Electronic Supplementary Information (ESI)

Detrifluoroacetylative Generation of Halogenated Enolates: Practical Access to Perhalogenated Ketones and Alkenes

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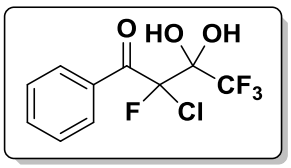
1. General Information

Commercially available bisoxazoline ligands, trifluoromethyl diketones, reagents and solvents were used as purchased without further purification. NMR spectra were obtained at 400 MHz (^{1}H NMR), 376 MHz (^{19}F NMR) and 100 MHz (^{13}C NMR) in deuterated chloroform or DMSO. Chemical shifts are reported in ppm relative to TMS or relative to the DMSO-d_6 solvent peak. Reaction products were purified by column chromatography on silica gel (particle size 40-63 μm) as described below.

2. Experimental Section

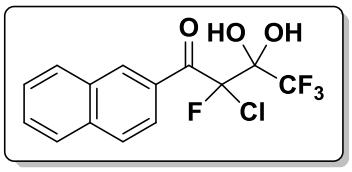
2.1 General procedure for the synthesis of 1-aryl-2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxybutanones.

The corresponding 1-aryl-4,4,4-trifluoro-butane-1,3-dione (1.0 equiv.) and *N*-chlorosuccinimide (1.2 equiv.) were triturated together in a mortar under inert atmosphere. The reaction was monitored by ^{19}F NMR and trituration was continued until full conversion was achieved. The crude reaction mixture was then dissolved in anhydrous acetonitrile and stirred together with Selectfluor (1.5 equiv.) at room temperature. After full conversion was achieved based on ^{19}F NMR analysis, the solvent was removed and replaced with dichloromethane. The insoluble Selectfluor was filtered from the reaction mixture and the filtrate was extracted with water. The combined organic layers were dried over sodium sulfate and the solvent was removed *in vacuo*. The crude product was purified by flash chromatography on silica gel using with hexanes-ethyl acetate (90:10) as mobile phase.

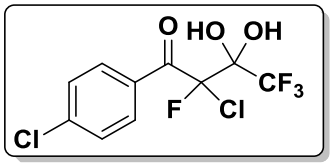


2-Chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one (3). Compound **3** was obtained as a colorless solid in 76% yield (4.34 g, 15.2 mmol) from 4,4,4-trifluoro-1-phenylbutane-1,3-dione (4.32 g, 20.0 mmol) by following the general procedure described above. mp: 53-55 °C; R_f = 0.4 (hexanes / EtOAc, 8:2); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 8.09 (d, *J* = 7.4 Hz, 2H), 7.70 (dd, *J* = 7.5, 7.4 Hz, 1H), 7.53 (dd, *J* = 7.5, 7.4 Hz, 2H), 5.14 (s, 1H), 4.99 (s, 1H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 193.8 (d, $J_{C\text{-}F}$ = 29.2 Hz), 135.3,

131.4 (d, $J_{C\text{-}F}$ = 3.0 Hz), 130.6 (d, $J_{C\text{-}F}$ = 6.6 Hz), 128.8, 121.5 (qd, $J_{C\text{-}F}$ = 289.6, 2.5 Hz), 103.9 (d, $J_{C\text{-}F}$ = 275.9 Hz), 94.9 (qd, $J_{C\text{-}F}$ = 32.5, 23.9 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -78.8 (d, *J* = 14.8 Hz), -127.9 (q, *J* = 14.7 Hz) ppm; Anal. Calcd. for $C_{10}H_7ClF_4O_3$: C, 41.91; H, 2.46. Found: C, 41.84; H, 2.44.

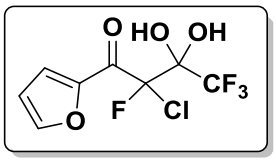


2-Chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (4). Compound **4** was obtained as a pale yellow solid in 84% yield (2.82 g, 8.4 mmol) from 4,4,4-trifluoro-1-(naphthalen-2-yl)butane-1,3-dione (2.66 g, 10.0 mmol) by following the general procedure described above. mp: 82-84 °C; R_f = 0.3 (hexanes / EtOAc, 8:2); ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.78 (s, 1H), 8.59 (m, 1H), 8.12 – 8.05 (m, 4H), 7.73 – 7.58 (m, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*) δ 193.5 (d, $J_{C\text{-}F}$ = 28.7 Hz), 171.4, 136.4, 133.8 (d, $J_{C\text{-}F}$ = 9.3 Hz), 132.3, 130.3, 130.1, 128.7, 127.8 (d, $J_{C\text{-}F}$ = 1.6 Hz), 127.3, 124.9 (d, $J_{C\text{-}F}$ = 4.4 Hz), 121.6 (qd, $J_{C\text{-}F}$ = 289.7, 2.4 Hz), 104.2 (d, $J_{C\text{-}F}$ = 276.1 Hz), 95.0 (qd, $J_{C\text{-}F}$ = 32.3, 23.9 Hz) ppm; ^{19}F NMR (376 MHz, DMSO-d_6) δ = -77.6 (d, *J* = 13.4 Hz), -118.3 (d, *J* = 13.4 Hz); Anal. Calcd. for $C_{14}H_9ClF_4O_3$: C, 49.95; H, 2.69. Found: C, 49.91; H, 2.64.



2-Chloro-1-(4-chlorophenyl)-2,4,4,4-tetrafluoro-3,3-dihydroxybutan-1-one (5). Compound **5** was obtained as a colorless solid in 81% yield (2.08 g, 6.48 mmol) from 1-(4-chlorophenyl)-4,4,4-trifluorobutane-1,3-dione (2.0 g, 8.0 mmol) by following the general procedure described above. mp: 68-70 °C; R_f = 0.4 (hexanes / EtOAc, 8:2); ^{1}H NMR (400 MHz, DMSO-d_6) δ = 8.83 (s, 1H), 8.61 (s, 1H), 8.09 (d, *J* = 8.2 Hz, 2H), 7.63 (d, *J* = 8.6 Hz, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*) δ = 192.4 (d, $J_{C\text{-}F}$ = 29.3 Hz), 142.3, 132.0 (d, $J_{C\text{-}F}$ = 6.8 Hz), 129.7 (d, $J_{C\text{-}F}$ = 3.7 Hz), 129.3, 121.4 (qd, $J_{C\text{-}F}$ = 289.7, 2.4 Hz), 103.9 (d, $J_{C\text{-}F}$ = 275.2 Hz), 94.8 (qd, $J_{C\text{-}F}$ =

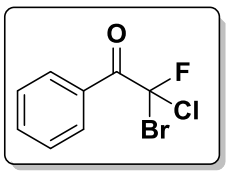
32.5, 23.6 Hz) ppm; ^{19}F NMR (376 MHz, DMSO-d_6) δ = -77.7 (d, J = 13.5 Hz), -118.6 (q, J = 13.4 Hz) ppm; Anal. Calcd. for $C_{10}H_6Cl_2F_4O_3$: C, 37.41; H, 1.88. Found: C, 37.53; H, 1.92.



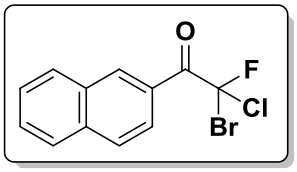
2-Chloro-2,4,4,4-tetrafluoro-1-(furan-2-yl)-3,3-dihydroxybutan-1-one (6). Compound **6** was obtained as a colorless solid in 69% yield (1.90 g, 6.9 mmol) from 4,4,4-trifluoro-1-(furan-2-yl)butane-1,3-dione (2.06 g, 10.0 mmol) by following the general procedure described above. mp: 48-50 °C; R_f = 0.5 (hexanes / EtOAc, 8:2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ = 7.87 (bs, 1H), 7.69 (m, 1H), 6.71 (m, 1H), 4.92 (s, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*) δ = 179.8 (d, $J_{C\text{-}F}$ = 28.4 Hz), 150.8, 146.7 (d, $J_{C\text{-}F}$ = 4.4 Hz), 126.4 (dd, $J_{C\text{-}F}$ = 14.8, 2.0 Hz), 121.5 (qd, $J_{C\text{-}F}$ = 289.4, 2.4 Hz), 113.6 (d, $J_{C\text{-}F}$ = 2.9 Hz), 103.8 (d, $J_{C\text{-}F}$ = 272.9 Hz), 94.6 (qd, $J_{C\text{-}F}$ = 32.6, 23.3 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -79.1 (d, J = 14.3 Hz), -131.0 (q, J = 14.3 Hz) ppm; Anal. Calcd. for $C_8H_5ClF_4O_4$: C, 34.74; H, 1.82. Found: C, 34.82; H, 1.85.

2.2 General procedure for the synthesis of 2-bromo-2-chloro-2-fluoromethyl ketones.

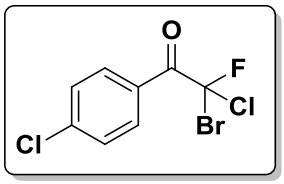
Copper(II) triflate (0.10 equiv.) and (4*R*,5*S*)-bis(4,5-diphenyl-4,5-dihydrooxazol-2-yl)methane (0.12 equiv.) in 0.5 mL of anhydrous tetrahydrofuran were stirred together under inert atmosphere for one hour. The complex solution was added to a solution of the corresponding 1-aryl-2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxybutanone (1.0 equiv.), *N*-bromosuccinimide (1.5 equiv.) and potassium carbonate (2.5 equiv.) in 0.5 mL of anhydrous tetrahydrofuran under inert atmosphere. The mixture was stirred vigorously until conversion of the starting material was complete based on ^{19}F NMR analysis. The crude product was loaded onto a silica gel column and purified by flash chromatography using hexanes as mobile phase.



2-Bromo-2-chloro-2-fluoro-1-phenylethan-1-one (8). Compound **8** was obtained as a colorless liquid in 90% yield (45 mg, 0.18 mmol) from 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one (57 mg, 0.2 mmol) by following the general procedure described above. R_f = 0.5 (hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 8.19 (d, *J* = 7.9 Hz, 2H), 7.66 (dd, *J* = 7.9, 7.5 Hz, 1H), 7.52 (dd, *J* = 7.5, 7.5 Hz, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 182.3 (d, $J_{C\text{-}F}$ = 24.7 Hz), 134.7, 131.0 (d, $J_{C\text{-}F}$ = 3.5 Hz), 129.0 (d, $J_{C\text{-}F}$ = 2.2 Hz), 128.7, 103.6 (d, $J_{C\text{-}F}$ = 319.3 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -60.6 ppm; Anal. Calcd. for C_8H_5BrClF: C, 38.21; H, 2.00. Found: C, 37.91; H, 1.88.

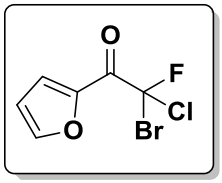


2-Bromo-2-chloro-2-fluoro-1-(naphthalen-2-yl)ethan-1-one (10). Compound **10** was obtained as a colorless liquid in 98% yield (59 mg, 0.19 mmol) from 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (67 mg, 0.2 mmol) by following the general procedure described above. R_f = 0.4 (hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 8.80 (s, 1H), 8.16 (d, *J* = 8.9 Hz, 1H), 8.00 (d, *J* = 8.1 Hz, 1H), 7.92 (dd, *J* = 10.1, 10.7 Hz, 2H), 7.67 (dd, *J* = 8.2, 8.1 Hz, 1H), 7.60 (dd, *J* = 7.1, 7.9 Hz, 1H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 182.3 (d, $J_{C\text{-}F}$ = 24.6 Hz), 136.0, 133.6 (d, $J_{C\text{-}F}$ = 4.5 Hz), 132.1, 130.1, 129.7, 128.5, 127.8, 127.2, 126.1 (d, $J_{C\text{-}F}$ = 2.1 Hz), 125.6 (d, $J_{C\text{-}F}$ = 2.6 Hz), 103.9 (d, $J_{C\text{-}F}$ = 319.5 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -59.9 ppm; Anal. Calcd. for $C_{12}H_7BrClFO$: C, 47.80; H, 2.34. Found: C, 47.78; H, 2.36.



2-Bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (11). Compound **11** was obtained as a colorless liquid in 82% yield (47 mg, 0.16 mmol) from 2-chloro-1-(4-chlorophenyl)-2,4,4,4-tetrafluoro-3,3-dihydroxybutan-1-one (64 mg, 0.2 mmol) by following the general procedure described above. R_f = 0.5 (hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 8.14 (d, *J* = 8.4 Hz,

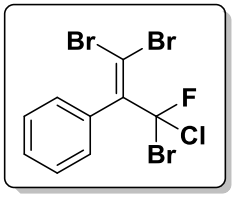
2H), 7.49 (d, J = 8.5 Hz, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 181.3 (d, $J_{C\text{-}F}$ = 25.1 Hz), 141.5, 132.4 (d, $J_{C\text{-}F}$ = 3.7 Hz), 129.1, 127.5, 103.5 (d, $J_{C\text{-}F}$ = 318.8 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -61.0 ppm; Anal. Calcd. for $C_8H_4BrCl_2FO$: C, 33.61; H, 1.41. Found: C, 33.85; H, 1.39.



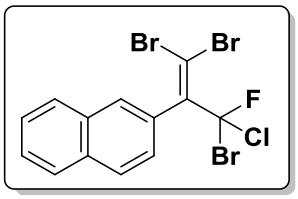
2-Bromo-2-chloro-2-fluoro-1-(furan-2-yl)ethan-1-one (12). Compound **12** was obtained as a colorless liquid in 85% yield (41 mg, 0.17 mmol) from 2-chloro-2,4,4,4-tetrafluoro-1-(furan-2-yl)-3,3-dihydroxybutan-1-one (55 mg, 0.2 mmol) by following the general procedure described above. R_f = 0.6 (hexanes); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.78 (d, J = 1.8 Hz, 1H), 7.55 (m, 1H), 6.66 (dd, J = 3.7, 1.7 Hz, 1H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 171.5 (d, $J_{C\text{-}F}$ = 26.5 Hz), 149.3 , 144.9, 123.9 (d, $J_{C\text{-}F}$ = 6.6 Hz), 112.9, 102.4 (d, $J_{C\text{-}F}$ = 317.8 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -64.1 ppm; Anal. Calcd. for $C_6H_3BrClFO_2$: C, 29.85; H, 1.25. Found: C, 29.97; H, 1.29.

2.3 General procedure for the dibromo olefination of 2-bromo-2-chloro-2-fluoroketones.

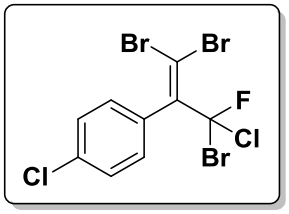
A solution of triphenylphosphine (4 equiv.) in 2 mL of anhydrous dichloromethane was added dropwise to a solution of carbon tetrabromide (2 equiv.) in 2 mL of anhydrous dichloromethane at 0 °C over 30 minutes. The solution was stirred for 10 minutes and 2-bromo-2-chloro-2-fluoromethyl ketone (1 equiv.) in 2 mL of anhydrous dichloromethane was then added over 10 minutes. The resulting solution was stirred at 0 °C until conversion was complete based on TLC and ^{19}F NMR analysis and 5 mL of water was added. The organic phase was washed with brine, dried over anhydrous sodium sulfate and the solvent was removed *in vacuo*. The crude product was purified by flash chromatography on silica gel using hexanes as mobile phase.



1,1,3-Tribromo-3-chloro-3-fluoro-2-phenylprop-1-ene (13). Compound **13** was obtained after 4 hours as a colorless liquid in 98% yield (47 mg, 0.117 mmol) from 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (30 mg, 0.119 mmol) by following the general procedure described above. R_f = 0.6 (hexanes); Rotation about the aryl-vinyl bond appears to be slow on the NMR time scale and more than one conformer is observed. ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.44 – 7.41 (m, 3H), 7.33 – 7.28 (m, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 146.3 (d, $J_{C\text{-}F}$ = 24.5 Hz), 137.7 (d, $J_{C\text{-}F}$ = 2.4 Hz), 129.2, 129.1, 128.8, 128.7, 128.6, 103.0 (d, $J_{C\text{-}F}$ = 308.6 Hz), 99.1 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -40.5 ppm; Anal. Calcd. for $C_9H_5Br_3ClF$: C, 26.54; H, 1.24. Found: C, 26.77; H, 1.49.



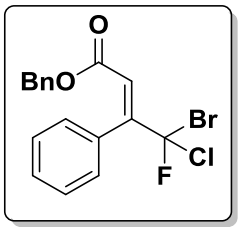
2-(1,1,3-Tribromo-3-chloro-3-fluoroprop-1-en-2-yl)naphthalene (14). Compound **14** was obtained after 4 hours as a colorless solid in 88% yield (67 mg, 0.146 mmol) from 2-bromo-2-chloro-2-fluoro-1-(naphthalen-2-yl)ethan-1-one (50 mg, 0.166 mmol) by following the general procedure described above. mp: 66-67 °C; R_f = 0.5 (hexanes); Rotation about the aryl-vinyl bond appears to be slow on the NMR time scale and more than one conformer is observed. ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.93 – 7.88 (m, 2H), 7.88 (d, *J* = 6.5 Hz, 1H), 7.83 (d, *J* = 8.9 Hz, 1H), 7.60 – 7.50 (m, 2H), 7.39 (d, *J* = 7.8 Hz, 1H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 146.3 (d, $J_{C\text{-}F}$ = 13.5 Hz), 146.1 (d, $J_{C\text{-}F}$ = 12.5 Hz), 135.0 (d, $J_{C\text{-}F}$ = 2.3 Hz), 134.9 (d, $J_{C\text{-}F}$ = 2.5 Hz), 133.2, 132.9, 128.7, 128.4, 128.4, 127.8, 127.1, 126.6, 126.3, 126.1, 103.1 (d, $J_{C\text{-}F}$ = 308.3 Hz), 103.0 (d, $J_{C\text{-}F}$ = 307.0 Hz), 99.4 (d, $J_{C\text{-}F}$ = 6.8 Hz) ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -40.3, -40.6 ppm; Anal. Calcd. for $C_{13}H_7Br_3ClF$: C, 34.14; H, 1.54. Found: C, 34.26; H, 1.56.



1-Chloro-4-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)benzene (15). Compound **15** was obtained after 6 hours as a colorless solid in 86% yield (52 mg, 0.12 mmol) from 2-bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (40 mg, 0.14 mmol) by following the general procedure described above. mp: 70-72 °C; R_f = 0.6 (hexanes); Rotation about the aryl-vinyl bond appears to be slow on the NMR time scale and more than one conformer is observed. ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.41 (d, *J* = 8.6 Hz, 2H), 7.25 (d, *J* = 8.5 Hz, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 145.2 (d, $J_{C\text{-}F}$ = 24.5 Hz), 136.0 (d, $J_{C\text{-}F}$ = 2.5 Hz), 135.5, 130.5, 130.3 (d, $J_{C\text{-}F}$ = 1.5 Hz), 129.0 (d, $J_{C\text{-}F}$ = 1.4 Hz), 102.6 (d, $J_{C\text{-}F}$ = 308.8 Hz), 99.7 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -41.1 ppm; Anal. Calcd. for $C_9H_4Br_3Cl_2F$: C, 24.47; H, 0.91. Found: C, 24.72; H, 1.18.

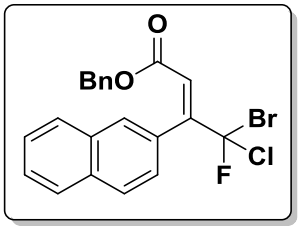
2.4 General procedure for the Wittig olefination of 2-bromo-2-chloro-2-fluoromethyl ketones.

The 2-bromo-2-chloro-2-fluoromethyl ketone (1.0 equiv.) and benzyl 2-(triphenyl-phosphanylidene)acetate (1.2 equiv.) were dissolved in 1 mL of anhydrous tetrahydrofuran under inert atmosphere at room temperature. The reaction was monitored by TLC using hexanes-ethyl acetate (96:4) as mobile phase. The crude product was purified by flash chromatography on silica gel using hexanes-ethyl acetate (96:4).

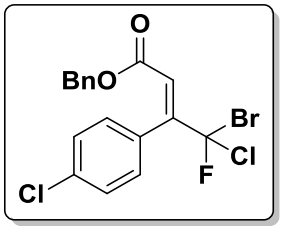


Benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (16). Compound **16** was obtained as a colorless solid in 81% yield (62 mg, 0.16 mmol) from 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (50.3 mg, 0.2 mmol) by following the general procedure described above.

R_f = 0.4 (hexanes / EtOAc, 9:1); ^{1}H NMR (400 MHz, Chloroform-*d*) δ = 7.45 – 7.35 (m, 5H), 7.29 (m, 3H), 7.16 – 7.05 (m, 2H), 6.57 (s, 1H), 4.97 (s, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*) δ = 164.1 (d, J_{C-F} = 1.2 Hz), 152.9 (d, J_{C-F} = 18.4 Hz), 135.0, 132.4 (d, J_{C-F} = 1.5 Hz), 130.0, 129.1, 128.5, 128.4, 128.3, 127.8, 120.1 (d, J_{C-F} = 9.8 Hz), 105.4 (d, J_{C-F} = 310.7 Hz), 66.9 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -54.2 ppm. Anal. Calcd. for $C_{17}H_{13}O_2BrClF$: C, 53.22; H, 3.42. Found: C, 53.30; H, 3.04.

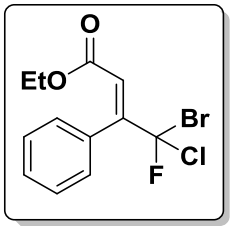


Benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-(naphthalen-2-yl)but-2-enoate (17). Compound **17** was obtained as a colorless solid in 92% yield (43 mg, 0.11 mmol) from 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (36 mg, 0.12 mmol) by following the general procedure described above. mp: 102-105 °C; R_f = 0.2 (hexanes / EtOAc, 98:2); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.88 – 7.81 (m, 4H), 7.57 – 7.51 (m, 2H), 7.47 (d, *J* = 8.3 Hz, 1H), 7.20 (dd, *J* = 7.5, 7.4 Hz, 1H), 7.10 (dd, *J* = 7.6, 7.5 Hz, 2H), 6.91 (d, *J* = 7.4 Hz, 2H), 6.67 (s, 1H), 4.93 (s, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 164.2, 152.6 (d, J_{C-F} = 18.5 Hz), 134.7, 133.3, 132.5, 129.9, 129.4, 128.4, 128.3, 128.2, 128.2, 127.8, 127.6, 127.3, 126.9, 126.4, 120.5 (d, J_{C-F} = 9.8 Hz), 105.5 (d, J_{C-F} = 310.8 Hz), 66.9 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -53.8 ppm; Anal. Calcd. for $C_{21}H_{15}BrClFO_2$: C, 58.16; H, 3.49. Found: C, 58.22; H, 3.55.



Benzyl (*E*)-4-bromo-4-chloro-3-(4-chlorophenyl)-4-fluorobut-2-enoate (18). Compound **18** was obtained as a colorless solid in 91% yield (62 mg, 0.15 mmol) from 2-bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (46 mg, 0.16 mmol) by following the general procedure

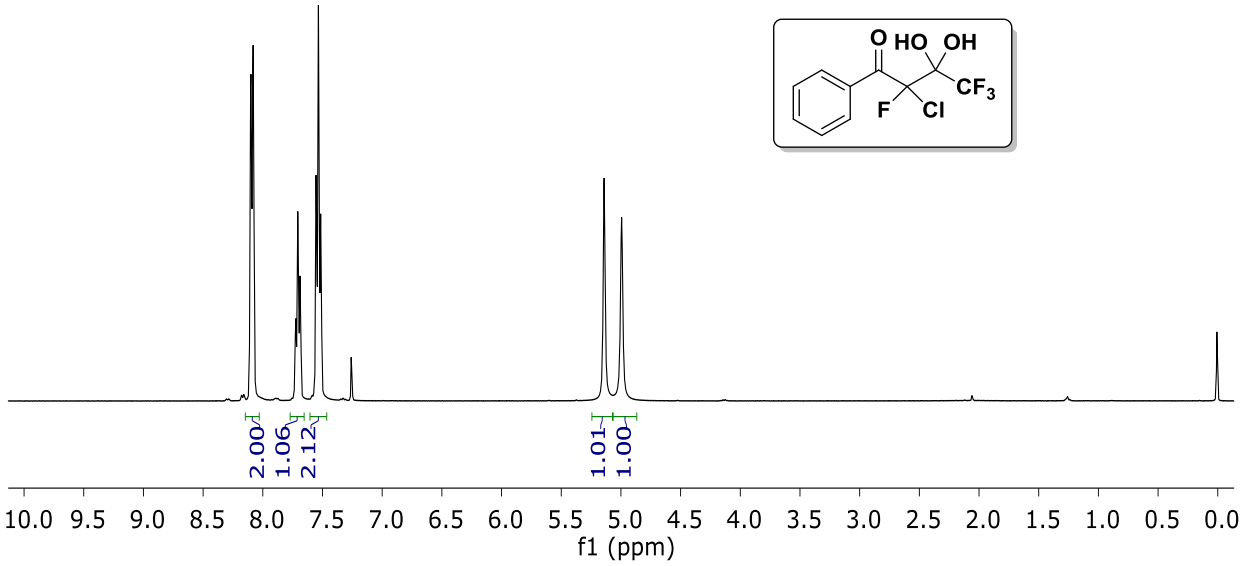
described above. mp: 51-52 °C; R_f = 0.3 (hexanes / EtOAc, 98:2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ = 7.36 – 7.28 (m, 7H), 7.15 – 7.10 (m, 2H), 6.58 (s, 1H), 5.00 (s, 2H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*) δ = 163.8 (d, J_{C-F} = 1.6 Hz), 151.6 (d, J_{C-F} = 18.8 Hz), 135.4, 134.7, 131.4, 130.8 (d, J_{C-F} = 1.5 Hz), 128.6, 128.5, 128.4, 128.1, 120.6 (d, J_{C-F} = 9.8 Hz), 105.0 (d, J_{C-F} = 310.7 Hz), 67.1 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -54.71 ppm. Anal. Calcd. for $C_{17}H_{12}BrCl_2FO_2$: C, 48.84; H, 2.89. Found: C, 48.83; H, 2.89.



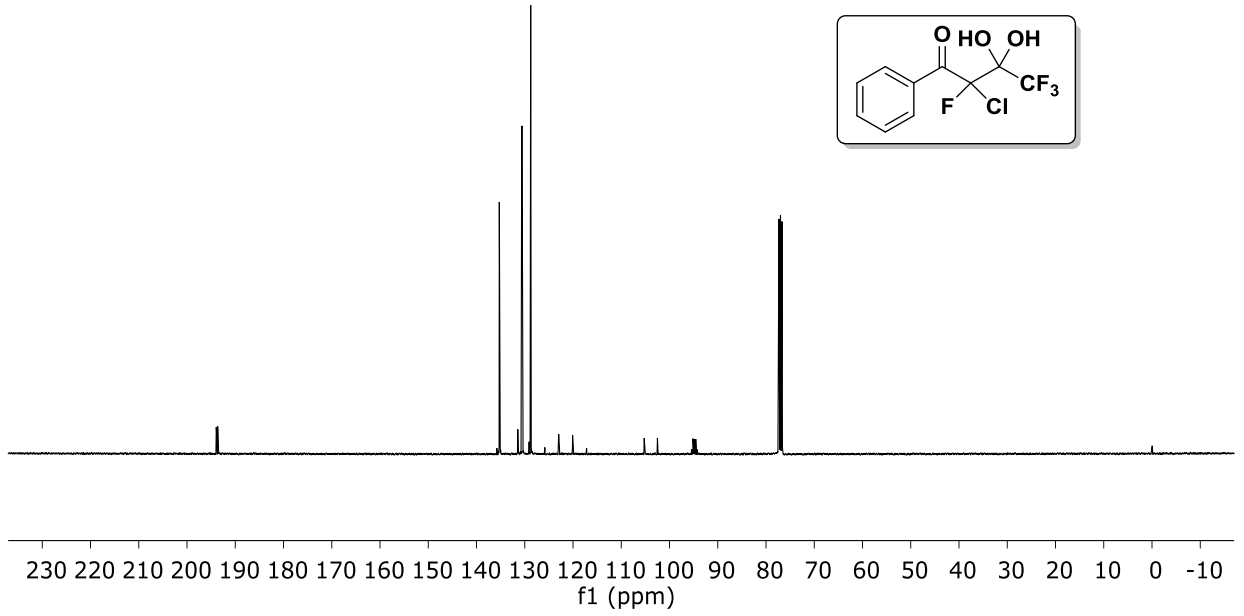
Ethyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (19). To a solution of 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (50 mg, 0.2 mmol) in anhydrous tetrahydrofuran was added sodium hydride (10 mg, 0.24 mmol) at 0 °C under inert atmosphere. After stirring for 30 minutes, triethyl phosphonoacetate (0.047 mL, 0.24 mmol) was added. The resulting solution was stirred for 2 h at 0 ºC and quenched with water. The organic phase was washed with brine, dried over anhydrous sodium sulfate and the solvent was removed *in vacuo*. The crude product was purified by flash chromatography on silica gel using hexanes-ethyl acetate (95:5) as mobile phase. Compound **19** was obtained in 95% yield as a colorless liquid (61 mg, 0.19 mmol); R_f = 0.4 (hexanes / EtOAc, 19 : 1); ^{1}H NMR (400 MHz, Chloroform-*d*): δ = 7.51 – 7.33 (m, 5H), 6.53 (s, 1H), 3.99 (q, *J* = 7.1 Hz, 2H), 1.02 (t, *J* = 7.2 Hz, 3H) ppm; ^{13}C NMR (100 MHz, Chloroform-*d*): δ = 164.3, 152.4 (d, J_{C-F} = 18.5 Hz), 132.6 (d, J_{C-F} = 1.5 Hz), 130.1, 129.0, 127.7, 120.4 (d, J_{C-F} = 9.6 Hz), 105.4 (d, J_{C-F} = 310.5 Hz), 60.9, 13.7 ppm; ^{19}F NMR (376 MHz, Chloroform-*d*) δ = -54.3 ppm; Anal. Calcd. for $C_{12}H_{11}BrClFO_2$: C, 44.82; H, 3.45. Found: C, 44.35; H, 3.61.

3. NMR spectra

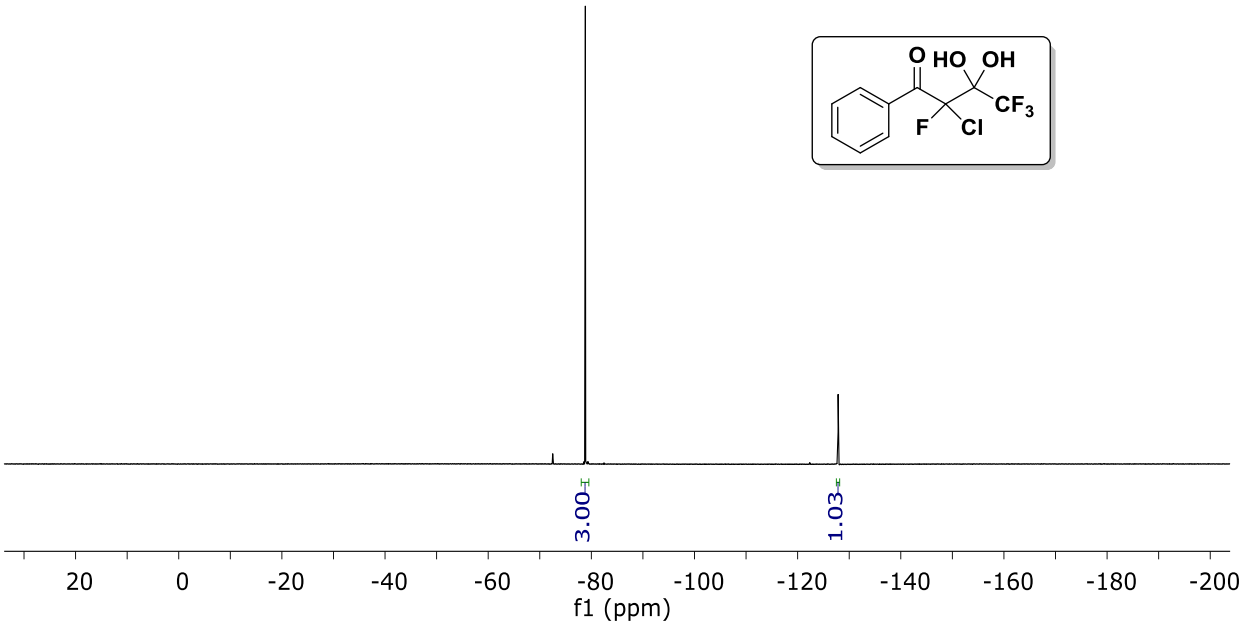
^{1}H NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one (3):



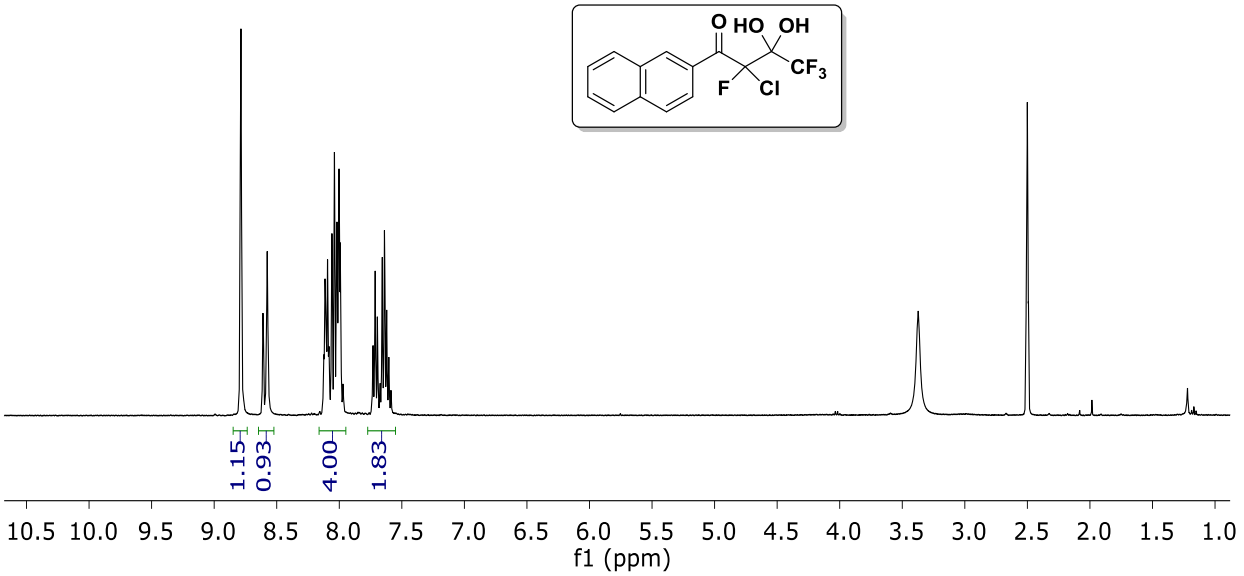
^{13}C NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one (3):



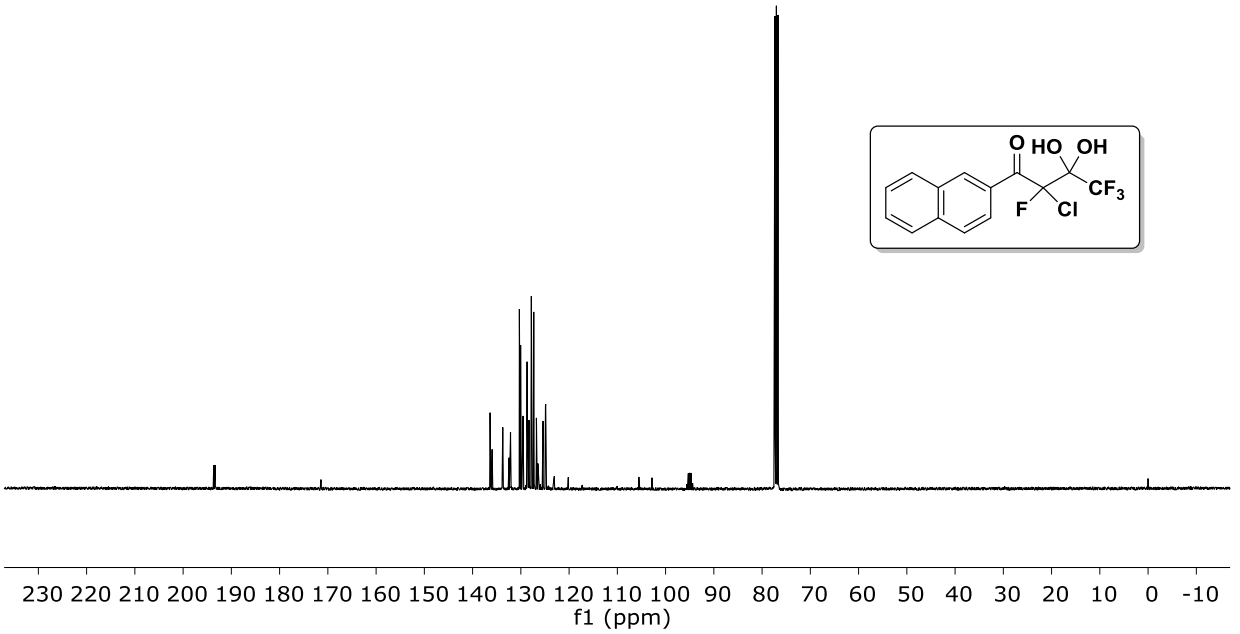
^{19}F NMR spectra of 2-Chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one (3):



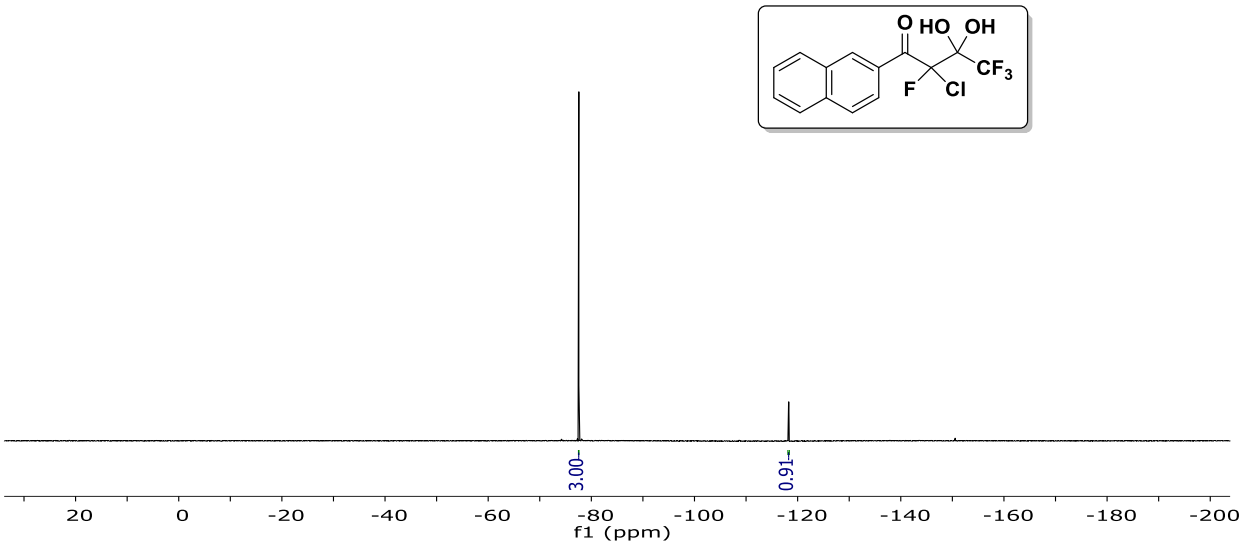
^{1}H NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (4):



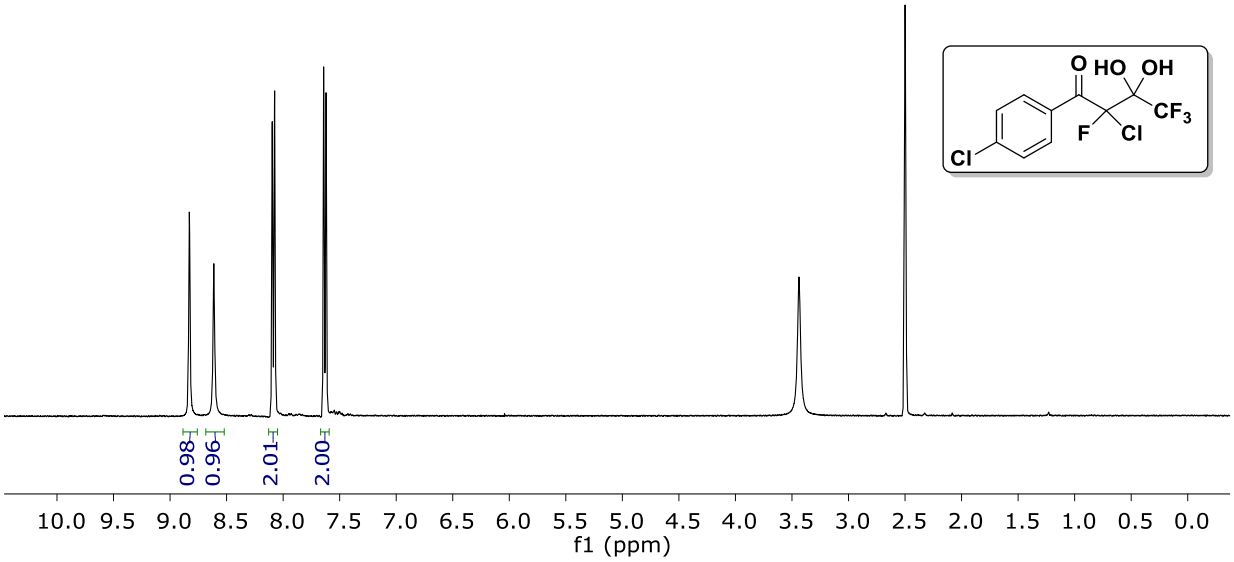
^{13}C NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (4):



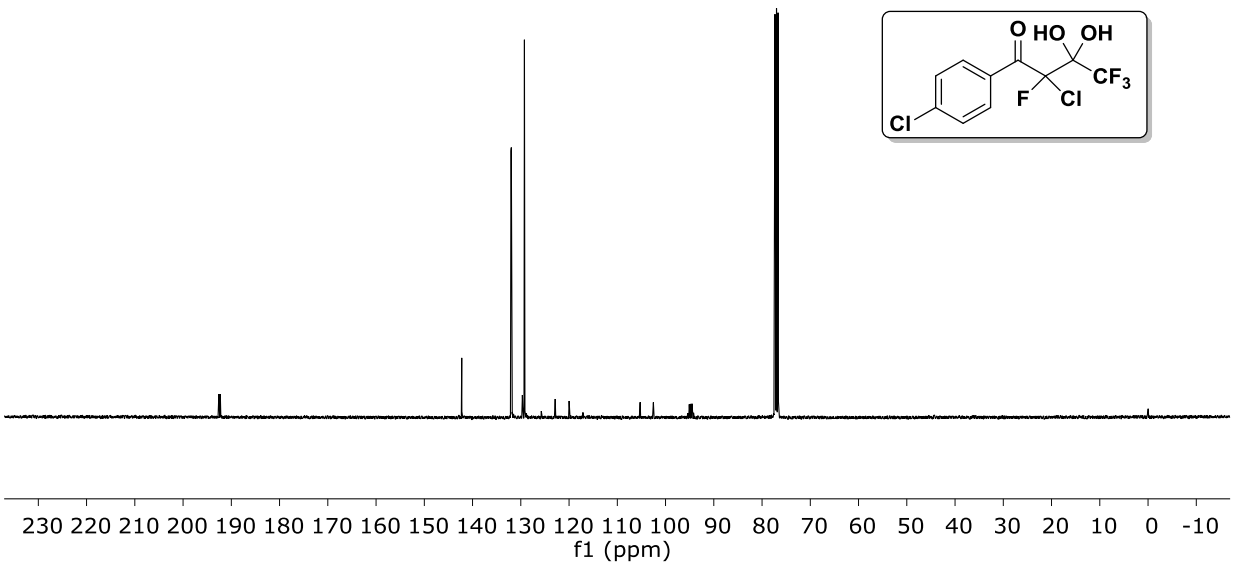
^{19}F NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-(naphthalen-2-yl)butan-1-one (4):



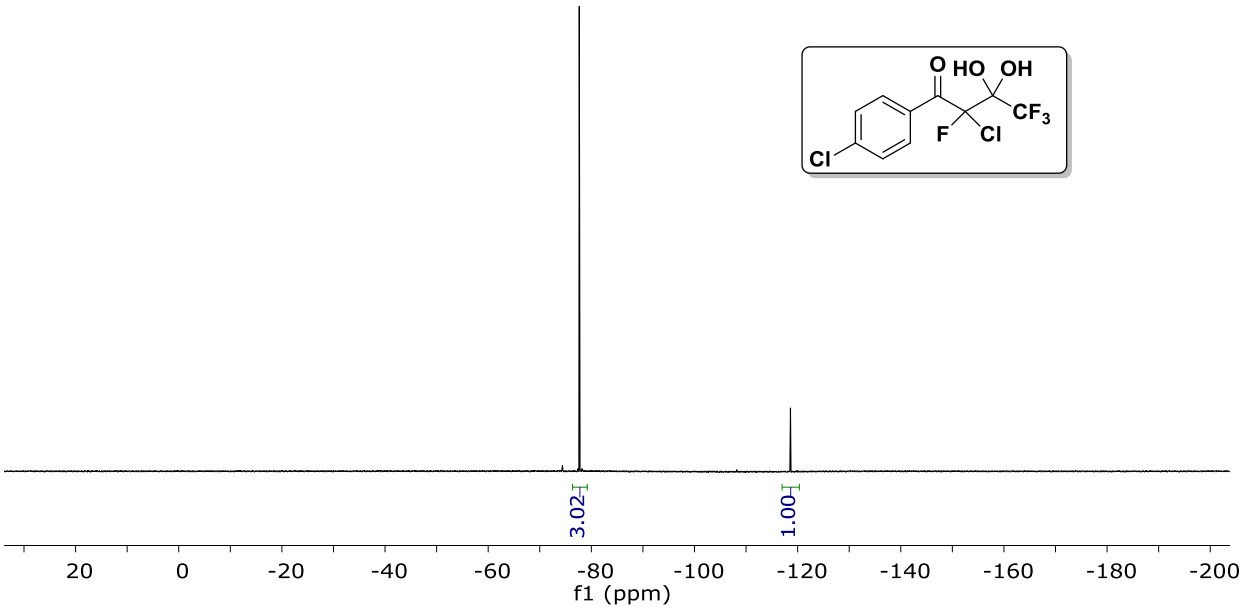
[1]H NMR spectra of 2-Chloro-1-(4-chlorophenyl)-2,4,4,4-tetrafluoro-3,3-dihydroxybutan-1-one (5):



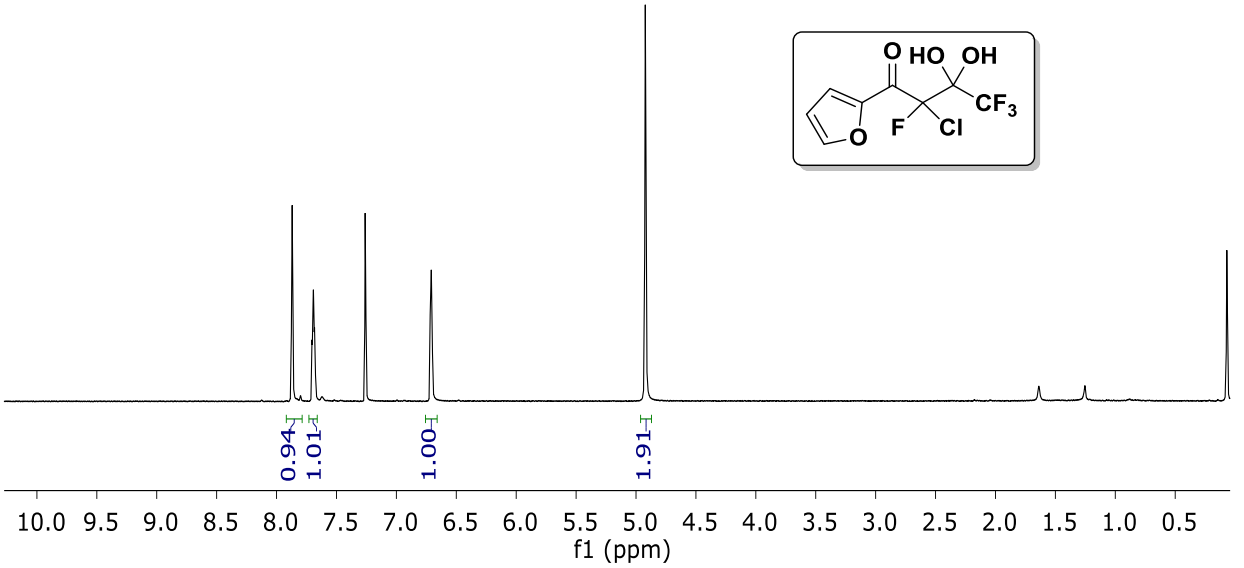
[13]C NMR spectra of 2-Chloro-1-(4-chlorophenyl)-2,4,4,4-tetrafluoro-3,3-dihydroxybutan-1-one (5):



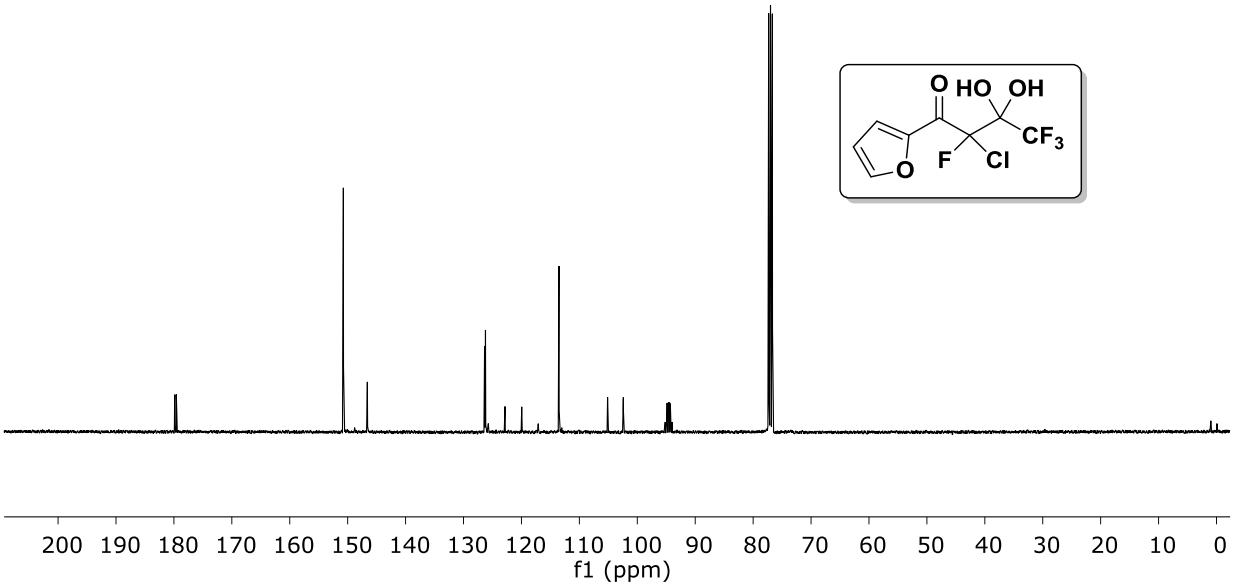
^{19}F NMR spectra of 2-Chloro-1-(4-chlorophenyl)-2,4,4,4-tetrafluoro-3,3-dihydroxybutan-1-one (5):



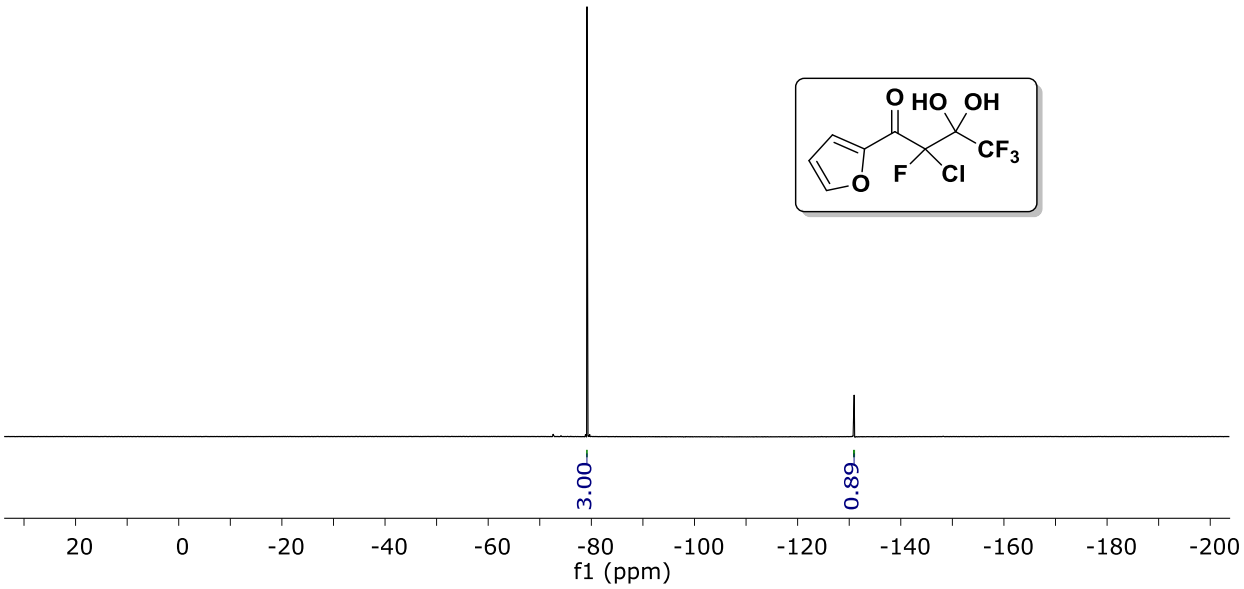
^{1}H NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-1-(furan-2-yl)-3,3-dihydroxybutan-1-one (6):



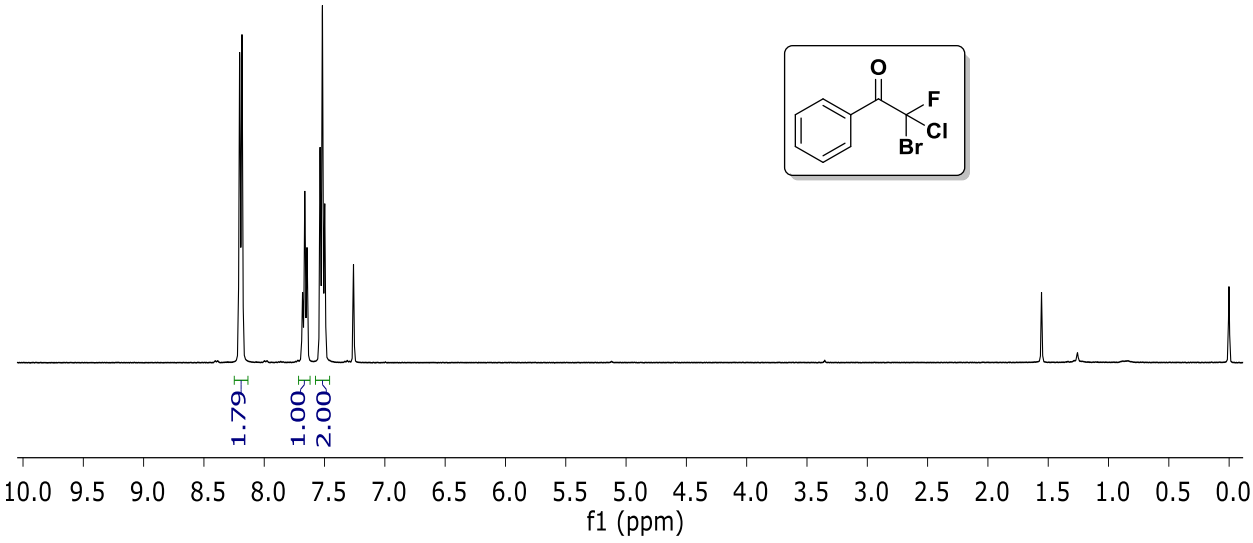
^{13}C NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-1-(furan-2-yl)-3,3-dihydroxybutan-1-one (6):



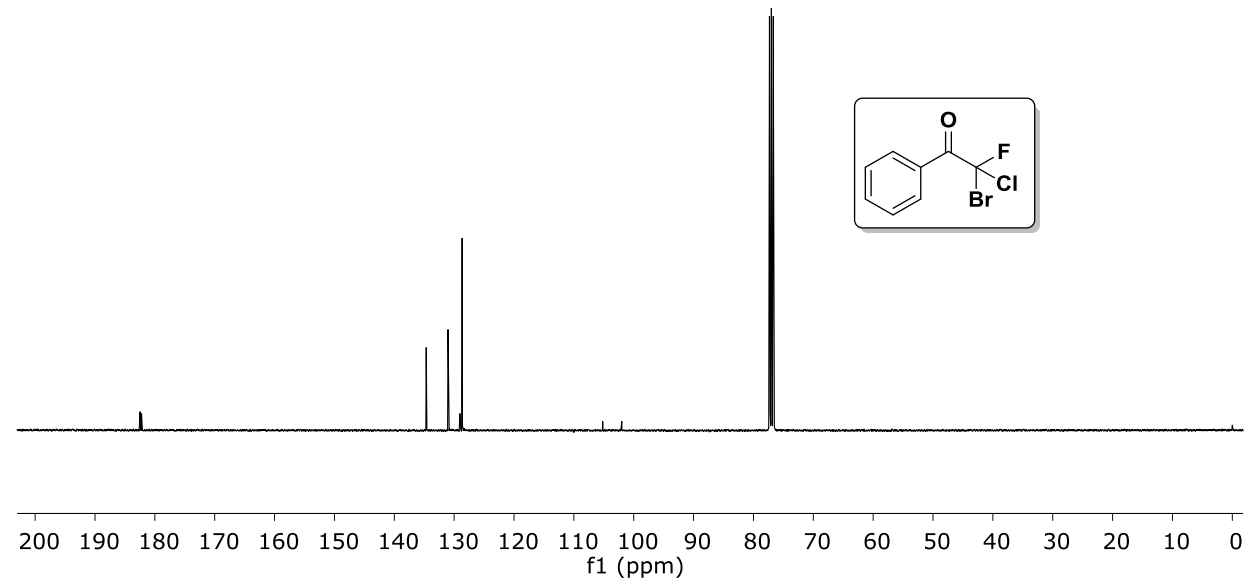
^{19}F NMR spectra of 2-chloro-2,4,4,4-tetrafluoro-1-(furan-2-yl)-3,3-dihydroxybutan-1-one (6):



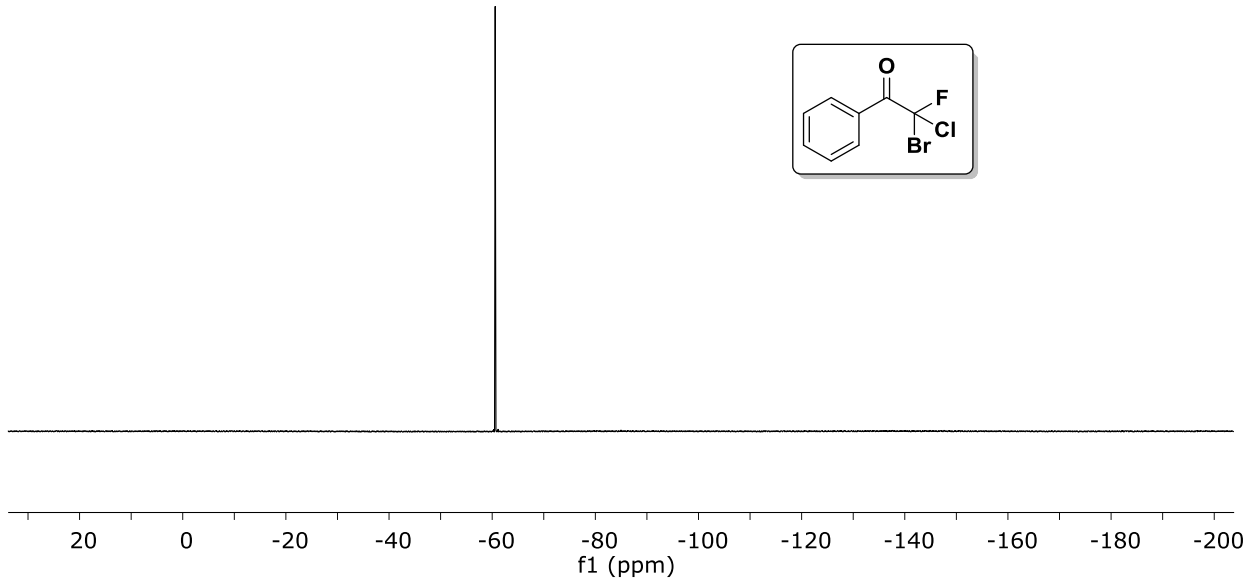
^{1}H NMR spectra of 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (8):



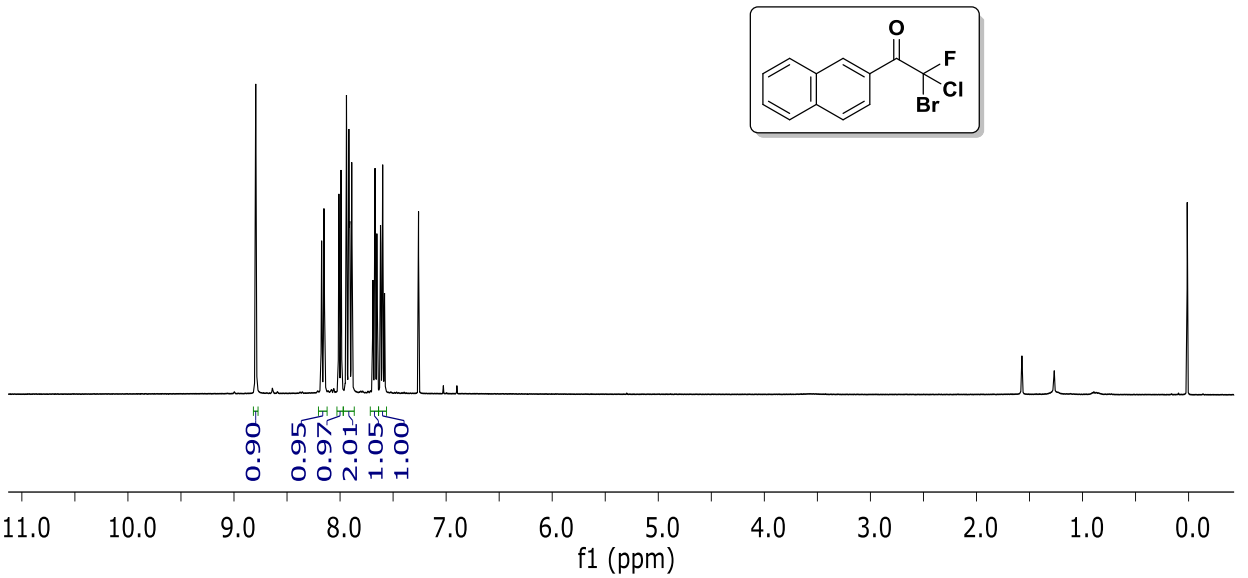
^{13}C NMR spectra of 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (8):



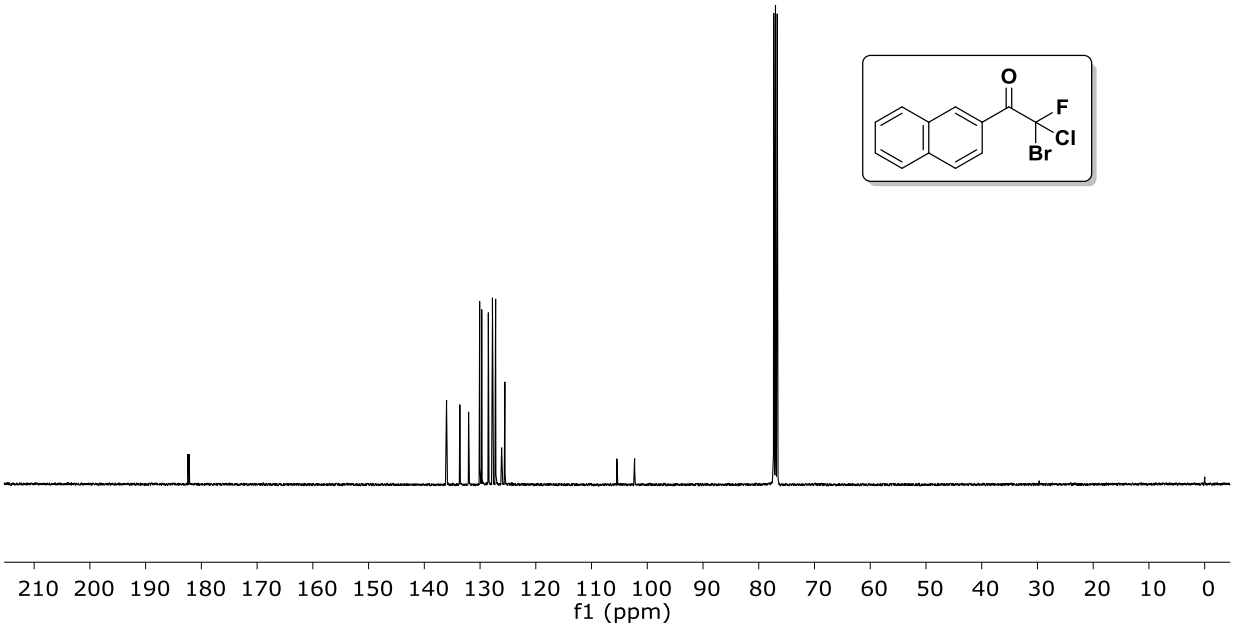
^{19}F NMR spectra of 2-bromo-2-chloro-2-fluoro-1-phenylethan-1-one (8):



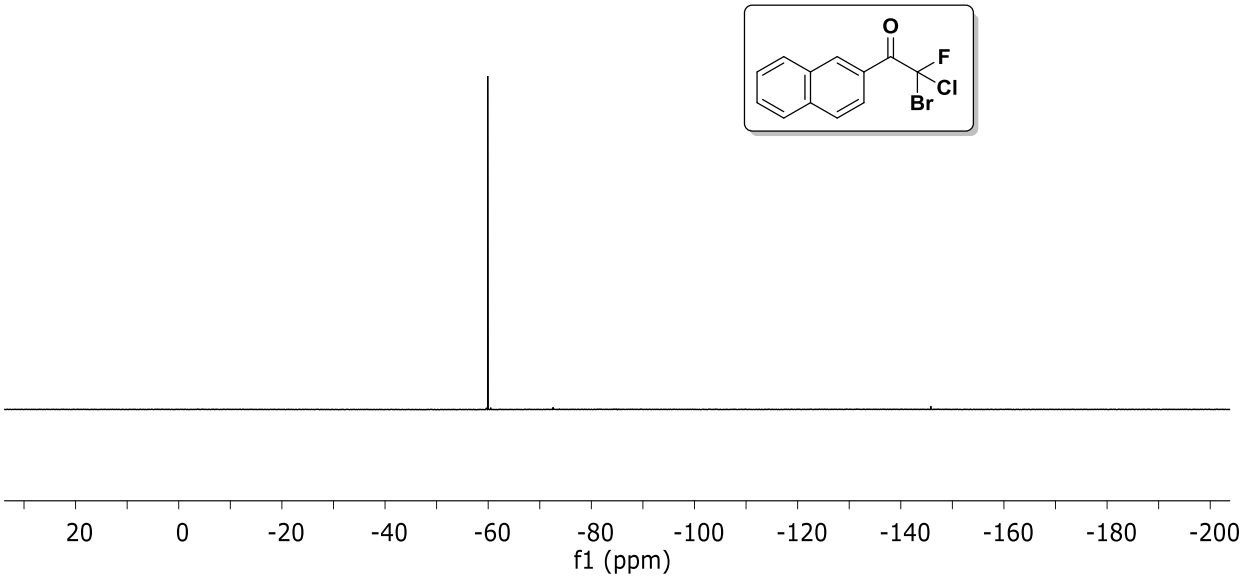
^{1}H NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(naphthalen-2-yl)ethan-1-one (10):



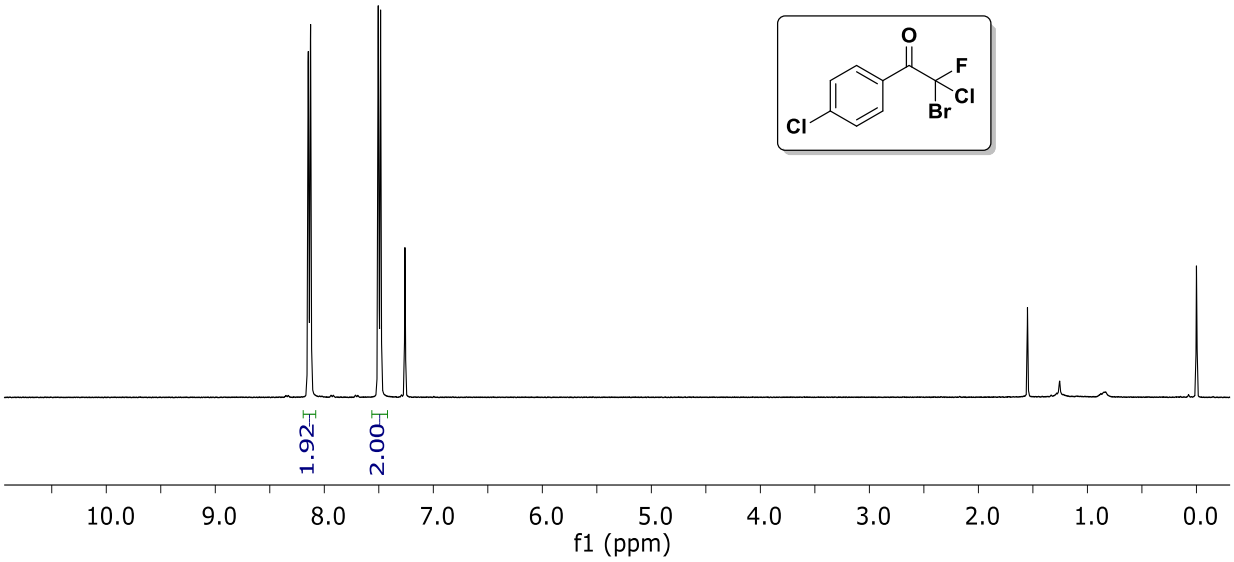
^{13}C NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(naphthalen-2-yl)ethan-1-one (10):



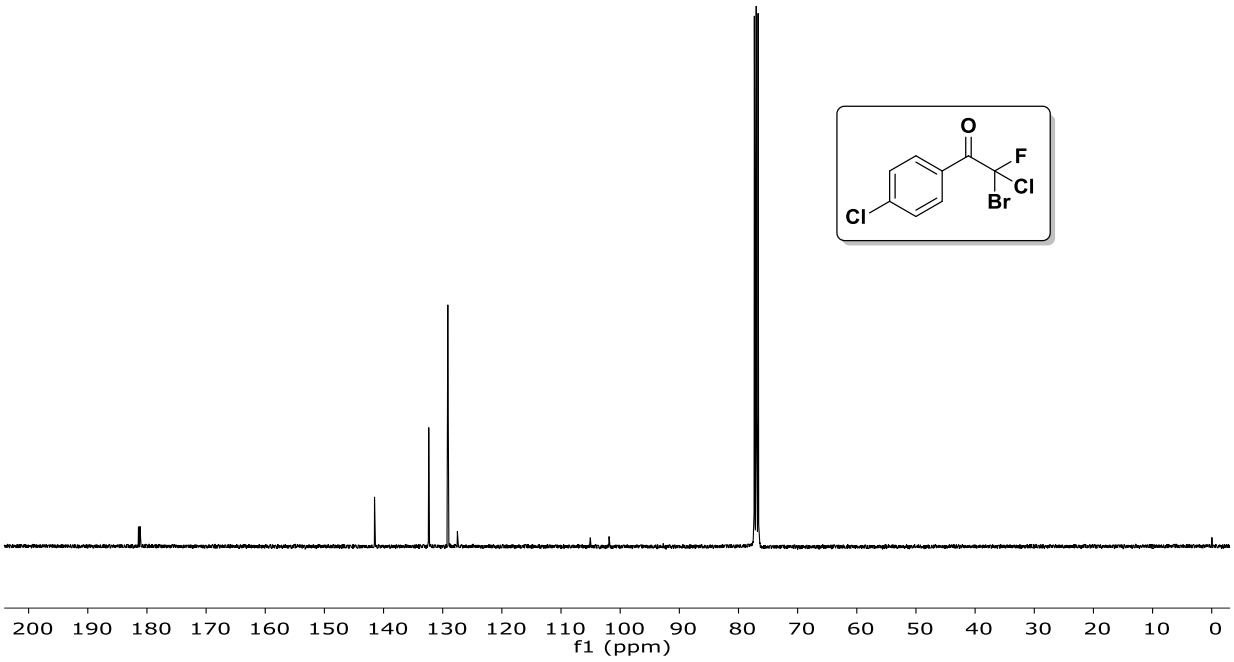
^{19}F NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(naphthalen-2-yl)ethan-1-one (10):



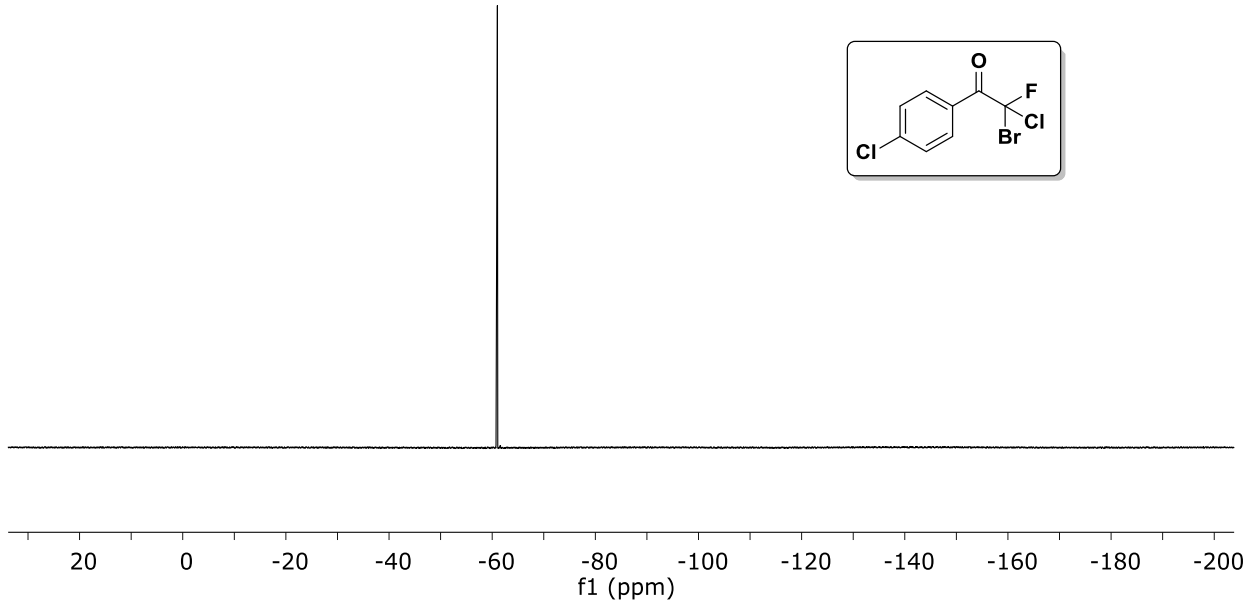
^{1}H NMR spectra of 2-bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (11):



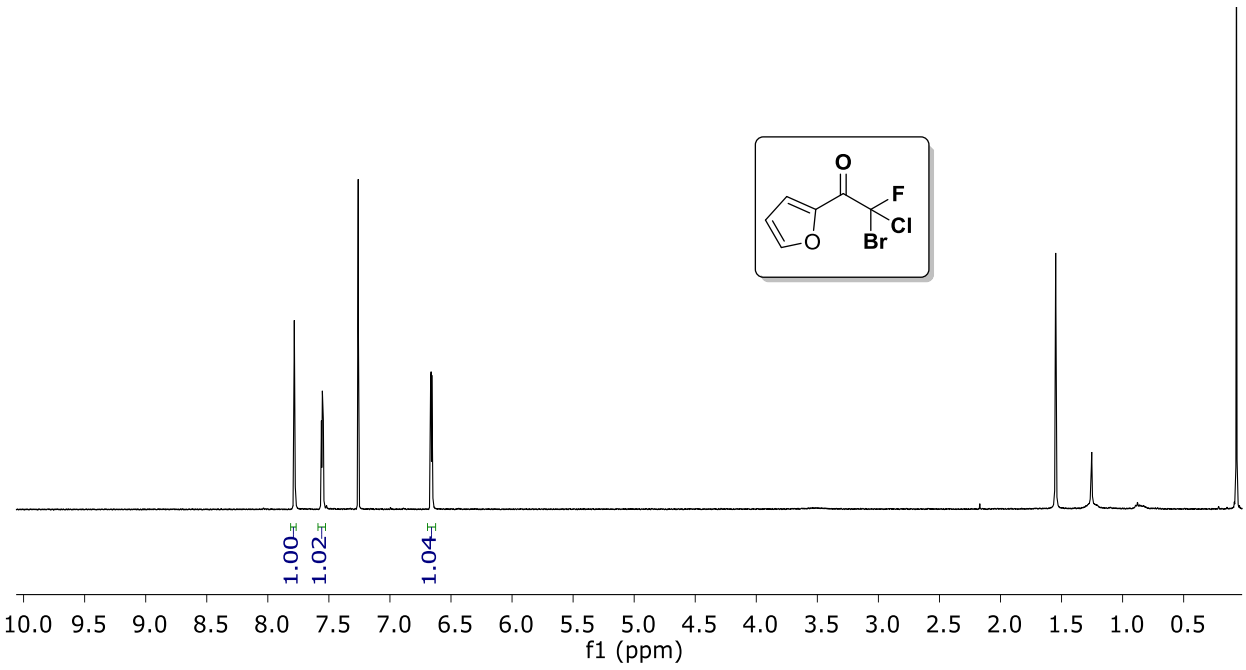
^{13}C NMR spectra of 2-bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (11):



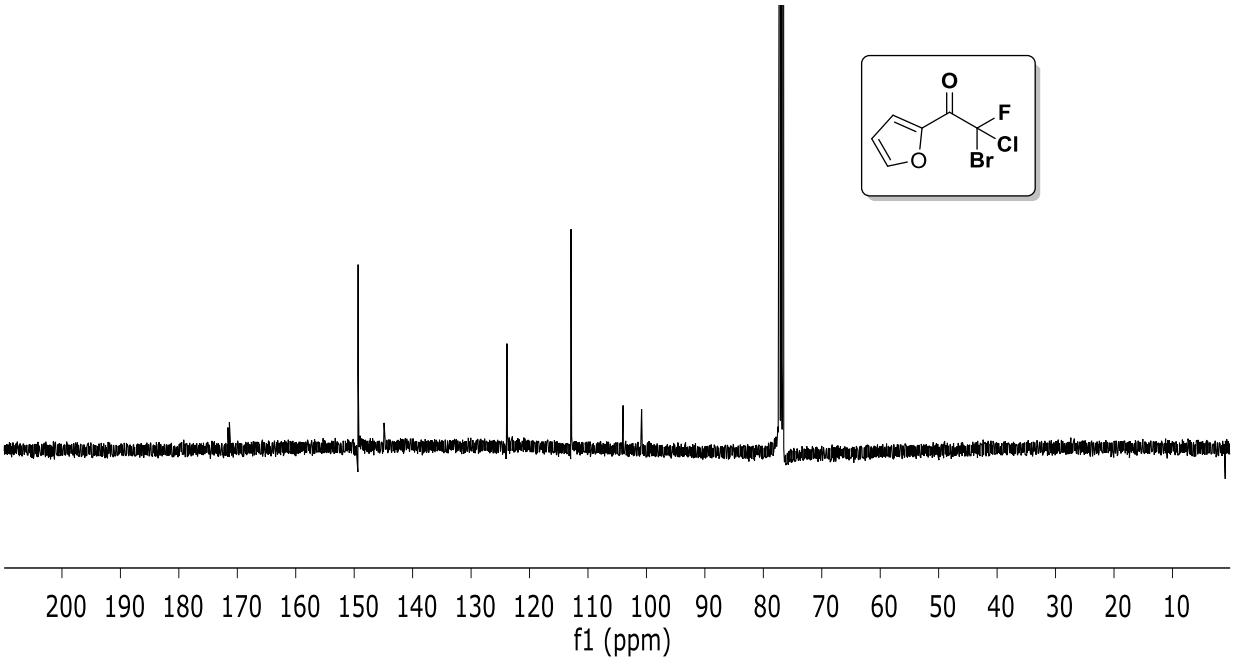
^{19}F NMR spectra of 2-bromo-2-chloro-1-(4-chlorophenyl)-2-fluoroethan-1-one (11):



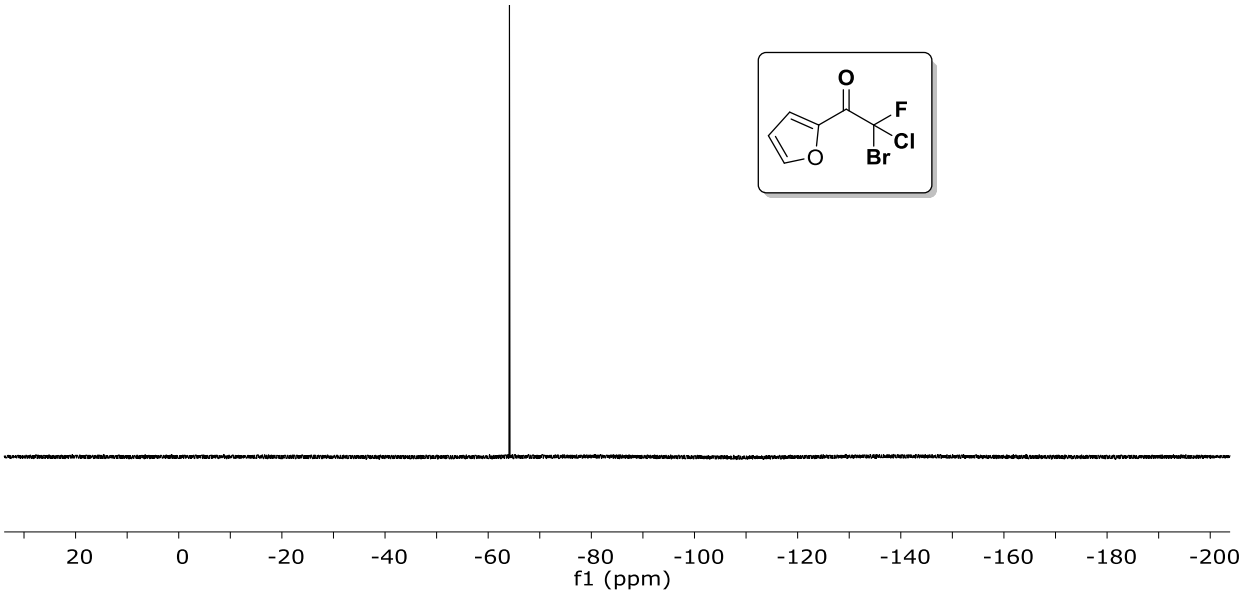
^{1}H NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(furan-2-yl)ethan-1-one (12):



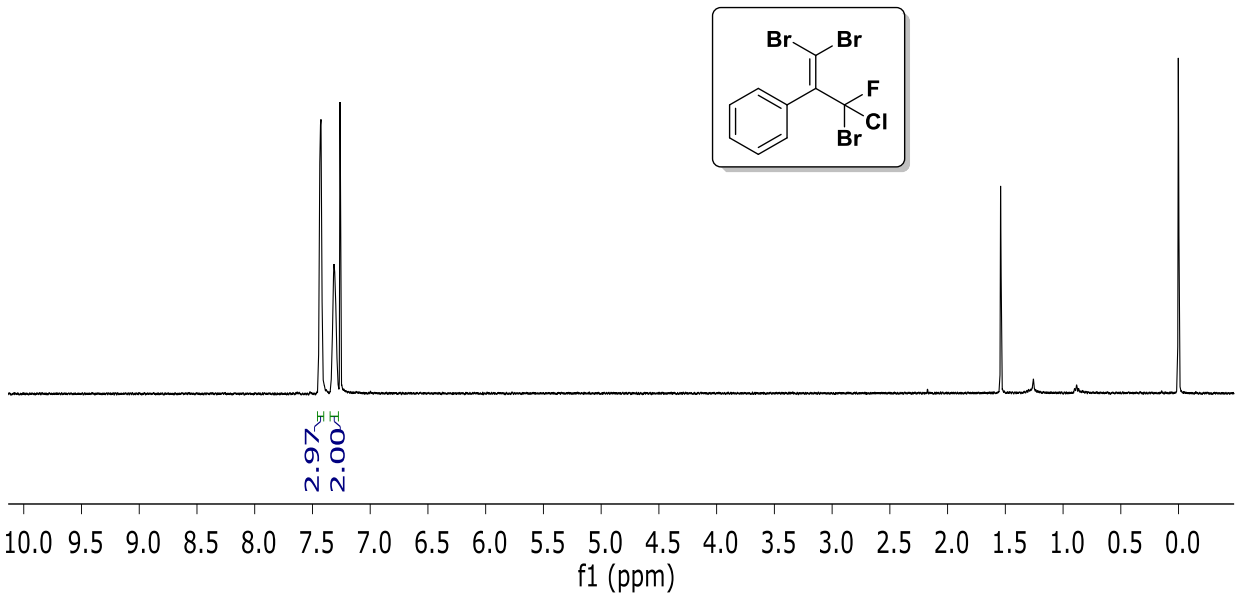
^{13}C NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(furan-2-yl)ethan-1-one (12):



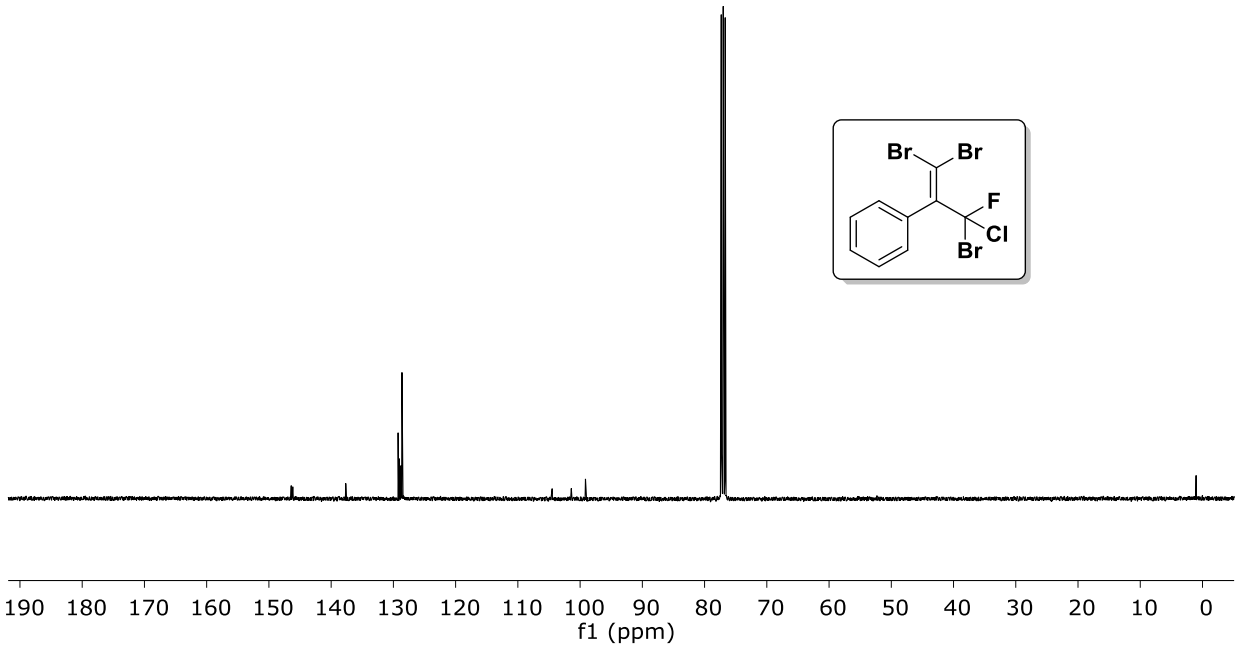
^{19}F NMR spectra of 2-bromo-2-chloro-2-fluoro-1-(furan-2-yl)ethan-1-one (12):



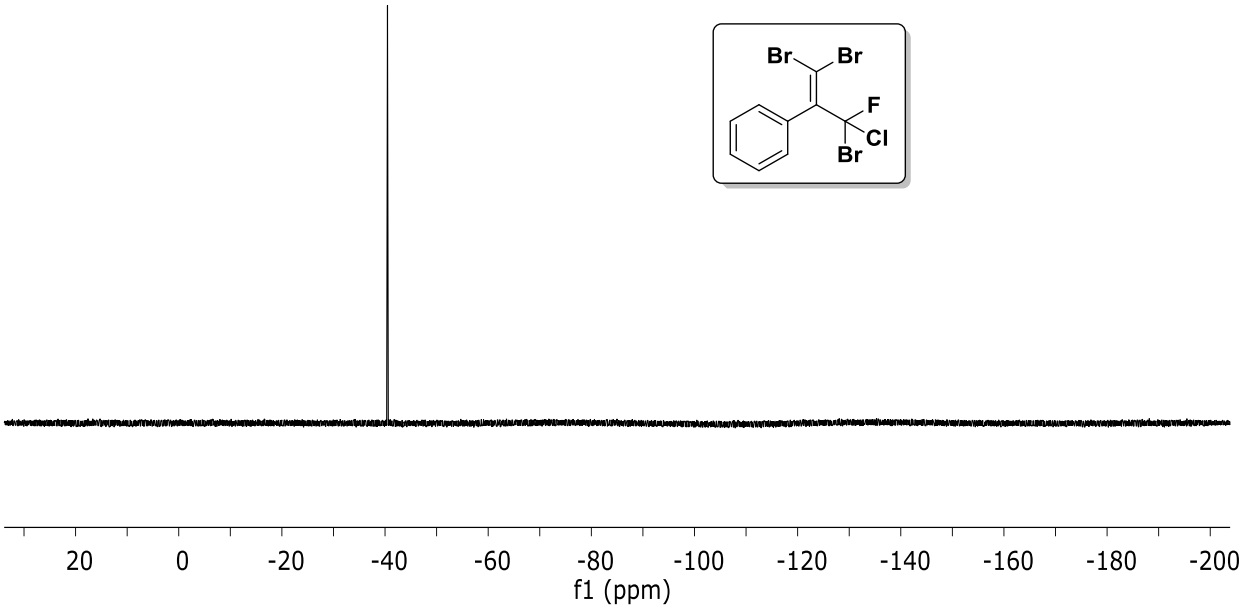
^{1}H NMR spectra of 1,1,3-tribromo-3-chloro-3-fluoro-2-phenylprop-1-ene (13):



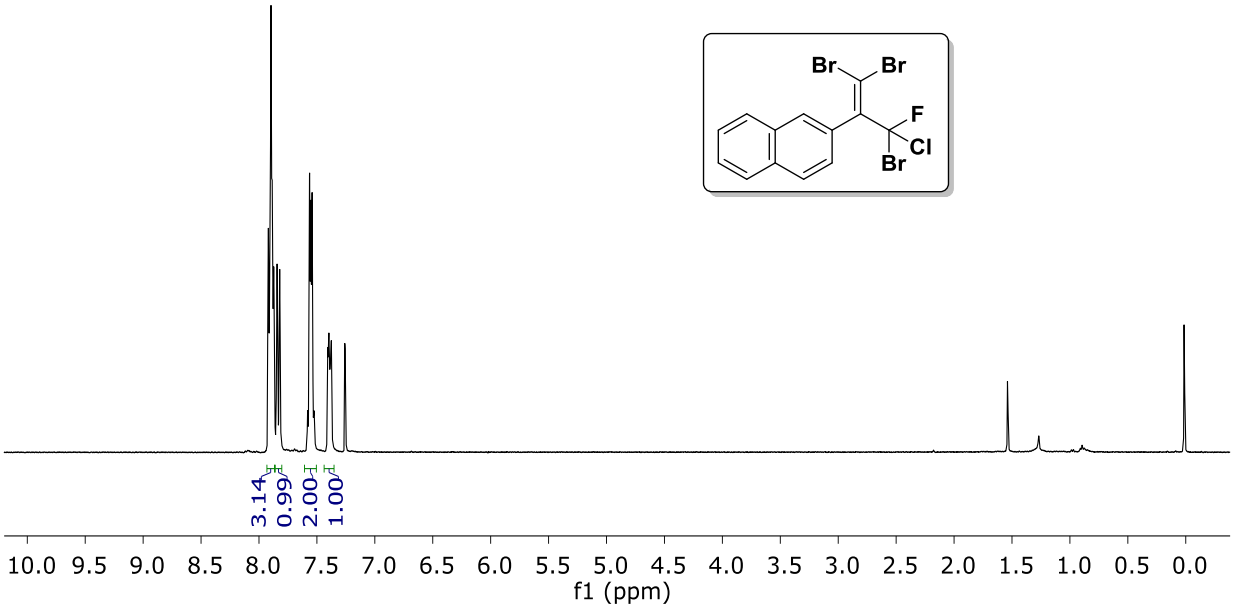
^{13}C NMR spectra of 1,1,3-tribromo-3-chloro-3-fluoro-2-phenylprop-1-ene (13):



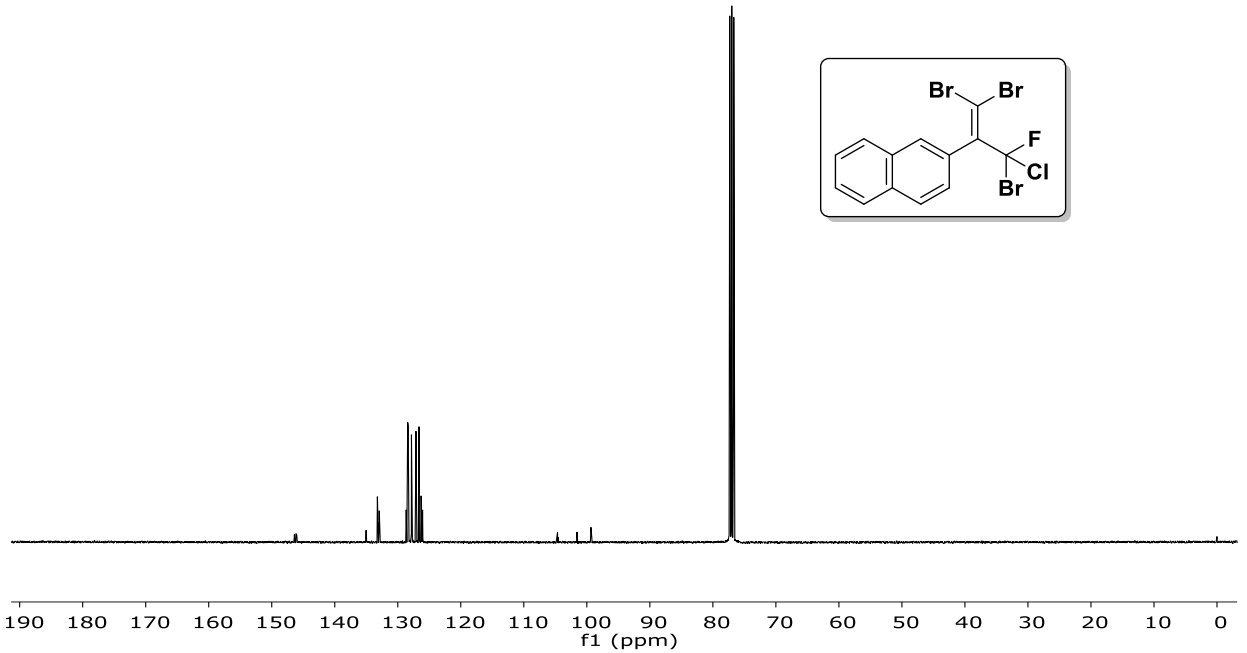
^{19}F NMR spectra of 1,1,3-tribromo-3-chloro-3-fluoro-2-phenylprop-1-ene (13):



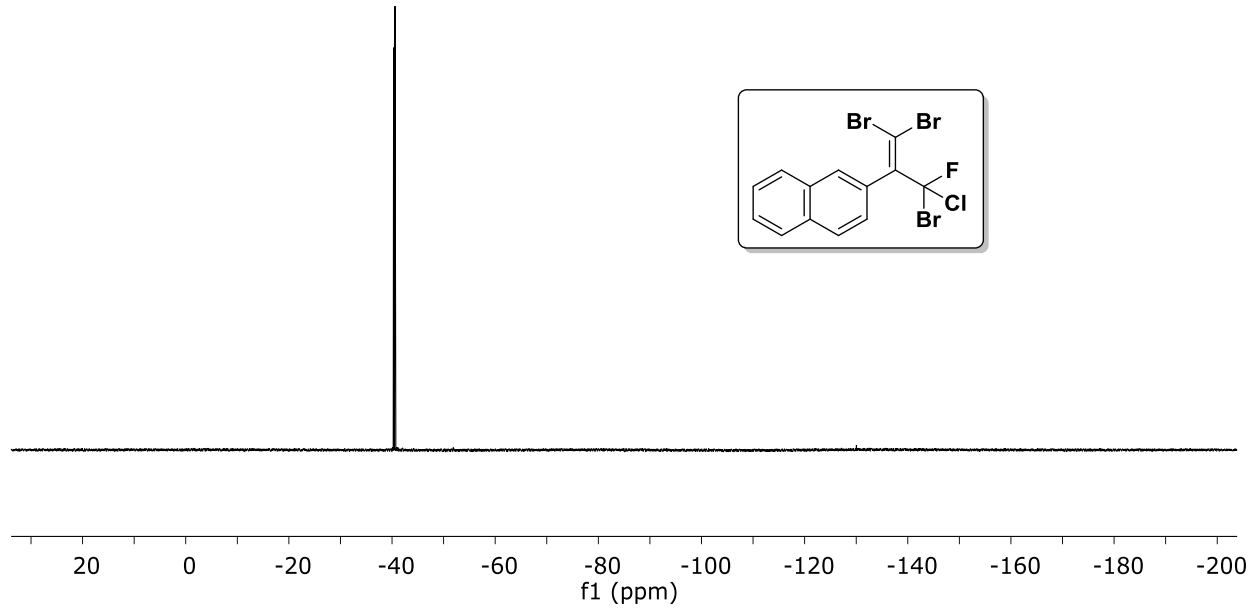
^{1}H NMR spectra of 2-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)naphthalene (14):



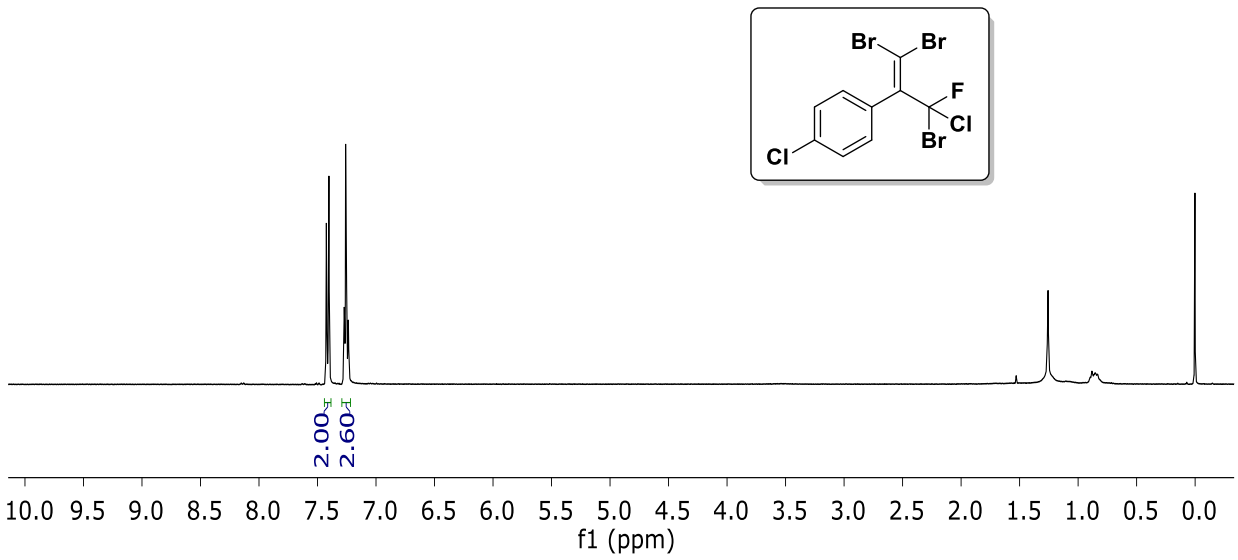
^{13}C NMR spectra of 2-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)naphthalene (14):



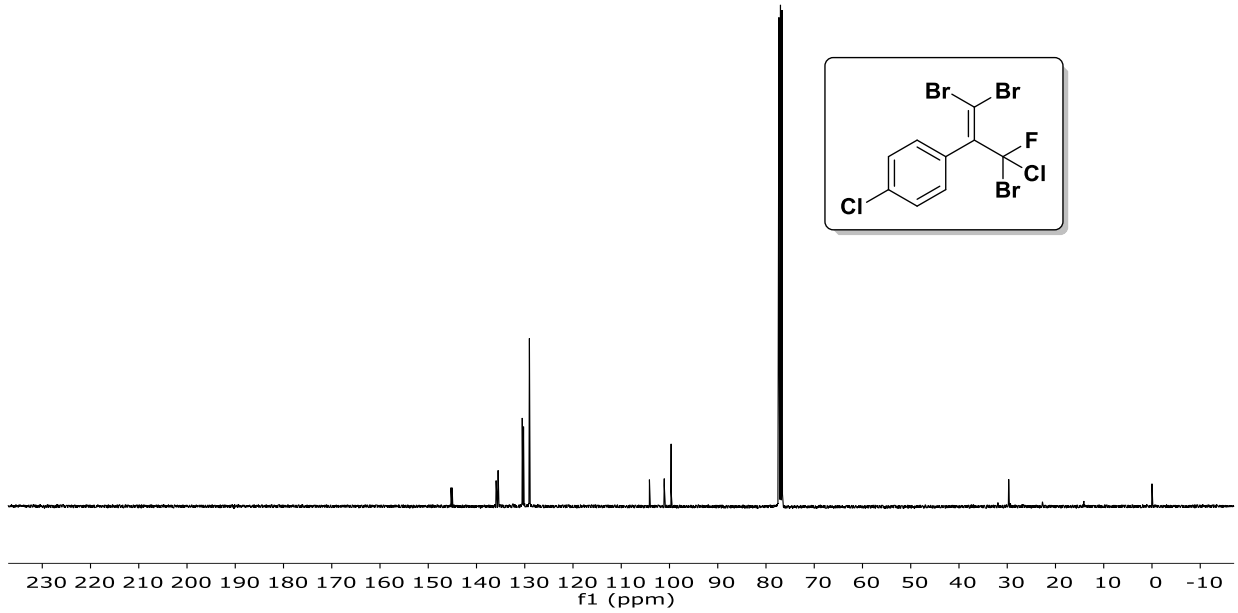
^{19}F NMR spectra of 2-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)naphthalene (14):



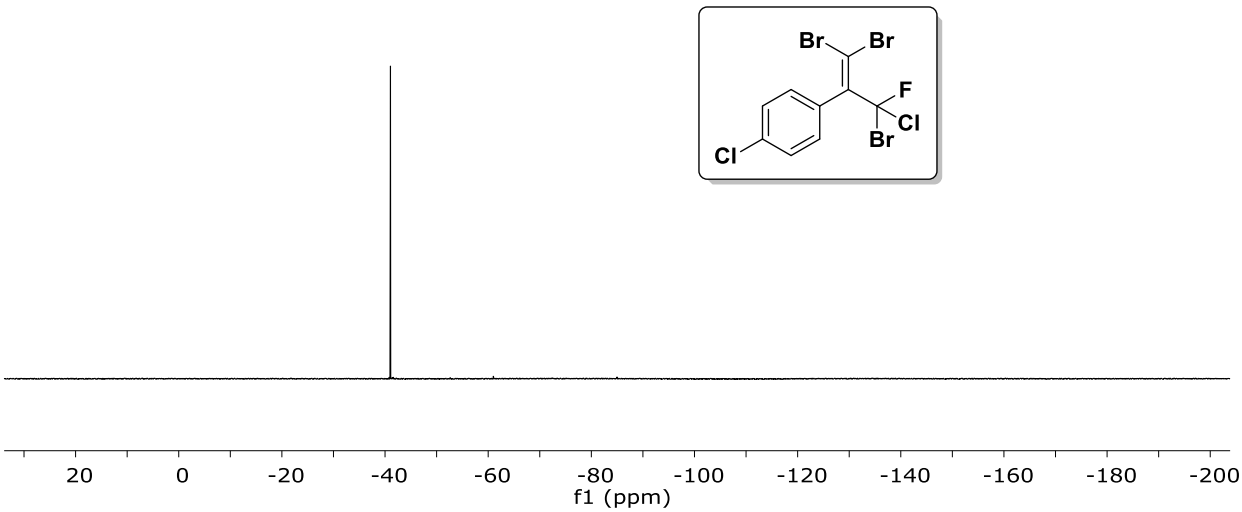
^{1}H NMR spectra of 1-chloro-4-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)benzene (15):



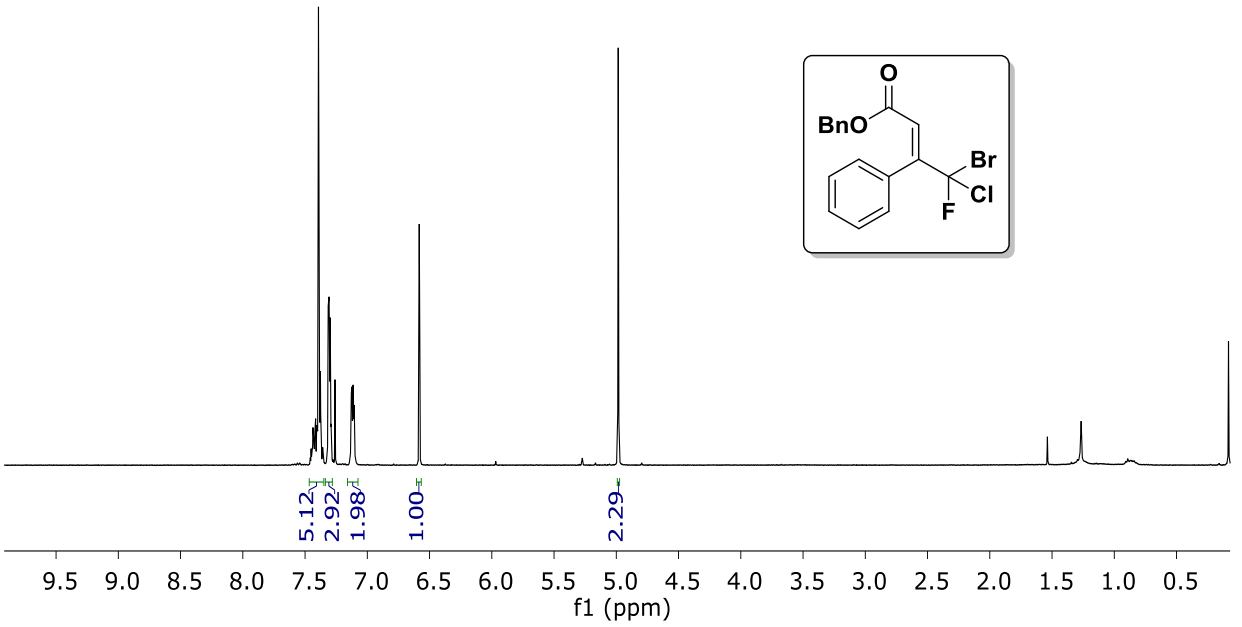
^{13}C NMR spectra of 1-chloro-4-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)benzene (15):



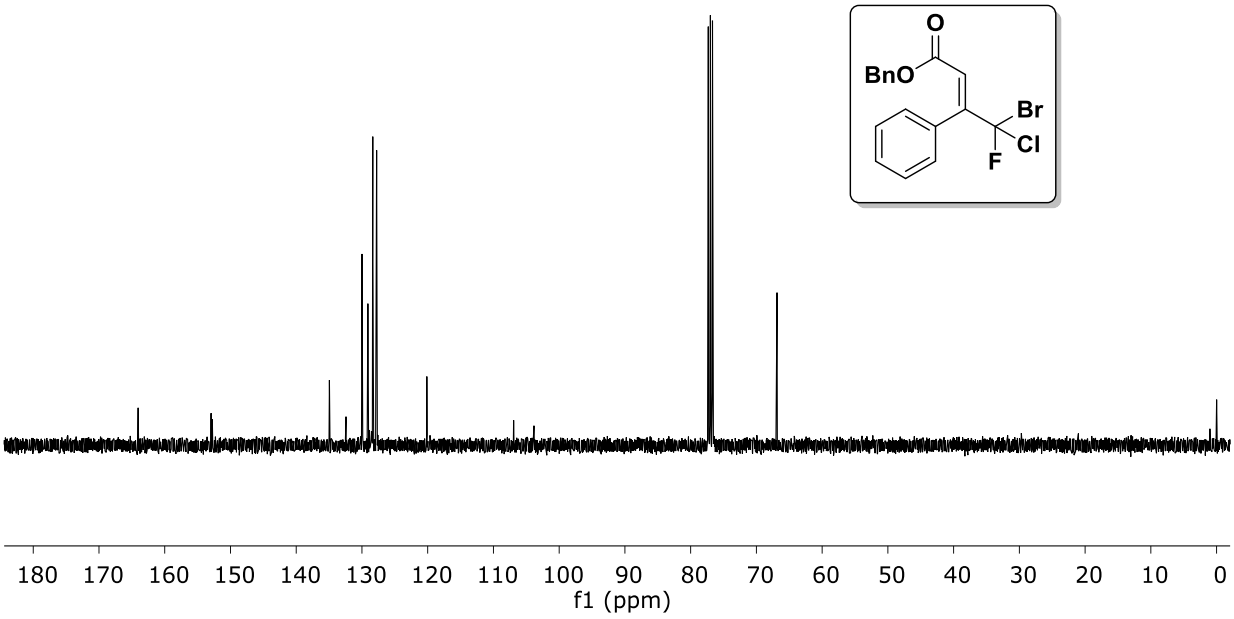
^{19}F NMR spectra of 1-chloro-4-(1,1,3-tribromo-3-chloro-3-fluoroprop-1-en-2-yl)benzene (15):



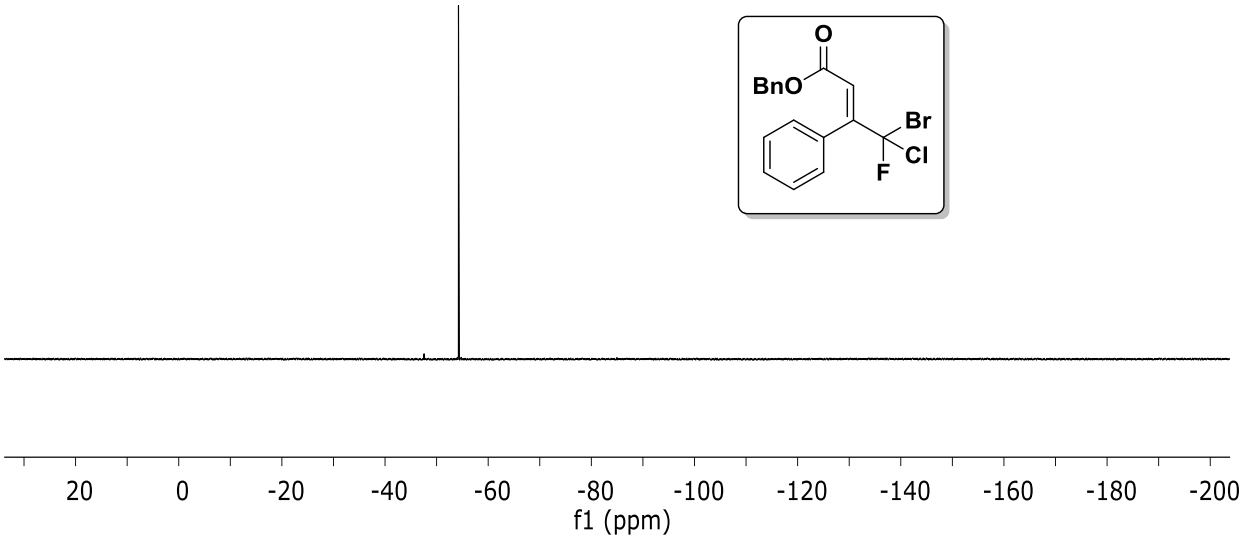
^{1}H NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (16):



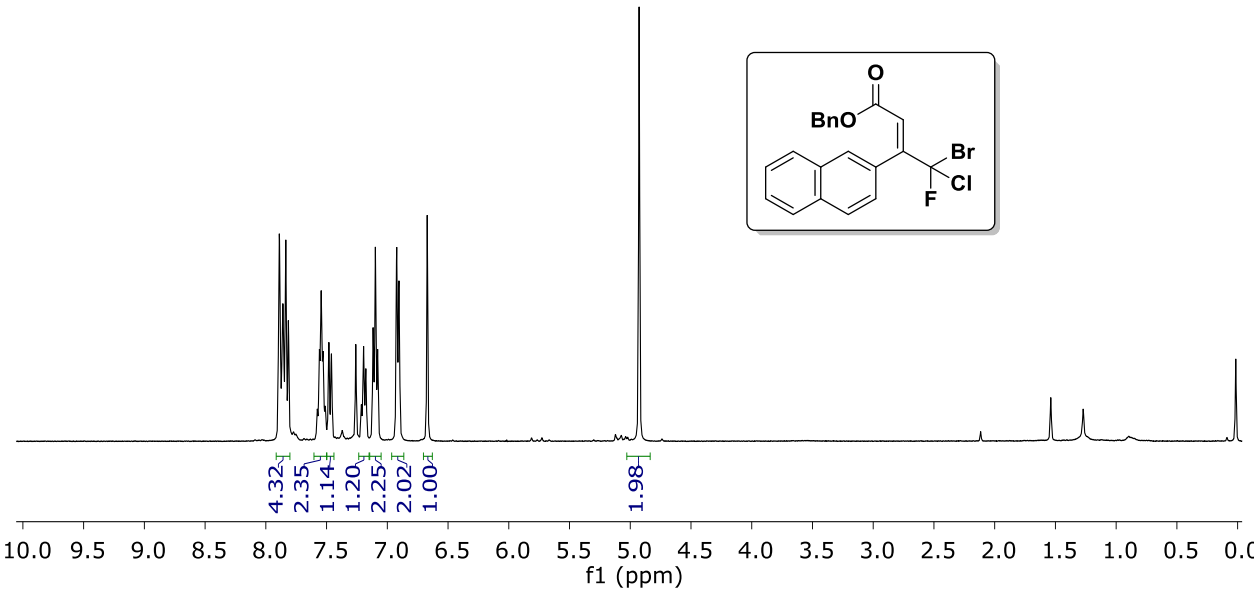
^{13}C NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (16):



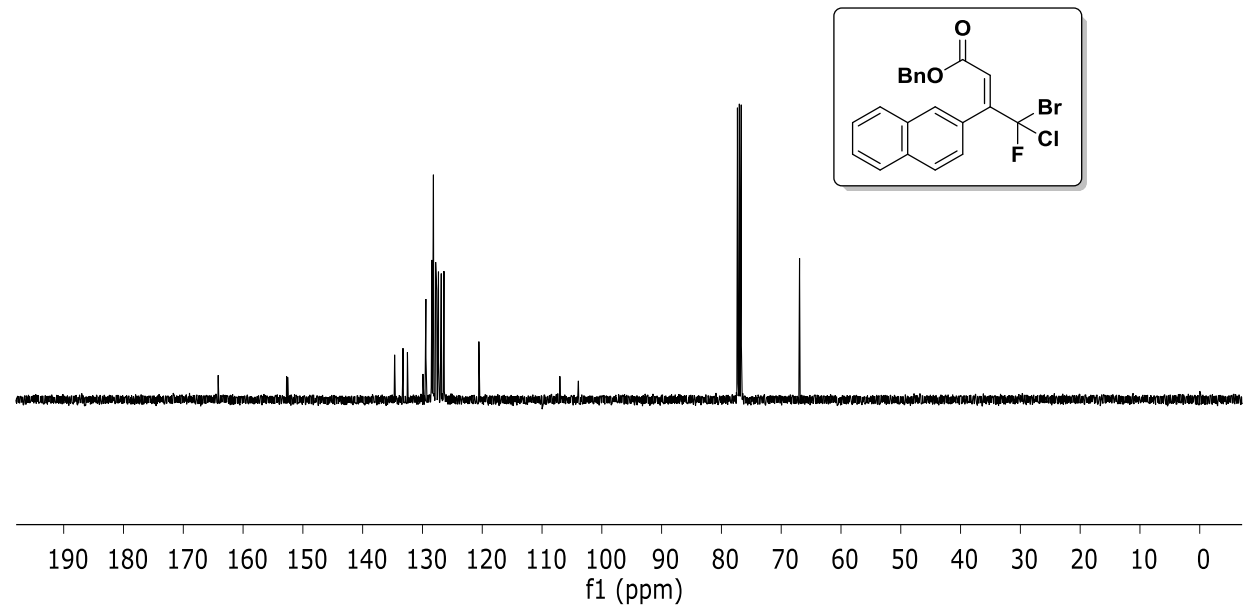
^{19}F NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (16):



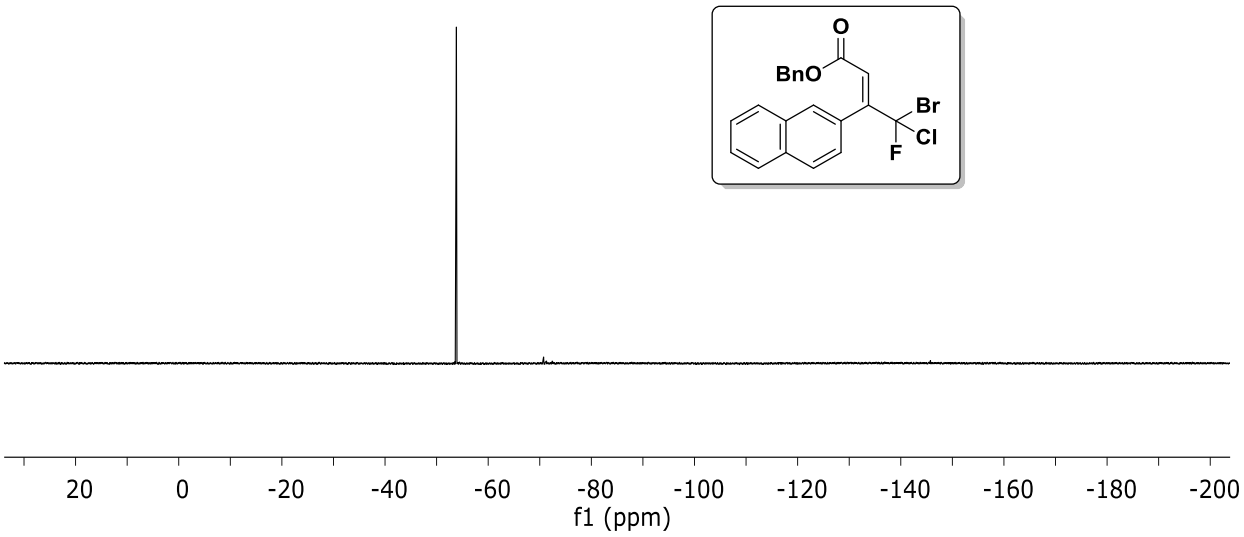
^{1}H NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-(naphthalen-2-yl)but-2-enoate (17):



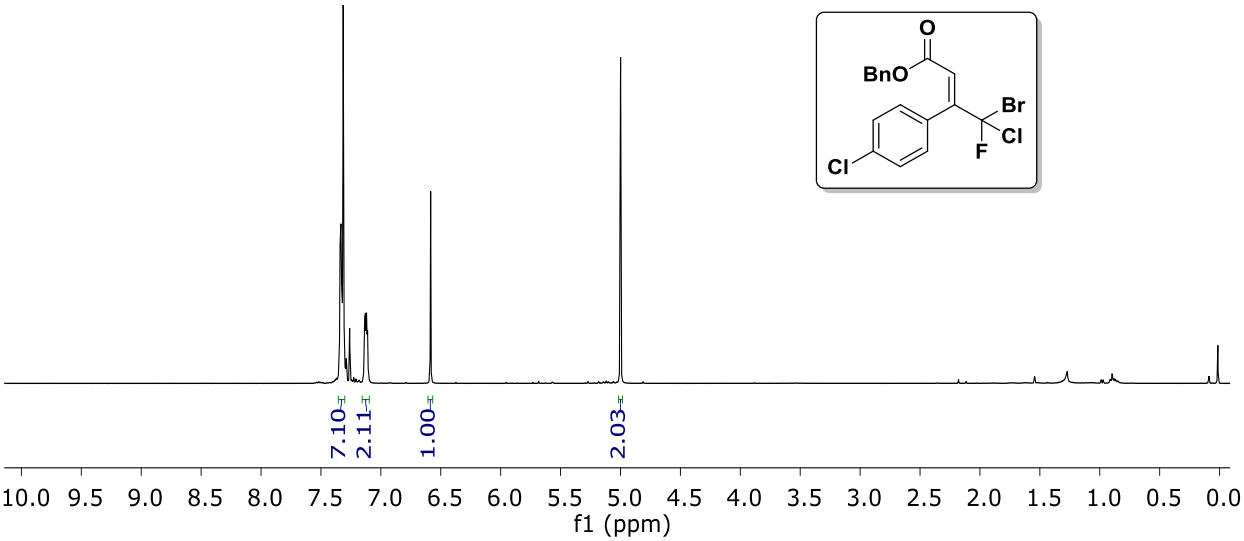
^{13}C NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-(naphthalen-2-yl)but-2-enoate (17):



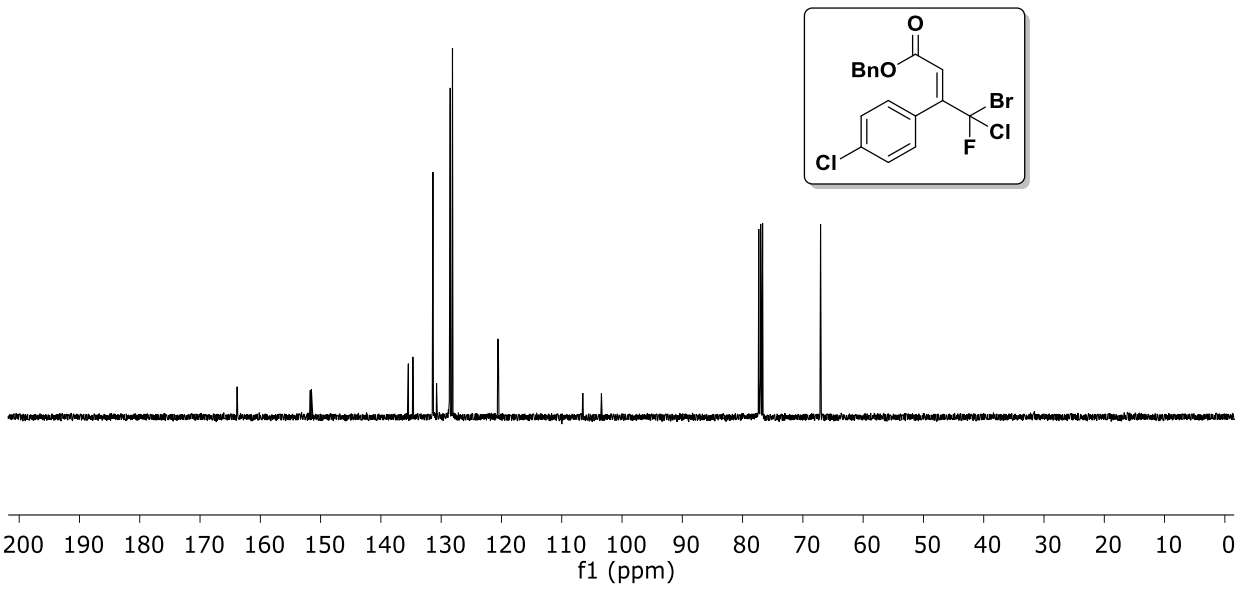
^{19}F NMR spectra of benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-(naphthalen-2-yl)but-2-enoate (17):



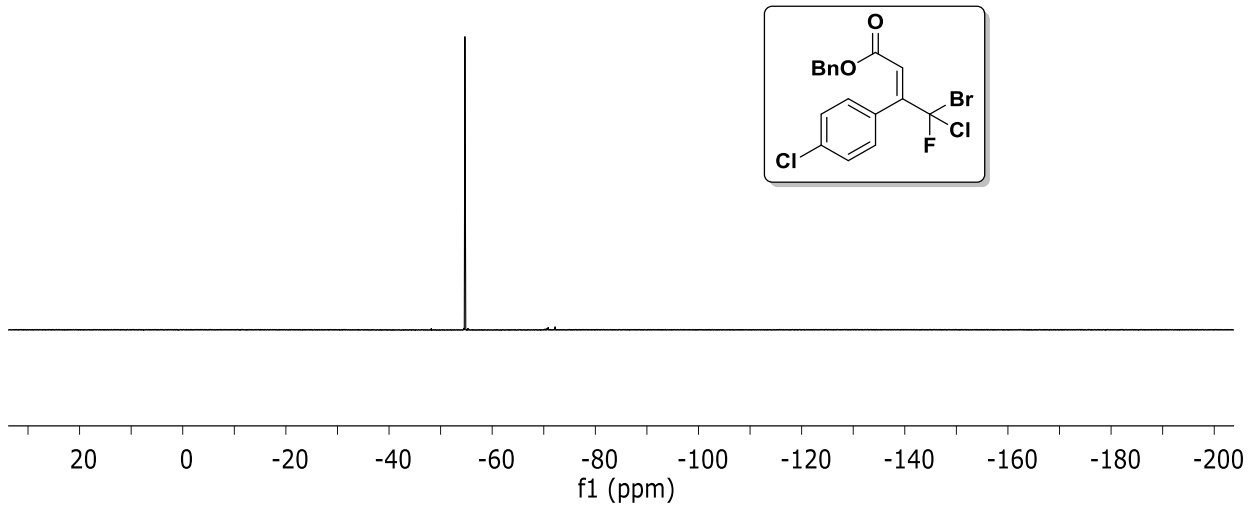
^{1}H NMR spectra of benzyl (*E*)-4-bromo-4-chloro-3-(4-chlorophenyl)-4-fluorobut-2-enoate (18):



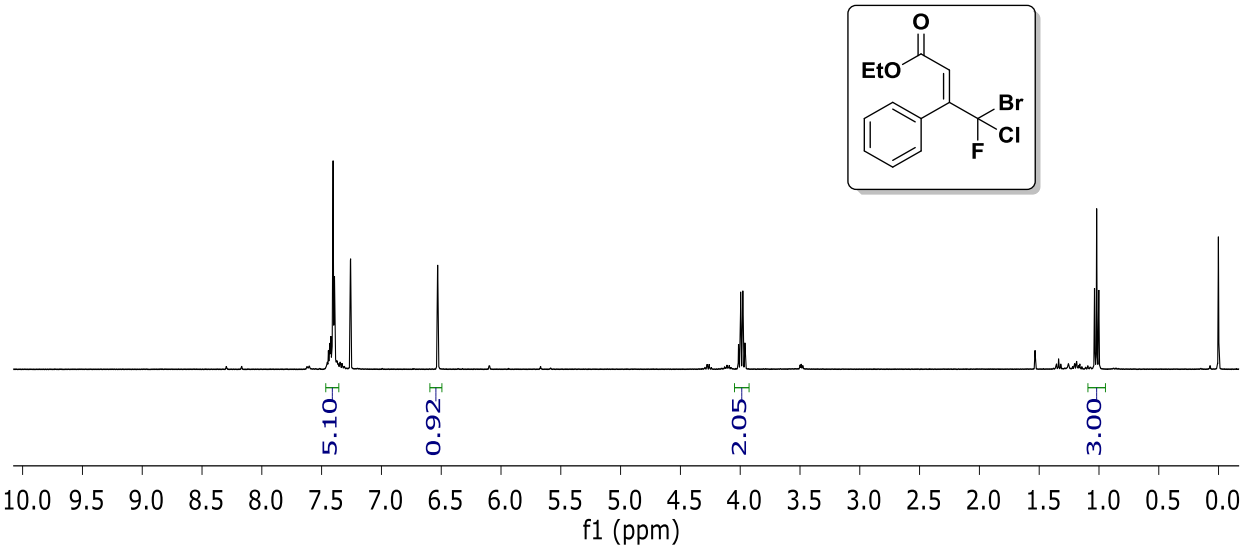
^{13}C NMR spectra of benzyl (*E*)-4-bromo-4-chloro-3-(4-chlorophenyl)-4-fluorobut-2-enoate (18):



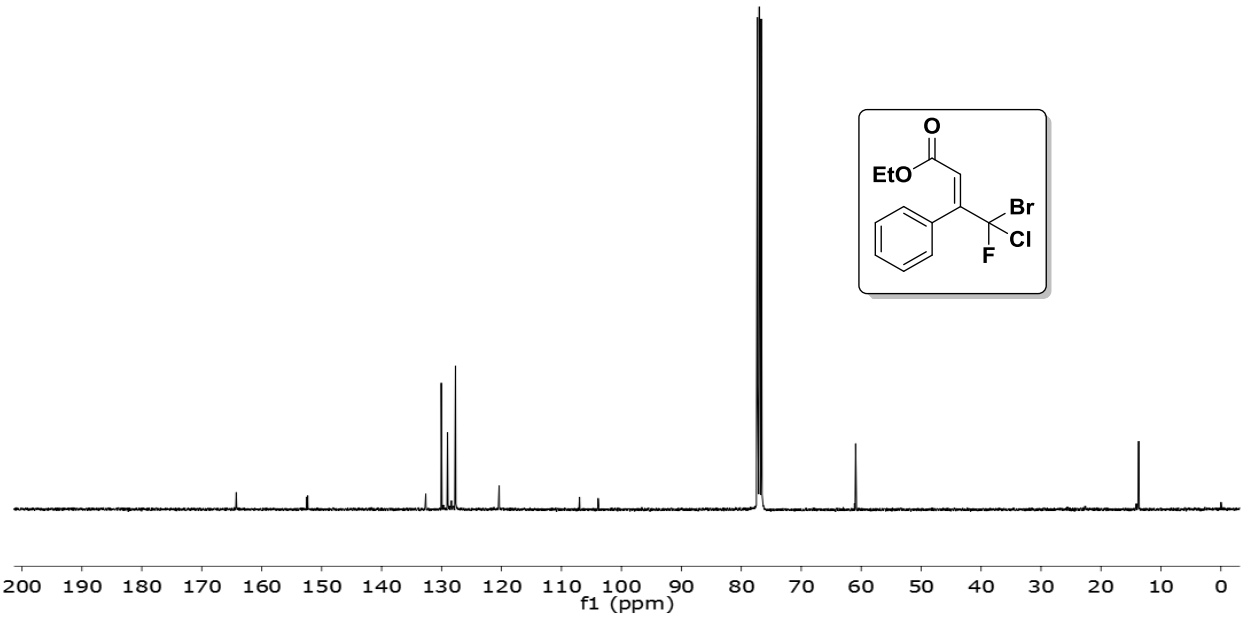
^{19}F NMR spectra of benzyl (*E*)-4-bromo-4-chloro-3-(4-chlorophenyl)-4-fluorobut-2-enoate (18):



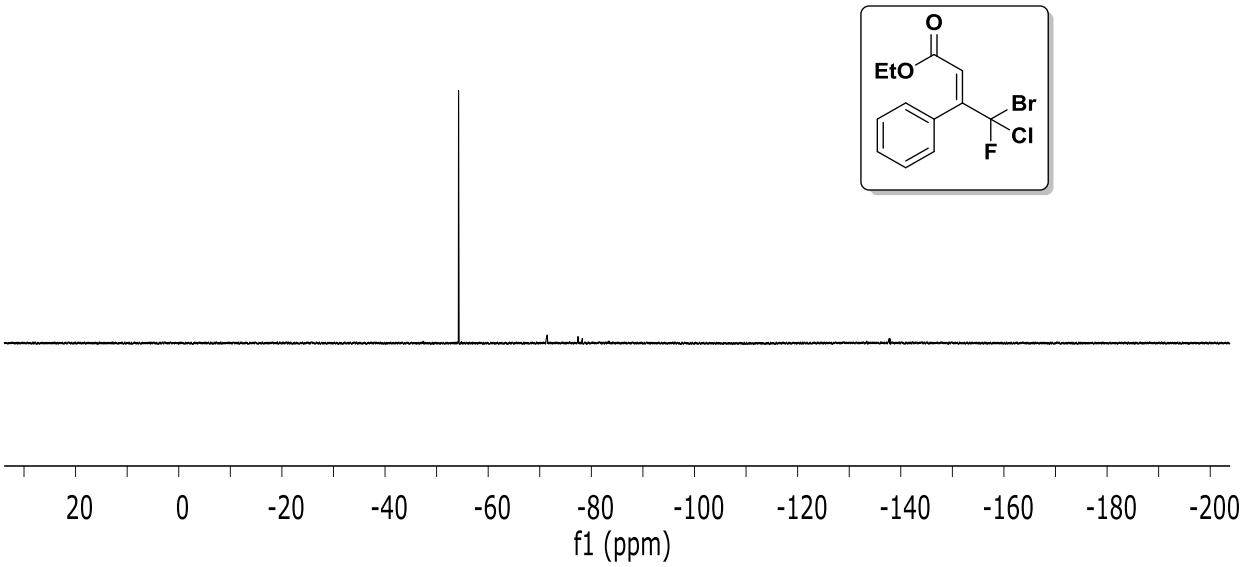
^{1}H NMR spectra of ethyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (19):



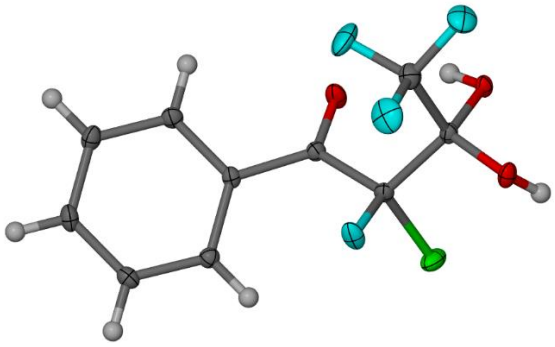
^{13}C NMR spectra of ethyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (19):



^{19}F NMR spectra of ethyl (*E*)-4-bromo-4-chloro-4-fluoro-3-phenylbut-2-enoate (19):

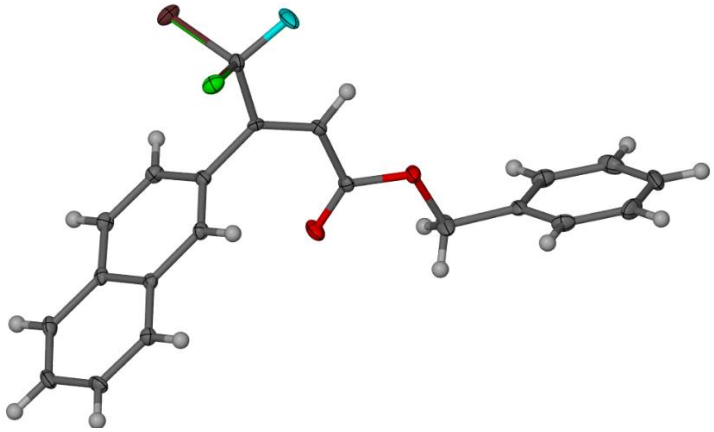


4. Crystallographic Analysis



2-Chloro-2,4,4,4-tetrafluoro-3,3-dihydroxy-1-phenylbutan-1-one

A single crystal was obtained by slow evaporation of a solution of the compound in a mixture of ethyl acetate and hexanes (5% EtOAc in hexanes). Single crystal X-ray analysis was performed at 296 K using a Siemens platform diffractometer with graphite monochromated Mo-Kα radiation (λ = 0.71073 Å). Data were integrated and corrected using the APEX II program. The structures were solved by SHELXT and refined with full-matrix least-square analysis using SHELX-97-2 software. Non-hydrogen atoms were refined with anisotropic displacement parameter. Crystal data: $C_{10}H_7ClF_4O_3$, M = 286.61, colorless prism, 0.3 x 0.2 x 0.1 mm^3, monoclnic, space group $P2_1/c$, a = 8.0622(11), b = 18.116(2), c = 7.6291(10) Å, V = 1113.3(3) $Å^3$, Z = 4.



Benzyl (*E*)-4-bromo-4-chloro-4-fluoro-3-(naphthalen-2-yl)but-2-enoate

A single crystal was obtained by slow evaporation of a solution of the compound in a mixture of ethyl acetate and hexanes (5% EtOAc in hexanes). Single crystal X-ray analysis was performed at 296 K using a Siemens platform diffractometer with graphite monochromated Mo-Kα radiation (λ = 0.71073 Å). Data were integrated and corrected using the APEX II program. The structures were solved by SHELXT and refined with full-matrix least-square analysis using SHELX-97-2 software. Non-hydrogen atoms were refined with anisotropic displacement parameter. Crystal data: $C_{21}H_{15}BrClFO_2$, M = 433.69, colorless needle, 0.12 x 0.07 x 0.05 mm^3, orthorombic, space group $P2_12_12_1$, a = 5.9238(9), b = 8.0989(12), c = 37.622(6) Å, V =1805.0(5) $Å^3$, Z = 4.