 (m, 1H), 5.10-5.02 (m, 2H), 2.77 (t, ³J 7.2, 2H), 2.17-2.00 (m, 2H), 1.80 (quint, *J* 7.2, 2H); δ_C (75MHz, CDCl₃) 191.7 (dd, ²J_{C-F} 29.0, 29.0), 137.0, 119.8 (t, ¹J_{C-F} 306.1), 116.0, 34.2, 32.5, 21.8; δ_F (282MHz, CDCl₃) -68.2 (s); ν_{max}(film)/cm⁻¹ 2930w, 1760s, 1115s, 1148s, 911s; *m/z* (EI⁺) 182 (10%, M⁺), 135 (5), 97 (100), 85 (22), 79 (12), 69 (87), 55 (40), 54 (46); HRMS (EI⁺, [M]⁺) Calcd for C₇H₉F₂OCl 182.03111: found: 182.03100. The impurities in the product appear to arise from Wurtz coupling of the Grignard reagent.

Attempted preparation of 12 by reductive defluorination.

Ketone **11a** (0.5 g, 3 mmol) was added to a stirred suspension of magnesium (0.145 g, 6 mmol), TMSCl (1.52 mL, 12 mmol) and DMF (12 mL) at 0 °C under argon. The suspension was stirred for 30 min then an aliquot was withdrawn by syringe and analysed by ¹⁹F NMR, revealing a complex mixture from which the pair of doublets indicative of the vinylic CF₂ was absent.

Attempted direct preparation of **13**

A suspension of zinc powder (325 mesh, 0.196 g, 3 mmol), and freshly-purified CuCl (0.030 g, 0.3 mmol) in dry THF (5 mL) was stirred for 30 min under an argon atmosphere. Acrolein (0.06 mL, 1.1 mmol) and **11b** (0.182 g, 1 mmol) were added by syringe and the mixture was stirred at reflux for 4 hr, then an aliquot was withdrawn by syringe and analysed by ^{19}F NMR. Some conversion of starting material was observed (*ca.* 50%) but the signals consistent with the formation of **13** (dd and dd, $^2J_{\text{F-F}}$ *ca.* 250 Hz) were not present.

4,4-Difluoro-5-oxo-deca-1,9-dien-3-ol **13**

Thionyl chloride (3.54 mmol, 259 mL) was added to a stirred solution of homoallylic alcohol **17** (3.54 mmol, 1.04 g) in methanol (35.4 mL) at 0 °C. The solution was allowed to warm to room temperature and stirred for 18h after which the solvent was removed in *vacuo*. The resulting paste was diluted with water (20 mL) and extracted with diethyl ether (3 x 30 mL). The combined organic extracts were washed with NaHCO₃ (20 mL), brine (50 mL), dried (MgSO₄), filtered and concentrated in *vacuo* to give ketone **13** (706 mg, 98%) as a brown oil, which could be used crude or purified by distillation (Kugelrohr) to afford **13** as a clear oil (48 %, 100% by GC); bp 75-80 °C/0.1 mmHg; *R*_f (10 % diethyl ether in hexane) 0.22; δ_{H} (300 MHz, CDCl₃) 5.92 (ddd, *J* 17.2, 10.5, 5.8, 4J 0.6, 1H), 5.76 (ddt, *J* 17.0, 10.2, 6.7, 1H), 5.50 (dt, *J* 17.2, 2J 1.3, 1H), 5.42 (dt, *J* 10.5, 2J 1.3, 1H), 5.07-4.97 (m, 2H), 4.56-4.43 (dd, m, 1H), 2.72 (t, *J* 7.2, 3H), 2.18 (q, *J* 7.2, 2H), 1.73 (pentet, *J* 7.2, 2H); δ_{C} (75 MHz, CDCl₃) 201.8 (dd, $^2J_{\text{C-F}}$ 30.9, 25.5), 137.5, 131.1, 120.4, 114.8 (dd, $^1J_{\text{C-F}}$ 258.8, 255.0), 115.6, 72.1 (dd, $^2J_{\text{C-F}}$ 28.1, 25.1), 37.1, 32.6, 21.4;

δ_F (282 MHz, $CDCl_3$) -113.7 (dd, $^2J_{F-F}$ 273.0, J_{H-F} 7.1, 1F), -123.3 (dd, $^2J_{F-F}$ 273.0, J_{H-F} 15.2, 1F); $\nu_{max}(\text{film})/\text{cm}^{-1}$ 3380br, 3060w, 2994w, 1740w; m/z (CI) 222 (100%, $[M+NH_4]^+$), 204 (9); HRMS (EI, $M+H^+$) Calcd for $C_{10}H_{14}O_2F_2$ 204.09621: found: 204.09621. In the 1H NMR, the OH signal lies under the t at 2.72 ppm.

2,2-Difluoro-3-oxo-cyclooct-7Z-en-1-ol 14

A solution of **13** (0.29mmol, 60 mg) and titanium(IV)*isopropoxide* (0.09 mmol, 27 μ L) in DCM (300 mL) was refluxed for 30 minutes. Catalyst **21** (0.015 mmol, 12 mg) was added as a solution in DCM (5 mL) and the reaction was refluxed for 2 hours. The DCM was distilled off carefully at atmospheric pressure to leave a brown oil (54 mg). Purification by column chromatography (40 % diethyl ether in pentane, with careful evaporation of the solvent at >200 mmHg) afforded **14** (32 mg, 60 %, 83% by GC-MS); R_f (40 % diethyl ether in hexane ether) 0.33; δ_H (400 MHz, $CDCl_3$) 5.86-5.78 (m, 1H), 5.65-5.57 (m, 1H), 4.88 (dddd, J_{H-F} 21.0, 3.5, J 7.2, 4J 1.2, 1H), 2.66-2.62 (m, 2H), 2.57-2.48 (m, 1H), 2.33 (dddd, 2J 17.2, J 8.8, 5.6, 3.6, 1H), 2.06-1.88 (m, 2H), 1.74-1.61 (m, 1H); δ_C (100 MHz, 300K, $CDCl_3$) 200.9 (t, $^2J_{C-F}$ 25.6), 133.3, 128.5 (d, $^3J_{C-F}$ 6.4), 117.7 (t, $^1J_{C-F}$ 258.8), 68.1 (t, $^2J_{C-F}$ 23.2), 36.2, 27.2, 26.2; δ_F (282 MHz, $CDCl_3$) -113.2 (d, $^2J_{F-F}$ 236.0, 1F), -123.8 (dd, $^2J_{F-F}$ 236.0, J_{H-F} 21.0, 1F); m/z (EI) 175 (42 %, $[M-H]$), 83 (100). An HRMS was not recorded given the relatively low purity of the product.

(±)-Syn and achiral and meso 3,16-dibenzoyloxy-4,4,15,15-tetrafluoro-octadeca-1,9E,17-trien-5,14-diones **26a and **27a****

A solution of ketone **19a** (0.17 mmol, 52 mg) and titanium tetra *iso*-propoxide (0.051 mmol, 15.2 μ L) in freshly degassed DCM (8.5 mL) was refluxed under a nitrogen atmosphere for 20 min.. Neolyst catalyst **25** (0.0084 mmol, 8 mg, 5 mol%) was added and the resulting solution refluxed for 18hr. The solvent was removed in *vacuo* and the residue taken up in diethyl ether (10 mL) then the suspension was filtered through celite. The filtrate was concentrated *in vacuo* to leave a black oil which was purified by flash chromatography (silica gel, 10% diethyl ether in hexane) to afford an inseparable mixture of dimers **26a** and **27a** as a yellow oil (14 mg, 34%); R_f (30% diethyl ether in hexane) 0.24; δ_H (400MHz, $CDCl_3$) 8.06-8.01 (m, 4H), 7.63-7.56 (m, 2H), 7.49-7.42 (m, 4H), 6.05-5.87 (m, 4H), 5.57 (d, J 16.0, 2H), 5.50 (d, J 9.4, 2H), 5.32-5.27 (m, 2H), 2.65 (t, 3J 7.2, 4H), 2.00-1.91 (m, 4H), 1.65 (quintet, 3J 7.2, 2H), 1.64 (quintet, 3J 7.2, 2H); δ_C (100MHz, $CDCl_3$) 199.7 (dd, $^2J_{C-F}$ 29.6, 28.0), 164.3 (d, $^4J_{C-F}$ 1.6), 133.7, 130.1, 129.8, 129.5, 129.0 (d, $^5J_{C-F}$ 2.4), 128.6, 127.7-127.6 (m), 122.8, 114.1 (dd, $^1J_{C-F}$ 262.0, 255.6), 72.34 (dd, $^2J_{C-F}$ 30.0, 25.2), 72.31 (dd, $^2J_{C-F}$ 30.0, 25.2), 36.9, 36.7, 31.4, 26.1, 22.3, 22.1; $\{^1H\}\delta_F$ (376 MHz, $CDCl_3$) -113.6 (d, $^2J_{F-F}$ 274.4, 1F), -113.6 (d, $^2J_{F-F}$ 274.4, 1F), -113.7 (d, $^2J_{F-F}$ 274.9, 2F), -118.8 (d, $^2J_{F-F}$ 274.9, 1F), -118.8 (d, $^2J_{F-F}$ 274.9, 1F), -118.9 (d, $^2J_{F-F}$ 274.4, 1F), -118.9 (d, $^2J_{F-F}$ 274.4, 1F); $\nu_{max}(\text{film})/\text{cm}^{-1}$ 2935s, 1742s, 1601w, 1452s, 1264s, 1108s, 987w, 711s; m/z (ES^+) 611 (100%, $[M+Na]^+$), 419 (14); HRMS (ES^+ , $[M+NH_4]^+$) Calcd for $C_{32}H_{36}F_4O_6N$: 606.2473; found: 606.2470; and recovered starting material **19a** (22mg, 42%) as a yellow oil.

(±)-*Syn* and achiral and *meso* 3,16-dibenzyloxy-4,4,15,15-tetrafluoro-octadeca-1,9*E*,17-trien-5,14-diones **26b and **27b****

A solution of ketone **19b** (0.190 mmol, 56 mg) and Neolyst catalyst **25** (0.0095 mmol, 9 mg, 10%) in freshly degassed DCM (25 mL) was refluxed under a nitrogen atmosphere for 18 hr. The solvent was removed in *vacuo* and the residue taken up in diethyl ether (5 mL) then the suspension was filtered through celite. The filtrate was concentrated *in vacuo* to leave a black oil which was purified by flash chromatography (silica gel, 20% diethyl ether in hexane) to afford an inseparable mixture of dimers **26b** and **27b** as a yellow oil (20 mg, 38%); R_f (10% diethyl ether in hexane) 0.40; δ_H (400MHz, $CDCl_3$) 7.39-7.28 (envelope, 10H), 5.85 (ddd, J 17.1, 10.5, 7.6, 2H), 5.53 (d, J 10.5, 2H), 5.48 (d, J 17.1, 2H), 5.30 (t, J 3.8, 2H), 4.61 (d, 2J 11.6, 2H), 4.38 (d, 2J 11.6, 2H), 4.25 (dt, J_{H-F} 16.4, J 7.2, 2H), 2.69-2.61 (m, 4H), 2.00-1.90 (m, 4H), 1.63 (quintet, J 7.3, 4H); δ_C (100MHz, $CDCl_3$) 201.7 (dd, $^2J_{C-F}$ 31.2, 25.6), 201.6 (dd, $^2J_{C-F}$ 32.0, 24.8), 136.8, 130.2, 129.6, 128.4, 128.1, 128.0, 128.0, 123.2, 115.0 (dd, $^1J_{C-F}$ 262.0, 254.0), 79.3 (dd, $^2J_{C-F}$ 31.2, 24.0), 71.4, 37.7, 37.6, 31.5, 26.2, 22.3, 22.1; $\{^1H\}\delta_F$ (376 MHz, $CDCl_3$) -110.7 (d, $^2J_{F-F}$ 263.5, 4F), -124.0 (d, $^2J_{F-F}$ 263.5, 2F), -124.1 (d, $^2J_{F-F}$ 263.5, 1F), -124.1 (d, $^2J_{F-F}$ 263.5, 1F); $\nu_{max}(\text{film})/\text{cm}^{-1}$ 2933s, 1730s, 1455w, 1402w, 1208w, 1098s, 738s, 699s; m/z (Cl^+) 578 (24%, $[M+NH_4]^+$), 358 (13), 172 (38), 106 (100); HRMS (ES^+ , $[M+NH_4]^+$) Calcd for $C_{32}H_{40}F_4O_4N$ 578.2888; found: 578.2899; then cyclooctenone **20b** (2 mg, 4%) as a yellow oil and recovered **19b** (20 mg, 36%).

3*R,4*R**-Diacetoxy-2,2-difluoro-9-oxa-1*S**,5*R**-bicyclo[3.3.1]nonan-1*S**-ol 30**

A solution of epoxide **29a** (0.2 g, 0.68 mmol), in water (2 mL) was made up in a CEM microwave vial which was then sealed with a crimp cap. The tube was irradiated in a CEM Discover microwave for 10 minutes at 100°C (30W power with cooling). The solution was transferred to a flask and stirred, and a mixture of NaOH (10 mL of a 0.1 M aqueous solution, 1 mmol) and methanol (5 mL) was added. The solution was stirred at room temperature for one hour and neutralised with HCl (3 mL of a 0.5 M aqueous solution, 1.5 mmol). The whole mixture was concentrated *in vacuo* to yield a white solid (a mixture of triol, benzoic acid and NaCl). The solid mixture was dissolved in water (2 mL) and passed through a short column (*ca.* 6 cm) containing pre-swollen Sephadex G-10 size exclusion beads. The product mixture was collected and re-concentrated *in vacuo* before dissolving again in the minimum amount of water (1 mL) and passing through a Supelco DSC-NH₂ SPE tube conditioned with water (2 mL) and a small amount of 5% HCl solution (0.5 mL). The product was eluted with a 50% mixture of water/methanol and the solution concentrated *in vacuo* to yield a solid triol (0.1 g, *ca.* 0.48 mmol) which was *bis*-acetylated directly.

Acetic anhydride (0.24 mL, 2.4 mmol) and PVP (0.48 g, 0.48 mmol) were added to a solution of crude triol in DCM (4.8 mL), and the mixture was swirled gently at room temperature overnight. The resin was filtered off and washed with a saturated solution of NaHCO₃ (10 mL) and dried for reuse. The washings were extracted with DCM (3 x 10 mL) and the combined organic extracts washed with saturated NaHCO₃ solution (10 mL), brine (10 mL), dried (MgSO₄) and concentrated *in vacuo* to afford a white solid. This solid was washed through a Supelco DSC-NH₂ SPE tube preconditioned with DCM (2

mL) to remove excess acetic anhydride. The product was eluted with DCM (3 x 2 mL) and the resulting solution concentrated *in vacuo* to afford **30** as a white solid (98 mg, 49% over 3 steps,). Crystals were grown by vapour diffusion of hexane into ethyl acetate. R_f (35% ethyl acetate in hexane) 0.24.; mp 170 °C. δ_H (300MHz, $CDCl_3$) 5.83-5.73 (ddd, J_{H-F} 20.8, 7.0, J 17.4, 1H), 5.28 (dd, J 17.4, 3.5, 1H), 4.43 (dd, J 6.5, 3.5, 1H), 3.43 (br. s), 1.94-1.91 (m 2H), 1.89-1.86 (m, 2H), 2.17-2.14 (s, 3H), 2.12-2.10 (m, 2H), 1.82-1.78 (s, 3H), δ_C (100 MHz, $CDCl_3$) 169.8, 169.6, 116.4 (dd, $^1J_{C-F}$ 262.2, 261.0), 93.9 (dd, $^2J_{C-F}$ 25.7, 20.8), 71.1 (dd, $^2J_{C-F}$ 8.6, 1.2), 69.9, 69.7 (t, $^2J_{C-F}$ 23.2), 27.4, 20.7 (2 signals), 20.6, 18.0, δ_F (282 MHz, $CDCl_3$), -117.6 (dd, $^2J_{F-F}$ 259.0, J_{F-H} 7.0, 1F), -127.5 (dd, $^2J_{F-F}$ 259.0, J_{F-H} 20.8, 1F); Calcd for $C_{12}H_{15}O_6F_2$ C, 49.0; H, 5.5: found C, 49.1; H, 5.43. A satisfactory ion could not be obtained for this compound (ES-MS, GC-MS)

Crystal data: $C_{12}H_{16}F_2O_6$, crystal size 0.27 x 0.13 x 0.10 mm³, $M = 294.25$, monoclinic, $a = 12.1162(19)$ Å, $b = 7.5984(12)$ Å, $c = 15.339(3)$ Å, $\alpha = 90$, $\beta = 110.262(3)^\circ$, $\gamma = 90$ deg, $U = 1324.8(4)$ Å³, $T = 150(2)$ K, space group P2(1)/c, $Z = 4$, $\mu(Mo-K\alpha) = 0.135$ mm⁻¹, 9151 reflections measured, 2323 [R(int) = 0.0473] which were used in all calculations. Final R indices [$F^2 > 2\sigma(F^2)$] $R1 = 0.0428$, $wR2 = 0.0978$; R indices (all data) $R1 = 0.0542$, $wR2 = 0.1034$.

Diols **37** and **38** under stoichiometric Os(VIII) conditions

TMEDA (1.1 mmol, 0.166 mL) was added to a solution of cyclooctenone **20b** (0.87 mmol, 0.232 g) in dry DCM (100 mL). The solution was cooled to -78 °C and osmium tetroxide (0.98 mmol, 250 mg) was added in one portion. The solution was stirred at this temperature for 12h then Na_2SO_3 (1 g) was added in one portion and stirred as the

reaction warmed to rt over 3hr. Water was added (30 mL) and the layers separated, then the aqueous layer was extracted with DCM (2 x 20 mL). The combined organic extracts were washed with brine and concentrated *in vacuo*. The ^{19}F NMR spectrum ($\{^1\text{H}\}\delta_{\text{F}}$ (282 MHz, CDCl_3) -108.6 (d, $^2J_{\text{F-F}}$ 265.8, 1F), (-111.8)-(-116.0) (m, 2F), -131.2 ((d, $^2J_{\text{F-F}}$ 265.8, 1F) was not consistent with the formation of **37** and **38**, and electrospray MS showed the product still bound as the osmate ester (m/z , (ES-MS, ES^+) 637 (44%, $[\text{M-H}]^+$, 635 (62)) therefore the crude material was taken up in CD_3OD (0.5 mL) and conc. HCl (3 drops, 0.3 mL) was added. The ^{19}F NMR spectrum then showed the presence of **37** and **38** (1:1) alone.

Diols **37** and **38** under catalytic Ru(VIII) conditions

A solution of NaIO_4 (1.4 mmol, 300 mg) and $\text{CeCl}_3 \cdot 7\text{H}_2\text{O}$ (0.1 mmol, 38 mg) in H_2O (2 mL) was prepared and stirred at rt for 10 min., then cooled to 0°C . Ethyl acetate (3 mL), acetonitrile (6 mL) and $\text{RuCl}_3 \cdot \text{H}_2\text{O}$ (0.025 mmol, 5.2 mg) were added sequentially and the solution stirred for a further 3 min. A solution of **20b** (0.98 mmol, 261 mg) in ethyl acetate (3 mL) was added and the solution stirred vigorously (to ensure intimate mixing of the two phases which tended to separate), allowed to warm to room temperature over 2h then stirred at this temperature for 18 hr. The reaction mixture was diluted with ethyl acetate (80 mL), and the mixture washed with NaHCO_3 (10 mL), brine (10 mL), then dried (MgSO_4), filtered and concentrated *in vacuo* to afford a viscous red oil. Flash chromatography (silica gel eluted with 30-50% gradient of ethyl acetate in hexane for 4 column volumes, then 50% ethyl acetate in hexane) afforded **38** (62 mg, 21%) then **37** (71 mg, 24%).

3*R-Benzyloxy-1*R**(dibenzylphosphoryloxy)-2,2-difluoro-9-oxa-1*R**,5*S**-**

bicyclo[3.3.1]nona-4*R-ol 44 and 3*R**-Benzyloxy-1*R**,4*R**-**

***bis*(dibenzylphosphoryloxy)- 2,2-difluoro-9-oxa-1*R**,5*S**-bicyclo[3.3.1]nonane 45**

n-Butyllithium (0.035 mmol, 0.015 mL of a 2.03M solution in hexanes) was added to a stirred solution of **37** (0.035 mmol, 10.5 mg) in dry THF (1.5 mL) under an atmosphere of nitrogen at -78°C. The solution was stirred at -78°C for 6 hr then tetrabenzylpyrophosphate (0.035 mmol, 19 mg) was added as a solution in THF (0.5 mL) in one portion and the solution allowed to warm to rt over 2 hr, then stirred overnight. The reaction was quenched with buffer (5 mL of a pH 7 solution) and the aqueous phase was extracted with ethyl acetate (3 x 20 mL). The combined organic extracts were washed with brine (10 mL), dried (MgSO₄), and concentrated *in vacuo* to afford a grey paste which was purified (flash silica, 70% ethyl acetate in hexane) to afford phosphate ester **44** (15 mg, 14%) as a grey paste; *R*_f (70% ethyl acetate in hexane) 0.21; δ_H (400 MHz, CDCl₃) 7.41-7.28 (m, 15H), 5.14 (dd, ²*J* 11.8, *J*_{H-P} 7.4, 1H), 5.11 (dd, ²*J* 11.8, *J*_{H-P} 7.4, 1H), 5.09 (s, 1H), 5.06 (s, 1H), 4.91 (d, ²*J* 11.7, 1H), 4.78 (d, ²*J* 11.7, 1H), 4.43 (d, *J* 6.6, 1H), 4.01 (ddd, *J*_{H-F} 19.4, *J* 7.0, 4.4, 1H), 3.83 (br. s, 1H), 2.54-2.40 (m, 1H), 2.18-2.06 (m, 1H), 2.03-1.75 (m, 2H), 1.51-1.35 (m, 2H); δ_C (100 MHz, CD₃OD) 136.5, 136.0 (d, ²*J*_{C-P} 8.8), 135.8 (d, ²*J*_{C-P} 8.0), 128.7, 128.5, 128.5, 128.4, 128.4, 128.2, 128.2, 128.0, 127.9, 116.6 (dd, ¹*J*_{C-F} 258.0, 251.7), 99.7 (ddd, ²*J*_{C-F} 27.2, 17.6, ²*J*_{C-P} 7.2), 74.3 (ddd, ²*J*_{C-F} 20.0, 16.8, ⁴*J*_{C-P} 1.6), 73.2 (d, ⁴*J*_{C-F} 1.6), 70.8 (d, ³*J*_{C-F} 8.0), 69.7 (d, ²*J*_{C-P} 6.4), 69.4 (d, ²*J*_{C-P} 6.4) 28.0, 22.7, 18.4; δ_F (282 MHz, CDCl₃) -115.5 (1F, m. incl. app. d, ²*J*_{F-F} 246.7), -121.6 (ddd, ²*J*_{F-F} 246.7, *J*_{H-F} 19.4, ⁴*J*_{H-F} 4.3, 1F); δ_P (121 MHz, CDCl₃) -8.50 (quintet, *J*_{P-}

δ_{H} 7.3); $\nu_{\text{max}}(\text{film})/\text{cm}^{-1}$ 3425br, 2943, 1490w, 1455s, 1279, 1214s, 1108s, 1038s, 744s, 697s; m/z (ES^+) 561 (97%, $[\text{M}+\text{H}]^+$), 404 (4), 381 (4), 228 (100), 158 (13); HRMS (ES^+ , $[\text{M}+\text{H}]^+$) Calcd for $\text{C}_{29}\text{H}_{32}\text{F}_2\text{O}_7\text{P}$: 561.1848; found: 561.1845; and *bis*-phosphate **45** (7 mg, 3%) as a grey paste; R_f (70% ethyl acetate in hexane) 0.15; δ_{H} (300 MHz, CDCl_3) 7.44-7.17 (m, 20H), 5.15-5.02 (m, 2H), 5.02 (d, 2J 10.4, 1H), 4.97 (d, 2J 10.4, 1H), 4.96 (d, 2J 11.8, 1H), 4.91 (d, 2J 11.8, 1H), 4.86 (d, 2J 11.5, 1H), 4.81 (d, 2J 11.5, 1H), 4.76-4.69 (m, 1H), 4.38 (d, J 6.1, 1H), 4.03 (1H, br. d, $J_{\text{H-F}}$ 19.9), 2.48-range please (m, 1H), 2.48-1.78 (m, 3H), 1.48-1.32 (m, 2H); δ_{F} (282 MHz, CDCl_3) -117.5 (d, $^2J_{\text{F-F}}$ 246.4, 1F), -123.4 (ddd, $^2J_{\text{F-F}}$ 246.4, $J_{\text{H-F}}$ 19.9, $^4J_{\text{H-F}}$ 5.2, 1F); δ_{P} (121 MHz, CDCl_3) -1.86 (quintet, $J_{\text{P-H}}$ 7.3, 1P), -8.68 (quintet, $J_{\text{P-H}}$ 7.3, 1P); m/z (ES^+) 821 (79%, $[\text{M}+\text{H}]^+$), 583 (19), 561 (23), 404 (6), 228 (100), 158 (32). [HRMS (ES^+ , $[\text{M}+\text{H}]^+$) Found: 821.2448. Calc. for $\text{C}_{43}\text{H}_{45}\text{F}_2\text{O}_{10}\text{P}_2$: 821.2451]; and **37** (21 mg, 35%).

Insufficient material was obtained for a ^{13}C NMR spectrum of **45**.

Attempted Selective Phosphorylation of the Sodium Salt of 31 in the presence of 15-crown-5

A solution of sodium hexamethyldisilazane (0.041 mmol, 0.023 mL of a 1.8 M solution in THF) was added to a stirred solution of bicyclic diol **37** (0.041 mmol, 12.2 mg) in dry THF (0.5 cm^3) at 0 $^{\circ}\text{C}$. 15-Crown-5 (0.041 mmol, 8.1 μL) was added and the solution cooled to -20°C and stirred at that temperature for 24 hours. A solution of tetrabenzyl pyrophosphate (0.041 mmol, 22.1 mg) in dry THF (0.2 cm^3) was added and the solution stirred at -20°C for a further 27 hours. The reaction was quenched with pH 7 buffer solution (5 mL) and extracted with ethyl acetate (3 x 20 mL). The combined organic

extracts were washed with brine (10 mL), dried (MgSO_4), filtered and concentrated in *vacuo* to give a grey paste. Analysis by ^{19}F NMR indicated the presence of mono-phosphate **44** (40%), bis-phosphate **45** (16%) and recovered starting material **37** (44%).

Cartesian coordinates for geometry optimised structures for **39-41** (RHF 6-31G*) and energies

RHF geometry optimisations and energy calculations were carried out using PC Spartan Pro 1.0.5 (Intel Pentium 4 (2.66 GHz with 1.02GB RAM)).

Frequency calculations were carried out for both conformers of each of **39-41** using Spartan04 ((Intel Pentium 4 (3.80 GHz with 1.99GB RAM)). No imaginary frequencies were obtained for any of the six structures.

39 *boat-boat*

		Coordinates (Angstroms)		
ATOM		X	Y	Z
1	C	0.778580	1.170112	0.436141
2	C	-0.021919	-0.959828	1.110720
3	C	-1.371208	0.255695	-0.677580
4	C	-1.395958	-0.751668	0.469671
5	C	-0.538248	1.472813	-0.307229
6	O	0.458262	0.314999	1.496590
7	H	-0.939273	-0.202525	-1.551378
8	H	-0.178216	-1.498822	2.034083
9	C	1.032035	-1.702743	0.289199
10	H	1.839223	-1.947155	0.973509
11	H	0.618817	-2.637050	-0.070215
12	C	1.879940	0.571854	-0.432276
13	H	2.764847	0.599775	0.192922
14	H	2.062708	1.216260	-1.282795
15	C	1.602429	-0.872157	-0.866848
16	H	2.529846	-1.319560	-1.208062
17	H	0.938045	-0.897456	-1.722273
18	O	1.269770	2.337193	0.964476
19	H	0.630770	2.698331	1.566953
20	O	-2.671589	0.613642	-1.048339
21	H	-3.019485	1.237894	-0.423776
22	F	-0.301095	2.223668	-1.389016
23	F	-1.297517	2.238816	0.527207
24	O	-1.893805	-1.981733	0.036672
25	H	-2.741982	-1.843138	-0.366230
26	H	-2.034978	-0.337219	1.247875

Energy is -808.249119373 au

39 *boat-chair*

		Coordinates (Angstroms)		
ATOM		X	Y	Z
1	C	0.683375	1.184044	0.417614
2	C	0.101763	-1.050457	0.984545
3	C	-1.493128	0.205341	-0.488831
4	C	-1.361507	-0.874353	0.576283
5	C	-0.751543	1.458855	-0.059551
6	O	0.574083	0.212074	1.419802
7	H	-1.042748	-0.146251	-1.410691
8	H	0.130851	-1.674231	1.864598
9	C	1.022331	-1.639420	-0.110307
10	H	1.412113	-2.594731	0.220621
11	H	0.458729	-1.843668	-1.013349
12	C	1.629990	0.726019	-0.708120
13	H	2.432197	1.448611	-0.770896
14	H	1.123870	0.736285	-1.667177
15	C	2.170804	-0.673599	-0.411398
16	H	2.841388	-0.625681	0.439005
17	H	2.749833	-1.031930	-1.256119
18	O	1.204063	2.316743	0.990011
19	H	0.658271	2.566086	1.726627
20	O	-2.856122	0.443536	-0.682290
21	H	-2.981701	1.079169	-1.375073
22	F	-0.756591	2.342676	-1.078772
23	F	-1.414275	2.051172	0.953738
24	O	-1.856509	-2.095009	0.115814
25	H	-2.766938	-1.980675	-0.126359
26	H	-1.912597	-0.540605	1.450275

Energy is -808.245239886 au

40 *boat-boat*

		Coordinates (Angstroms)		
ATOM		X	Y	Z
1	C	0.321029	1.236447	0.493786
2	C	0.131170	-1.089502	0.939645
3	C	-1.250012	-0.190321	-1.003890
4	C	-1.128651	-1.260741	0.089242
5	C	-0.902794	1.187093	-0.443119
6	O	0.126168	0.230515	1.456862
7	H	-0.557824	-0.395632	-1.804613
8	H	0.009490	-1.729631	1.802324
9	H	-1.150291	-2.238437	-0.373467

S17

10	C	1.477485	-1.400620	0.283408
11	H	2.206043	-1.451933	1.086378
12	H	1.444843	-2.383910	-0.176535
13	C	1.673201	1.074294	-0.191623
14	H	2.399964	1.311870	0.576524
15	H	1.771350	1.817282	-0.972528
16	C	1.931796	-0.338775	-0.725093
17	H	2.993148	-0.454978	-0.915383
18	H	1.448384	-0.483423	-1.683653
19	O	0.348453	2.444622	1.140614
20	H	-0.487646	2.595905	1.564050
21	O	-2.514263	-0.189049	-1.572308
22	H	-3.151122	-0.295946	-0.875580
23	O	-2.263490	-1.201542	0.918785
24	H	-2.162838	-0.480136	1.528733
25	F	-0.752213	2.067872	-1.438794
26	F	-1.961382	1.618678	0.296235

Energy is -808.250065318 au

40 *boat-chair*

Coordinates (Angstroms)				
ATOM	X	Y	Z	
1	C	0.347800	1.209630	0.400546
2	C	0.146947	-1.123296	0.818485
3	C	-1.374692	-0.146167	-0.944872
4	C	-1.202020	-1.244050	0.115011
5	C	-0.977690	1.213489	-0.377118
6	O	0.235385	0.185901	1.356864
7	H	-0.724453	-0.340554	-1.786626
8	H	0.128572	-1.769094	1.683744
9	H	-1.295011	-2.208758	-0.366317
10	C	1.369655	-1.451330	-0.068398
11	H	1.867371	-2.335238	0.313516
12	H	1.057708	-1.692310	-1.081163
13	C	1.582703	1.006263	-0.497530
14	H	2.209853	1.880008	-0.386356
15	H	1.293888	0.958938	-1.541659
16	C	2.333040	-0.264474	-0.100762
17	H	2.781472	-0.131189	0.877021
18	H	3.138823	-0.453860	-0.801610
19	O	0.497760	2.394503	1.073661
20	H	-0.257714	2.535109	1.631817
21	O	-2.669233	-0.120408	-1.440098
22	H	-3.266080	-0.224502	-0.707998
23	O	-2.253515	-1.172499	1.042986

S18

24	H	-2.089578	-0.455356	1.643518
25	F	-0.938040	2.130764	-1.349190
26	F	-1.942953	1.618480	0.492527

Energy is -808.246689139 au

41 *boat-boat*

Coordinates (Angstroms)				
ATOM		X	Y	Z
1	O	-0.049877	0.148226	-1.516268
2	C	-1.129282	-1.385169	-0.040374
3	C	-1.082273	1.113509	0.358977
4	C	-1.390271	-0.257117	0.968490
5	C	0.110516	1.210794	-0.614549
6	C	0.091847	-1.141649	-0.936880
7	H	-1.018748	-2.305625	0.515360
8	H	-2.449530	-0.261124	1.198035
9	H	-0.014407	-1.829398	-1.763893
10	C	1.494580	-1.307824	-0.351275
11	H	1.565512	-2.262307	0.161172
12	H	2.170798	-1.352761	-1.199940
13	C	1.502120	1.195450	0.008878
14	H	1.567811	1.973680	0.759121
15	H	2.159165	1.477992	-0.805574
16	C	1.926111	-0.164635	0.572975
17	H	1.514887	-0.310842	1.557940
18	H	3.006268	-0.177004	0.676270
19	O	0.013255	2.385738	-1.318532
20	H	-0.827208	2.421006	-1.757999
21	F	-2.180399	1.467363	-0.360280
22	F	-0.966538	2.020019	1.346392
23	O	-0.642302	-0.486944	2.122714
24	H	-0.814037	0.200961	2.752362
25	O	-2.258190	-1.545963	-0.857622
26	H	-2.299808	-0.826375	-1.475500

Energy is -808.245696213 au

41 *boat-chair*

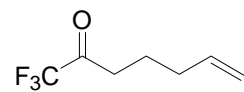
Coordinates (Angstroms)				
ATOM		X	Y	Z
1	O	0.333046	0.238873	-1.444475
2	C	-1.068871	-1.143319	-0.011835
3	C	-0.765844	1.311190	0.367400
4	C	-1.753795	0.209684	0.012857
5	C	0.548298	1.230405	-0.478166

6	C	0.171416	-1.073976	-0.926763
7	H	-0.789574	-1.396590	1.006139
8	H	-2.122952	0.421372	-0.984230
9	H	-0.032325	-1.691102	-1.787861
10	C	1.462759	-1.507422	-0.241530
11	H	1.343007	-2.507660	0.164168
12	H	2.243883	-1.552063	-0.994291
13	C	1.808992	0.922595	0.326982
14	H	1.915622	1.643202	1.126913
15	H	2.623000	1.082494	-0.370873
16	C	1.857358	-0.513649	0.855725
17	H	1.203528	-0.617704	1.714439
18	H	2.859587	-0.730221	1.209970
19	O	0.781940	2.415203	-1.126790
20	H	0.014027	2.680183	-1.616357
21	F	-1.391119	2.492755	0.146181
22	F	-0.493840	1.285418	1.681981
23	O	-2.804327	0.138089	0.929794
24	H	-3.308697	0.941002	0.913431
25	O	-1.932448	-2.123243	-0.513361
26	H	-2.702669	-2.155516	0.040554

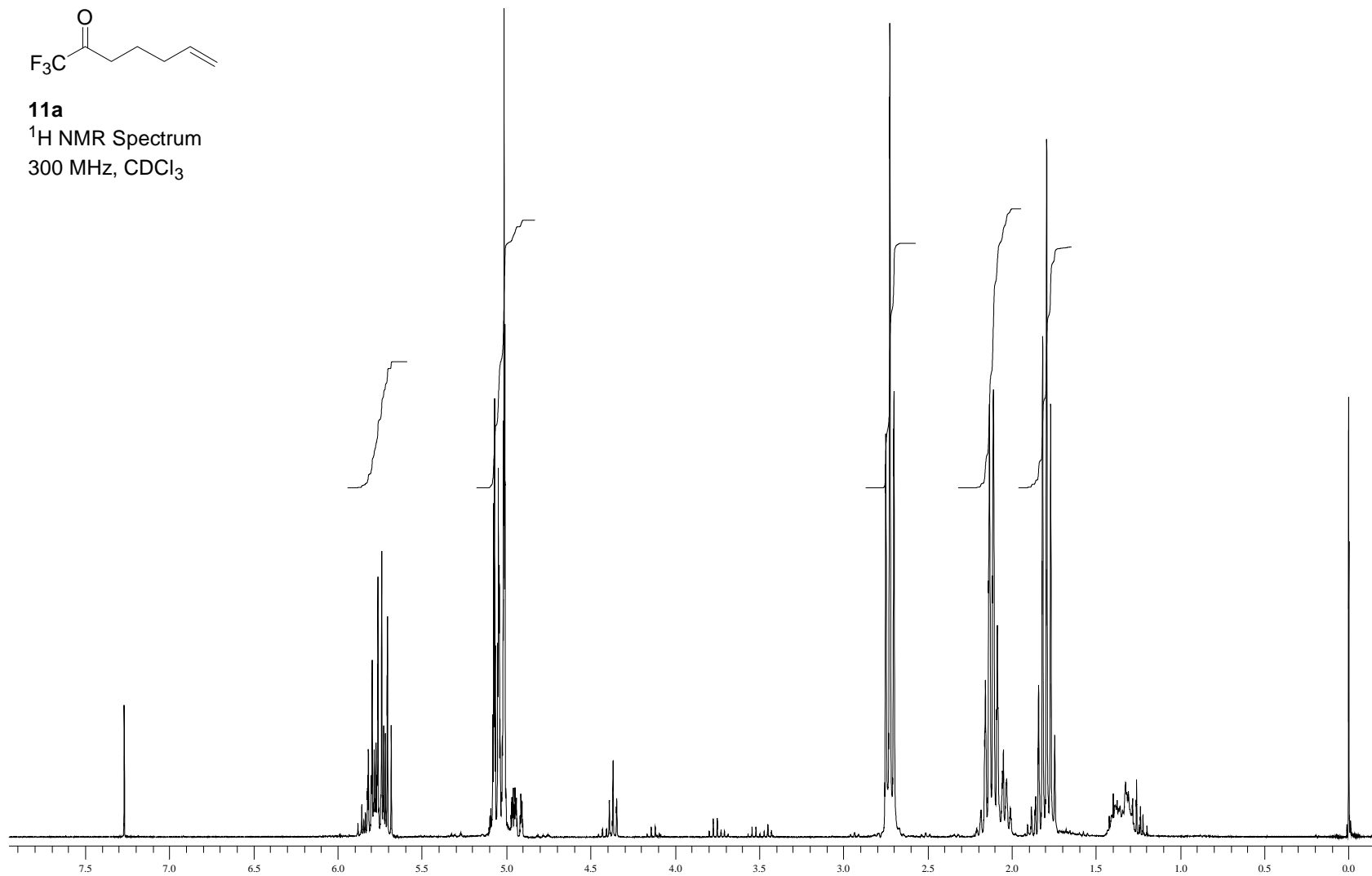
Energy is -808.242457349 au

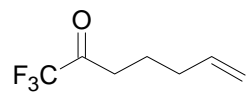
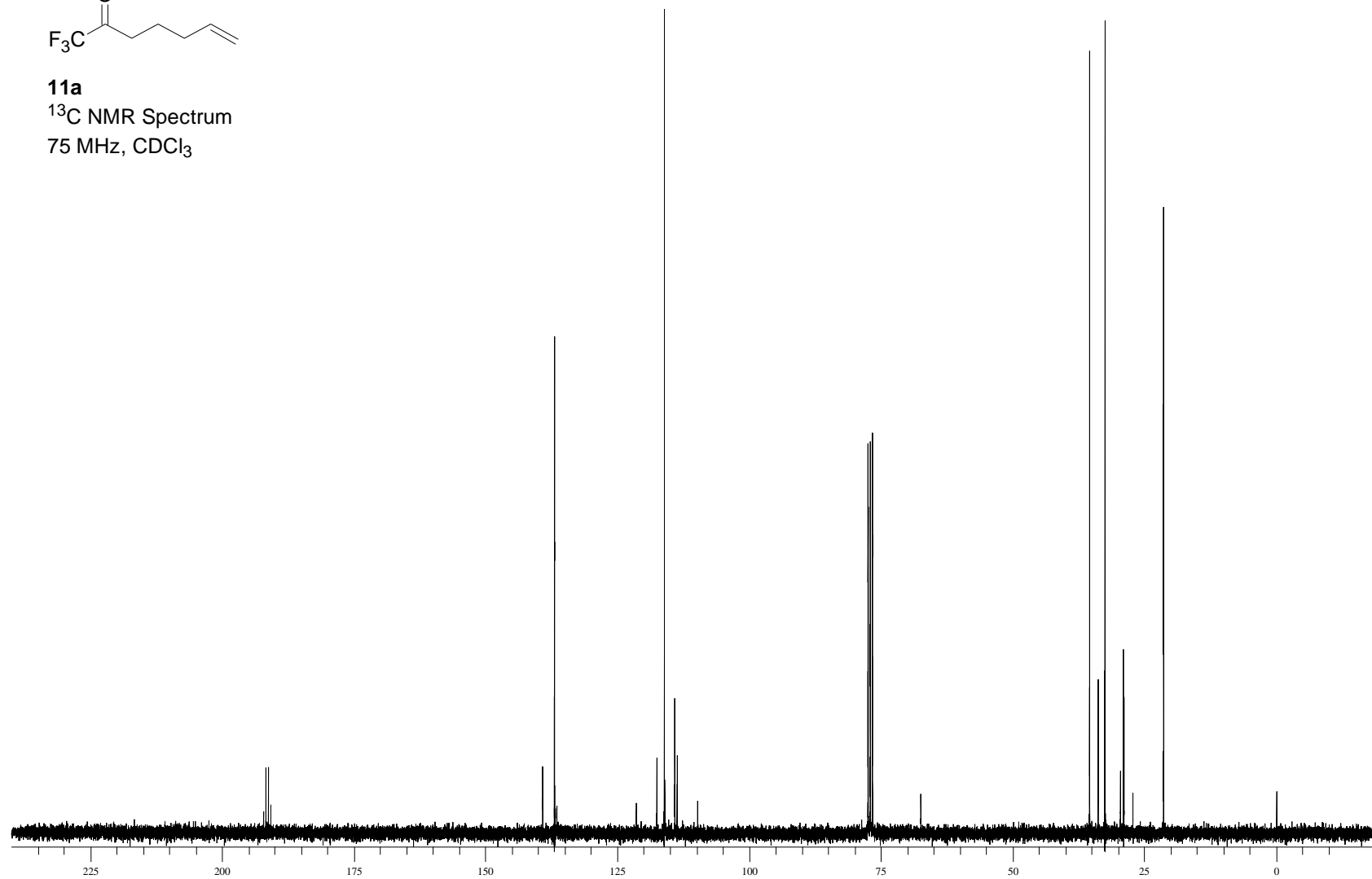
Table S1. Energies for 39-41 (RHF 6-311+G**)

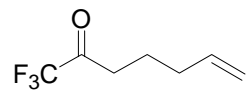
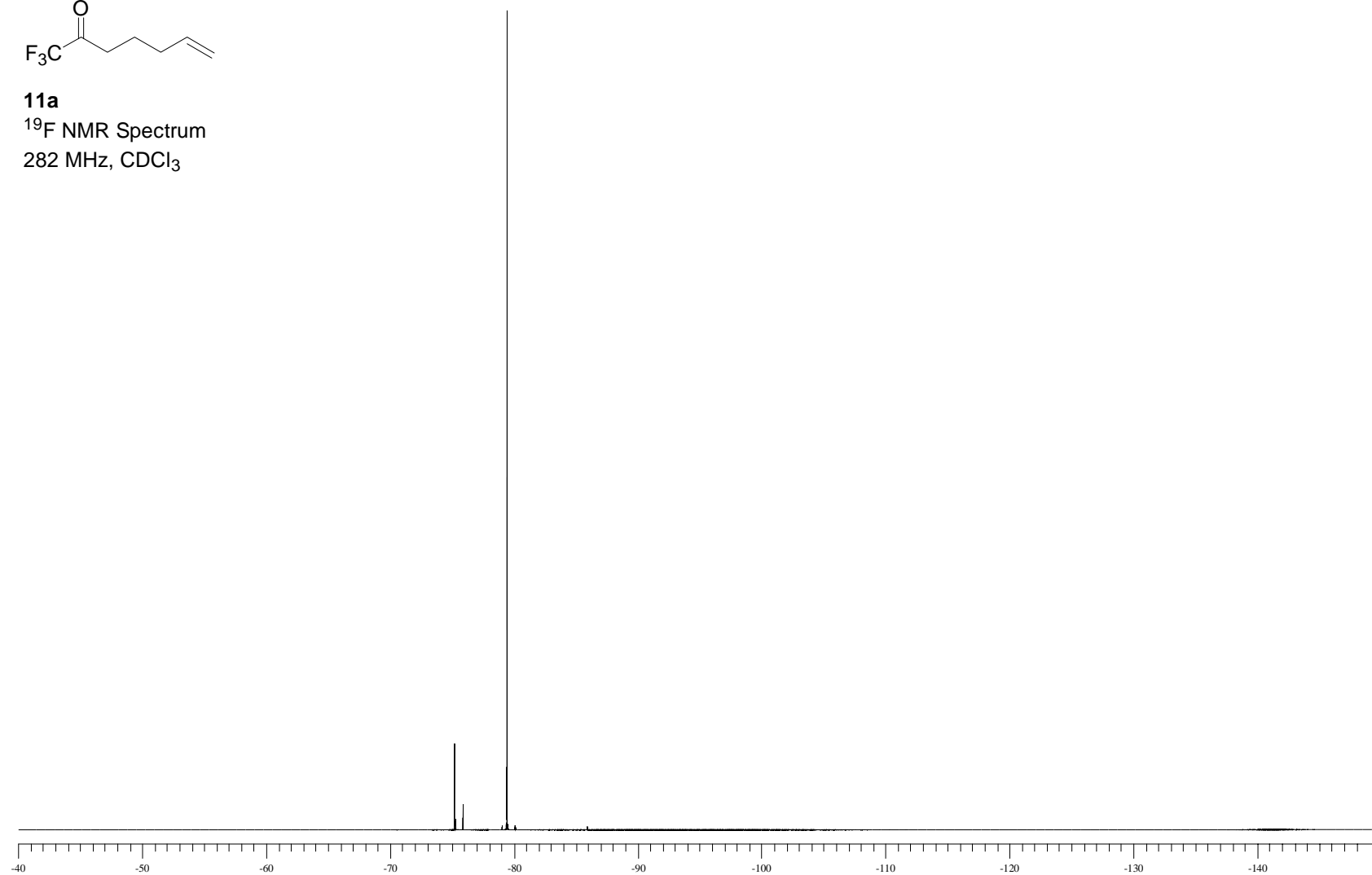
Triol	E/au (SPE, RHF 6-311+G**)
39 boat-boat	-808.4898918
39 boat-chair	-808.4862114
40 boat-boat	-808.4894521
40 boat-chair	-808.4860717
41 boat-boat	-808.4848713
41 boat-chair	-808.4833165

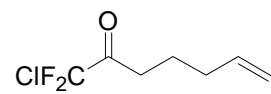
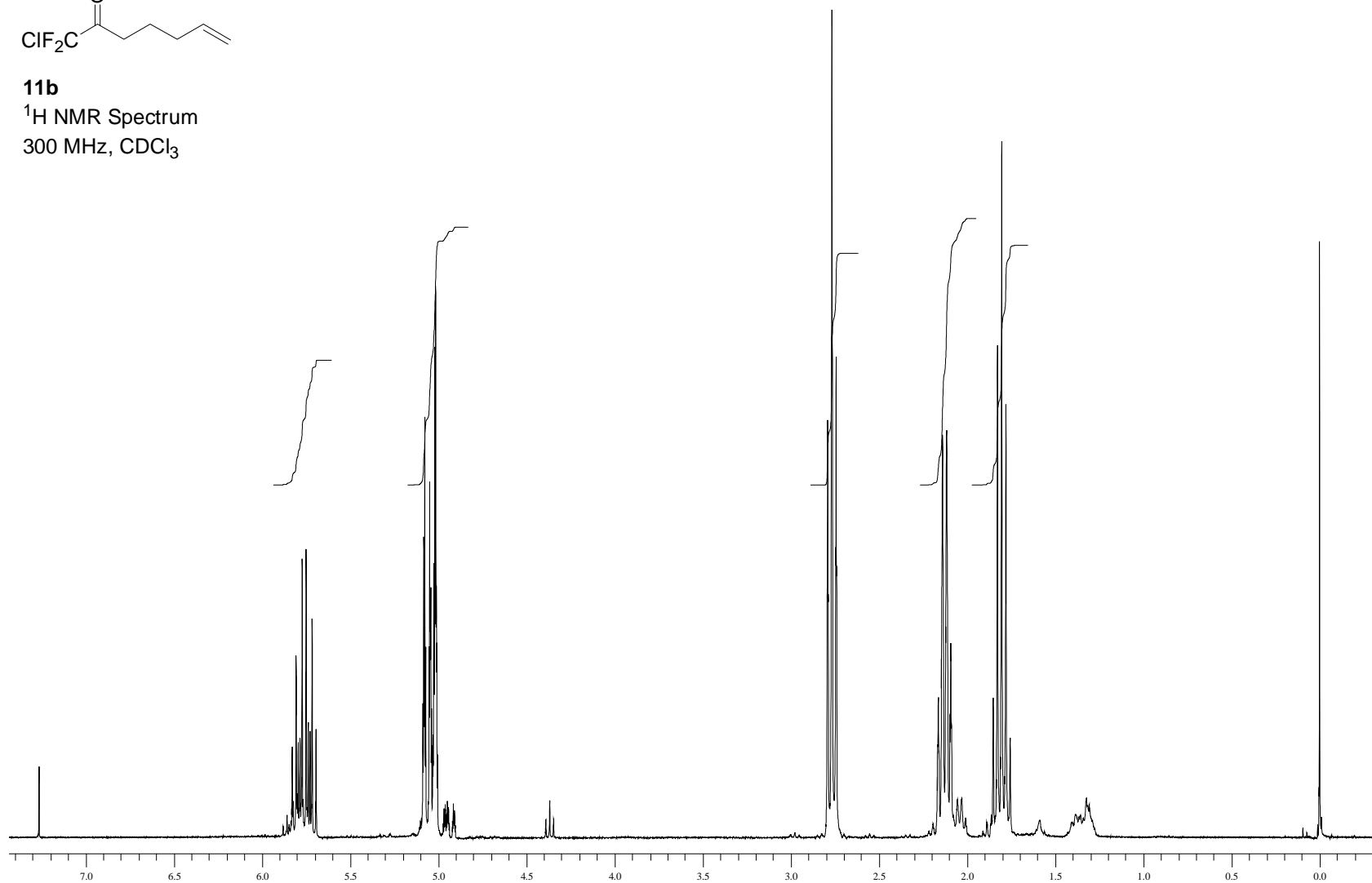


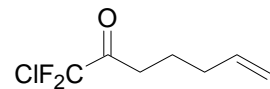
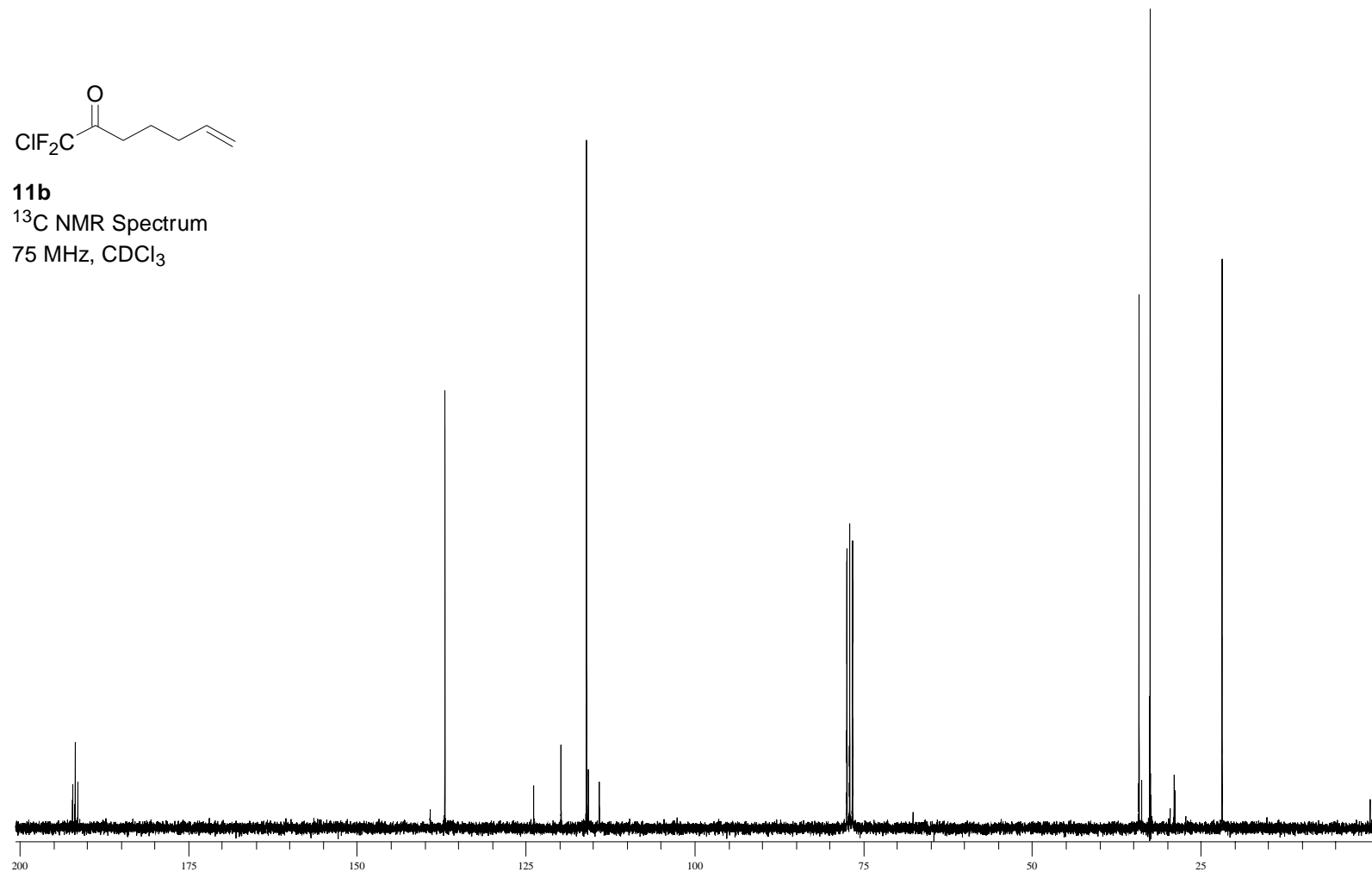
11a
 ^1H NMR Spectrum
300 MHz, CDCl_3

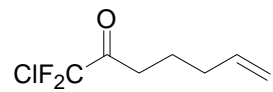
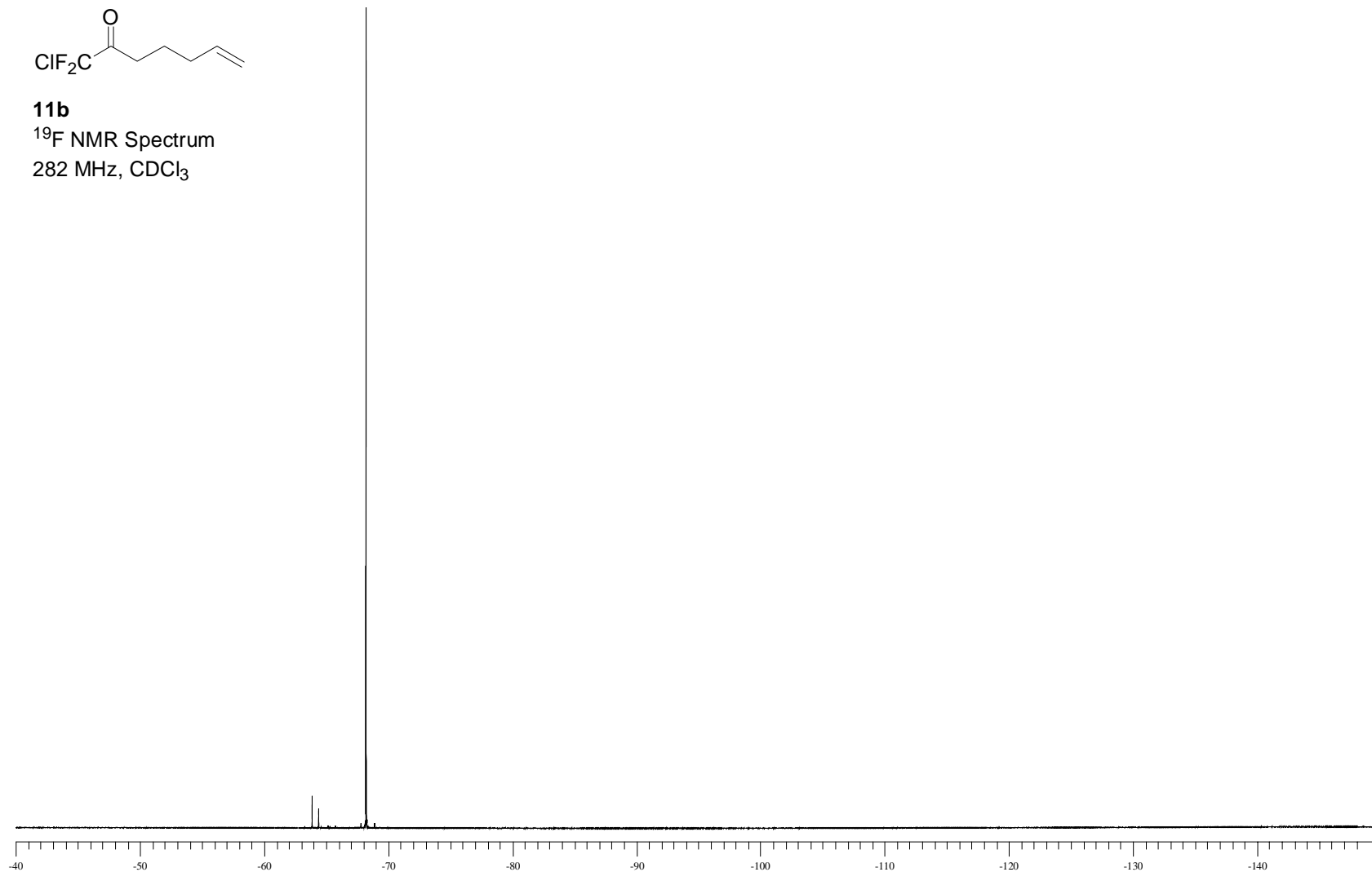


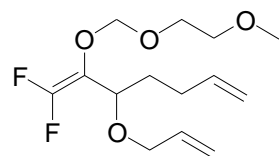
**11a**¹³C NMR Spectrum75 MHz, CDCl₃

**11a**¹⁹F NMR Spectrum282 MHz, CDCl₃

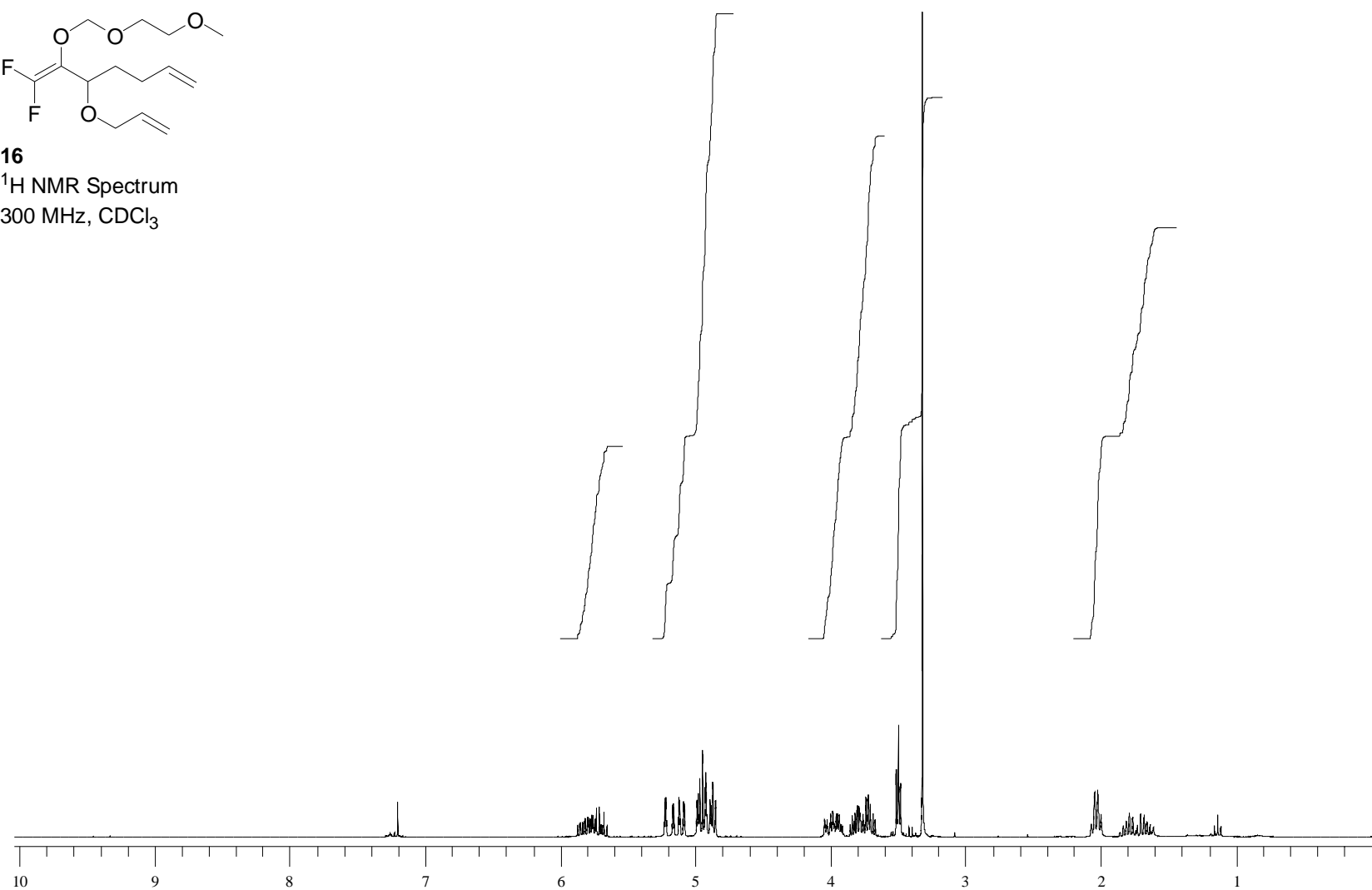
**11b**¹H NMR Spectrum300 MHz, CDCl₃

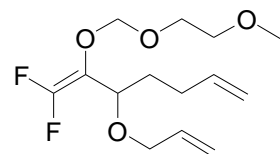
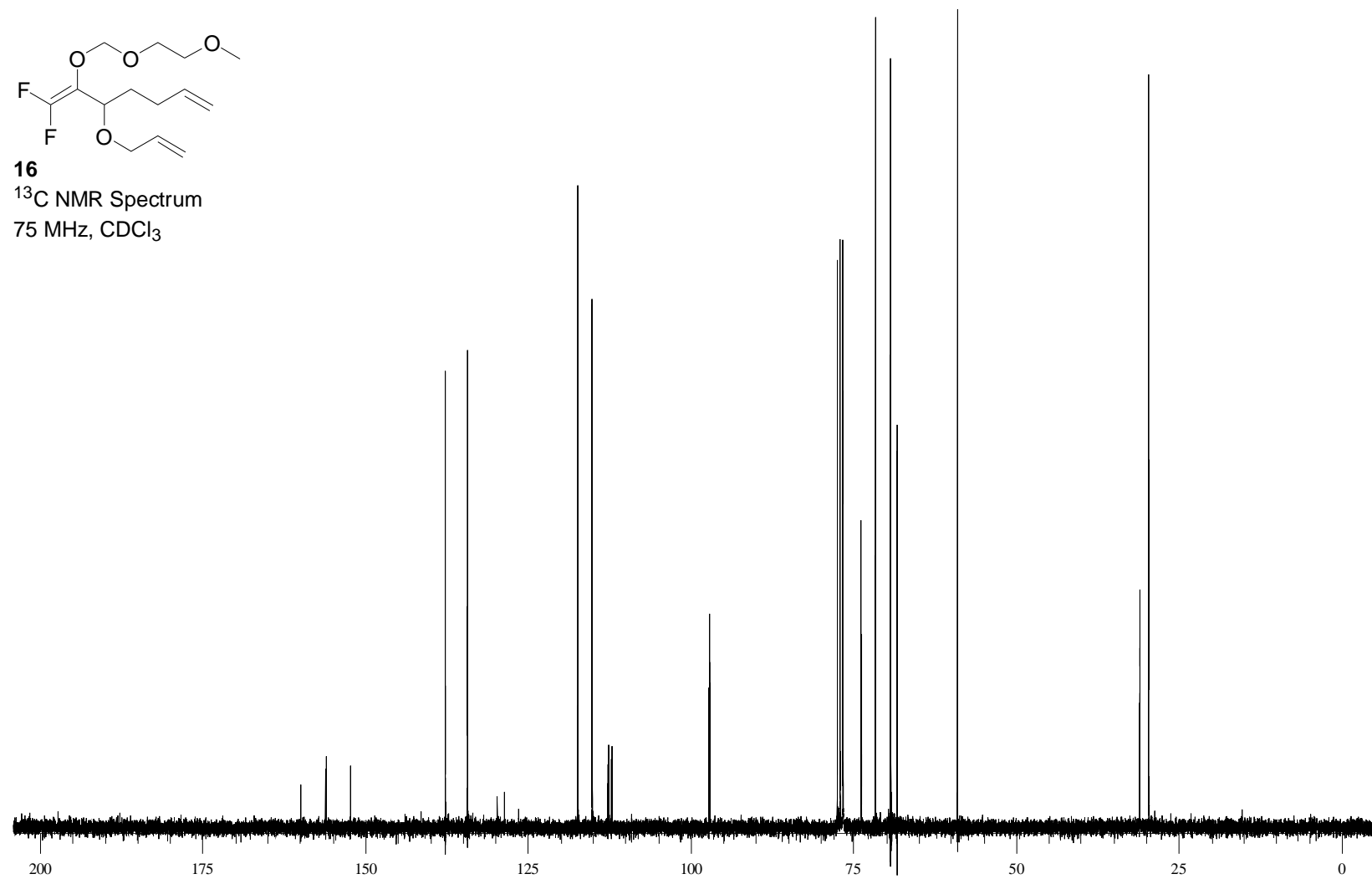
**11b**¹³C NMR Spectrum75 MHz, CDCl₃

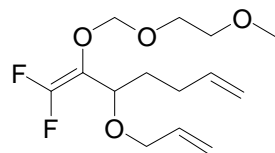
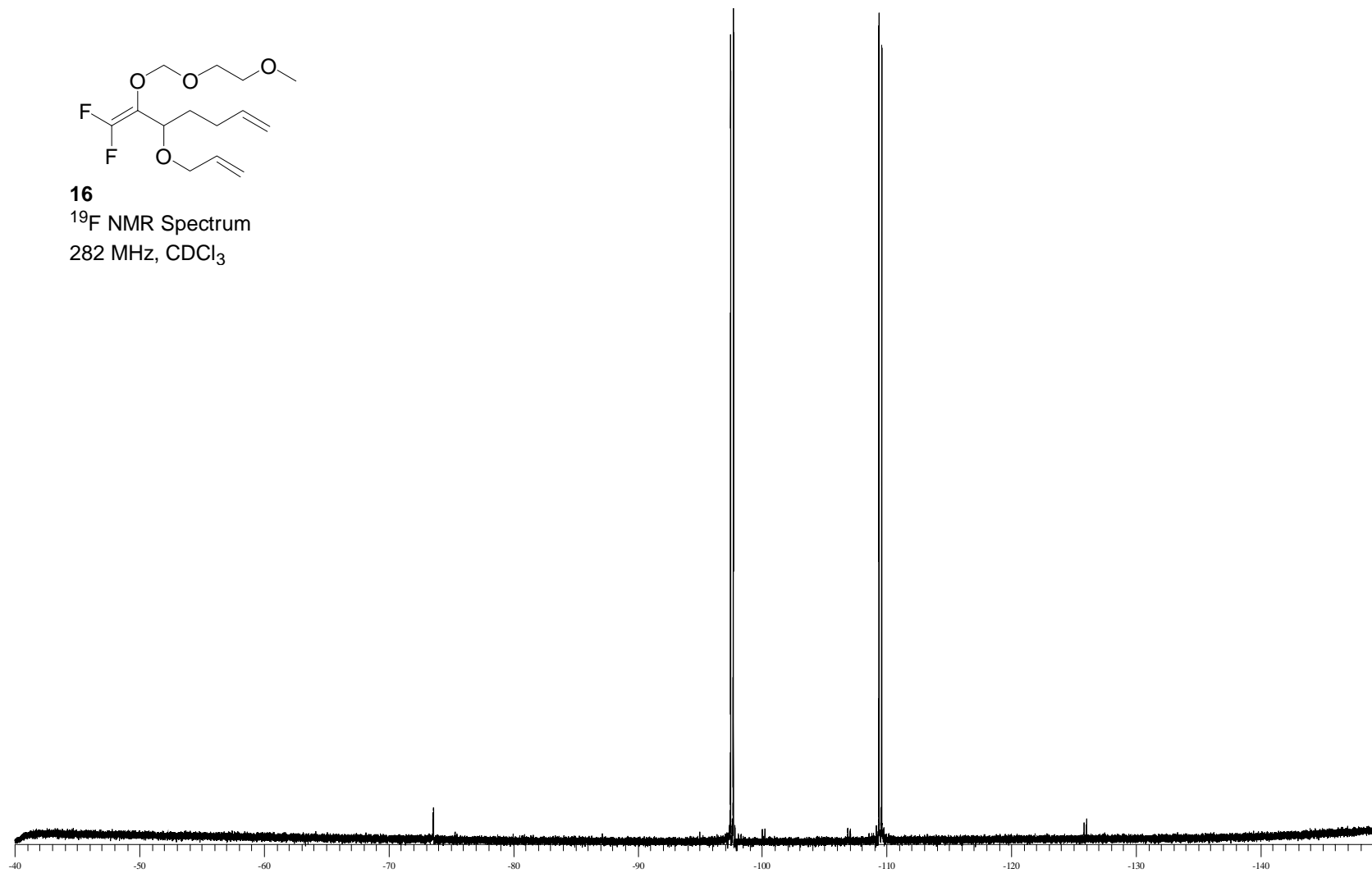
**11b**¹⁹F NMR Spectrum282 MHz, CDCl₃

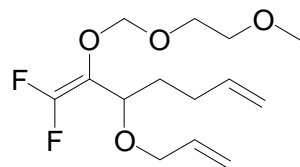
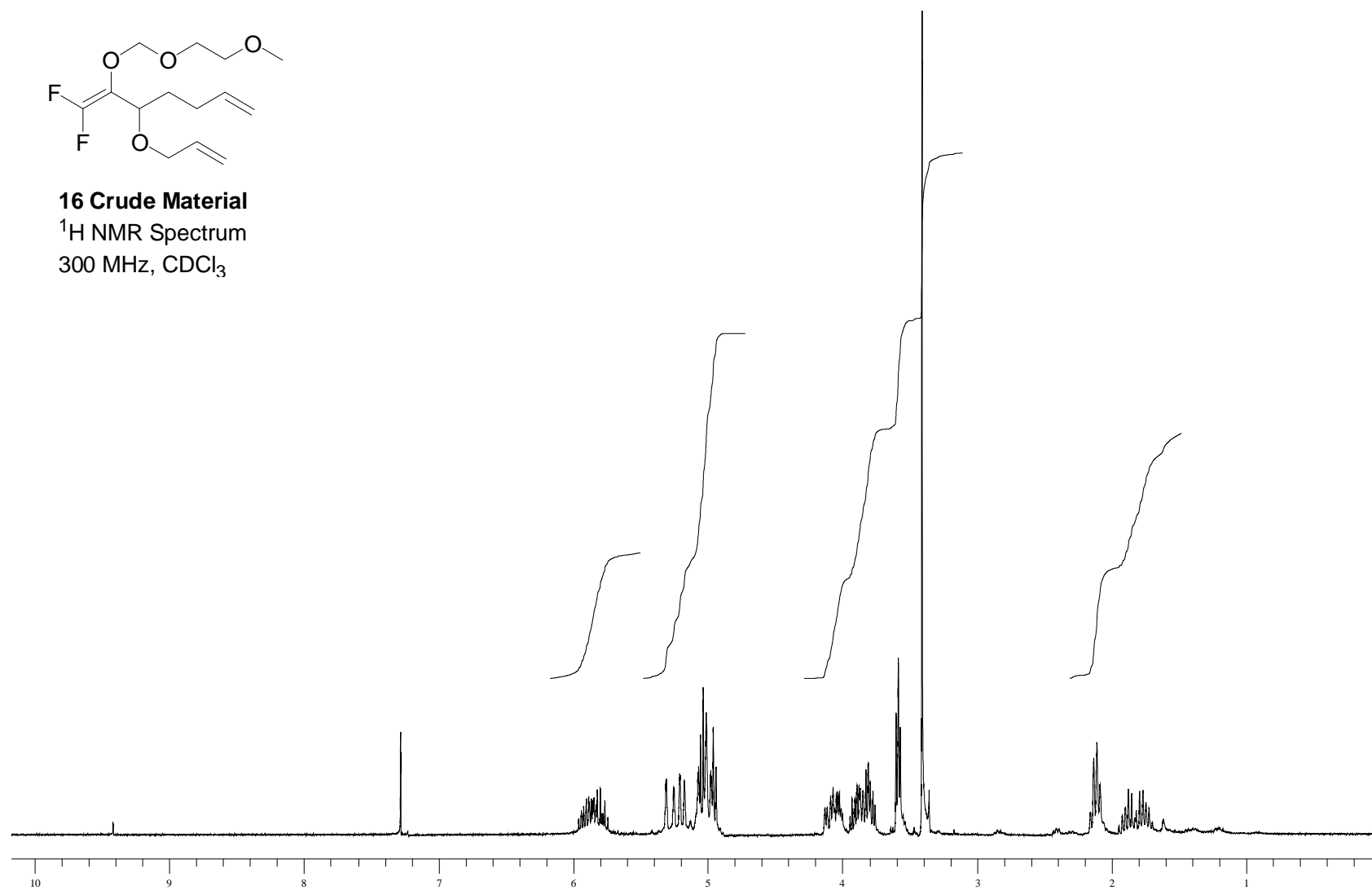
**16**

^1H NMR Spectrum
300 MHz, CDCl_3

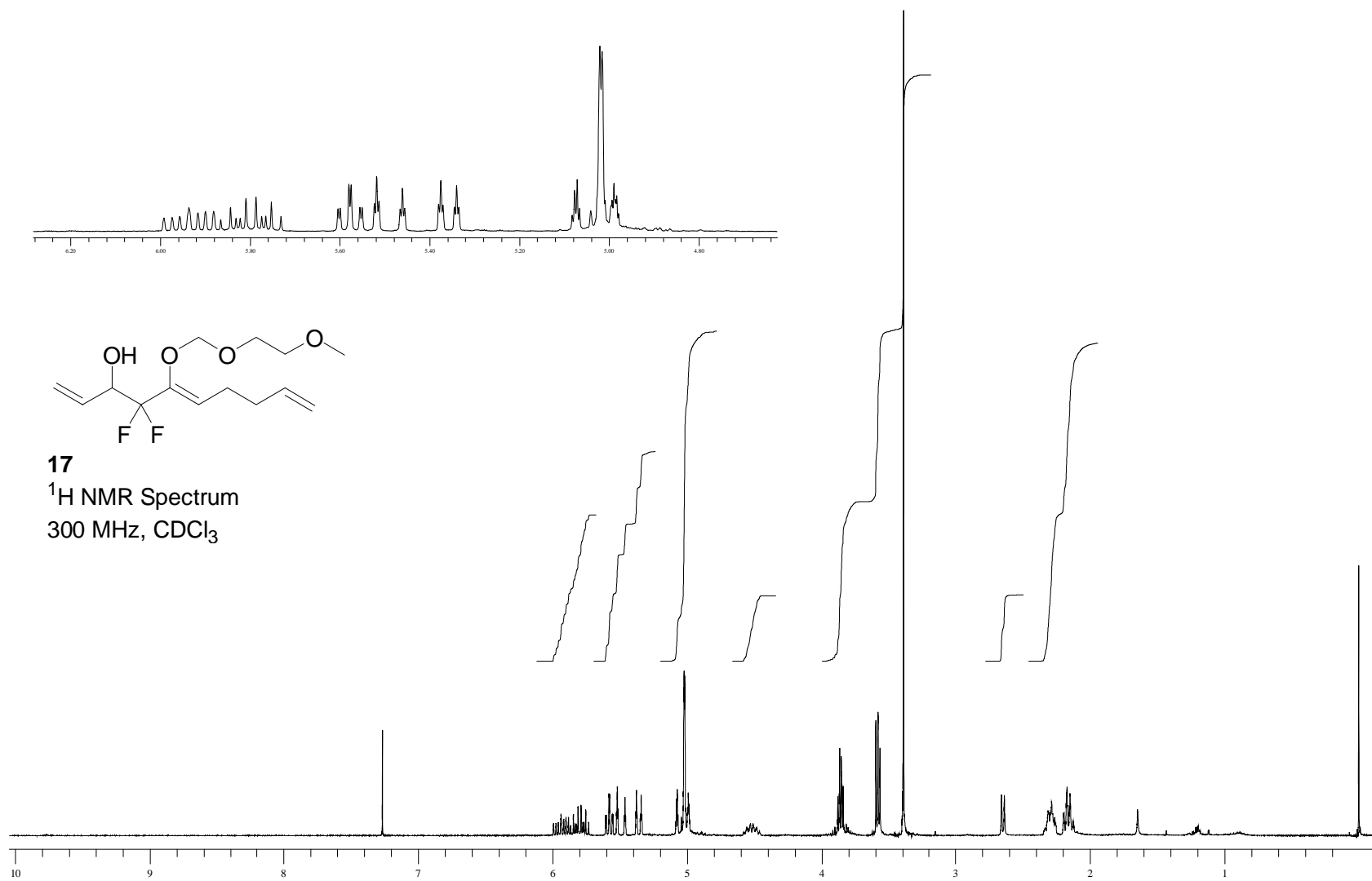


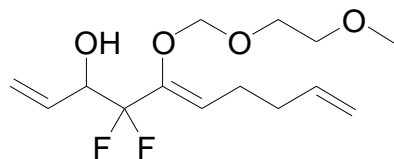
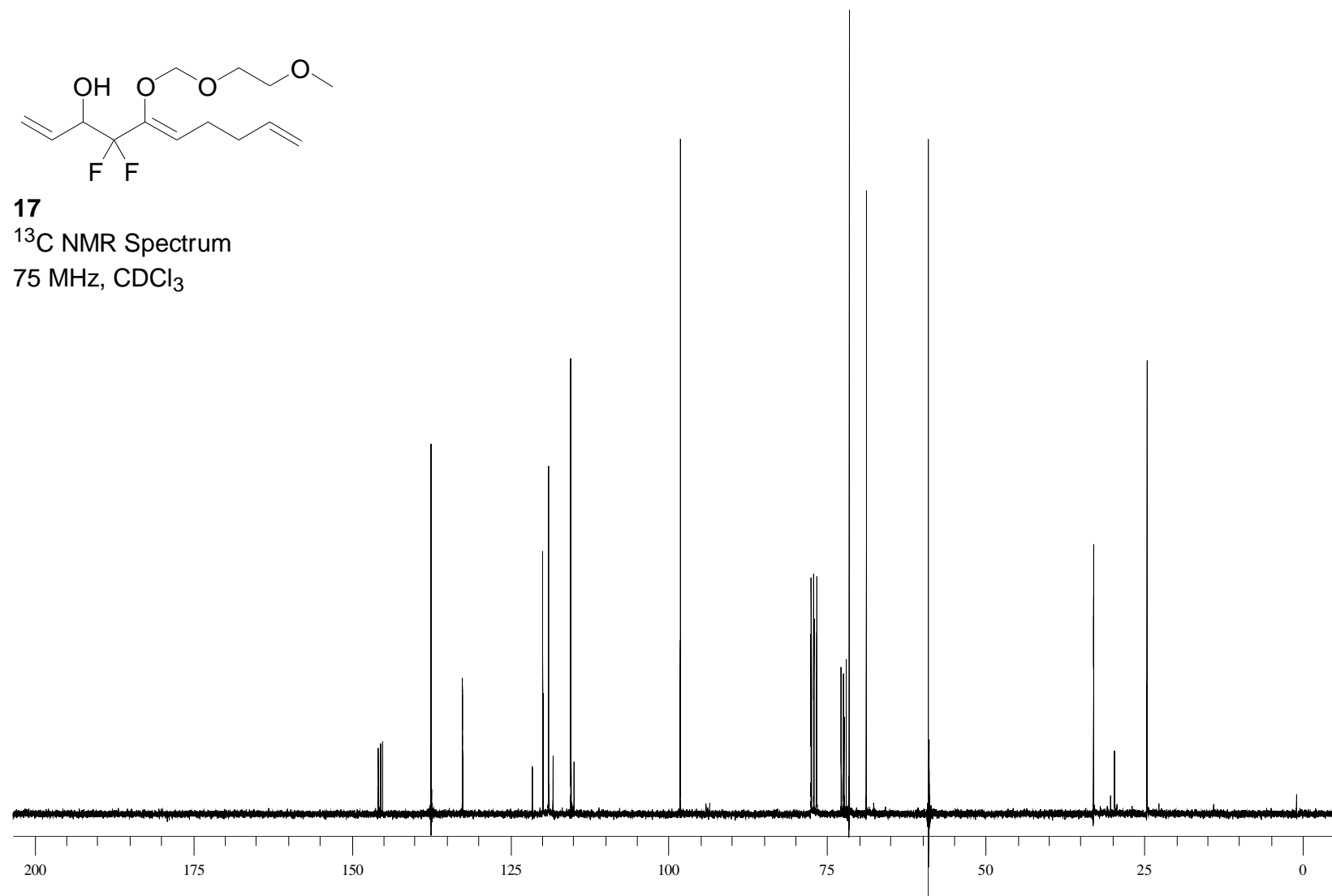
**16**¹³C NMR Spectrum75 MHz, CDCl₃

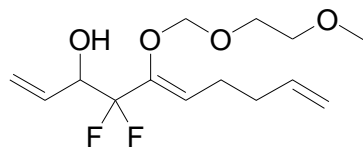
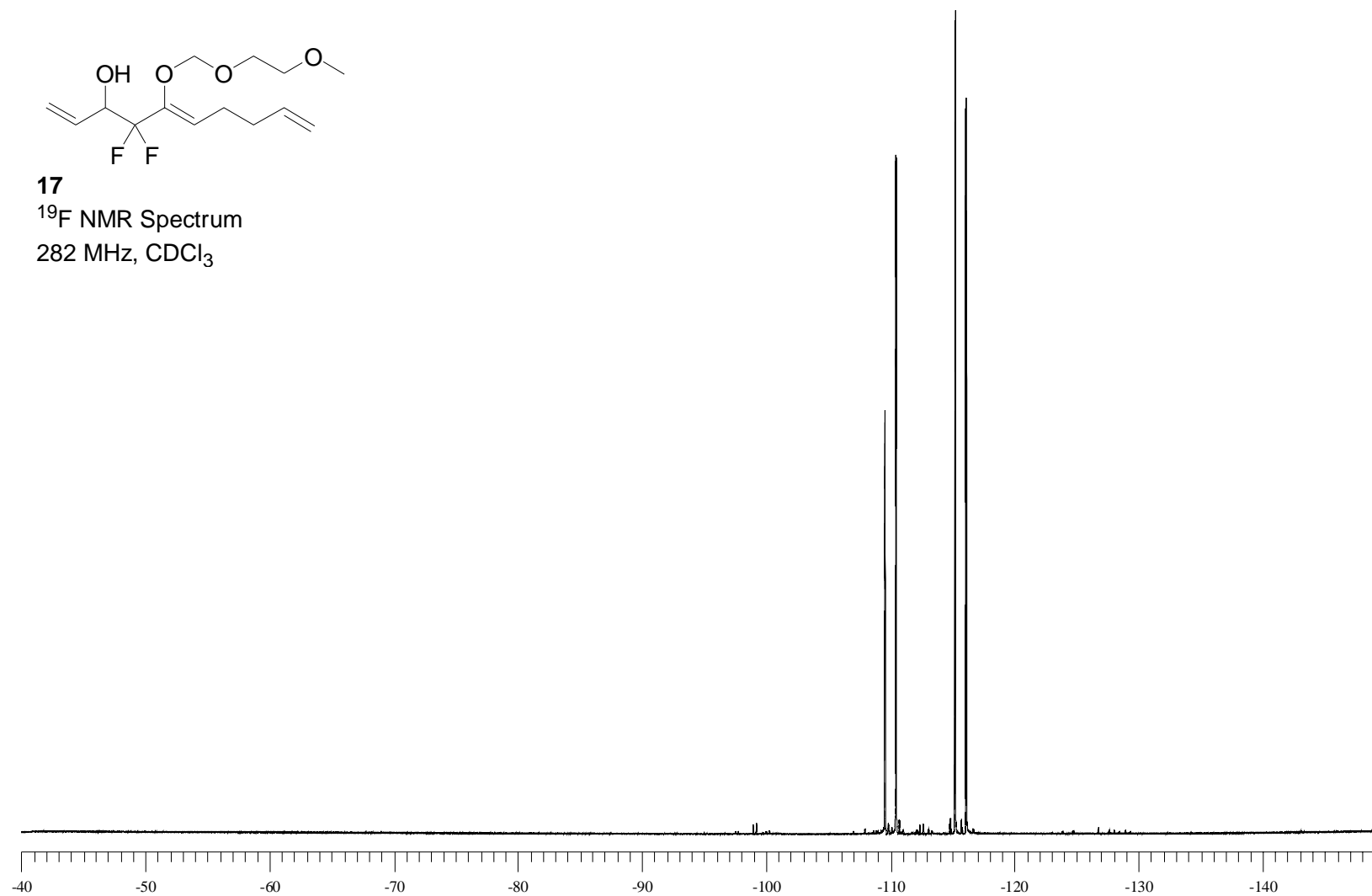
**16**¹⁹F NMR Spectrum282 MHz, CDCl₃

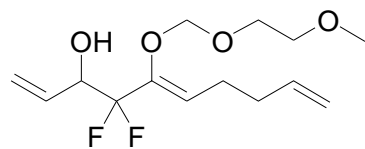
**16 Crude Material**¹H NMR Spectrum300 MHz, CDCl₃

S30

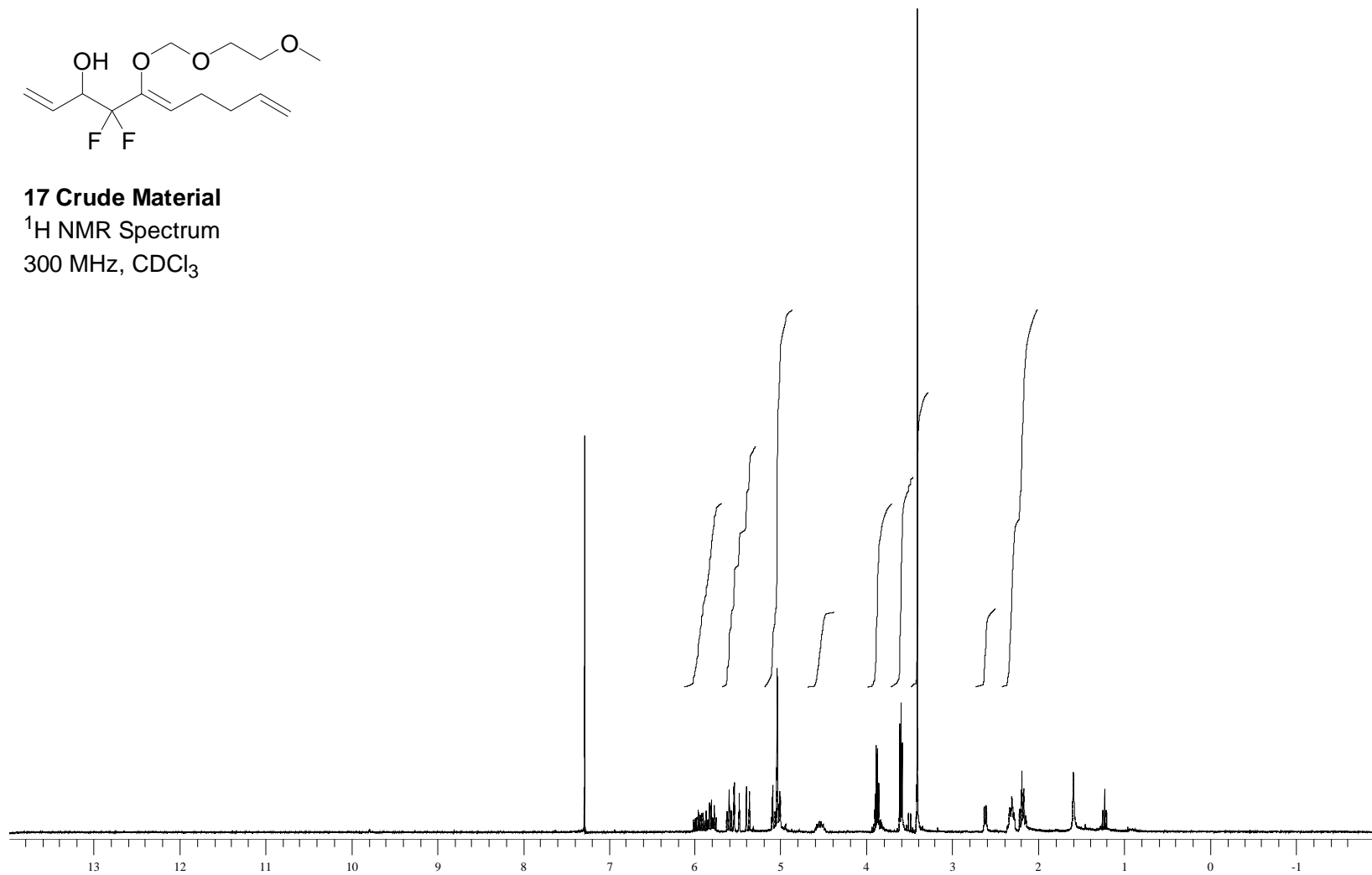


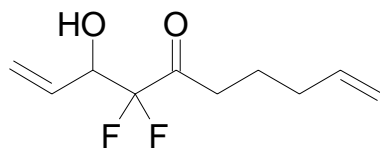
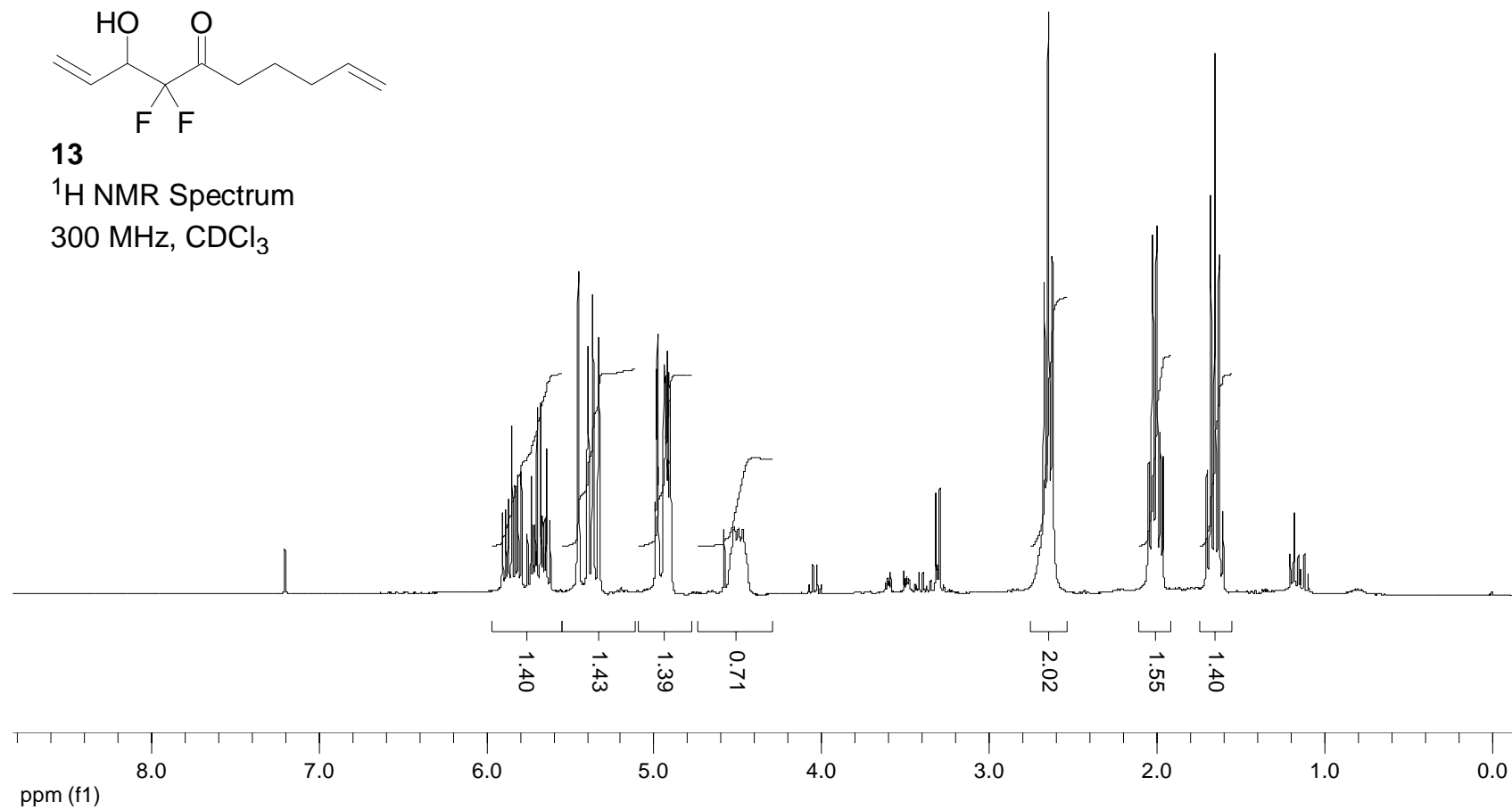
**17**¹³C NMR Spectrum75 MHz, CDCl₃

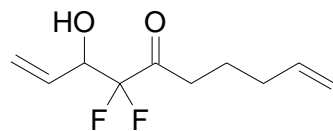
**17**¹⁹F NMR Spectrum282 MHz, CDCl₃



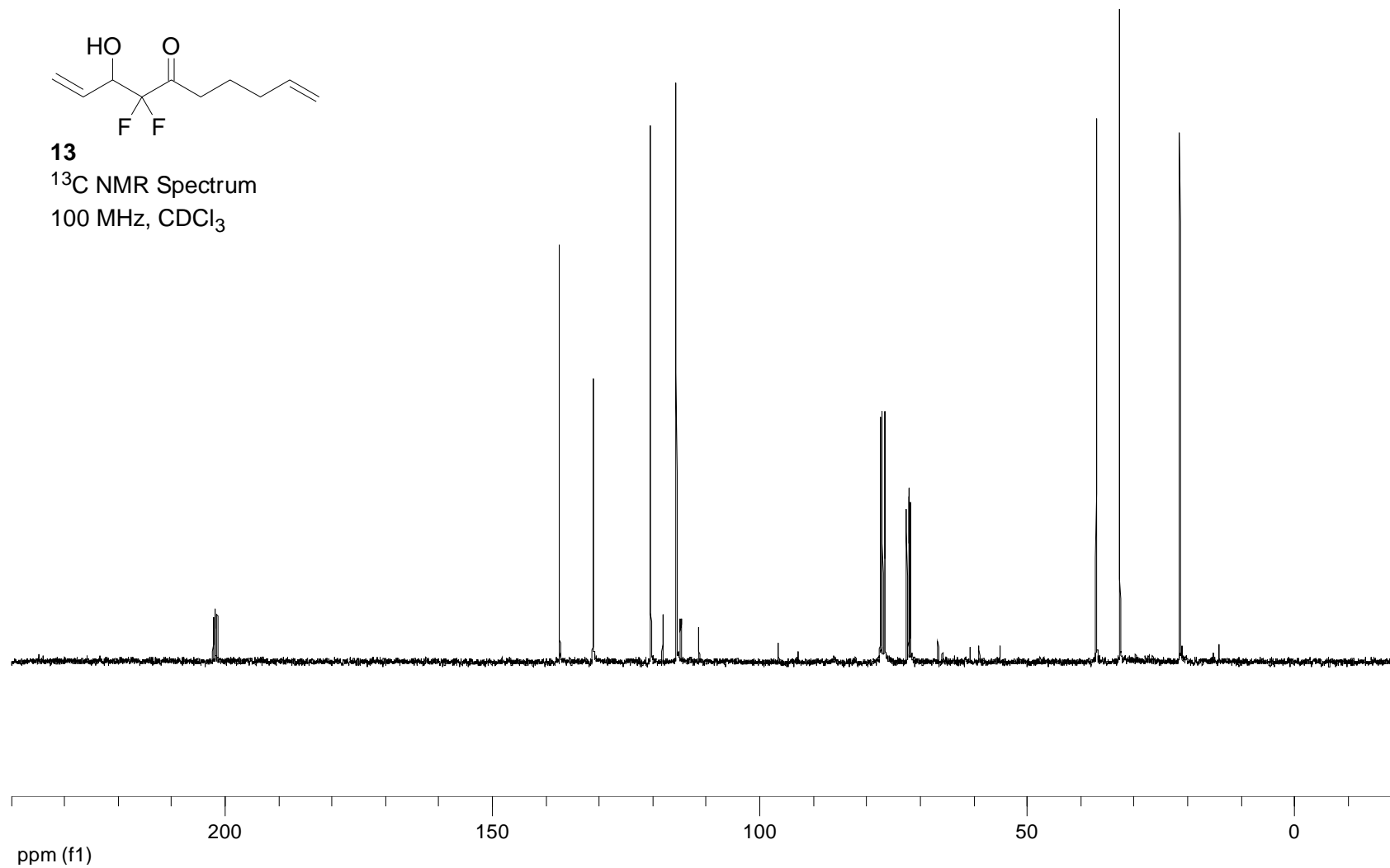
17 Crude Material
 ^1H NMR Spectrum
300 MHz, CDCl_3

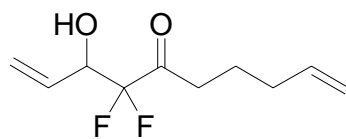
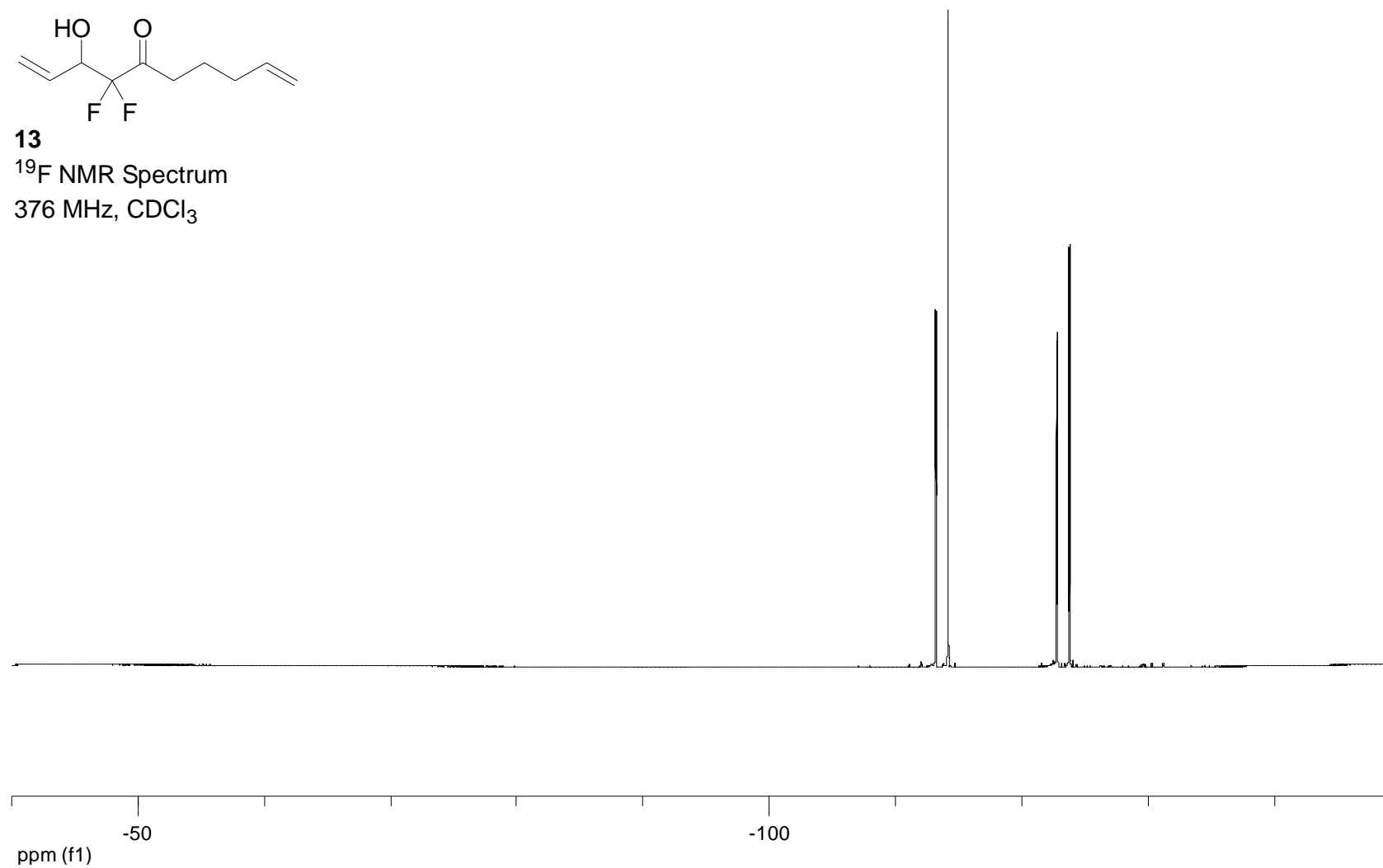


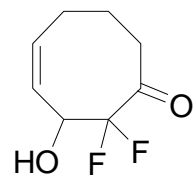
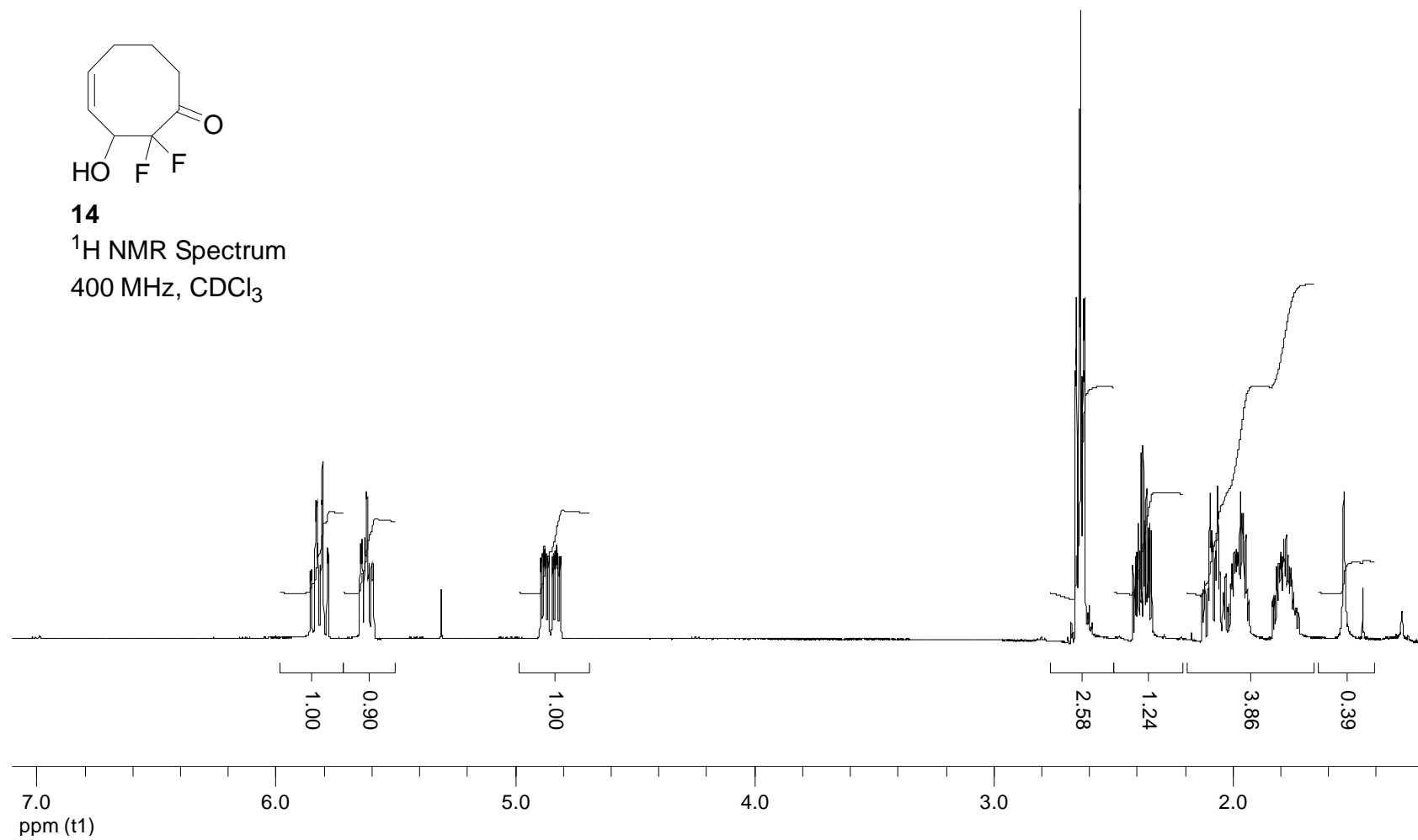
**13**¹H NMR Spectrum300 MHz, CDCl₃

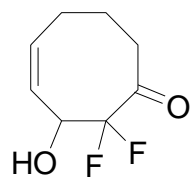
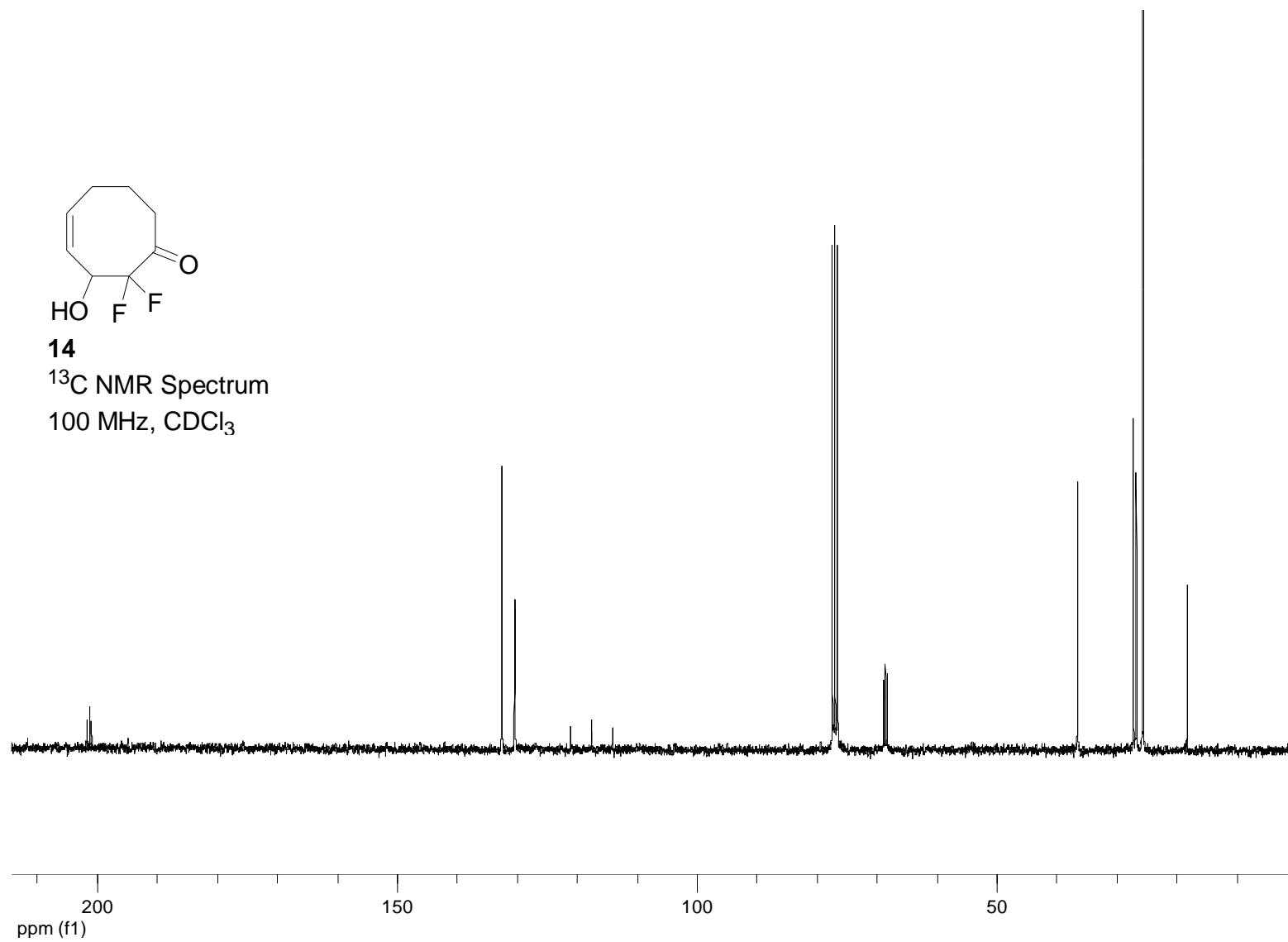


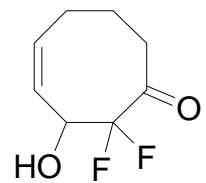
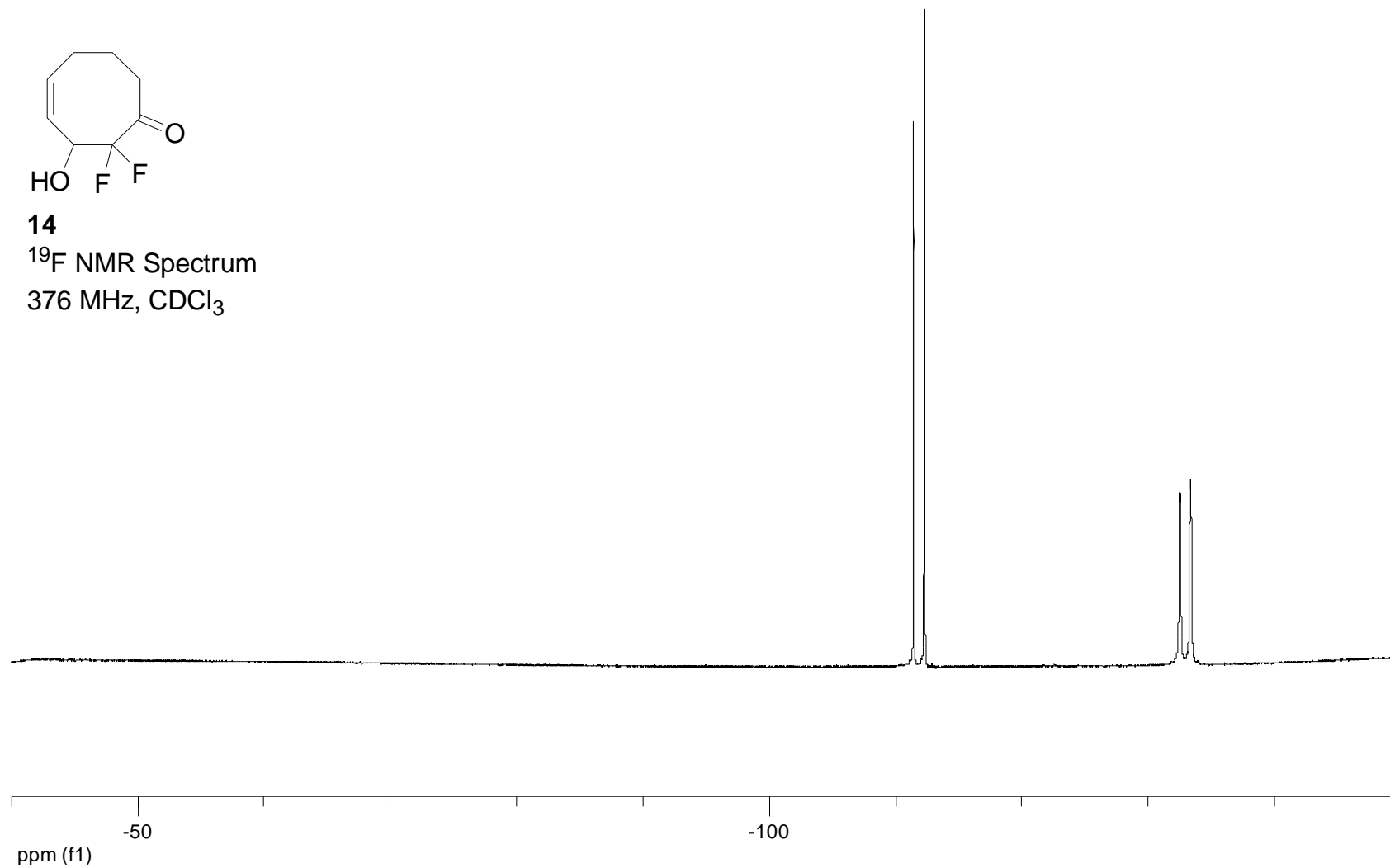
13
 ^{13}C NMR Spectrum
100 MHz, CDCl_3



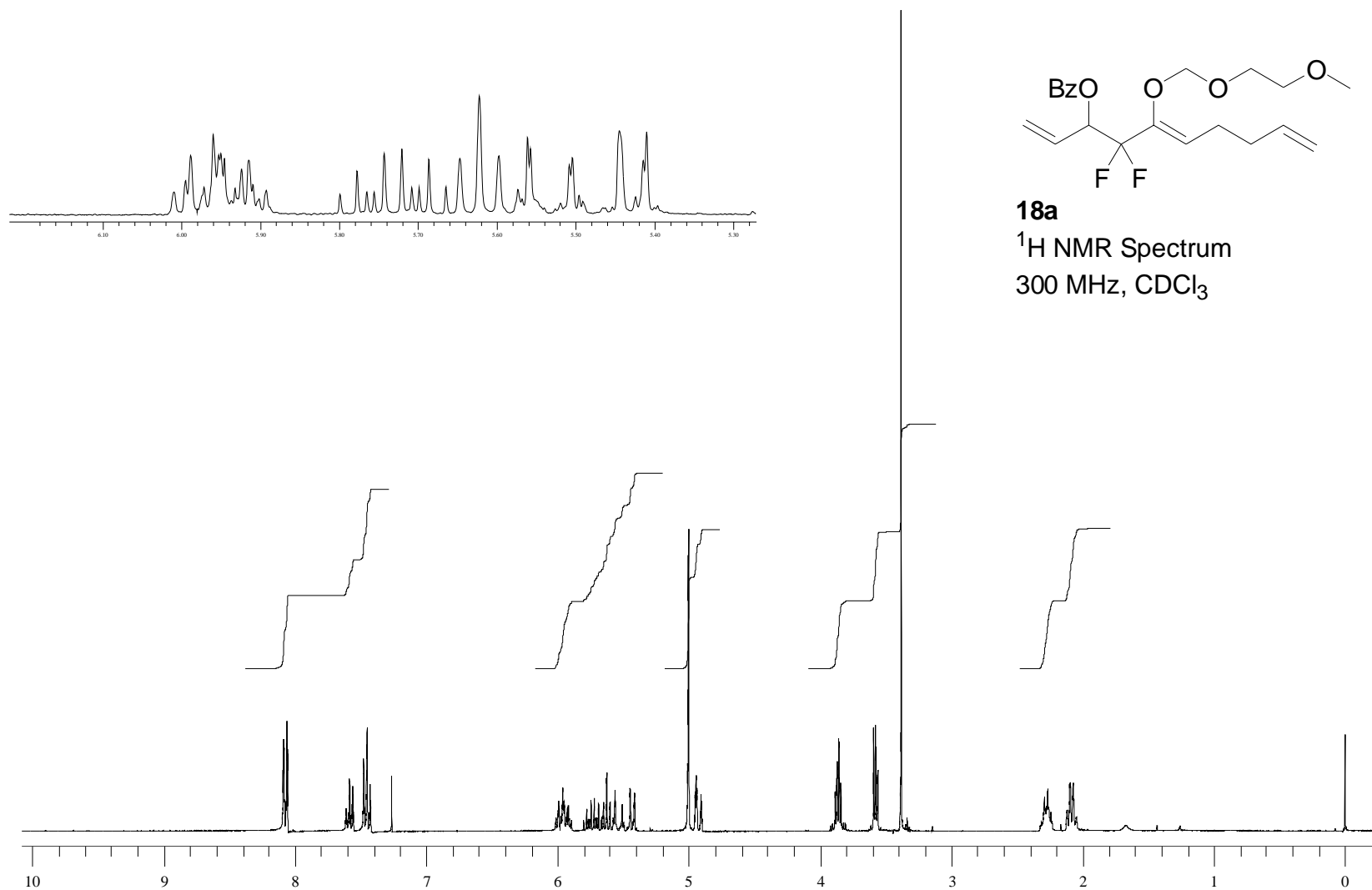
**13**¹⁹F NMR Spectrum376 MHz, CDCl₃

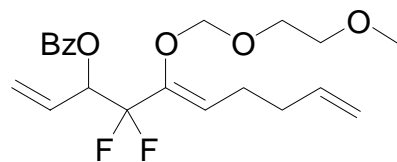
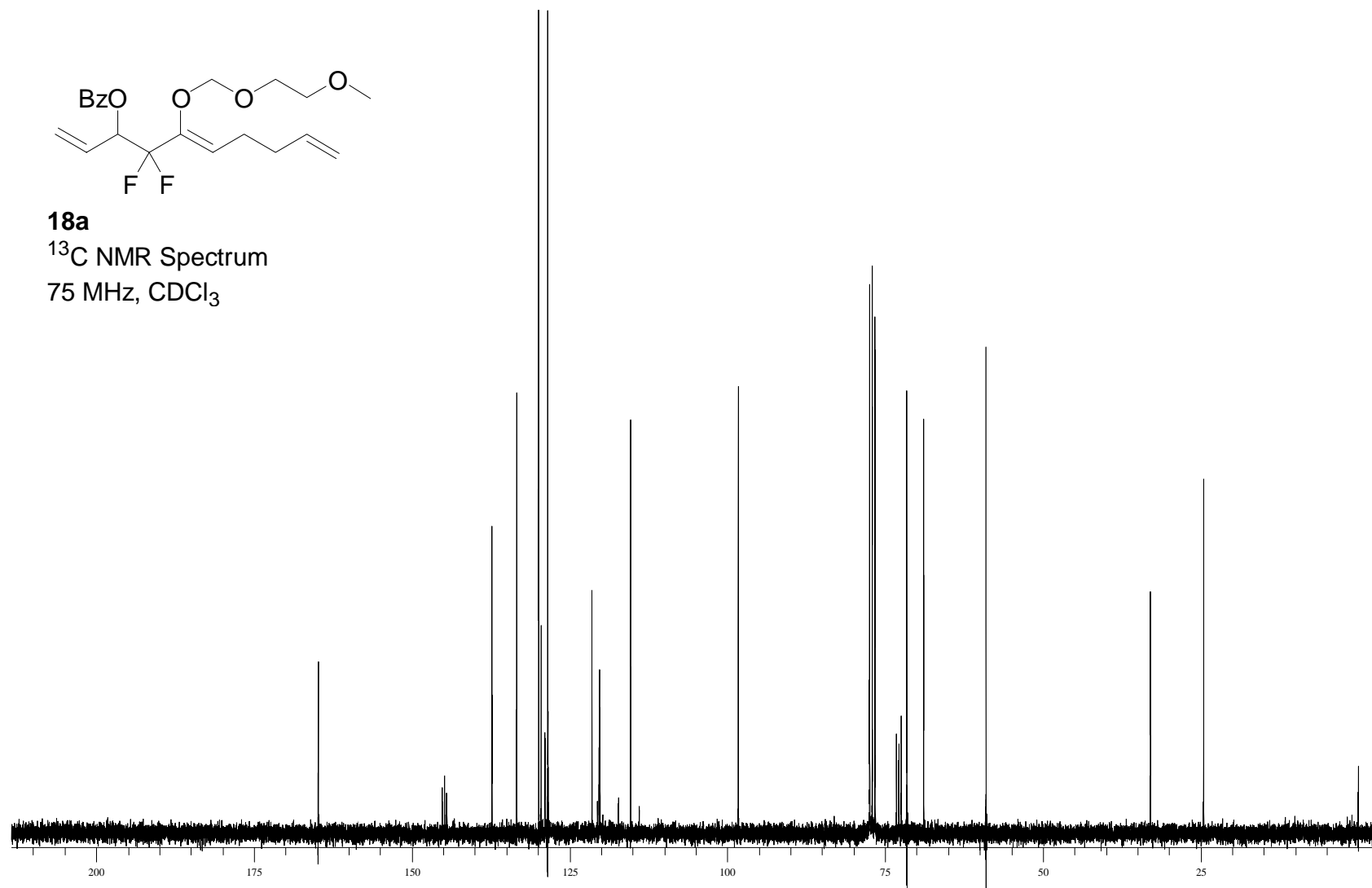
**14**¹H NMR Spectrum400 MHz, CDCl₃

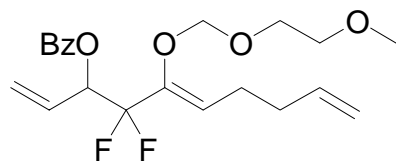
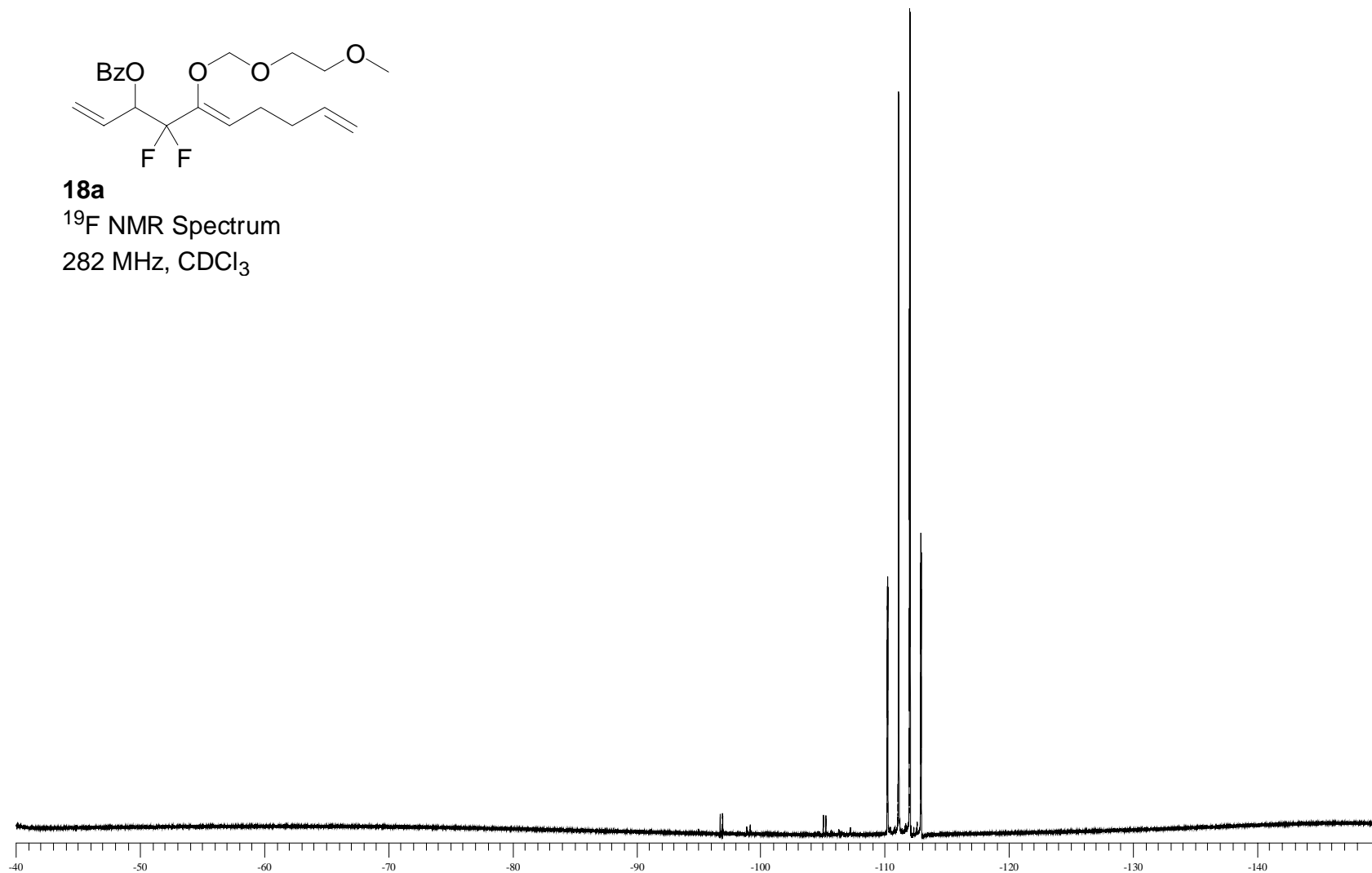
**14**¹³C NMR Spectrum100 MHz, CDCl₃

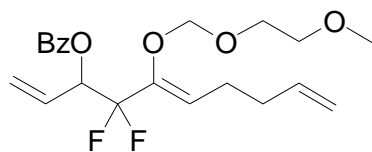
**14**¹⁹F NMR Spectrum376 MHz, CDCl₃

S40



**18a** ^{13}C NMR Spectrum75 MHz, CDCl_3 

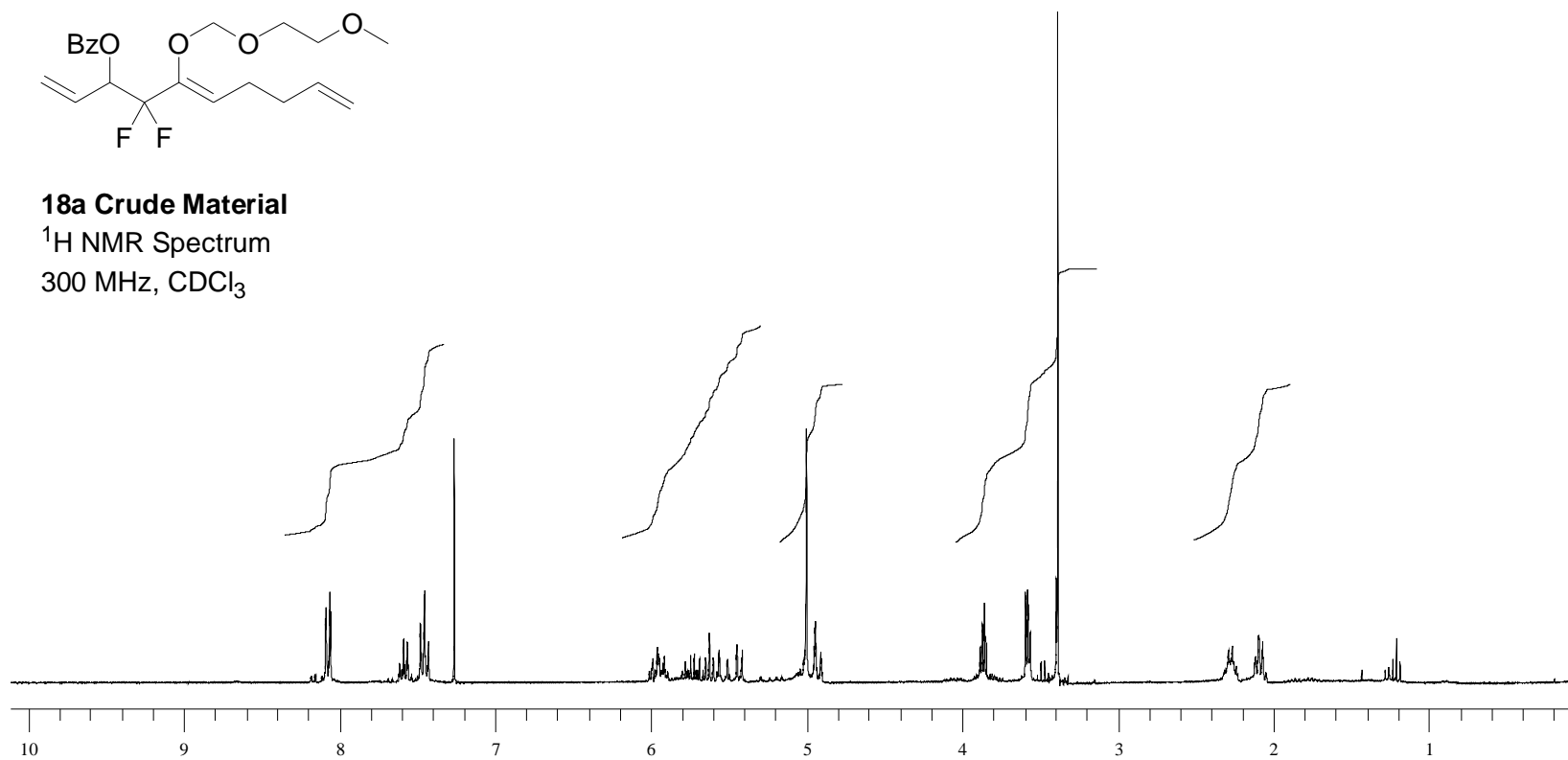
**18a**¹⁹F NMR Spectrum282 MHz, CDCl₃



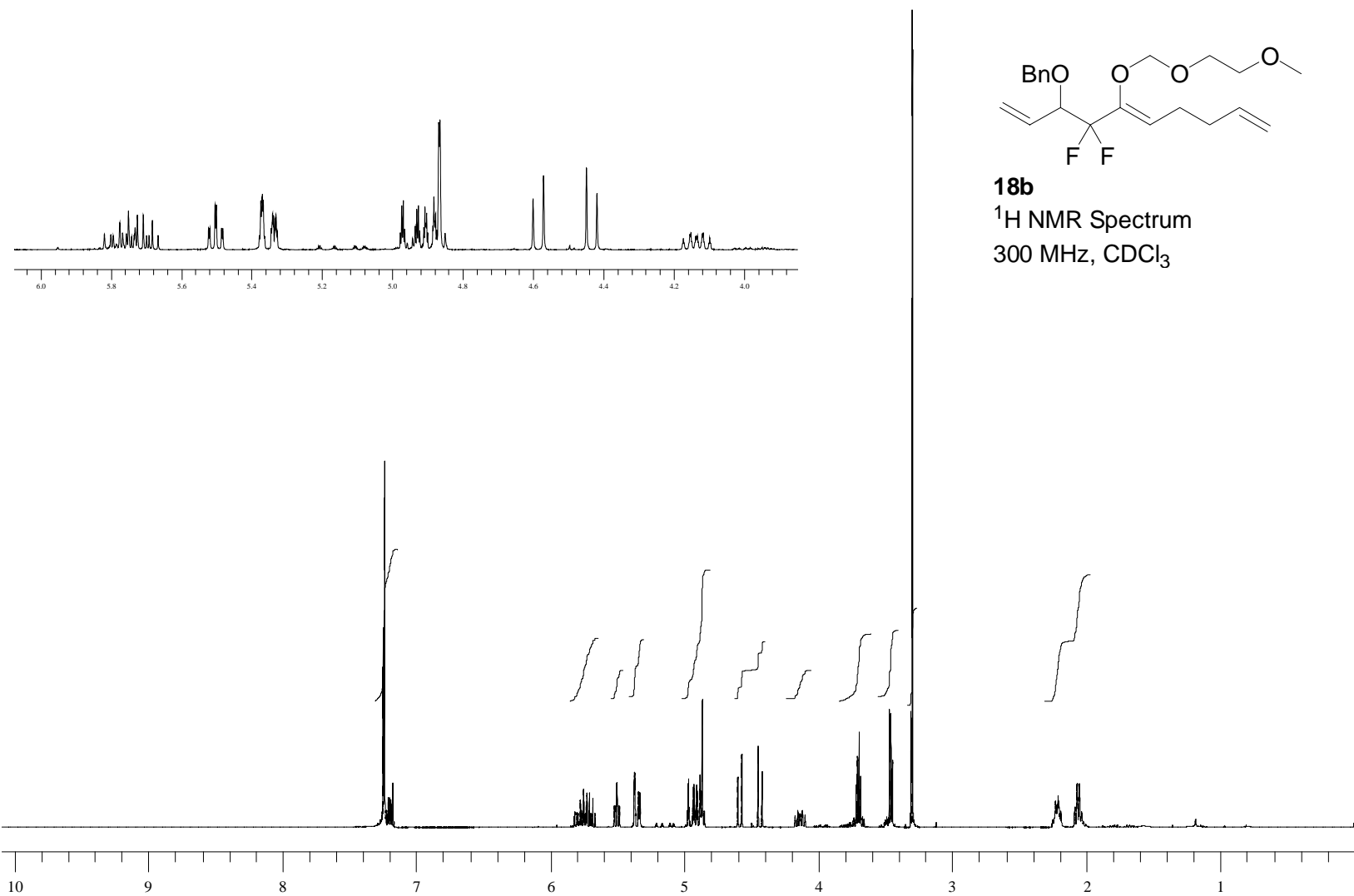
18a Crude Material

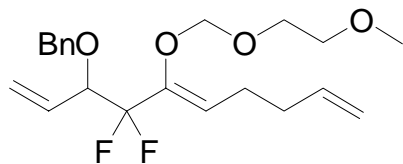
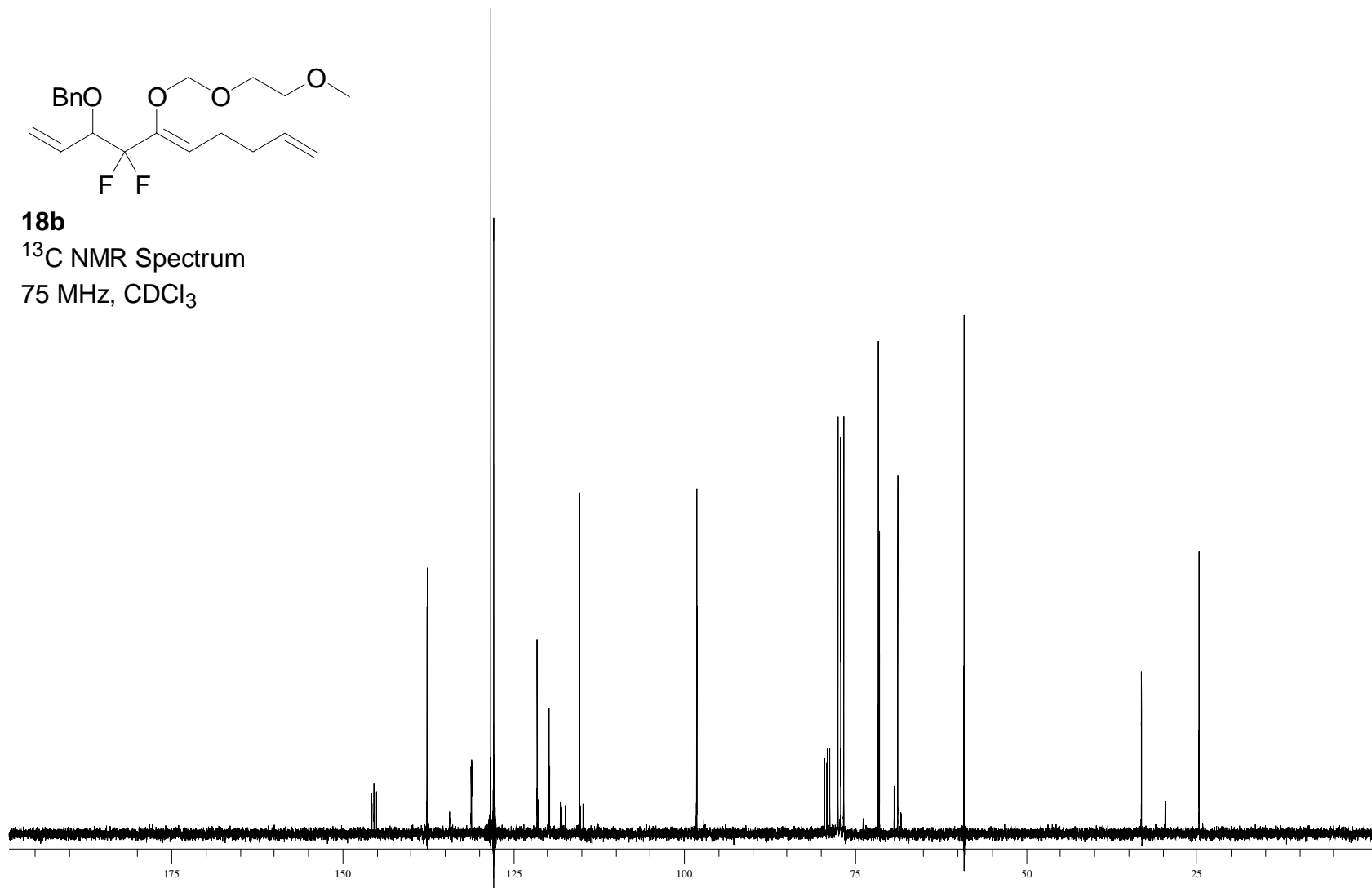
¹H NMR Spectrum

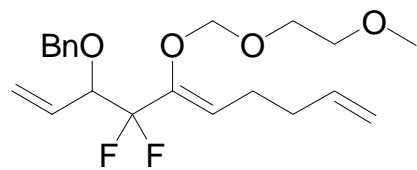
300 MHz, CDCl₃



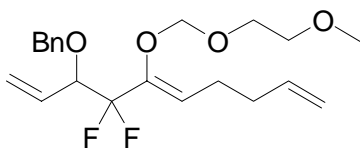
S44



**18b** ^{13}C NMR Spectrum75 MHz, CDCl_3 



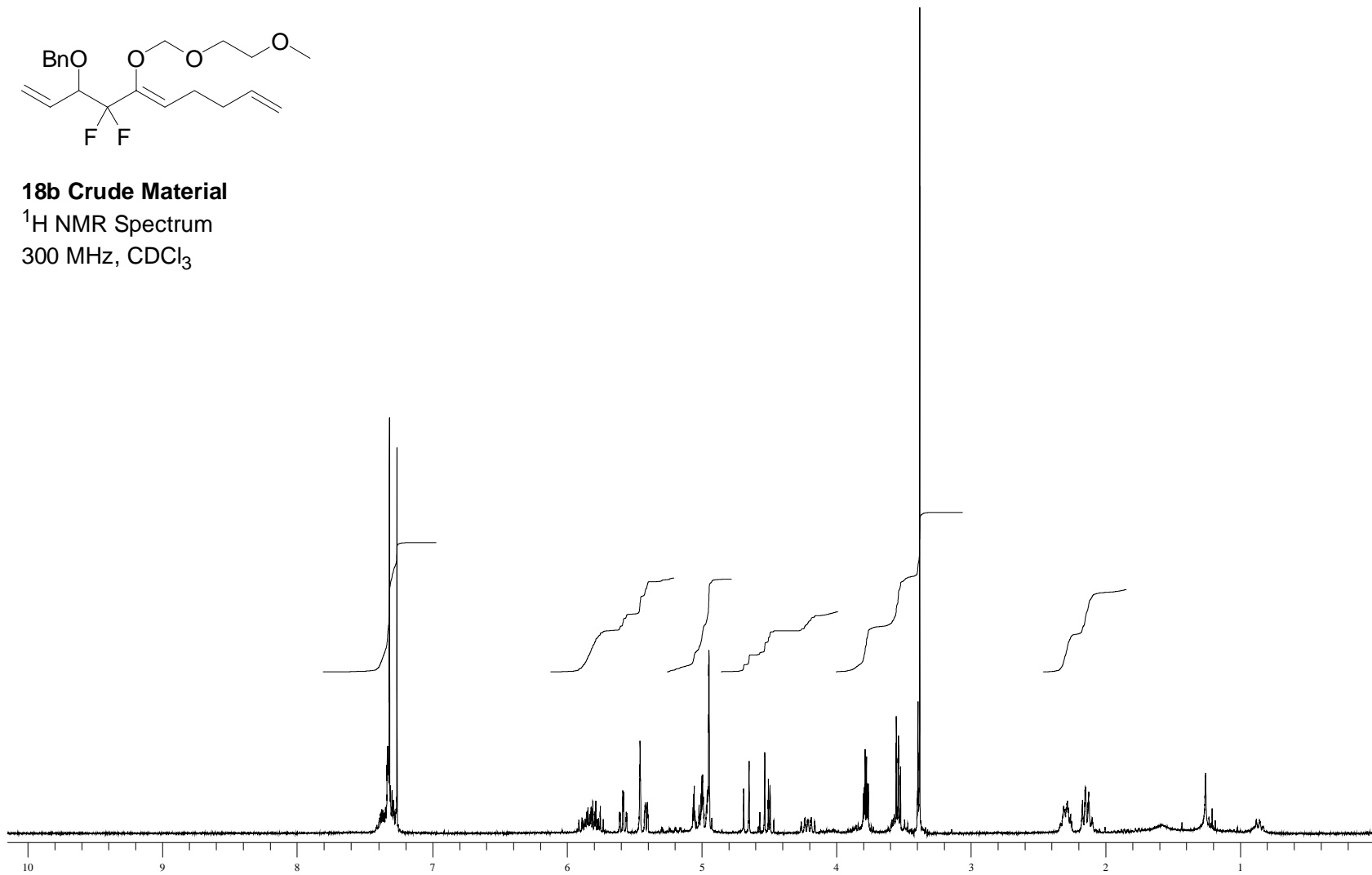
18b
¹⁹F NMR Spectrum
 282 MHz, CDCl₃

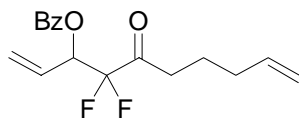


18b Crude Material

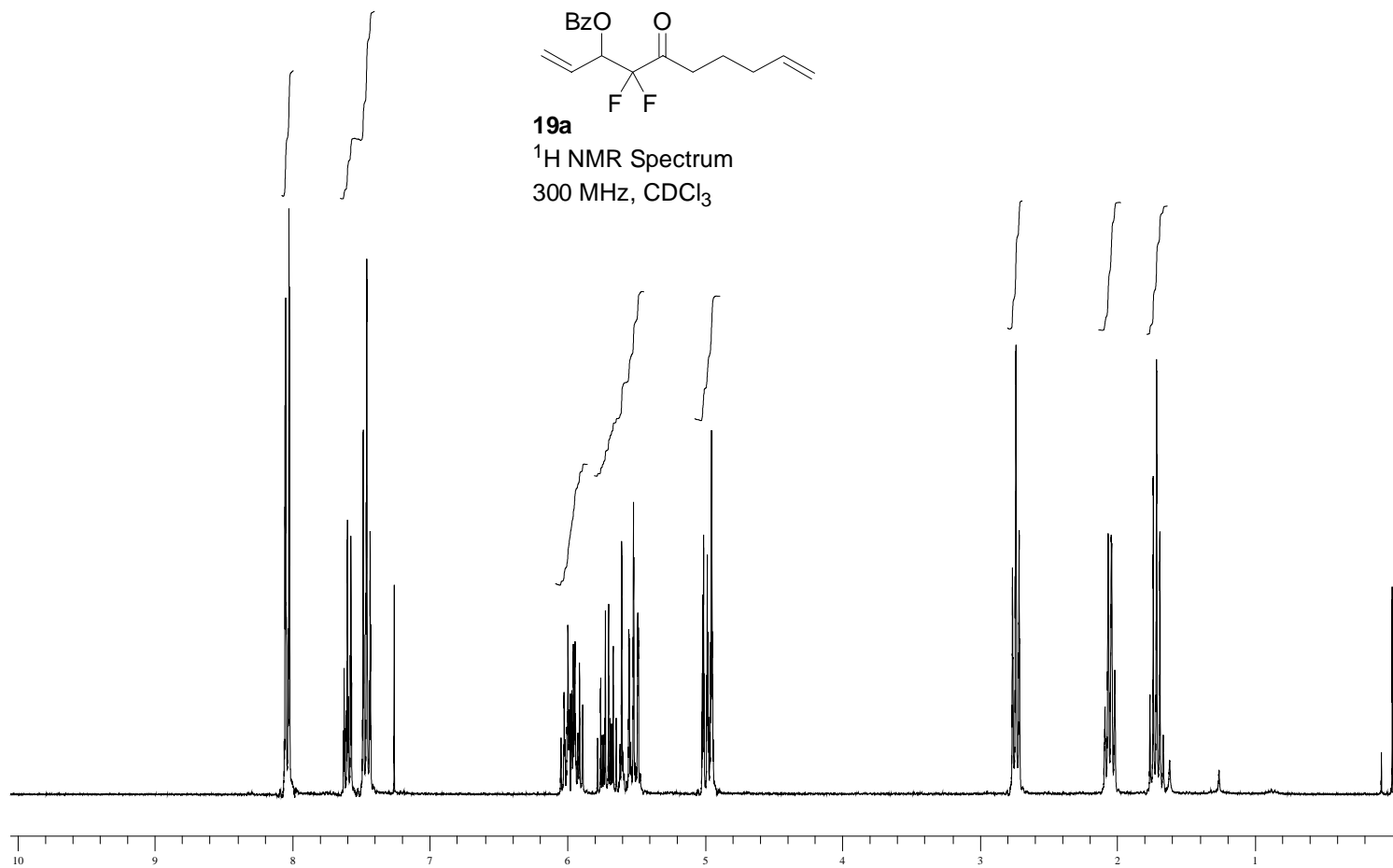
 ^1H NMR Spectrum

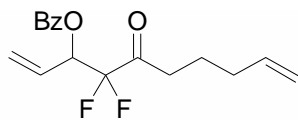
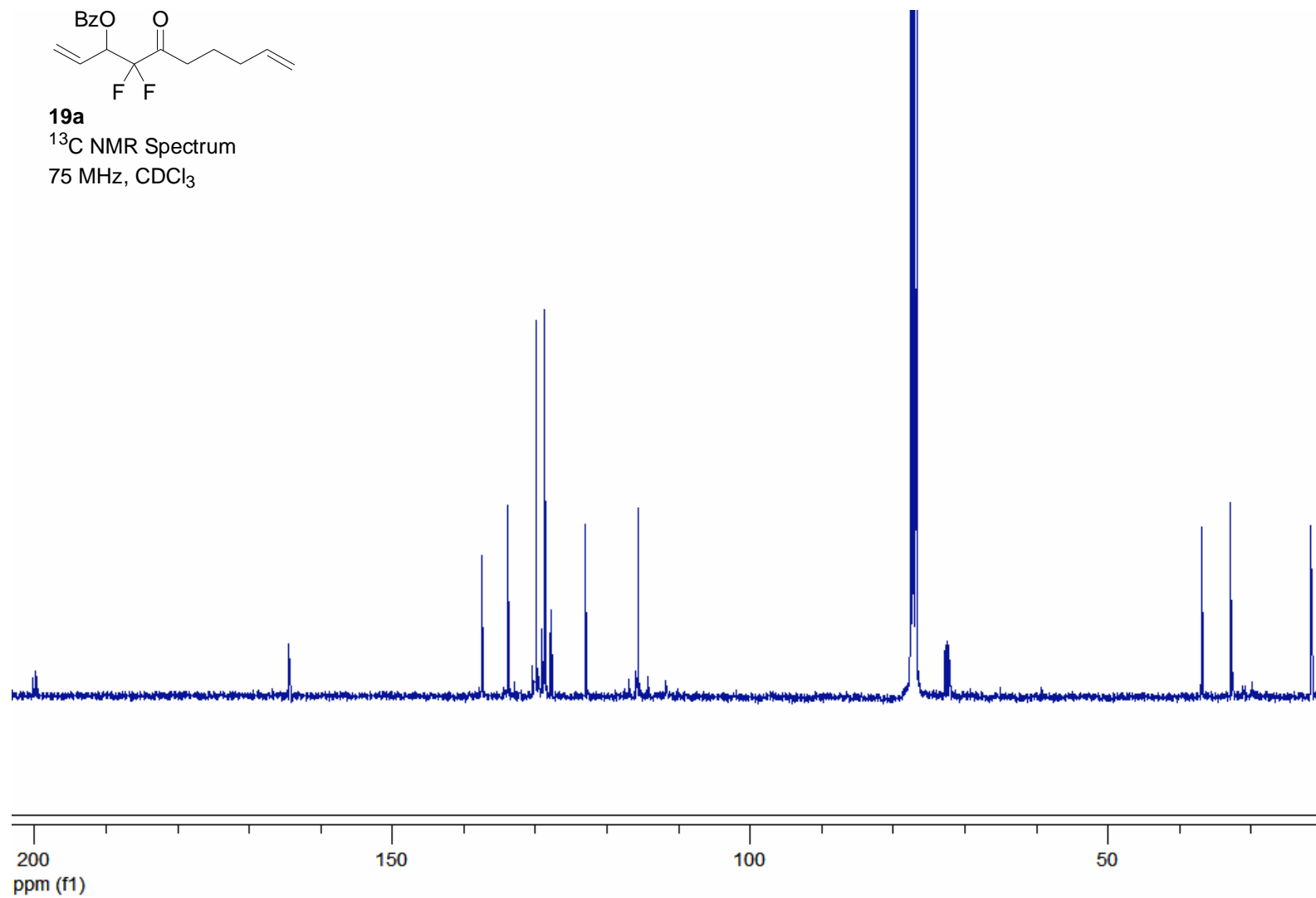
300 MHz, CDCl₃

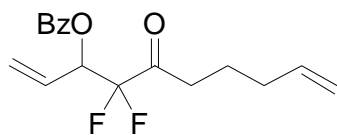




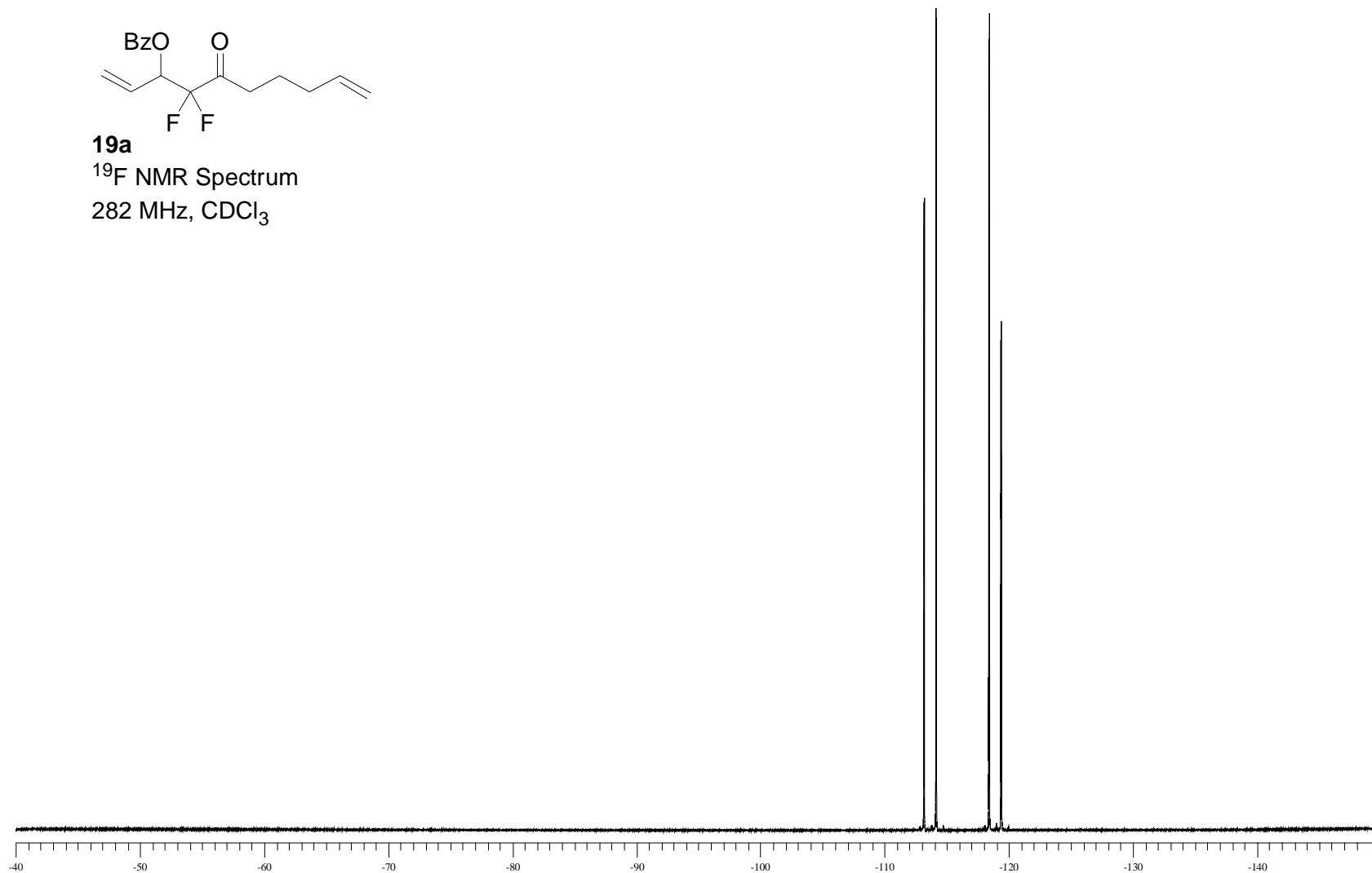
19a
¹H NMR Spectrum
300 MHz, CDCl₃

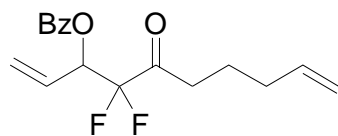
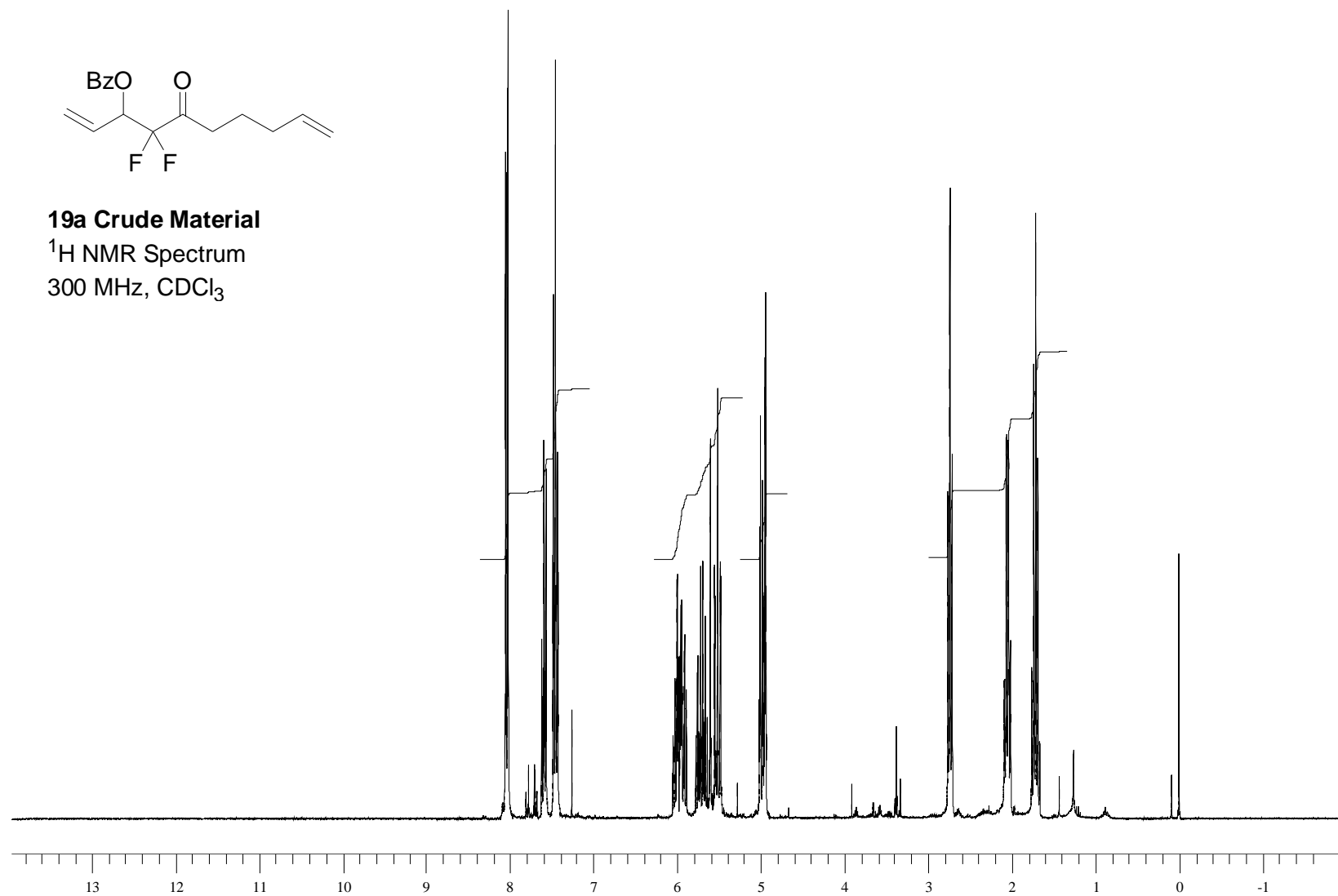


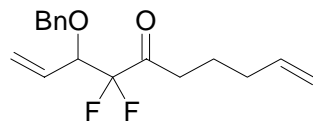
**19a**¹³C NMR Spectrum75 MHz, CDCl₃



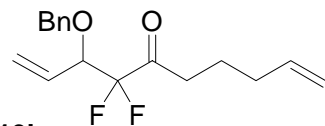
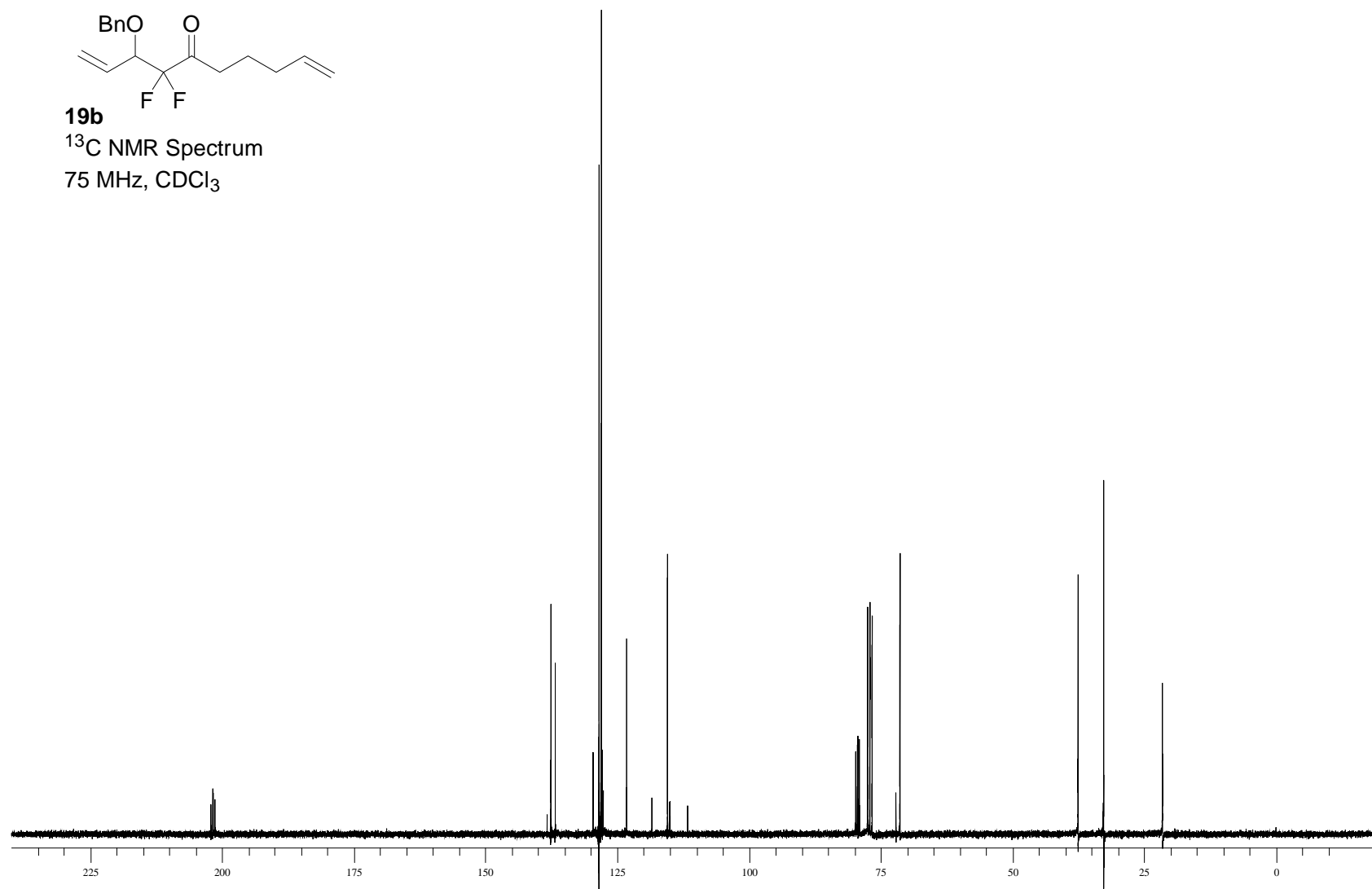
19a
¹⁹F NMR Spectrum
282 MHz, CDCl₃

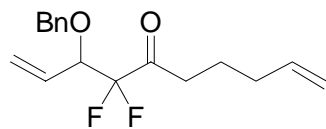
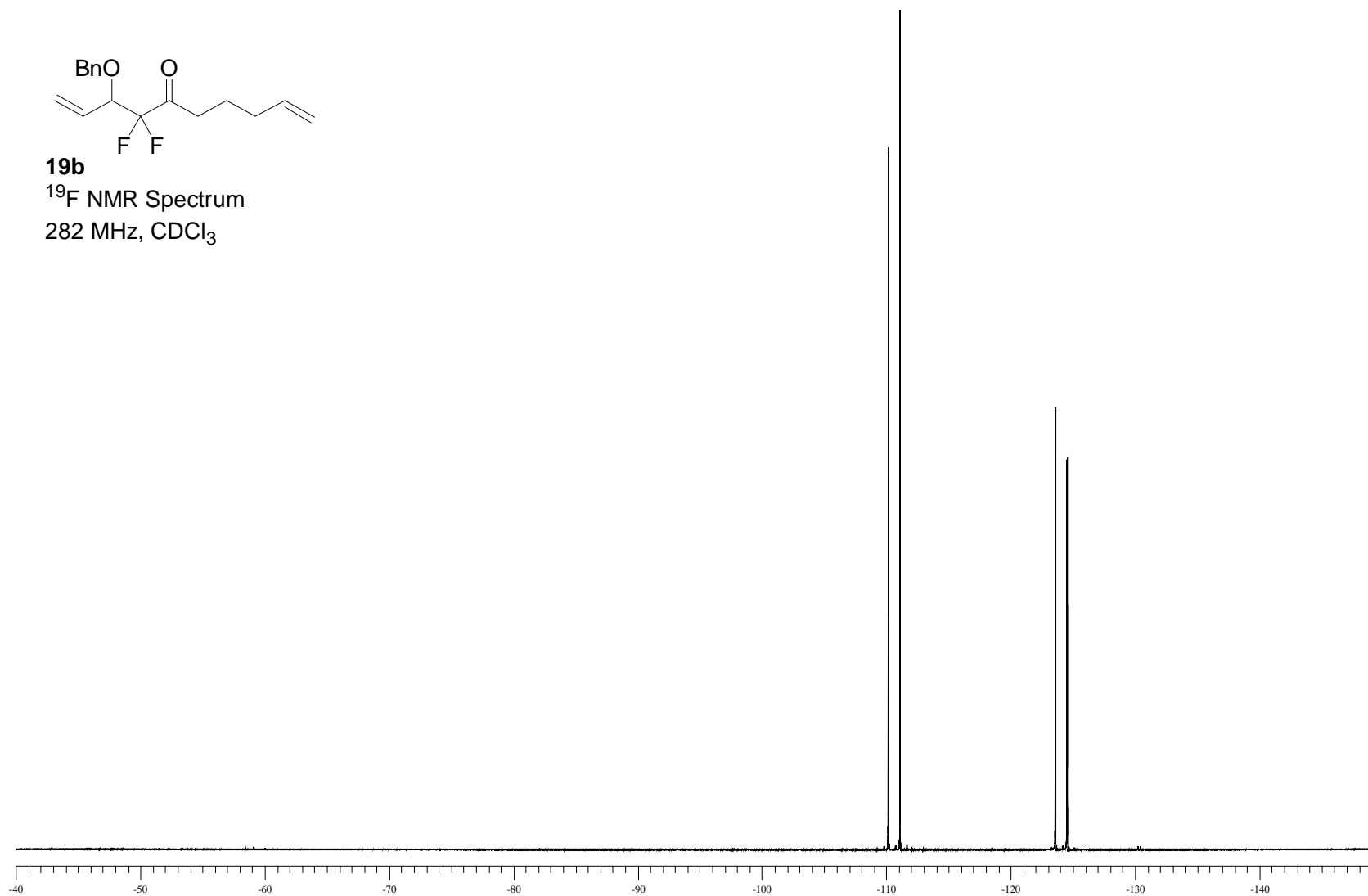


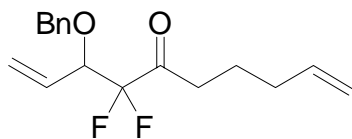
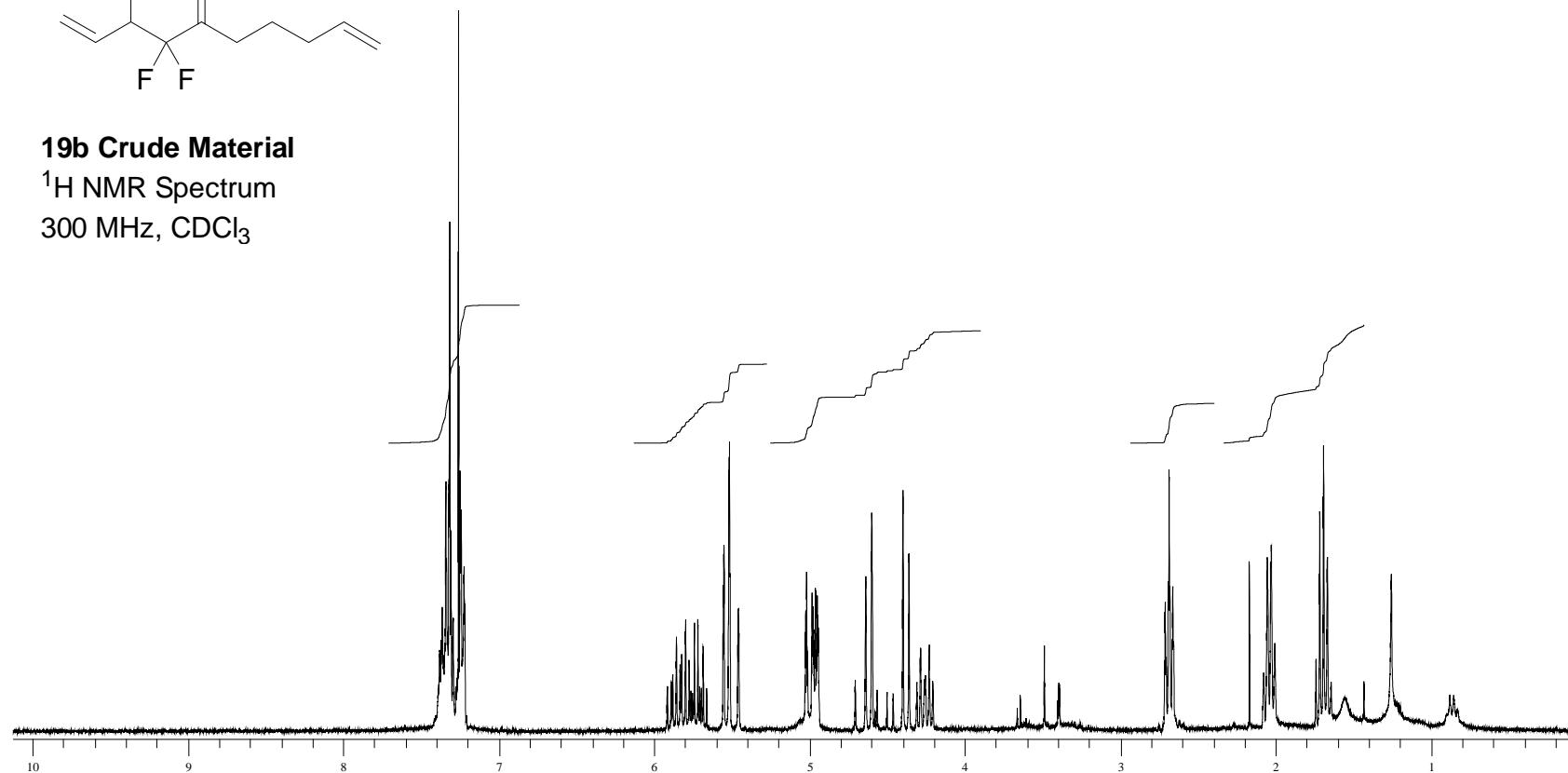
**19a Crude Material**¹H NMR Spectrum300 MHz, CDCl₃

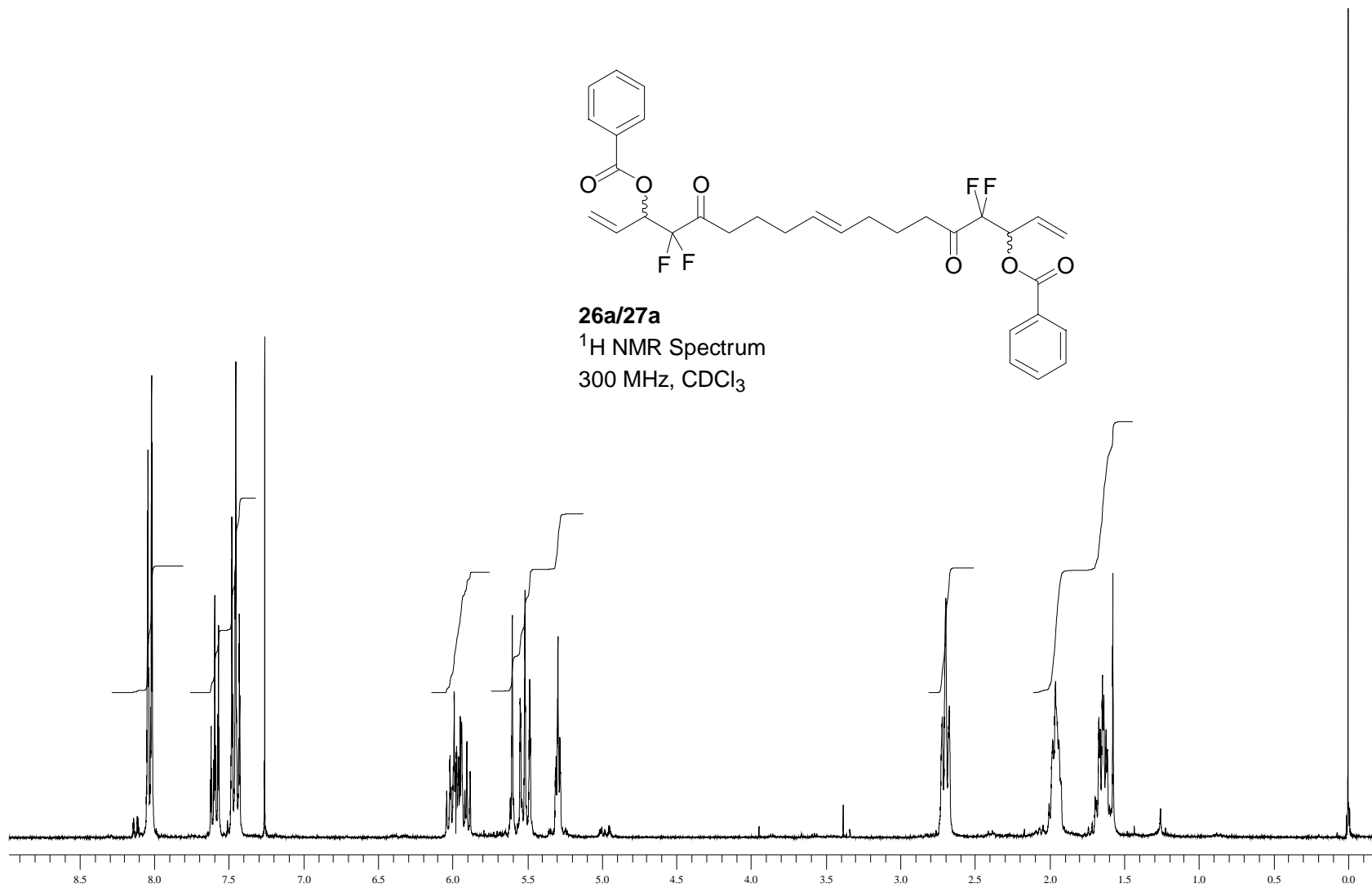
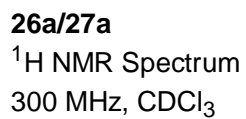


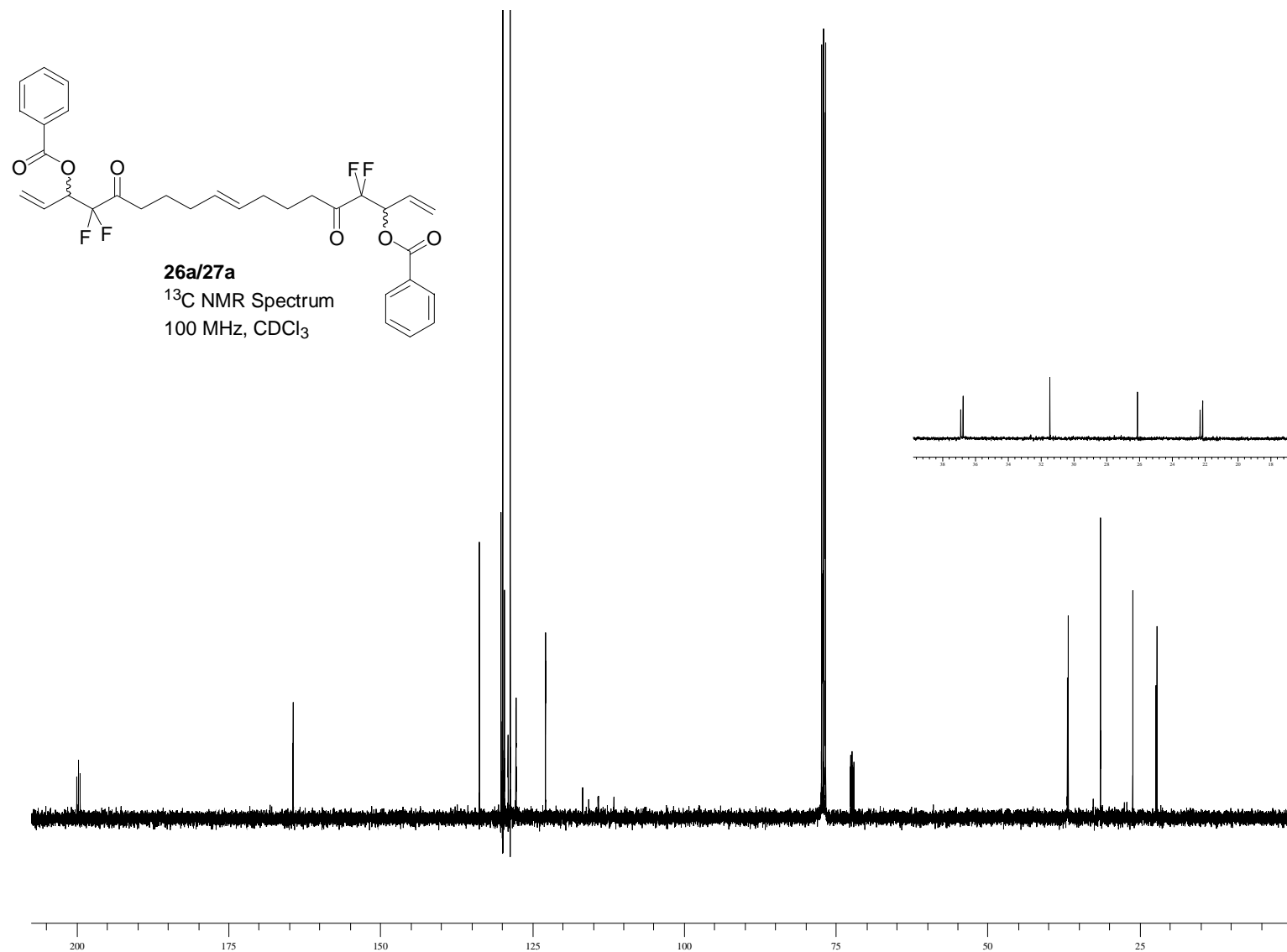
19b
¹H NMR Spectrum
 300 MHz, CDCl₃

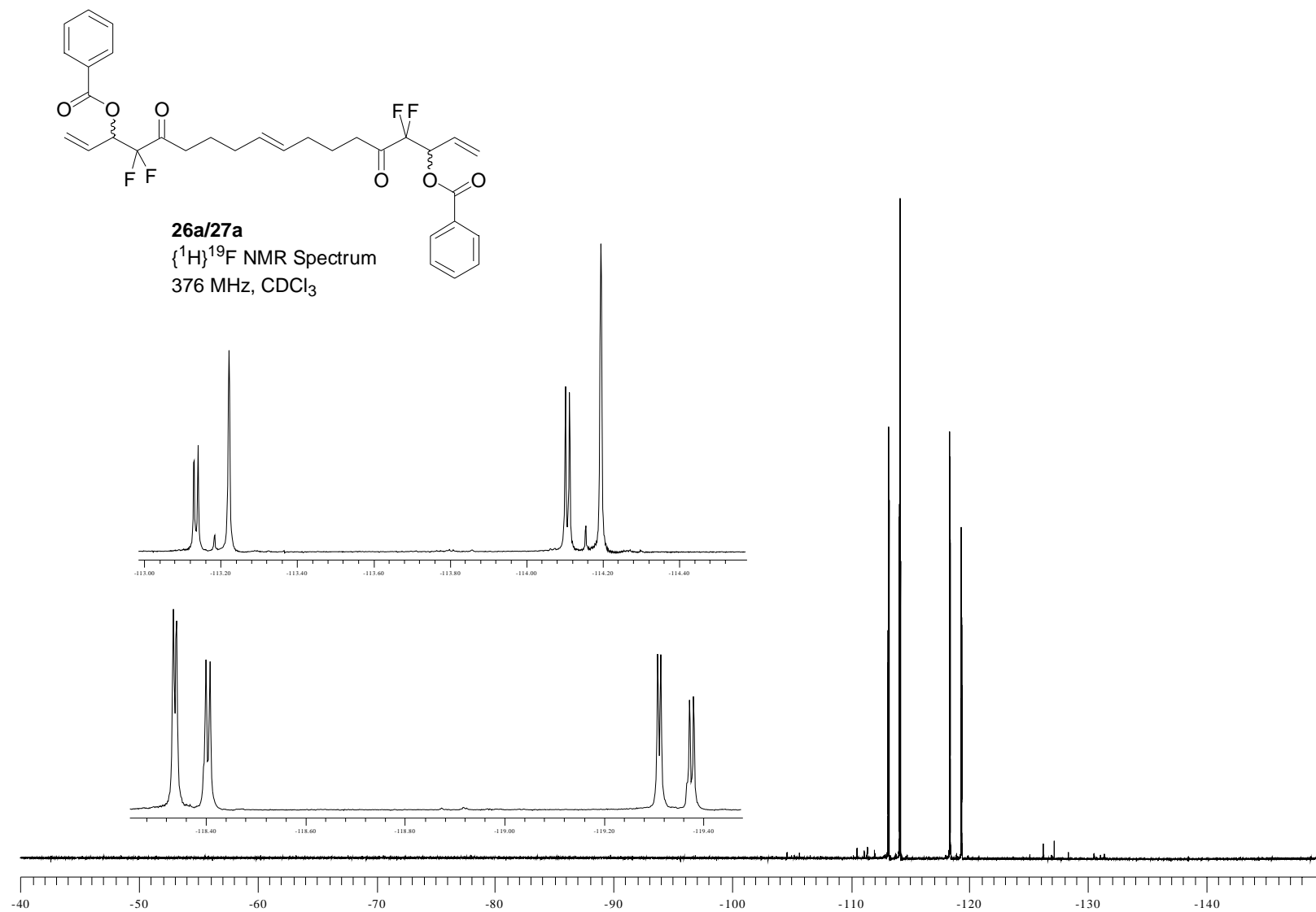
**19b**¹³C NMR Spectrum75 MHz, CDCl₃

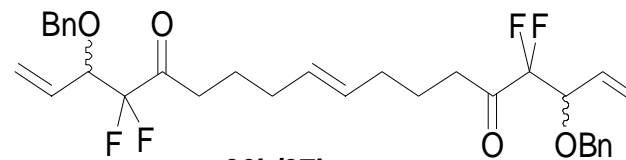
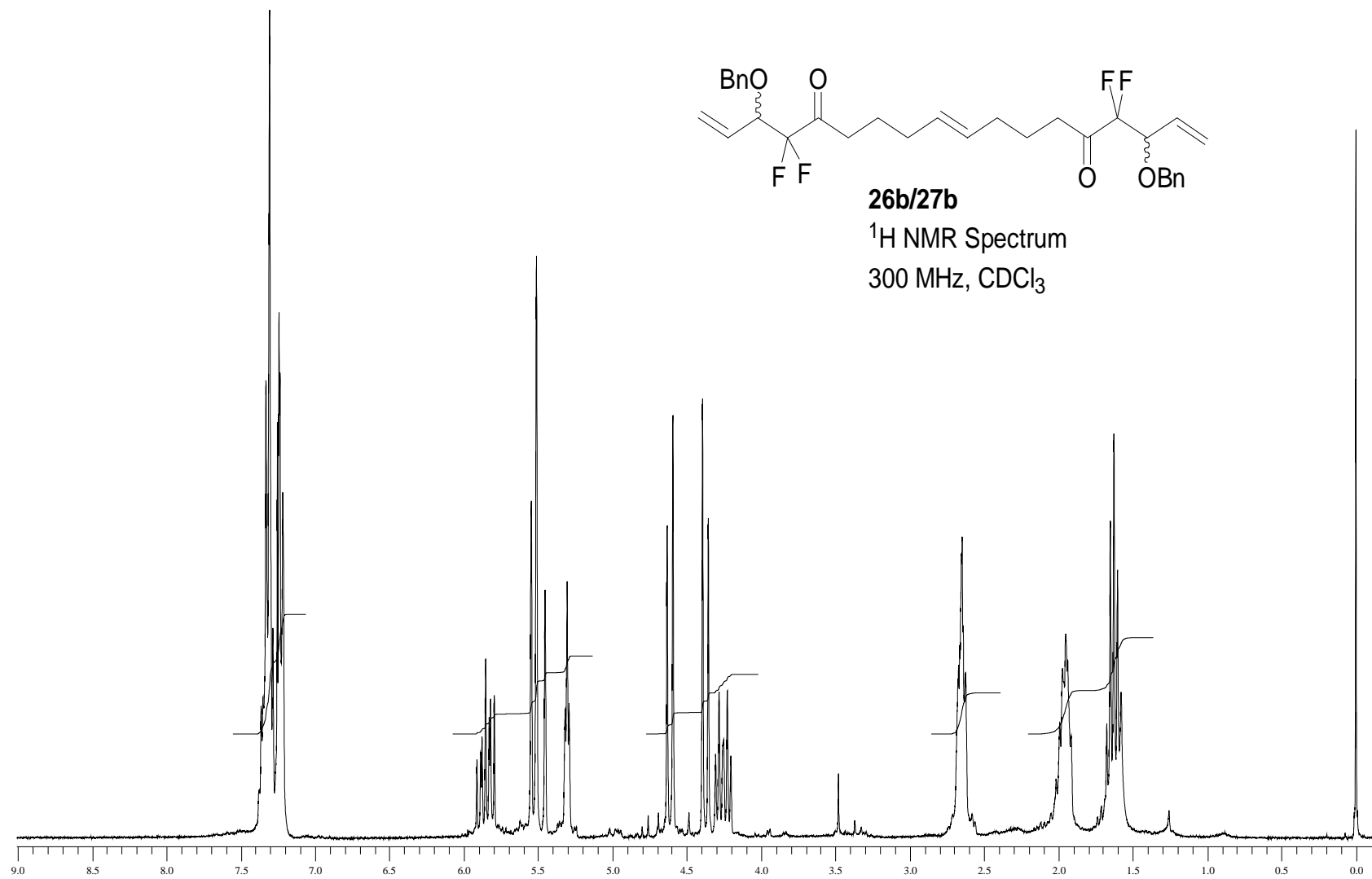
**19b**¹⁹F NMR Spectrum282 MHz, CDCl₃

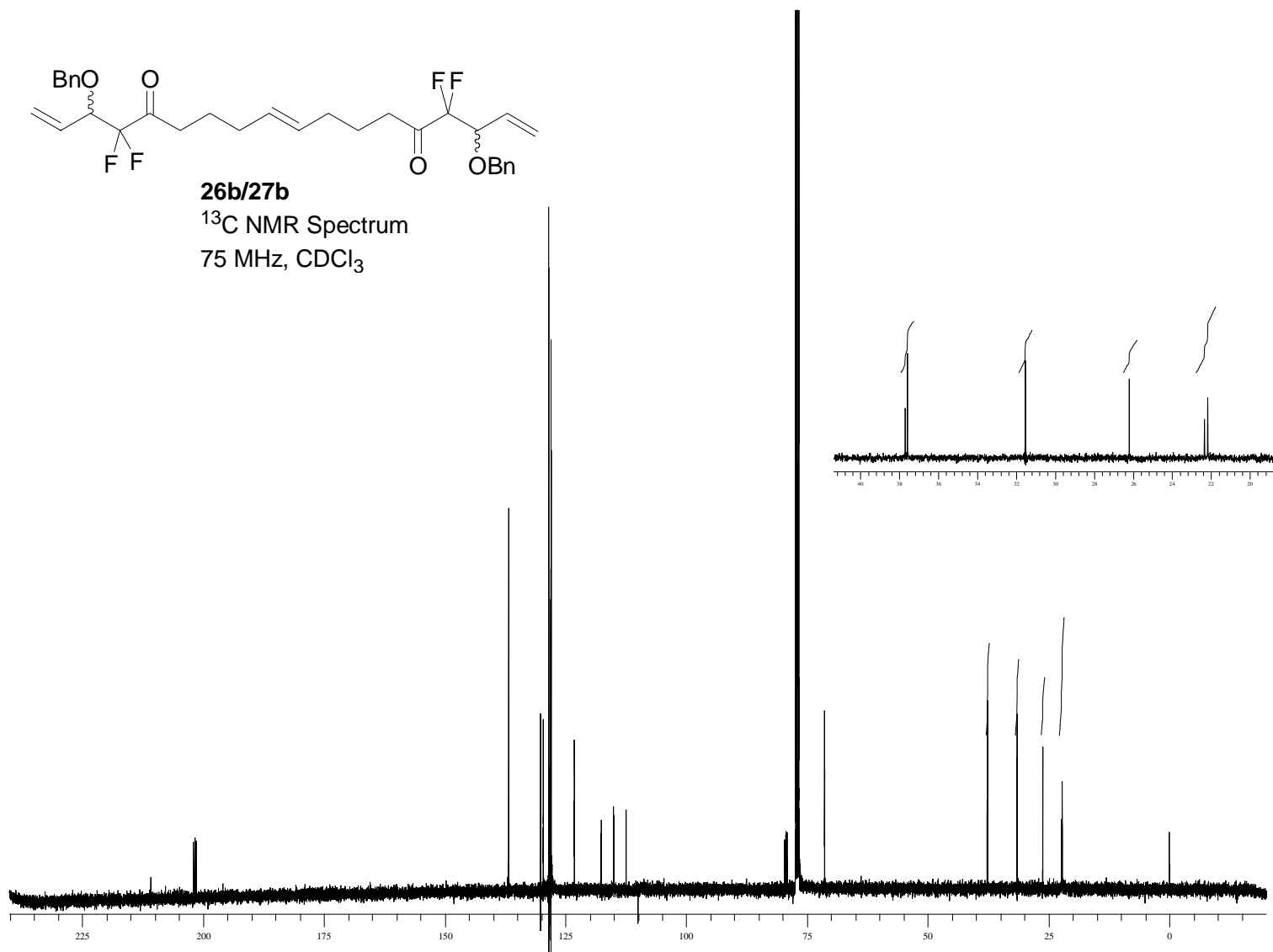
**19b Crude Material**¹H NMR Spectrum300 MHz, CDCl₃

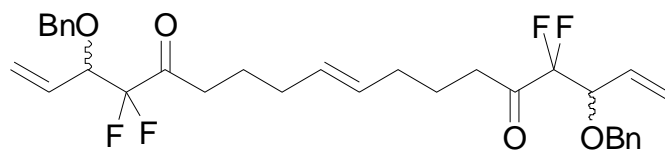




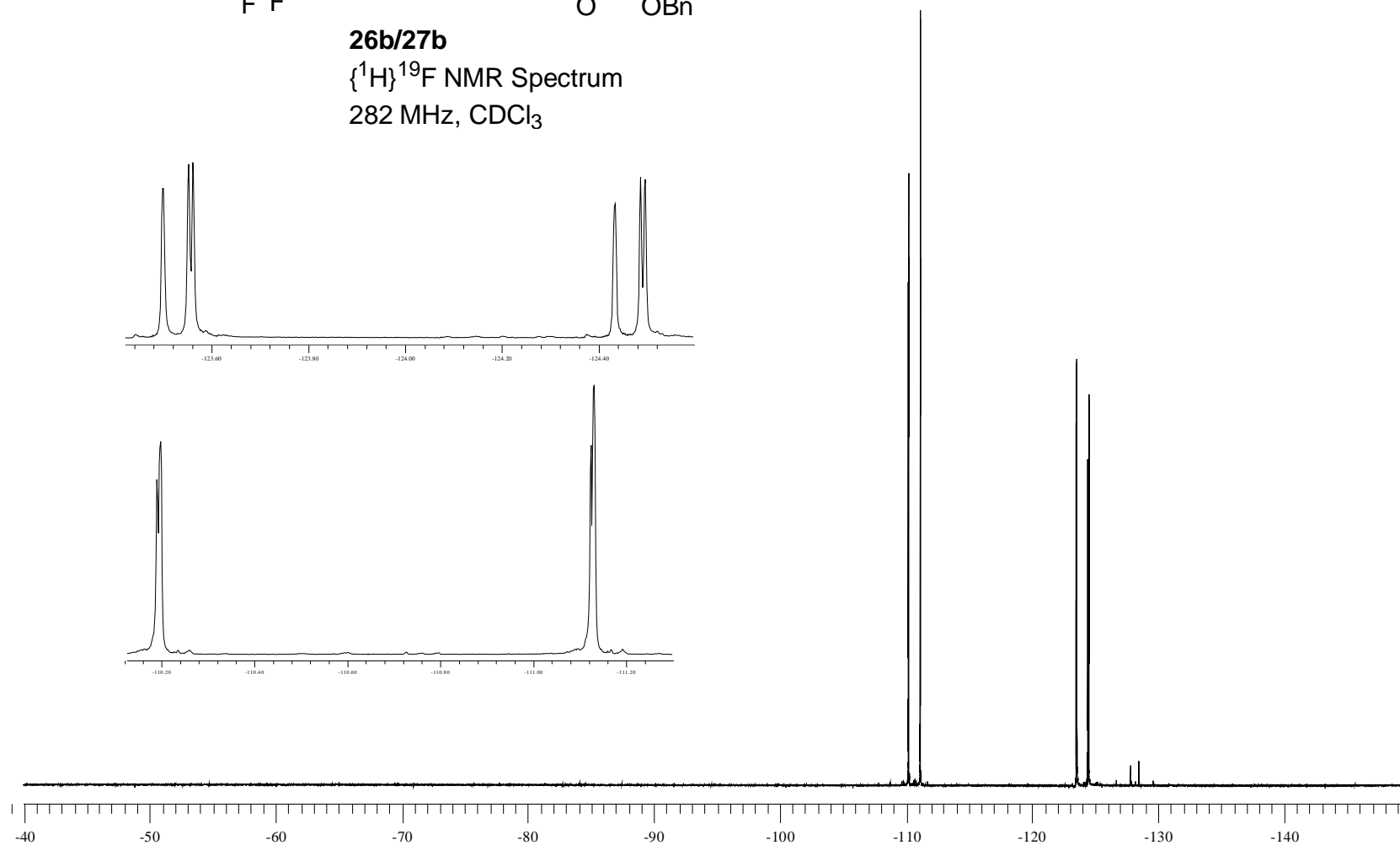


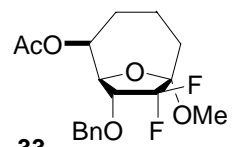
**26b/27b**¹H NMR Spectrum300 MHz, CDCl₃



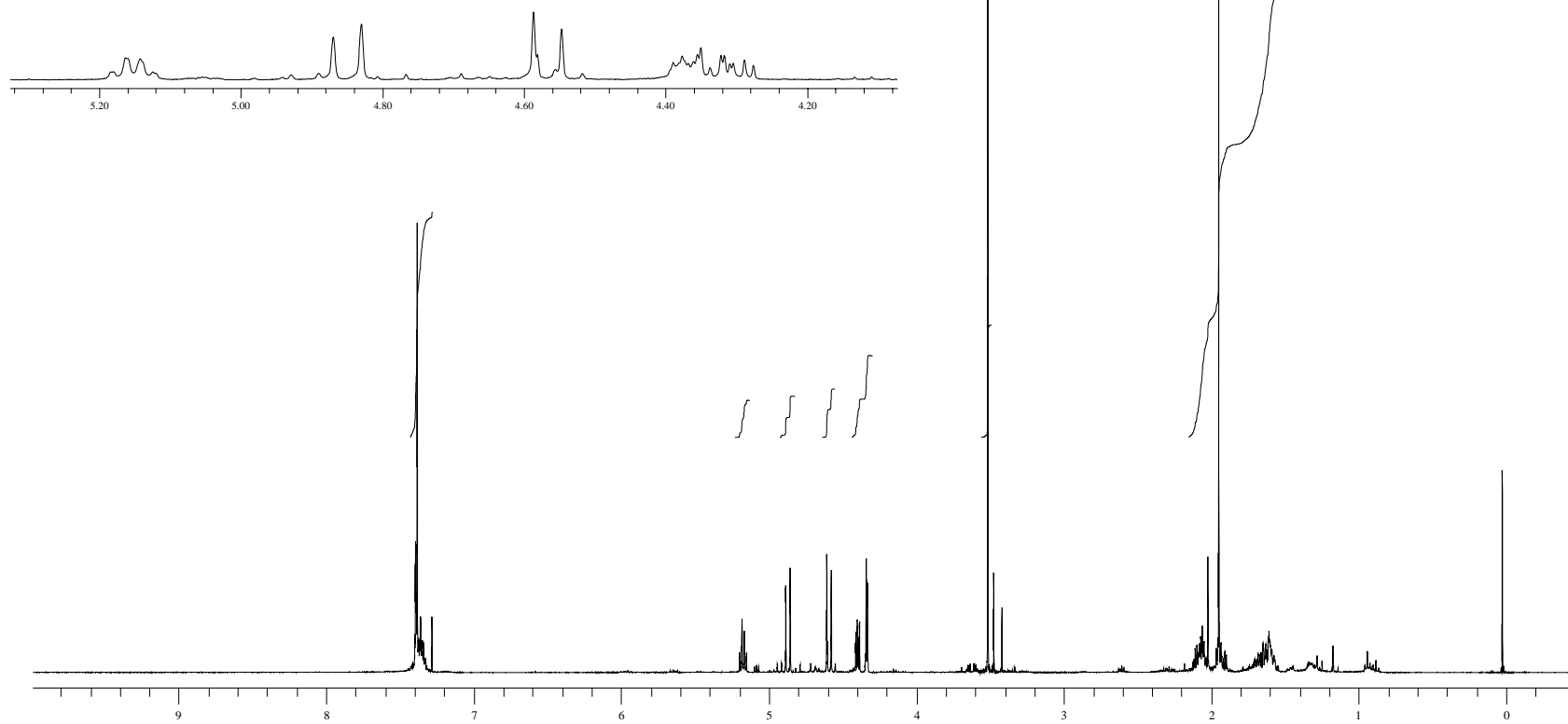


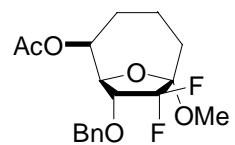
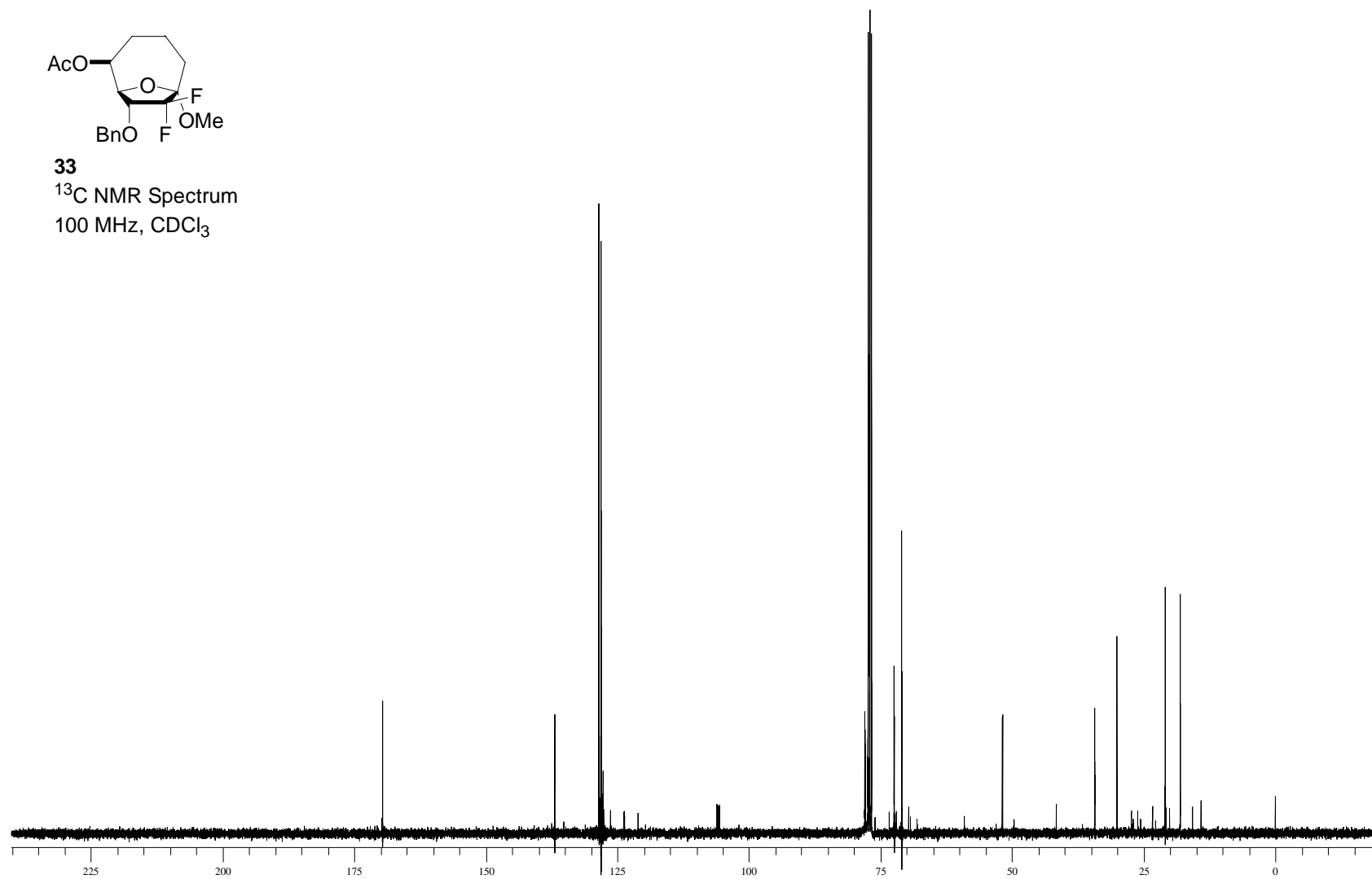
26b/27b
{¹H}¹⁹F NMR Spectrum
282 MHz, CDCl₃

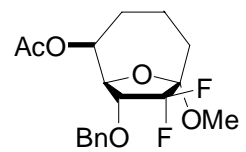
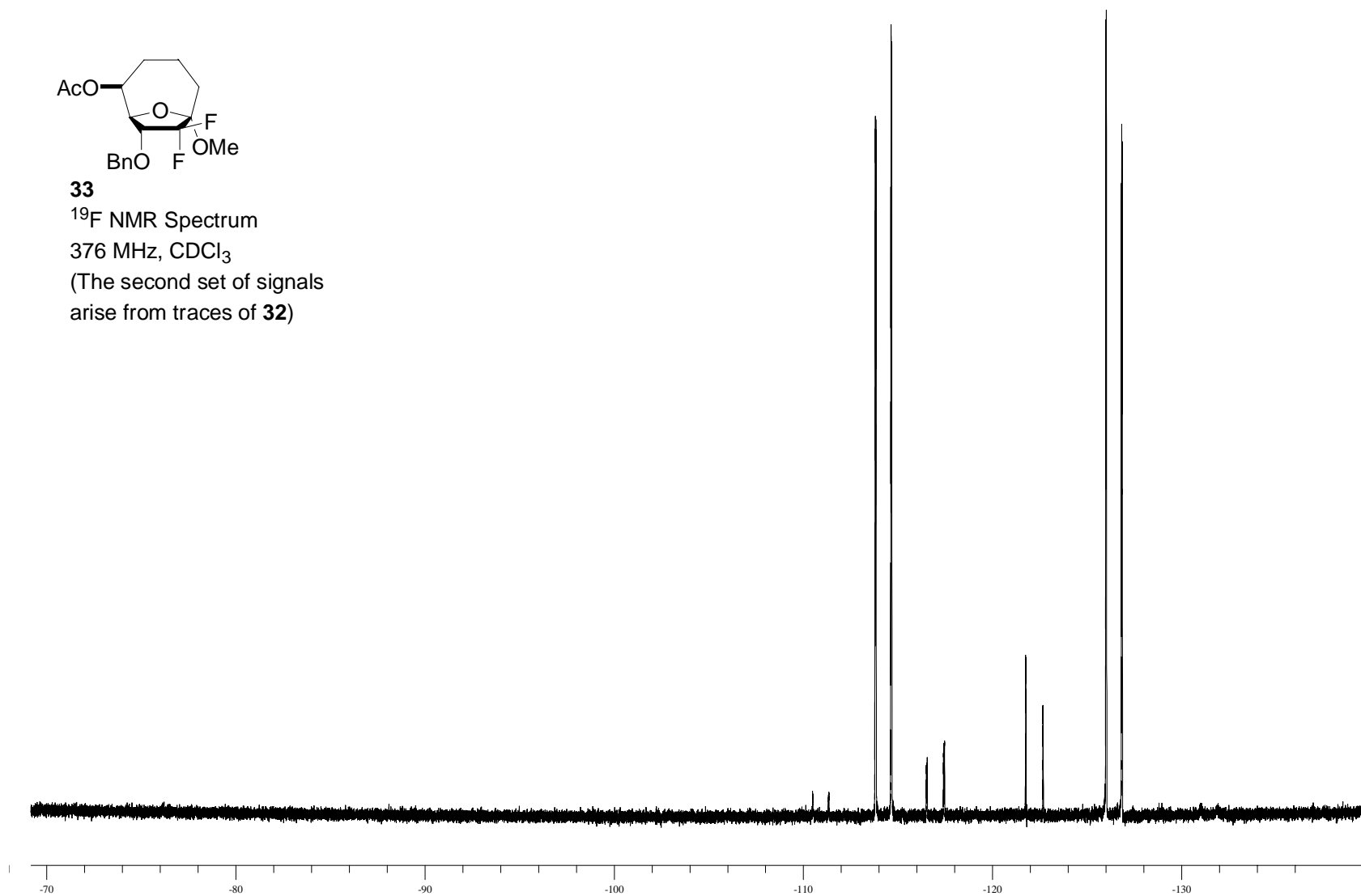


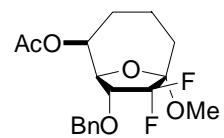
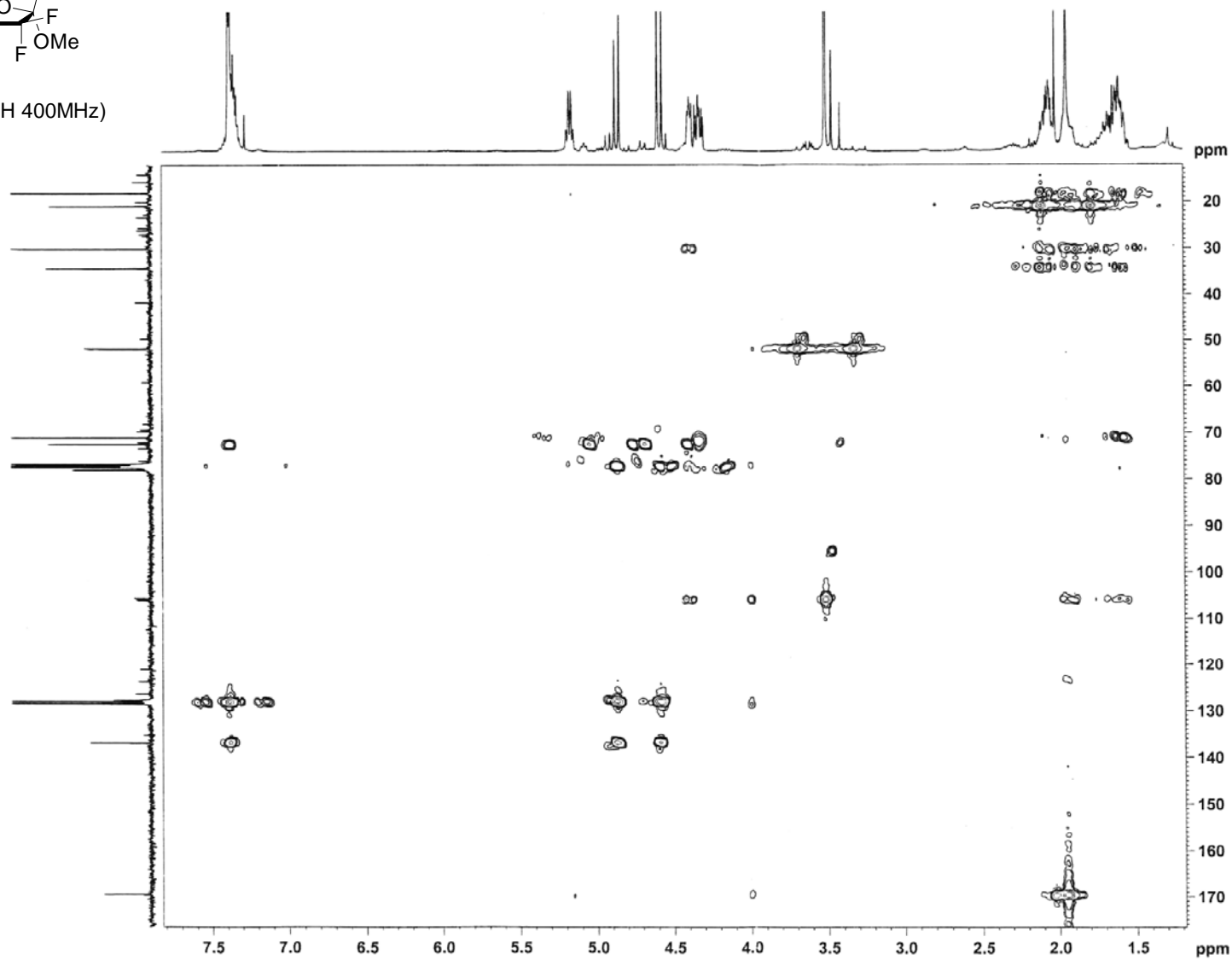


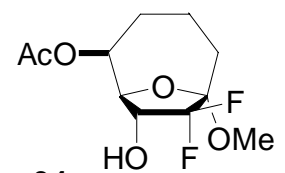
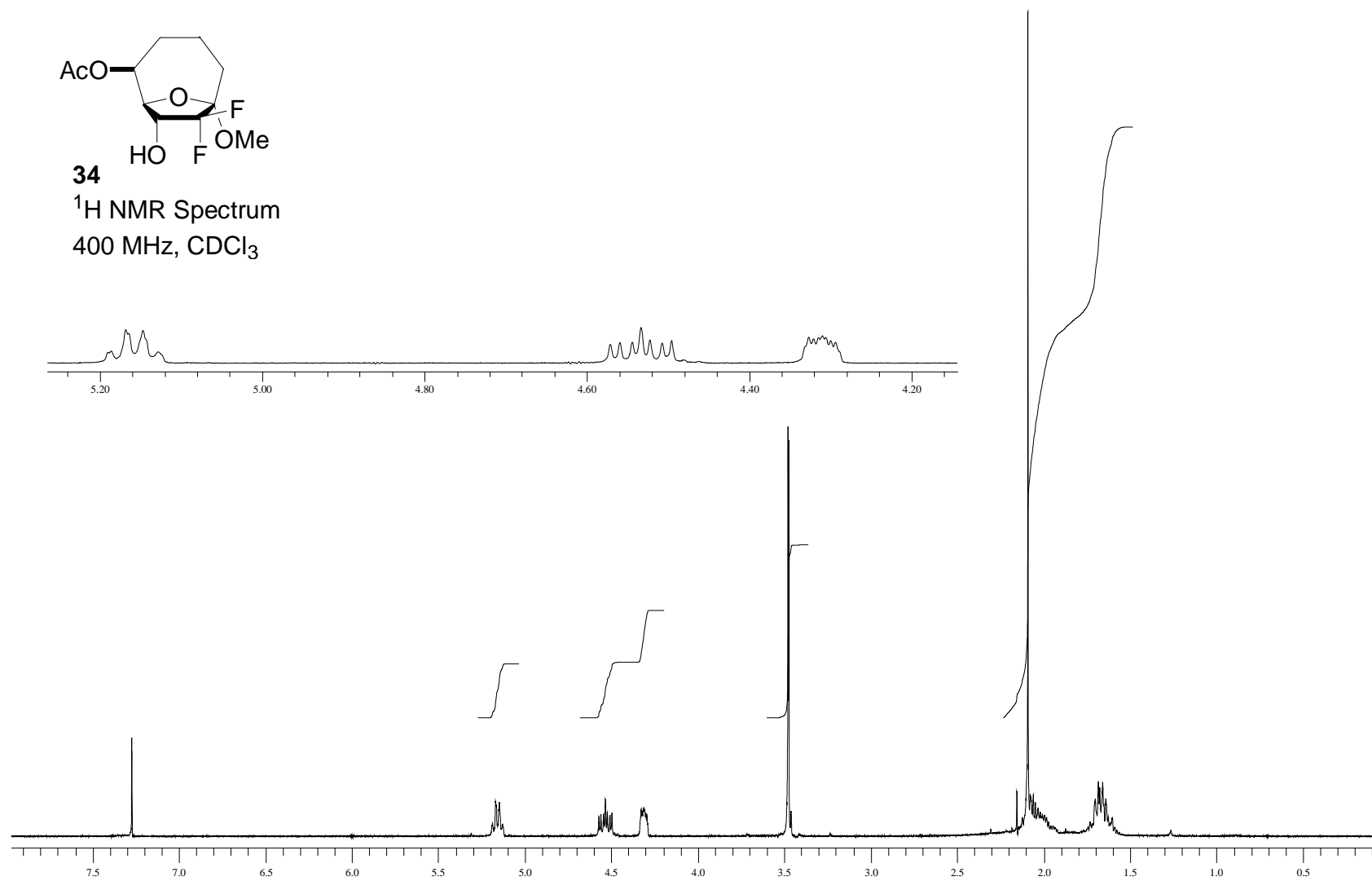
^1H NMR Spectrum
400 MHz, CDCl_3

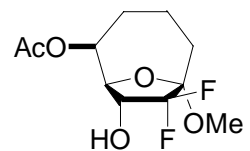
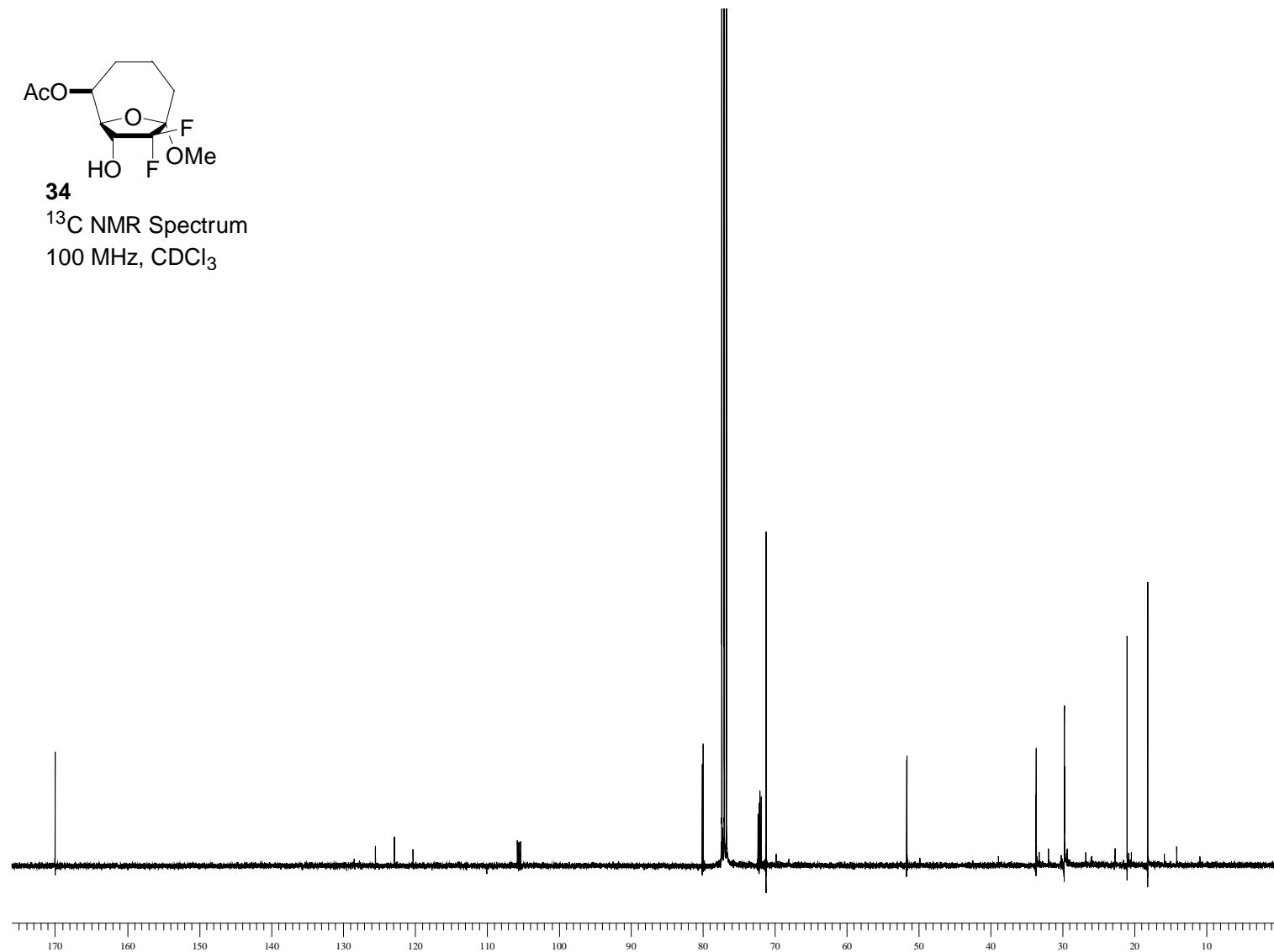


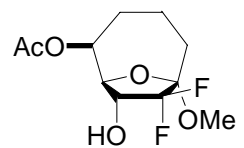
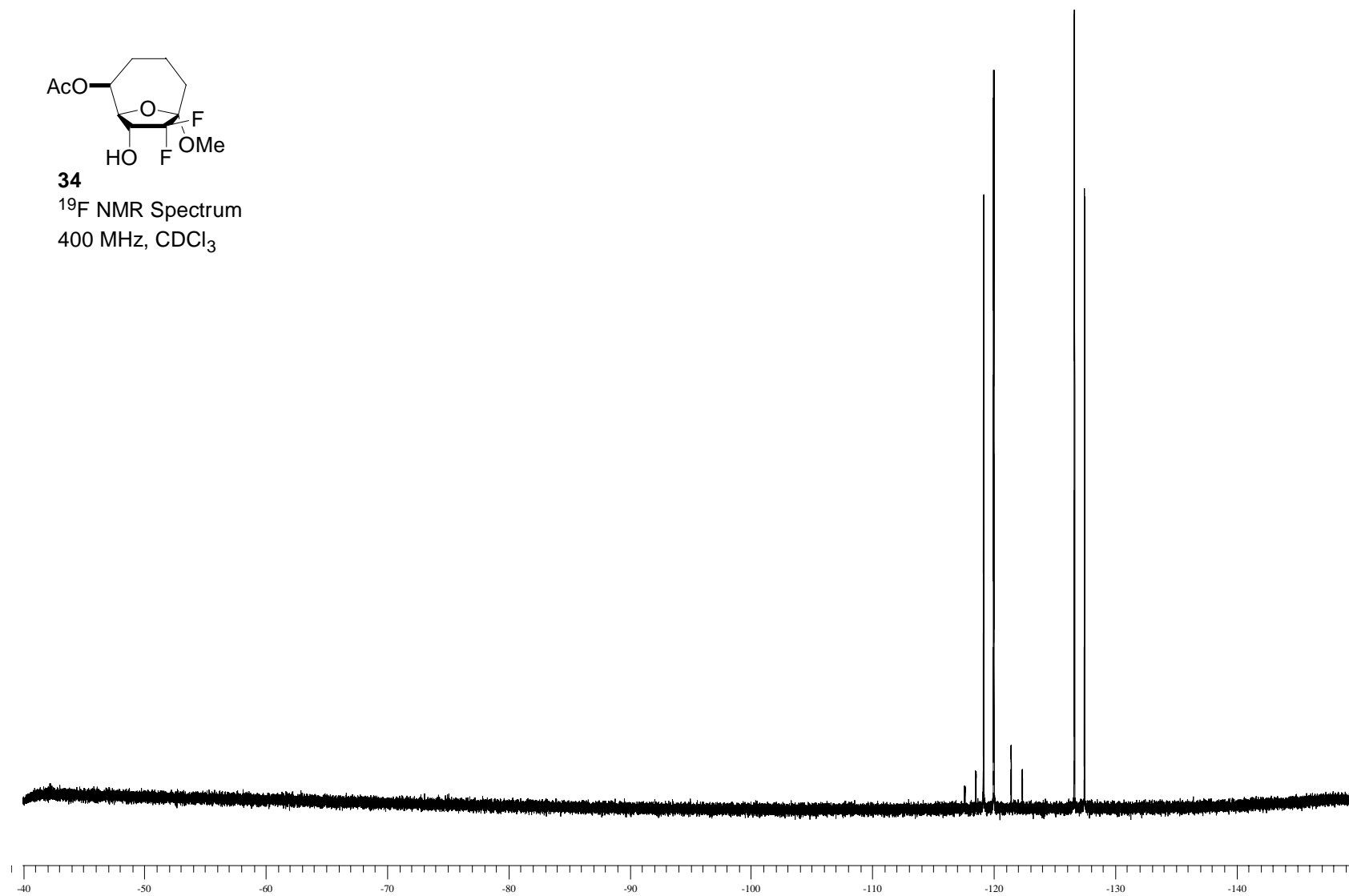
**33**¹³C NMR Spectrum100 MHz, CDCl₃

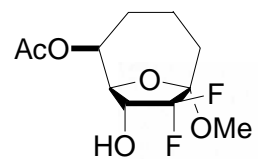
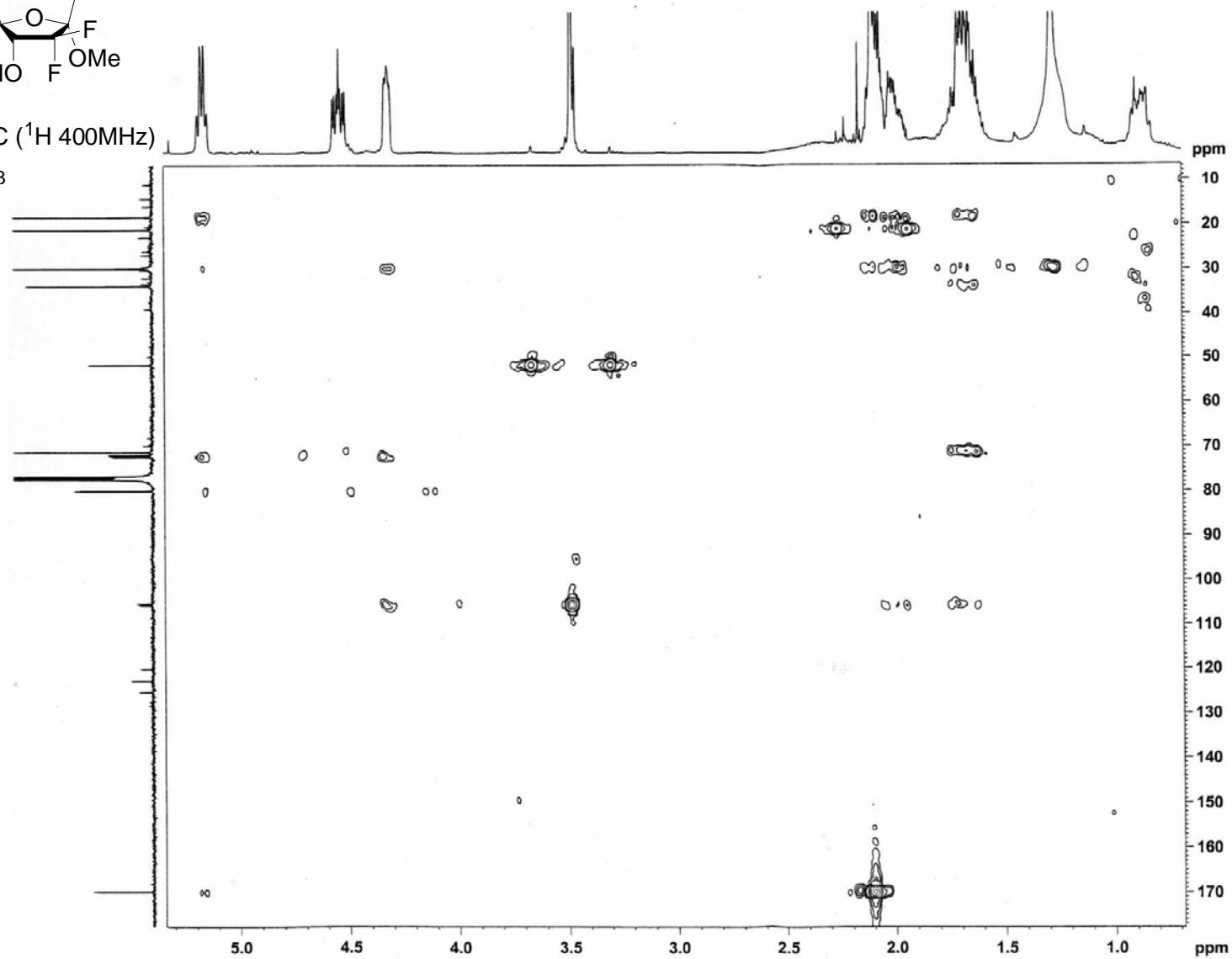
**33**¹⁹F NMR Spectrum376 MHz, CDCl₃(The second set of signals
arise from traces of **32**)

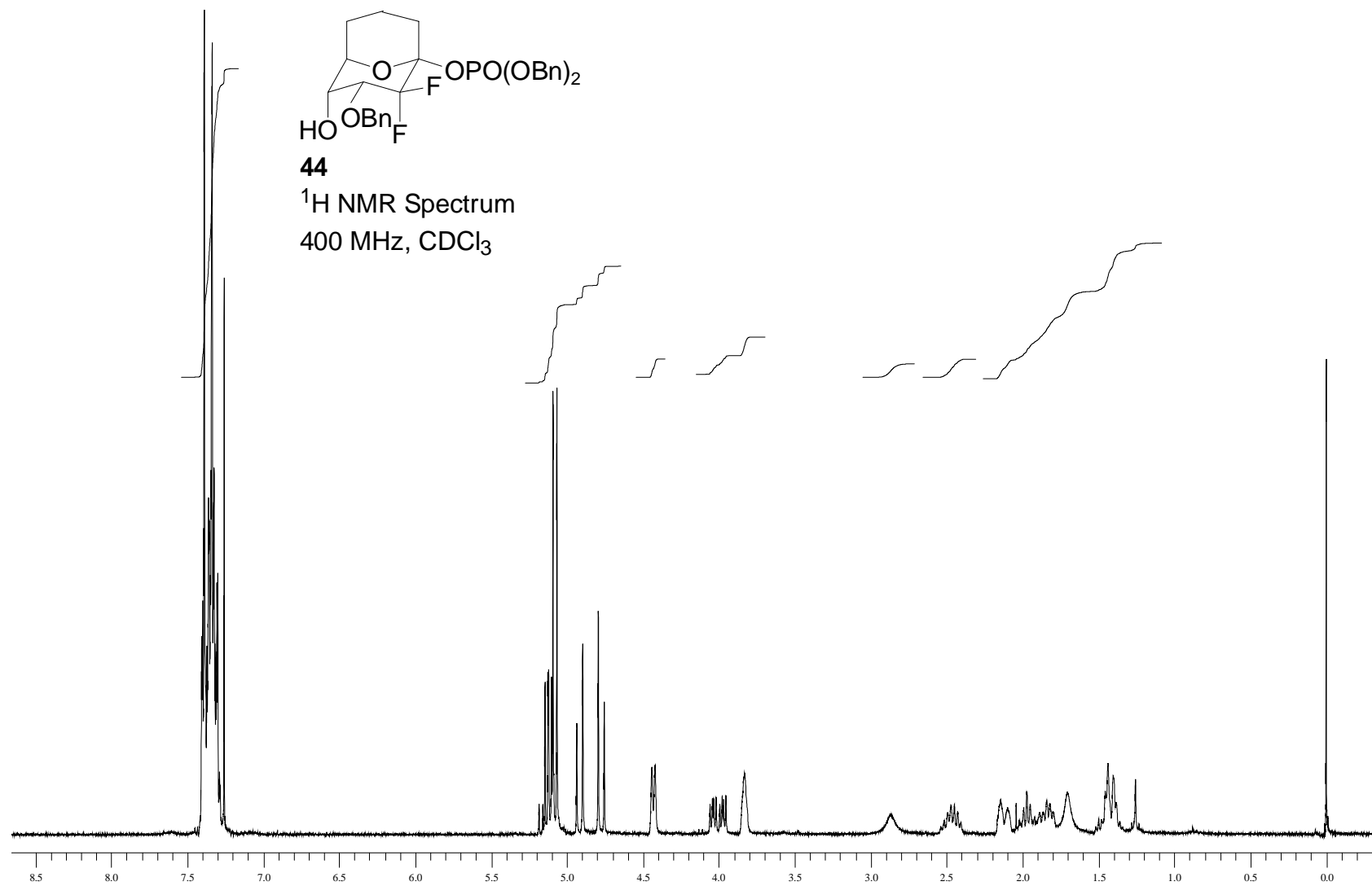
**33**HMBC (^1H 400MHz) CDCl_3 

**34**¹H NMR Spectrum400 MHz, CDCl₃

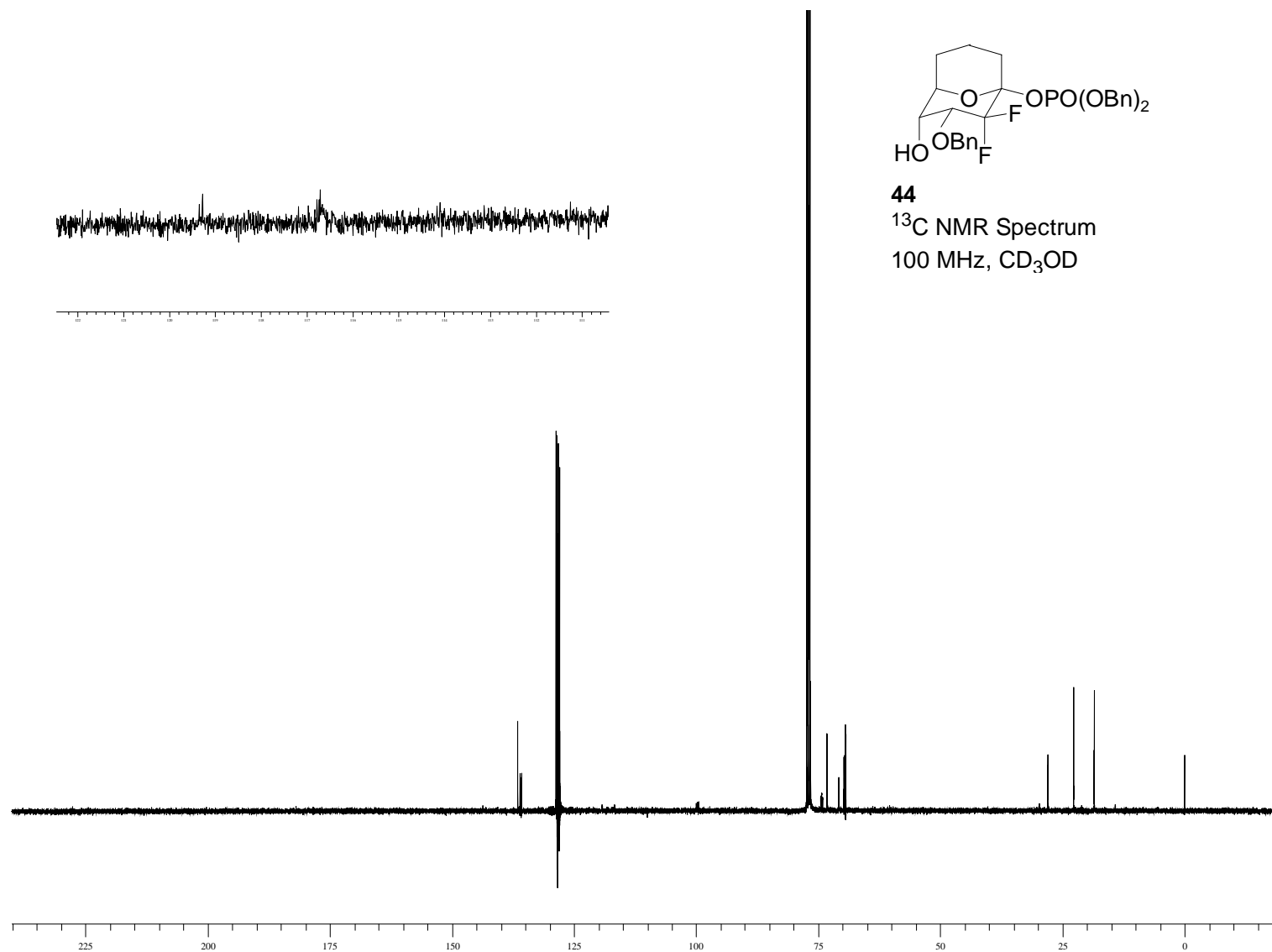
**34**¹³C NMR Spectrum100 MHz, CDCl₃

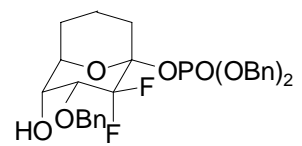
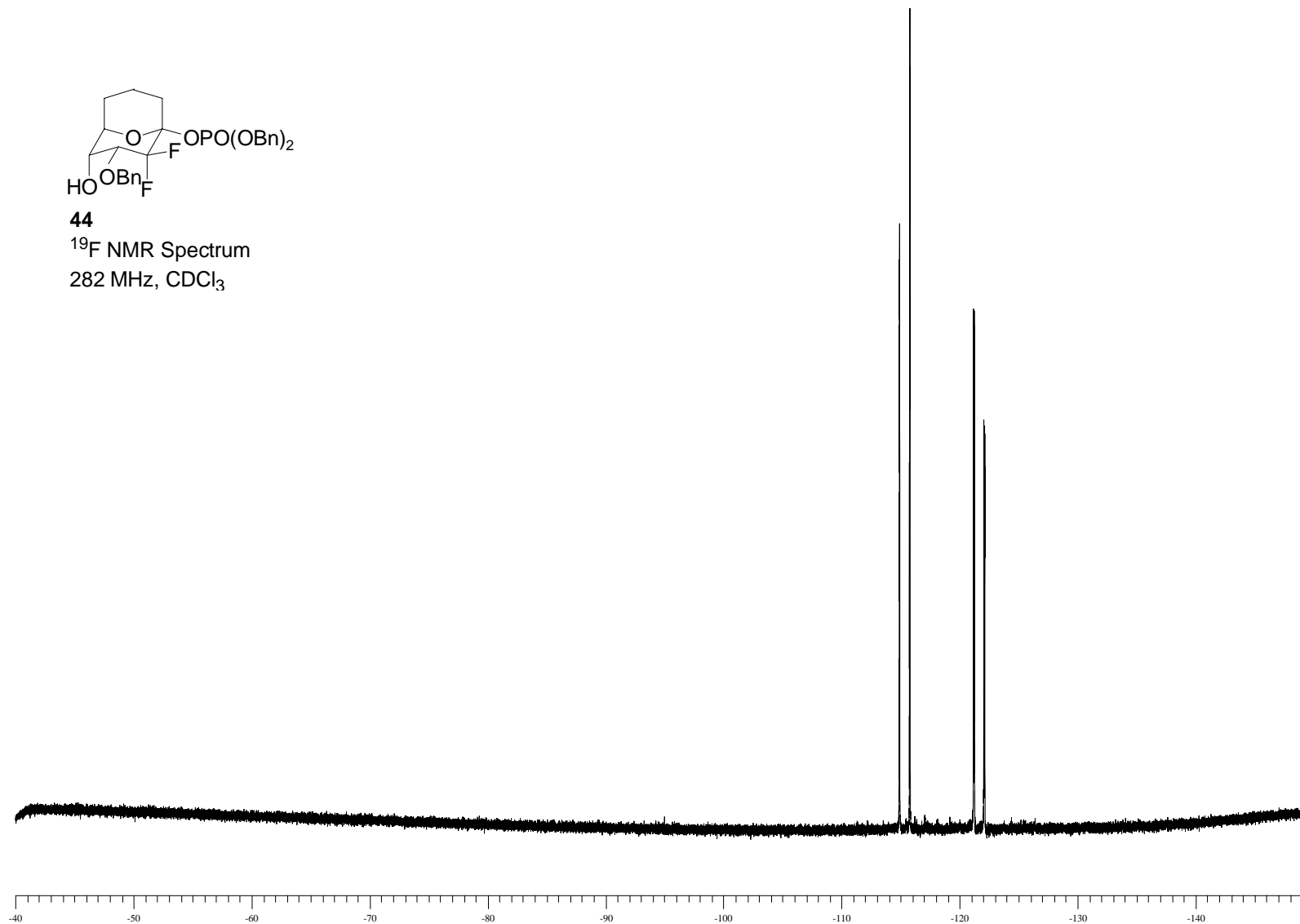
**34**¹⁹F NMR Spectrum400 MHz, CDCl₃

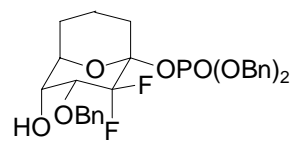
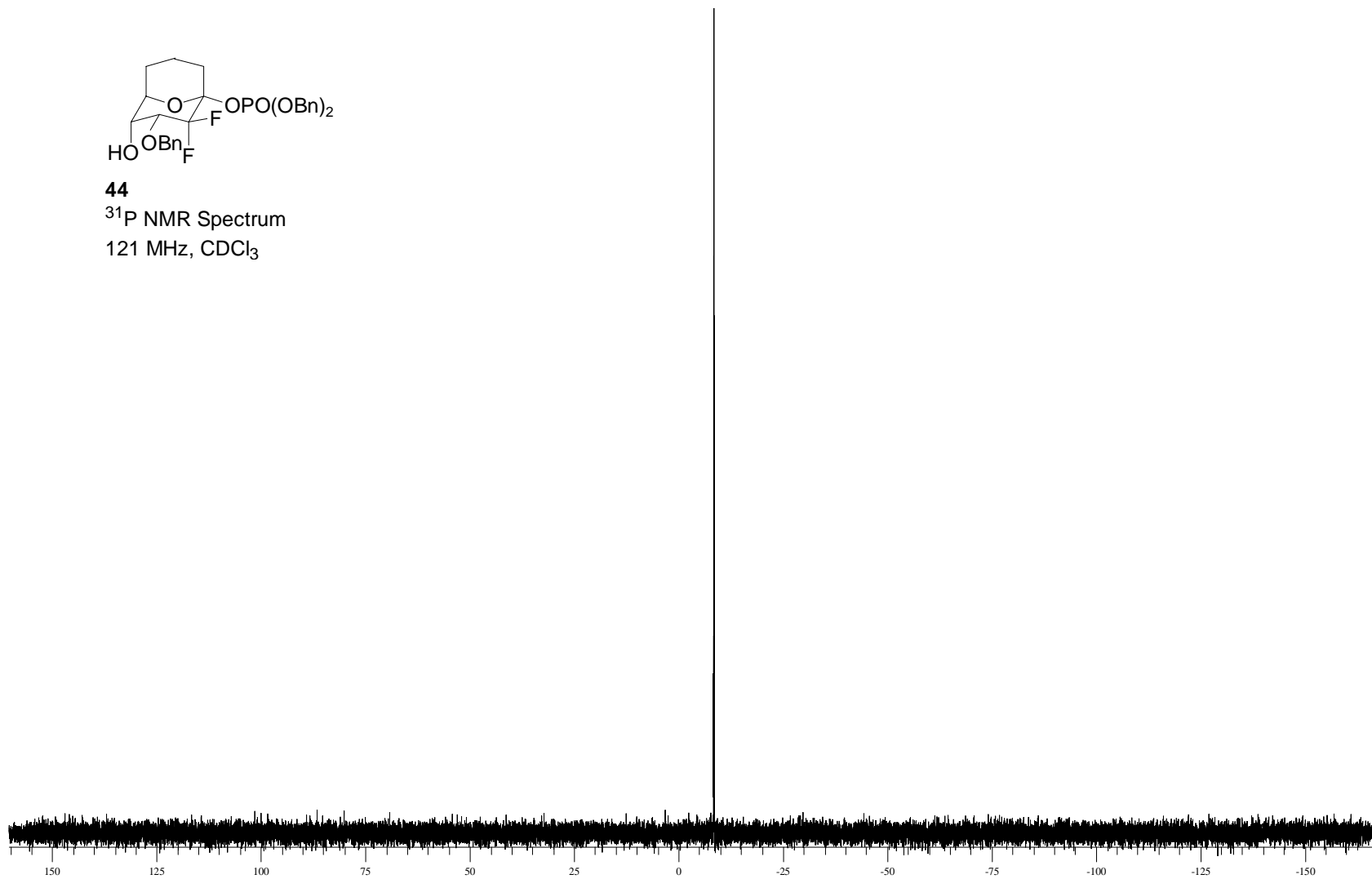
**34**HMBC (^1H 400MHz) CDCl_3 

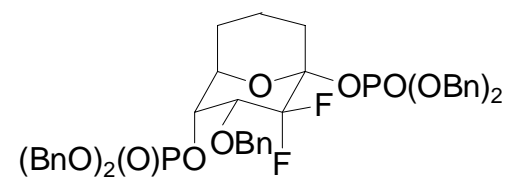
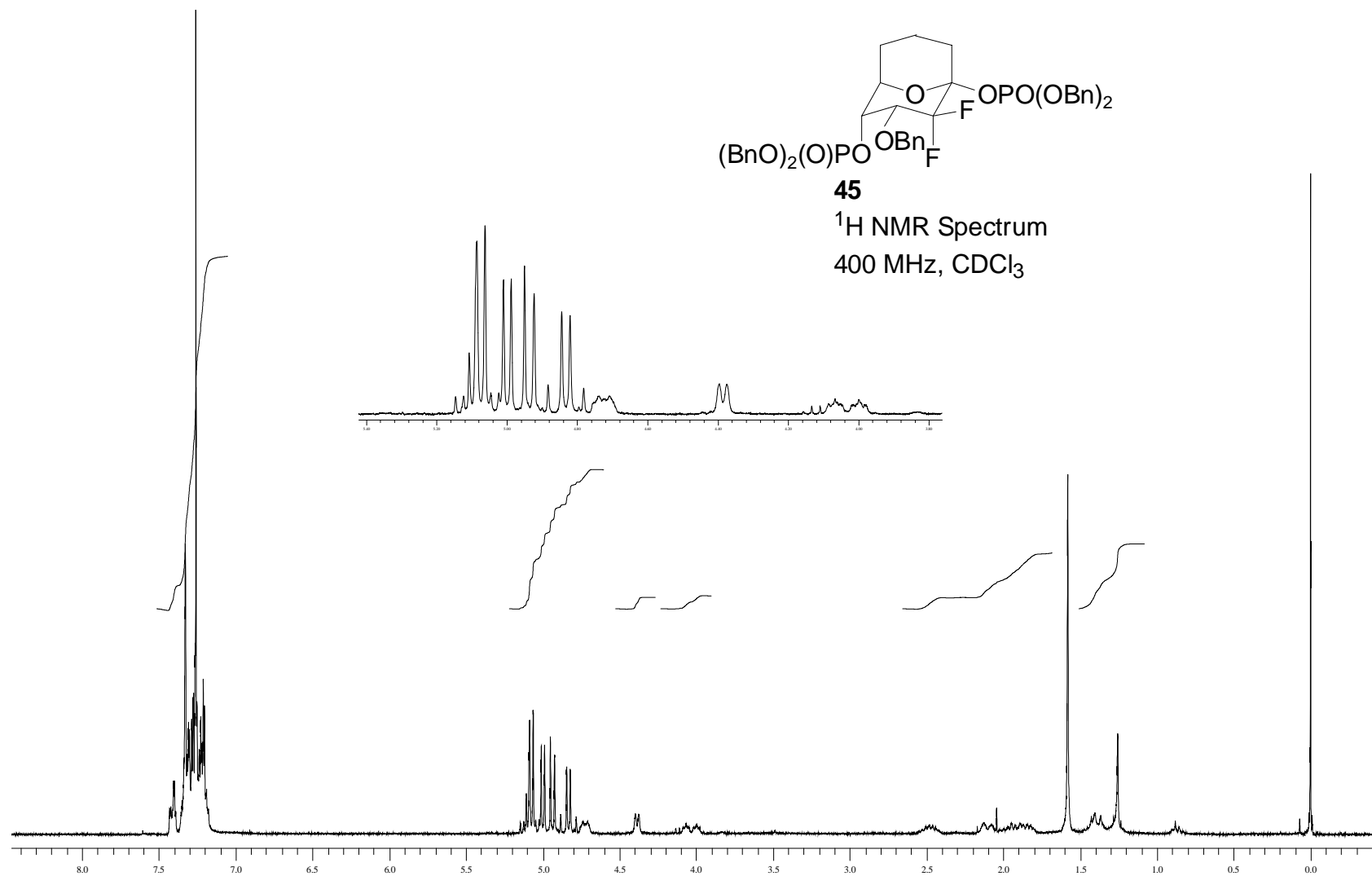


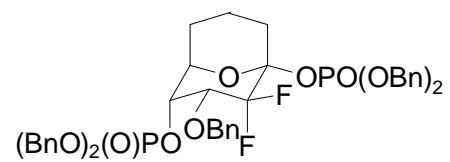
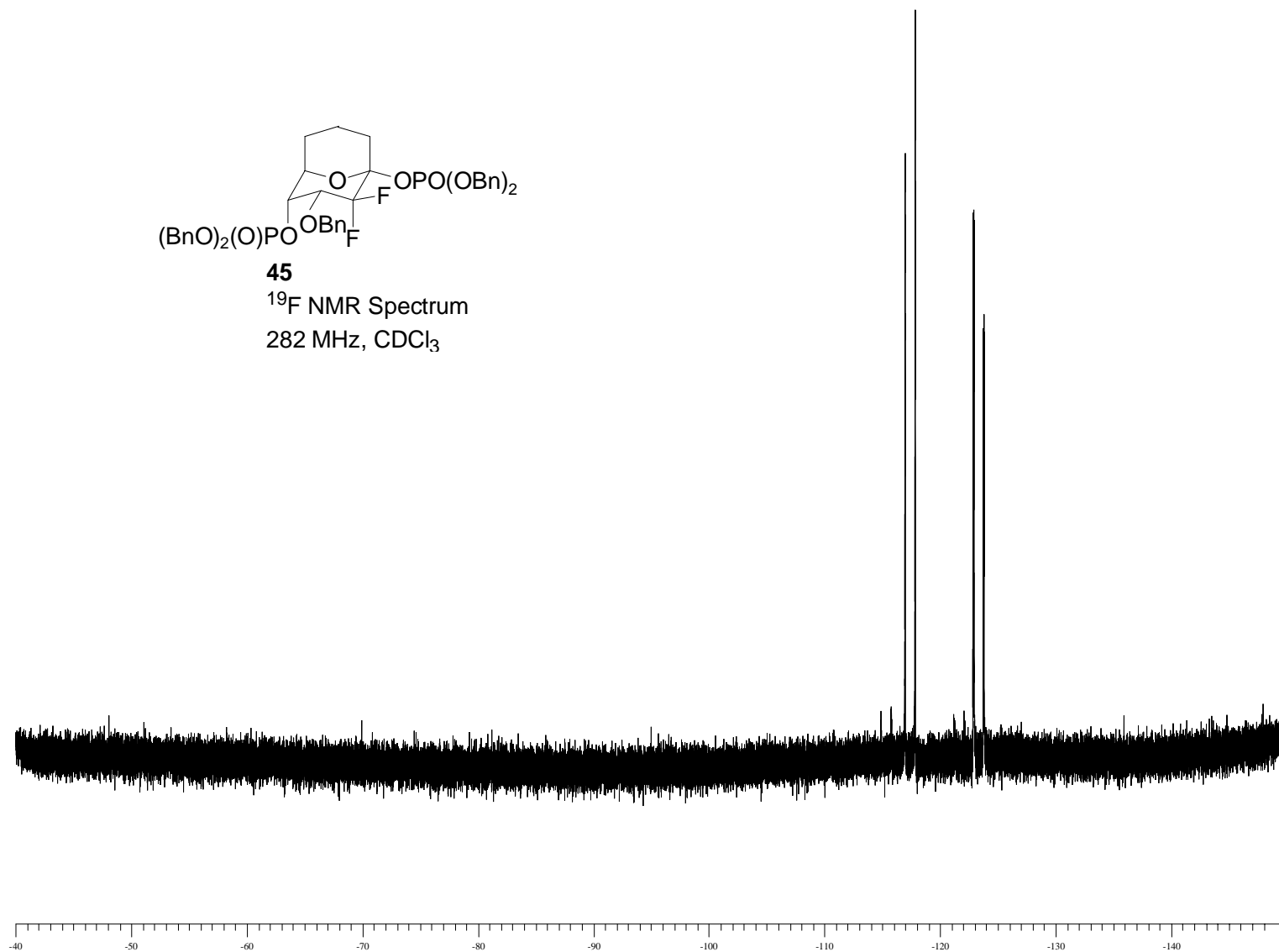
S71

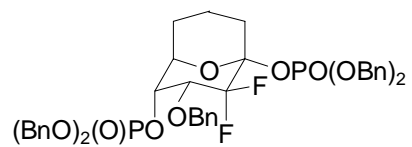
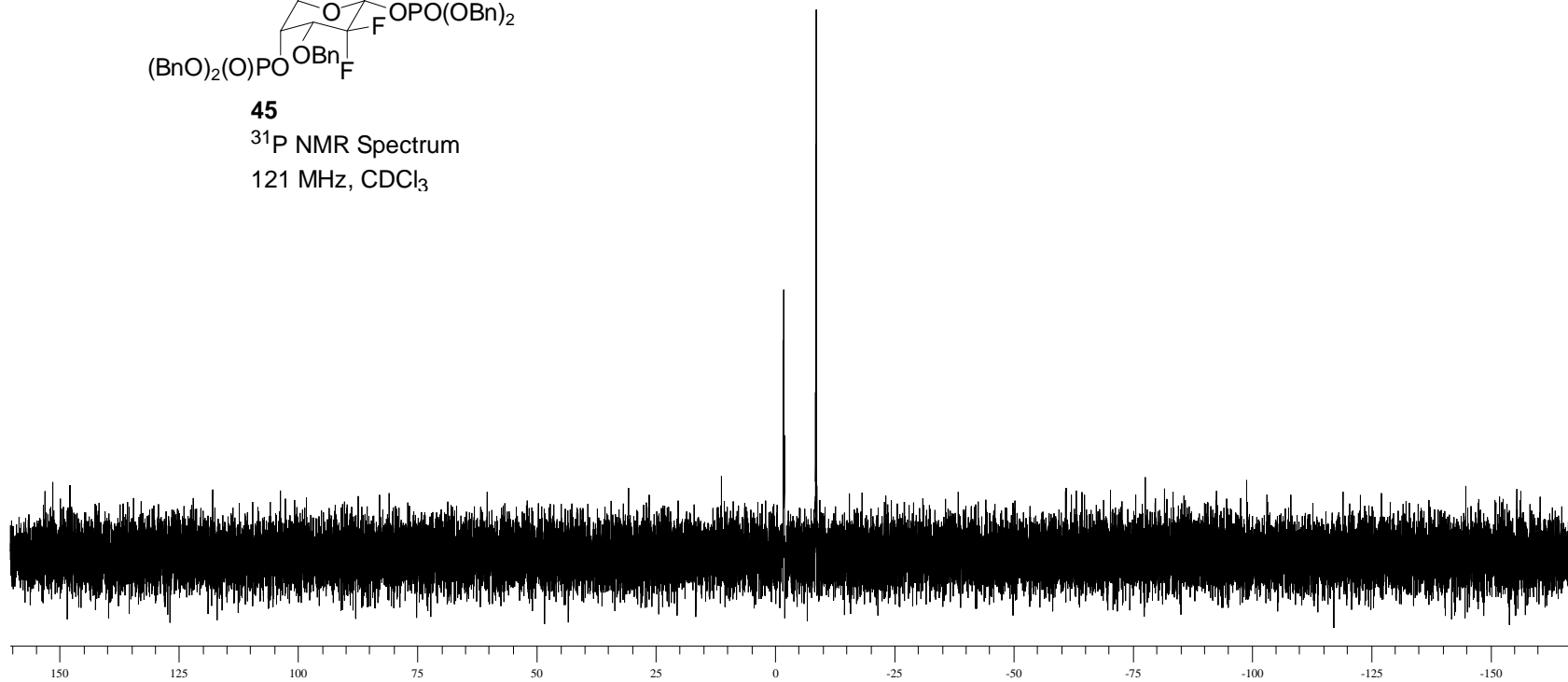


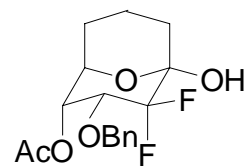
**44**¹⁹F NMR Spectrum282 MHz, CDCl₃

**44** ^{31}P NMR Spectrum121 MHz, CDCl_3 

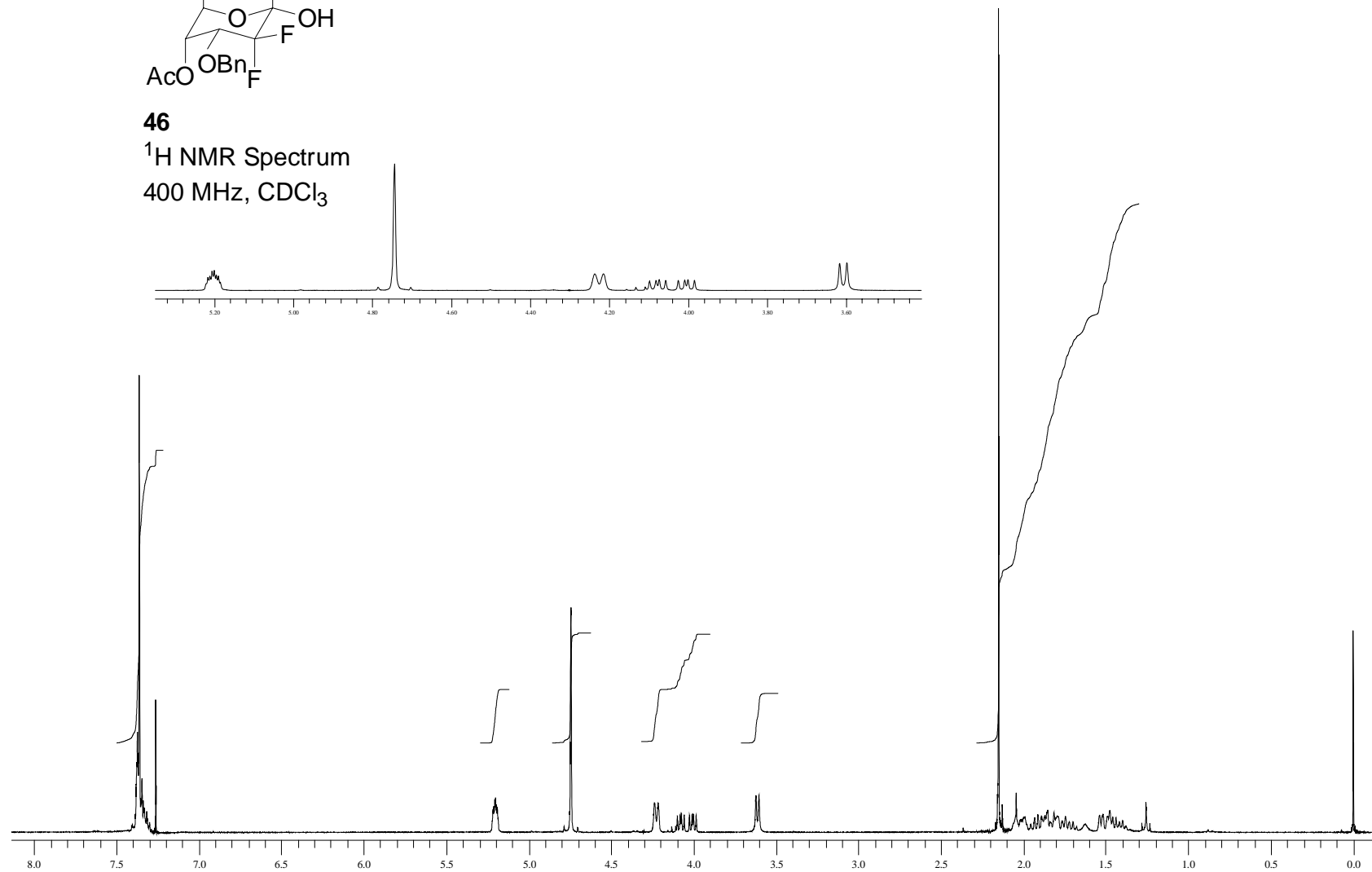
**45** ^1H NMR Spectrum400 MHz, CDCl_3 

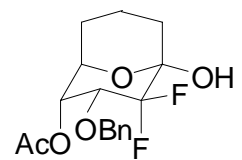
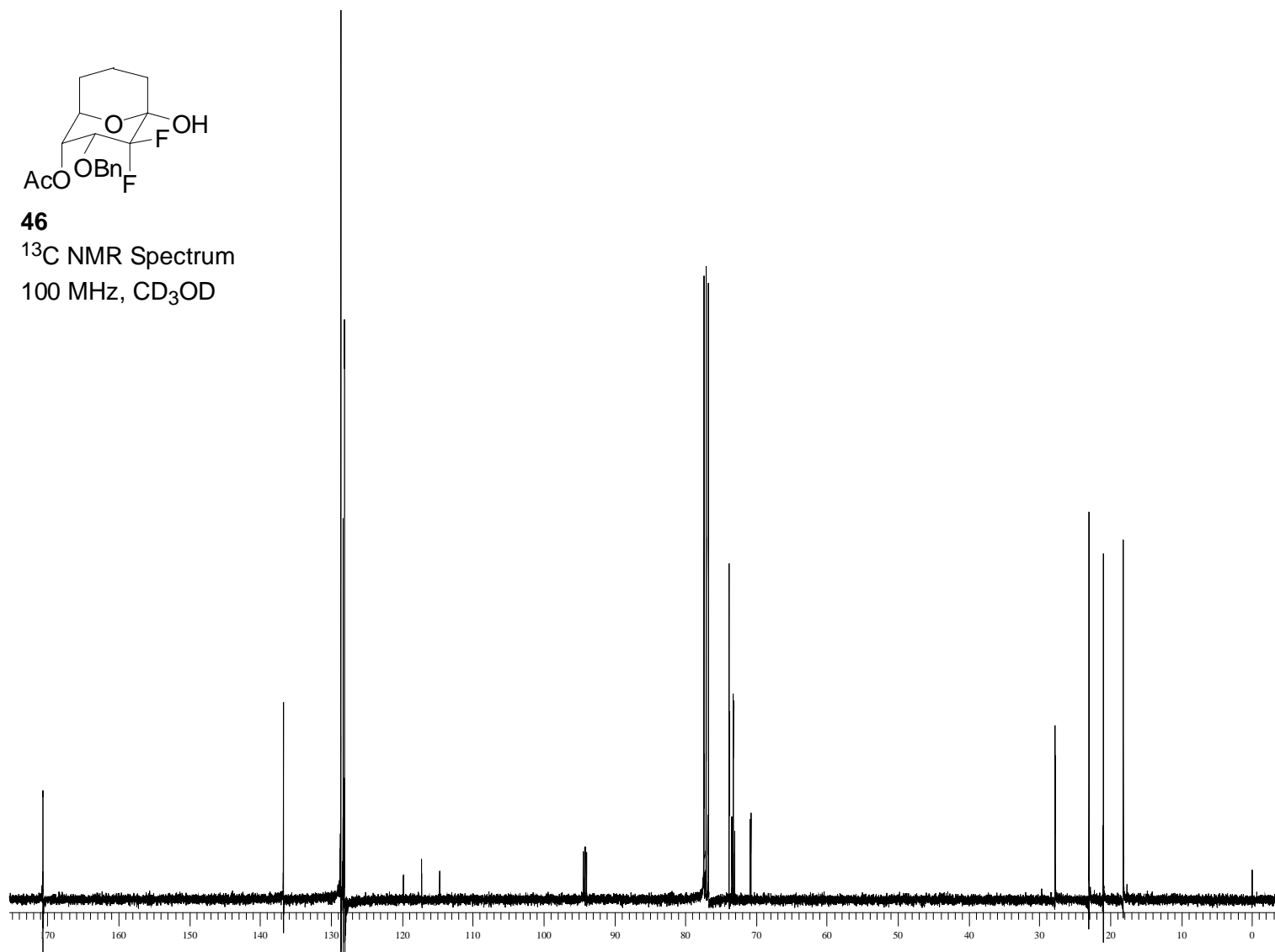
**45** ^{19}F NMR Spectrum282 MHz, CDCl_3 

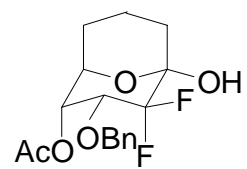
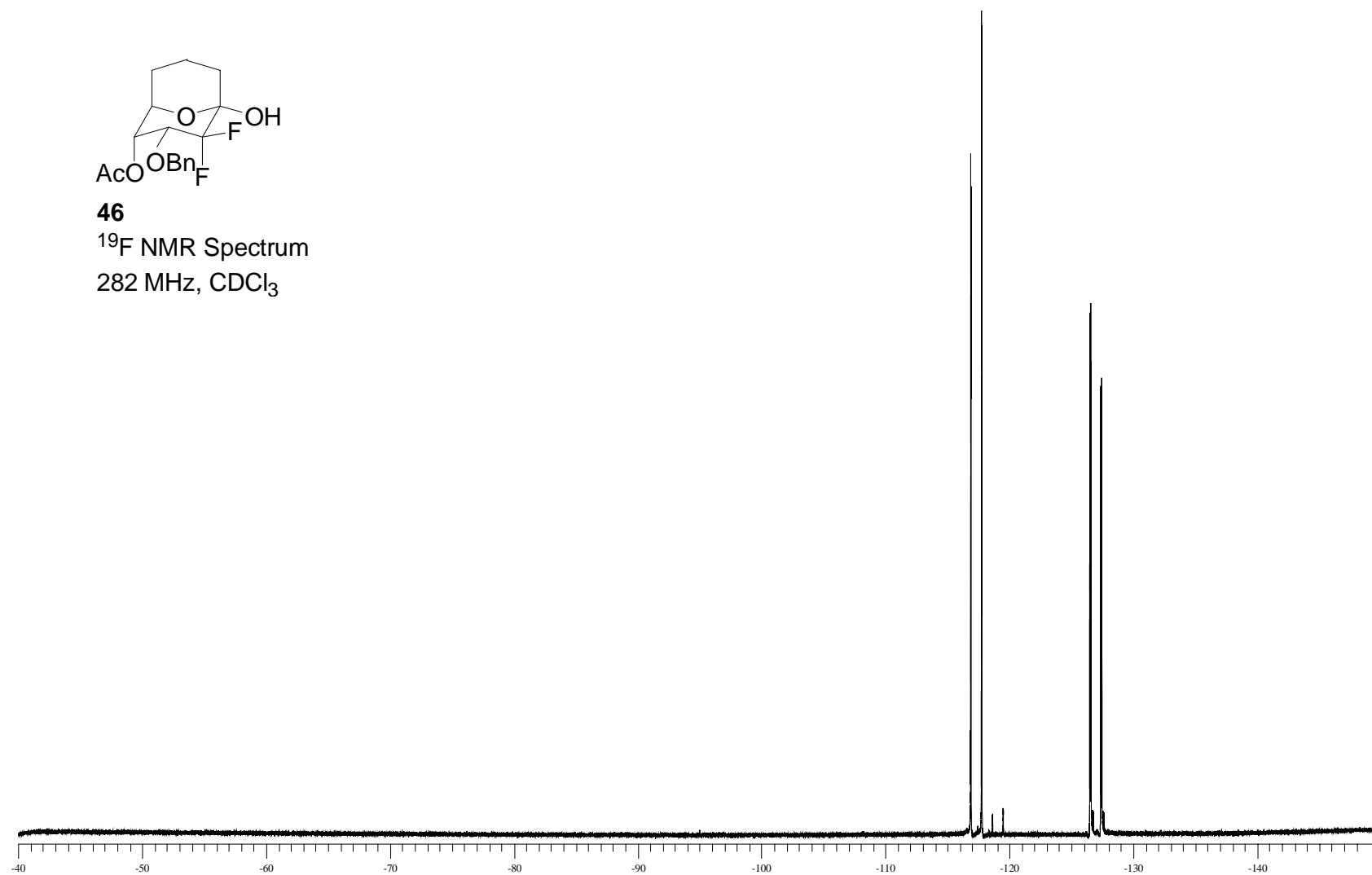
**45** ^{31}P NMR Spectrum121 MHz, CDCl_3 

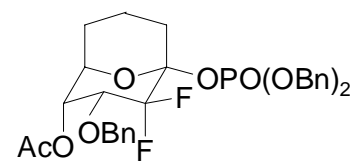
**46**

^1H NMR Spectrum
400 MHz, CDCl_3

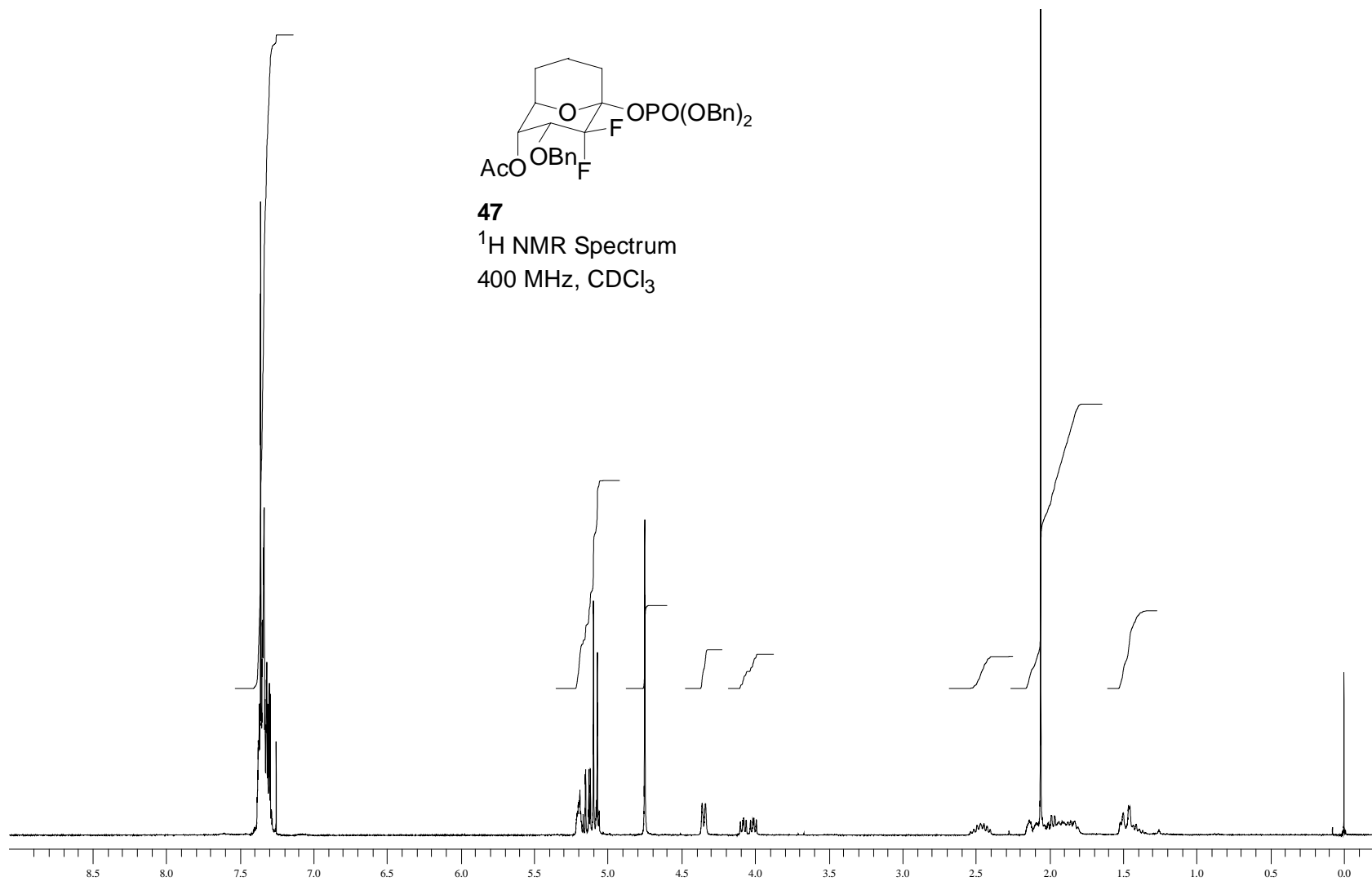


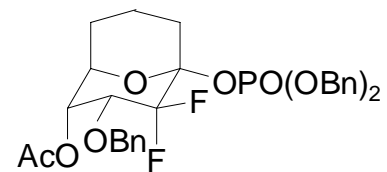
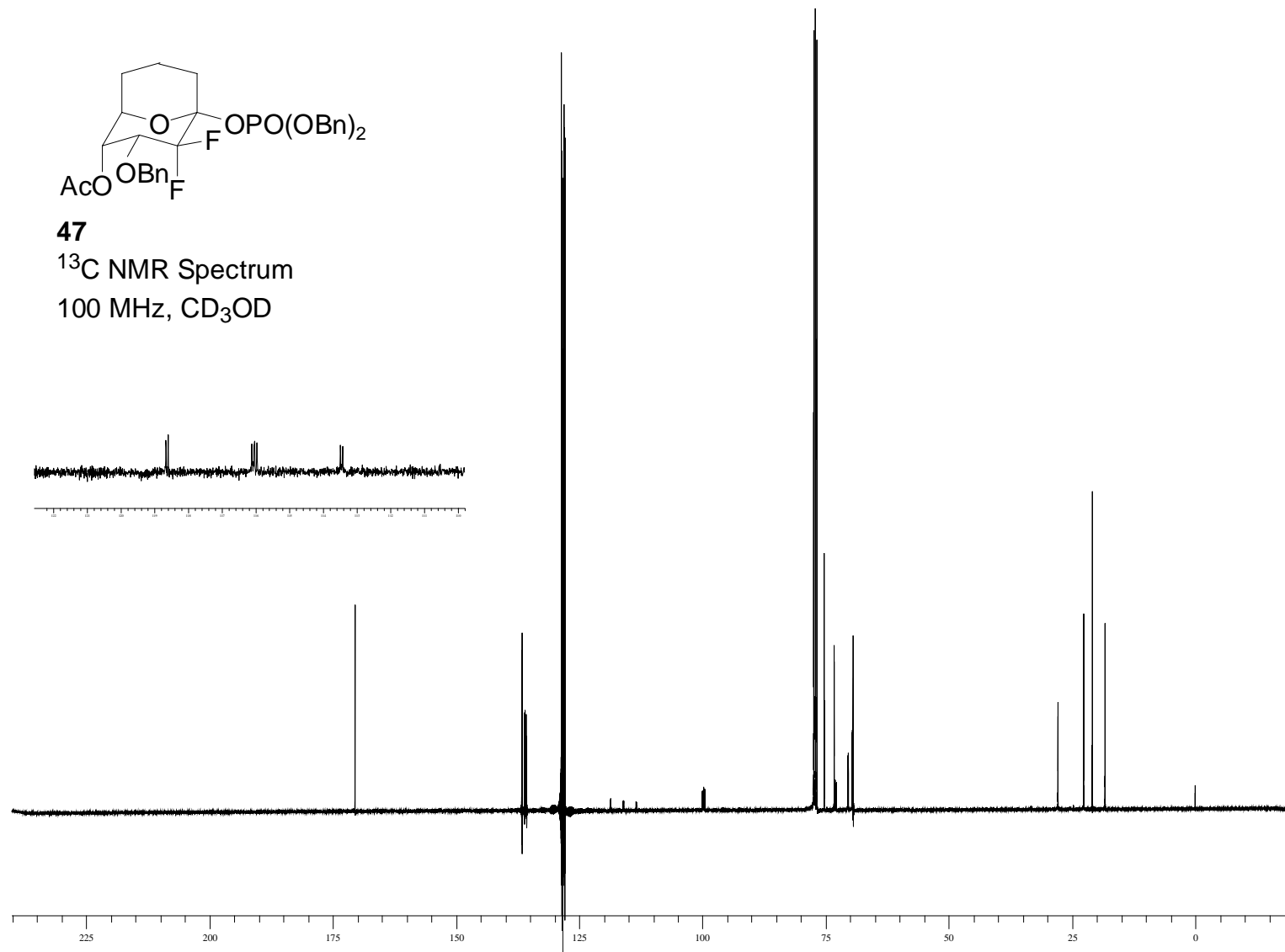
**46** ^{13}C NMR Spectrum100 MHz, CD_3OD 

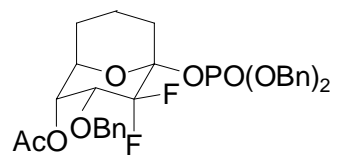
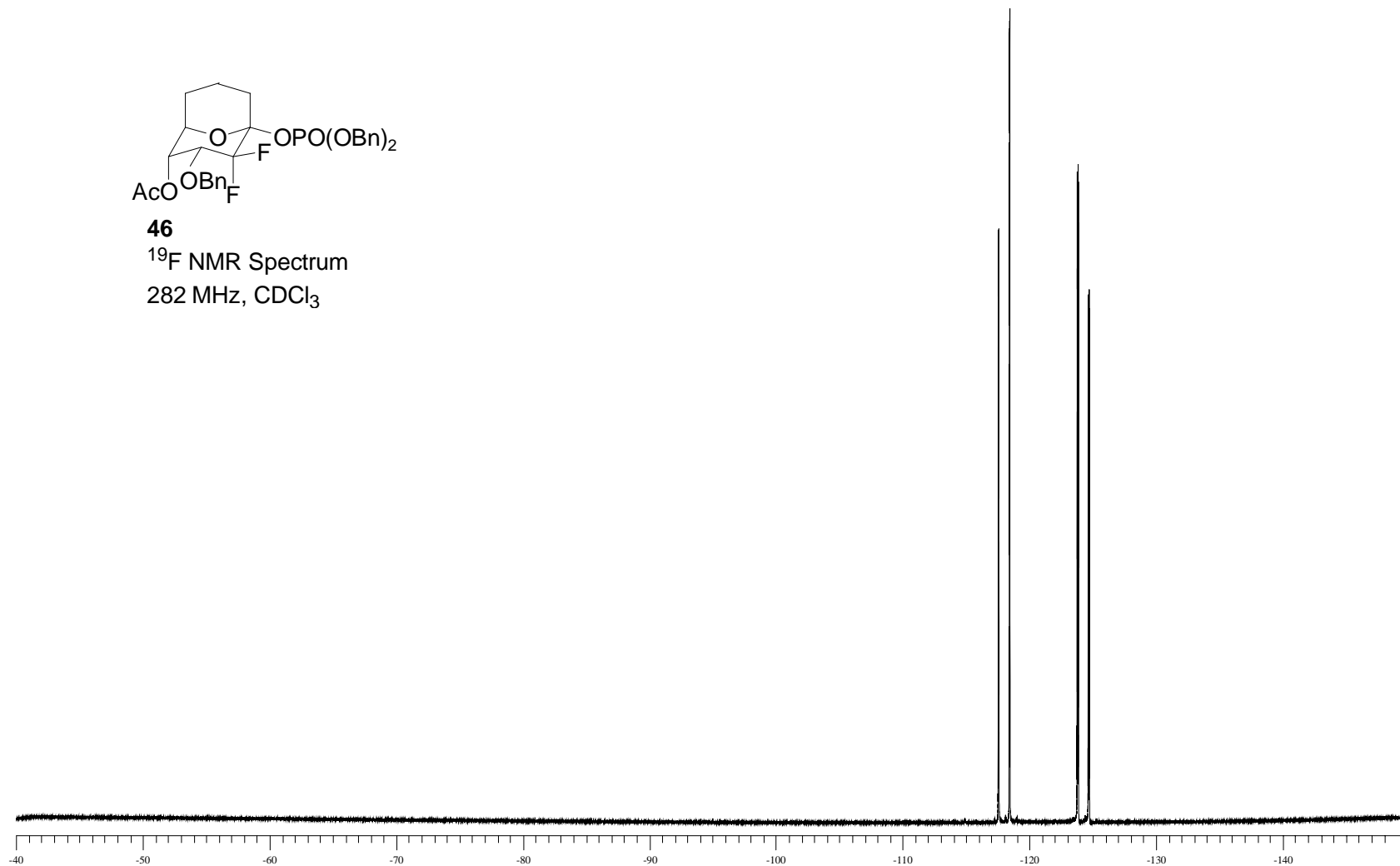
**46**¹⁹F NMR Spectrum282 MHz, CDCl₃

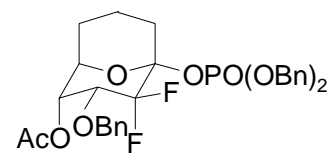
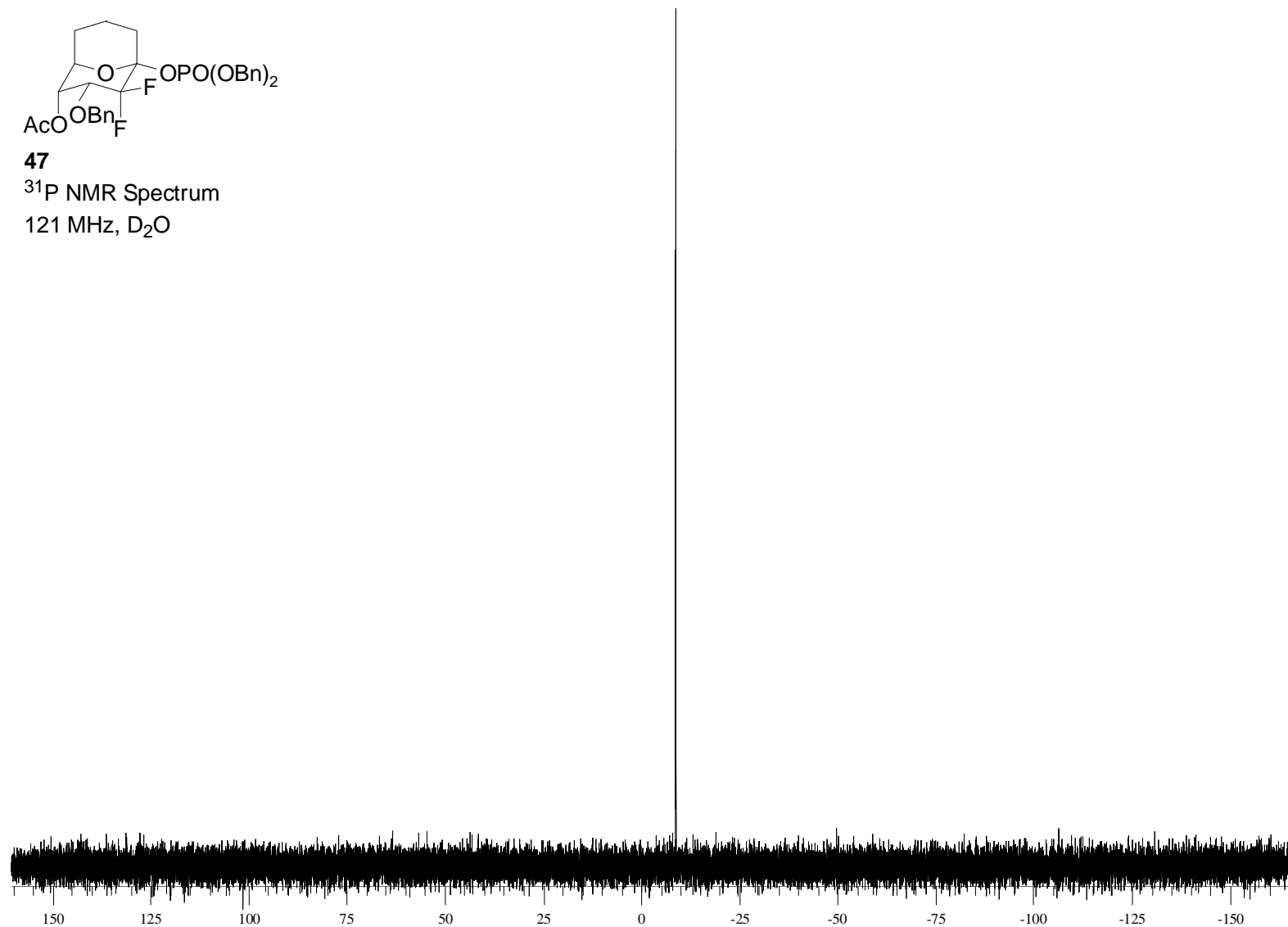


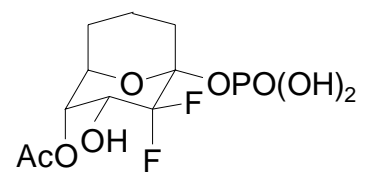
47
¹H NMR Spectrum
400 MHz, CDCl₃



**47**¹³C NMR Spectrum100 MHz, CD₃OD

**46**¹⁹F NMR Spectrum282 MHz, CDCl₃

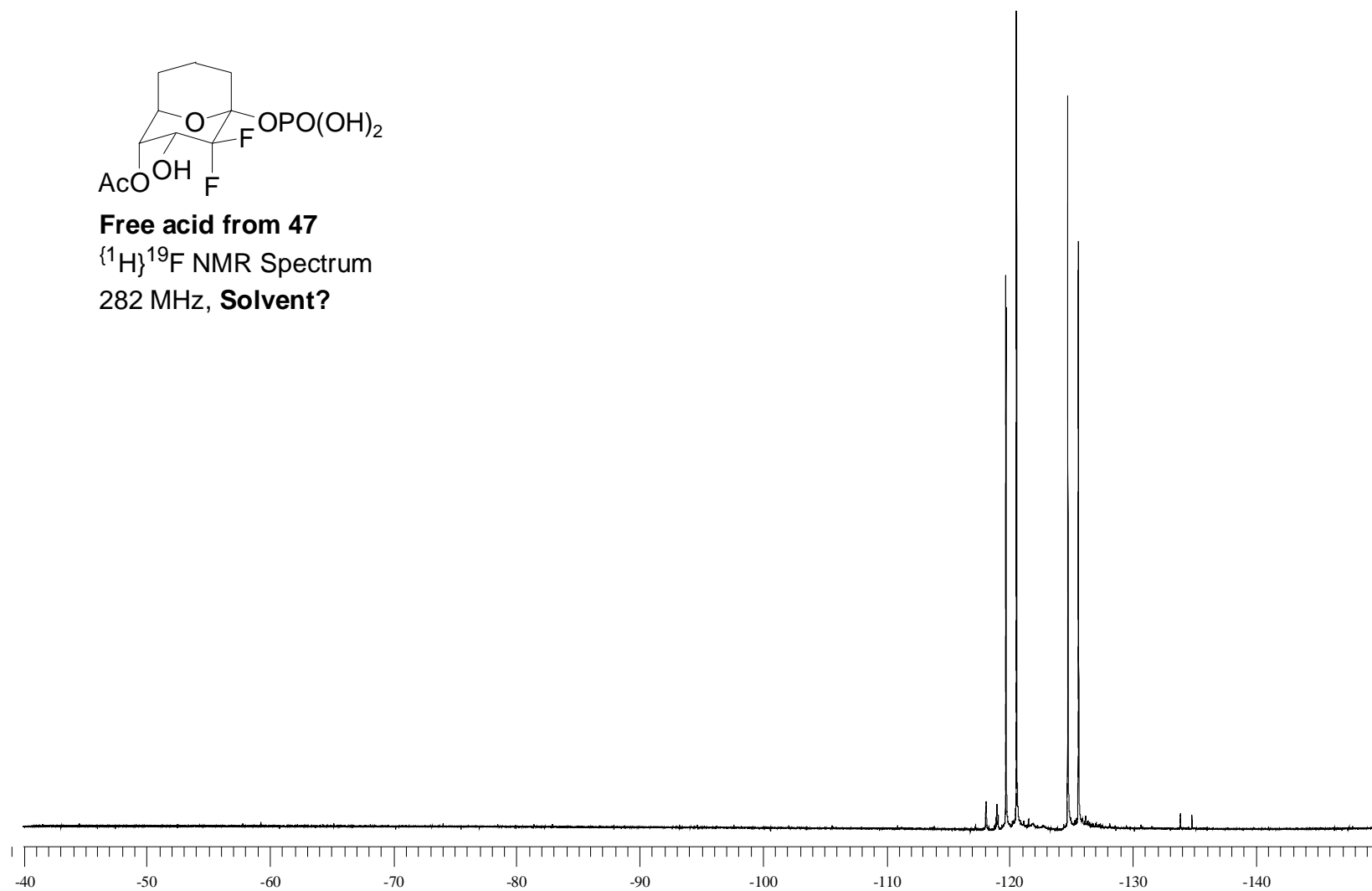
**47**³¹P NMR Spectrum121 MHz, D₂O

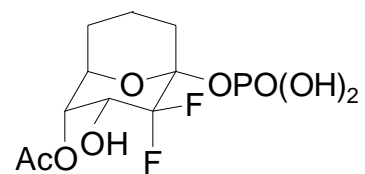


Free acid from 47

¹H/¹⁹F NMR Spectrum

282 MHz, Solvent?

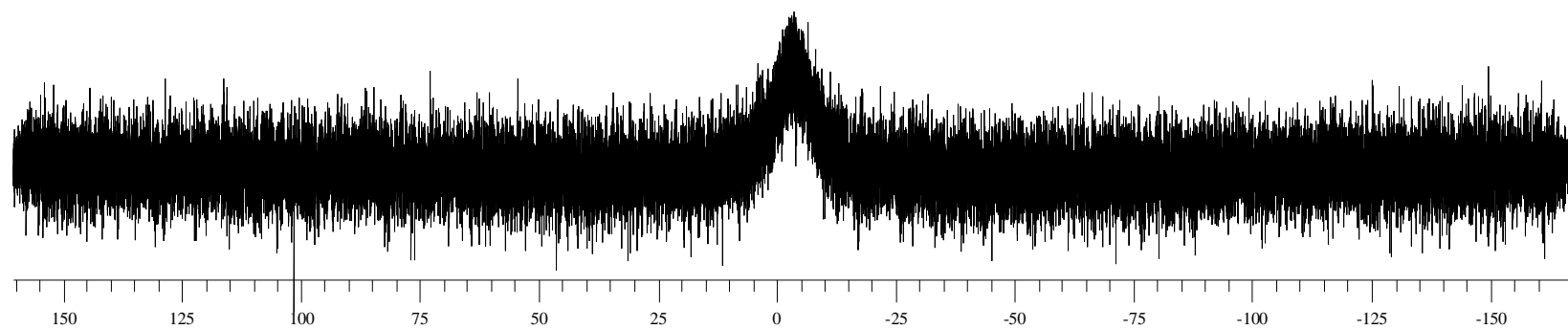


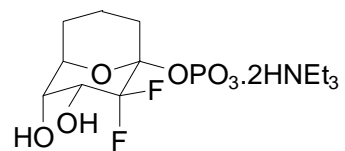


Free acid from 47

³¹P NMR Spectrum

121 MHz, D₂O

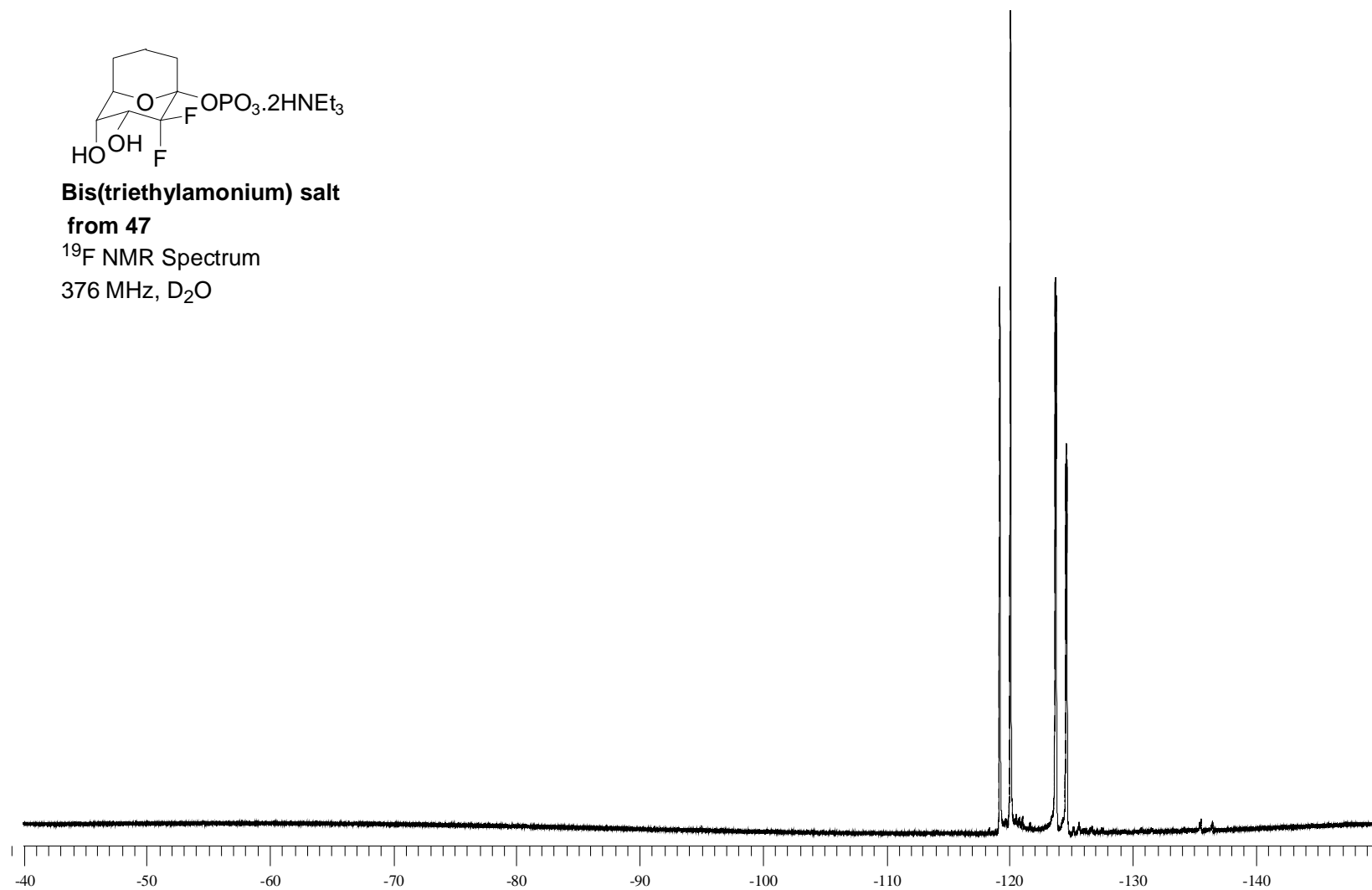


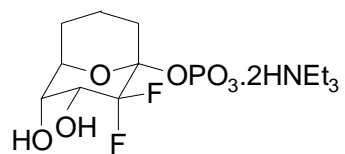


**Bis(triethylamonium) salt
from 47**

¹⁹F NMR Spectrum

376 MHz, D₂O



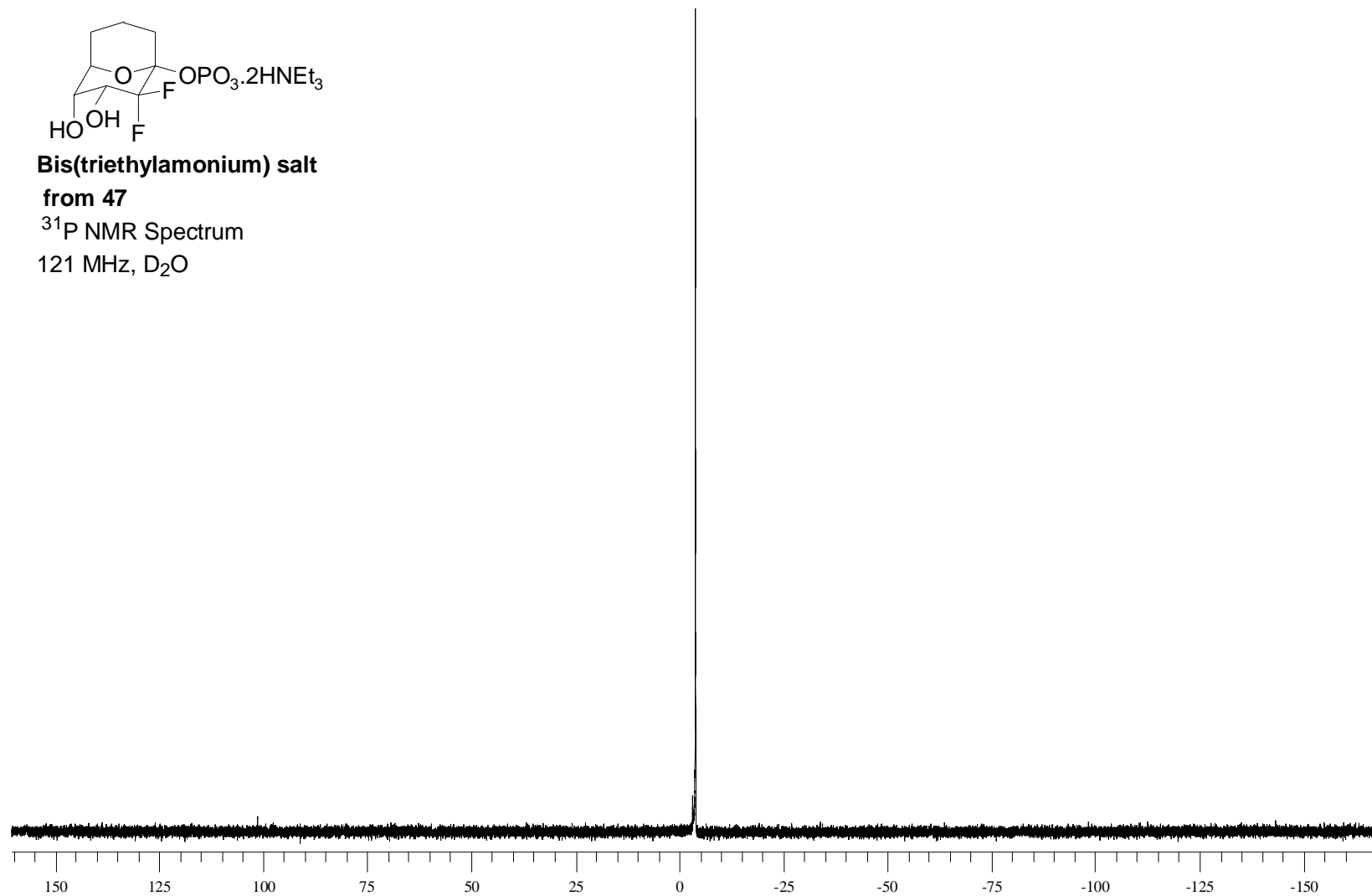


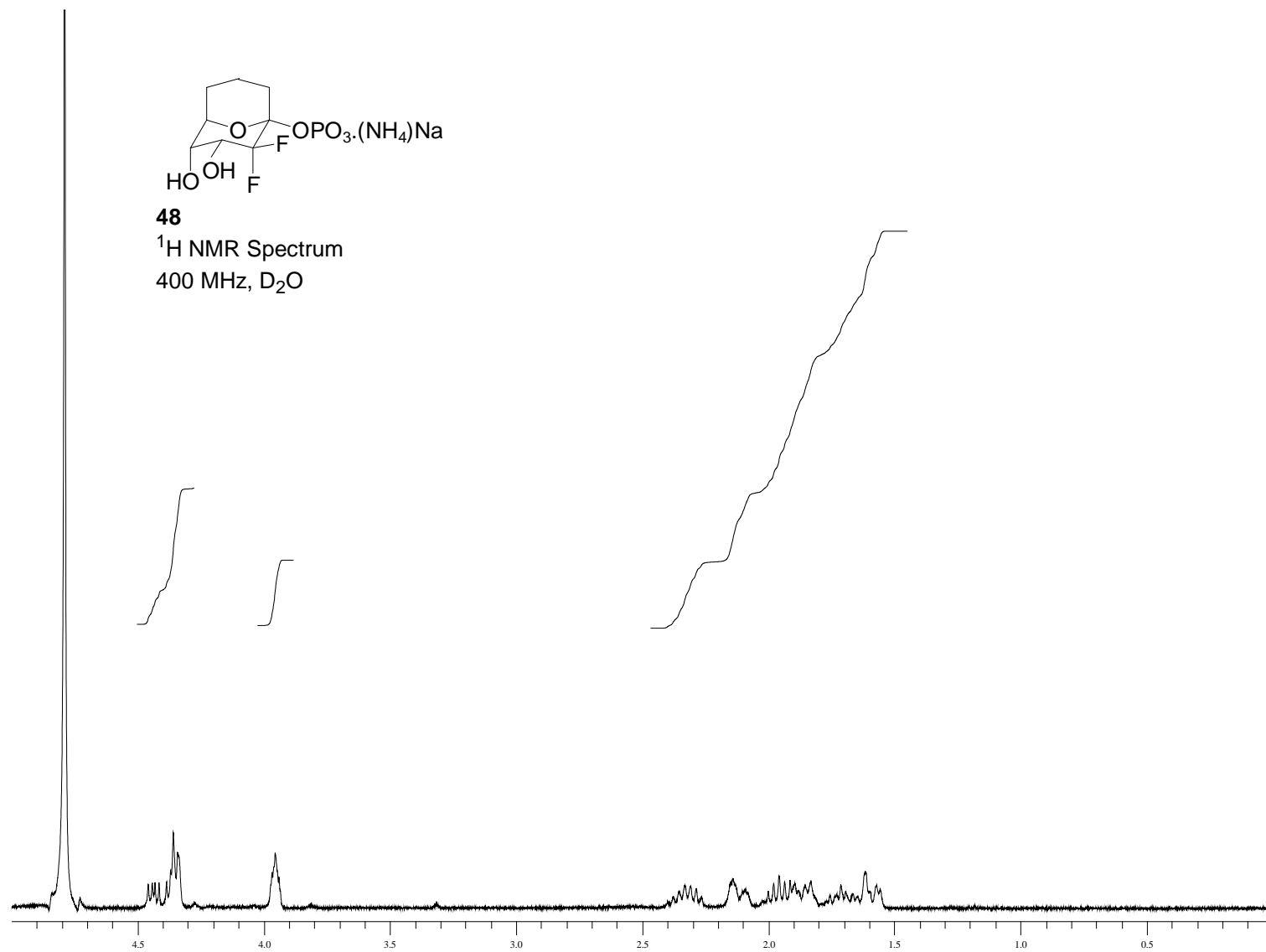
Bis(triethylammonium) salt

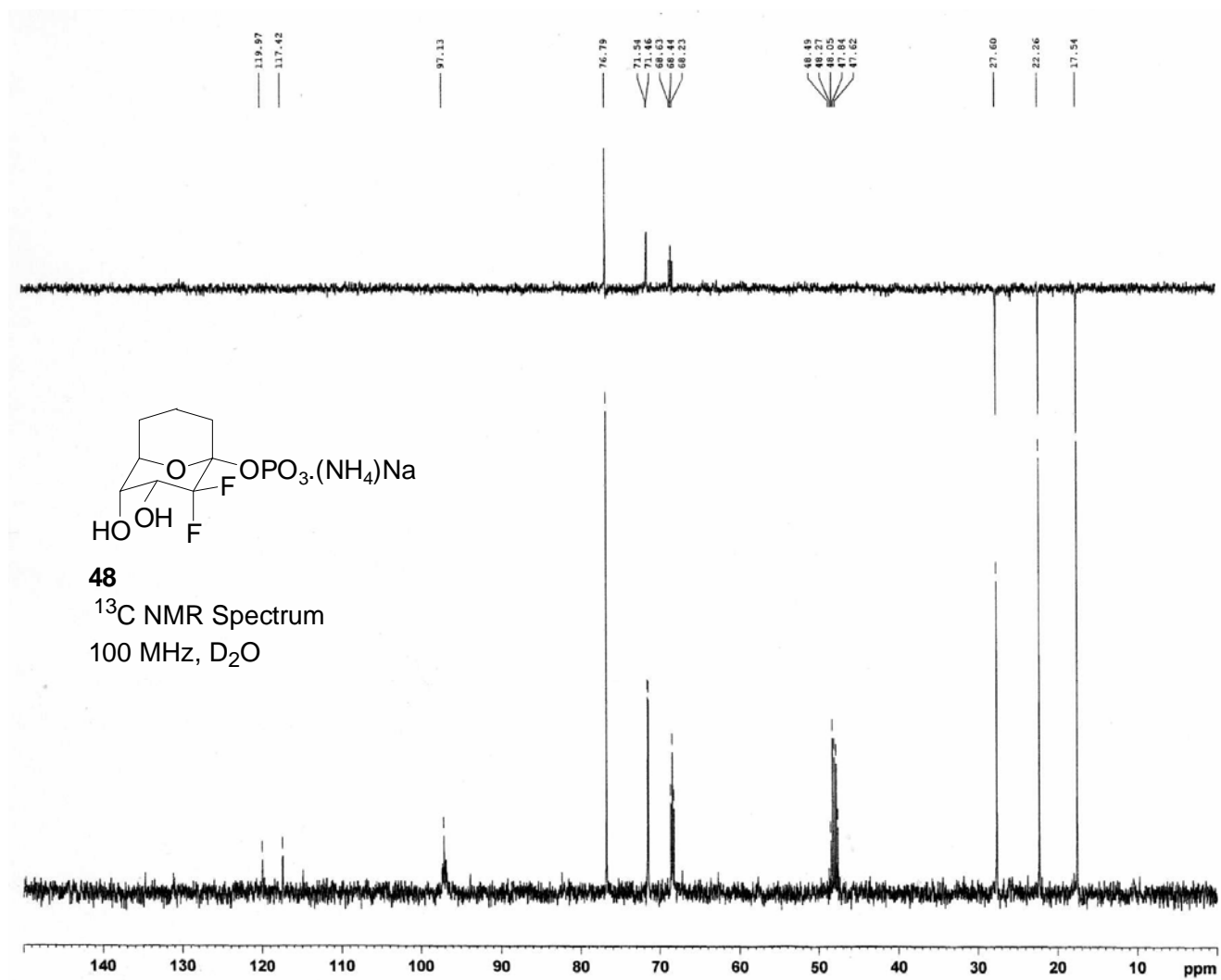
from 47

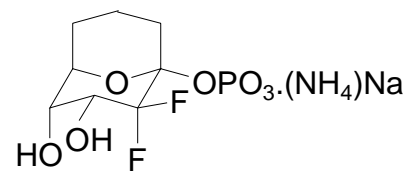
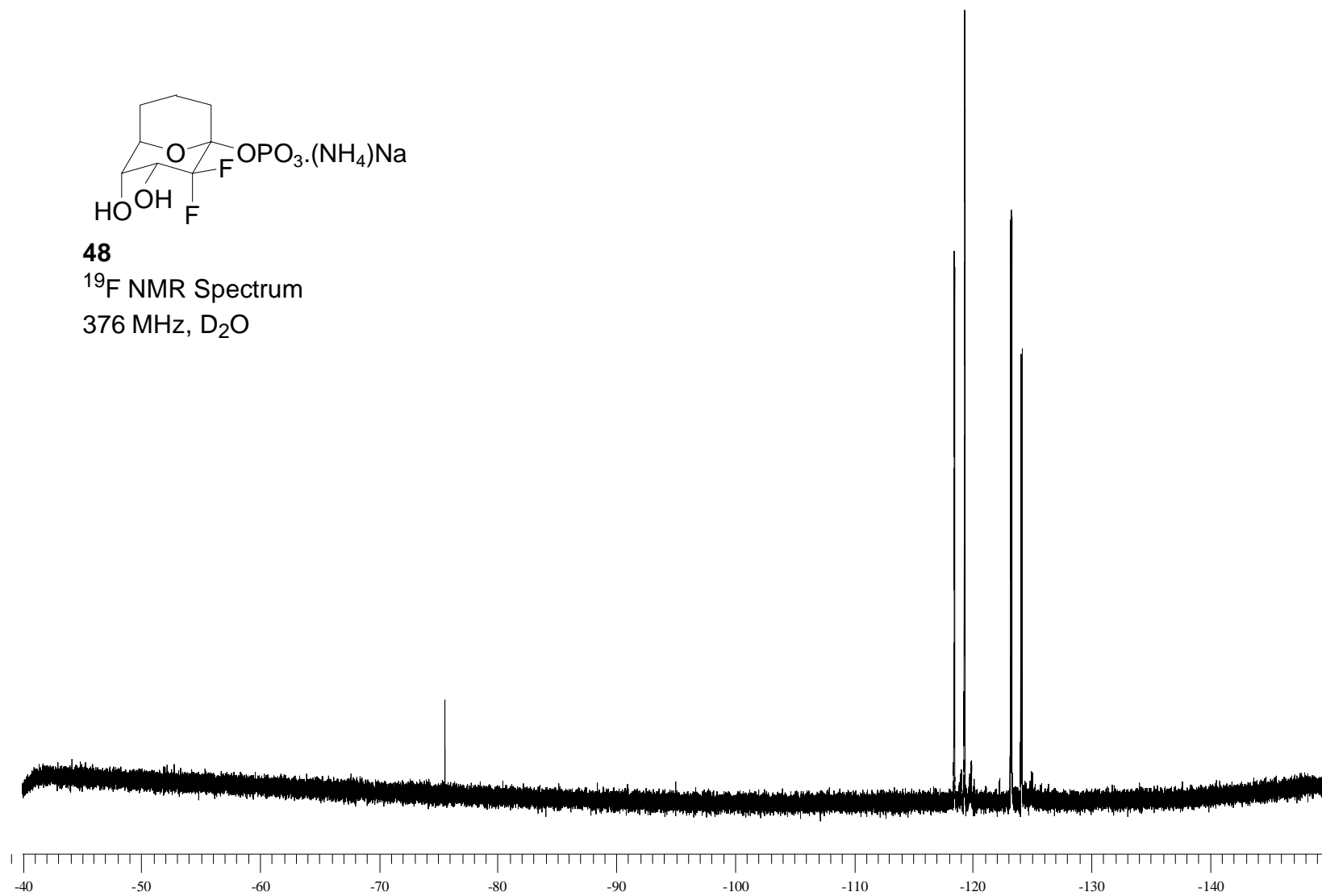
³¹P NMR Spectrum

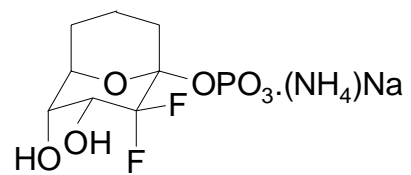
121 MHz, D₂O







**48**¹⁹F NMR Spectrum376 MHz, D₂O

**48** ^{31}P NMR Spectrum121 MHz, D_2O 