Asymmetric aza-Henry reaction of chiral fluoroalkyl α,β-unsaturated *N*-*tert*-butanesulfinyl ketoimines: an efficient approach to enantiopure fluoroalkylated α,β-diamines and α,β-diamino acids

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General information

Solvents were freshly distilled using general method to remove water. Column chromatography was performed on silica gel employing petroleum ether-ethyl acetate mixture as eluant. Substrates **1a-1h** were prepared according to literature procedures.[1]

Melting points were taken on a Melt-Temp apparatus and uncorrected. IR spectra were obtained with a Nicolet AV-360 spectrophotometer. ^{1}H NMR spectra were recorded in $CDCl_3$ on a Bruker AM-300 spectrometer (300 MHz) with TMS as internal standard. ^{19}F NMR spectra were taken on a Bruker AM-300 (282 MHz) spectrometer using $CFCl_3$ as external standard. ^{13}C NMR spectra were recorded on Bruker DPX-400 (100 MHz) spectrometer. Mass spectra were obtained on a Shimadzu LCMS-2010EV spectrometer. High-resolution mass data was obtained on Bruker Daltonics, Inc. APEXIII 7.0 TESLA FTMS spectrometer. Elemental analyses were performed on a Foss-Heraeus Vario EL III instrument. Specific rotations were determined on a Perkin-Elmer 241 spectrometer at room temperature.

Synthesis of substrate 1g

Procedure is the same with Reference 1.

(*R*,*E*)-*N*-((*E*)-1,1-difluoro-4-phenylbut-3-en-2-ylidene)-*tert*-butanesulfinamide (1g)

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Yellowish viscious liquid; IR (film): *v* 1615, 1580, 1450, 1365, 1108, 1081, 1048 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.97 (d, *J* = 16.2 Hz, 1 H), 7.62-7.50 (m, 3H), 7.43-7.33 (m, 3H), 6.20 (t, *J* = 54.6 Hz, 1 H), 1.33 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -114.92 - -114.61 (m, 2 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 165.4 (t, *J* = 26.5 Hz), 144.0, 135.3, 130.9, 129.2, 128.6, 116.3, 115.1 (t, 250.2 Hz), 60.1, 23.2; MS (ESI, *m/z*, %): 286 $[M+H]^+$; HRMS calcd. for $C_{14}H_{17}F_2NOSK([M+K]^+)$: 324.0631. Found: 324.0627.

Typical procedure for aza-Henry reaction of 1

Potassium carbonate anhydrous (2.8 mg, 0.02 mmol) was added to a solution of **1a** (30.0 mg, 0.1 mmol) in nitromethane (0.5 mL) at room temperature. The reaction mixture was stirred for 3 hours. After removal of the volatile solvent under vacuum, **2a** was obtained via silica gel chromatography (Petroleum Ether/EtOAc = 5/1) in the yield of 31.0 mg (85%).

(*E*)-2-methyl-*N*-(1,1,1-trifluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)propane-2-sulfinamide (2a)

Colorless crystal, yield 85%; mp: 72-74 ^oC; IR (film): *v* 3306, 3285, 2962, 1560, 1471, 1368, 1397, 1185, 1124, 1081, 1054 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.48-7.36 (m, 5 H), 6.91 (d, *J* = 16.2 Hz, 1 H), 6.30 (d, *J* = 16.2 Hz, 1 H), 5.45 (s, 1H), 5.08-4.99 (m, 2 H), 1.32 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.4 (s, 3 F); MS (ESI, *m/z*, %): 365 $[M+H]^+$; Anal. Calcd. For $C_{15}H_{19}F_3N_2O_3S$: C, 49.44; H, 5.26; N, 7.69. Found: C, 49.24; H, 5.37; N, 7.56. The chiral HPLC analytical data: chiralpak IC column, detected at 214 nm, eluent: *n*-hexane/*iso*-propanol = 60/40, 0.7 mL/min, retention times: tr (minor) = 5.85 min, tr (major) = 6.19 min; ee% = 96.7%; Crystal data: $C_{15}H_{19}F_3N_2O_3S$; *M* = 364.38; Triclinic, P-1; *a* = 9.1431(10) Å, *b* = 9.1984(11) Å, *c* = 21.398(3) Å; α = 98.890(2), β = 92.687(2), γ = 95.661(2), *V* = 1765.8(4) $Å^3$; *Z* = 4; 9748 reflections; R_{int}= 0.0668; R_1 = 0.0562 and wR_2 = 0.1244. Crystallographic data for the structures of **2a** have been deposited with the Cambridge Crystallographic Data Centre (CCDC 756867). Copies of the data can be obtained, free of charge, on

application to the Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, United Kingdom (Fax: 44-1223-336033 or email: deposit@ccdc.cam.uk).

(*E*)-2-methyl-*N*-(1,1,1-trifluoro-4-(4-methoxyphenyl)-2-(nitromethyl)but-3-en-2-yl)propane-2-sulfinamide (2b)

Colourless oil, yield 95%; IR (film): *v* 3303, 2963, 1651, 1608, 1562, 1515, 1468, 1375, 1253, 1179, 1074 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.31 (d, *J* = 8.7 Hz, 2 H), 6.82-6.72 (m, 3 H), 6.05 (d, *J* = 16.8 Hz, 1 H), 5.36 (s, 1H), 4.98-4.88 (m, 2 H), 3.72 (s, 3 H), 1.16 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.6 (s, 3 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 160.9, 137.3, 128.9, 127.4, 124.3 (q, *J* = 213.6 Hz), 115.9, 114.5, 66.1, 63.4 (q, *J* = 21.3 Hz), 57.2, 55.5, 22.8; MS (ESI, *m/z*, %): 395 $[M+H]^+$, 417 $[M+Na]^+$; HRMS calcd. for $C_{16}H_{21}F_3N_2O_4$ SNa ($[M+Na]^+$): 417.1066. Found: 417.1062.

(*E*)-*N*-(4-(4-chlorophenyl)-1,1,1-trifluoro-2-(nitromethyl)but-3-en-2-yl)-2-methyl propane-2-sulfinamie (2c)

Colourless oil, yield 91%; IR (film): *v* 3302, 2965, 1734, 1652, 1563, 1493, 1374, 1138, 1014 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.41-7.32 (m, 4 H), 6.89 (d, *J* = 16.8 Hz, 1 H), 6.27 (d, *J* = 16.8 Hz, 1 H), 5.43 (s, 1H), 5.06-4.96 (m, 2 H), 1.31 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.2 (s, 3 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 136.9, 135.7, 133.2, 129.4, 128.8, 124.2 (q, *J* = 212.9 Hz), 119.2, 66.1, 63.7 (q, *J* = 21.4 Hz), 57.5, 22.8; MS (ESI, *m/z*, %): 399 $[M+H]^+$, 421 $[M+Na]^+$; HRMS calcd. for $C_{15}H_{19}ClF_3N_2O_3S$ ($[M+H]^+$): 399.0752. Found: 399.0747.

(*E*)-2-methyl-*N*-(1,1,1-trifluoro-4-(naphthalen-1-yl)-2-(nitromethyl)but-3-en-2-yl) propane-2-sulfinamide (2d)

Colourless oil, yield 91%; IR (film): *v* 3302, 3048, 2966, 1735, 1561, 1474, 1373, 1230, 1074; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.10-8.06 (d, J = 8.1 Hz, 1 H), 7.88-7.85 (m, 2 H), 7.75 (d, *J* = 16.8 Hz, 1 H), 7.63-7.44 (m, 4 H), 6.32 (d, *J* = 16.8 Hz, 1 H), 5.46 (s, 1H), 5.14-5.05 (m, 2 H), 1.34 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.3

(s, 3 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 136.4, 133.8, 133.0, 131.4, 130.1, 128.9, 127.3, 126.6, 125.8, 125.2, 124.3 (q, J = 213.8 Hz), 123.9, 121.8, 66.2, 64.1 (q, J = 21.0 Hz), 57.6, 22.9; MS (ESI, *m/z*, %): 415 $[M+H]^+$, 437 $[M+Na]^+$; HRMS calcd. for $C_{19}H_{21}F_3N_2NaO_3S$ ($[M+Na]^+$): 437.1117. Found: 437.1113.

(*E*)-2-methyl-*N*-(1,1,1-trifluoro-2-(nitromethyl)dodec-3-en-2-yl)propane-2-sulfinamide (2e)

Colourless oil, yield 68%; IR (film): *v* 3303, 2960, 2930, 2858, 1564, 1469, 1374, 1185, 1133, 1075 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.07-5.98 (m, 1 H), 5.63 (d, J = 16.8 Hz, 1 H), 5.32 (s, 1H), 4.96-4.85 (m, 2 H), 2.24-2.16 (m, 2H), 1.45-1.42 (m, 2H), 1.30-1.18 (m, 19H), 0.88 (t, J = 5.6 Hz, 3H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.8 (s, 3 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 140.8, 124.2 (q, J = 213.2 Hz), 119.9, 66.1, 63.2 (q, J = 21.3 Hz), 57.1, 33.2, 32.1, 29.5, 29.2, 28.5, 22.9, 22.8, 22.5, 14.3; MS (ESI, *m/z*, %): 401 $[M+H]^+$, 423 $[M+Na]^+$; HRMS calcd. for $C_{17}H_{31}F_3N_2NaO_3S$ ($[M+Na]^+$): 423.1900. Found: 423.1902.

(*E*)-*N*-(1-chloro-1,1-difluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)-2-methylpropane-2-sulfinamide (2f)

Colourless crystal, yield 80%; Mp: 95-96 ^{o}C; IR (film): *v* 3303, 2964, 1649, 1561, 1372, 1263, 1176, 1075 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.47-7.35 (m, 5 H), 6.87 (d, J = 16.8 Hz, 1 H), 6.35 (d, J = 16.8 Hz, 1 H), 5.48 (s, 1H), 5.17, 5.10 (AB, J_{AB} = 12.0 Hz, 2 H), 1.34 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -62.2 (s, 2 F); MS (ESI, *m/z*, %): 381 $[M+H]^+$, 403 $[M+Na]^+$; Anal. Calcd. For $C_{15}H_{19}ClF_2N_2O_3S$: C, 47.31; H, 5.03; N, 7.36. Found: C, 47.35; H, 5.17; N, 7.27.

(*E*)-*N*-(1,1-difluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)-2-methylpropane-2-sulfinamide (2g)

Colourless crystal, yield 54%; Mp: 118-119 ^{o}C; IR (film): *v* 3292, 2975, 1654, 1559, 1469, 1381, 1317, 1261, 1171, 1140, 1060 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.45-7.32 (m, 5 H), 6.85 (d, J = 16.8 Hz, 1 H), 6.20 (d, J = 16.8 Hz, 1 H), 6.09 (t, J =

55.2 Hz, 1 H), 5.02-5.00 (m, 2H), 4.79 (s, 1H), 1.30 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -127.9, -130.1 (ABd, J_{AB} = 280.4 Hz, J_d = 54.2 Hz, 2 F); MS (ESI, *m/z*, %): 347 $[M+H]^+$, 369 $[M+Na]^+$; Anal. Calcd. For $C_{15}H_{20}F_2N_2O_3S$: C, 52.01; H, 5.82; N, 8.09. Found: C, 52.31; H, 5.87; N, 7.90.

(*R*)-*N*-(1,1,1,2,2,3,3-heptafluoro-7-nitro-6-phenylheptan-4-ylidene)-2-methylpropane-2-sulfinamide (2h-1)

Colorless sticky thick oil, yield 35%; IR (film): *v* 2968, 1639, 1558, 1379, 1346, 1232, 1121, 1087 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.36-7.27 (m, 5 H), 4.75-4.68 (m, 2 H), 4.06-4.01 (m, 1 H), 3.74-3.66 (m, 1 H), 3.21-3.14 (m, 1 H), 1.30 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -79.9 (t, *J* = 16.8 Hz, 3 F), -112.3, -113.5 (AB, J_{AB} = 282.4 Hz, 2 F), -124.6 (s, 2 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 166.3 (t, *J* = 20.1 Hz), 137.4, 129.5, 128.8, 128.0, 79.3, 60.6, 42.3, 34.6, 23.0; MS (ESI, *m/z*, %): 465 $[M+H]^+$, 487 $[M+Na]^+$; HRMS calcd. for $C_{17}H_{19}F_7N_2NaO_3S$ ($[M+Na]^+$): 487.0897; Found: 487.0907.

(*R*)-2-methyl-*N*-((*Z*)-1,1,1-trifluoro-5-nitro-4-phenylpent-2-en-2-yl)propane-2-sulfinamide (2h-2)

Colorless sticky thick oil, yield 52%; IR (film): *v* 3285, 2966, 1657, 1558, 1457, 1376, 1345, 1232, 1116, 1079 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.41-7.30 (m, 3 H), 7.30-7.23 (m, 2 H), 6.45 (d, *J* = 8.1 Hz, 1 H), 4.87-4.81 (m, 1H), 4.81-4.63 (m, 3 H), 1.20 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -80.5 (m, 3 F), -113.0, -115.4 (AB, J_{AB} = 282.4 Hz, 2 F), -125.4, -126.5 (AB, J_{AB} = 289.2 Hz, 2 F); ^{13}C NMR (75 MHz, $CDCl_3$): δ 136.8, 131.1 (t, *J* = 5.8 Hz), 130.4 (t, *J* = 24.1 Hz), 130.0, 128.9, 128.2, 79.7, 57.7, 47.8, 22.4; MS (ESI, *m/z*, %): 465 $[M+H]^+$, 487 $[M+Na]^+$; HRMS calcd. for $C_{17}H_{19}F_7N_2NaO_3S$ ($[M+Na]^+$): 487.0897. Found: 487.0905.

Synthesis of 4a

An ethereal solution of hydrogen chloride (saturated, 25 mL) was added to a solution of **2a** (3.0 g, 8.38 mmol) in 20 mL methanol at 0^{o}C. After stirred at room temperature

for 0.5 hour, the mixture was concentrated in vacuo to give the crude hydrolysis product **3a**. Without further purification, **3a** was dissolved into 80 mL methanol and cooled to 0^{o}C, then hydrochloric acid (1.0N, 80 mL) and zinc powder (5.5 g, 83.8 mmol) were added successively. After stirred at room temperature overnight, the reaction mixture was neutralized by sodium hydroxide aqueous (1.0 N) till PH = 7. Removing CH_3OH by evaporation in vacuo afforded a lot of inorganic salts, which was dissolved by 200 mL water. The mixture was extracted with dichloromethane (200 mL x 3) and washed with brine (200 mL x 2). The combined organic layer was dried over anhydrous sodium sulfate. Filtration and evaporation of the solvents afforded the crude product, which was purified by flash column chromatography on silica gel (Petroleum Ether/Ethyl Acetate = 3/1).

(*S*, *E*)-4-phenyl-2-(trifluoromethyl)but-3-ene-1,2-diamine 4a

Vicious colourless oil, Over all yield of two steps: 69%; $[\alpha]_D^{20}$ 1.57 (c = 1.58, $CHCl_3$); IR (film): *v* 3371, 3028, 2944, 2889, 1603, 1492, 1449, 1289, 1255, 1169, 1030 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.46-7.39 (m, 2 H), 7.39-7.24 (m, 3 H), 6.86 (d, J = 16.2 Hz, 1 H), 6.18 (d, J = 16.2 Hz, 1 H), 2.94, 2.89 (AB, J_{AB} = 13.8 Hz, 2H), 1.59 (s, 4 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -79.8 (s, 3 F); ^{13}C NMR (75 MHz, CD_3OD): δ 138.3, 136.1, 130.6, 130.1, 128.7, 126.5, 63.7 (q, J = 24.4 Hz), 46.9; MS (ESI, *m/z*, %): 230 $[M]^+$; HRMS calcd. for $C_{11}H_{14}F_3N_2$ ($[M+H]^+$): 231.1104. Found: 231.1112. Anal. Calcd. For $C_{11}H_{13}F_3N_2$: C, 57.39; H, 5.69; N, 12.17. Found: C, 57.24; H, 5.77; N, 11.86.

Synthesis of 5a

Di-*tert*-butyl dicarbonate (5.78 g, 26.5 mmol, dissolved in 50 mL dichloromethane) was added dropwisely to a solution of **4a** (1.23 g, 5.3 mmol) and *N*, *N*-4-dimethylaminopyridine (DMAP) (647 mg, 5.3 mmol) in 50 mL dichloromethane at 0 ^{o}C. After stirring for 1 hour at room temperature, 100 mL water was added. The mixture was extracted with dichloromethane (100 mL x 3) and washed with brine (200 mL x 2). The combined organic layer was dried over anhydrous sodium sulfate.

Filtration and evaporation of the solvents afforded the crude product, which was purified by flash column chromatography on silica gel (Petroleum Ether/Ethyl Acetate = 5/1).

(*S*,*E*)-di-*tert*-butyl 4-phenyl-2-(trifluoromethyl)but-3-ene-1,2-diyldicarbamate (5a)

Vicious colourless oil, yield 95%; $[\alpha]_D^{20}$ -30.92 (c = 1.19, $CHCl_3$); IR (film): *v* 3063, 2981, 2935, 1817, 1721, 1652, 1477, 1451, 1371, 1287, 1148, 1061, 1011 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.45-7.31 (m, 5 H), 6.76 (d, *J* = 16.5 Hz, 1 H), 6.51 (d, *J* = 16.5 Hz, 1 H), 4.13 (d, *J* = 11.7 Hz, 1 H), 3.83 (d, *J* = 11.7 Hz, 1 H), 1.55 (s, 9 H), 1.46 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -75.2 (m, 3 F); MS (*m/z*, %): 300 ($[M-C_4H_9-C_4H_9O]^+$, 89), 57 (100); HRMS calcd. for $C_{13}H_{11}F_3N_2O_3$ ($[M-C_4H_9-C_4H_9O]^+$): 300.0722. Found: 300.0718; Anal. Calcd. For $C_{21}H_{29}F_3N_2O_4$: C, 58.59; H, 6.79; N, 6.51. Found: C, 58.80; H, 6.60; N, 6.24. The chiral HPLC analytical data: chiralpak IB column, detected at 214 nm, eluent: *n*-hexane/*iso*-propanol = 70/30, 0.7 mL/min, retention times: tr (major) = 5.37 min, tr (minor) = 6.17 min; ee % = 99.3%.

Synthesis of 6a

Ozone was bubbled to a solution of **5a** (2.28 g, 5.3 mmol) in 70 mL dichloromethane at -78 ^oC till the mixture turned to be dark blue. After stirring at this temperature for 0.5 hour, triphenyl phosphine (1.39 g, 5.3 mmol) was added. The mixture was warmed to room temperature and stirred for a while till it was colourless. Flash chromatography was performed to give pure **6a** (Petroleum Ether/Ethyl Acetate = 1/2).

(*R*)-di-*tert*-butyl 3,3,3-trifluoro-2-formylpropane-1,2-diyldicarbamate (6a)

Vicious colourless oil, yield 95%; IR (film): *v* 3416, 2983, 1785, 1482, 1397, 1344, 1292, 1163, 1041 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 9.70 (s, 1 H), 3.96, 3.86 (AB,

J_{AB} = 12.0 Hz, 2 H), 1.56 (s, 9 H), 1.53 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -76.1 (s, 3 F); MS (*m/z*, %): 242 ($[M-2C_4H_9]^+$, 29), 57 (100).

Synthesis of 7a

Sodium chlorite (216 mg, 2.4 mmol) and 2-methyl-2-butene (0.8 mL) were added to a solution of **6a** (238 mg, 0.67 mmol) and sodium phosphate monobasic dihydrate (328 mg, 2.1 mmol) in 5 mL water and 4.0 g *tert*-butyl alcohol at 0 ^oC. After stirred at this temperature for 0.5 hour, the mixture was warmed to room temperature and stirred overnight. The reaction mixture was neutralized by sodium hydroxide aqueous (2.0 N) till PH = 9. *tert*-Butyl alcohol was removed by evaporation in vacuo. The mixture was extracted with dichloromethane (20 mL x 3). The combined water layer was neutralized with hydrochloride aqueous (1.4 N) till PH = 3. The mixture was extracted with dichloromethane (20 mL x 3). Evaporation of the solvents afforded the crude product.

(*R*)-2-(*tert*-butoxycarbonylamino)-2-((*tert*-butoxycarbonylamino)methyl)-3,3,3-trifluoropropanoic acid (7a)

White solid, yield 95%; Mp: 116-118 ^oC; $[\alpha]_D^{20}$ -4.52 (c = 0.92, CH_3OH); IR (film): *v* 3459, 2986, 1804, 1771, 1742, 1478, 1374, 1277, 1221, 1144, 1075 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04-7.67 (br, 2 H), 4.00, 3.91 (AB, J_{AB} = 12.0 Hz, 2 H), 1.47 (s, 9 H), 1.42 (s, 9 H); ^{19}F NMR (282 MHz, $CDCl_3$): δ -74.7 (s, 3 F); MS (*m/z*, %): 242 ($[M-C_4H_9-C_4H_9O]^+$, 1.41), 57 (100); HRMS calcd. for $C_6H_5F_3N_2O_5$ ($[M-C_4H_9-C_4H_9O]^+$): 242.0151. Found: 242.0153.

Synthesis of 8a

Thionyl chloride (2.8 mg, 0.02 mmol) was added to a solution of **7a** (37 mg, 0.1 mmol) in methanol (0.5 mL) at room temperature. The reaction mixture was stirred for 3 hours. After removal of the volatile solvent under vacuum, **8a** was obtained in 95% yield.

(*R*)-methyl 2-amino-2-(aminomethyl)-3,3,3-trifluoropropanoate (8a)

White solid, yield 95%; Mp: 155-157 ^{o}C; $[\alpha]_D^{20}$ 6.06 (c = 0.48, CH_3OH); IR (film): ν 3245, 2923, 1720, 1497, 1459, 1374, 1306, 1193, 1085, 1059 cm^{-1}; ^{1}H NMR (300 MHz, CD_3OD): δ 3.92, 3.78 (AB, J_{AB} = 10.5 Hz, 2 H), 3.89 (s, 3H); ^{19}F NMR (282 MHz, CD_3OD): δ -78.1 (s, 3H); ^{13}C NMR (75 MHz, CD_3OD): δ 169.4, 123.8 (J = 281.4 Hz), 67.9 (q, J = 30.8 Hz), 55.2, 46.3; MS (EI, *m/z*, %): 154 ($[M-CH_3-H_2O]^+$, 8.09), 153 (100); HRMS calcd. for $C_4H_5F_3N_2O$ ($[M-CH_3-H_2O]^+$): 154.0354. Found: 154.0351.

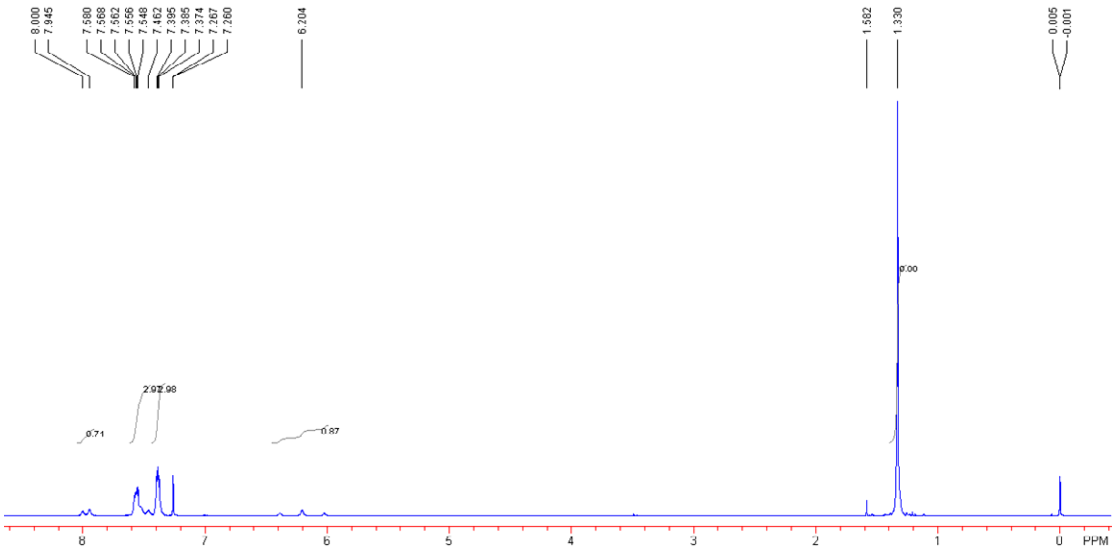
Reference

1. Liu, Z.-J. Ph. D. Dissertation, Shanghai institute of organic chemistry, Chinese academy of sciences, **2008**.

(*R*,*E*)-*N*-((*E*)-1,1-difluoro-4-phenylbut-3-en-2-ylidene)-*tert*-butanesulfinamide

(1g)

^{1}H NMR Spectra



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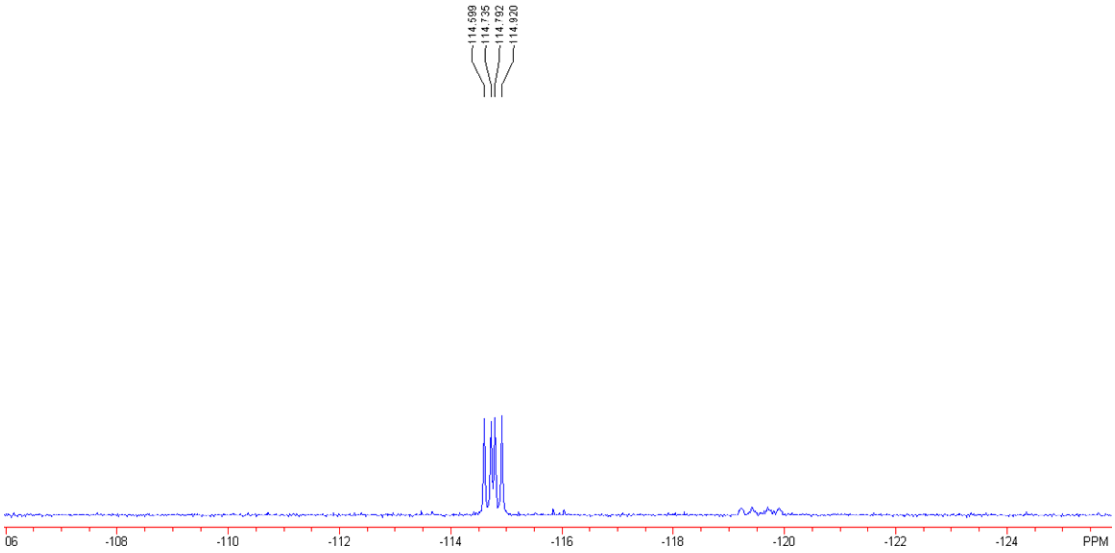
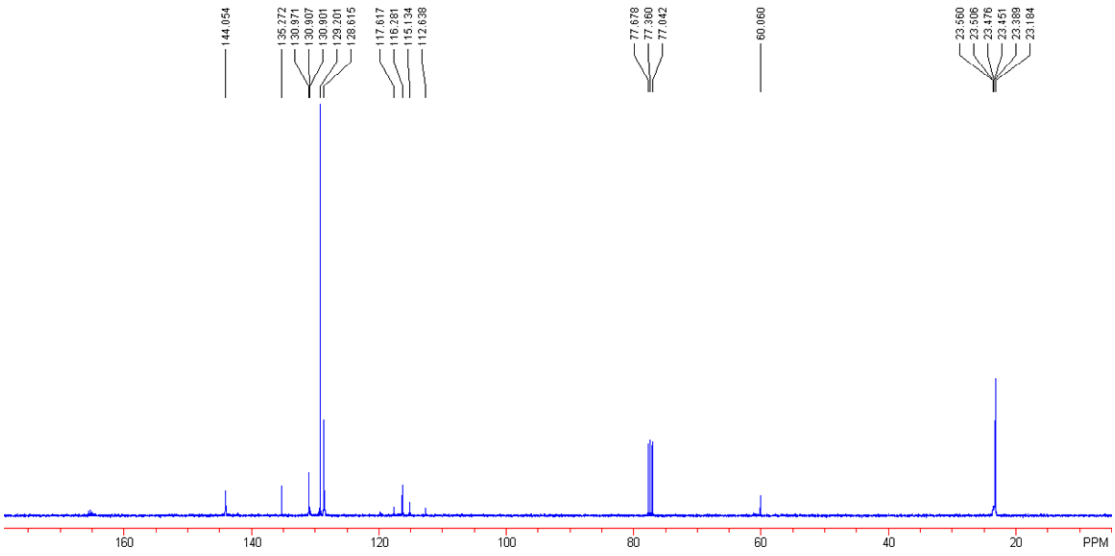
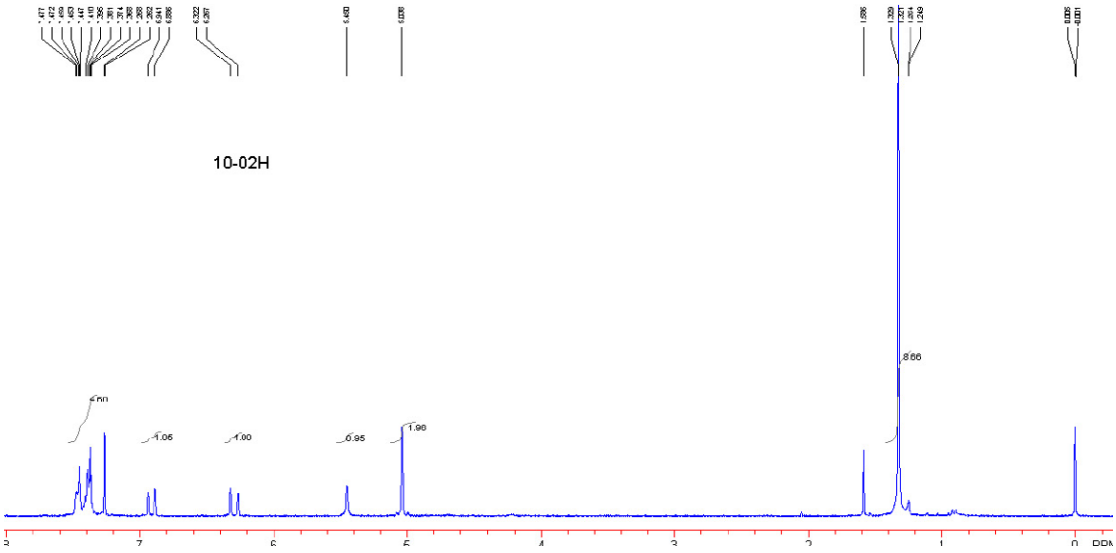


^{13}C NMR Spectra

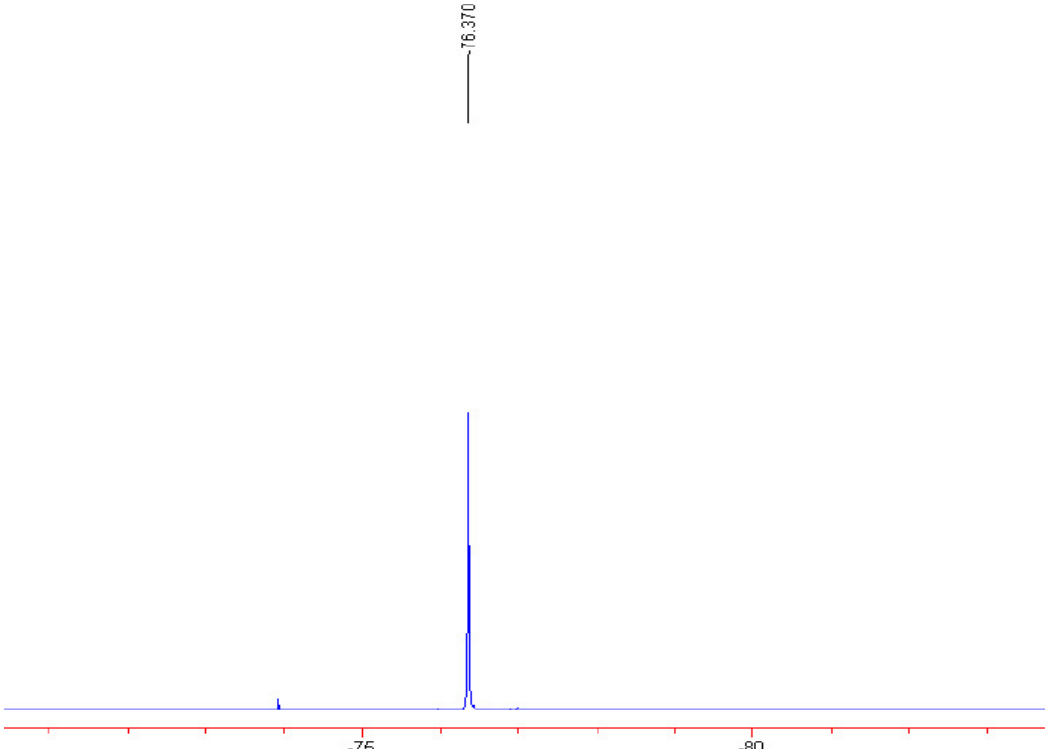


(*E*)-2-methyl-*N*-(1,1,1-trifluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)propane-2-sulfinamide (2a)

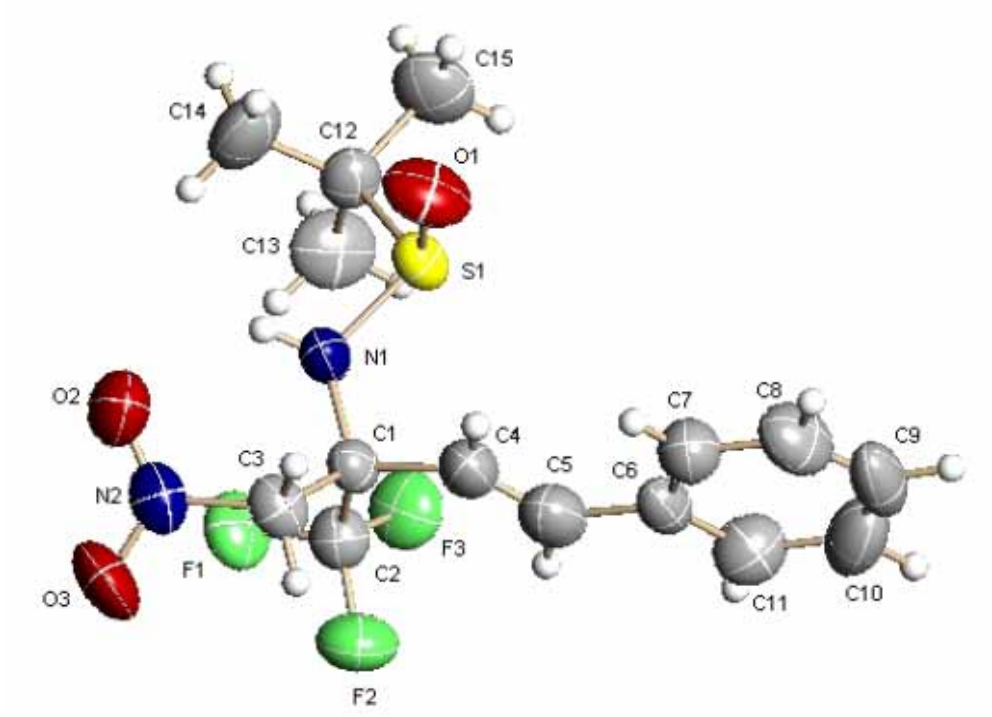
^{1}H NMR Spectra



^{19}F NMR Spectra



X-ray crystal structure of **2a**:



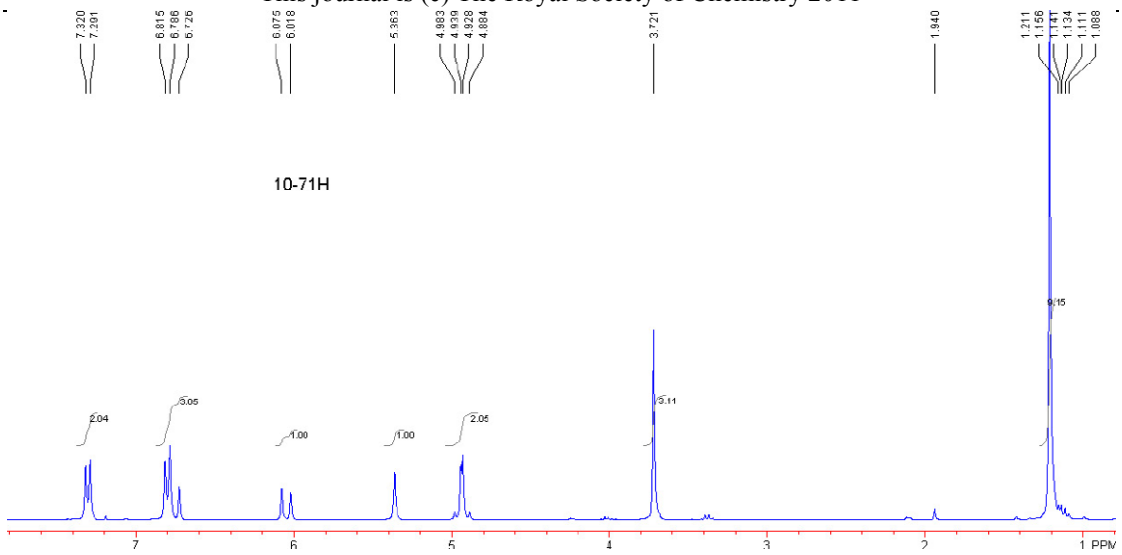
Crystal data and structure refinement for **2a**

Identification code	**2a**
Empirical formula	$C_{15}H_{19}F_3N_2O_3S$
Formula weight	323.27

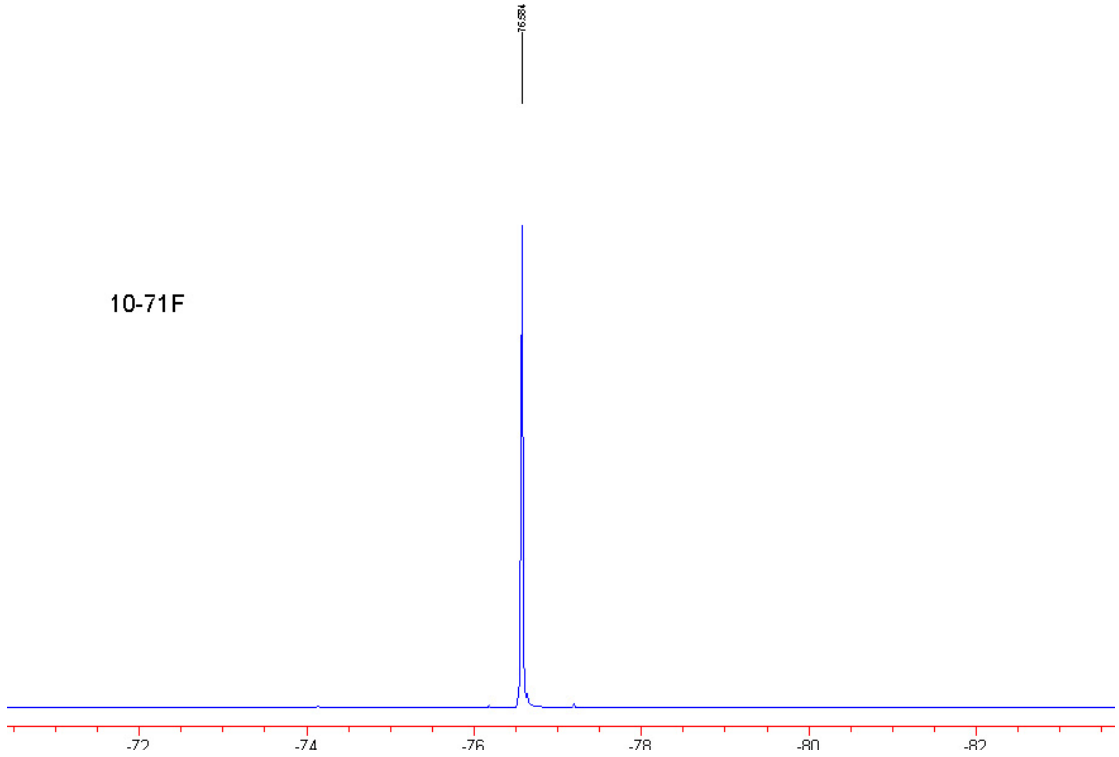
Temperature	293(2) K
Wavelength	0.71073 A
Crystal system, space group	Triclinic, P-1
Unit cell dimensions	a = 9.1431(10) A alpha = 98.890(2) deg.
	b = 9.1984(11) A beta = 92.687(2) deg.
	c = 21.398(3) A gamma = 95.661(2) deg.
Volume	1765.8(4) A^3
Z, Calculated density	4, 1.371 Mg/m^3
Absorption coefficient	0.228 mm^-1
F(000)	760
Crystal size	0.421 x 0.396 x 0.223 mm
Theta range for data collection	1.93 to 26.00 deg.
Limiting indices	-9<=h<=11, -11<=k<=11, -23<=l<=26
Reflections collected / unique	9748 / 6628 [R(int) = 0.0668]
Completeness to theta = 26.00	98.2 %
Absorption correction	Empirical
Max. and min. transmission	1.0000 and 0.8044
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	6828 / 2 / 447
Goodness-of-fit on F^2	0.888
Final R indices [I>2sigma(I)]	R1 = 0.0562, wR2 = 0.1244
R indices (all data)	R1 = 0.0917, wR2 = 0.1391
Largest diff. peak and hole	0.512 and -0.279 e.A^-3

(*E*)-2-methyl-*N*-(1,1,1-trifluoro-4-(4-methoxyphenyl)-2-(nitromethyl)but-3-en-2-yl)propane-2-sulfinamide (2b)

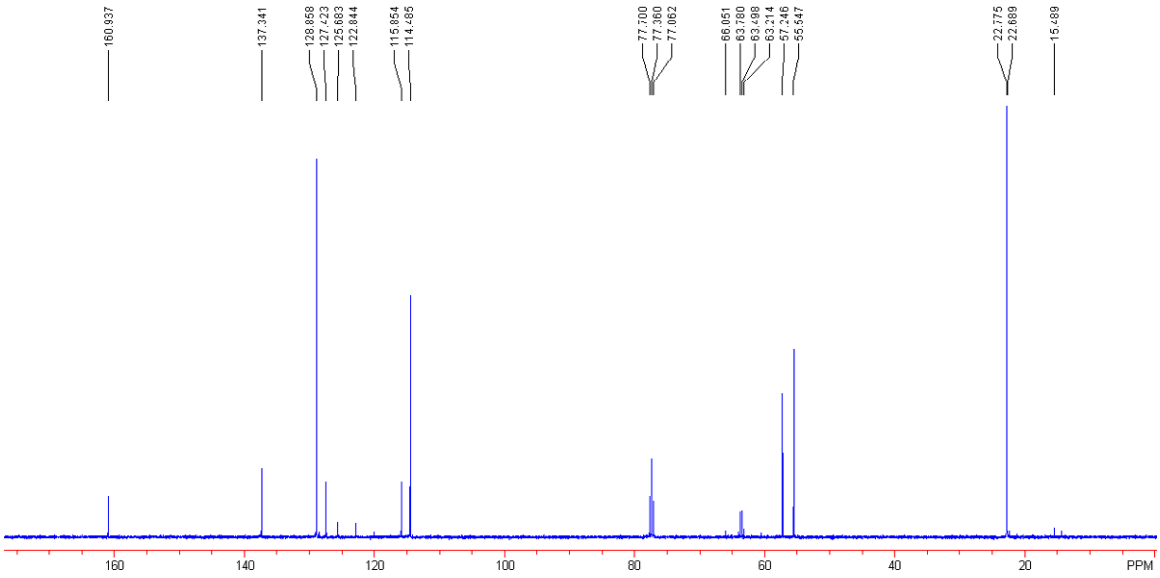
^{1}HNMR



^{19}F NMR

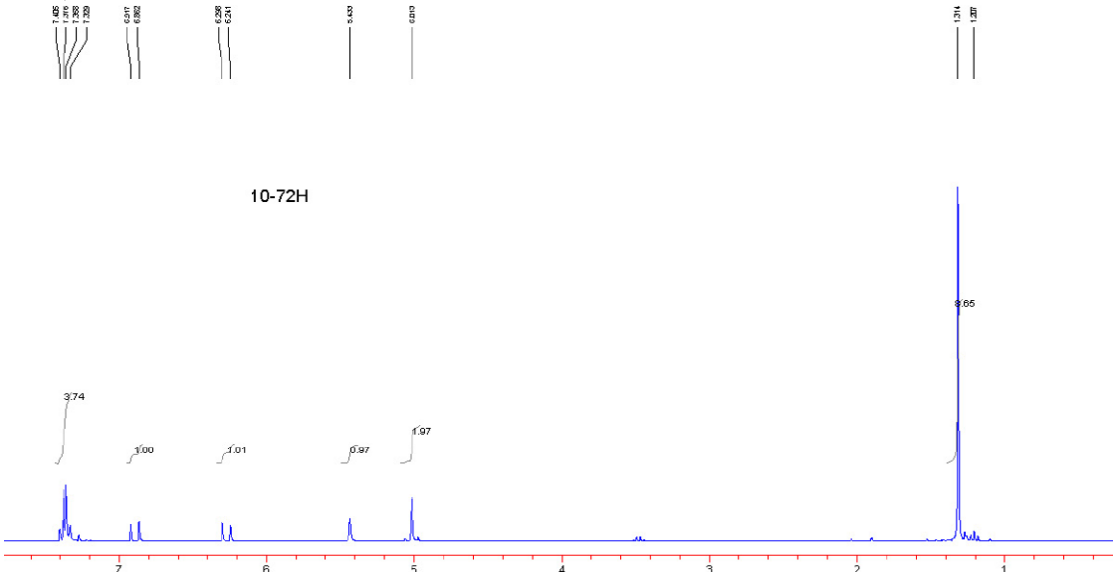


^{13}C NMR

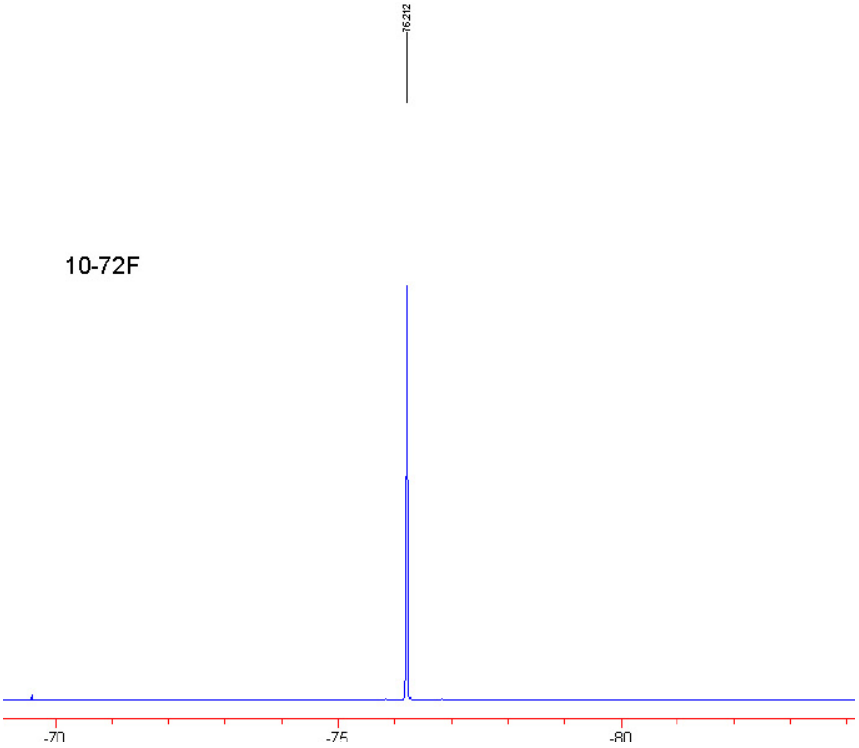


(*E*)-*N*-(4-(4-chlorophenyl)-1,1,1-trifluoro-2-(nitromethyl)but-3-en-2-yl)-2-methyl propane-2-sulfinamie (2c)

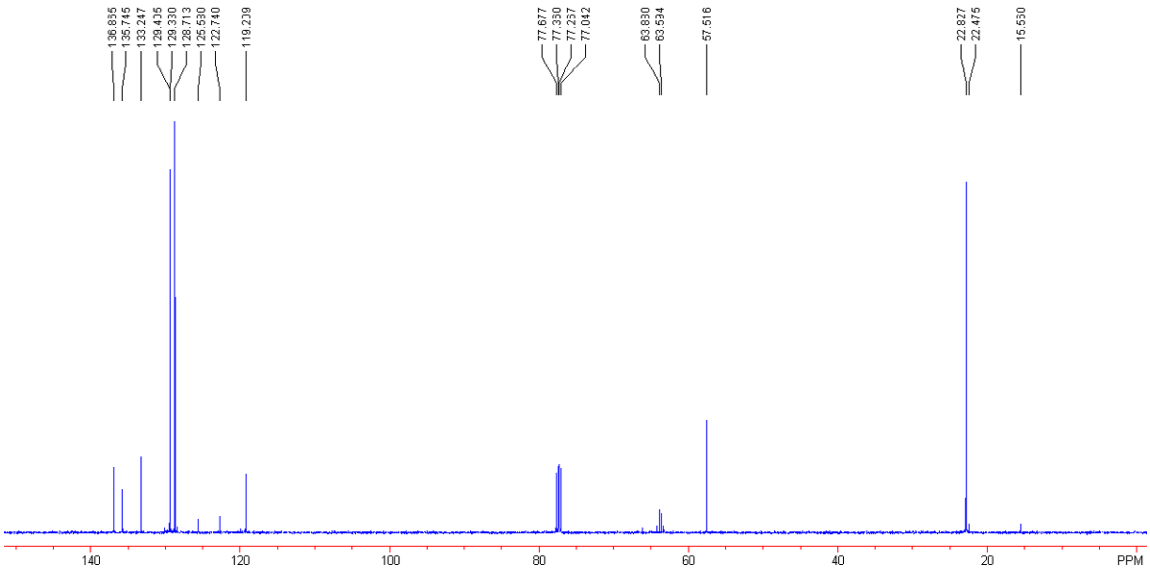
^{1}H NMR



^{19}F NMR

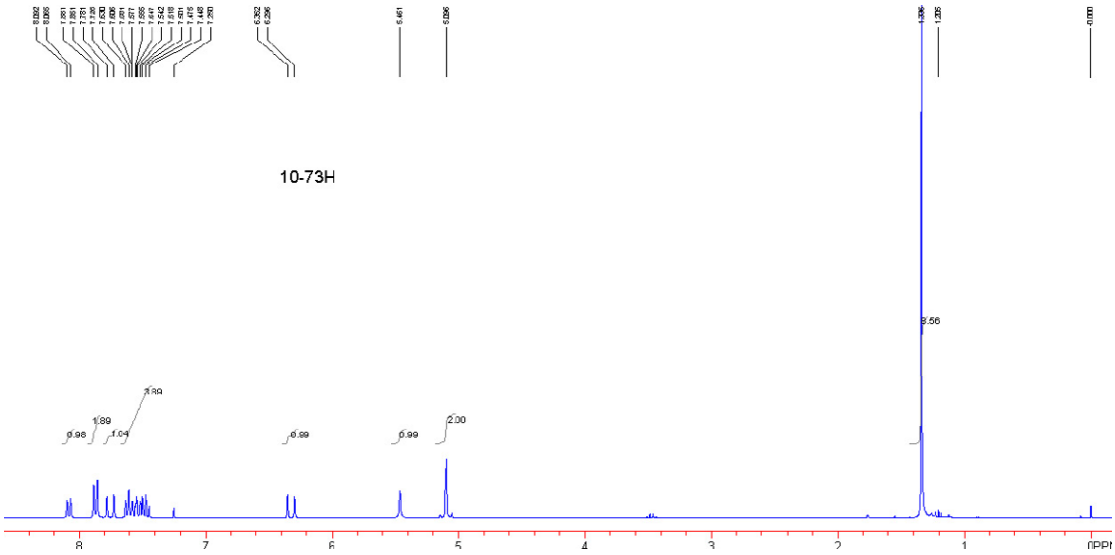


^{13}C NMR

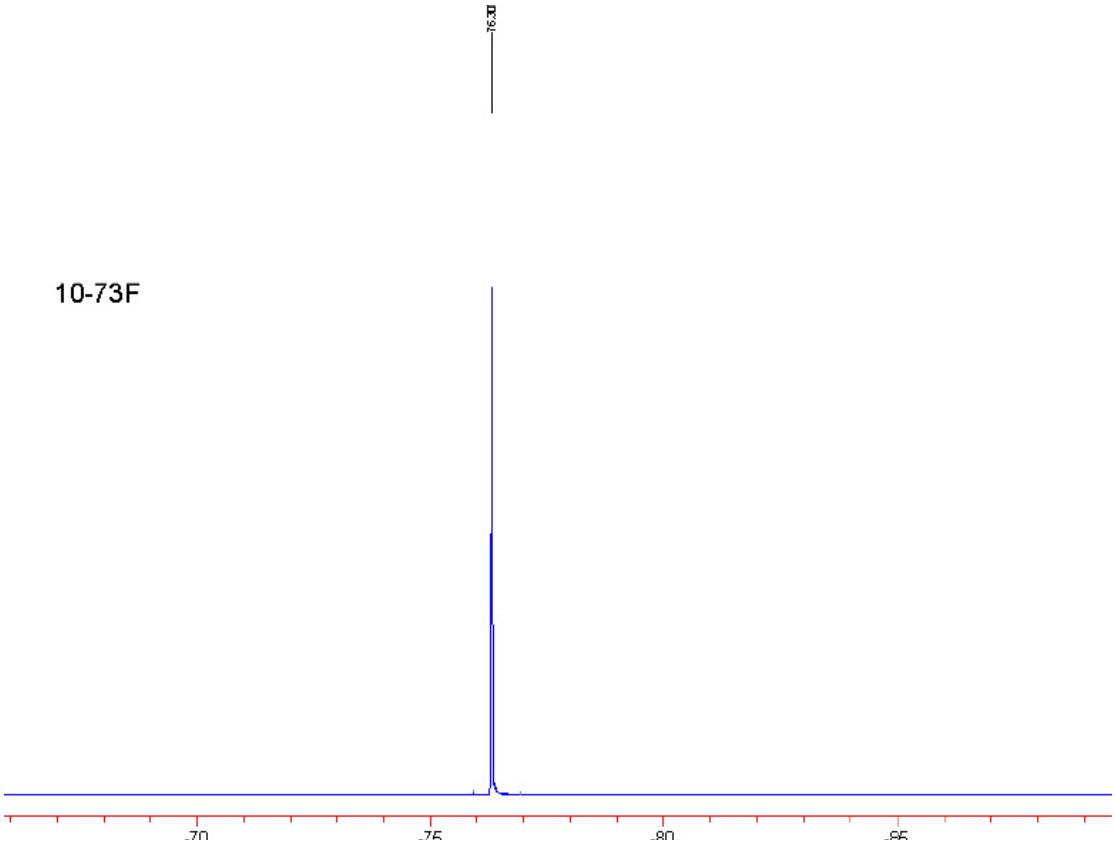


(*E*)-2-methyl-*N*-(1,1,1-trifluoro-4-(naphthalen-1-yl)-2-(nitromethyl)but-3-en-2-yl) propane-2-sulfinamide (2d)

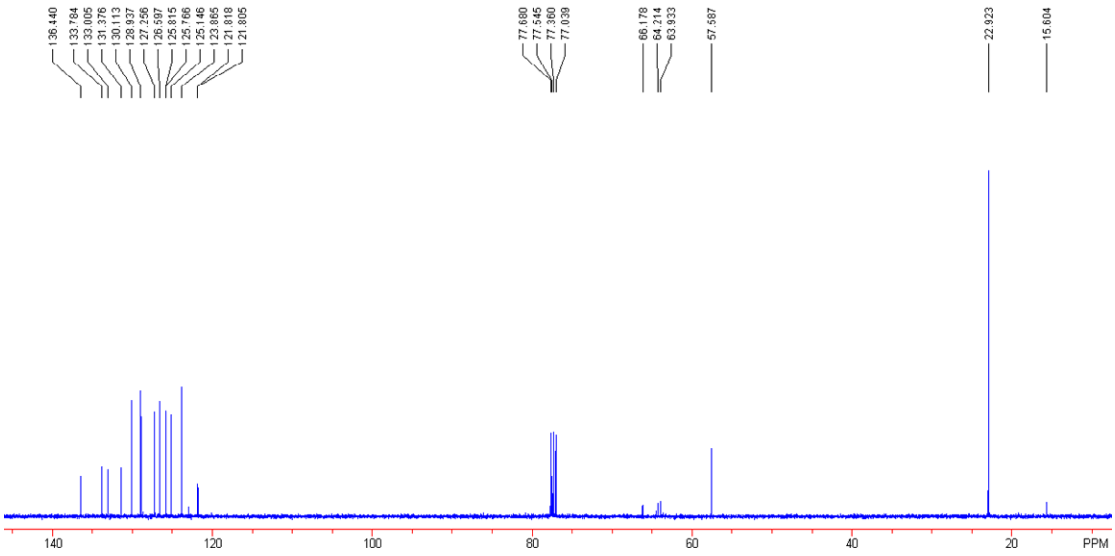
^{1}H NMR



^{19}F NMR

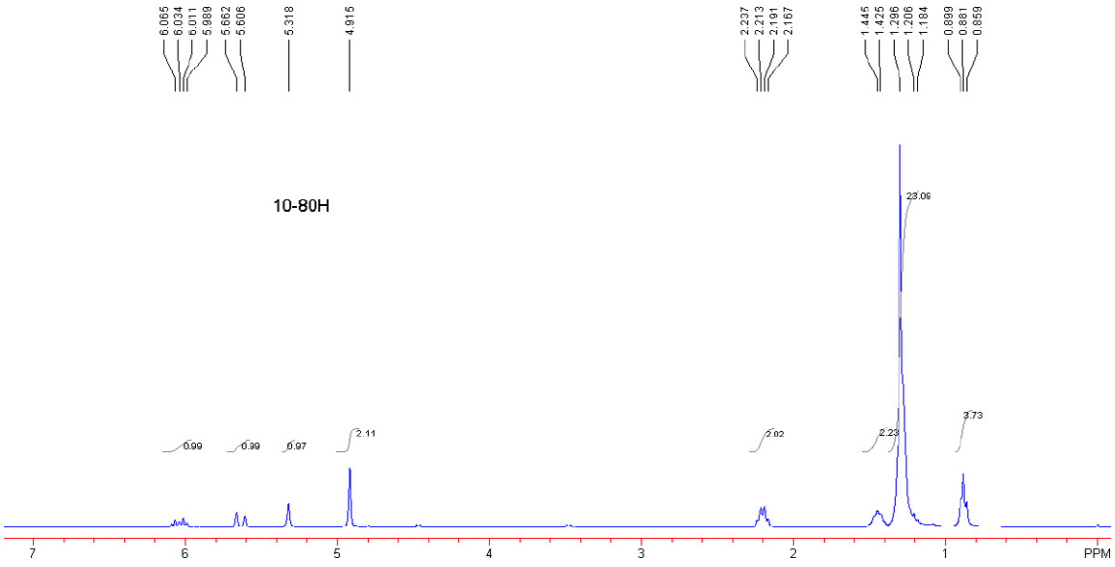


^{13}C NMR

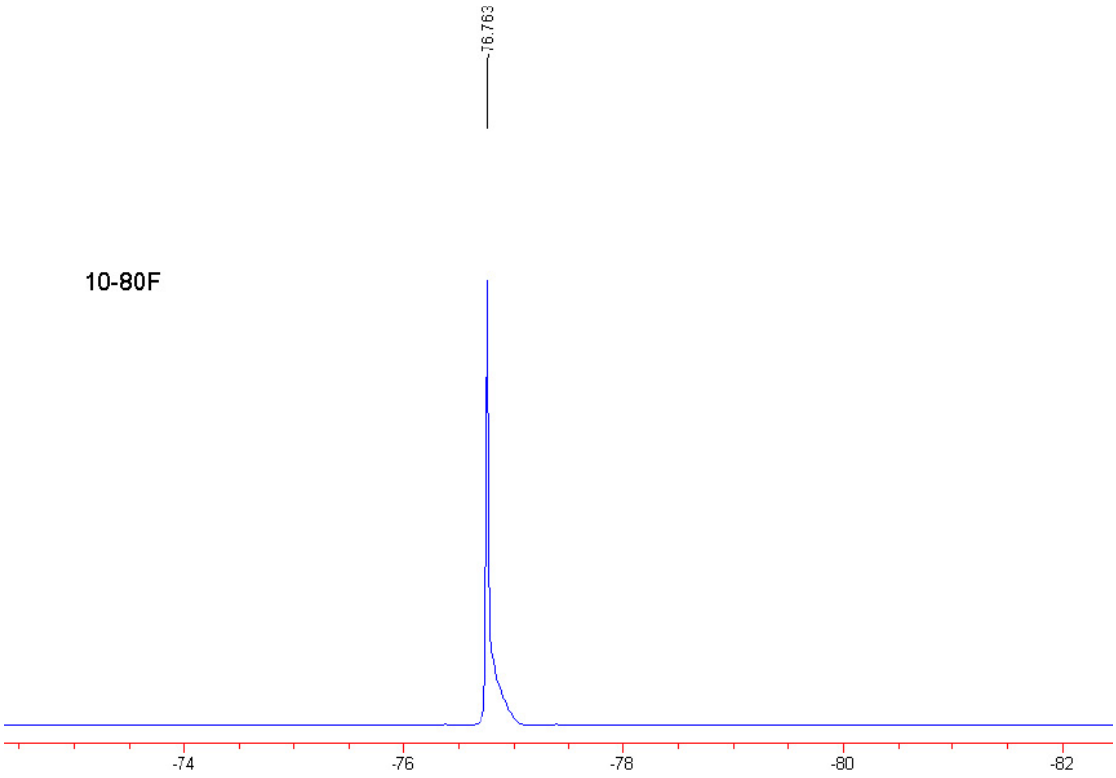


(*E*)-2-methyl-*N*-(1,1,1-trifluoro-2-(nitromethyl)dodec-3-en-2-yl)propane-2-sulfinamide (2e)

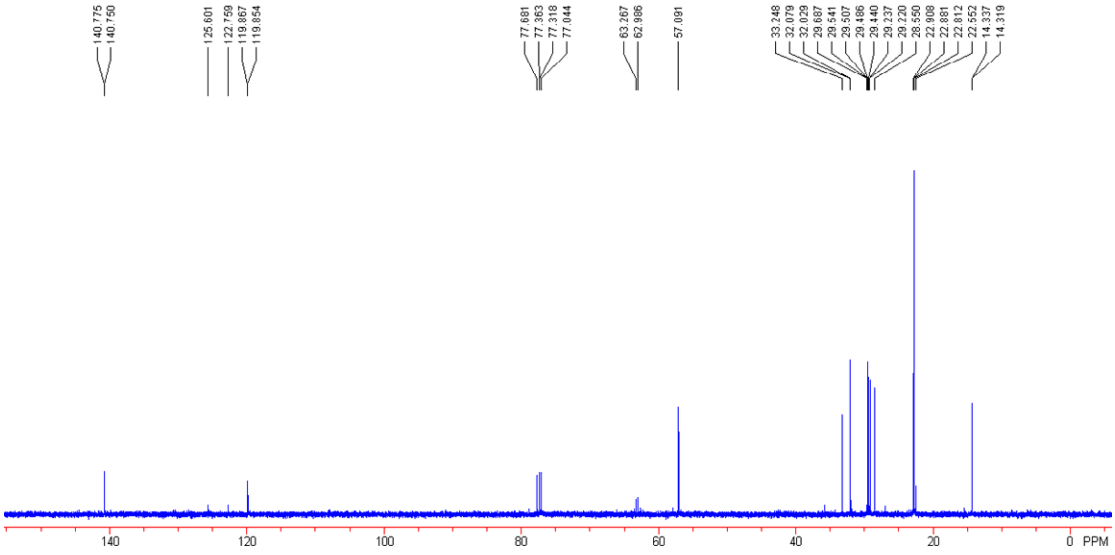
^{1}H NMR



^{19}F NMR

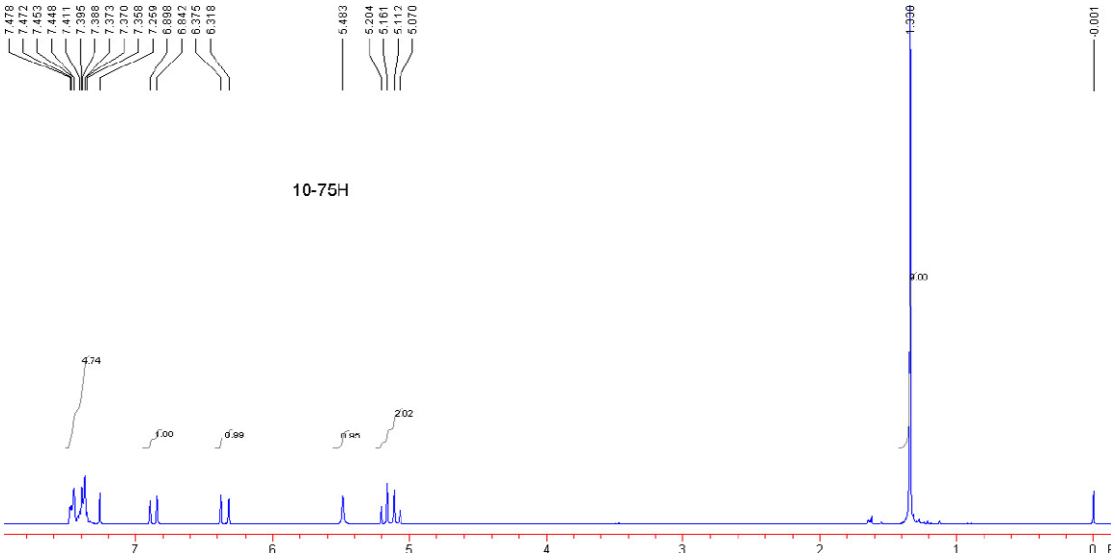


^{13}C NMR

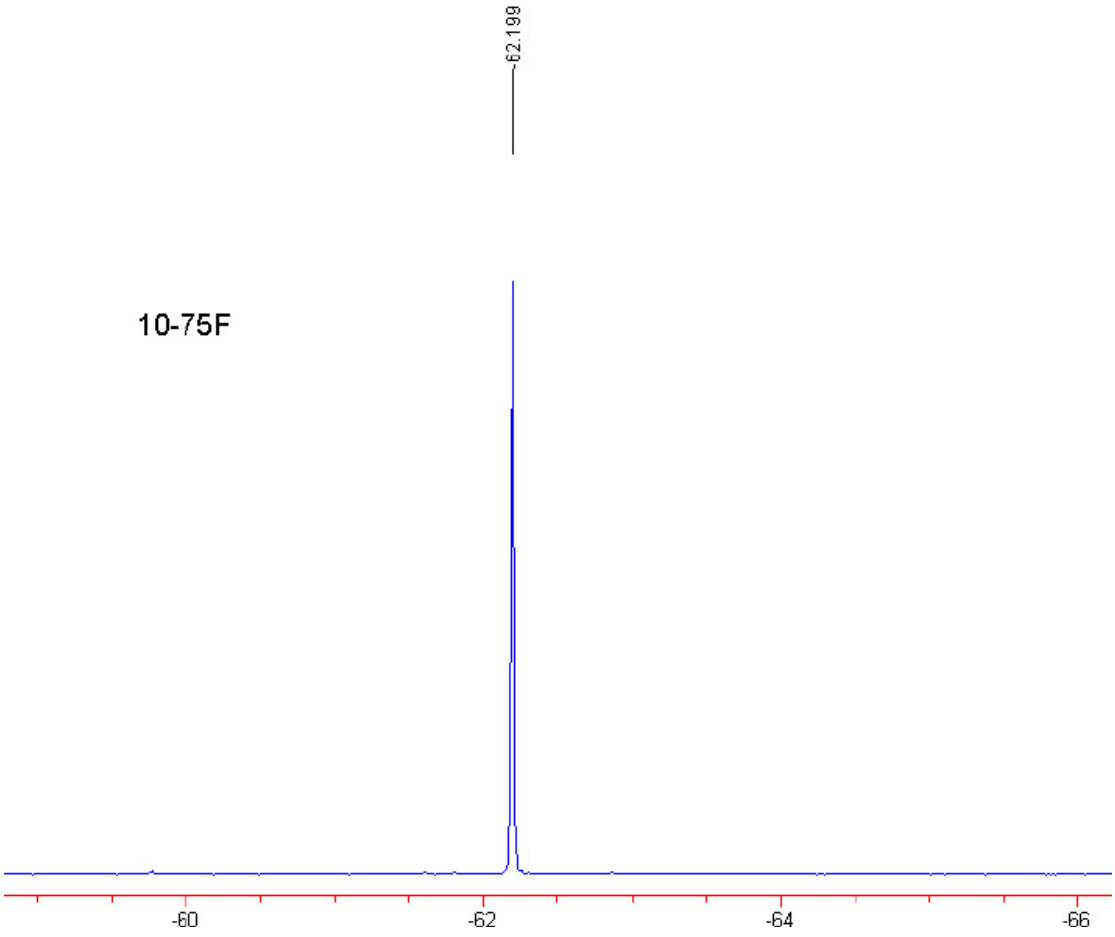


(*E*)-*N*-(1-chloro-1,1-difluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)-2-methylpropane-2-sulfinamide (2f)

^{1}H NMR

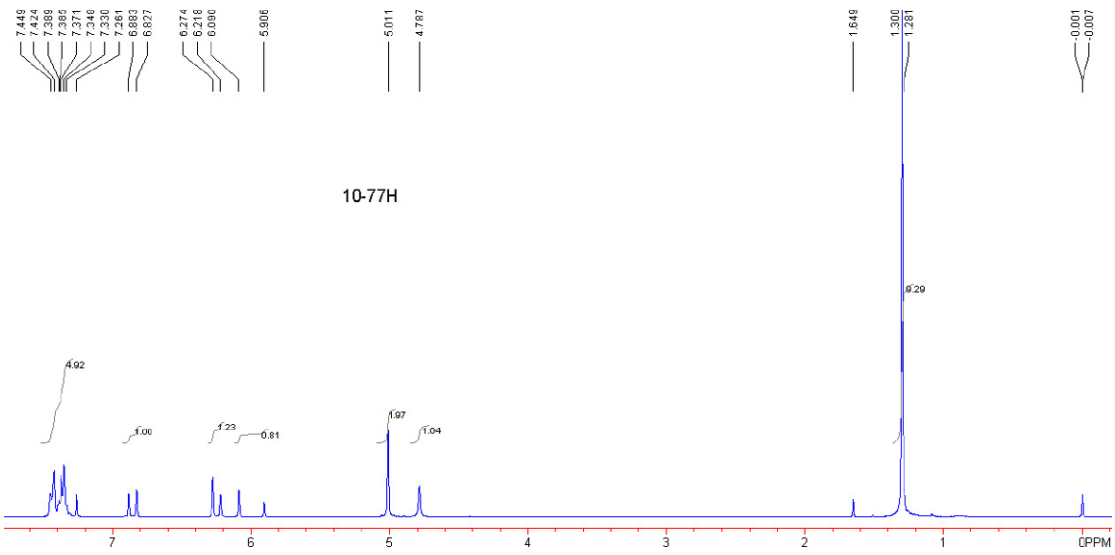


^{19}F NMR

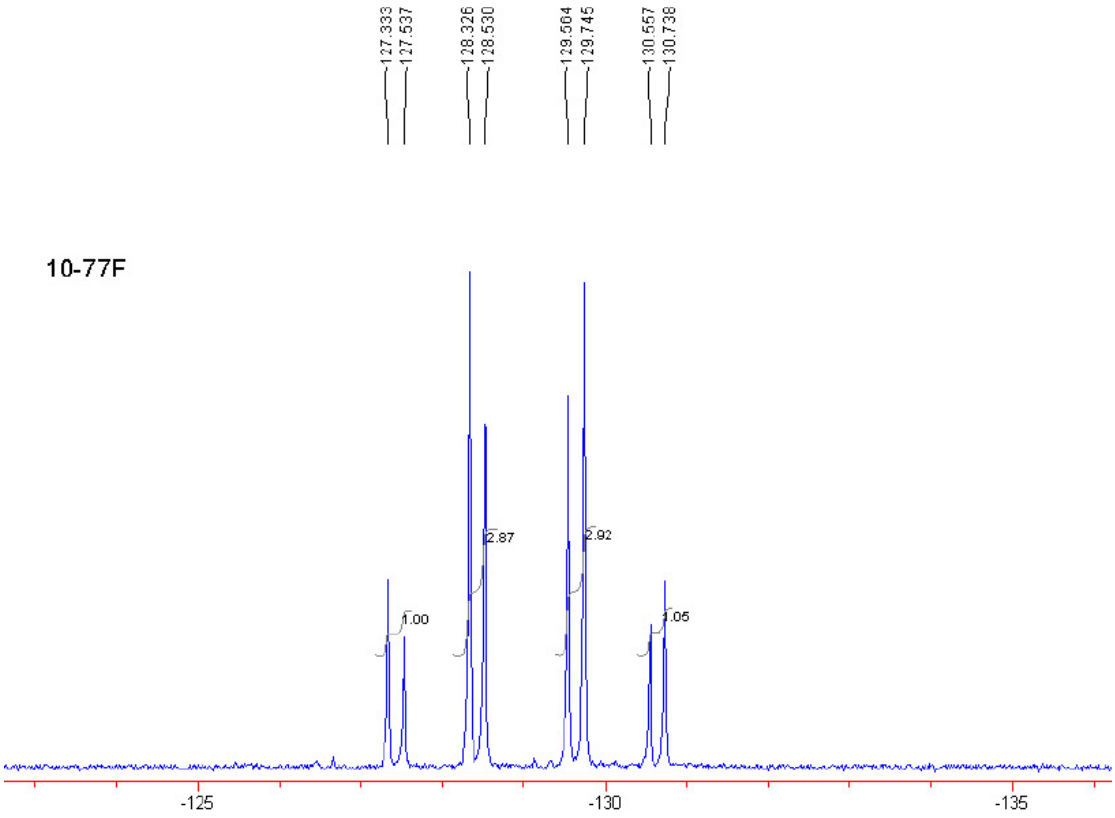


(*E*)-*N*-(1,1-difluoro-2-(nitromethyl)-4-phenylbut-3-en-2-yl)-2-methylpropane-2-sulfinamide (2g)

^{1}H NMR

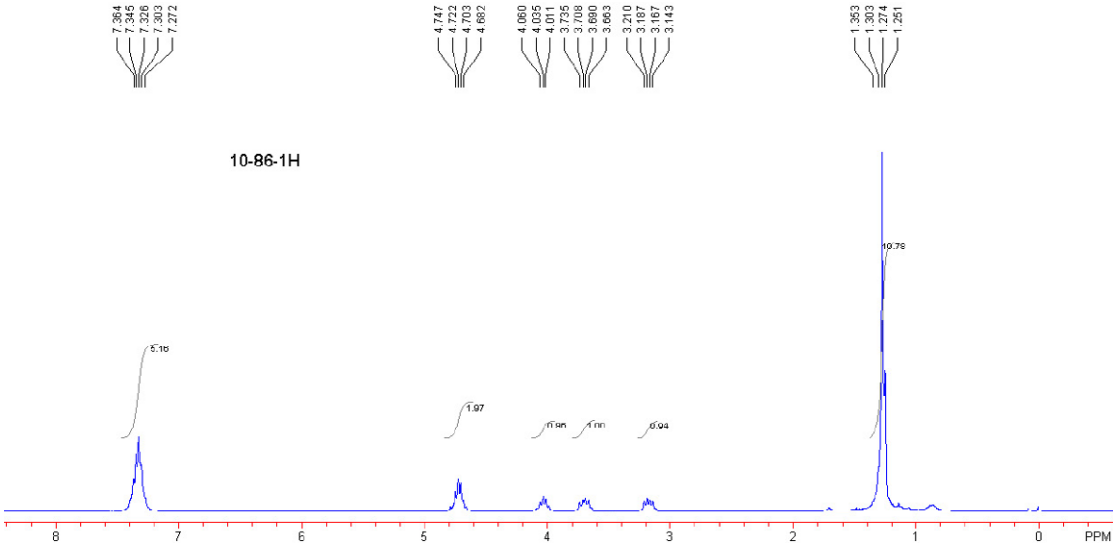


^{19}F NMR

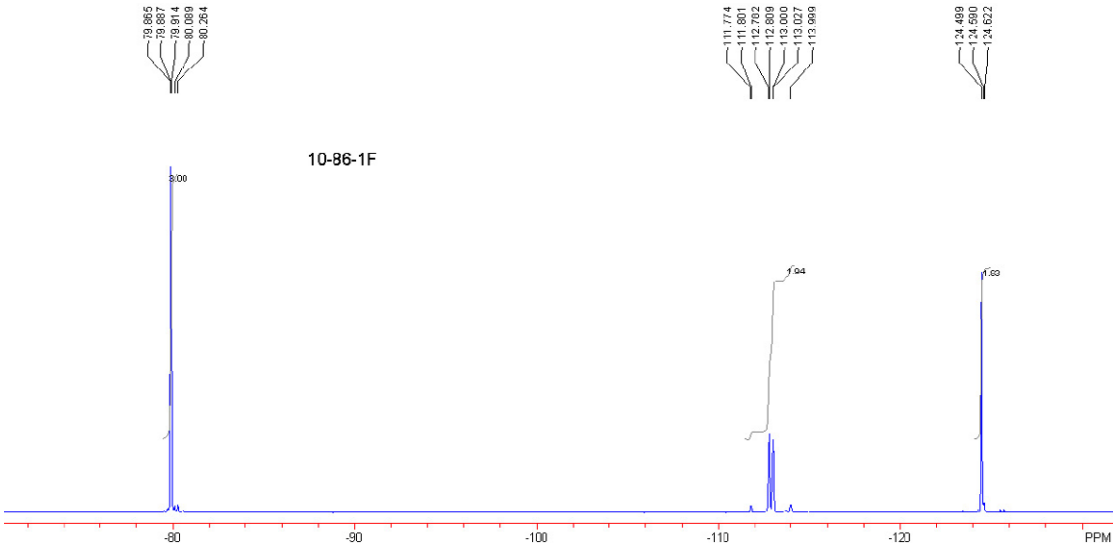


(*R*)-*N*-(1,1,1,2,2,3,3-heptafluoro-7-nitro-6-phenylheptan-4-ylidene)-2-methylpropane-2-sulfinamide (2h-1)

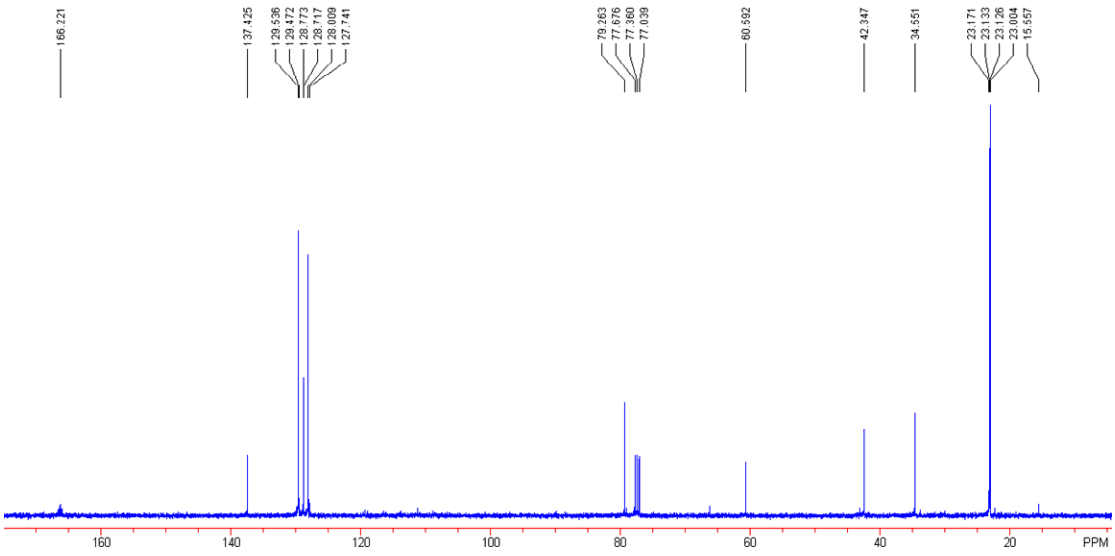
^{1}H NMR



^{19}F NMR

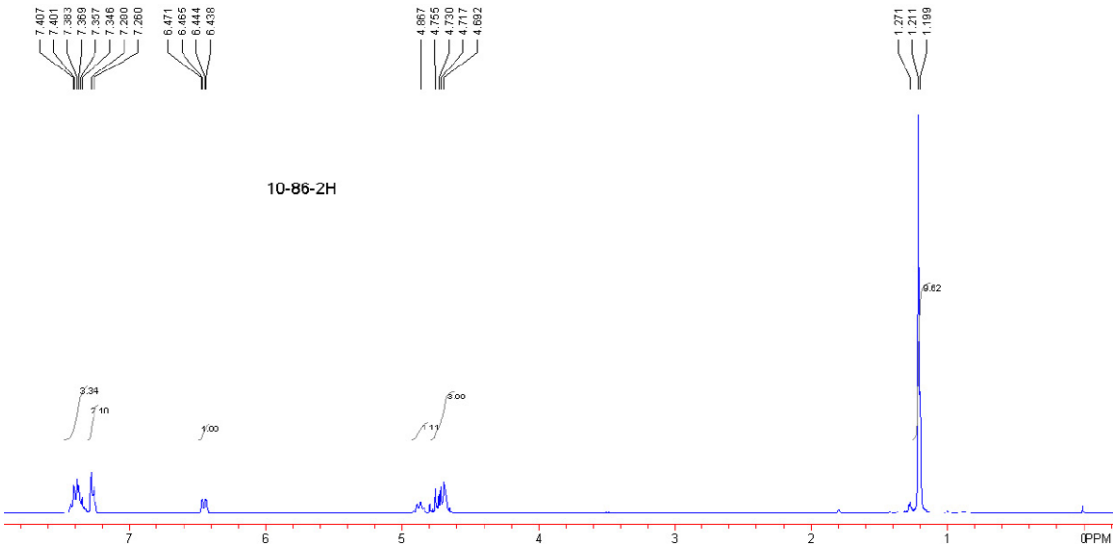


^{13}C NMR

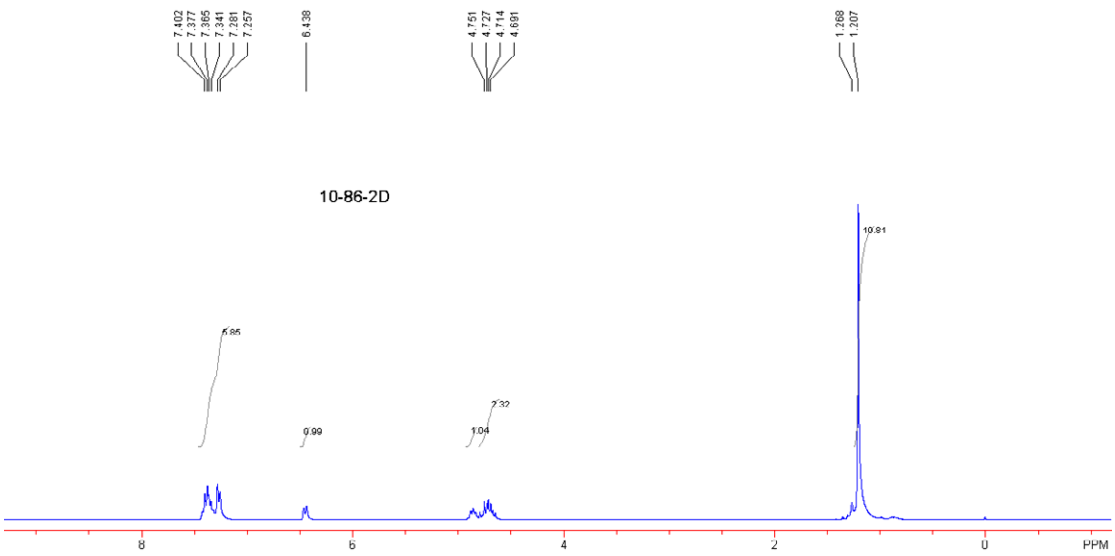


(*R*)-2-methyl-*N*-((*Z*)-1,1,1-trifluoro-5-nitro-4-phenylpent-2-en-2-yl)propane-2-sulfinamide (2h-2)

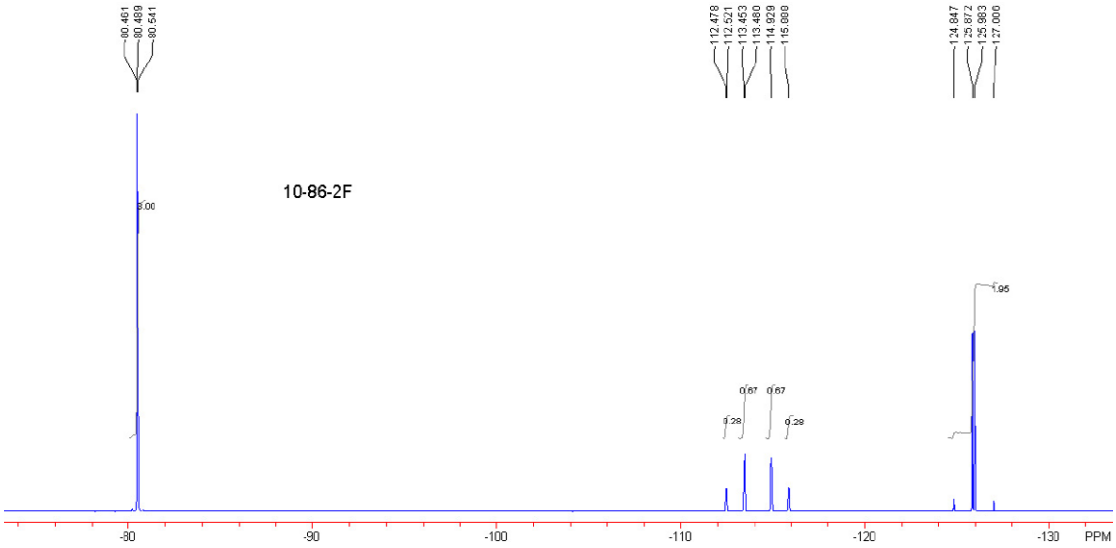
^{1}H NMR



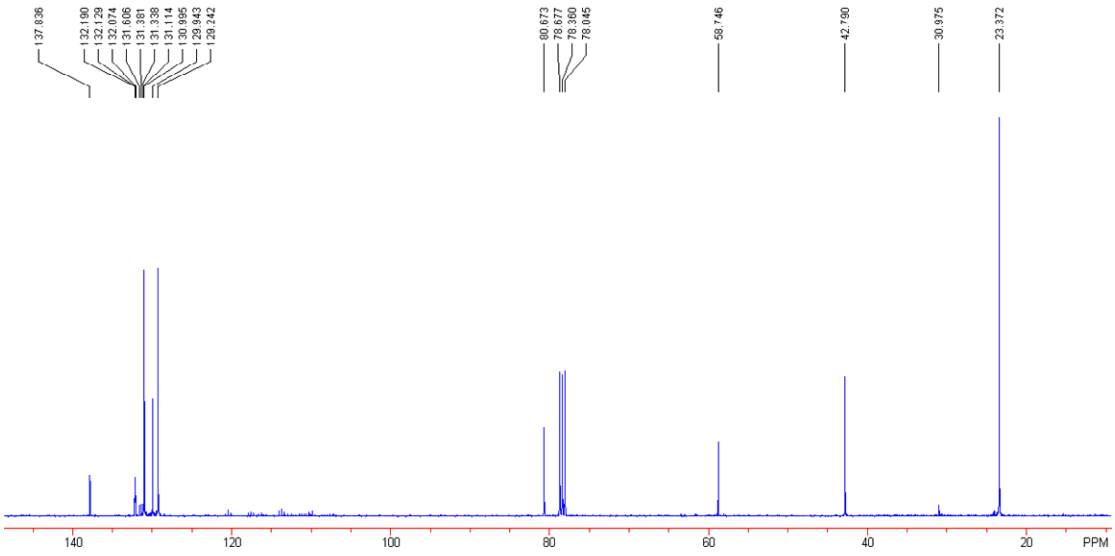
^{1}H NMR (after D_2O exchanging)



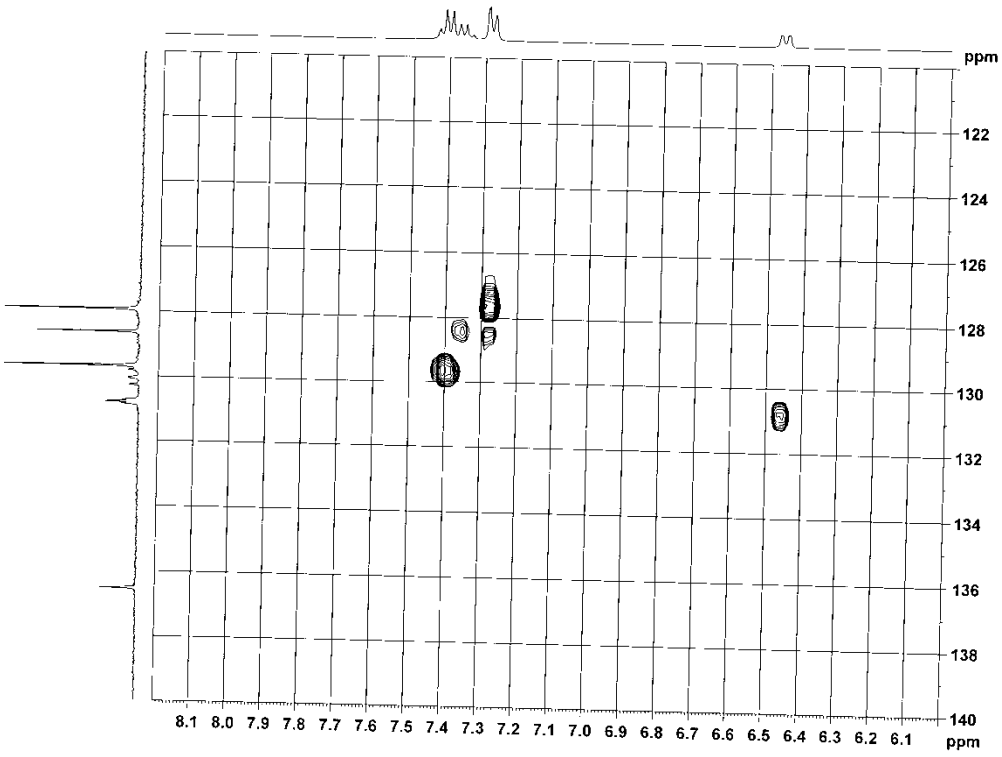
^{19}F NMR

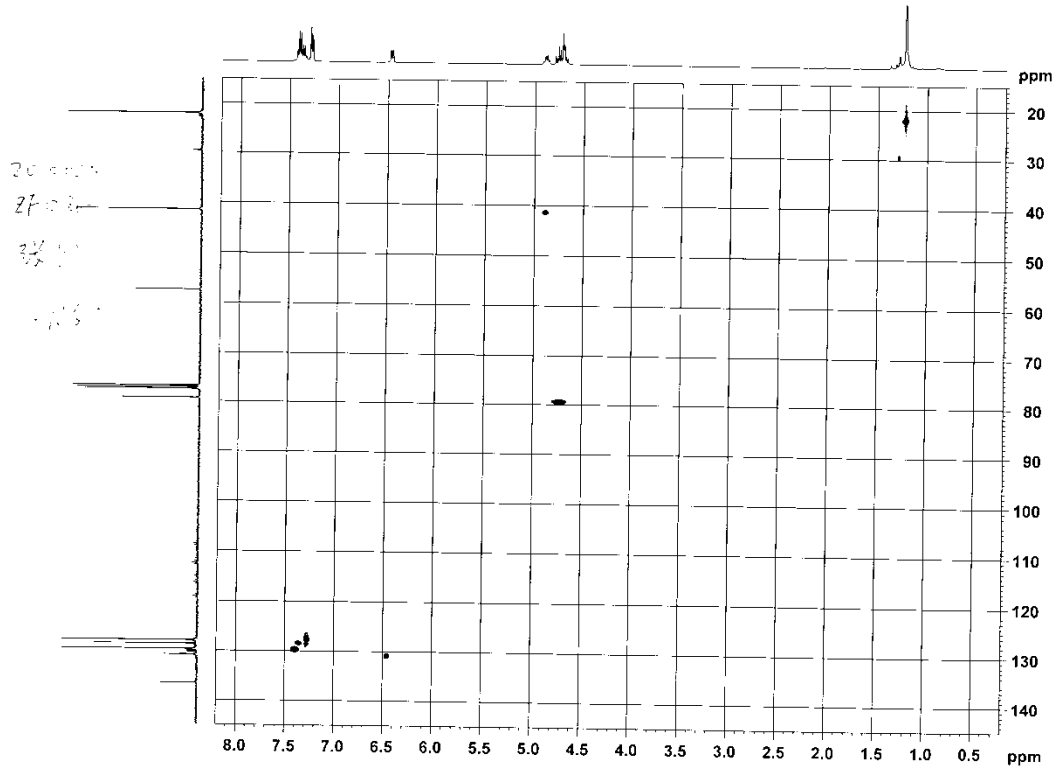


^{13}C NMR


137.836
132.190
132.129
132.074
131.606
131.381
131.338
131.114
130.995
129.943
129.242
80.673
78.677
78.360
78.045
58.746
42.790
30.975
23.372
140
120
100
80
60
40
20
PPM

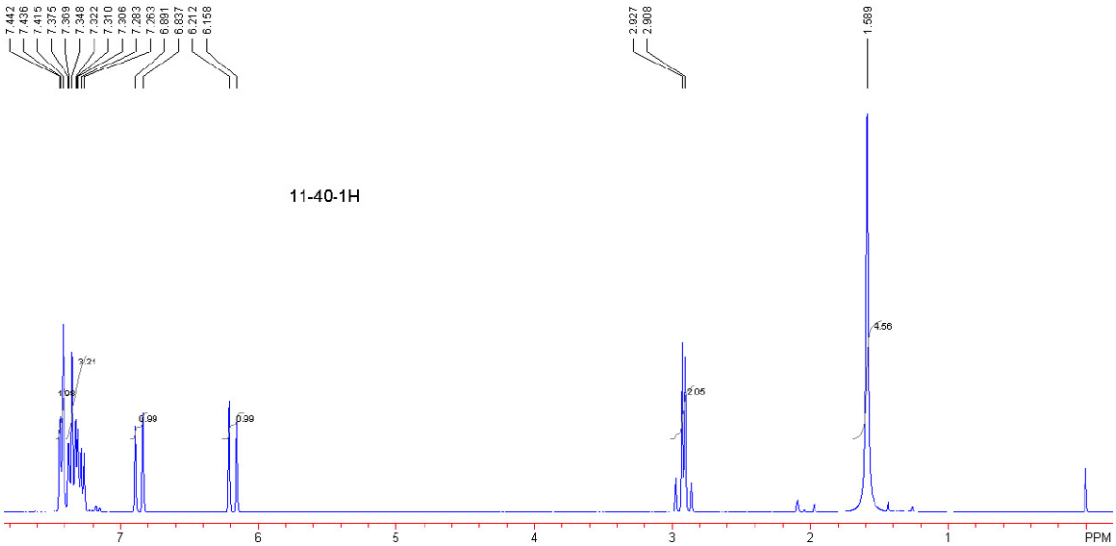
HMQC


ppm
122
124
126
128
130
132
134
136
138
140
8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6 6.5 6.4 6.3 6.2 6.1
ppm

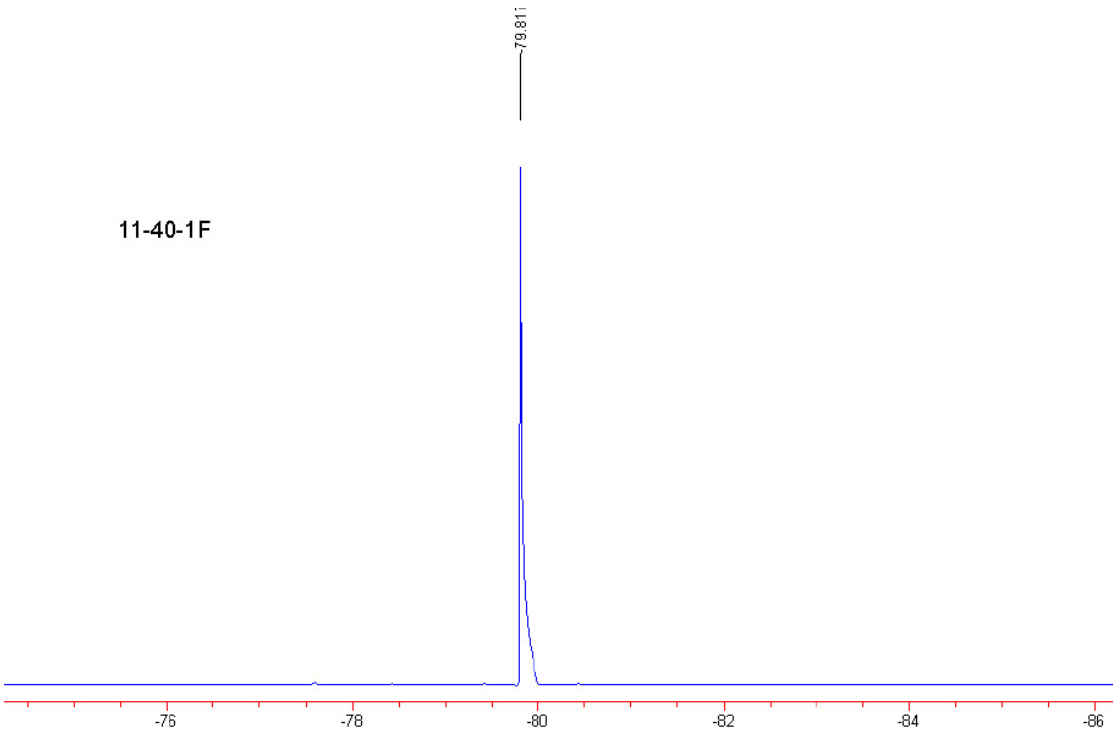


(*S*, *E*)-4-phenyl-2-(trifluoromethyl)but-3-ene-1,2-diamine 4a

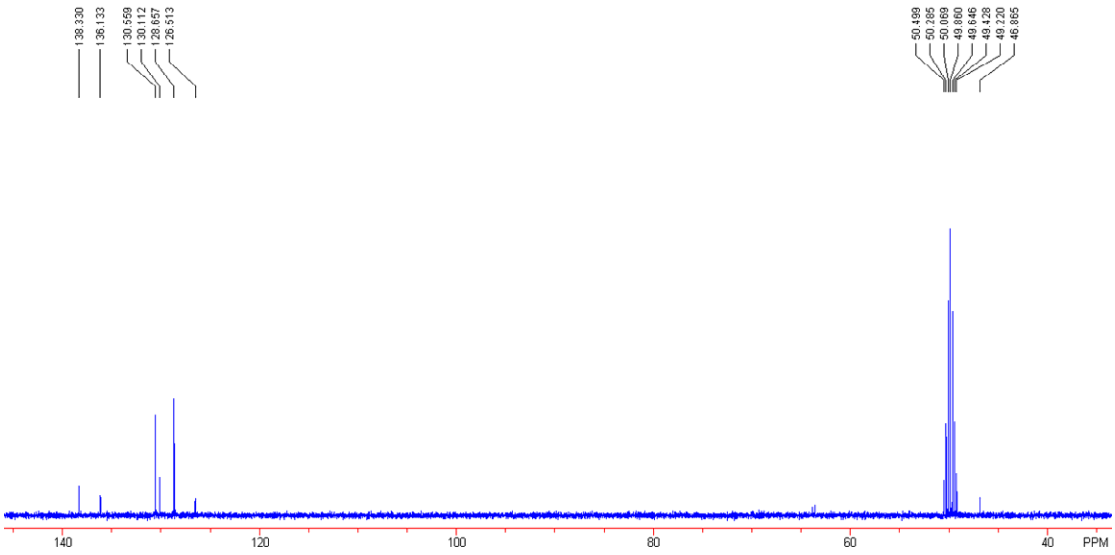
^{1}H NMR



^{19}F NMR

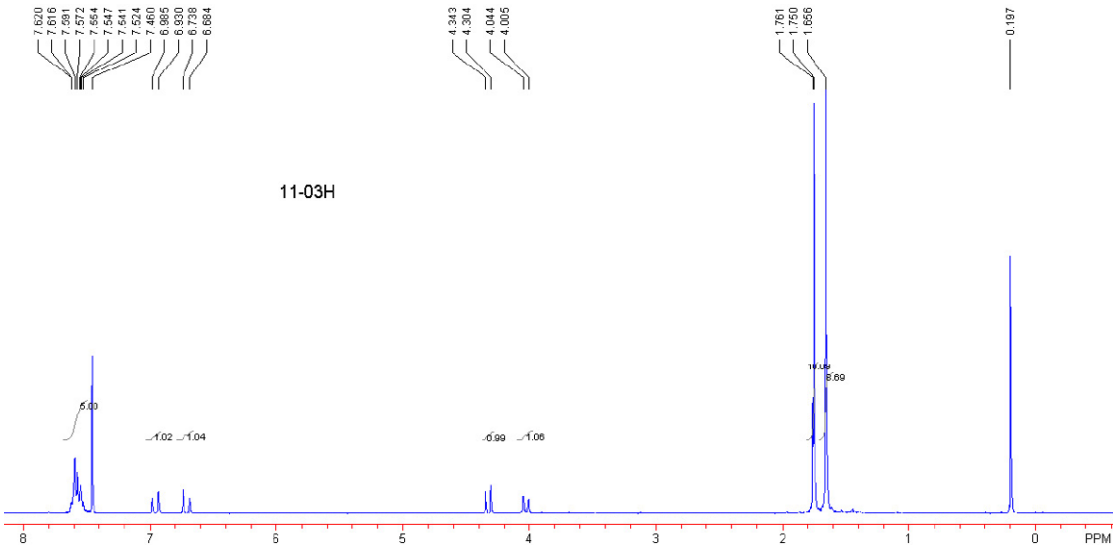


^{13}C NMR

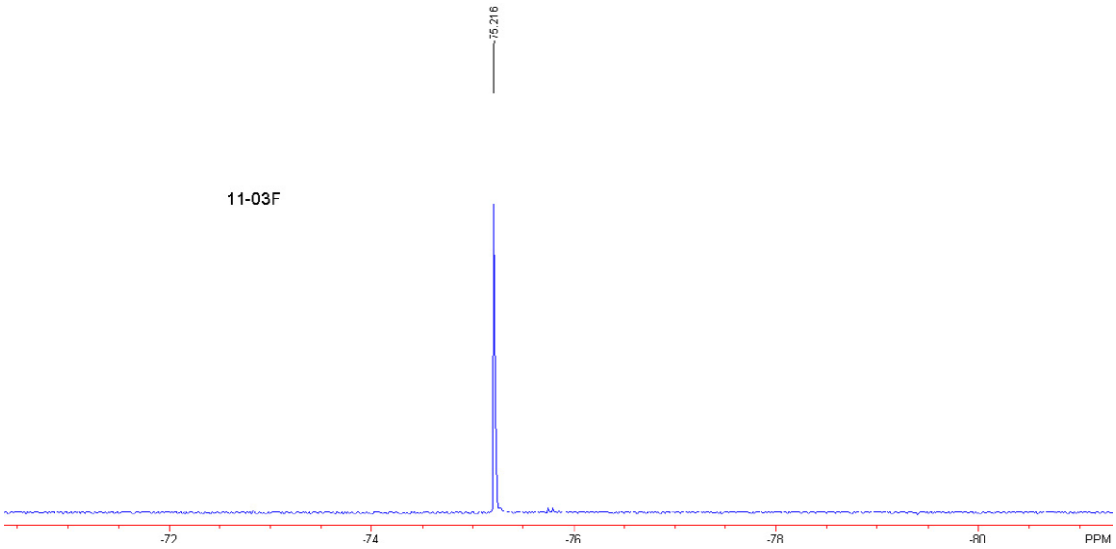


(*S, E*)-di-*tert*-butyl 4-phenyl-2-(trifluoromethyl)but-3-ene-1,2-diyldicarbamate (5a)

^{1}H NMR

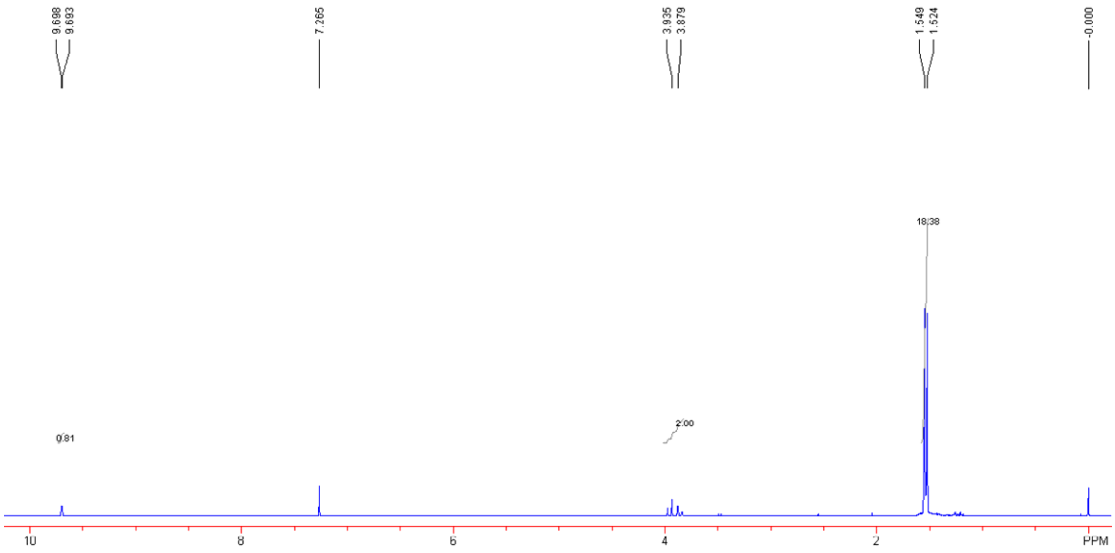


^{19}F NMR

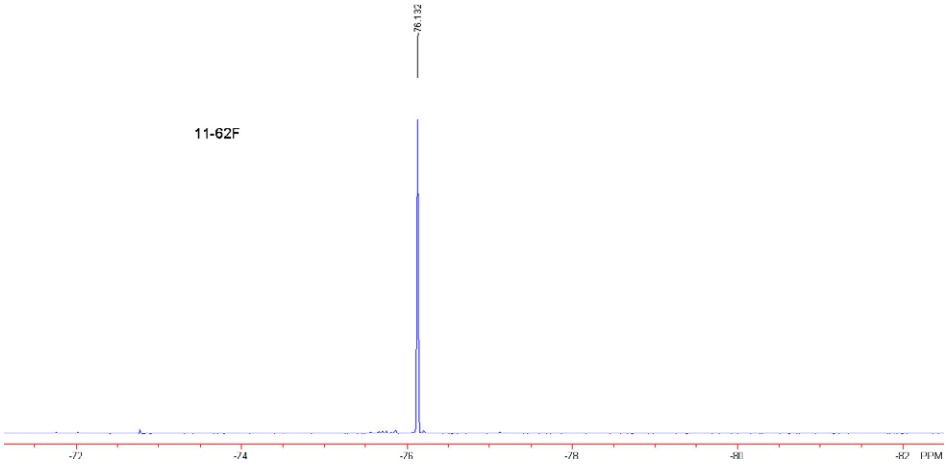


(*R*)-di-tert-butyl 3,3,3-trifluoro-2-formylpropane-1,2-diyldicarbamate (6a)

^{1}H NMR

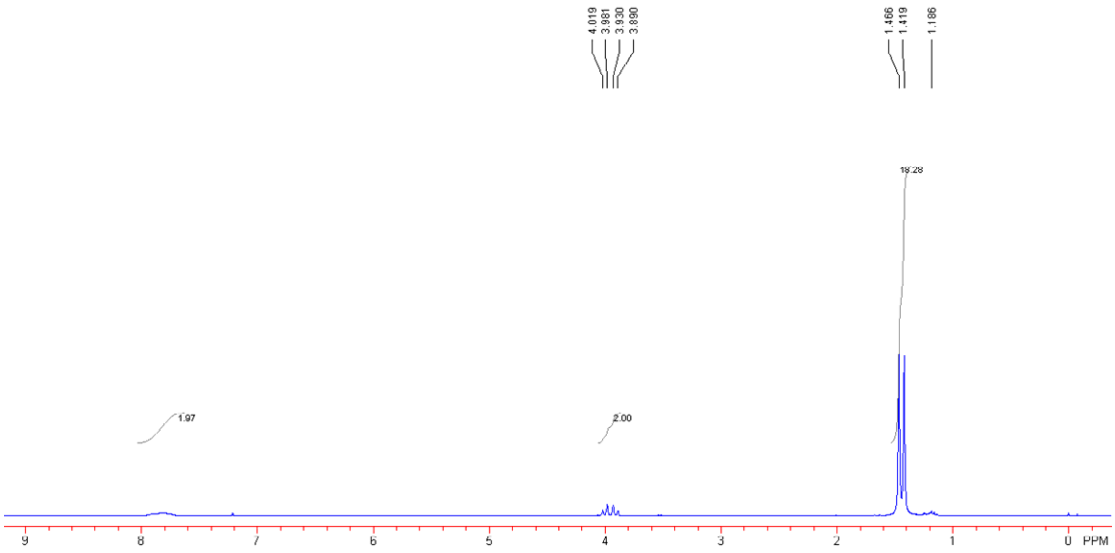


^{19}F NMR

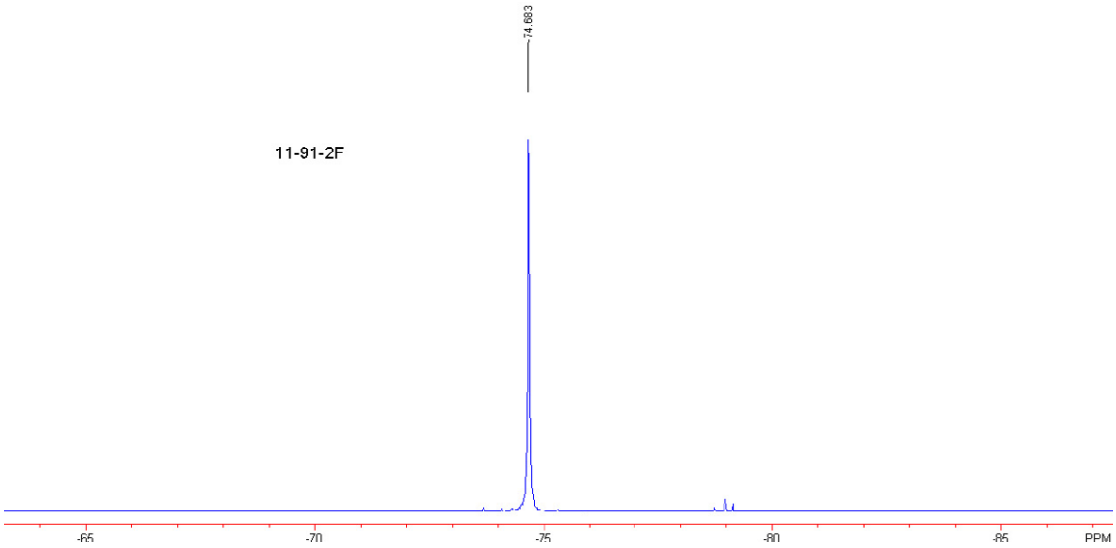


(*R*)-2-(tert-butoxycarbonylamino)-2-((tert-butoxycarbonylamino)methyl)-3,3,3-trifluoropropanoic acid (7a)

^{1}H NMR

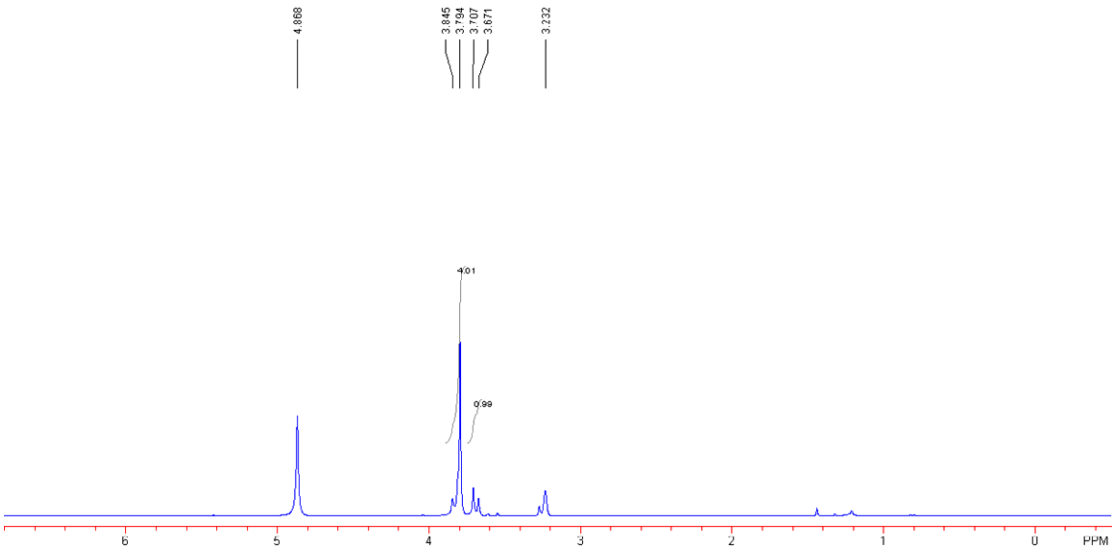


^{19}F NMR

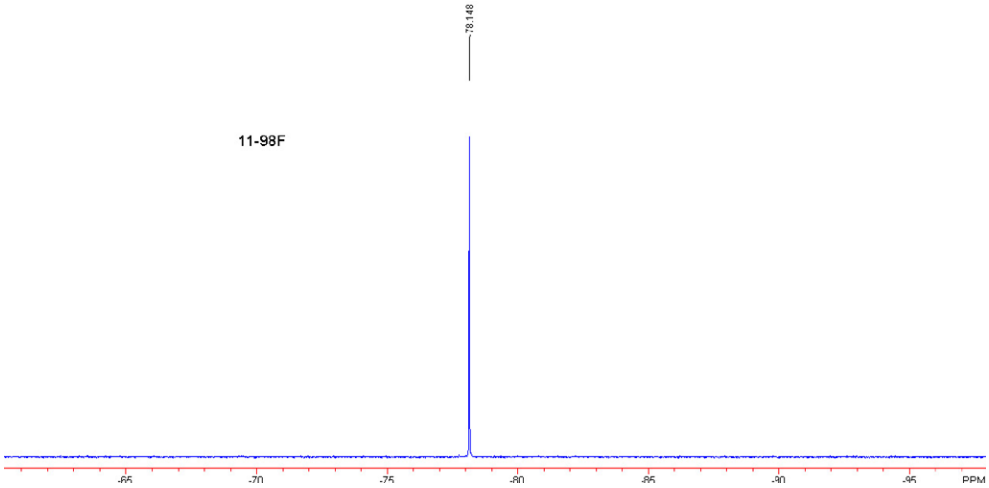


(*R*)-methyl 2-amino-2-(aminomethyl)-3,3,3-trifluoropropanoate (8a)

^{1}H NMR



^{19}F NMR



^{13}C NMR