



Supporting Information

for

Phenylseleno trifluoromethoxylation of alkenes

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Additional experimental and analytical data and NMR spectra

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General information

All reactions were carried out in a sealed vial under a nitrogen atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. Acetonitrile (MeCN, 99.8%, anhydrous in a Sure/Seal™ bottle), dimethylformamide (DMF anhydrous, >99.8%), and toluene (THF anhydrous, >99.9%, inhibitor free) were purchased from Merck Sigma Aldrich.

Reagents and solvents were purchased at commercial quality available and used without further purification, unless otherwise stated.

Thin-layer chromatography analyses were realized using ALUGRAM SIL G/UV254, 0.20 mm on an aluminium support (Macherey-Nagel) and revealed with UV irradiation (254 nm). Flash chromatography purifications were made with Silica 60M, 0.04–0.063 mm supplied from Macherey-Nagel Kieselgel.

NMR spectra were recorded on a Bruker AV 500 spectrometer at 500 MHz (¹H NMR), 126 MHz (¹³C NMR), 471 MHz (¹⁹F NMR), 95 MHz (⁷⁷Se), on a Jeol ECZ400 spectrometer at 400 MHz (¹H NMR), 101 MHz (¹³C NMR), 376 MHz (¹⁹F NMR), 76 MHz (⁷⁷Se), or on a Bruker AV 300 spectrometer at 300 MHz (¹H NMR), 282 MHz (¹⁹F NMR). Coupling constants (*J*) are reported in hertz (Hz), and the following abbreviations were used to designate multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, m = multiplet, br = broad.

¹³C NMR spectra and ⁷⁷Se NMR spectra were recorded with complete proton decoupling. Chemical shifts for ¹H and ¹³C are reported in ppm from tetramethylsilane. Chemical shifts for ¹⁹F NMR spectra are recorded in ppm from CCl₃.

Assignments of NMR signals were made by homonuclear (COSY) and heteronuclear (HSQC, HMBC, and ¹⁹F gc2HSQC) two-dimensional correlation spectroscopy

Melting points were determined using a Kofler bench apparatus (calibration substances were specified).

HRMS measurements were performed on a Bruker MicrOTOFQ II (electrospray ionization, ESI) and an Agilent 7200 GC/Q-TOF (electron ionization, EI) mass spectrometers.

Caution: Reactions involving **DNTFB** (2,4-dinitro-1-(trifluoromethoxy)benzene) may generate difluorophosgene, which is a very toxic gas. As such, reactions must be carried out in a well-ventilated fume hood.

General procedures

Procedure A

In a 10 mL vial, **DNTFB** (160 µL, 1 mmol, 2 equiv) was added in one portion into a stirred solution of **DMAP** (119 mg, 0.975 mmol, 1.95 equiv) in anhydrous MeCN (1.5 mL). The vial is closed and the reaction is stirred in an ice bath for 15 minutes (of note, the reaction quickly becomes orange after **DNTFB** addition and quickly turns yellow). Then, the tube was opened and **PhSeBr** (118 mg, 0.5 mmol, 1 equiv) is added in one portion. The reaction mixture is stirred in the same ice bath for 15 minutes. Then, the tube is opened and the alkene **1** is added (0.5 mmol, 1 equiv). The reaction mixture is stirred at room temperature for 2.5 h (unless otherwise stated). Of note, a yellowish precipitate was formed during the reaction for high-yielding substrates. The yield of the reaction was determined by ¹⁹F NMR using trifluoromethylbenzene as an internal standard. After the end of the reaction, the content of the vial is transferred to a separatory funnel and 10 mL of water are added. The aqueous layer is extracted three times with 10 mL of diethyl ether. The organic layers are combined and washed with 10 mL of water. The organic layer is dried using MgSO₄, filtered, and then concentrated under vacuum. Two different purification processes can be used to get the pure compounds. Compounds **2** are obtained after purification.

Purification of compounds 2 on alumina

For the purification process, a mix of 3.5 mL pentane and 0.5 mL DCM is added to the crude in a flask (an ultrasonic bath can be used to obtain a homogenous solution). The mix is collected using a syringe. The needle of the syringe is removed, and the syringe is fixed to an aluminium oxide cartridge (Waters Sep-Pak Alumina B Plus Long Cartridge) for filtration. The crude flask is rinsed using 4 mL pentane and the same process is repeated using the same cartridge. The filtrate obtained is concentrated under vacuum. The isolated compound is stored under nitrogen in a fridge.

Purification of compounds 2 on silica

Before the flash chromatography, the silica underwent a basic treatment. In a large beaker, a suspension of silica in diethyl ether is prepared. Then, Et₃N is added to the beaker (about 5% of the volume of diethyl ether) and the mixture is stirred for approximately 2 hours. The silica is then filtered and washed abundantly with diethyl ether. The silica is then dried and can be easily stored and used for future flash chromatography.

Procedure B

In a 10 mL vial, compound **2** (mixture of regioisomers, 0.3 mmol, 1 equiv) is dissolved in anhydrous toluene (1.5 mL). The reaction vial is flushed with N₂ and degassed. AIBN (10 mg, 0.06 mmol, 0.2 equiv) and (TMS)₃SiH (95 μ L, 0.3 mmol, 1 equiv) are added to the vial. The reaction mixture is stirred at 80 °C for 2.5 h. The yield of the reaction was determined by ¹⁹F NMR using trifluoromethylbenzene as an internal standard. For non-volatile compounds (**5k** and **5l**), water (10 mL) is added to the vial and the reaction mixture is transferred to a separatory funnel. The aqueous layer is extracted with diethyl ether (3 $\times$ 10 mL). The organic layers are combined, dried using MgSO₄, filtered, and concentrated under vacuum. The crude mixture is purified by flash chromatography.

Procedure C: preparation of the clofibrate derivative 1k

The clofibrate derivative was prepared according to a procedure described in the literature^[1]. Allyl bromide (2.8 mL, 32 mmol, 8 equiv) was slowly added to a solution of clofibric acid (854 mg, 4 mmol, 1 equiv) and NaHCO₃ (1.3 g, 16 mmol, 4 equiv) in dry DMF. The reaction mixture was stirred at room temperature for 24 h. The mixture was then washed with water and extracted three times with DCM. The organic layers were combined, dried using MgSO₄, filtered, and concentrated under vacuum.

Procedure D: preparation of the estrone derivative 1l

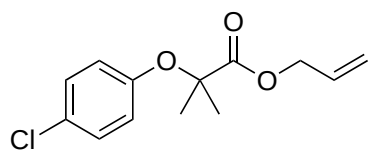
The estrone derivative was prepared according to a procedure described in the literature^[2]. Estrone (811 mg, 3 mmol, 1 equiv) was dissolved in 45 mL of acetone. Then, allyl bromide (520 μ L, 6 mmol, 2 equiv) and K₂CO₃ (2.9 g, 21 mmol, 7 equiv) are added under stirring. The reaction mixture was stirred at 50 °C for 48 h. The acetone is evaporated under vacuum. Water is added and the aqueous layer is extracted three times with DCM. The organic layers were combined, dried with MgSO₄, filtered, and concentrated under vacuum. The crude product is purified by flash chromatography.

Procedure E

In a 10 mL vial, compound **2a** (135 mg, 0.39 mmol, 1 equiv) is dissolved in anhydrous DCM (0.5 mL). Then, trifluoroacetic acid (40 μ L, 0.52 mmol, 1.3 equiv) is added and the mixture is stirred at room temperature for 16 h and analyzed by ¹⁹F NMR with PhCF₃ as an internal standard. The mixture is then concentrated under vacuum using a rotary evaporator. The resulting product was analyzed by ¹⁹F NMR and by ¹H NMR. Compound **4a** was obtained in accordance with literature data.^[3]

Products characterization

Allyl 2-(4-chlorophenoxy)-2-methylpropanoate (1k)



Procedure C

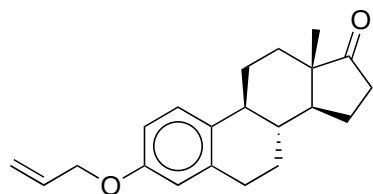
Light-yellow liquid, 696 mg, 68%

^1H NMR (300 MHz, CDCl_3) δ 7.19 (m, 2H), 6.79 (m, 2H), 5.87 (m, 1H), 5.28 (m, 2H), 4.66 (dt, $J_{\text{H-H}} = 5.8, 5.8, 1.4$ Hz, 2H), 1.59 (s, 6H).

^{13}C NMR (101 MHz, CDCl_3) δ 173.68, 154.05, 131.52, 129.20, 127.42, 120.81, 119.11, 79.64, 66.07, 25.40.

HRMS (ESI): Calc. for $[\text{M}+\text{Na}^+]$ $\text{C}_{13}\text{H}_{15}\text{ClNaO}_3$: 277.0602, measured : 277.0607

(8R,9S,13S,14S)-3-(Allyloxy)-13-methyl-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (1l)



Procedure D

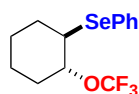
White solid, 747 mg, 80%

Eluant for flash chromatography: 100%DCM

^1H NMR (300 MHz, CDCl_3) δ 7.20 (dd, $J_{\text{H-H}} = 8.6$ Hz, 1.1 Hz, 1H), 6.73 (dd, $J_{\text{H-H}} = 8.6$ Hz, 2.8 Hz, 1H), 6.66 (dd, $J_{\text{H-H}} = 2.7$ Hz, 1.1 Hz, 1H), 6.05 (ddt, $J_{\text{H-H}} = 17.3, 10.5, 5.3$ Hz, 1H), 5.40 (ddt, $J_{\text{H-H}} = 17.3$ Hz, 1.6 Hz, 1.6 Hz, 1H), 5.27 (ddt, $J_{\text{H-H}} = 10.5$ Hz, 1.6 Hz, 1.6 Hz, 1H), 4.51 (dt, $J_{\text{H-H}} = 5.3$ Hz, 1.6 Hz, 2H), 3.01 – 2.84 (massif, 2H), 2.62 – 1.91 (massif, 7H), 1.75 – 1.34 (massif, 6H), 0.91 (s, 3H).

The results are in accordance with the literature^[2]

Phenyl(2-(trifluoromethoxy)cyclohexyl)selane (2a)



Procedure A

Purification on alumina

Light-yellow oil, 136 mg, 85%

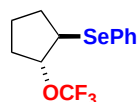
^{19}F NMR (376 MHz, CDCl_3) δ -57.35 (s).

^1H NMR (300 MHz, CDCl_3) δ 7.58 (m, 2H), 7.35 – 7.24 (massif, 3H), 4.31 (ddd, $J_{\text{H-H}} = 7.3, 7.3, 3.6$ Hz, 1H), 3.37 (ddd, $J_{\text{H-H}} = 7.3, 7.3, 4.1$ Hz, 1H), 2.20 – 2.16 (massif, 2H), 1.82 – 1.52 (massif, 4H), 1.50 – 1.33 (massif, 2H).

^{13}C NMR (101 MHz, CDCl_3) δ 134.81, 129.11, 128.53, 127.85, 121.60 (q, $J_{\text{C-F}} = 254.6$ Hz, Cq), 79.49, 45.31, 30.37, 30.29, 24.04, 22.10.

HRMS (EI): calc. for $[\text{M}^+]$ $[\text{C}_{13}\text{H}_{15}\text{F}_3\text{OSe}]$: 324.0235, measured 324.0221

Phenyl(2-(trifluoromethoxy)cyclopentyl)selane (2b)



Procedure A

Purification on alumina

Light-yellow oil, 116 mg, 74%

^{19}F NMR (376 MHz, CDCl_3) δ -58.01 (s).

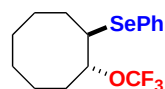
^1H NMR (300 MHz, CDCl_3) δ 7.56 (m, 2H), 7.36 – 7.27 (massif, 3H), 4.64 (ddd, $J_{\text{H-H}} = 5.3, 2.3, 2.3$ Hz, 1H), 3.74 (m, 1H), 2.34 – 2.13 (massif, 2H), 1.90 – 1.62 (massif, 4H).

^{13}C NMR (101 MHz, CDCl_3) δ 134.3, 129.34, 128.88, 128.02, 121.50 (q, $J_{\text{C-F}} = 255.1$ Hz), 85.81 (q, $J_{\text{C-F}} = 2.2$ Hz), 46.14, 31.21, 30.69, 22.64.

^{77}Se NMR (76 MHz, CDCl_3) δ 366.51 (s).

HRMS (EI): calc. for $[\text{M}^+]$ $[\text{C}_{12}\text{H}_{13}\text{F}_3\text{OSe}]$: 310.0079, measured 310.0079

Phenyl(2-(trifluoromethoxy)cyclooctyl)selane (2c)



Procedure A

Purification on treated silica

Eluent for flash chromatography: 100% pentane

Light-yellow oil, 36 mg, 20% (24h)

^{19}F NMR (376 MHz, CDCl_3) δ -57.38 (s).

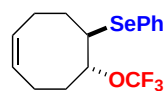
^1H NMR (300 MHz, CDCl_3) δ 7.55 (m, 2H), 7.28 – 7.22 (massif, 3H), 4.48 (ddd, $J_{\text{H-H}} = 8.7, 6.4, 2.5$ Hz, 1H), 3.51 (ddd, $J_{\text{H-H}} = 8.7, 7.9, 2.6$ Hz, 1H), 2.20 – 1.93 (massif, 3H), 1.87 – 1.30 (massif, 9H).

^{13}C NMR (101 MHz, CDCl_3) δ 134.93, 129.49, 129.19, 127.85, 121.67 (q, $J_{\text{C-F}} = 255.0$ Hz), 83.13 (q, $J_{\text{C-F}} = 1.8$ Hz), 48.71, 30.78, 28.77, 26.19, 25.98, 25.68, 23.92.

^{77}Se NMR (76 MHz, CDCl_3) δ 386.46.

HRMS (APCI): Calc. for $[\text{M}^+]$ $[\text{C}_{15}\text{H}_{19}\text{F}_3\text{OSe}]$: 352.0548, measured: 352.0550

Phenyl(Z)-8-(trifluoromethoxy)cyclooct-4-en-1-yl)selane (2d)



Procedure A

Purification on alumina

Light-yellow oil, 120 mg, 70%

^{19}F NMR (376 MHz, CDCl_3) δ -57.98 (s).

^1H NMR (300 MHz, CDCl_3) δ 7.55 (m, 2H), 7.32 – 7.24 (massif, 3H), 5.79 – 5.63 (massif, 2H), 4.60 (ddd, $J_{\text{H-H}} = 8.3, 6.6, 3.1$ Hz, 1H), 3.72 (ddd, $J_{\text{H-H}} = 8.3, 8.3, 3.4$ Hz, 1H), 2.48 – 2.13 (massif, 6H), 2.10 – 1.93 (massif, 2H).

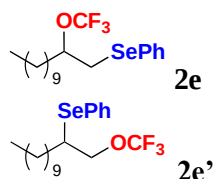
^{13}C NMR (101 MHz, CDCl_3) δ 134.46, 130.51, 130.33, 129.56, 129.27, 127.78, 121.64 (q, $J_{\text{C-F}} = 254.7$ Hz), 81.24 (d, $J_{\text{C-F}} = 2.0$ Hz), 46.90, 33.38, 32.96, 25.14, 22.34.

^{77}Se NMR (76 MHz, CDCl_3) δ 381.00 (q, $J = 5.7$ Hz)

HRMS (ESI): calc. for $[\text{M}+\text{H}^+]$ $[\text{C}_{15}\text{H}_{18}\text{F}_3\text{OSe}]$: 350.0397, measured 350.0472

Phenyl(2-(trifluoromethoxy)dodecyl)selane (2e)

Phenyl(1-(trifluoromethoxy)dodecan-2-yl)selane (2e')



Procedure A

Purification on alumina

Light-yellow oil, 155 mg, 76%, Ratio **2e/2e'**: 83/17 (24h)

^{19}F NMR (376 MHz, CDCl_3) δ -57.65 (s, **2e**, 0.83), -60.30 (s, **2e'**, 0.17).

^1H NMR (400 MHz, CDCl_3) δ 7.58 – 7.49 (massif, 2H), 7.32 – 7.26 (massif, 3H), 4.32 (dddd, $J_{\text{H-H}} = 7.9, 7.9, 4.6, 4.6$ Hz, 0.83H), 4.13 (dd, $J_{\text{H-H}} = 10.0$ Hz, 4.7 Hz, 0.17H), 3.98 (dd, $J_{\text{H-H}} = 10.0$ Hz, 8.9 Hz, 0.17H), 3.28 (dddd, $J_{\text{H-H}} = 8.9, 8.9, 4.7, 4.7$ Hz, 0.17H), 3.20 (dd, $J_{\text{H-H}} = 12.8$ Hz, 4.6 Hz, 0.83H), 3.06 (dd, $J_{\text{H-H}} = 12.8$ Hz, 7.9 Hz, 0.83H), 1.90 – 1.77 (massif, 1H), 1.75 – 1.60 (massif, 1H), 1.34 – 1.18 (massif, 16H), 0.92 – 0.86 (massif, 3H).

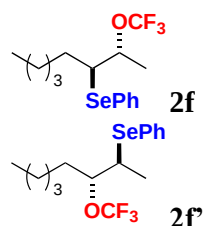
^{13}C NMR (101 MHz, CDCl_3) δ 135.29, 133.18, 129.40, 129.37, 128.29, 127.71, 127.62, 121.76 (q, $J_{\text{C-F}} = 254.8$ Hz), 79.15 (q, $J_{\text{C-F}} = 1.9$ Hz), 70.05 (q, $J_{\text{C-F}} = 3.1$ Hz), 42.91, 33.69, 32.05, 31.57, 31.34, 29.78 – 29.23 (massif), 27.48, 24.69, 22.84, 14.27.

^{77}Se NMR (76 MHz, CDCl_3) δ 337.89 (s, **2e'**, 0.17), 264.44 (s, **2e**, 0.83).

HRMS (EI): calc. for $[\text{M}^+]$ $[\text{C}_{19}\text{H}_{29}\text{F}_3\text{OSe}]$: 410.1331, measured 410.1337

Phenyl(2-(trifluoromethoxy)octan-3-yl)selane (2f)

Phenyl(3-(trifluoromethoxy)octan-2-yl)selane (2f')



Procedure A

Purification on treated silica, eluent for flash chromatography: Pentane

Colorless oil, 125 mg, 69%, Ratio **2f/2f'**: 55/45

^{19}F NMR (376 MHz, CDCl_3) δ -57.00 (s, **2f'**, 0.45), -57.69 (s, **2f**, 0.55).

^1H NMR (300 MHz, CDCl_3) δ 7.65 – 7.53 (massif, 2H), 7.34 – 7.24 (massif, 3H), 4.44 (m, 0.55H), 4.26 (ddd, $J_{\text{H-H}} = 7.1, 5.1, 5.1$ Hz, 0.45H), 3.44 (qd, $J_{\text{H-H}} = 7.1, 4.8$ Hz, 0.45H), 3.17 (ddd, $J_{\text{H-H}} = 9.5, 5.4, 4.1$ Hz, 0.55H), 1.86 – 1.21 (massif, 11H), 0.92–0.86 (massif, 3H).

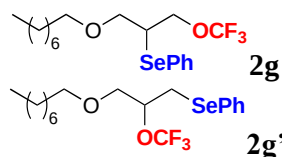
^{13}C NMR (101 MHz, CDCl_3) δ 135.48, 135.15, 129.25, 129.21, 128.70, 128.15, 127.93, 121.79 (q, $J_{\text{C-F}} = 254.4$ Hz), 82.87 (q, $J_{\text{C-F}} = 1.7$ Hz), 78.47 (q, $J_{\text{C-F}} = 2.0$ Hz), 52.06, 42.28, 32.18, 31.60, 31.57, 31.54, 27.71, 24.48, 22.60, 22.57, 18.97, 17.82, 14.12, 14.05.

^{77}Se NMR (95 MHz, CDCl_3) δ 382.70 (s, **2f'**, 0.45), 333.43 (s, **2f**, 0.55).

HRMS (EI): calc. for $[\text{M}^+]$ $[\text{C}_{15}\text{H}_{21}\text{F}_3\text{OSe}]$: 354.0704, measured 354.0685

(1-(Octyloxy)-3-(trifluoromethoxy)propan-2-yl)(phenyl)selane (2g)

(3-(Octyloxy)-2-(trifluoromethoxy)propyl)(phenyl)selane (2g')



Procedure A

Purification on treated silica, eluent for flash chromatography: Pentane to Pentane/Diethylether 9/1

Light-yellow oil, 123 mg, 60%, Ratio **2g/2g'**: 75/25 (24h)

¹⁹F NMR (282 MHz, CDCl₃) δ -58.17 (s, **2g'**, 0.25), -60.47 (s, **2g**, 0.75).

¹H NMR (300 MHz, CDCl₃) δ 7.65 – 7.45 (massif, 2H), 7.32 – 7.22 (massif, 3H), 4.41 (m, 0.25H), 4.29 (dd, *J*_{H-H} = 10.0, 8.0 Hz, 0.75H), 4.16 (dd, *J*_{H-H} = 10.0, 4.8 Hz, 0.75H), 3.85 – 3.58 (massif, 2H), 3.48 – 3.11 (massif, 3.25H), 1.62 – 1.45 (massif, 2H), 1.40 – 1.14 (massif, 10H), 0.91 – 0.83 (massif, 3H).

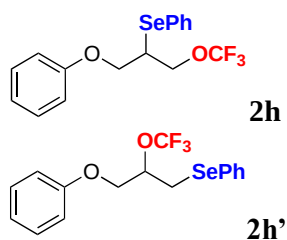
¹³C NMR (126 MHz, CDCl₃) δ 134.74, 132.95, 129.43, 129.38, 128.18, 128.16, 127.54, 121.70 (q, *J*_{C-F} = 255.5 Hz), 121.63 (q, *J*_{C-F} = 254.9 Hz), 77.52 (q, *J*_{C-F} = 2.1 Hz), 71.90, 71.61, 70.26, 69.55, 67.00 (q, *J*_{C-F} = 2.9 Hz), 42.38, 31.96, 29.64, 29.52, 29.39, 27.97, 26.19, 26.13, 22.80, 14.22.

⁷⁷Se NMR (76 MHz, CDCl₃) δ 341.35 (s, **2g**, 0.75), 264.21 (s, **2g'**, 0.25).

HRMS (ESI) : Calc. for [M+Na⁺] C₁₈H₂₇F₃NaO₂Se: 435.1021, measured: 435.1015

(1-Phenoxy-3-(trifluoromethoxy)propan-2-yl)(phenyl)selane (2h)

(3-Phenoxy-2-(trifluoromethoxy)propyl)(phenyl)selane (2h')



Procedure A

Purification on alumina

Colorless oil, 130 mg, 68%, Ratio **2h/2h'**: 80/20 (48h)

¹⁹F NMR (376 MHz, CDCl₃) δ -58.24 (s, **2h'**, 0.21), -60.50 (s, **2h**, 0.79).

¹H NMR (300 MHz, CDCl₃) δ 7.67 – 7.48 (massif, 2H), 7.42 – 7.19 (massif, 5H), 7.11 – 6.77 (massif, 3H), 4.63 (m, 0.21H), 4.43 – 4.20 (massif, 3.58H), 3.60 (m, 0.79H), 3.32 (m, 0.42H).

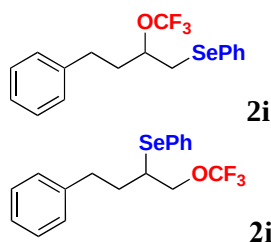
¹³C NMR (101 MHz, CDCl₃) δ 158.30, 158.09, 135.16, 133.09, 129.67, 129.64, 129.53, 129.47, 128.91, 128.57, 127.76, 127.51, 121.68 (q, *J*_{C-F} = 255.9 Hz), 121.60 (q, *J*_{C-F} = 255.6 Hz), 121.58, 121.51, 114.78, 114.70, 76.70 (q, *J*_{C-F} = 2.1 Hz), 67.46, 66.96, 66.74 (q, *J*_{C-F} = 3.0 Hz), 41.37, 27.80.

⁷⁷Se NMR (76 MHz, CDCl₃) δ 344.06 (s, **2h**, 0.79), 265.11 (s, **2h'**, 0.21).

HRMS (APCI) : Calc. for [M+[•]] C₁₆H₁₅F₃O₂Se: 376.0184, measured: 376.0180

Phenyl(4-phenyl-2-(trifluoromethoxy)butyl)selane (2i)

Phenyl(4-phenyl-1-(trifluoromethoxy)butan-2-yl)selane (2i')



Procedure A

Purification on alumina

Light-yellow oil, 134mg, 72%, Ratio **2i/2i'**: 89/11 (48h)

¹⁹F NMR (282 MHz, CDCl₃) δ -57.50 (s, **2i**, 0.89), -60.33 (s, **2i'**, 0.11).

¹H NMR (500 MHz, CDCl₃) δ 7.46 – 7.40 (massif, 2H), 7.29 – 7.05 (massif, 8H), 4.30 (m, 0.89H), 4.13 (dd, *J*_{H-H} = 10.1, 4.7 Hz, 0.11H), 3.97 (dd, *J*_{H-H} = 10.1, 8.8 Hz, 0.11H), 3.22 (m, 0.11H), 3.18 (dd, *J*_{H-H} = 12.9, 4.3 Hz, 0.89H), 3.01 (dd, *J*_{H-H} = 12.9, 8.3 Hz, 0.89H), 2.95 (m, 0.11H), 2.77 (m, 0.11H), 2.71 (m, 0.89H), 2.59 (m, 0.89H), 2.20 – 2.11 (massif, 1H), 2.00 (m, 0.89H), 1.81 (m, 0.11H).

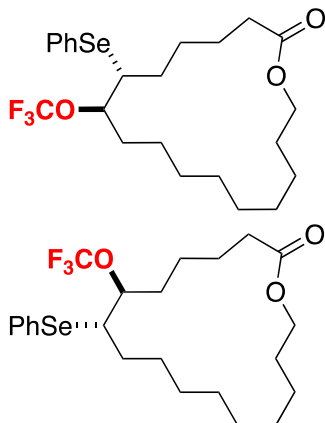
¹³C NMR (126 MHz, CDCl₃) δ 141.03, 140.77, 135.42, 133.40, 129.4, 129.06, 128.63, 128.59, 128.50, 128.42, 127.72, 126.28, 124.84, 121.80 (q, *J*_{C-F} = 255.1 Hz), 121.62 (q, *J*_{C-F} = 255.1 Hz), 78.43 (q, *J*_{C-F} = 1.9 Hz), 70.03 (q, *J*_{C-F} = 2.8 Hz), 42.03, 35.23, 33.59, 32.93, 31.44, 30.94.

⁷⁷Se NMR (76 MHz, CDCl₃) δ 335.87 (s, **2i'**, 0.11), 267.01 (s, **2i**, 0.89).

HRMS (APCI) : Calc. for [M+H⁺] [C₁₇H₁₈F₃OSe]: 375.0469, measured: 375.0465

7-(Phenylselanyl)-8-(trifluoromethoxy)-1-oxacycloheptadecan-2-one (2j/2j')

8-(Phenylselanyl)-7-(trifluoromethoxy)-1-oxacycloheptadecan-2-one (2j/2j')



Procedure A

Purification on treated silica, eluent for flash chromatography: Pentane/Diethylether 96/4

Colorless oil, 142 mg, 58%, Ratio: 53/47 (24h)

¹⁹F NMR (376 MHz, CDCl₃) δ -57.07 (s, 0.47), -57.23 (s, 0.53).

¹H NMR (400 MHz, CDCl₃) δ 7.62 – 7.51 (massif, 2H), 7.32 – 7.19 (massif, 3H), 4.38 – 4.31 (massif, 1H), 4.24 – 4.14 (massif, 1H), 4.07 – 3.97 (massif, 1H), 3.35 – 3.29 (massif, 1H), 2.43 – 2.20 (massif, 2H), 1.86 – 1.55 (massif, 8H), 1.52 – 1.17 (massif, 14H).

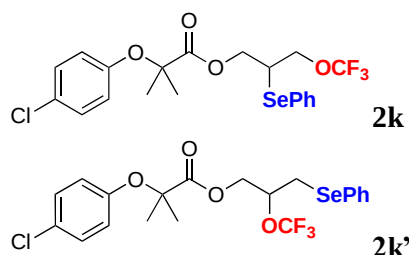
¹³C NMR (101 MHz, CDCl₃) δ 173.98, 173.91, 135.05, 135.02, 129.67, 129.65, 129.19, 129.17, 127.85, 127.80, 121.81 (q, *J*_{C-F} = 254.6 Hz), 121.80 (q, *J*_{C-F} = 254.6 Hz), 81.15, 80.99, 64.24, 64.06, 49.95, 49.06, 34.70, 30.60, 30.30, 28.61, 28.54, 28.38, 28.36, 28.17, 27.82, 27.79, 27.78, 27.61, 27.50, 26.65, 25.68, 25.52, 25.25, 25.15, 24.66, 23.73.

⁷⁷Se NMR (76 MHz, CDCl₃) δ 354.28 (s, 0.47), 343.14 (s, 0.53).

HRMS (APCI) : Calc. for [M+]⁺ [C₂₃H₃₃F₃O₃Se]: 494.1547, measured: 494.1541

2-(Phenylselanyl)-3-(trifluoromethoxy)propyl 2-(4-chlorophenoxy)-2-methylpropanoate (2k)

3-(Phenylselanyl)-2-(trifluoromethoxy)propyl 2-(4-chlorophenoxy)-2-methylpropanoate (2k')



Procedure A

Purification on treated silica, eluent for flash chromatography: Pentane/ Diethylether 90/10

Colorless oil, 105 mg, 43%, Ratio **2k/2k'**: 88/12 (24h)

¹⁹F NMR (282 MHz, CDCl₃) δ -58.43 (s, **2k'**, 0.12), -60.73 (s, **2k**, 0.88).

¹H NMR (500 MHz, CDCl₃) δ 7.60 – 7.49 (massif, 2H), 7.39 – 7.28 (massif, 3H), 7.23 – 7.16 (massif, 2H), 6.83 – 6.74 (massif, 2H), 4.54 – 4.35 (massif, 2.12H), 4.12 (dd, *J*_{H-H} = 10.3 Hz, 4.9 Hz, 0.88H), 4.06 (dd, *J*_{H-H} = 10.3 Hz, 7.9 Hz, 0.88H), 3.45 (m, 0.88H), 3.12 (dd, *J*_{H-H} = 13.3 Hz, 4.7 Hz, 0.12H), 2.98 (dd, *J*_{H-H} = 13.3, 8.6 Hz, 0.12H), 1.60 (s, 5.28H), 1.57 (s, 0.72H₆).

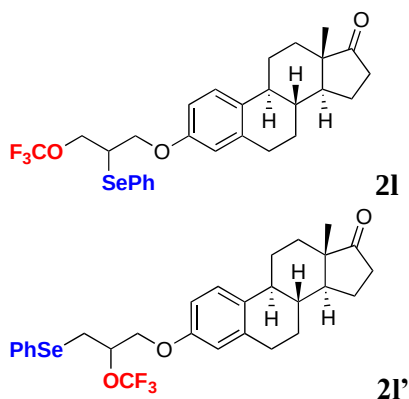
¹³C NMR (126 MHz, CDCl₃) δ 173.57, 173.52, 154.08, 154.00, 135.22, 133.37, 129.64, 129.60, 129.35, 128.83, 128.40, 128.08, 127.63, 127.53, 126.75, 121.44 (q, *J*_{C-F} = 255.7 Hz), 120.73, 120.50, 79.62, 75.97 (q, *J*_{C-F} = 2.2 Hz), 66.63 (q, *J*_{C-F} = 3.1 Hz), 64.53, 64.31, 40.06, 27.35, 25.50, 25.44, 25.40, 25.33.

⁷⁷Se NMR (95 MHz, CDCl₃) δ 342.44 (s, **2k**, 0.88), 268.20 (s, **2k'**, 0.12).

HRMS (ESI): Calc. for [M+Na⁺] C₂₀H₂₀ClF₃NaO₄Se: 519.0059, measured: 519.0063

((8R,9S,13S,14S)-13-Methyl-3-(2-(phenylselanyl)-3-(trifluoromethoxy)propoxy)-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (2l)

(8R,9S,13S,14S)-13-Methyl-3-(3-(phenylselanyl)-2-(trifluoromethoxy)propoxy)-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (2l')



Procedure A

Purification on treated silica, eluent for flash chromatography: Pentane/Diethylether 70/30

Light-yellow oil, 171 mg, 63%, Ratio **2l/2l'**: 78/22, (48h)

¹⁹F NMR (282 MHz, CDCl₃) δ -58.21 (s, **2l'**, 0.22), -60.47 (s, **2l**, 0.78).

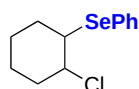
¹H NMR (500 MHz, CDCl₃) δ 7.53 (m, 1.56H), 7.44 (m, 0.44H), 7.29 – 7.14 (massif, 3H), 7.12 – 7.08 (massif, 1H), 6.62 – 6.56 (massif, 1H), 6.54 – 6.50 (massif, 1H), 4.52 (m, 0.22H), 4.29 (dd, *J*_{H-H} = 10.1 Hz, 7.5 Hz, 0.78H), 4.22 (m, 1.56H), 4.16 (dd, *J*_{H-H} = 10.1 Hz, 2.7 Hz, 0.78H), 4.11 (d, *J*_{H-H} = 4.5 Hz, 0.44H), 3.49 (tt, *J*_{H-H} = 7.5, 4.5 Hz, 0.78H), 3.25 (dd, *J*_{H-H} = 13.3, 7.8 Hz, 0.22H), 3.17 (dd, *J*_{H-H} = 13.2, 5.0 Hz, 0.22H), 2.86 – 2.73 (massif, 2H), 2.47 – 2.36 (massif, 1H), 2.33 – 2.27 (massif, 1H), 2.19 – 1.84 (massif, 5H), 1.59 – 1.28 (massif, 6H), 0.82 (massif, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ 221.03, 156.32 (d, $J_{\text{C-F}} = 1.7$ Hz), 156.18, 138.05, 138.02, 135.09, 133.09, 133.02, 132.93, 129.53, 129.47, 129.00, 128.54, 127.73, 127.62, 126.56, 126.54, 121.66 (q, $J_{\text{C-F}} = 255.6$ Hz), 121.58 (q, $J_{\text{C-F}} = 255.3$ Hz), 114.82, 114.80, 112.37 (d, $J_{\text{C-F}} = 3.6$ Hz), 112.30, 76.72 (q, $J_{\text{C-F}} = 2.2$ Hz), 67.64, 66.95 (d, $J_{\text{C-F}} = 2.3$ Hz), 66.70 (q, $J_{\text{C-F}} = 3.1$ Hz), 50.53, 48.13, 44.11, 41.44, 38.45, 36.00, 31.70, 29.75, 27.85, 26.63, 26.05, 21.72, 13.98.

^{77}Se NMR (95 MHz, CDCl_3) δ 342.67 (d, $J = 5.5$ Hz, **2l**, 0.78), 264.25 (s, **2l'**, 0.22).

HRMS (APCI) : Calc. for $[\text{M}+\text{H}^+]$ $\text{C}_{28}\text{H}_{32}\text{F}_3\text{O}_3\text{Se}$: 553.1463, measured: 553.1463

[(2-Chlorocyclohexyl)selanyl]benzene (3a)

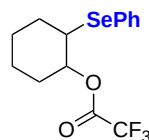


Colorless oil, 107 mg, 79%

^1H NMR (300 MHz, CDCl_3) δ 7.59 (m, 2H), 7.35 – 7.23 (massif, 3H), 4.15 (ddd, $J_{\text{H-H}} = 6.7, 6.7, 3.8$ Hz, 1H), 3.47 (ddd, $J_{\text{H-H}} = 6.7, 6.7, 3.8$ Hz, 1H), 2.46 – 2.21 (massif, 2H), 1.86 – 1.73 (massif, 4H), 1.36 – 1.51 (massif, 2H).

The results are in accordance with literature data ^[4]

2-(Phenylselanyl)cyclohexyl 2,2,2-trifluoroacetate (4a)



Procedure E

Colorless oil, 56% (NMR yield with PhCF_3 as an internal standard)

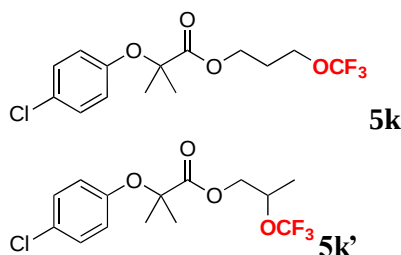
^{19}F NMR (282 MHz, CDCl_3) δ -75.11 (s).

^1H NMR (300 MHz, CDCl_3) δ 7.59 (m, 2H), 7.34 – 7.27 (massif, 3H), 5.00 (ddd, $J_{\text{H-H}} = 9.1, 9.1, 4.2$ Hz, 1H), 3.22 (ddd, $J_{\text{H-H}} = 9.1, 9.1, 4.2$ Hz, 1H), 2.27 – 2.10 (massif, 2H), 1.69 – 1.54 (massif, 4H), 1.43 – 1.35 (massif, 2H).

The results are in accordance with the literature ^[3]

3-(Trifluoromethoxy)propyl 2-(4-chlorophenoxy)-2-methylpropanoate (5k)

2-(Trifluoromethoxy)propyl 2-(4-chlorophenoxy)-2-methylpropanoate (5k')



Procedure B

Eluent for flash chromatography: Cyclohexane, then Pentane/Diethylether 95/5

Colorless oil, 70 mg, 51%, Ratio **5k/5k'**: 89/11

^{19}F NMR (282 MHz, CDCl_3) δ -58.49 (s, **5k'**, 0.11), -61.03 (s, **5k**, 0.89).

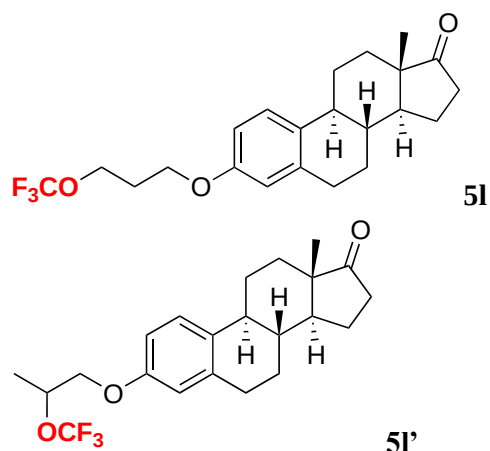
^1H NMR (500 MHz, CDCl_3) δ 7.23 – 7.16 (massif, 2H), 6.82 – 6.73 (massif, 2H), 4.53 (m, 0.11H), 4.26 (t, $J_{\text{H-H}} = 6.1$ Hz, 1.78H), 4.20 (m, 0.22H), 3.91 (t, $J_{\text{H-H}} = 6.1$ Hz, 1.78H), 2.00 (quint, $J_{\text{H-H}} = 6.1$ Hz, 1.78H), 1.63 – 1.54 (massif, 6H), 1.32 (d, $J_{\text{H-H}} = 6.5$ Hz, 0.33H).

^{13}C NMR (126 MHz, CDCl_3) δ 173.97, 173.71, 154.14, 154.03, 129.33, 129.29, 127.45, 126.67 (q, $J_{\text{C-F}} = 253.5$ Hz), 121.64 (q, $J_{\text{C-F}} = 254.4$ Hz), 120.97, 120.31, 79.68, 79.57, 73.10 (q, $J_{\text{C-F}} = 2.6$ Hz), 66.73, 63.70 (q, $J_{\text{C-F}} = 3.3$ Hz), 61.40, 28.00, 25.43, 17.37.

Calc. for $[\text{M}+\text{Na}^+]$ $[\text{C}_{14}\text{H}_{16}\text{ClF}_3\text{NaO}_4]$: 363.0581, measured: 363.0581

(8R,9S,13S,14S)-13-Methyl-3-(3-(trifluoromethoxy)propoxy)-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (5l)

(8R,9S,13S,14S)-13-Methyl-3-(2-(trifluoromethoxy)propoxy)-6,7,8,9,11,12,13,14,15,16-decahydro-17H-cyclopenta[a]phenanthren-17-one (5l')



Procedure B

Eluent for flash chromatography: Cyclohexane, then Pentane/Diethylether 90/10

Slightly yellow oil, 113 mg, 52%, Ratio **5l/5l'**: 74/26

¹⁹F NMR (471 MHz, CDCl₃) δ -58.24 (s, **5l'**, 0.26), -60.71 (s, **5l**, 0.74).

¹H NMR (500 MHz, CDCl₃) δ 7.23 – 7.19 (massif, 1H), 6.74 – 6.70 (massif, 1H), 6.67 - 6.64 (massif, 1H), 4.68 – 4.62 (m, 0.26H), 4.18 (t, *J*_{H-H} = 6.2 Hz, 1.48H), 4.08 – 4.01 (massif, 1.74H), 3.95 (m, 0.26H), 2.93 – 2.86 (massif, 2H), 2.57 – 2.47 (massif, 1H), 2.43 – 2.38 (massif, 1H), 2.32 – 2.23 (massif, 1H), 2.20 – 1.93 (massif, 5.48H), 1.69 – 1.43 (massif, 6.78H), 0.93-0.84 (massif, 3H).

¹³C NMR (126 MHz, CDCl₃) δ 221.01, 220.98, 156.75, 156.41, 138.04, 137.95, 132.89, 132.50, 126.54, 126.50, 121.79 (q, *J*_{C-F} = 254.5 Hz), 121.76 (q, *J*_{C-F} = 250.5 Hz), 114.81 (d, *J*_{C-F} = 2.3 Hz), 114.64, 112.24, 112.22, 73.82 (q, *J*_{C-F} = 2.4 Hz), 70.11, 64.24 (q, *J*_{C-F} = 3.3 Hz), 63.40, 50.50, 48.10, 44.08, 38.45, 38.42, 35.96, 31.68, 29.74, 29.71, 28.91, 26.63, 26.60, 26.02, 21.68, 17.77, 13.94.

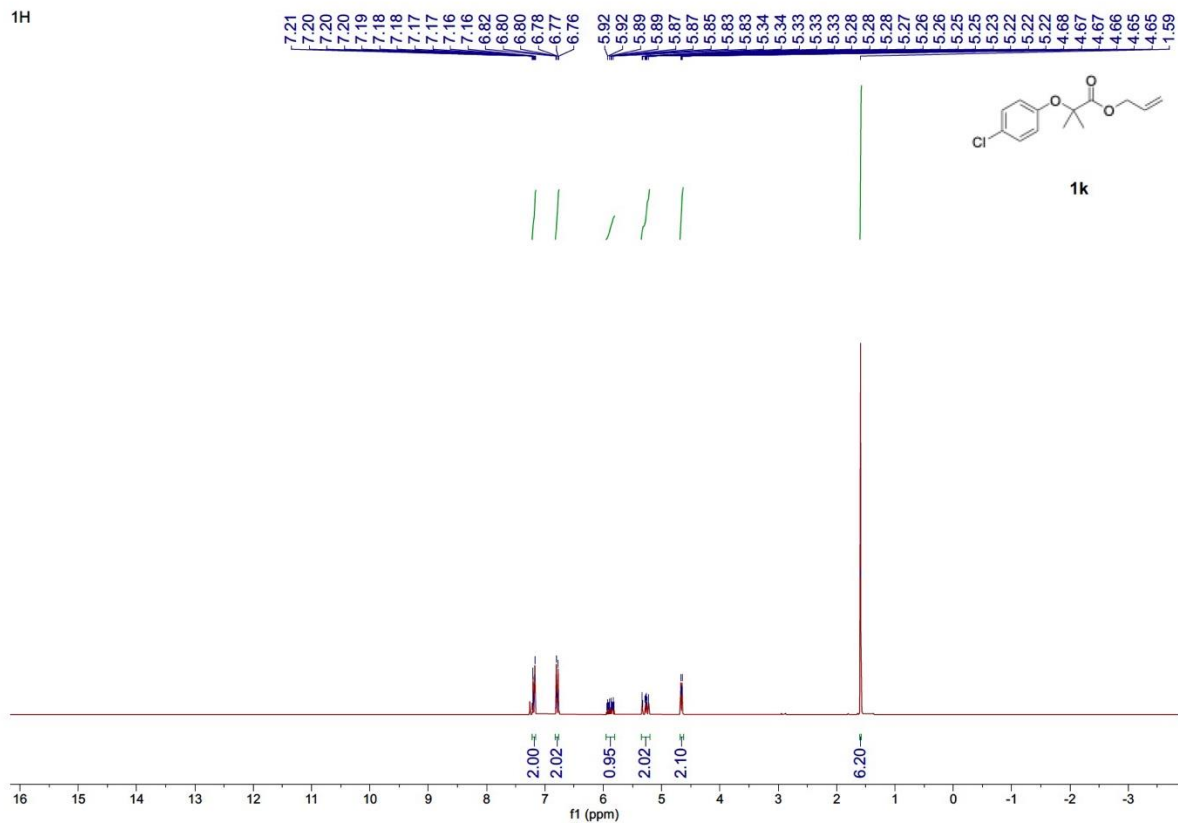
HRMS (ESI): Calc. for [M+H⁺] [C₂₂H₂₈F₃O₃]: 397.1985, measured: 397.1987

References

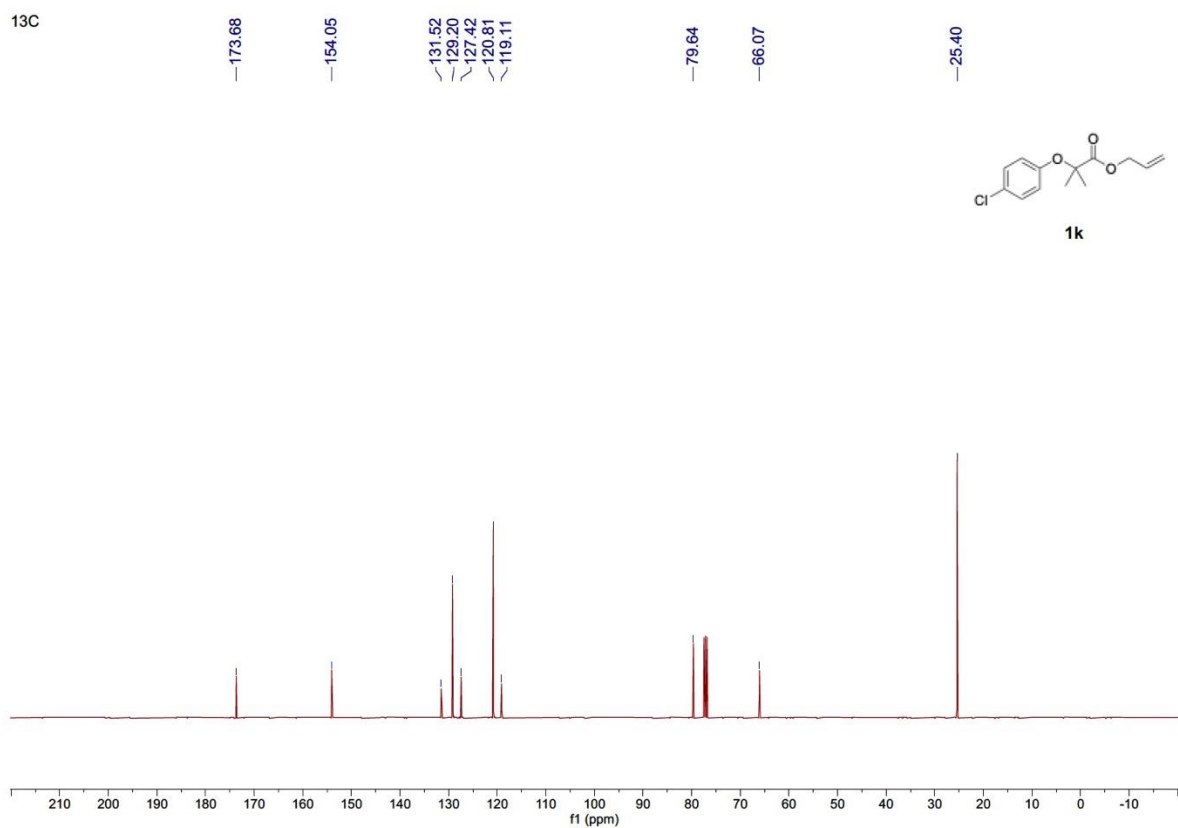
- [1] C. Guo, X. Han, Y. Feng, Z. Liu, Y. Li, H. Liu, L. Zhang, Y. Dong, X. Li, *J. Org. Chem.* **2022**, 87, 9232-9241.
- [2] T. Fujihara, K. Semba, J. Terao, Y. Tsuji, *Angew. Chem. Int. Ed.* **2010**, 49, 1472-1476.
- [3] J. M. White, J. B. Lambert, M. Spiniello, S. A. Jones, R. W. Gable, *Chem. Eur. J.* **2002**, 8 12, 2799-2811.
- [4] S. E. Denmark, W. R. Collins, M. D. Cullen, *J. Am. Chem. Soc.* **2009**, 131, 3490-3492.

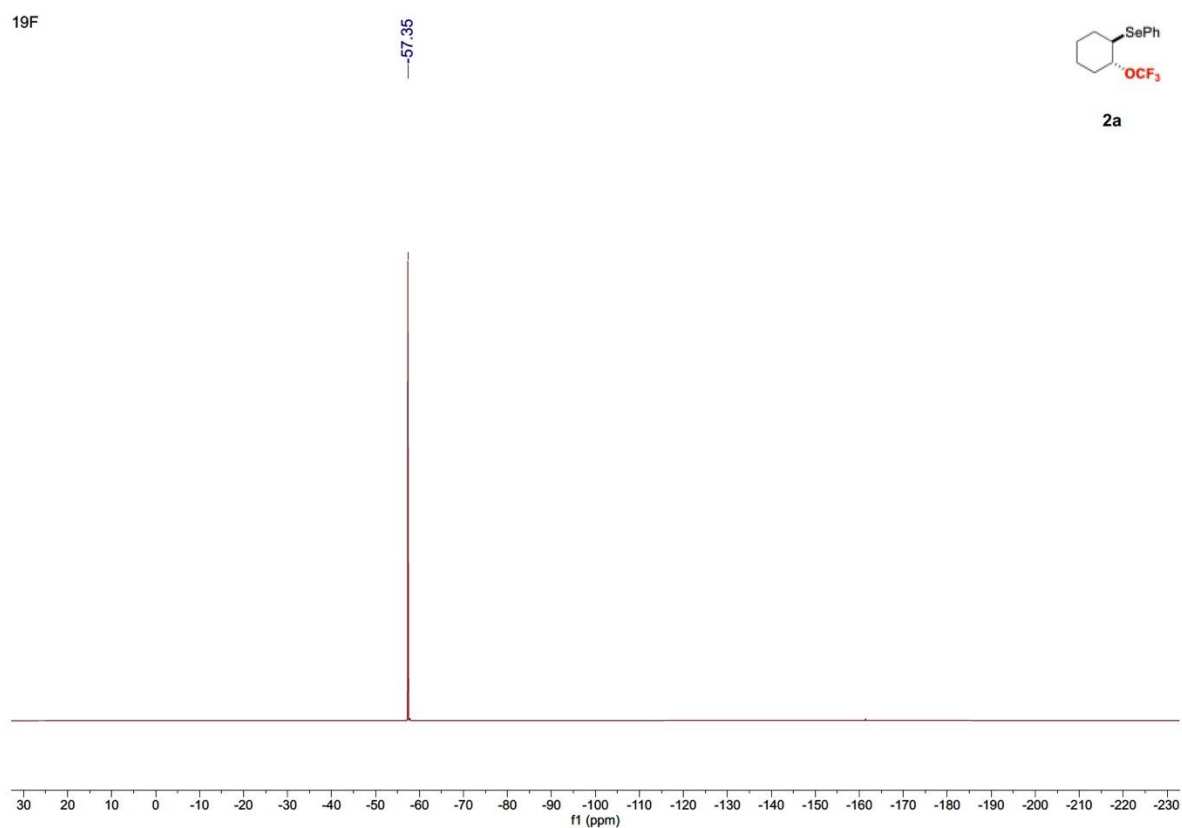
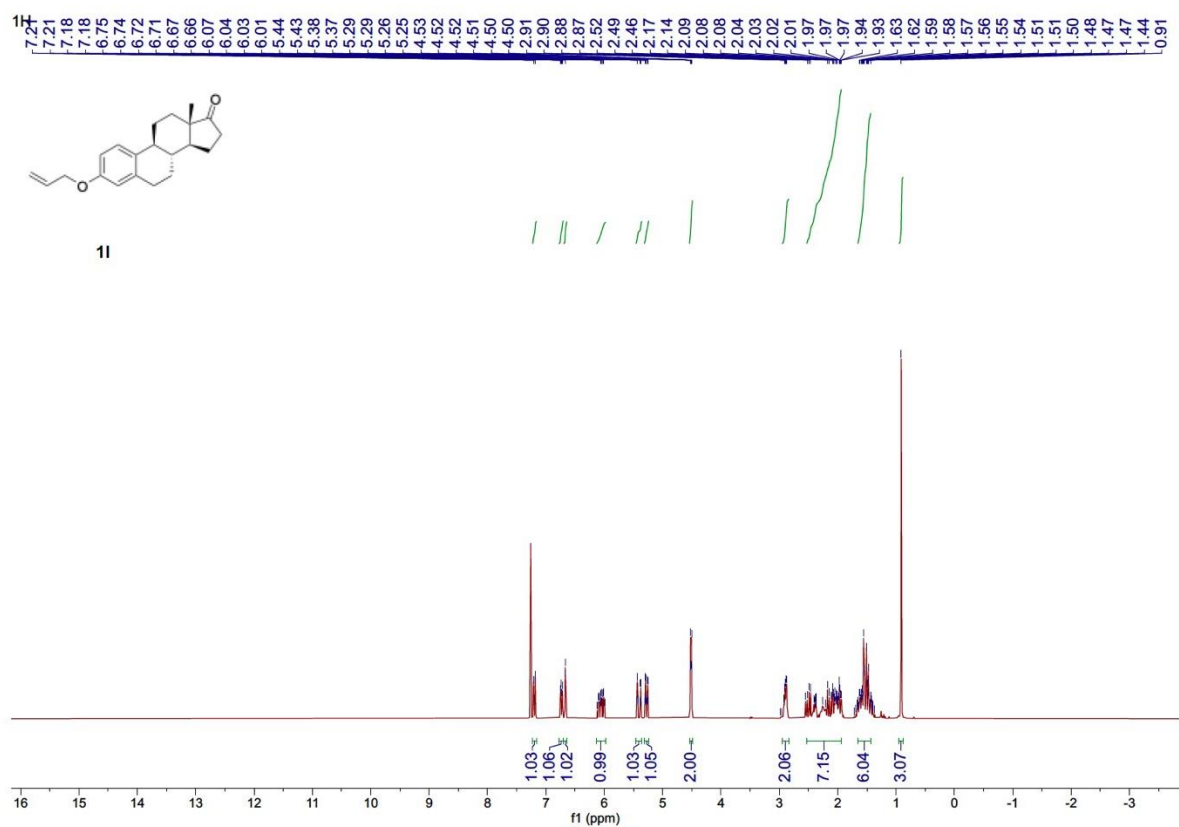
NMR Spectra

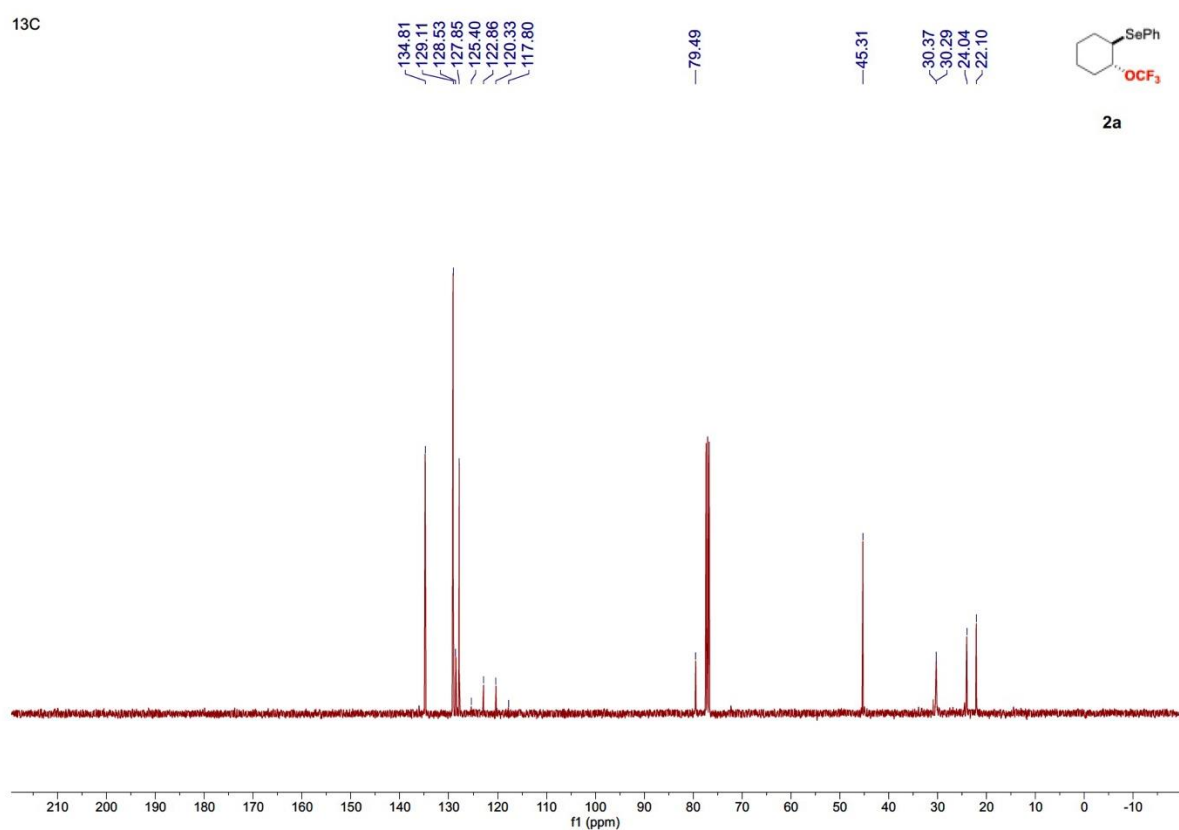
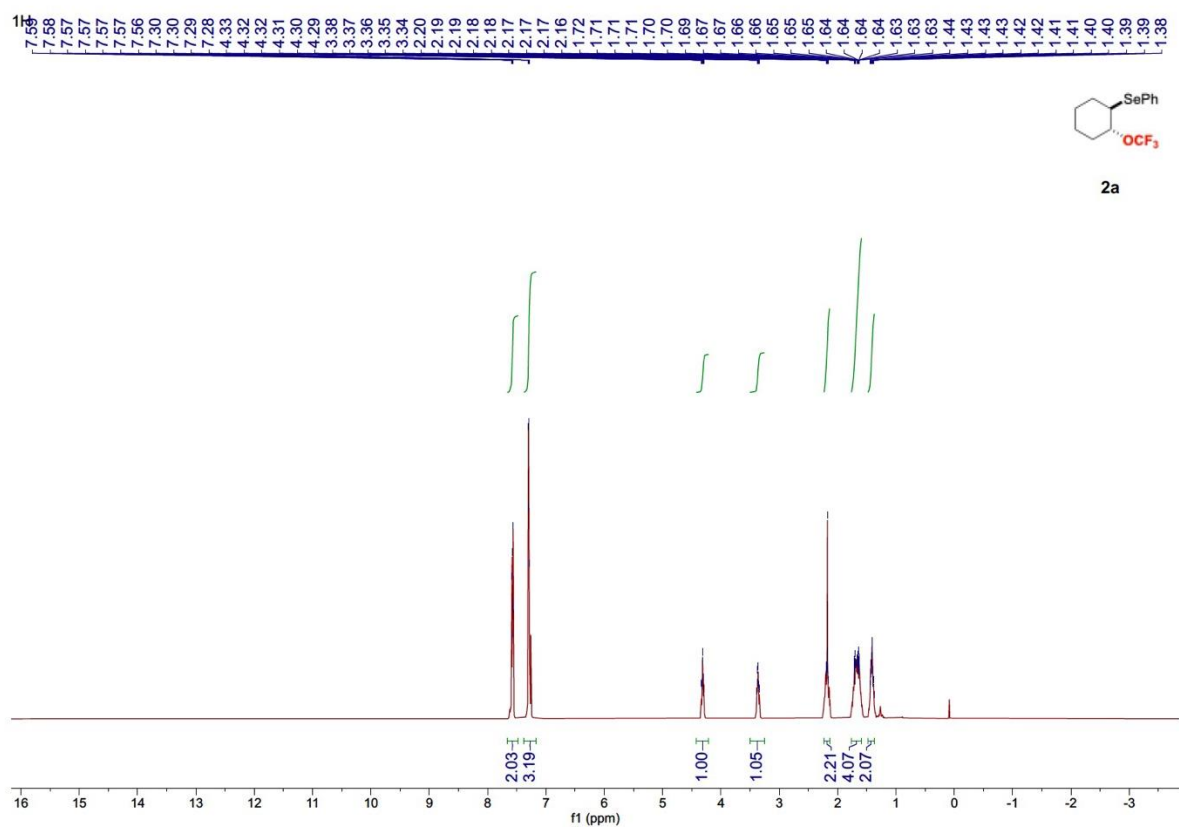
¹H



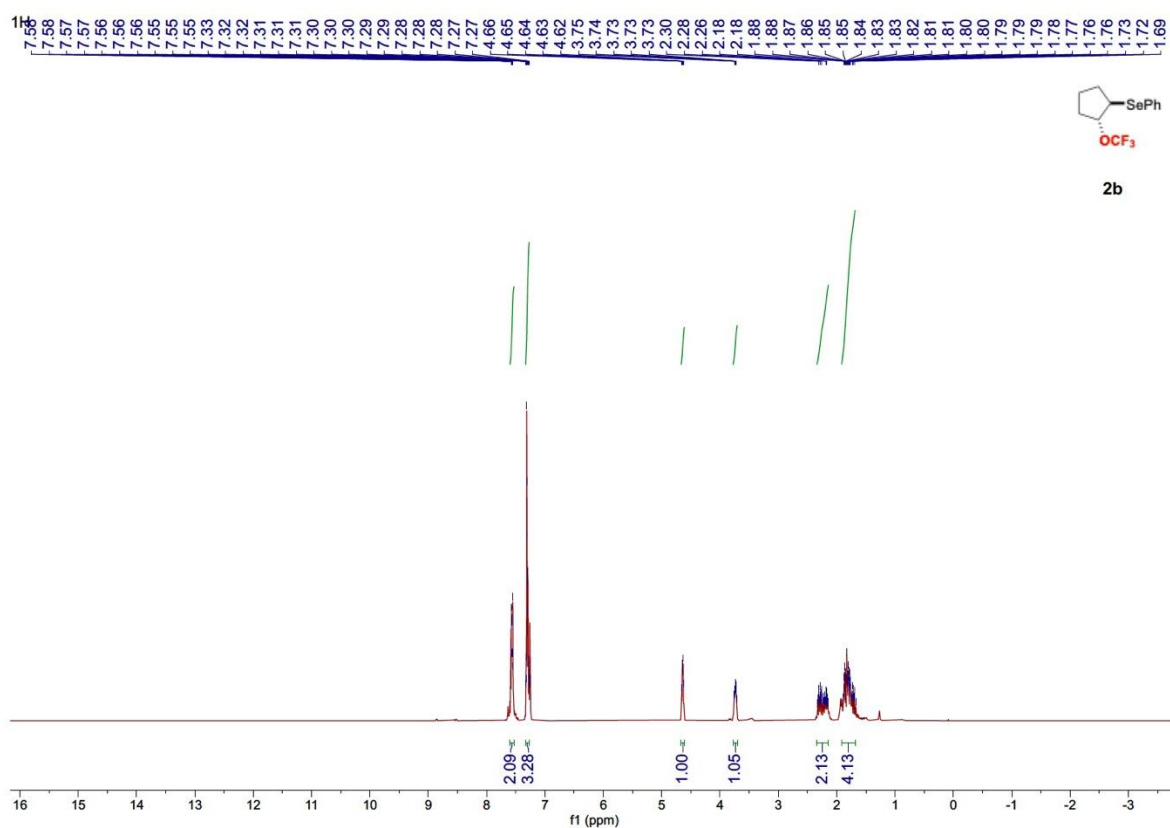
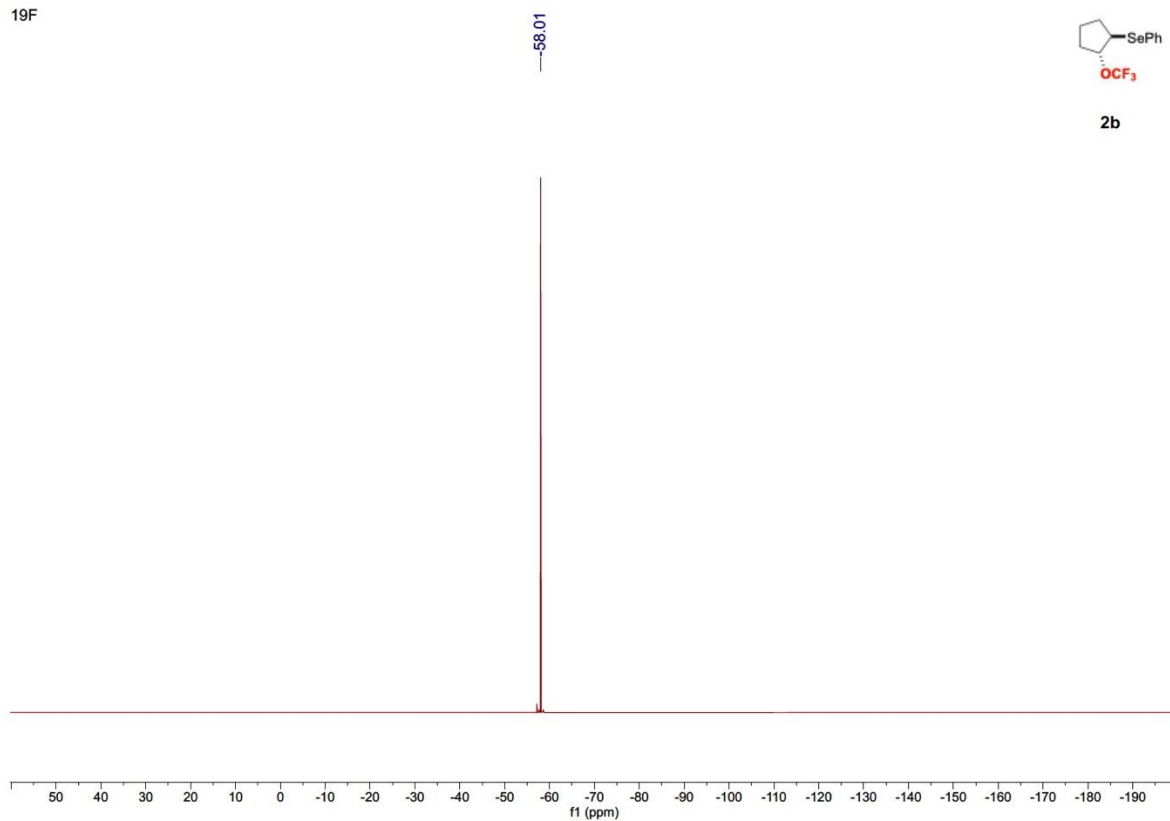
¹³C



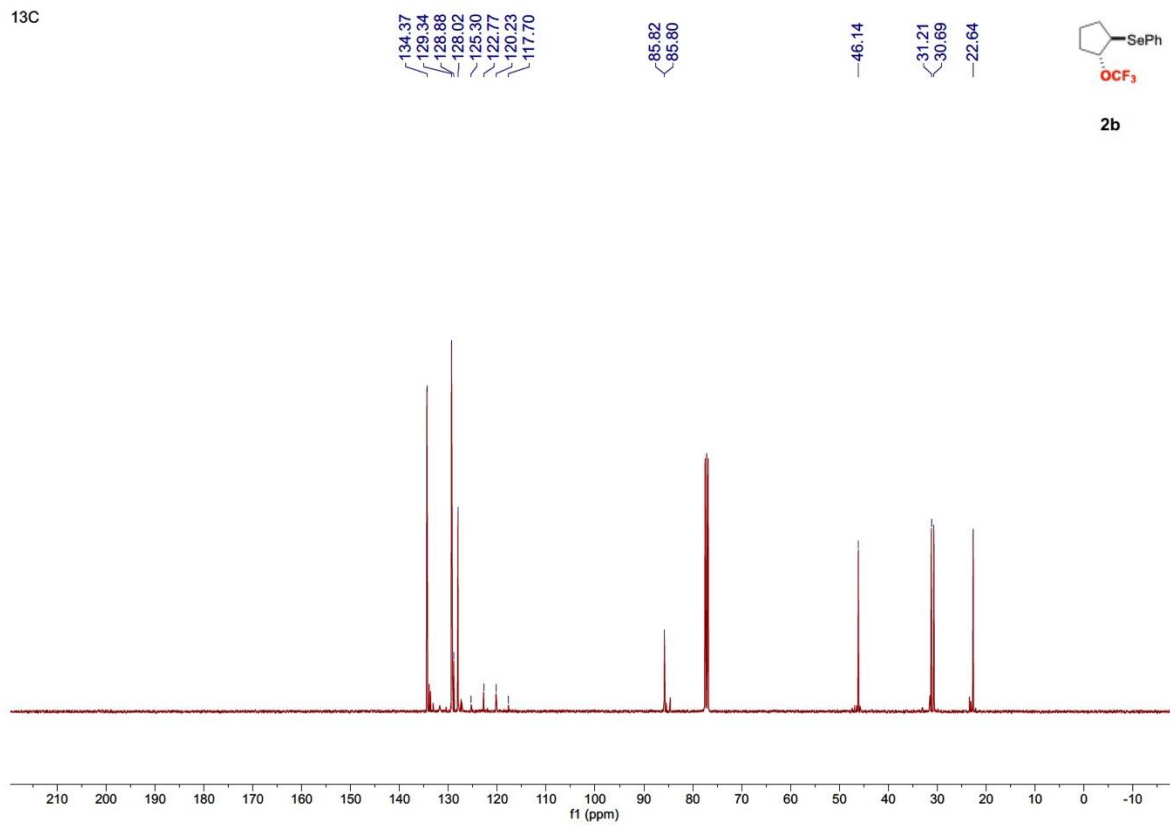




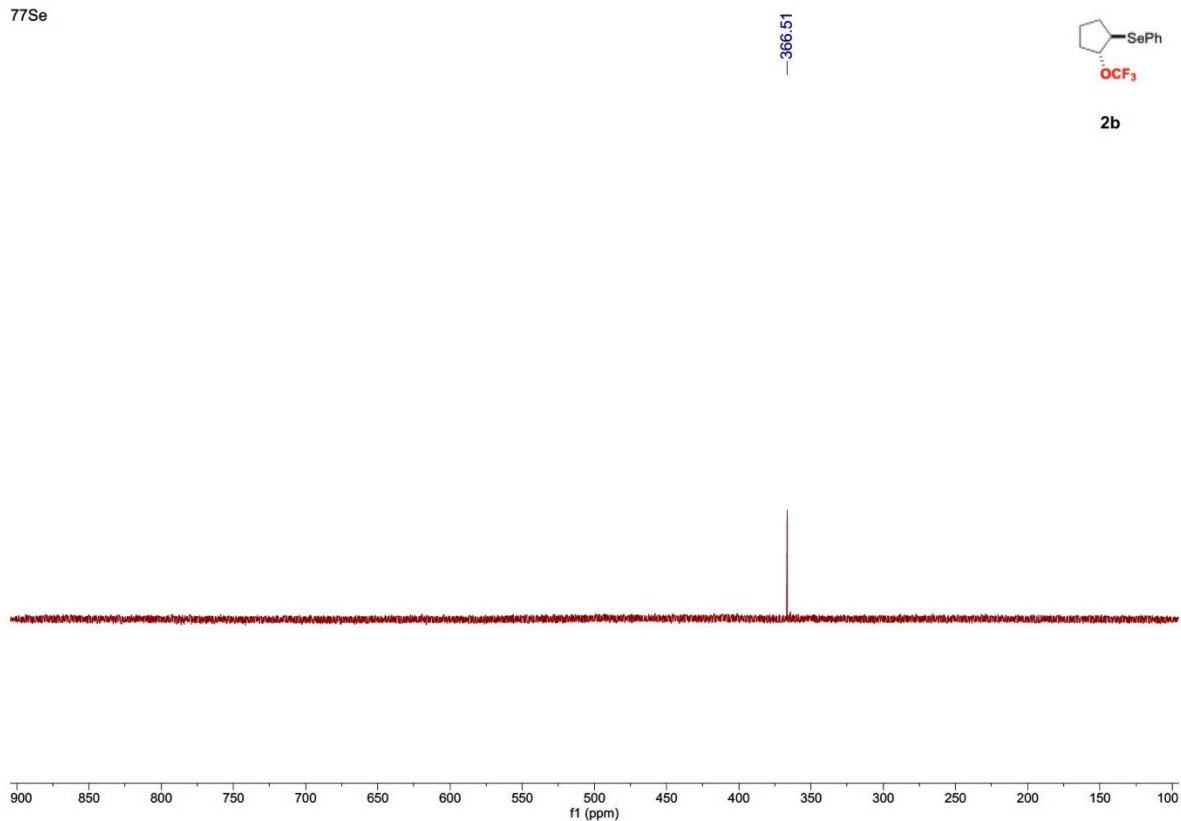
19F

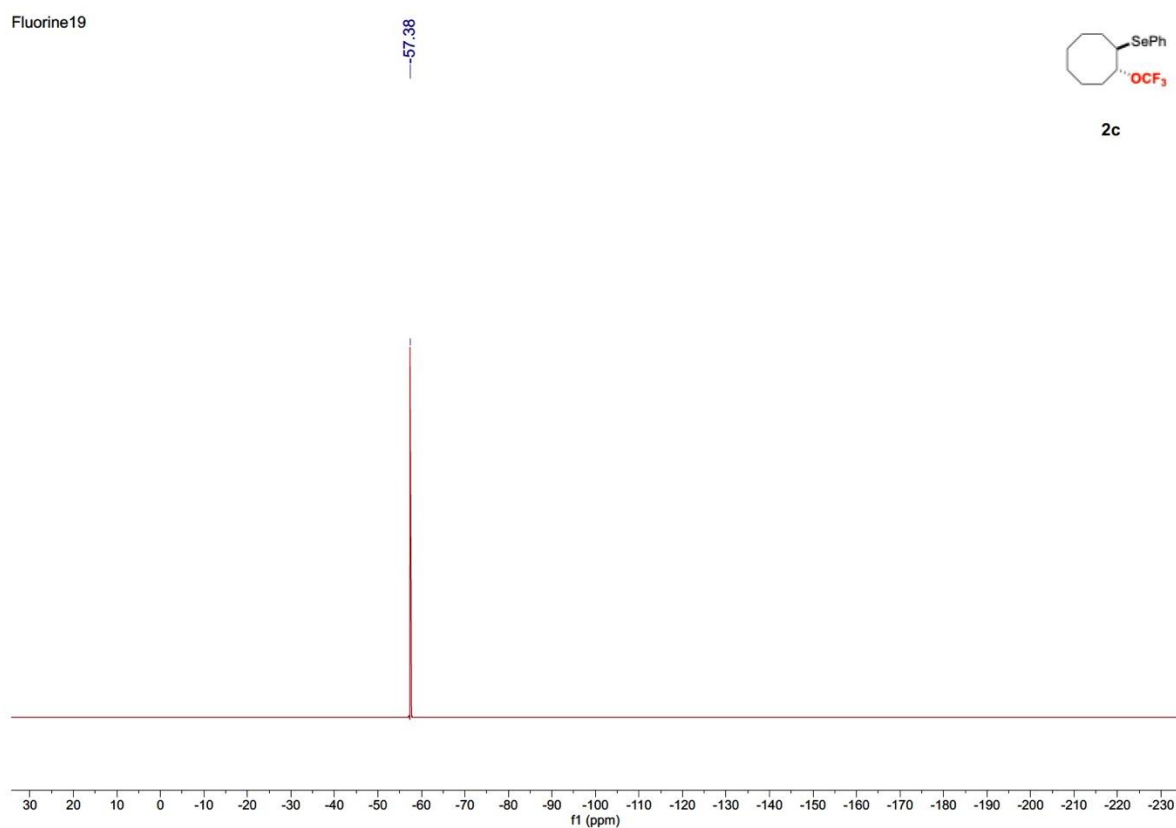
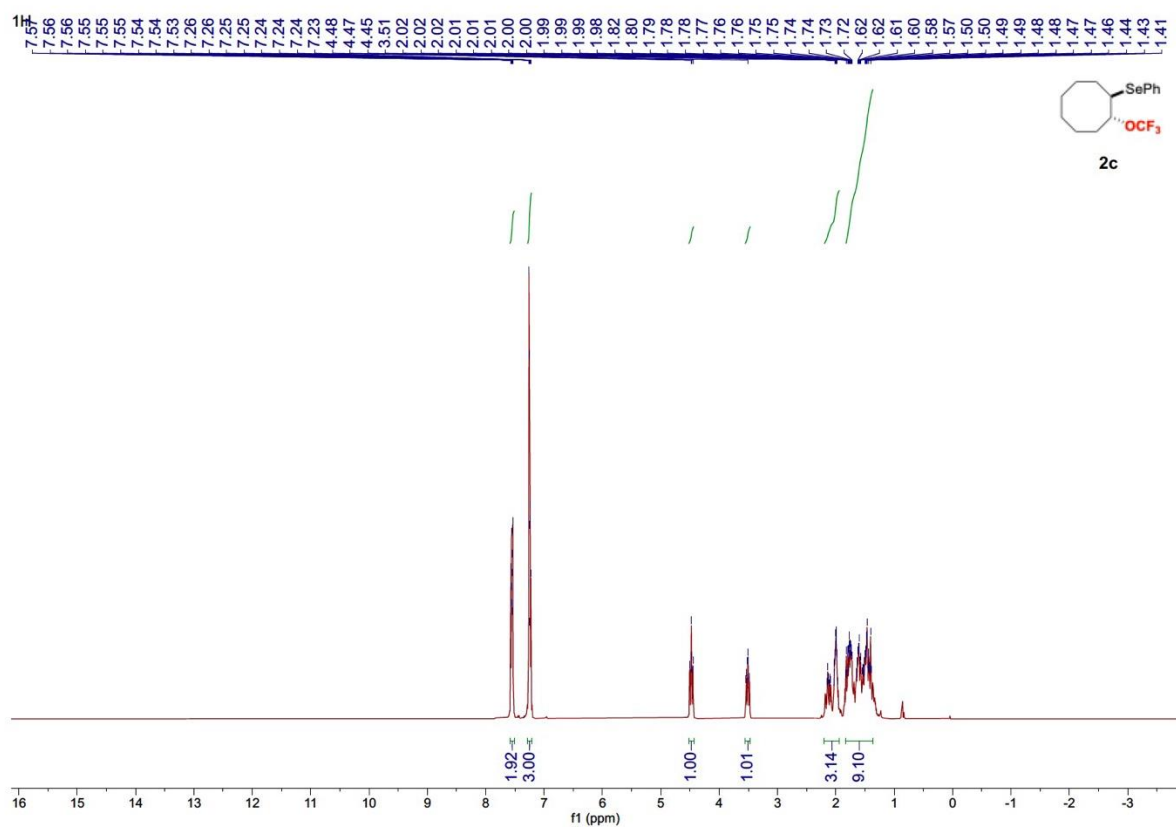


¹³C

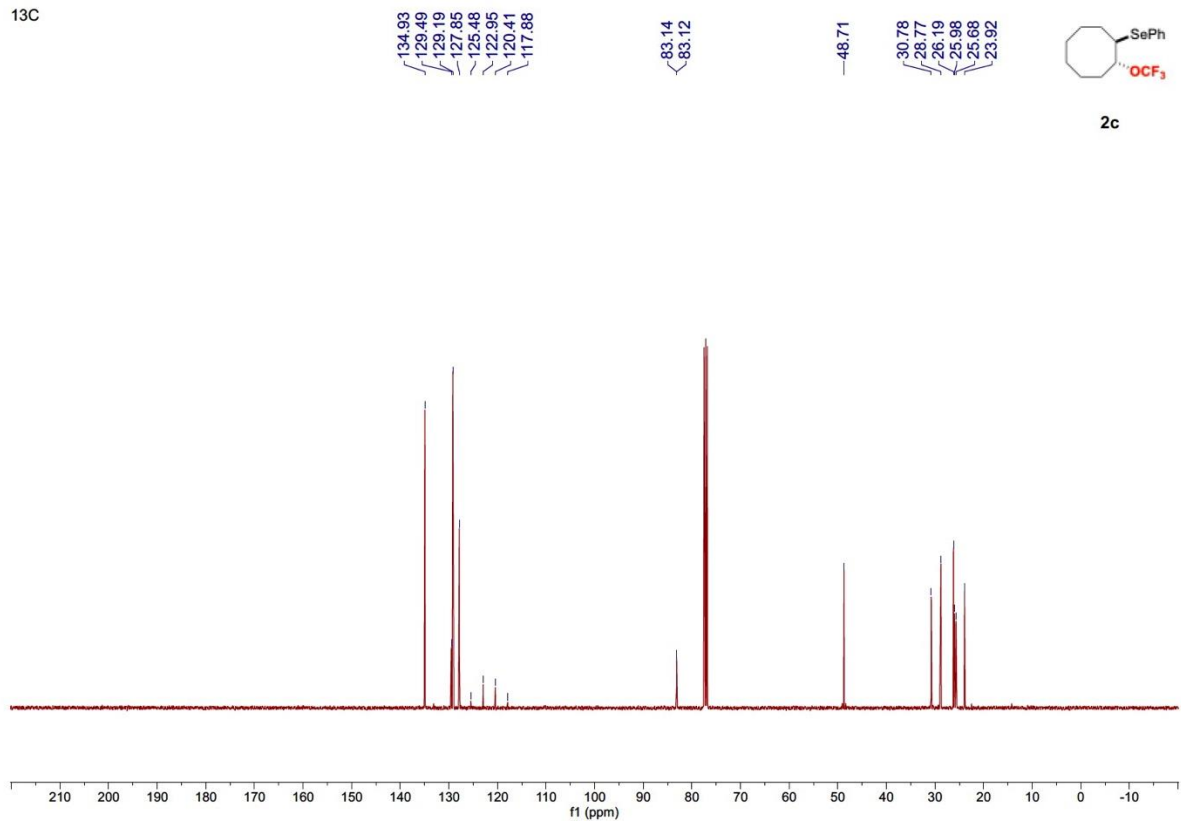


⁷⁷Se

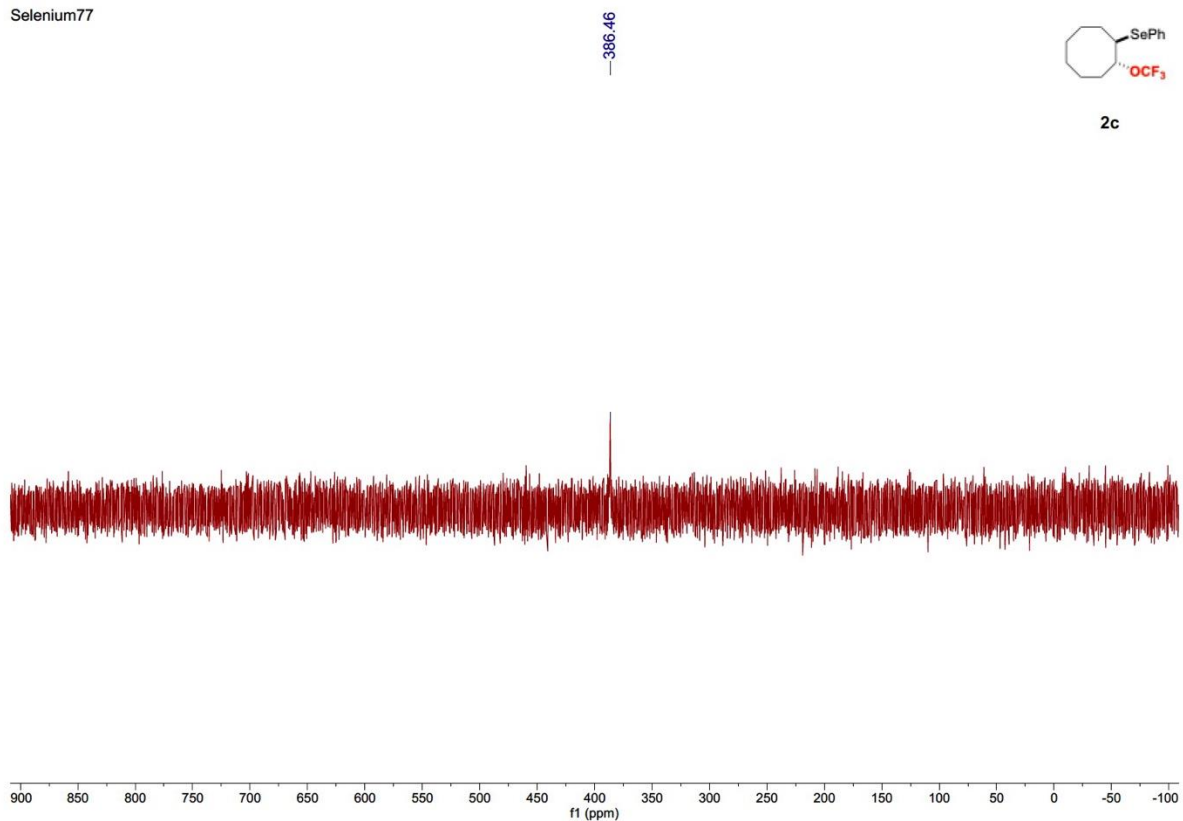




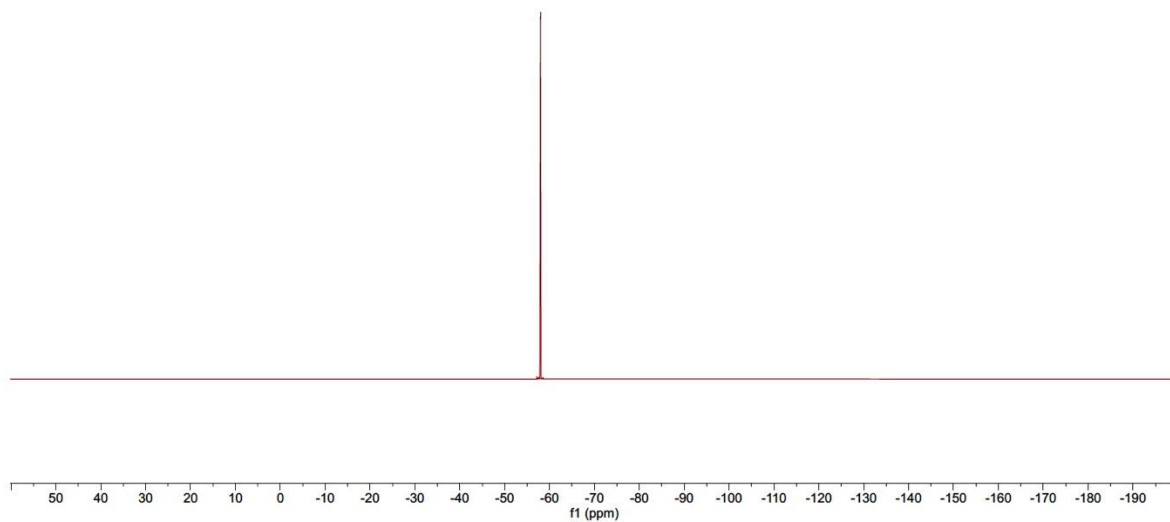
¹³C



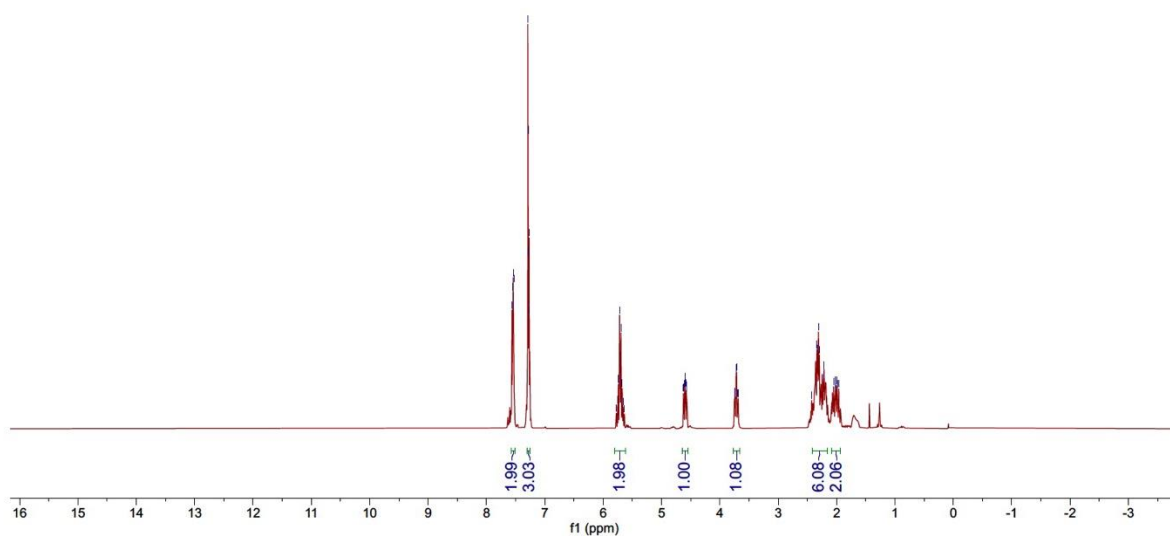
Selenium77



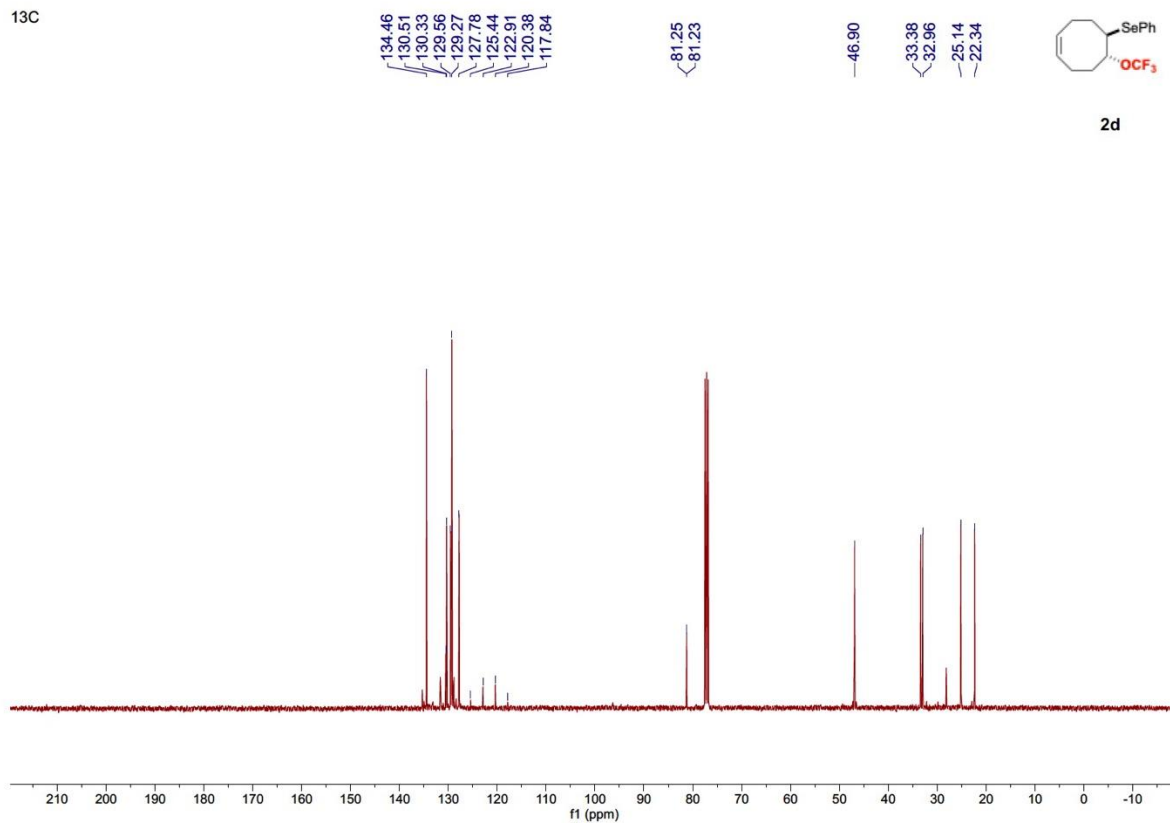
—57.98



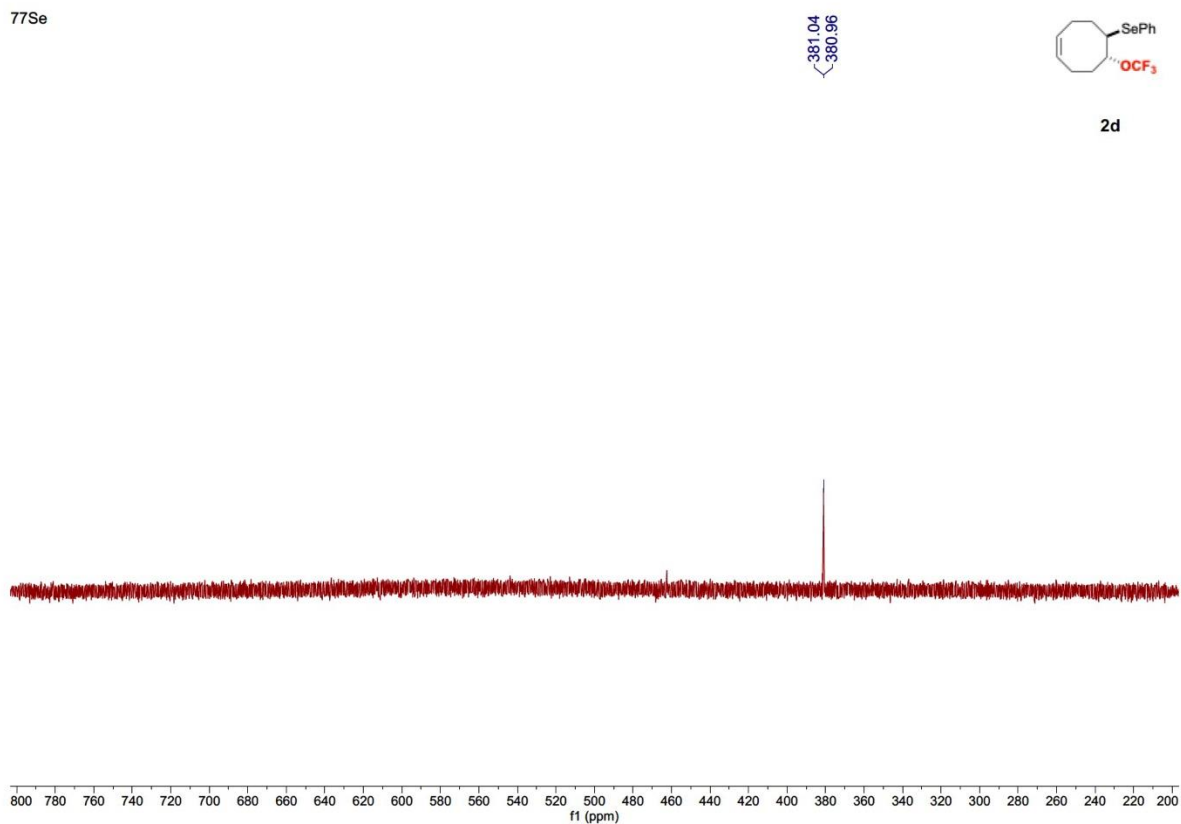
7.56
7.55
7.54
7.53
7.29
7.28
7.27
7.27
7.26
5.77
5.75
5.74
5.72
5.69
5.67
5.66
5.64
4.63
4.62
4.60
4.60
4.59
4.59
4.58
4.57
3.75
3.74
3.72
3.71
3.70
3.69
2.43
2.34
2.33
2.31
2.29
2.22
2.21
2.05
2.03
2.02
1.99
1.99
1.96



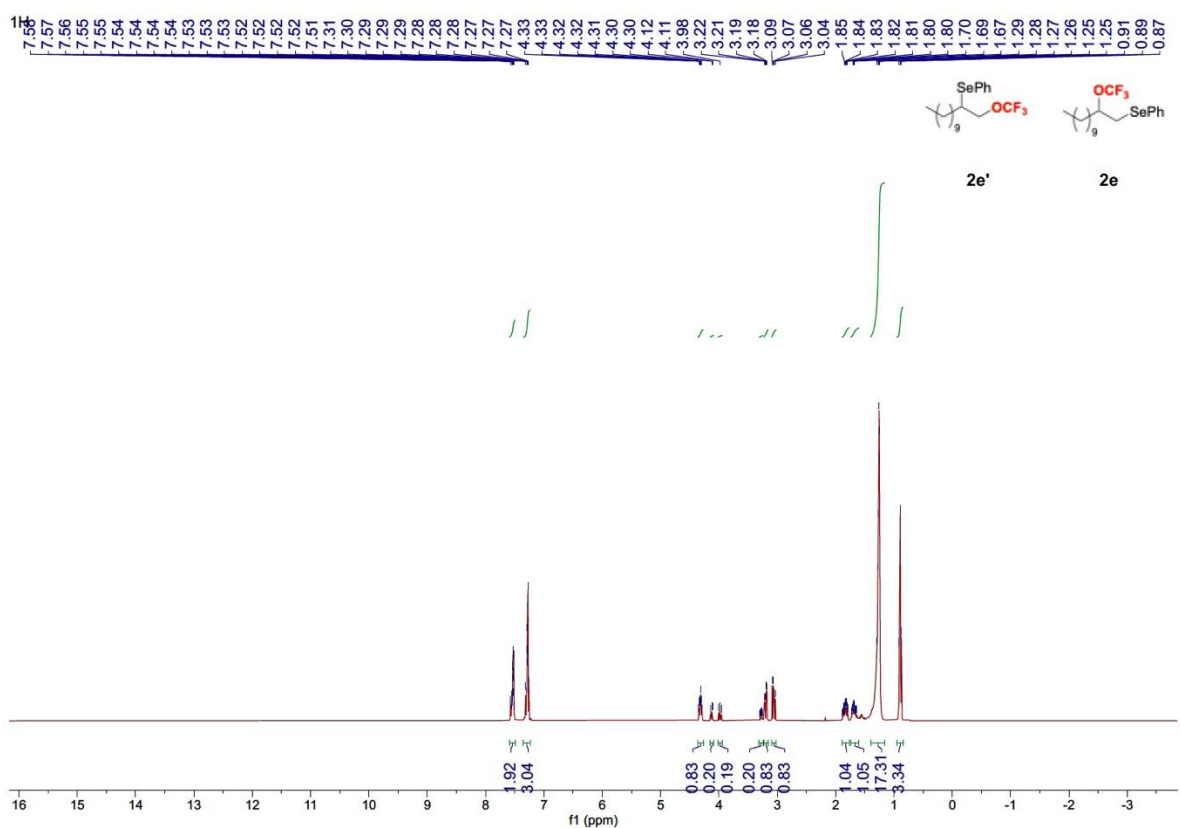
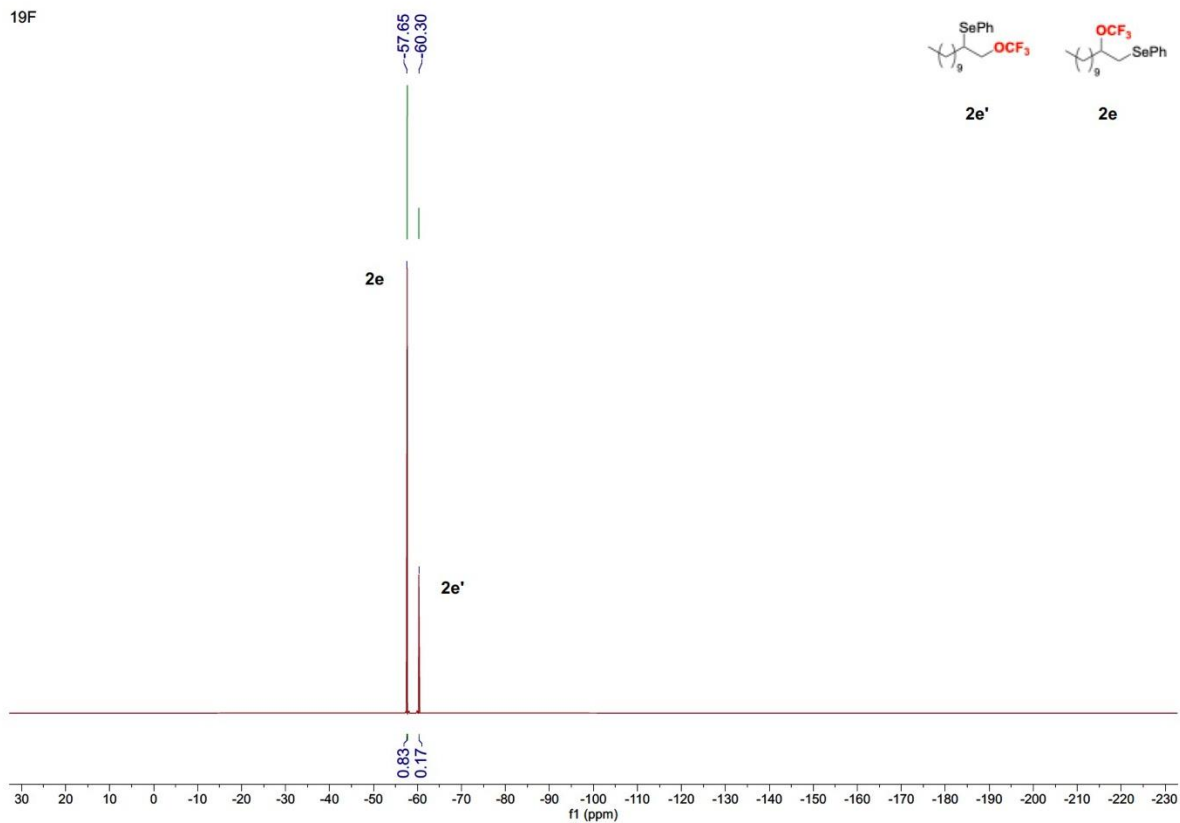
¹³C



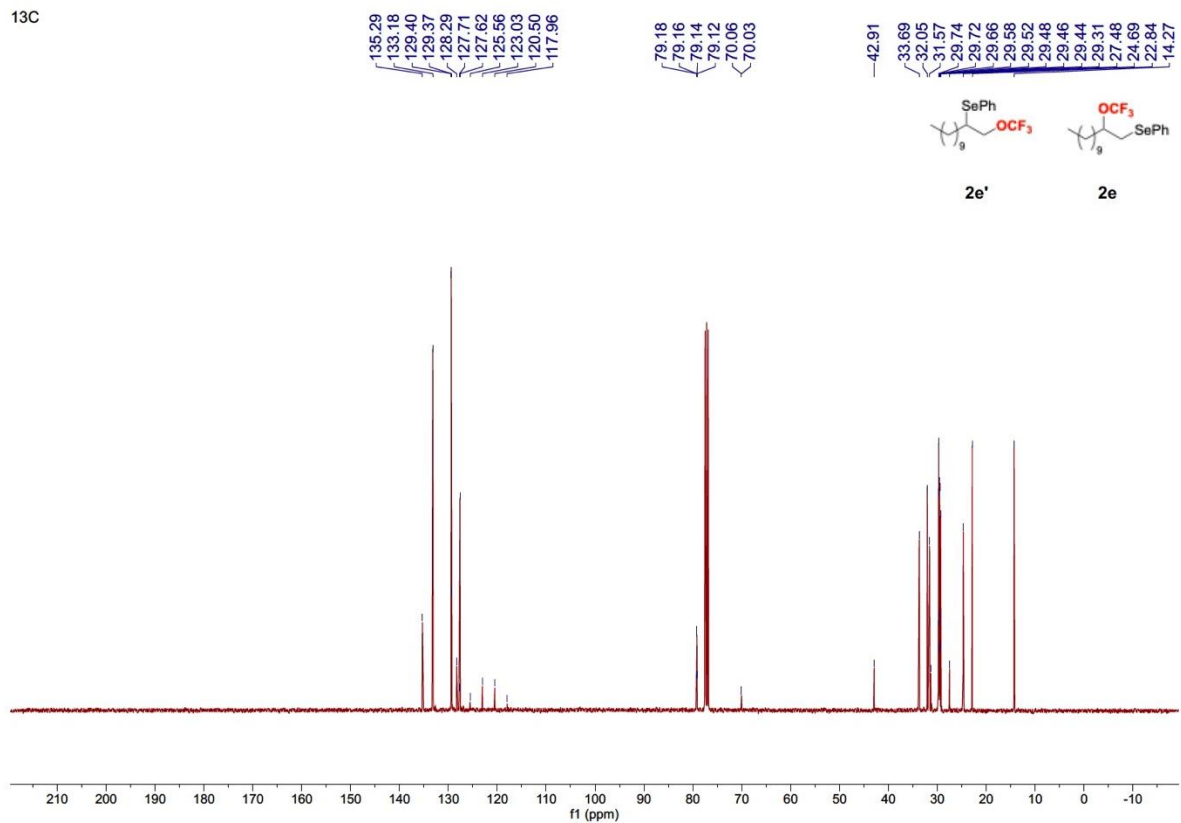
⁷⁷Se



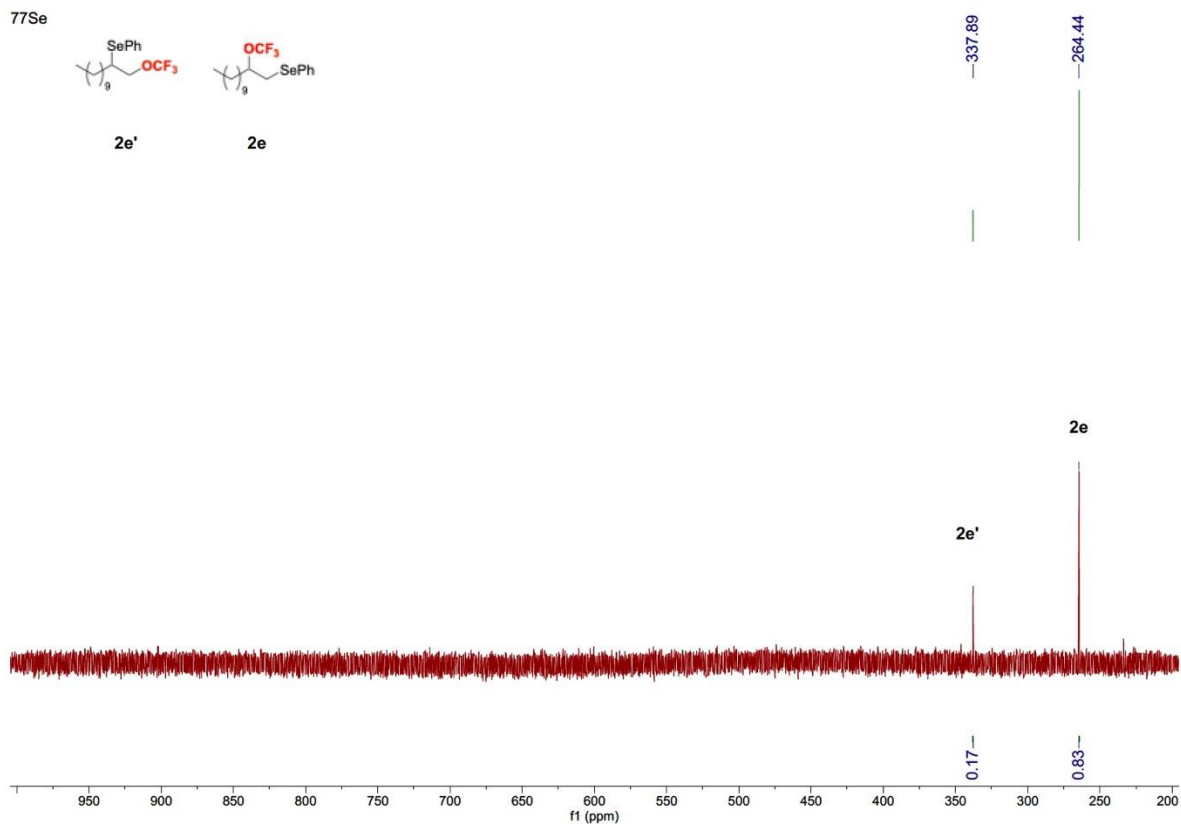
19F



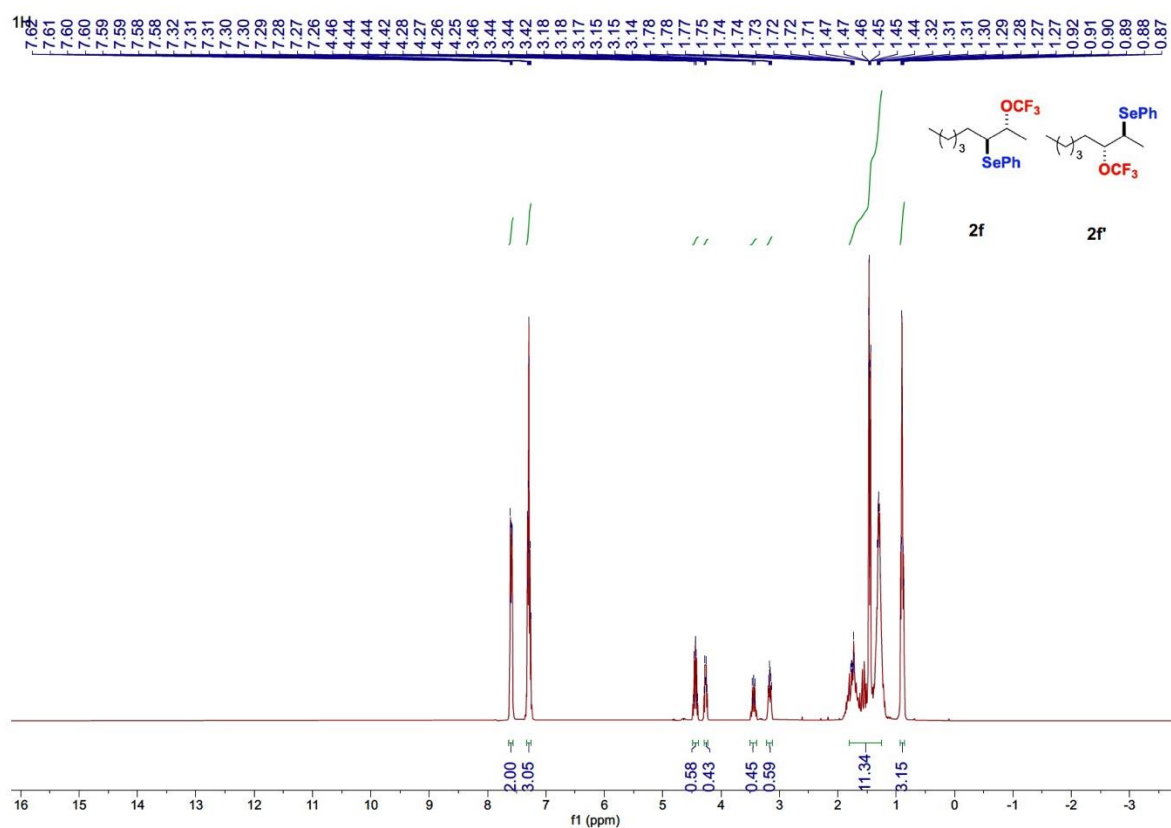
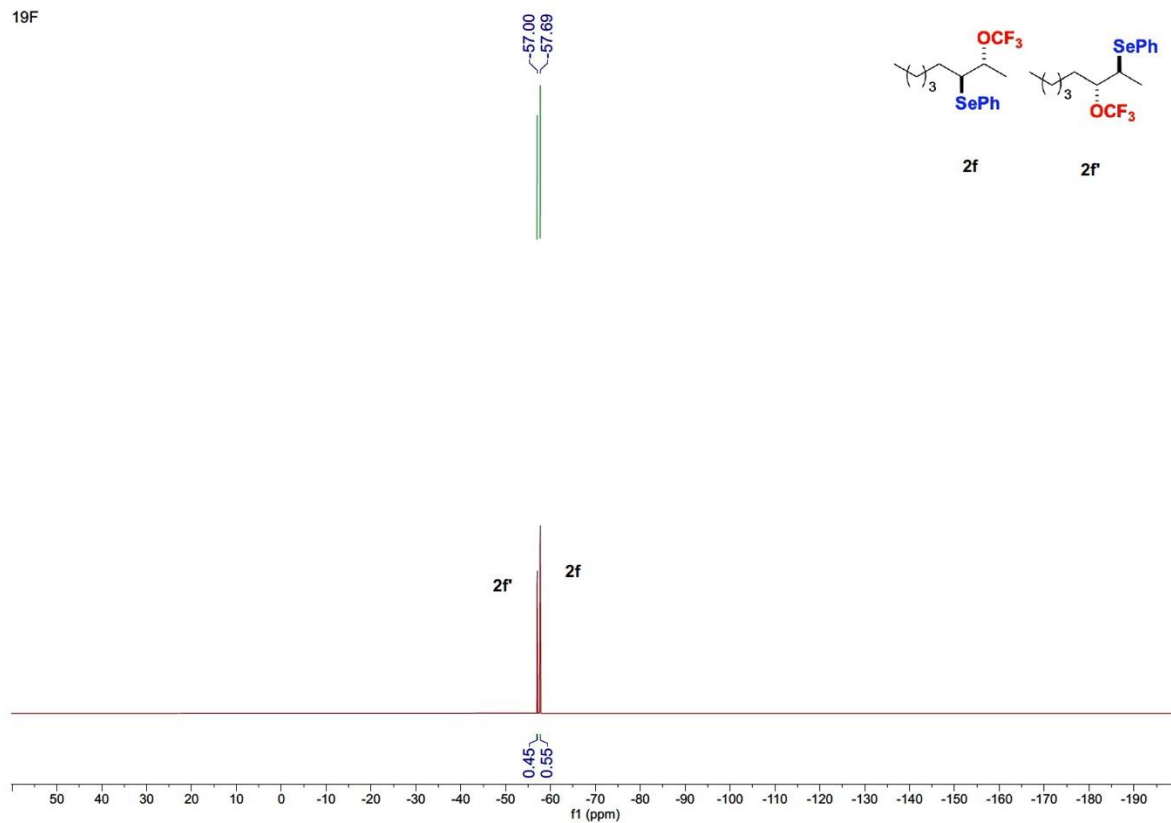
¹³C



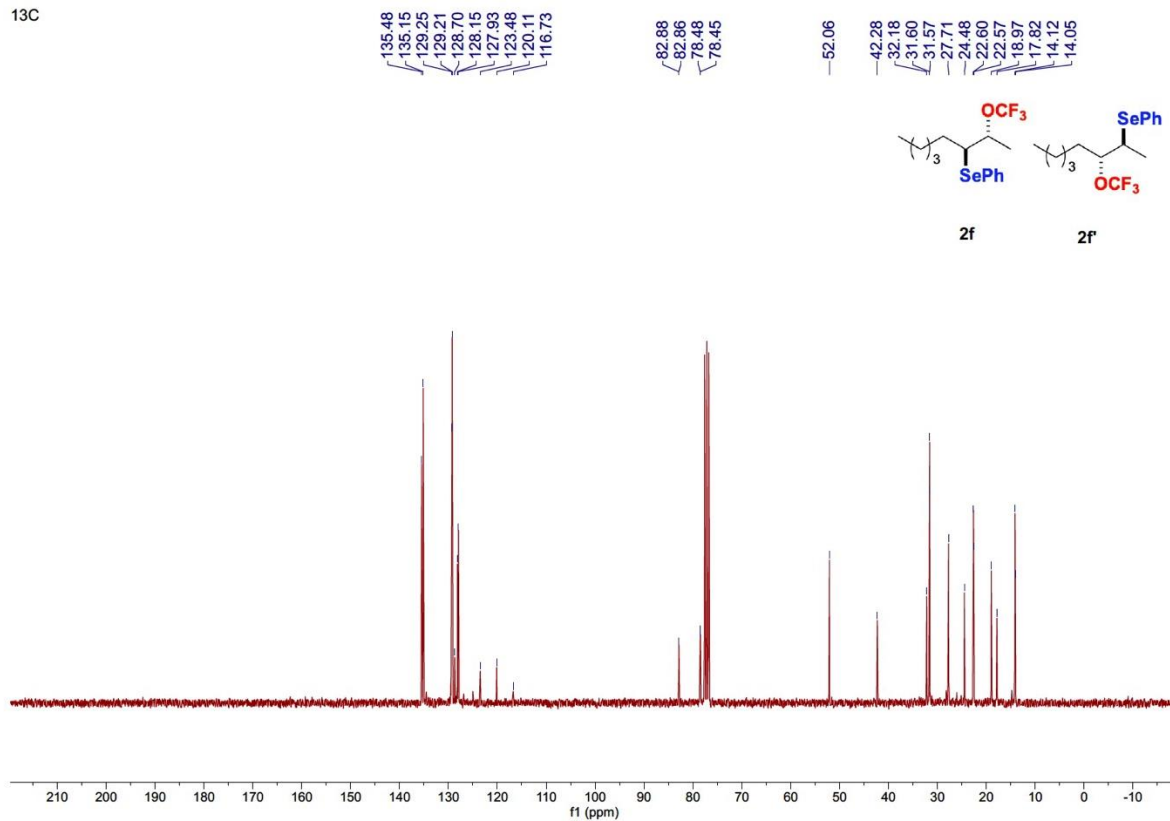
⁷⁷Se



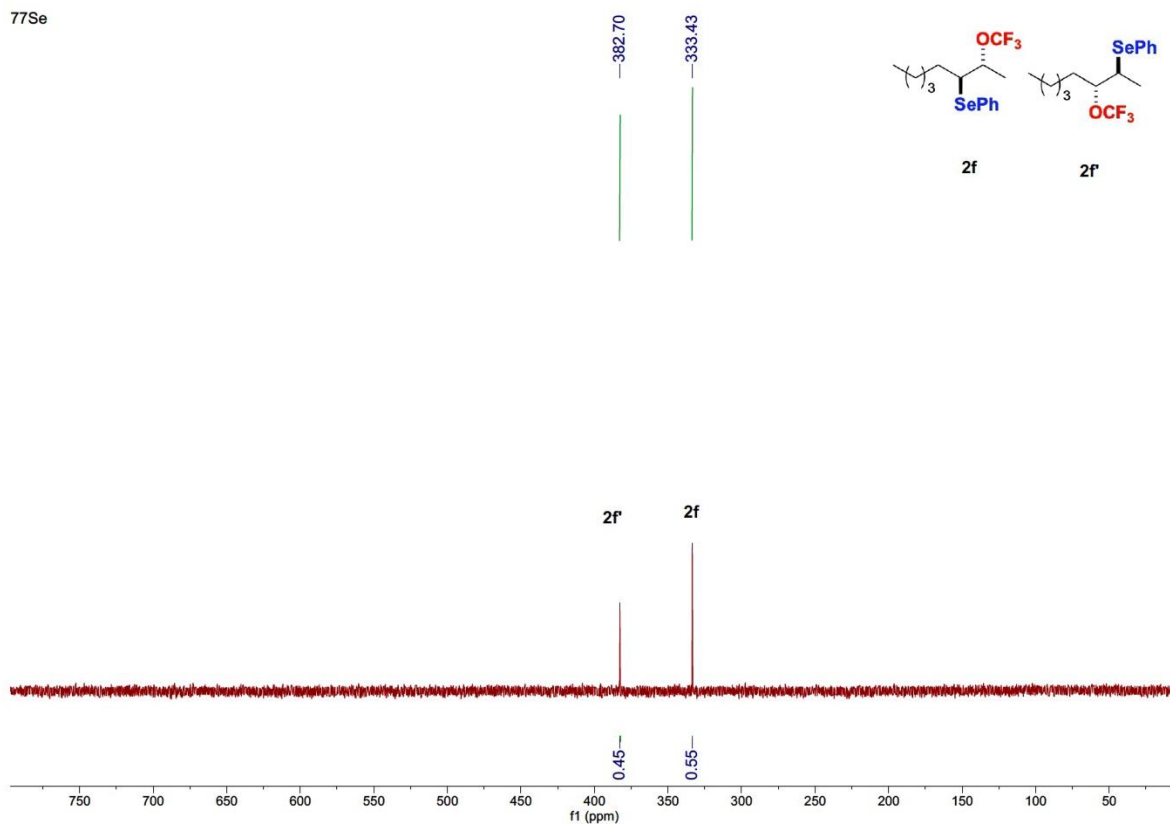
19F



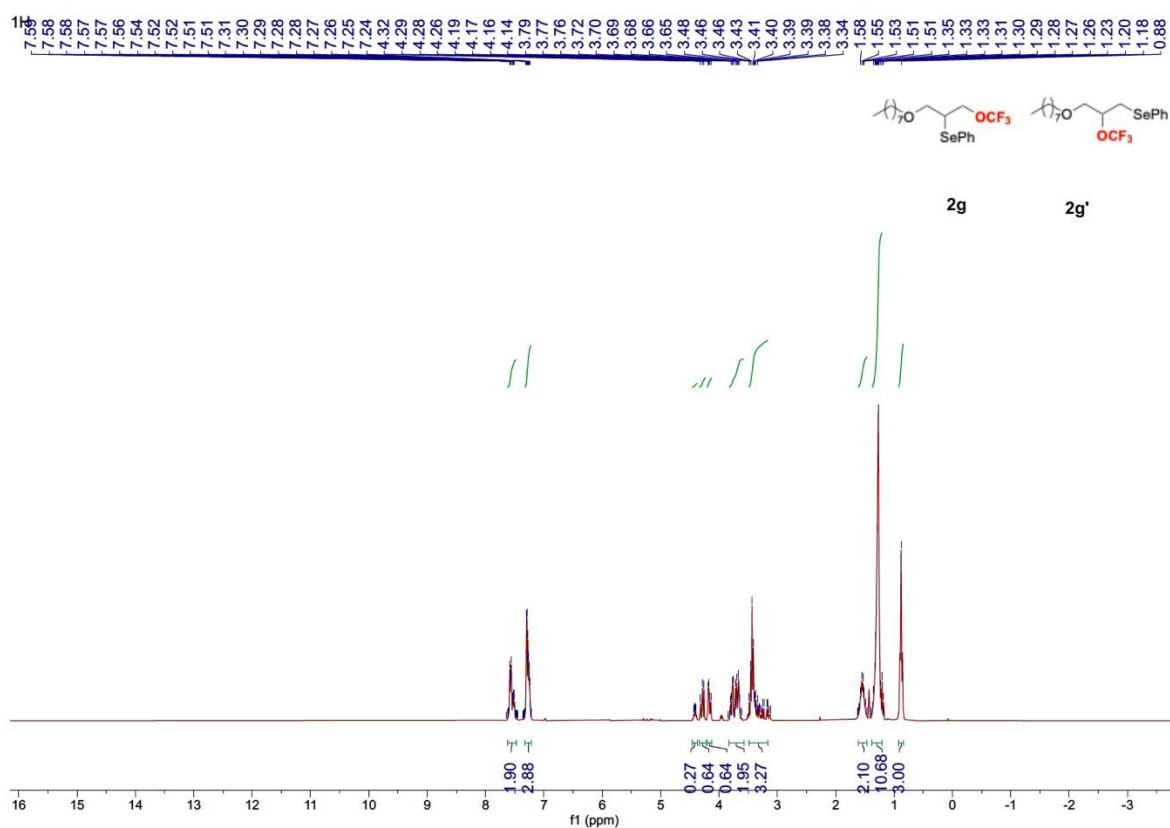
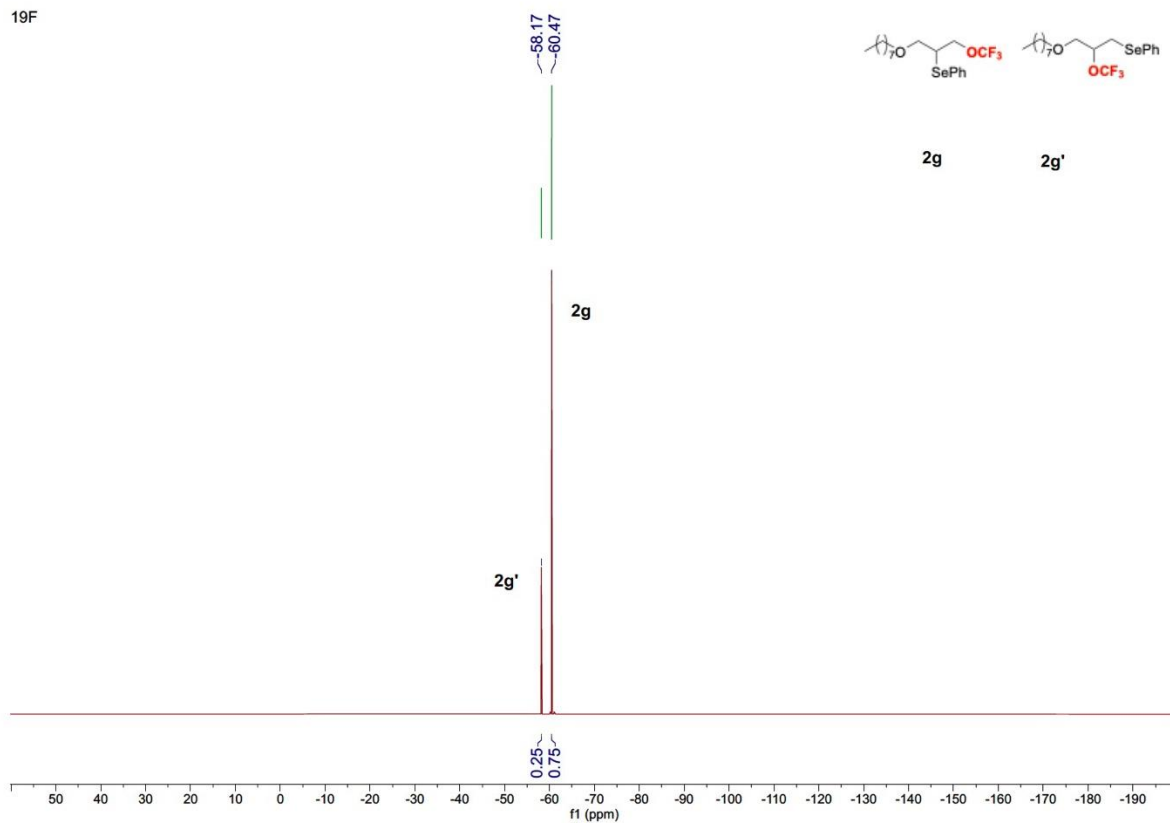
¹³C



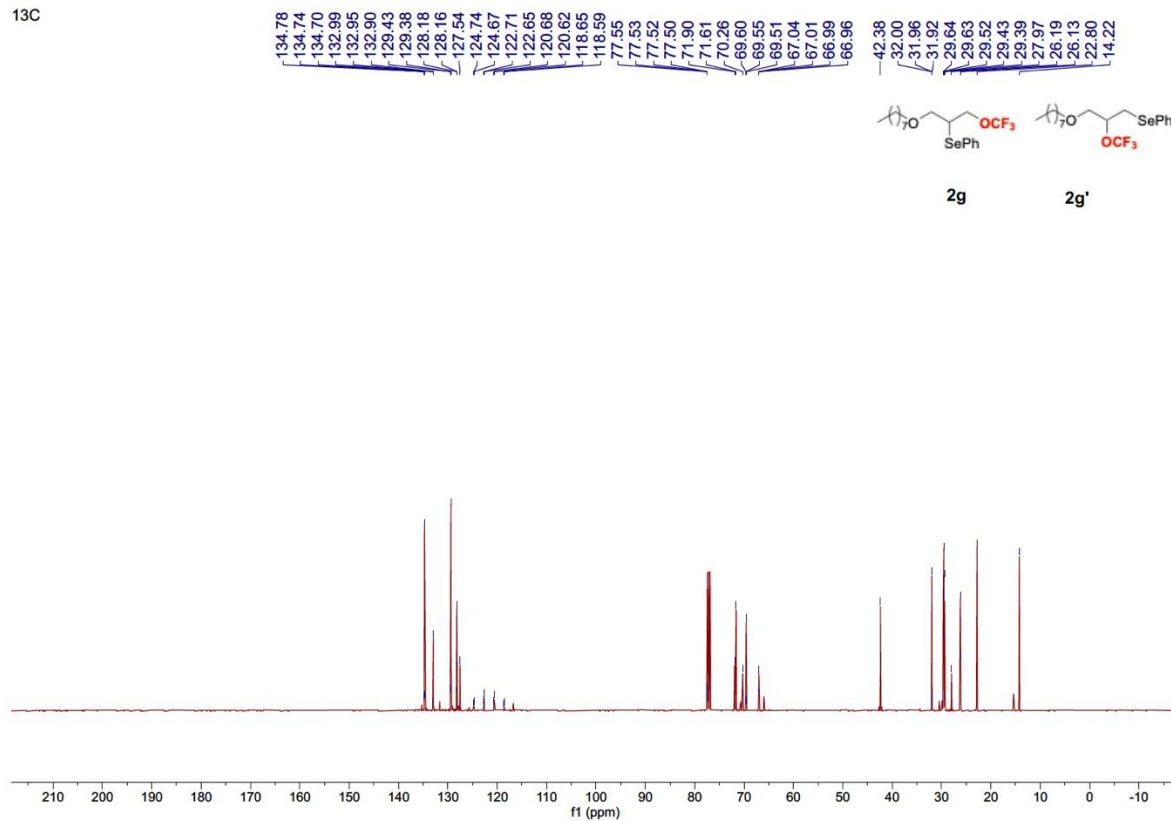
⁷⁷Se



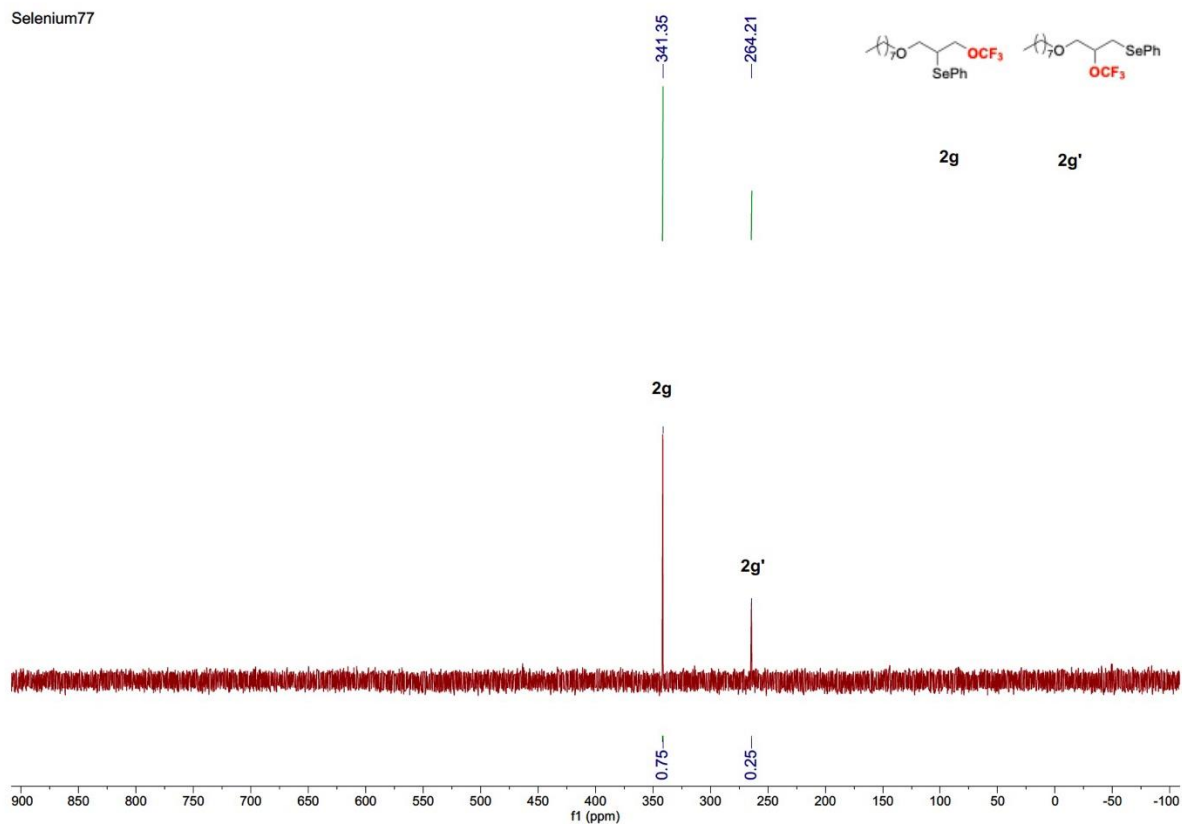
¹⁹F



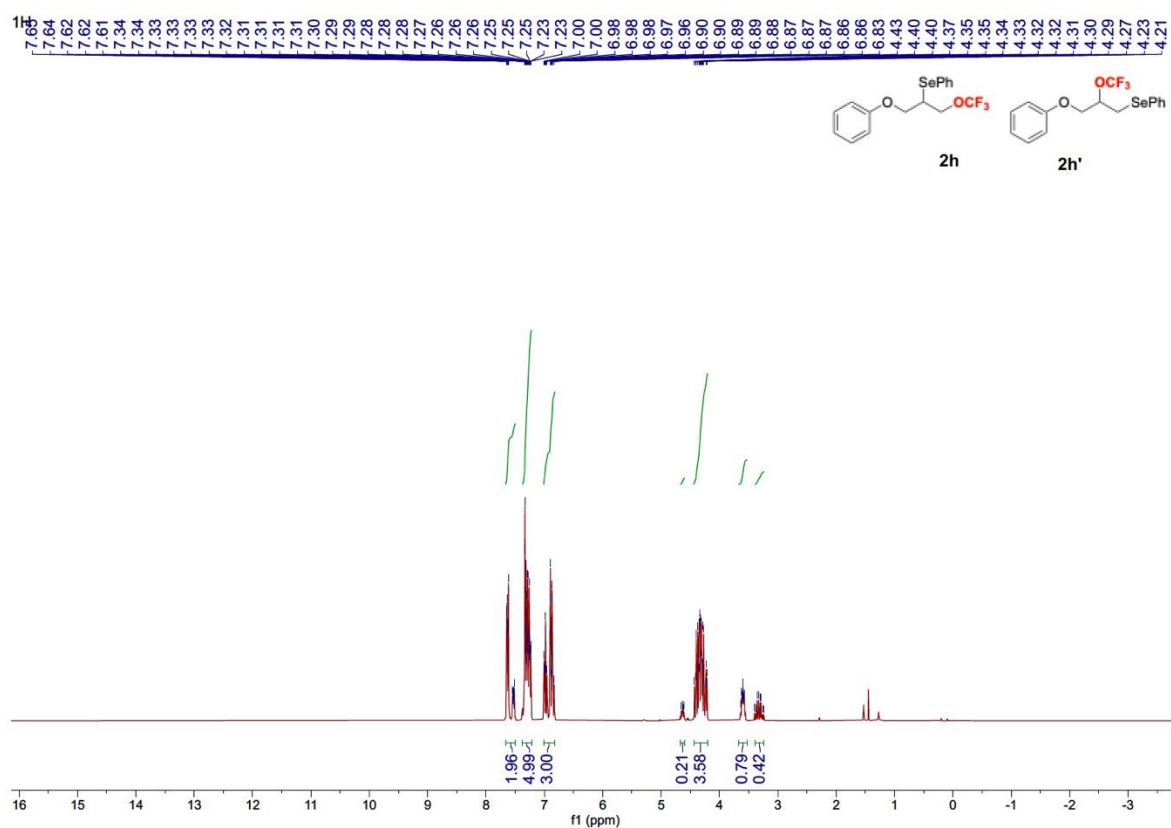
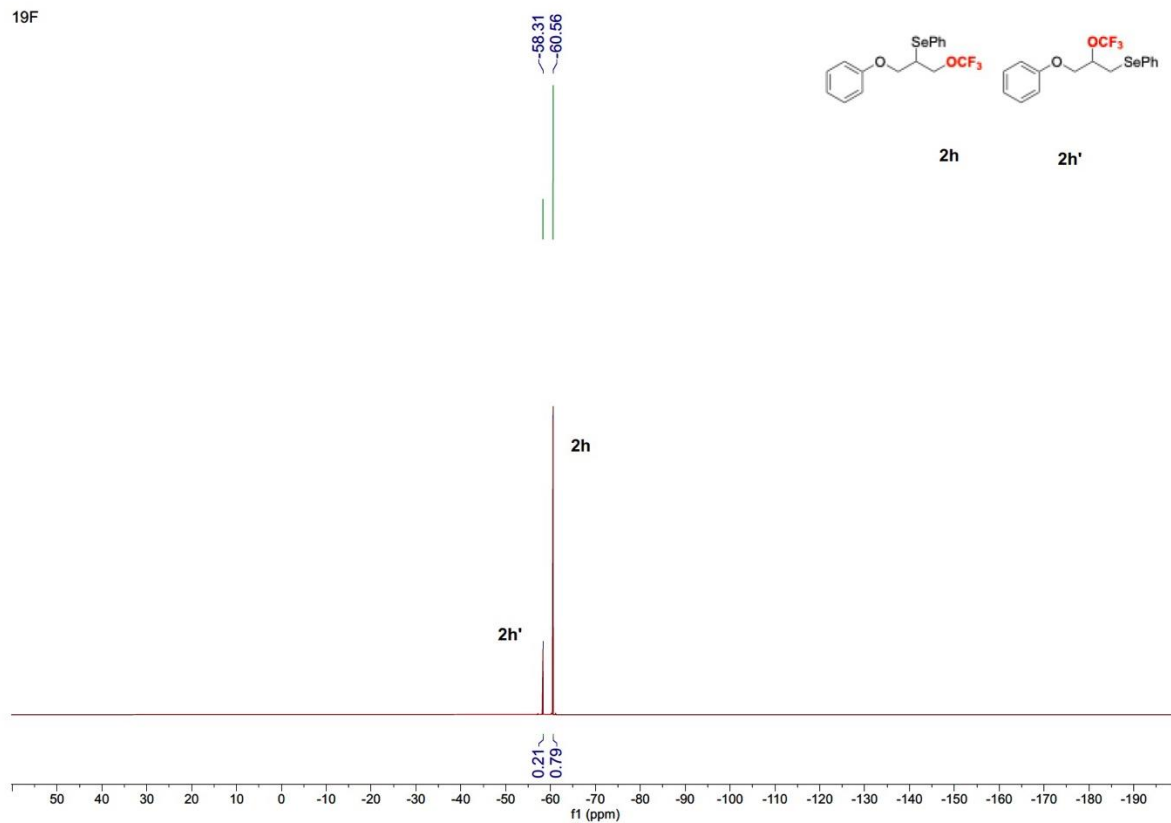
13C



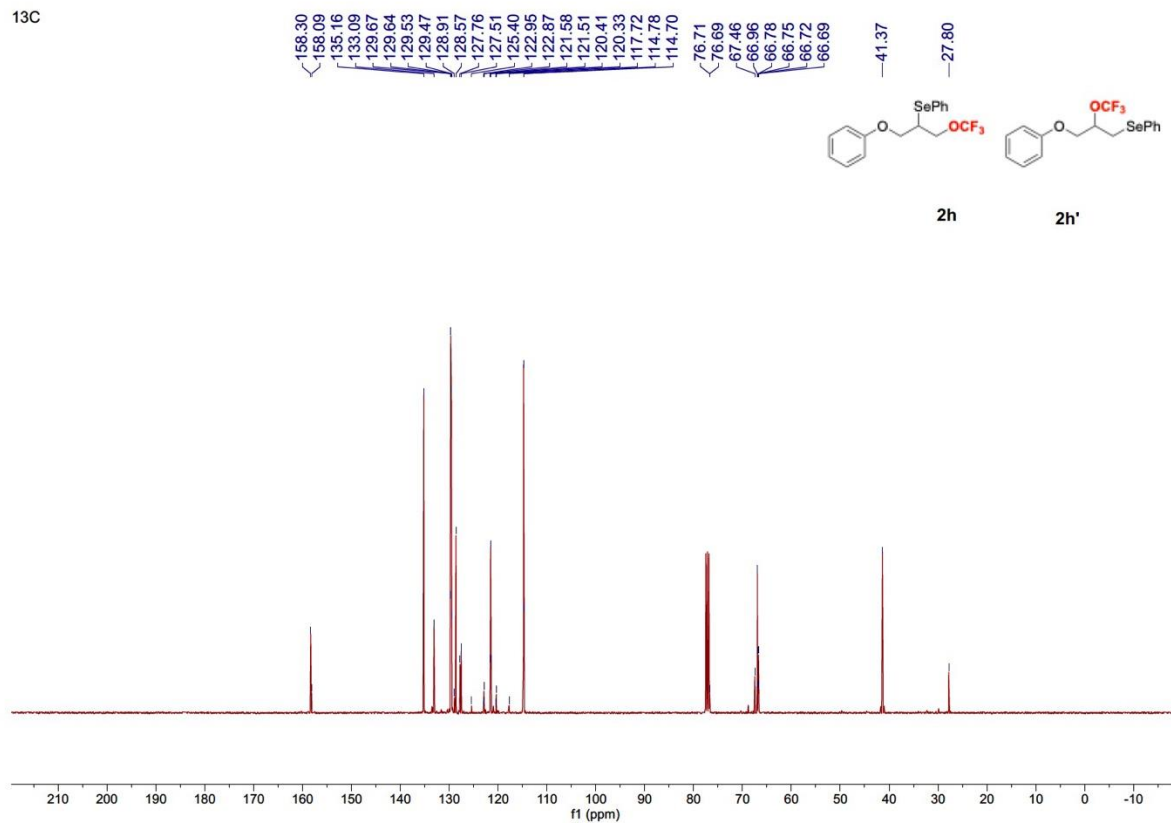
Selenium77



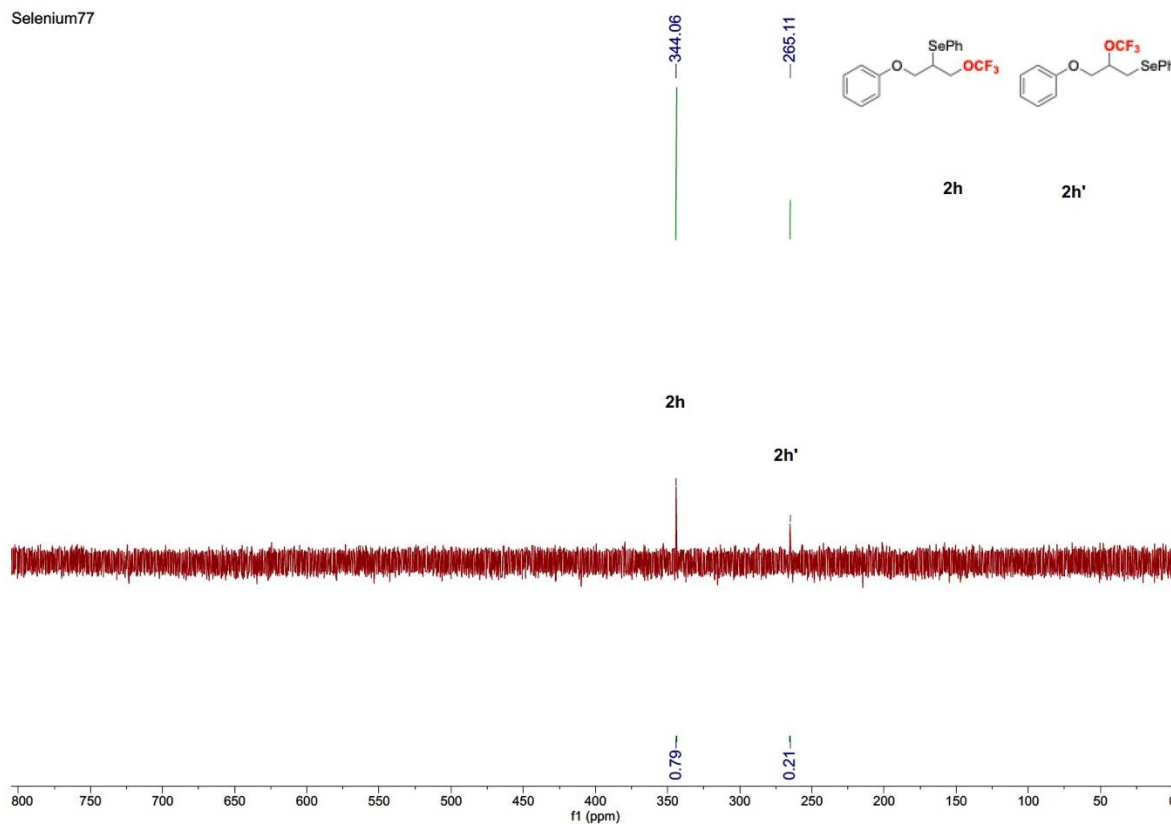
19F



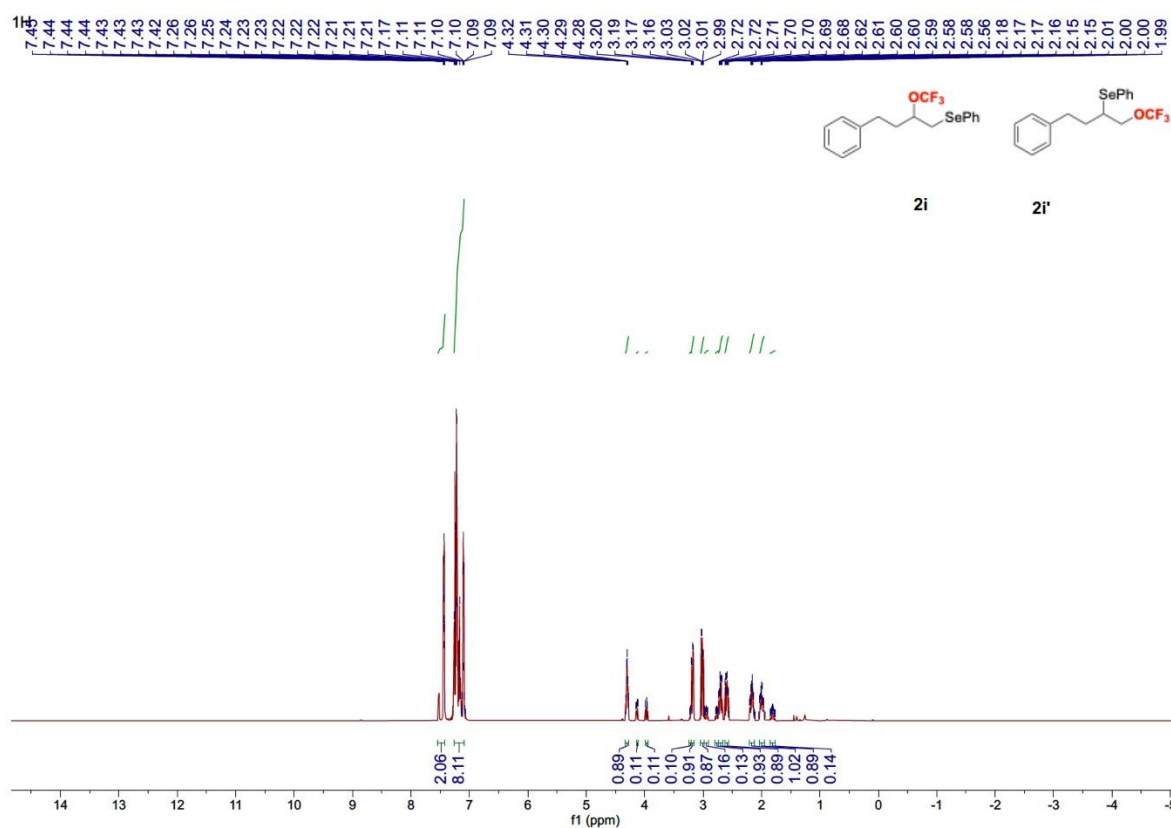
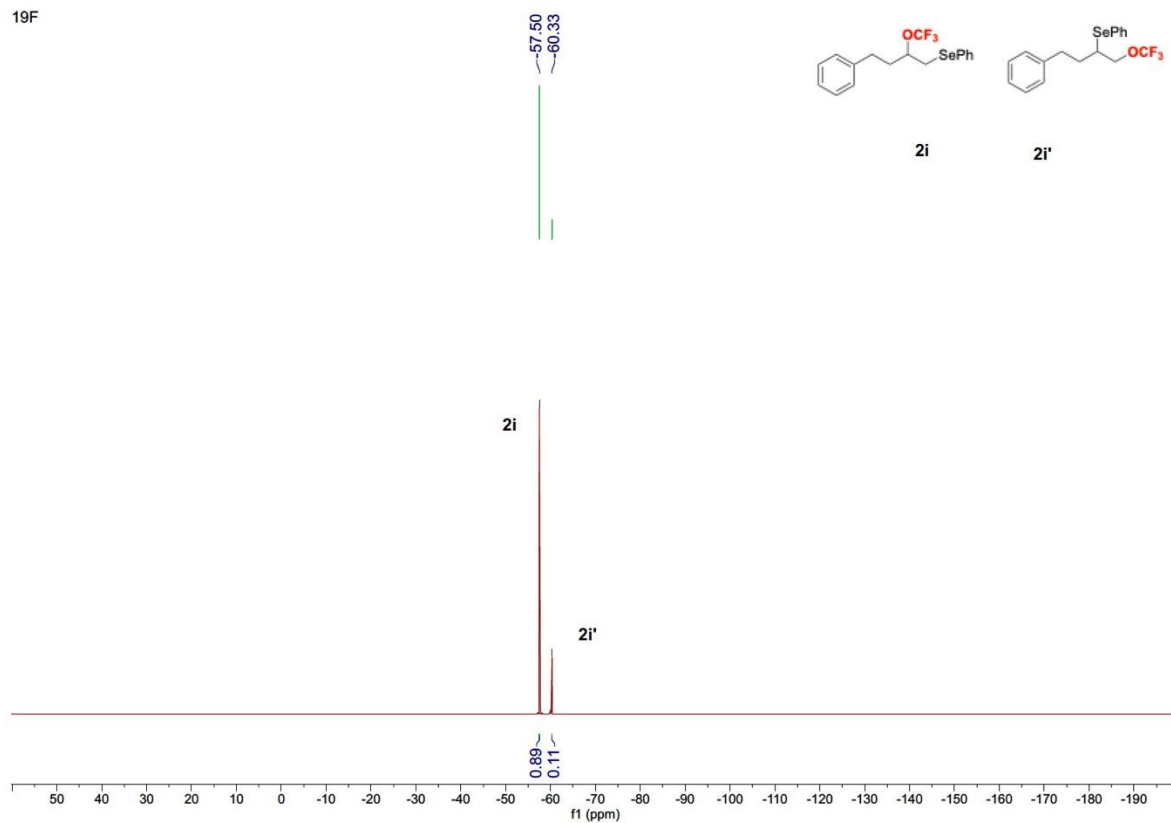
13C



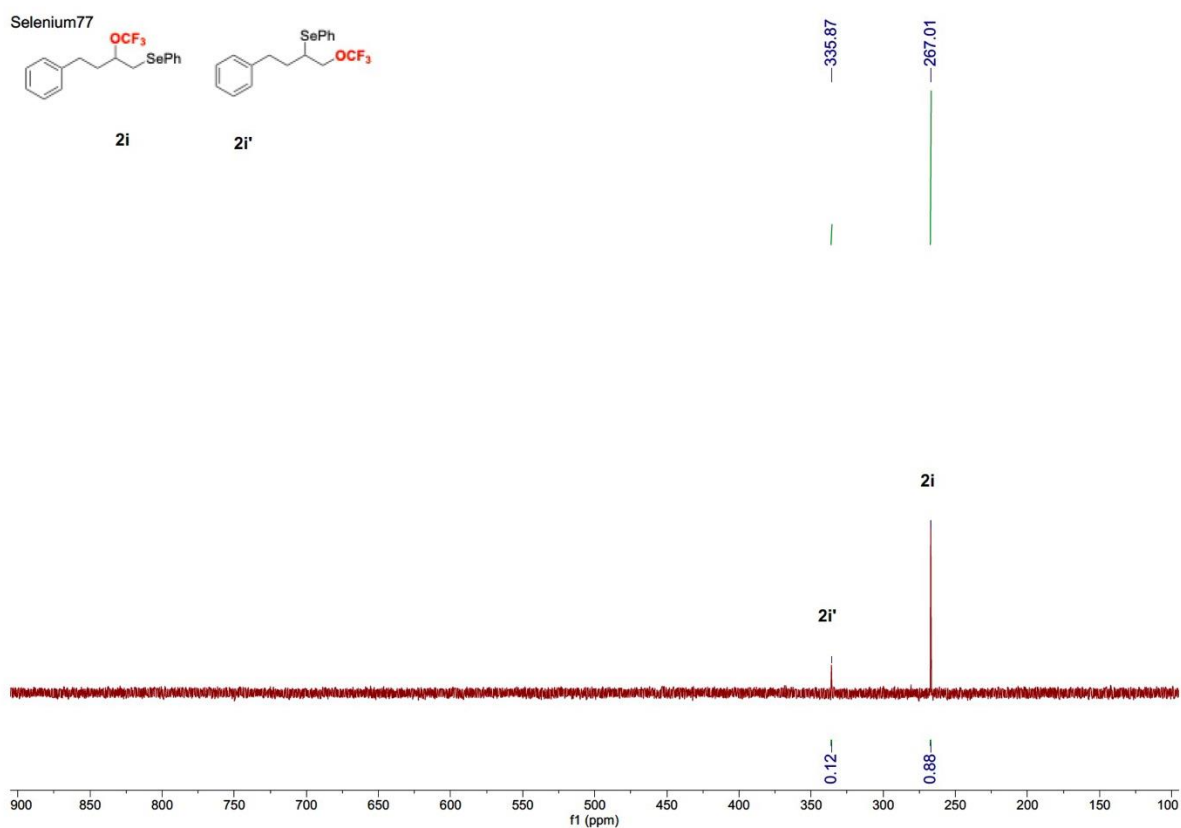
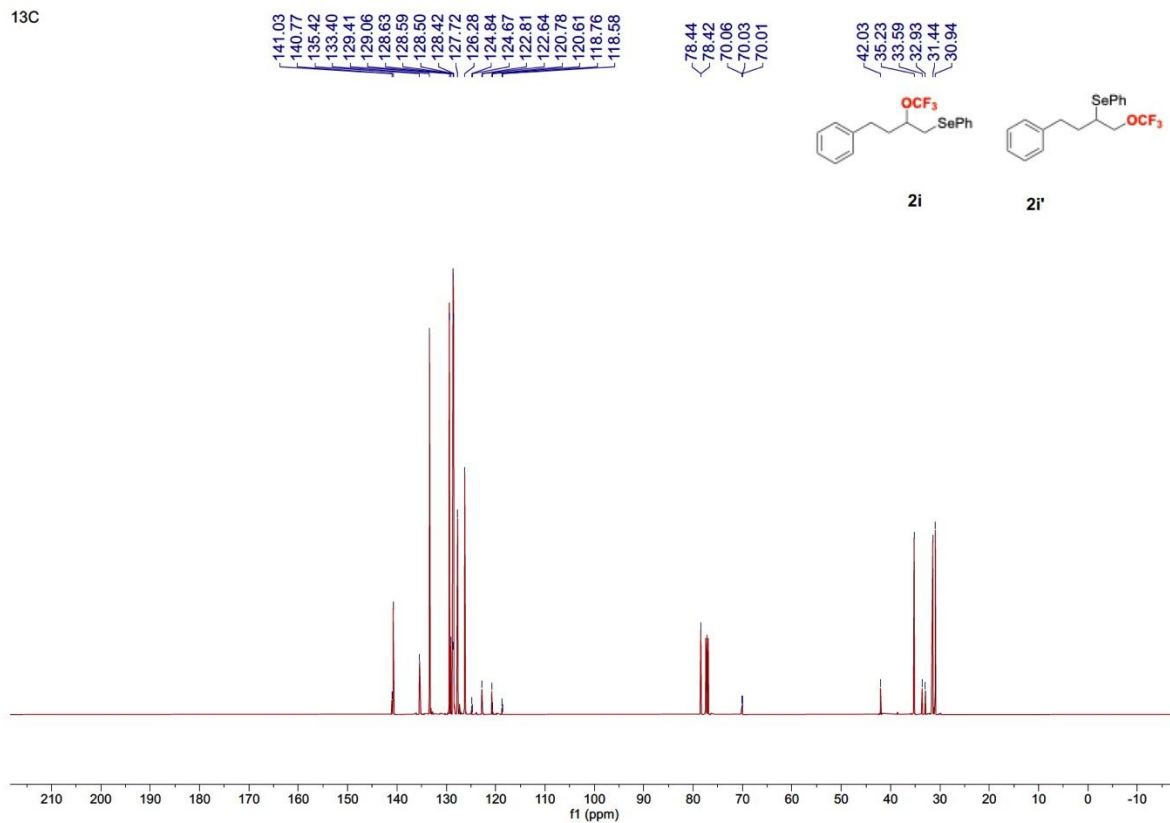
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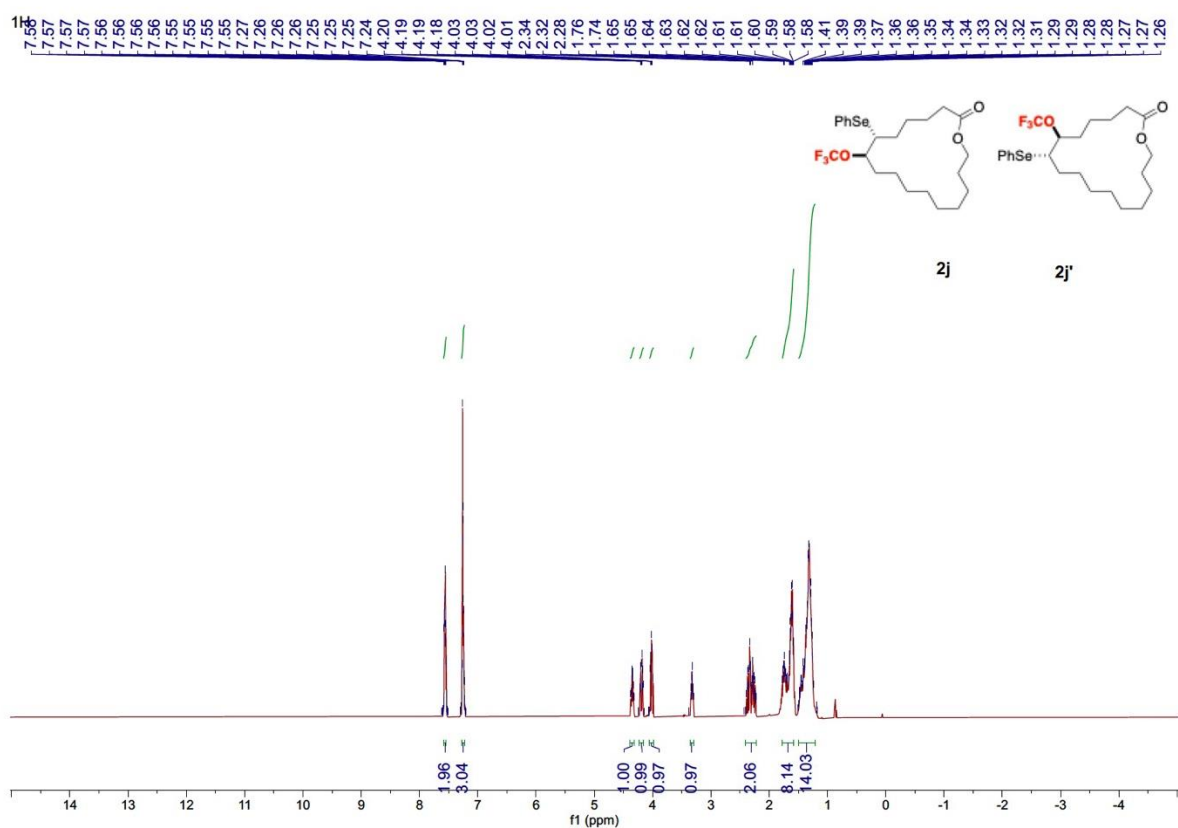
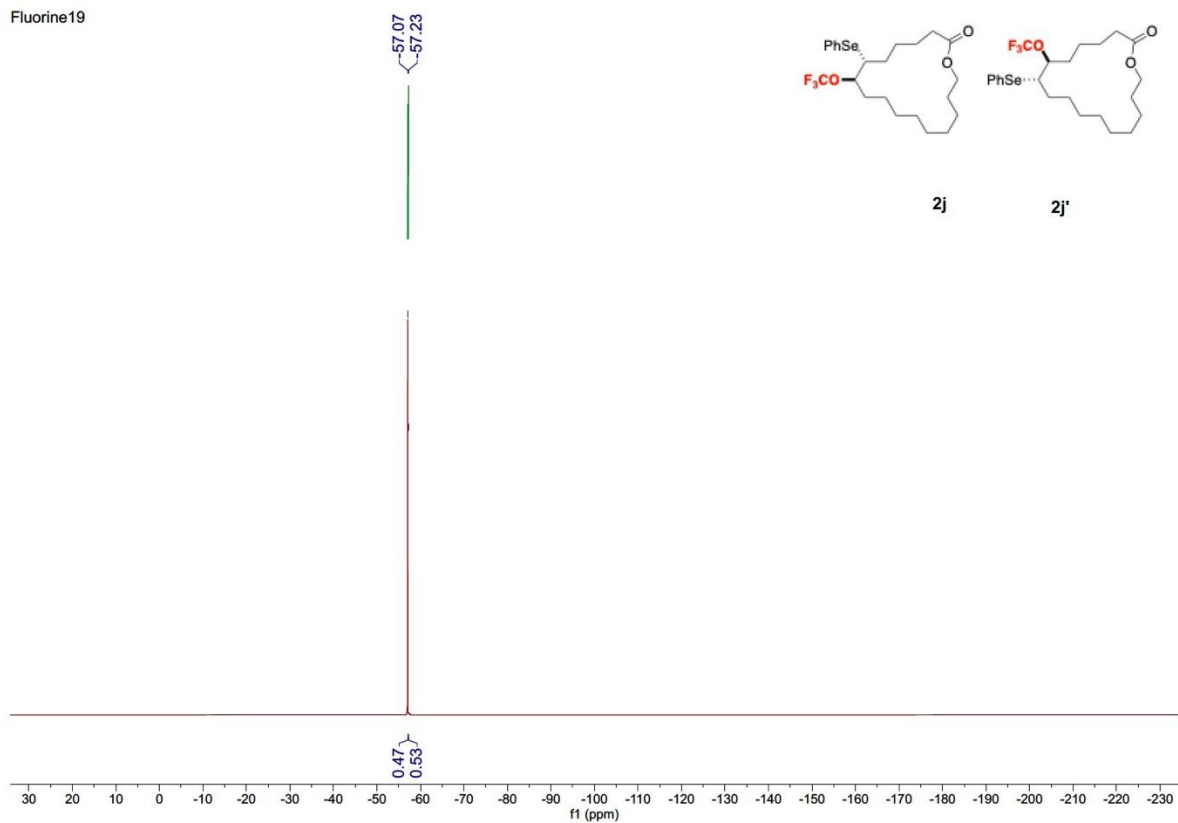
19F



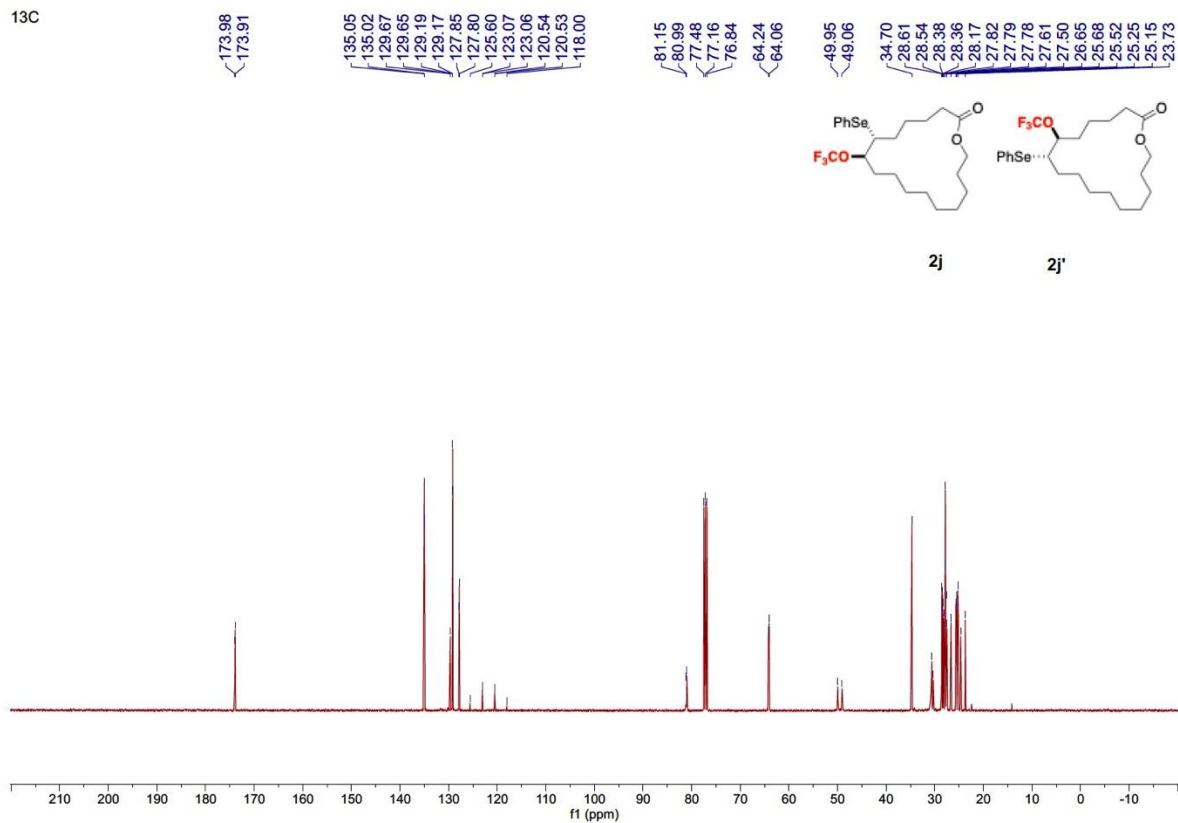
13C



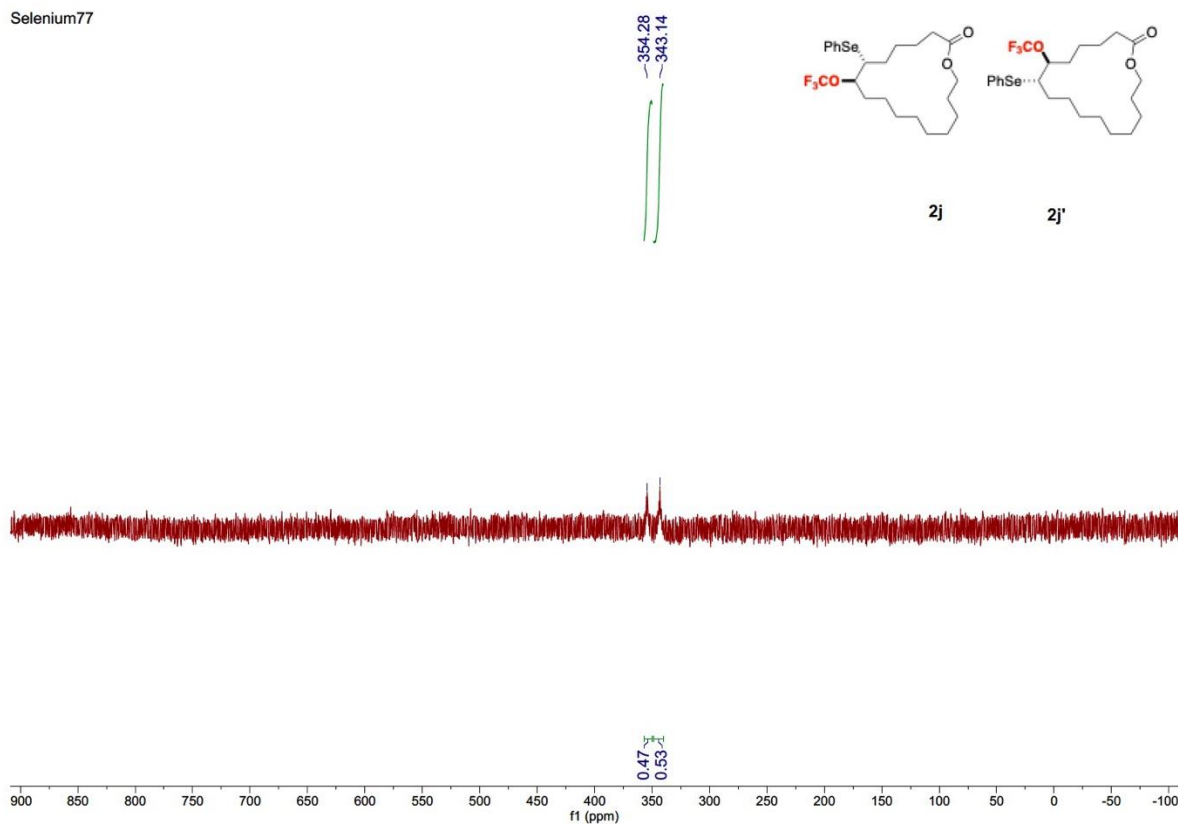
Fluorine19



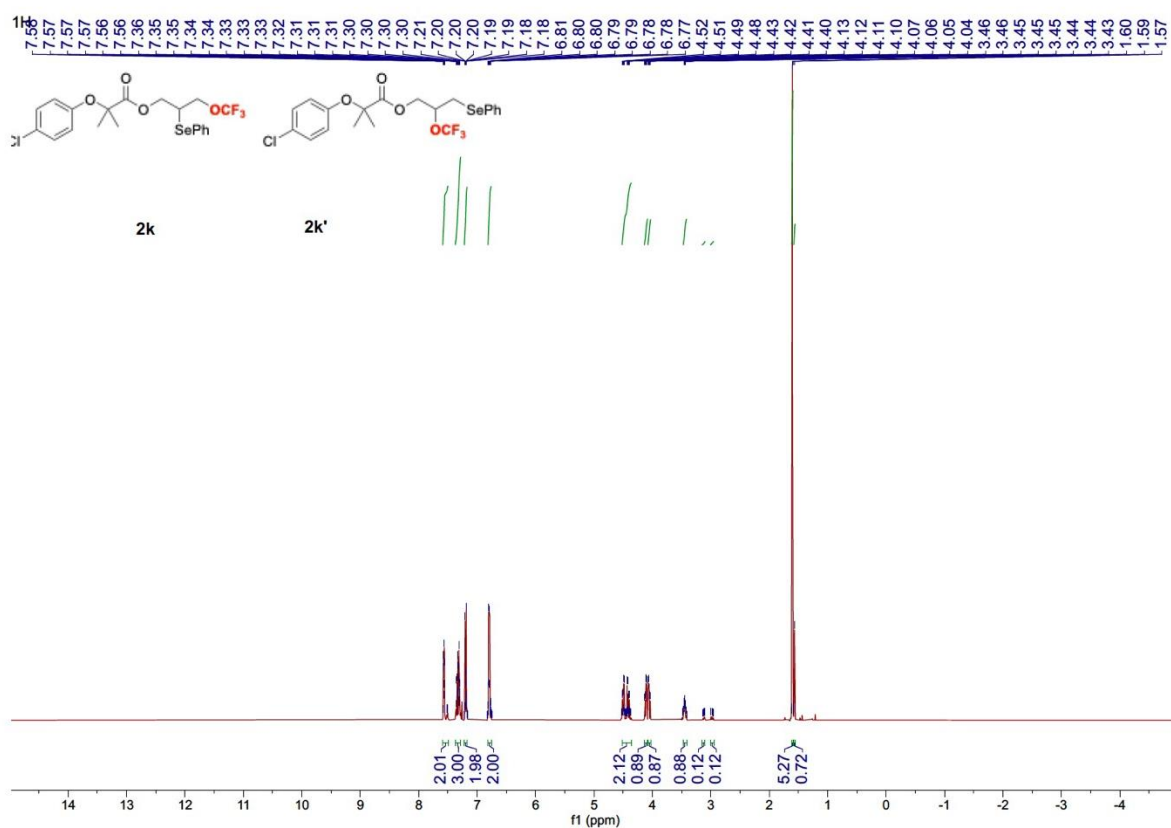
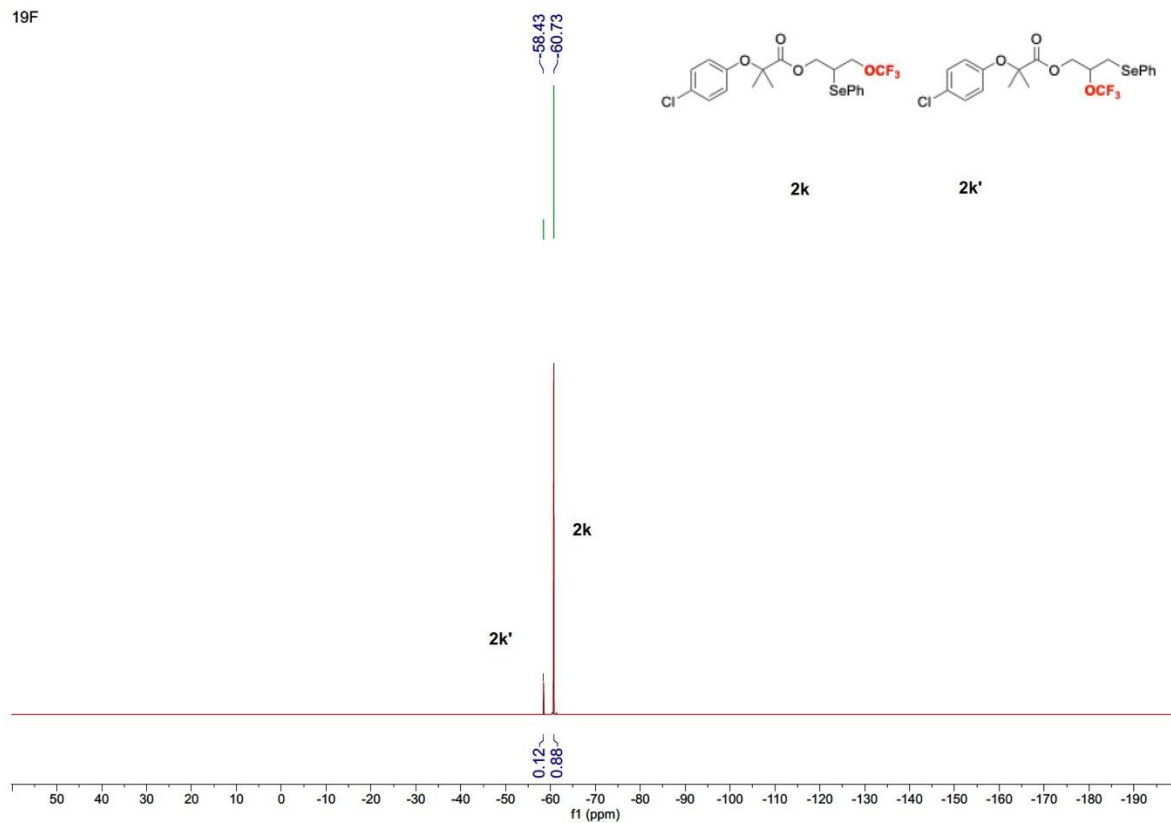
13C

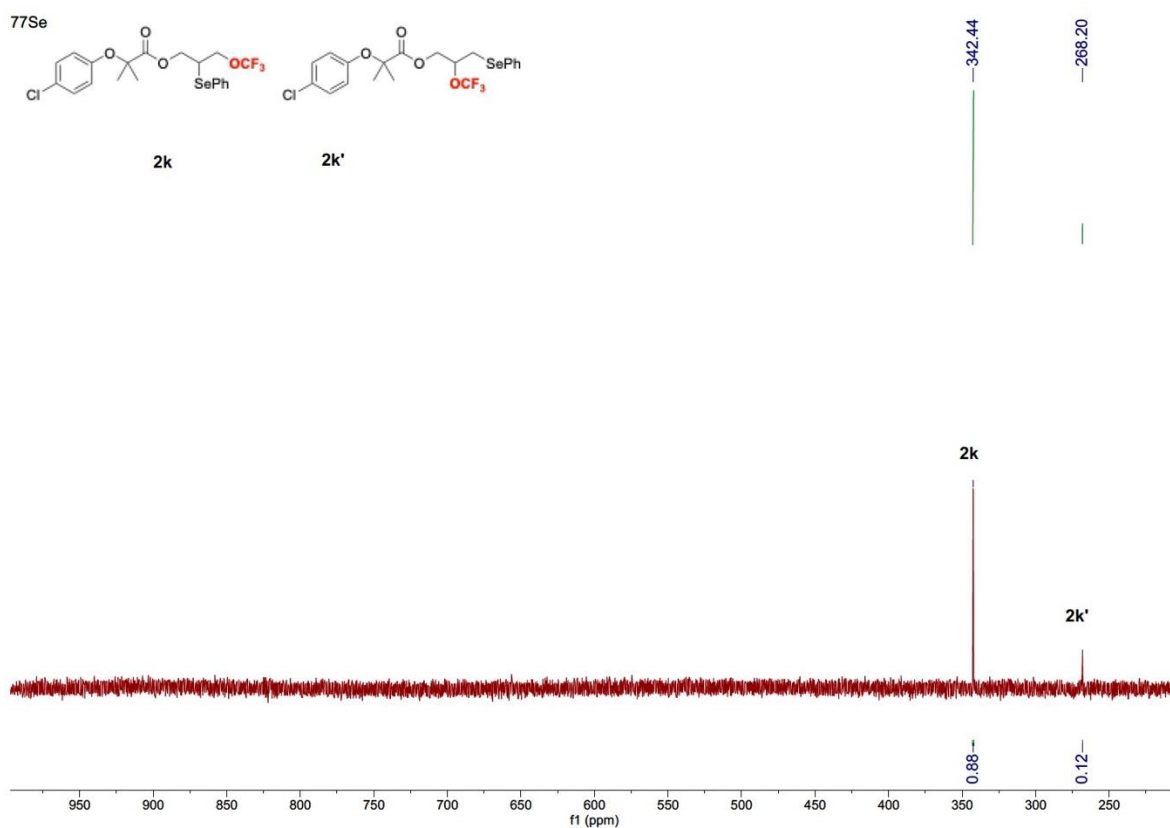
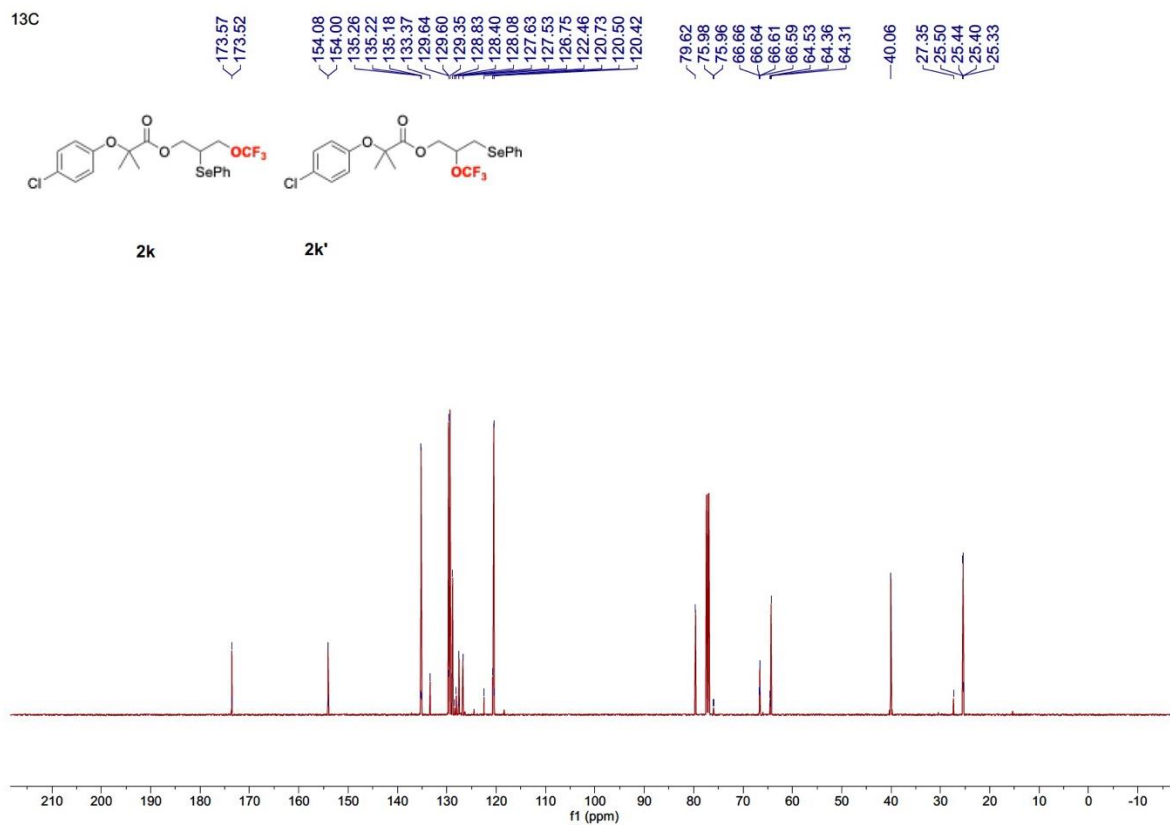


Selenium77

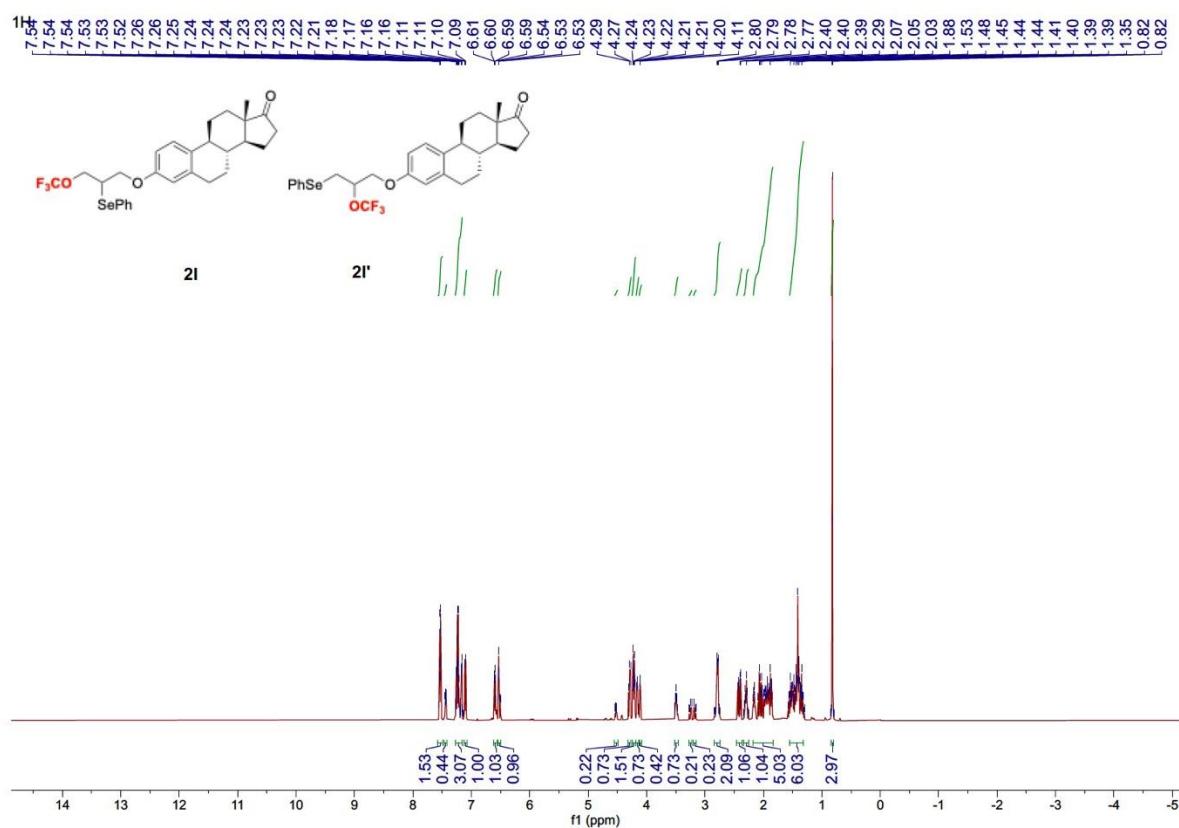
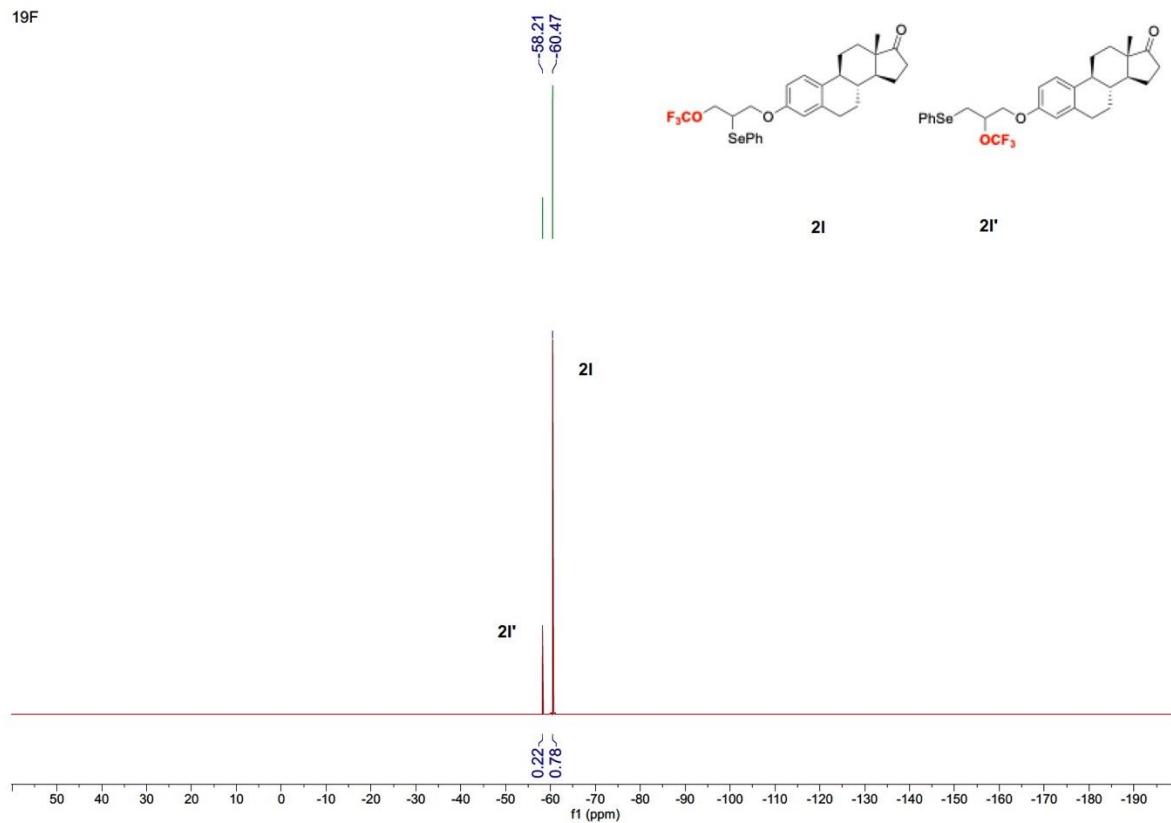


19F

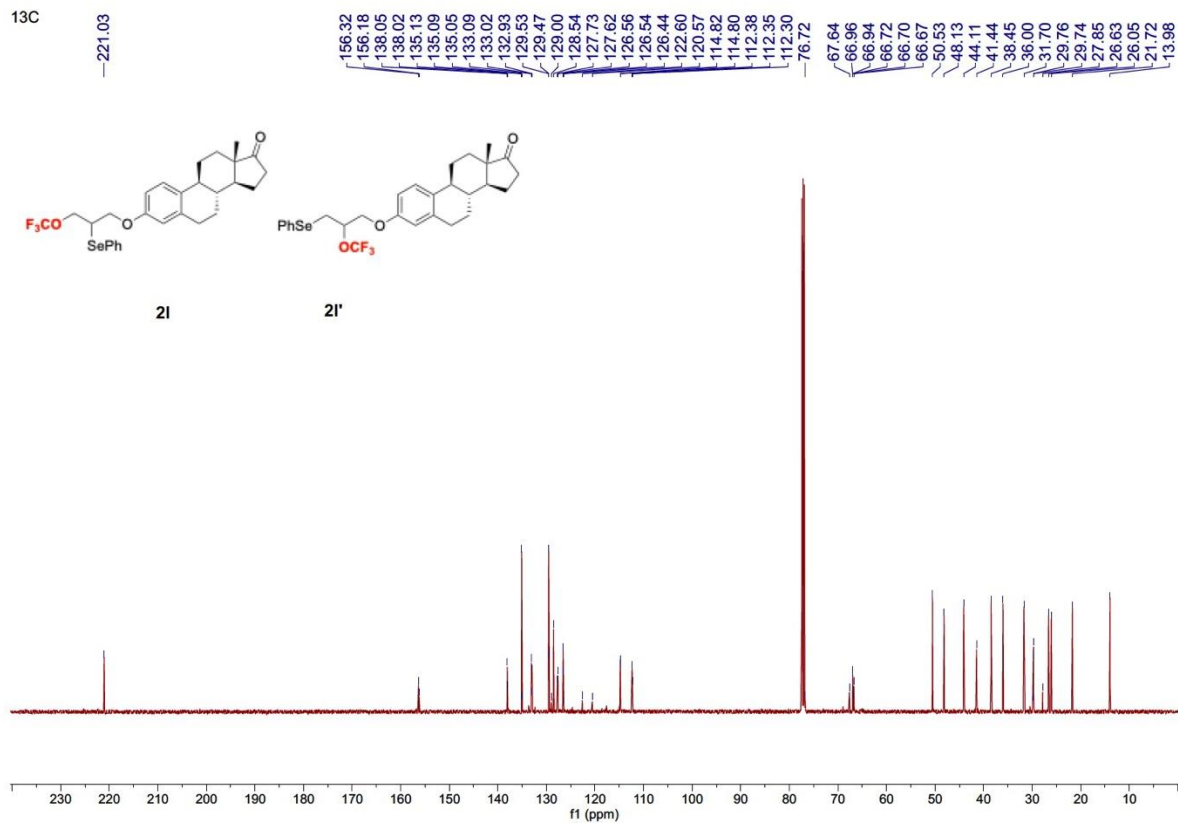




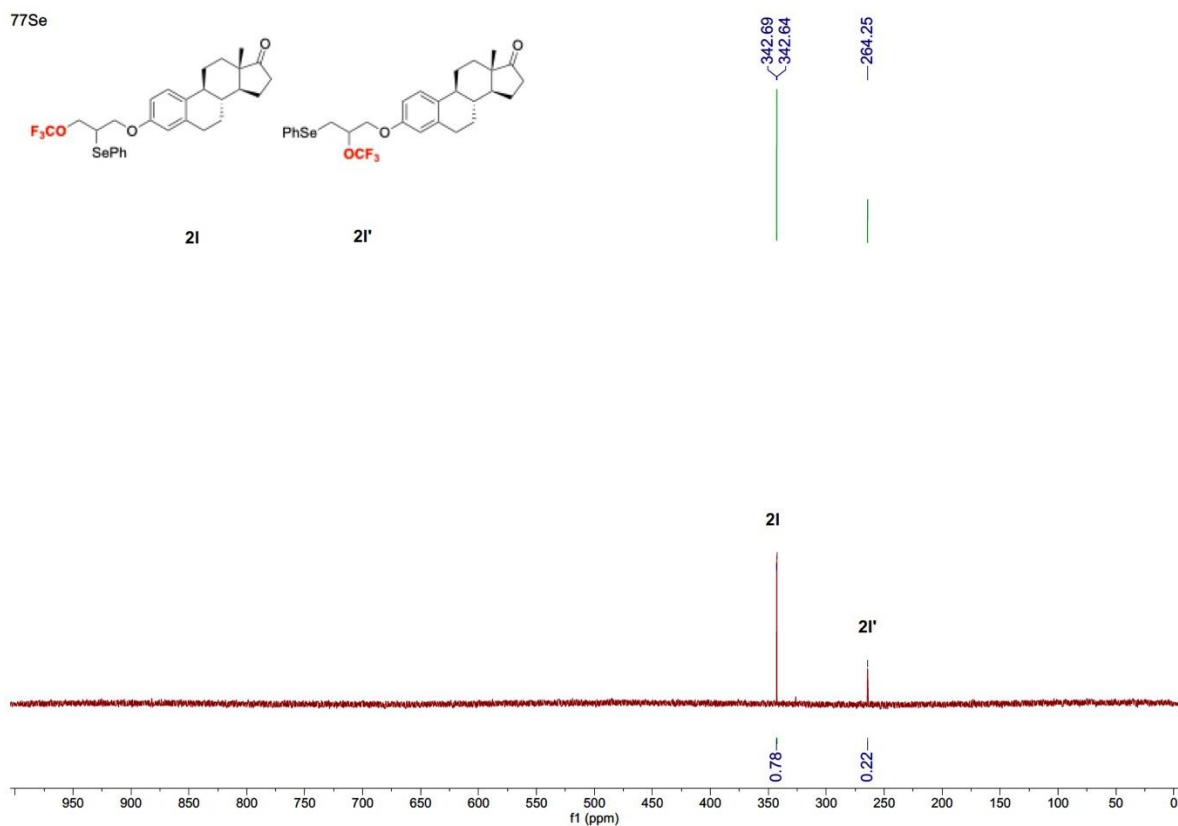
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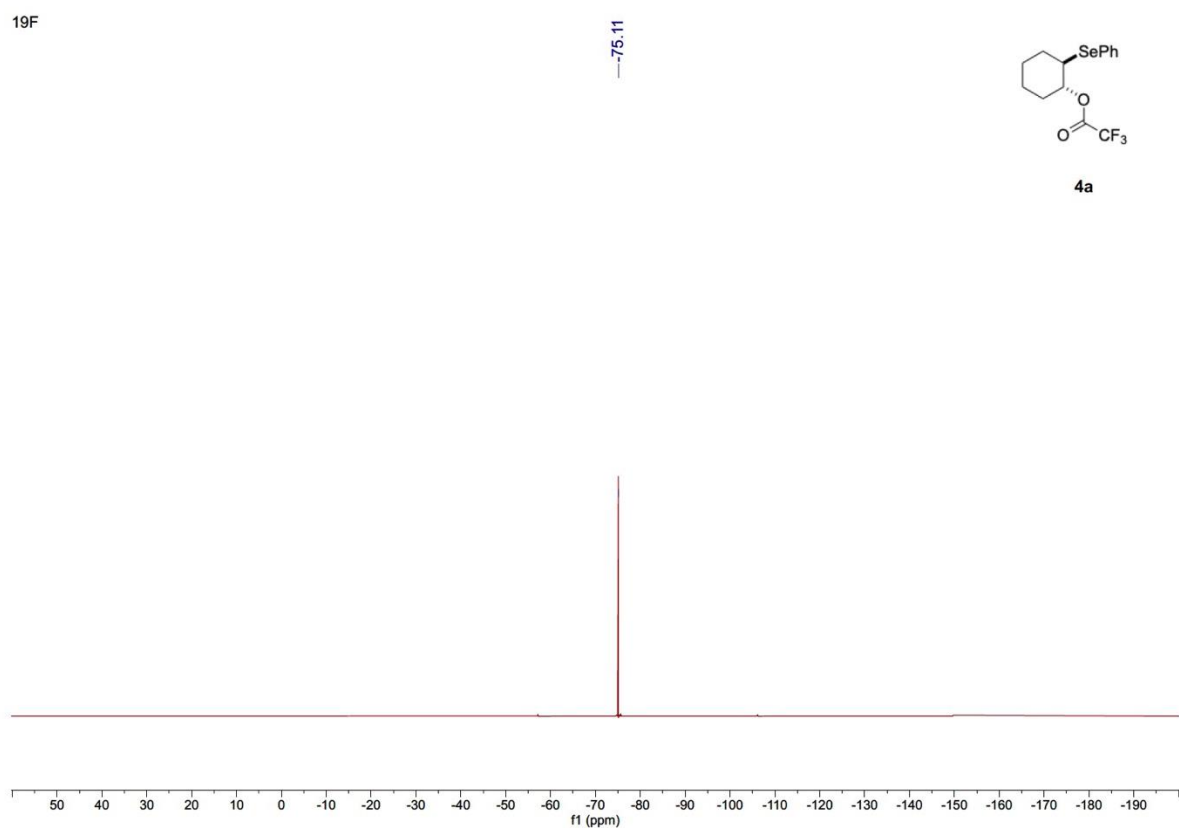
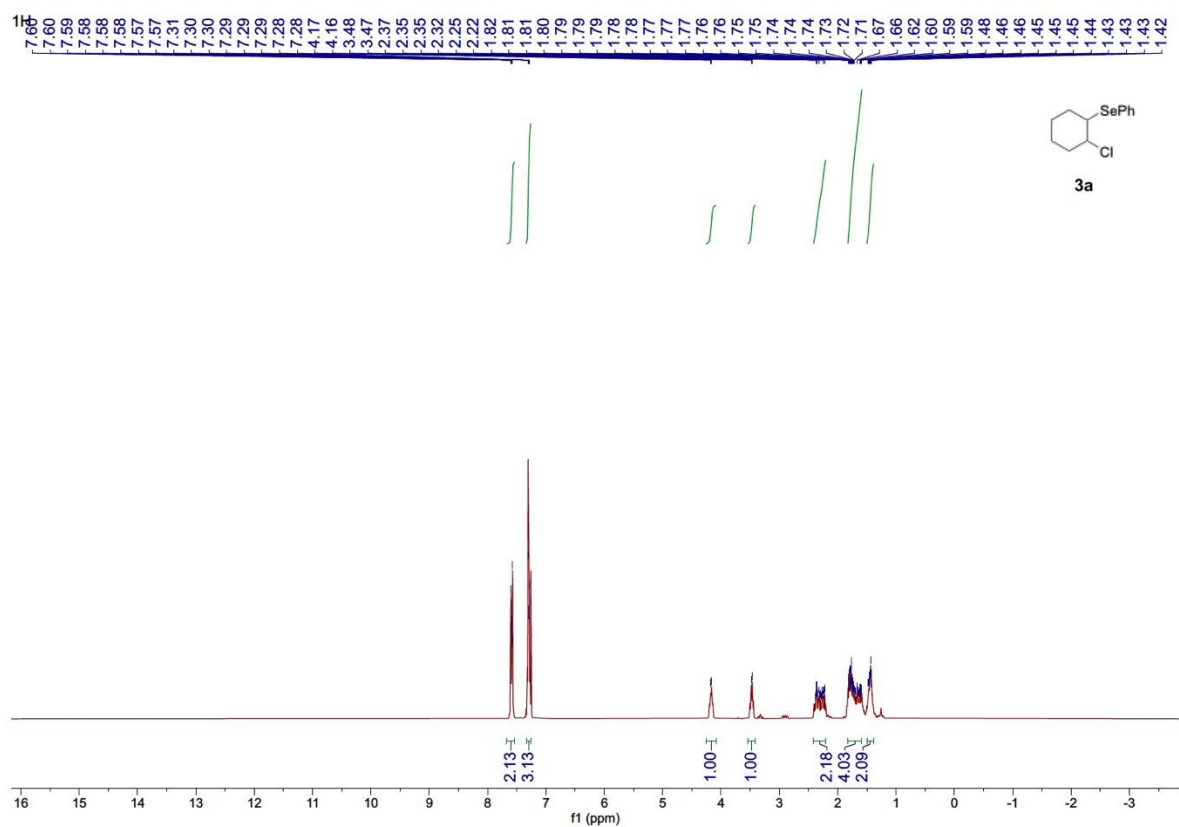


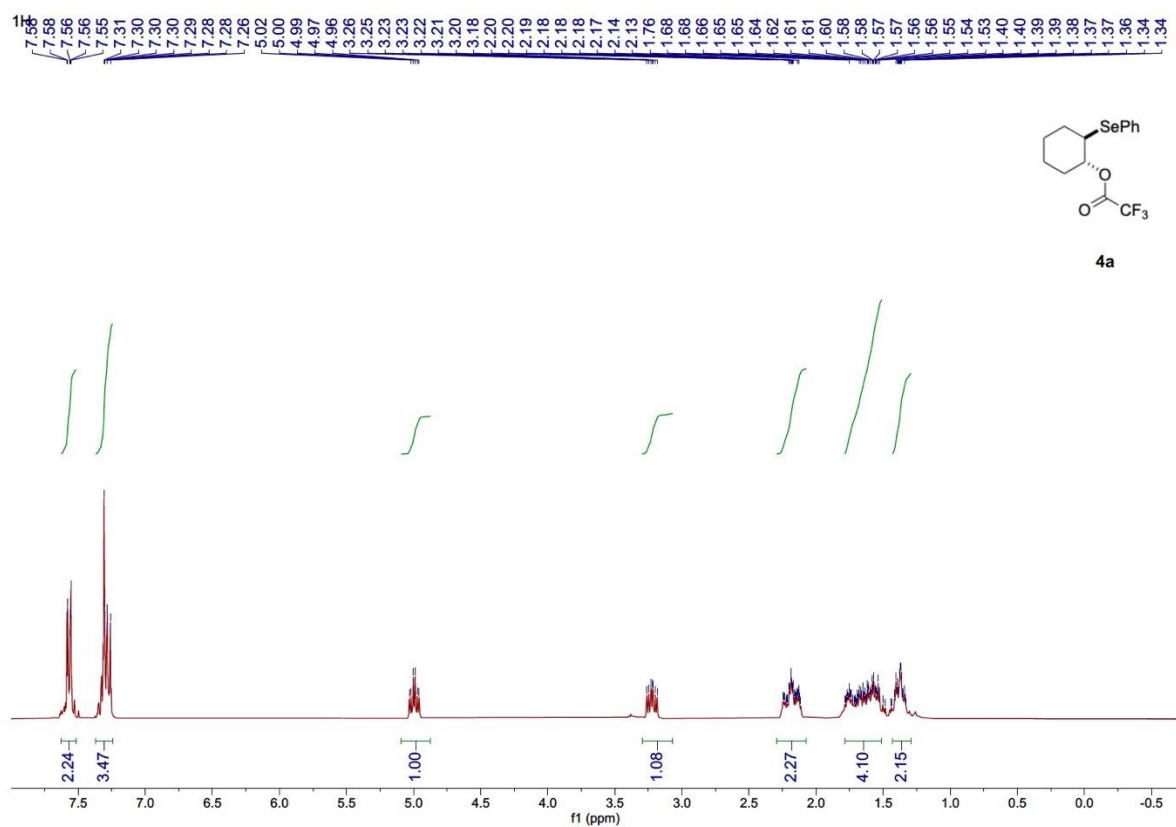
¹³C



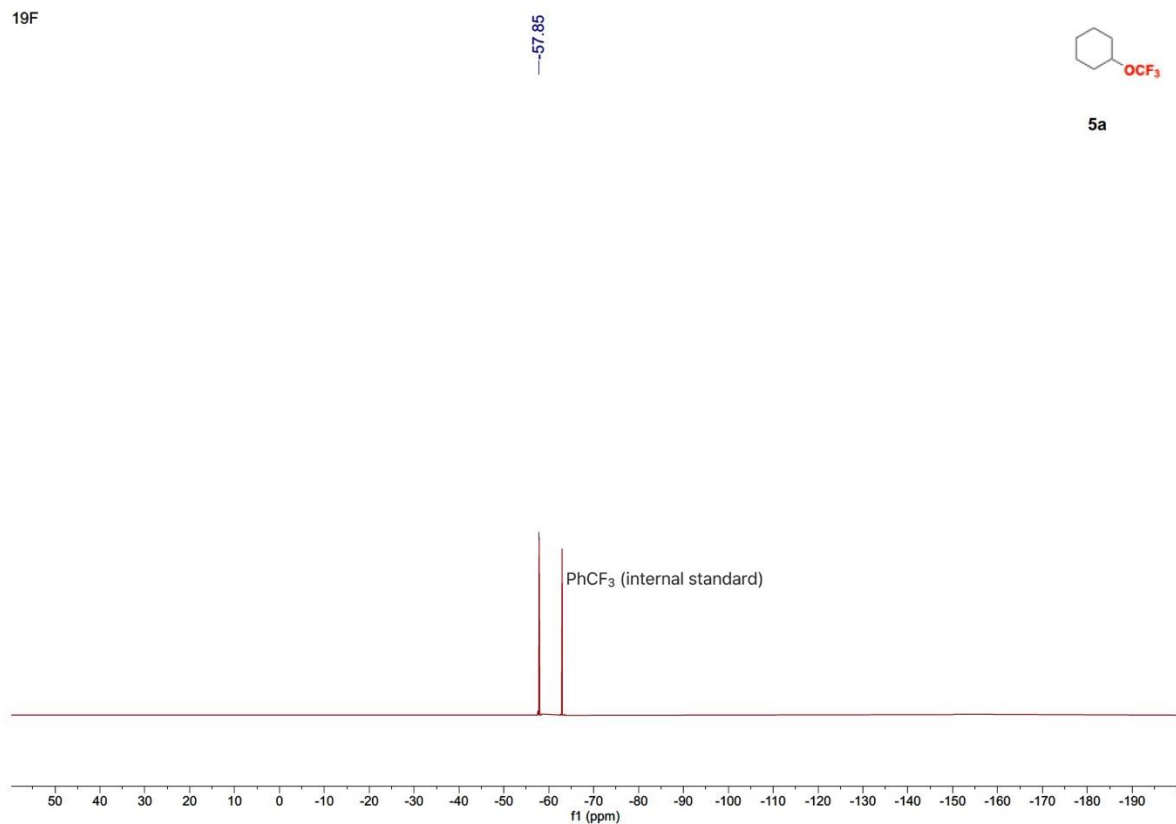
⁷⁷Se





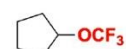


¹⁹F



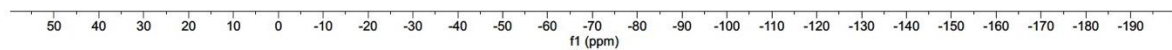
¹⁹F

-58.30



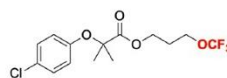
5b

PhCF₃ (internal standard)

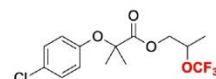


¹⁹F

-58.49
-61.03



5k

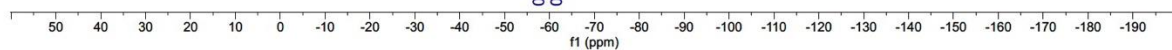


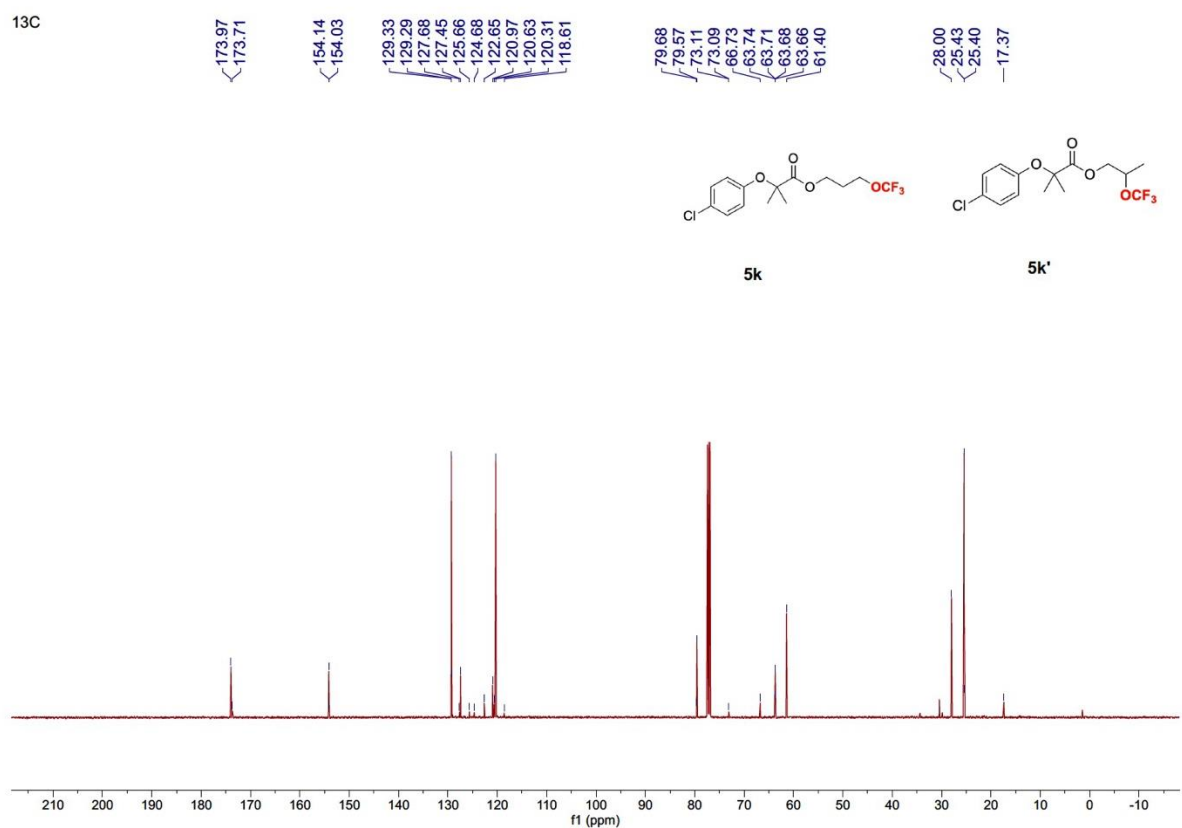
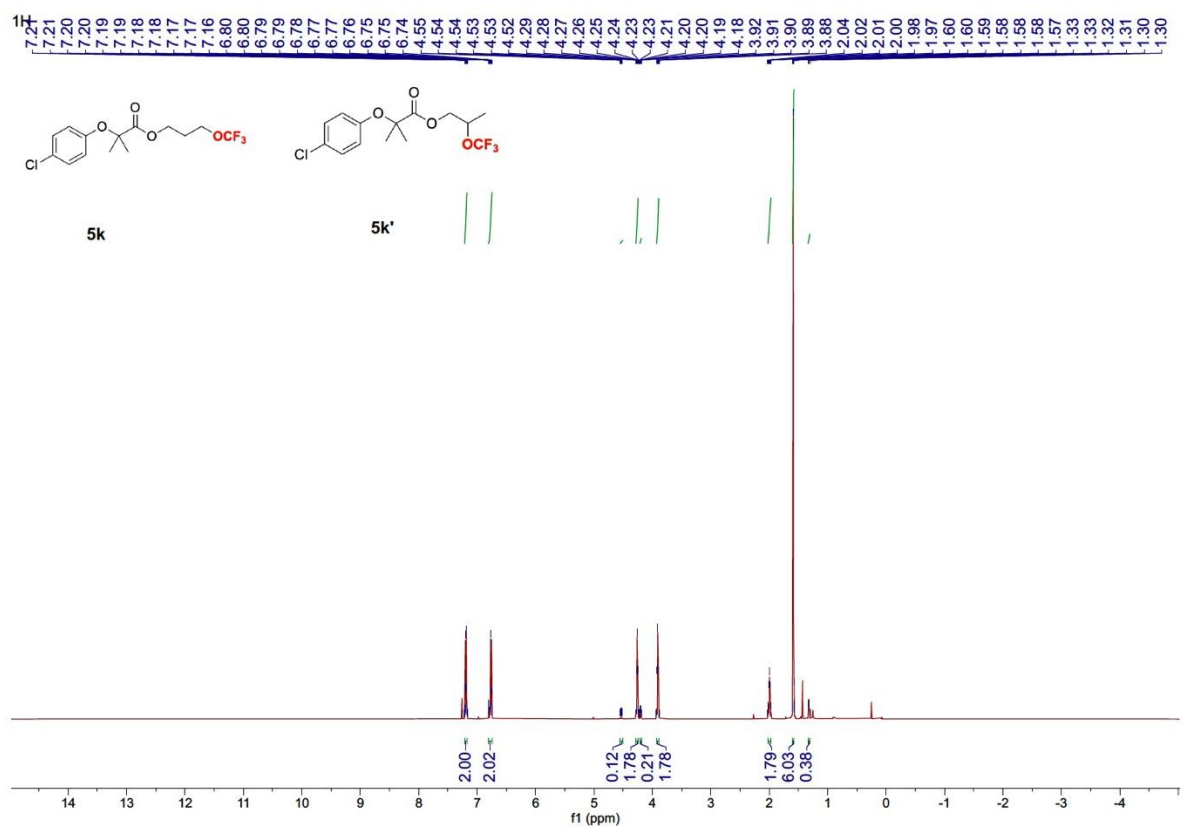
5k'

5k

5k'

0.11
0.89





19F

