Desulfurative Chlorination of Alkyl Phenyl Sulfides

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Supporting Information

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1. General remarks

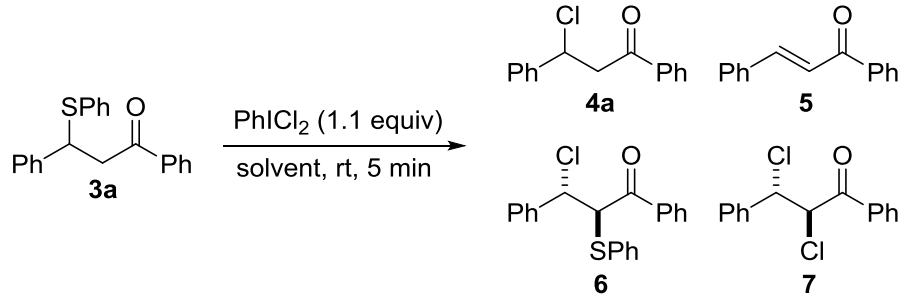
^{1}H, ^{19}F and ^{13}C NMR spectra were recorded on a Bruker 400 spectrometer. Chemical shifts (δ) are reported in ppm relative to residual solvent signals for ^{1}H and ^{13}C NMR (^{1}H NMR: 7.26 ppm for $CDCl_3$; ^{13}C NMR: 77.16 ppm for $CDCl_3$). ^{13}C NMR spectra were acquired with ^{1}H broad band decoupled mode. Coupling constants (*J*) are in Hz. Melting points were measured using a Stuart scientific melting point apparatus and are uncorrected. Infrared spectra (IR) were recorded with KBr discs using a Bruker Tensor27 FT-IR instrument. High resolution mass spectra were obtained on a Waters Micromass GCT Premier MS spectrometer or on a Bruker micrOTOF-Q III LC-MS spectrometer (APCI method). Optical rotations were measured on a Perkin-Elmer 343 polarimeter. The enantiomeric eccess (*ee*) was determined by chiral stationary phase HPLC using a Shimadzu SIL-20AHT HPLC instrument.

2. Materials

Analytical grade solvents and commercially available reagents were used as received. Dry CH_2Cl_2 was either purchased from commercial sources or freshly distilled over CaH_2 under inert atmosphere. Dry THF was obtained from an Inert Pure Solv Micro drying solvent system. Reactions were monitored by TLC analysis (Merck, silica gel 60 F_{254}). Flash column chromatography was performed using silica gel 60 (0.040-0.063 mm, 230-400 mesh). (Dichloroiodo)benzene was prepared using sodium chlorite according to a modified literature procedure.[1] Cinnamate esters,[2] sulfide **3l** and optically active sulfides (*S*)-**3i**, (*S*)-**3j** and (*S*)-**3l** were prepared according to published procedures.[3]

3. Optimization of Reaction Conditions with Sulfide (3a)

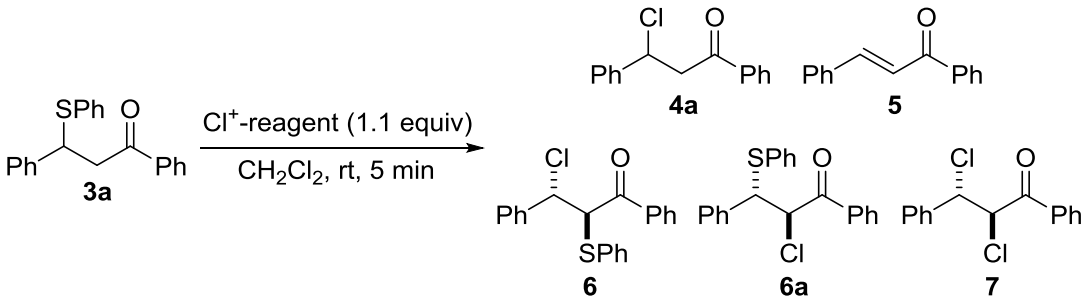
Table S1. Chlorination of Sulfide (3a) in Non-Purified Solvents[a]



entry	solvent	ratio (**4a**:**5**:**6**:**7**)[b]
1	CH_2Cl_2	76:0:20:4
2	THF	79:15:6:0
3	MeCN	complex mixture
4	EtOAc	68:28:4:0
5	toluene	80:0:20:0

[a]Conditions: **3a** (0.5 mmol), $PhICl_2$ (0.55 mmol), solvent (3 mL, 0.17 M); all reactions proceeded to complete conversion (≥98%). [b]Determined by ^{1}H NMR of the crude product

Table S2. Chlorination of Sulfide (3a) with NCS and SO_2Cl_2[a]

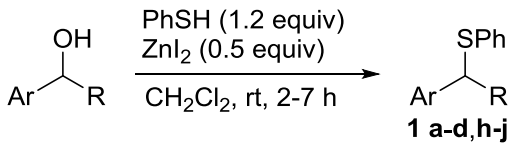


Cl^+-reagent	ratio (**4a**:**5**:**6**:**6a**:**7**)[b]
NCS	32:37:18:13:0
SO_2Cl_2	57:12:22:6:3

[a]Conditions: **3a** (0.5 mmol), Cl^+-reagent (0.55 mmol), CH_2Cl_2 (3 mL, 0.17 M); all reactions proceeded to complete conversion (≥98%). [b]Determined by ^{1}H NMR of the crude product

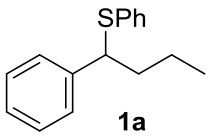
4. Procedures for the preparation of alkyl phenyl sulfides

4.1. General procedure for the preparation of alkyl phenyl sulfides 1a-d,h-j (GP1)[4]



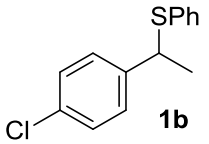
ZnI_2 (479 mg, 1.5 mmol, 0.5 equiv) was placed in a Schlenk tube and carefully dried under vacuum with a heatgun. Under N_2 atmosphere, dry CH_2Cl_2 (10 mL) and the alcohol (3.0 mmol) were added to the solid. Thiophenol (370 µL, 396 mg, 3.6 mmol, 1.2 equiv) was added to the obtained suspension and the mixture was stirred at rt until complete consumption of the starting material, as observed by TLC analysis (2-7 h). The reaction mixure was quenched with H_2O (10 mL) and extracted with CH_2Cl_2 (2 x 10 mL). The combined organic extracts were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to yield the crude product which was purified by flash column chromatography on silica gel.

Phenyl(1-phenylbutyl)sulfane (1a)



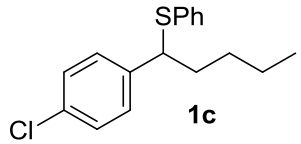
Prepared according to GP1. The reaction was completed within 5 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (552 mg, 76% yield). All analytical data are consistent with those reported in the literature.[5]

(1-(4-Chlorophenyl)ethyl)(phenyl)sulfane (1b)



Prepared according to GP1. The reaction was completed within 6 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 100:0 → 99:1) as a colorless oil (291 mg, 39% yield). All analytical data are consistent with those reported in the literature.[6]

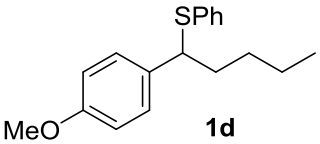
(1-(4-Chlorophenyl)pentyl)(phenyl)sulfane (1c)



Prepared according to GP1. The reaction was completed within 5 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 100:0 → 99:1) as a colorless oil (654 mg, 75% yield). IR (neat, cm^{-1}): *v* 2957, 2931, 2859, 1585, 1490, 1091, 836, 691. ^1H NMR

(400 MHz, $CDCl_3$): δ 0.85 (t, *J* = 7.0 Hz, 3H), 1.15–1.37 (m, 4H), 1.78-2.02 (m, 2H), 4.07 (dd, *J* = 8.8, 6.2 Hz, 1H), 7.12-7.24 (m, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.0, 22.5, 29.8, 36.0, 53.2, 127.4, 128.6, 128.8, 129.3, 132.7, 132.7, 134.8, 141.1. HRMS (EI): $C_{17}H_{19}ClS$ $[M]^+$ calculated: 290.0896, found: 290.0894.

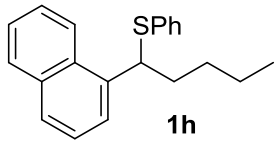
(1-(4-Methoxyphenyl)pentyl)(phenyl)sulfane (1d)



1d

Prepared according to GP1. The reaction was completed within 4 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 100:0 → 99:1) as a colorless oil (781 mg, 91% yield). All analytical data are consistent with those reported in the literature.[4]

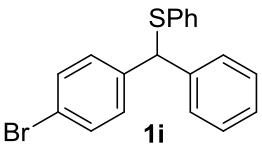
(1-(Naphthalen-1-yl)pentyl)(phenyl)sulfane (1h)



1h

Prepared according to GP1. The reaction was completed within 6 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 99:1 → 95:5) as a colorless oil (689 mg, 75% yield). IR (neat, cm^{-1}): *v* 3102, 2992, 2884, 1583, 1025, 778, 737, 691. ^1H NMR (400 MHz, $CDCl_3$): δ 0.84 (t, *J* = 7.1 Hz, 3H), 1.24–1.50 (m, 4H), 2.03–2.19 (m, 2H), 5.00 (brs, 1H), 7.12–7.24 (m, 5H), 7.38-7.42 (m, 1H), 7.49–7.56 (m, 3H), 7.75 (d, *J* = 8.2 Hz, 1H), 7.84–7.90 (m, 1H), 8.17 (brs, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.1, 22.7, 30.0, 36.0, 125.5, 125.6, 126.2, 127.0, 127.8, 128.9, 129.2, 131.4, 132.2, 134.1, 135.5, 137.6. HRMS (EI): $C_{21}H_{22}S$ $[M]^+$ calculated: 306.1442, found: 306.1457.

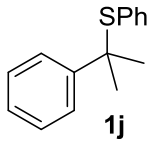
((4-Bromophenyl)(phenyl)methyl)(phenyl)sulfane (1i)



1i

Prepared according to GP1. The reaction was completed within 5 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 99:1) as a pale yellow oil (533 mg, 50% yield). IR (neat, cm^{-1}): *v* 3025, 2924, 2854, 1584, 1484, 1451, 1439, 1402, 1072, 1011, 739, 693. ^1H NMR (400 MHz, $CDCl_3$): δ 5.45 (s, 1H), 7.07–7.44 (m, 14H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 57.1, 121.3, 127.0, 127.6, 128.5, 128.8, 129.0, 130.3, 130.9, 131.8, 135.7, 140.3, 140.6. HRMS (EI): $C_{19}H_{15}BrS$ $[M]^+$ calculated: 354.0078, found: 354.0082.

Phenyl(2-phenylpropan-2-yl)sulfane (1j)

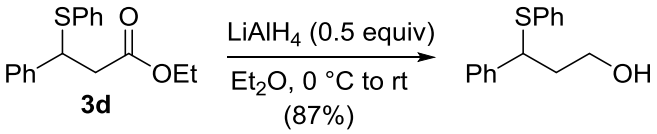


1j

Prepared according to GP1. The reaction was completed within 2 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 100:0 → 98:2) as a colorless oil (616 mg, 90% yield). All analytical data are consistent with those reported in the literature.[7]

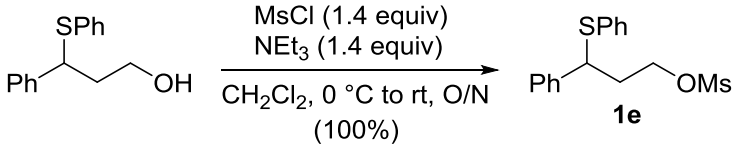
4.2. Synthesis of Sulfides (1e-g)

3-Phenyl-3-(phenylthio)propan-1-ol



To a stirred solution of sulfide **3d** (572 mg, 2.0 mmol) in dry Et_2O (4 mL) was added dropwise *via* syringe $LiAlH_4$ (1 mL, 1.0 mmol, 1M solution in Et_2O) at 0 °C. The reaction mixture was allowed to reach rt and stirred for a further 10 h, then carefully quenched with sat. aq. NH_4Cl (10 mL) and extracted with Et_2O (3 x 10 mL). The combined organic layers were dried over Na_2SO_4 and the solvent removed *in vacuo*. Purification of the remaining oil by flash column chromatography (silica gel; *n*-hexane/EtOAc, 70:30) afforded the corresponding alcohol as a yellow oil (425 mg, 87% yield). All analytical data are consistent with those reported in the literature.[8]

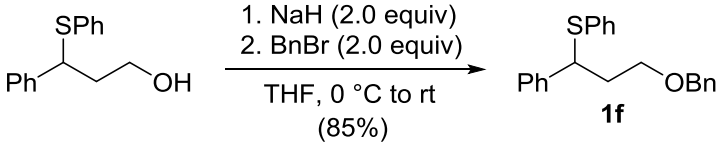
3-Phenyl-3-(phenylthio)propyl methanesulfonate (1e)



To a stirred solution of 3-phenyl-3-(phenylthio)propan-1-ol (488 mg, 2.0 mmol) and methanesulfonyl chloride (217 µL, 321 mg, 2.8 mmol, 1.4 equiv) in dry CH_2Cl_2 (5 mL) was added dropwise triethylamine (388 µL, 283 mg, 2.8 mmol, 1.4 equiv) at 0 °C. The reaction mixture was allowed to reach rt and stirred overnight, then diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 x 10 mL). The combined organic layers were washed with H_2O (3 x

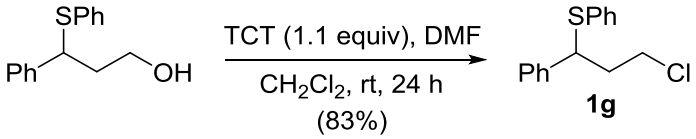
10 mL), brine and dried over Na_2SO_4. The solvent was removed *in vacuo*, giving the title compound as a yellow oil (644 mg, quantitative yield), which was used without further purifications. IR (neat, cm^{-1}): *v* 3028, 2937, 1582, 1351, 1170, 962, 692. ^1H NMR (400 MHz, $CDCl_3$): δ 2.16-2.54 (m, 2H), 2.90 (s, 3H), 4.13 (ddt, *J* = 8.5, 7.1, 4.2 Hz, 1H), 4.24-4.44 (m, 2H), 7.11-7.38 (m, 10H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 35.5, 37.3, 49.6, 67.7, 127.8, 127.9, 128.6, 128.8, 129.0, 133.1, 133.8, 140.6. HRMS (EI): $C_{16}H_{18}NaO_3S_2$ $[M + Na]^+$ calculated: 345.0595, found: 345.0588.

(3-benzyloxy-1-phenylpropyl)(phenyl)sulfane (1f)



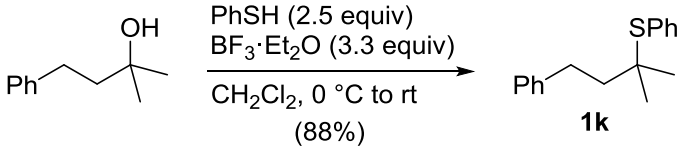
3-Phenyl-3-(phenylthio)propan-1-ol (243 mg, 1.0 mmol) was dissolved in dry THF (3 mL) at 0 °C, NaH (48 mg, 2.0 mmol, 2.0 equiv) and benzyl bromide (238 μL, 342 mg, 2.0 mmol, 2.0 equiv) were added and the reaction stirred at rt overnight. The reaction mixture was carefully quenched with sat. aq. NH_4Cl (10 mL) and extracted with CH_2Cl_2 (3 x 10 mL). The combined organic extracts were dried over Na_2SO_4 and the solvent removed *in vacuo*. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 99:1) as a colorless oil (284 mg, 85% yield). IR (neat, cm^{-1}): *v* 2992, 1584, 1453, 1103, 1026, 739, 697. ^1H NMR (400 MHz, $CDCl_3$): δ 2.13-2.22 (m, 1H), 2.30-2.38 (m, 1H), 3.38-3.42 (m, 1H), 3.55-3.59 (m, 1H), 4.41 (dd, *J* = 6.3, 2.6 Hz, 1H), 4.43 (dd, *J* = 19.0, 12.0 Hz, 2H), 7.18-7.37 (m, 15H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 36.4, 50.1, 67.7, 73.1, 127.1, 127.3, 127.7, 127.8, 128.0, 128.5, 128.8, 132.4, 135.0, 138.5, 141.9. HRMS (EI): $C_{22}H_{22}OS$ $[M]^+$ calculated: 334.1391, found: 334.1388.

(3-chloro-1-phenylpropyl)(phenyl)sulfane (1g)



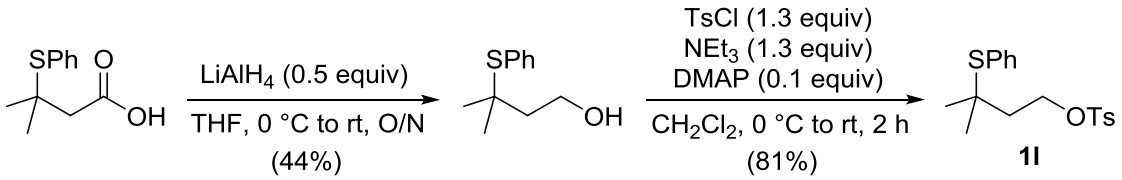
2,4,6-Trichloro-[1,3,5]-triazine (TCT, 203 mg, 1.1 mmol, 1.1 equiv) was added to DMF (200 μL) at rt and the reaction was monitored by TLC analysis until complete disappearance of TCT and the formation of a white solid. CH_2Cl_2 (3 mL) was added, followed by the alcohol (244 mg, 1.0 mmol) and the mixture was stirred at rt for 24 h. The reaction mixture was diluted with H_2O (5 mL) and extracted with CH_2Cl_2 (2 x 10 mL). The combined organic extracts were washed with sat. aq. Na_2CO_3 (3 x 10 mL), followed by 1M HCl (3 x 10 mL) and brine. The organic layer was dried over Na_2SO_4 and concentrated *in vacuo* to yield the title compound as a colorless oil, which was used without further purifications (218 mg, 83% yield). IR (neat, cm^{-1}): *v* 3059, 2958, 1582, 1438, 1025, 745, 690. ^1H NMR (400 MHz, $CDCl_3$): δ 2.22-2.53 (m, 2H) 3.40 (ddd, *J* = 11.0, 7.9, 5.8 Hz, 1H), 3.64 (dt, *J* = 11.0, 6.0 Hz, 1H), 4.40 (dd, *J* = 8.6, 6.5 Hz, 1H), 7.12-7.36 (m, 10H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 38.7, 42.6, 50.4, 127.5, 127.7, 127.9, 128.7, 128.9, 132.7, 134.3, 140.8. HRMS (APCI): $C_{15}H_{15}S$ $[M - Cl]^+$ calculated: 227.0889, found: 227.0889.

4.3. Synthesis of (2-methyl-4-phenylbutan-2-yl)(phenyl)sulfane (1k)

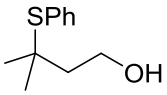


In a Schlenk tube under N_2 atmosphere, the alcohol (510 μL, 493 mg, 3.0 mmol) was dissolved in dry CH_2Cl_2 (50 mL) and thiophenol was added (768 μL, 826 mg, 7.5 mmol, 2.5 equiv). $BF_3{\cdot}Et_2O$ (1.23 mL, 1.42 g, 10 mmol, 3.3 equiv) was slowly added dropwise *via* syringe at 0 °C and the reaction stirred at 0 °C for 1 h, followed by 6 h at rt. The reaction mixture was quenched with H_2O and extracted with CH_2Cl_2 (3 x 30 mL). The combined organic extracts were washed with 2M NaOH (3 x 15 mL), dried over Na_2SO_4 and the solvent removed *in vacuo*. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 100:0 → 90:10) as a colorless oil (676 mg, 88% yield). All analytical data are consistent with those reported in the literature.[9]

4.4. Synthesis of 3-methyl-3-(phenylthio)butyl 4-methylbenzenesulfonate (1l)

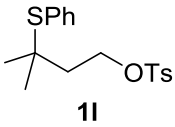


3-Methyl-3-(phenylthio)butan-1-ol



To a stirred solution of 3-methyl-3-(phenylthio)butanoic acid[10] (420 mg, 2.0 mmol) in dry THF (6 mL) was added dropwise *via* syringe $LiAlH_4$ (1.0 mL, 1.0 mmol, 0.5 equiv, 1M solution in THF) at 0 °C. The reaction mixture was allowed to reach rt and stirred overnight, then carefully quenched with sat. aq. NH_4Cl (5 mL) and extracted with Et_2O (3 x 10 mL). The combined organic layers were dried over Na_2SO_4 and concentrated *in vacuo* to yield the title compound as a colorless oil, which was used without further purification (172 mg, 44% yield). IR (neat, cm^{-1}): *v* 3346, 3073, 2959, 1126, 1022, 693. ^1H NMR (400 MHz, $CDCl_3$): δ 1.28 (s, 6H), 1.78 (t, *J* = 6.7 Hz, 2H), 2.04 (brs, 1H), 3.91 (t, *J* = 6.6 Hz, 2H), 7.31-7.47 (m, 3H), 7.50-7.61 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 29.4, 43.9, 48.0, 60.3, 128.8, 129.1, 131.7, 137.6. MS (EI): *m/z* (%) 163.1 (100) $[M - CH_5O]^-$. Anal. Calcd for $C_{11}H_{16}OS$: C, 67.30; H, 8.22; S, 16.33. Found: C, 67.14; H, 8.35; S, 16.31.

3-Methyl-3-(phenylthio)butyl 4-methylbenzenesulfonate (1l)

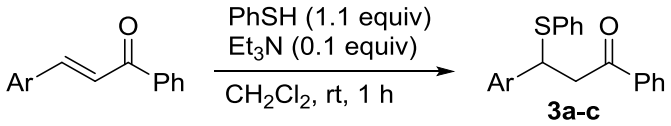


1l

To a stirred solution of 3-methyl-3-(phenylthio)butan-1-ol (196 mg, 1.0 mmol) in dry CH_2Cl_2 (5 mL) were added *p*-toluenesulfonyl chloride (248 mg, 1.3 mmol, 1.3 equiv), triethylamine (180 μL, 131 mg, 1.3 mmol, 1.3 equiv) and 4-dimethylaminopyridine (DMAP, 12 mg, 0.1 mmol, 0.1 equiv) at 0 °C. The reaction mixture was allowed to reach rt and stirred for a further 2 h, then quenched with sat. aq. NH_4Cl (10 mL) and extracted with CH_2Cl_2 (3 x 10 mL). The combined organic layers were washed with sat. aq. $NaHCO_3$ (3 x 10 mL), H_2O (3 x 10 mL), brine and dried over Na_2SO_4. The solvent was removed *in vacuo* and the remaining oil was purified by flash column chromatography (silica gel; *n*-hexane/EtOAc, 90:10) to afford the title compound as a yellow oil (284 mg, 81% yield). IR (neat, cm^{-1}): *v* 3058, 2964, 1598, 1359, 1211, 1096, 960, 663. ^1H NMR (400 MHz, $CDCl_3$): 1.21 (s, 6H), 1.81 (t, *J* = 7.2 Hz, 2H), 2.46 (s, 3H), 4.29 (t, *J* = 7.2 Hz, 2H), 7.26-7.41 (m, 7H), 7.82 (d, *J* = 8.3 Hz, 2H), ^{13}C NMR (101 MHz, $CDCl_3$): δ 21.8,

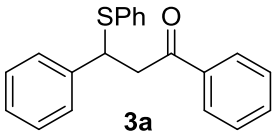
29.1, 40.2, 47.3, 68.0, 128.1, 128.8, 129.2, 130.0, 131.4, 133.2, 137.6, 145.0. HRMS (APCI): $C_{18}H_{23}O_3S_2$ $[M + H]^+$ calculated: 351.1093, found: 351.1083.

4.5. General procedure for sulfa-Michael addition to chalcones (GP2)



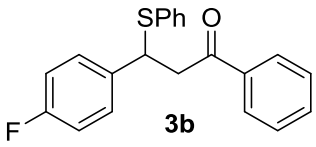
To a stirred solution of chalcone (5.0 mmol) in CH_2Cl_2 (15 mL) were added thiophenol (561 µL, 606 mg, 5.5 mmol, 1.1 equiv) and triethylamine (70 µL, 51 mg, 0.5 mmol, 0.1 equiv) and the reaction mixture was stirred at rt until complete consumption of the starting material was observed by TLC analysis (1 h). The solvent was removed *in vacuo* and the crude reaction mixture was purified by recrystallization from hot MeOH (ca. 100 mL).

1,3-Diphenyl-3-(phenylthio)propan-1-one (3a)



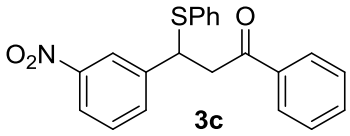
Prepared according to GP2. The title compound was isolated by recrystallization from hot MeOH as a white solid (1.40 g, 88% yield). All analytical data are consistent with those reported in the literature.[11]

3-(4-Fluorophenyl)-1-phenyl-3-(phenylthio)propan-1-one (3b)



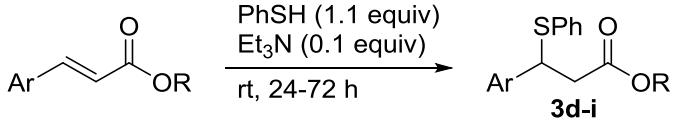
Prepared according to GP2. The title compound was isolated by recrystallization from hot MeOH as a white solid (1.46 g, 87% yield). Mp: 103-105 °C. IR (KBr, cm^{-1}): *v* 3071, 2907, 1678, 1512, 1227, 820, 742, 687. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.58 (dd, *J* = 17.2, 5.8 Hz, 1H), 3.65 (dd, *J* = 17.2, 8.4 Hz, 1H), 4.95 (dd, *J* = 8.4, 5.8 Hz, 1H), 6.89-7.02 (m, 2H), 7.21-7.39 (m, 7H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.80-7.98 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -115.0. ^{13}C NMR (101 MHz, $CDCl_3$): δ 44.7, 47.6, 115.3 (d, *J* = 21.5 Hz), 127.7, 128.1, 128.7, 128.9, 129.4 (d, *J* = 8.1 Hz), 133.0, 133.4, 133.9, 136.6, 137.0 (d, *J* = 3.2 Hz), 161.9 (d, *J* = 246.0 Hz), 196.8. HRMS (EI): $C_{21}H_{17}FOS$ $[M]^+$ calculated: 336.0984, found: 336.0975.

3-(3-Nitrophenyl)-1-phenyl-3-(phenylthio)propan-1-one (3c)



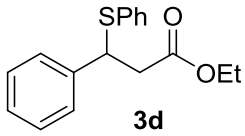
Prepared according to GP2. The title compound was isolated by recrystallization from hot MeOH as a white solid (1.63 g, 90% yield). All analytical data are consistent with those reported in the literature.[12]

4.6. General procedure for sulfa-Michael addition to cinnamate esters (GP3)



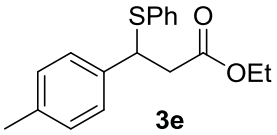
Thiophenol (337 μL, 364 mg, 3.3 mmol, 1.1 equiv) and triethylamine (42 μL, 30 mg, 0.3 mmol, 0.1 equiv) were added to the cinnamate ester (3.0 mmol) and the reaction mixture stirred at rt until complete consumption of the starting material was observed by TLC analysis (24-72 h). The crude mixture was purified by flash column chromatography on silica gel to afford the sulfa-Michael adduct.

Ethyl 3-phenyl-3-(phenylthio)propanoate (3d)



Prepared according to GP3. The reaction was completed within 24 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 95:5) as a colorless oil (704 mg, 82% yield). All analytical data are consistent with those reported in the literature.[13]

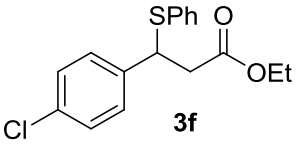
Ethyl 3-(phenylthio)-3-(*p*-tolyl)propanoate (3e)



Prepared according to GP3. The reaction was completed in 72 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a colorless oil (711 mg,, 79% yield). IR (neat, cm^{-1}): *v* 2982, 2925, 1734, 1583, 1514, 1371, 1024, 748, 693. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.09 (t, *J* = 7.1 Hz, 3H), 2.24 (s, 3H), 2.82 (dd, *J* = 15.8, 8.4, Hz, 1H), 2.87 (dd, *J* = 15.8, 7.1 Hz, 1H), 3.91-4.06 (m, 2H), 4.60 (dd, *J* = 8.4, 7.1 Hz, 1H), 6.98-7.04 (m, 2H), 7.09-7.13 (m, 2H), 7.15-7.21 (m, 3H), 7.25-7.31 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.1,

21.1, 41.2, 48.9, 60.6, 127.6, 127.7, 128.9, 129.2, 133.1, 134.1, 137.2, 137.5, 170.8. HRMS (EI): $C_{18}H_{20}O_2S$ $[M]^+$ calculated: 300.1184, found: 300.1189.

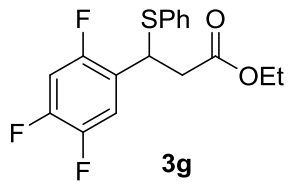
Ethyl 3-(4-chlorophenyl)-3-(phenylthio)propanoate (3f)



3f

Prepared according to GP3. The reaction was completed in 24 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2→ 95:5) as a colorless oil (904 mg, 94% yield). IR (neat, cm^{-1}) *v*: 3083, 3038, 2906, 1741, 1584, 1492, 1015, 837, 718, 661. ^1H NMR (400 MHz, $CDCl_3$) δ 1.15 (t, *J* = 7.1 Hz, 3H), 2.85 (dd, *J* = 15.8, 8.8 Hz, 1H), 2.94 (dd, *J* = 15.8, 6.9 Hz, 1H), 4.04 (m, 2H), 4.59 (dd, *J* = 8.8, 6.9 Hz, 1H), 7.12-7.20 (m, 2H), 7.18-7.28 (m, 5H), 7.23-7.33 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 14.2, 41.0, 48.7, 60.9, 128.2, 128.7, 129.1, 129.2, 133.3, 133.3, 133.7, 139.3, 170.6. HRMS (EI): $C_{17}H_{17}ClO_2S$ $[M]^+$ calculated: 320.0638, found: 320.0622.

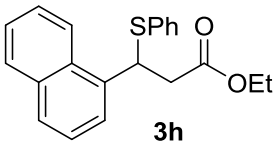
Ethyl 3-(phenylthio)-3-(2,4,5-trifluorophenyl)propanoate (3g)



3g

Prepared according to GP3. The reaction was completed in 24 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2→ 95:5) as a colorless oil (612 mg, 60% yield). IR (neat, cm^{-1}): *v* 3063, 2985, 1737, 1630, 1519, 1334, 751, 693. ^1H NMR (400 MHz, $CDCl_3$): δ 1.17 (t, *J* = 7.1 Hz, 3H), 2.85 (dd, *J* = 16.0, 8.7 Hz, 1H), 2.95 (dd, *J* = 16.0, 6.9 Hz, 1H), 4.07 (m, 2H), 4.84-4.88 (m, 1H), 6.80-6.87 (m, 1H), 6.99-7.06 (m, 1H), 7.24-7.33 (m, 5H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -142.0 (dd, *J* = 21.7, 15.2 Hz), -134.2 (dd, *J* = 21.7, 4.1 Hz),-118.4 (dd, *J* = 15.1, 4.1 Hz). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.2, 40.0, 41.5, 61.1, 105.7 (dd, *J* = 28.6, 20.8 Hz), 116.6 (dd, *J* = 19.4, 4.4 Hz), 124.7 (ddd, *J* = 15.8, 9.2, 4.7 Hz), 128.5, 129.2, 132.6, 133.8, 145.4-148.2 (m), 147.8-150.7 (m), 155.3 (ddd, *J* = 246.8, 9.4, 2.7 Hz), 170.1. HRMS (EI): $C_{17}H_{15}F_3O_2S$ $[M]^+$ calculated: 340.0745, found: 340.0747.

Ethyl 3-(naphthalen-1-yl)-3-(phenylthio)propanoate (3h)

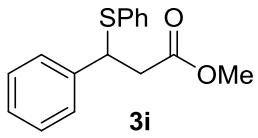


3h

Prepared according to GP3. The reaction was completed in 40 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a colorless oil (806 mg, 80% yield). IR (neat, cm^{-1}): *v* 3049, 2980, 1733, 1578, 1476, 1215, 1161, 769, 737. ^1H NMR (400 MHz, $CDCl_3$): δ 1.10 (t, *J* = 7.1 Hz, 3H), 3.11 (d, *J* = 7.6 Hz, 2H), 3.89-4.14 (m, 2H), 5.50 (t, *J* =

7.6 Hz, 1H), 7.16-7.25 (m, 3H), 7.23-7.31 (m, 2H), 7.31-7.39 (m, 2H), 7.49 (dd, *J* = 7.9, 6.7 Hz, 1H), 7.57 (dd, *J* = 8.4, 6.7 Hz, 1H), 7.74 (dd, *J* = 5.9, 3.6 Hz, 1H), 7.82-7.89 (m, 1H), 8.29 (d, *J* = 8.4 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.1, 41.0, 60.8, 123.3, 124.7, 125.2, 125.8, 126.4, 128.0, 128.4, 128.9, 129.1, 130.9, 133.7, 134.1, 135.9, 171.0. HRMS (EI): $C_{21}H_{20}O_2S$ $[M]^+$ calculated: 336.1184, found: 336.1171.

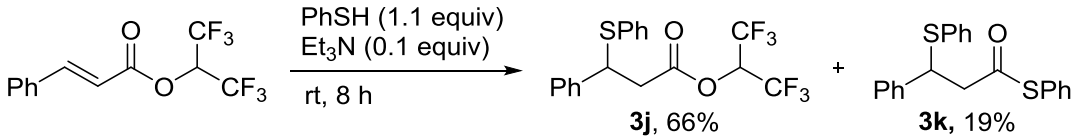
Methyl 3-phenyl-3-(phenylthio)propanoate (3i)



3i

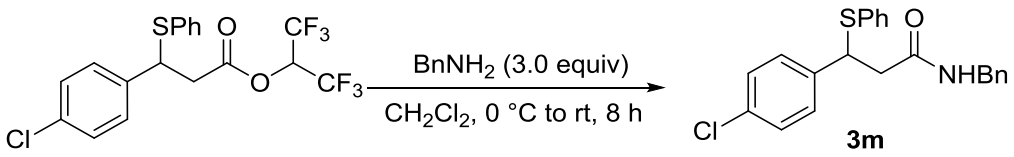
Prepared according to GP3. The reaction was completed within 24 h. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 95:5) as a colorless oil (751 mg, 92% yield). All analytical data are consistent with those reported in the literature.[14]

4.7. Synthesis of 1,1,1,3,3,3-hexafluoropropan-2-yl 3-phenyl-3-(phenylthio)propanoate (3j) and *S*-phenyl 3-phenyl-3-(phenylthio)propanethioate (3k)



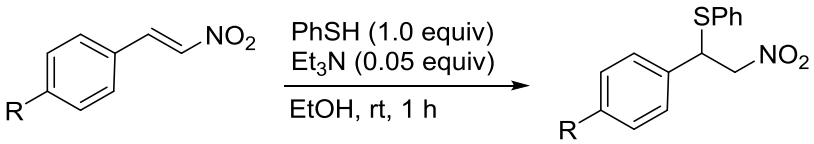
Thiophenol (337 μL, 364 mg, 3.3 mmol, 1.1 equiv) and triethylamine (42 μL, 30 mg, 0.3 mmol, 0.1 equiv) were added to 1,1,1,3,3,3-hexafluoropropan-2-yl cinnamate (895 mg, 3.0 mmol) and the reaction mixture was stirred at rt for 8 h. The crude mixture was directly purified by flash column chromatography (silica gel; *n*-hexane/EtOAc, 95:5) to afford as the first fraction sulfide **3j** as a colorless oil (808 mg, 66% yield). All analytical data are consistent with those reported in the literature.[3] This was followed by thioester **3k** as a second fraction, isolated as a colorless oil (200 mg, 19% yield). IR (neat, cm^{-1}): *v* 1693, 971, 747, 696 . ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.28 (d, *J* = 7.6 Hz, 2H), 4.76 (t, *J* = 7.6 Hz, 1H), 7.21-7.47 (m, 15H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 49.4, 49.5, 127.4, 127.8, 127.9, 128.0, 128.7, 129.1, 129.3, 129.6, 133.3, 133.7, 134.5, 140.0, 194.8. HRMS (EI): $C_{21}H_{18}OS_2Na$ $[M + Na]^+$ calculated: 373.0697, found: 373.0707.

4.8. Synthesis of *N*-benzyl-3-(4-chlorophenyl)-3-(phenylthio)propanamide (3m)



Benzylamine (491 μL, 482 mg, 4.5 mmol, 3.0 equiv) was added at 0 °C to a solution of the 1,1,1,3,3,3-hexafluoroester[3] (664 mg, 1.5 mmol) in CH_2Cl_2 (10 mL) and the reaction mixture was stirred at rt for 8 h. The solvent was removed *in vacuo* and the crude mixture was purified by flash column chromatography (silica gel; *n*-hexane/EtOAc, 70:30) to afford sulfide **3m** as a white solid (544 mg, 95% yield). Mp: 113-115 °C. IR (KBr, cm^{-1}): *v* 3309, 3094, 1644, 1566, 1493, 1265. ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.61 (dd, *J* = 14.4, 9.1 Hz, 1H), 2.83 (dd, *J* = 14.4, 6.3 Hz, 1H), 4.18 (dd, *J* = 14.8, 5.2 Hz, 1H), 4.38 (dd, *J* = 14.8, 6.3 Hz, 1H), 4.67 (dd, *J* = 9.1, 6.3 Hz, 1H), 5.63 (brs, 1H), 6.94 (dd, *J* = 7.2, 2.1 Hz, 2H), 7.12-7.30 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 43.7, 49.2, 127.7, 128.0, 128.8, 128.9, 129.1, 129.2, 133.0, 133.4, 133.6, 137.8, 139.6, 169.4. HRMS (EI): $C_{22}H_{20}ClNOS$ $[M]^+$ calculated: 381.0954, found: 381.0964.

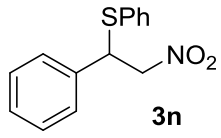
4.9. General procedure for the sulfa-Michael addition to nitrostyrenes.



3n, R = H; **3o**, R = Br

To a stirred solution of β-nitrostyrene (2.5 mmol) in EtOH (5 mL) were added thiophenol (255 μL, 275 mg, 2.5 mmol, 1.0 equiv) and triethylamine (17 μL, 13 mg, 0.125 mmol, 0.05 equiv) and the reaction mixture stirred at rt until complete consumption of the starting material was observed by TLC analysis (1 h). The solvent was removed *in vacuo* and the crude mixture was purified by flash column chromatography on silica gel to afford nitro sulfides **3n** and **3o**.

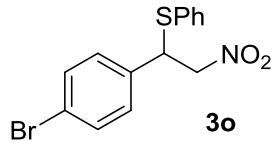
(2-Nitro-1-phenylethyl)(phenyl)sulfane (3n)



3n

The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a white solid (544 mg, 84% yield). All analytical data are consistent with those reported in the literature.[15]

(1-(4-Bromophenyl)-2-nitroethyl)(phenyl)sulfane (3o)

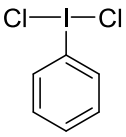


3o

The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 95:5) as a white solid (735 mg, 87% yield). All analytical data are consistent with those reported in the literature.[15]

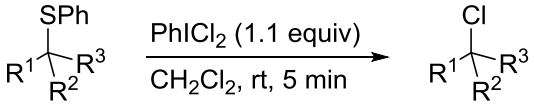
5. Desulfurative chlorination of alkyl phenyl sulfides

5.1. Synthesis of iodobenzene dichloride



Prepared by a modified literature procedure.[1] In a one-neck round-bottom flask protected from light by aluminium foil, $NaClO_2$ (5.66 g, 50 mmol, 5.0 equiv) was added portionwise over 30 min to a vigorously stirred emulsion of iodobenzene (1.12 mL, 2.04 g, 10 mmol) and diluted HCl (20 mL conc. HCl in 50 mL H_2O). The resulting mixture was stirred for a further 3 h. The precipitated yellow solid was collected by filtration in a Buchner funnel and washed with H_2O (500 mL), carefully breaking the clumps eventually formed with a spatula. The yellow solid is then washed with ice cold *n*-hexane (300 mL) and dried overnight at rt in the dark to afford $PhICl_2$ as a fluffy yellow solid (2.53 g, 92% yield). $PhICl_2$ was stored protected from light at 0 °C, and used within three weeks of preparation for chlorinations with sulfides **3**.

5.2. General procedures for desulfurative chlorination with $PhICl_2$



Liquid phenyl sulfide (GP4-A)

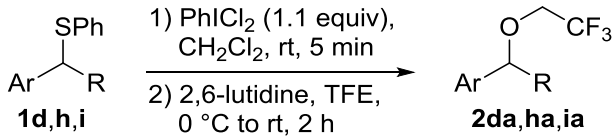
$PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) was added to a stirred solution of the sulfide (0.50 mmol) in dry CH_2Cl_2 (3 mL) under N_2 atmosphere, which resulted in a color change to

orange. The reaction was stirred at rt for 5 min, concentrated *in vacuo* and purified by flash column chromatography on silica gel to afford the corresponding chlorinated compound.

Solid phenyl sulfide (GP4-B)

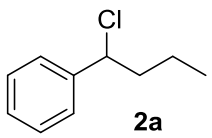
Dry CH_2Cl_2 (3 mL) was added to a stirred mixture of the sulfide (0.50 mmol) and $PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) under N_2 atmosphere, which resulted in a color change to orange. The reaction was stirred at rt for 5 min, concentrated *in vacuo* and purified by flash column chromatography on silica gel to afford the corresponding chlorinated compound.

Chlorination followed by solvolysis with 2,2,2-trifluoroethanol (GP5)[16]



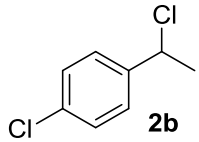
$PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) was added to a stirred solution of the sulfide (0.50 mmol) in dry CH_2Cl_2 (3 mL) under N_2 atmosphere. The reaction was stirred at rt for 5 min and concentrated *in vacuo*. The residue was redissolved in TFE (5 mL) and 2,6-lutidine (175 µL, 3.0 equiv) was added at 0 °C. The mixture was stirred for 2 h then HCl (5%, 5 mL) and *n*-hexane (20 mL) were added. The aqueous layer was extracted with *n*-hexane (2 x 20 mL) and the combined organic layers washed with HCl (5%, 2 x 5 mL), brine (3 x 10 mL), dried over Na_2SO_4 and concentrated *in vacuo* to yield the crude product which was purified by flash column chromatography on silica gel.

(1-Chlorobutyl)benzene (2a)



Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (60 mg, 71% yield). All analytical data are consistent with those reported in the literature.[17]

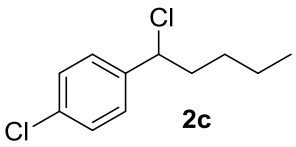
1-Chloro-4-(1-chloroethyl)benzene (2b)



Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (63 mg,

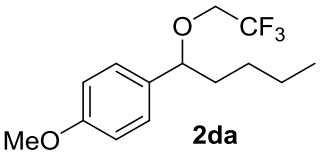
72% yield). All analytical data are consistent with those reported in the literature.[18]

1-Chloro-4-(1-chloropentyl)benzene (2c)



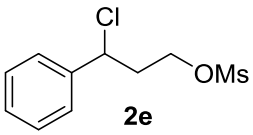
Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (74 mg, 68% yield). IR (neat, cm^{-1}): *v* 2974, 1597, 1493, 1410, 1094, 1015. ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.90 (t, *J* = 7.1 Hz, 3H), 1.22-1.49 (m, 4H), 1.94-2.16 (m, 2H), 4.81 (dd, *J* = 7.9, 6.8 Hz, 1H), 7.28-7.36 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.0, 22.2, 29.3, 39.8, 63.0, 128.5, 128.9, 134.0, 140.7. HRMS (EI): $C_{11}H_{14}Cl_2$ $[M]^+$ calculated: 216.0473, found: 216.0469.

1-Methoxy-4-(1-(2,2,2-trifluoroethoxy)pentyl)benzene (2da)



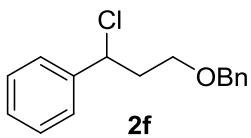
Prepared according to GP5. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a pale yellow oil (104 mg, 75% yield). All analytical data are consistent with those reported in the literature.[16]

3-Chloro-3-phenylpropyl methanesulfonate (2e)



Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 80:20) as a yellow oil (116 mg, 93% yield). IR (neat, cm^{-1}): *v* 3031, 2938, 1455, 1351, 1170, 965, 911. ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.41-2.54 (m, 2H), 3.03 (s, 3H), 4.32 (dt, *J* = 10.3, 5.2 Hz, 1H), 4.46 (ddd, *J* = 10.2, 7.5, 5.5 Hz, 1H), 5.06 (dd, *J* = 8.4, 6.2 Hz, 1H), 7.31-7.45 (m, 5H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 37.5, 39.3, 59.1, 67.0, 127.0, 129.0, 129.1, 140.5. MS (EI): *m/z* (%) 459.4 (100) $[2M - HCl]^-$. Anal. Calcd for $C_{10}H_{13}ClO_3S$ (248.72): C, 48.29; H, 5.27; Cl, 14.25; S, 12.89. Found: C, 48.69; H, 5.30; Cl, 13.99; S, 13.23.

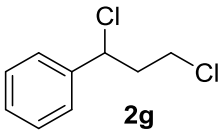
(3-(Benzyloxy)-1-chloropropyl)benzene (2f)



Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 99:1) as a colorless oil (95 mg, 73% yield). IR (neat, cm^{-1}): *v* 2991, 1495, 1454, 1361, 1105, 1028, 737, 697. ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.25-2.46 (m, 2H), 3.48-3.52 (m, 1H), 3.67-3.71 (m, 1H), 4.50 (dd, *J* = 18.1, 11.8 Hz, 2H), 5.15 (dd, *J* = 8.8, 5.9 Hz, 1H), 7.27-7.43

(m, 10H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 40.2, 60.5, 67.2, 73.3, 127.2, 127.8, 128.4, 128.6, 128.8, 138.4, 141.7. HRMS (EI): $C_{16}H_{17}ClO$ $[M]^+$ calculated: 260.0968, found: 260.1028. Anal. Calcd for $C_{18}H_{17}ClO$ (260.76): C, 73.70; H, 6.57. Found: C, 73.12; H, 6.58.

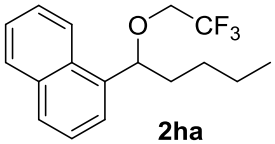
(1,3-Dichloropropyl)benzene (2g)



2g

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 95:5) as a yellow oil (79 mg, 84% yield). All analytical data are consistent with those reported in the literature.[19]

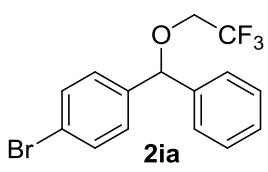
1-(1-(2,2,2-Trifluoroethoxy)pentyl)naphthalene (2ha)



2ha

Prepared according to GP5. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a yellow oil (104 mg, 70% yield). IR (neat, cm^{-1}): *v* 3066, 2960, 2863, 1511, 1279, 1162, 982, 968, 801, 779. ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.89 (t, *J* = 7.1 Hz, 3H), 1.29-1.44 (m, 3H), 1.48-1.62 (m, 1H), 1.90 (ddd, *J* = 14.6, 10.2, 4.9 Hz, 1H), 2.01 (ddd, *J* = 17.9, 9.3, 4.9 Hz, 1H), 3.58-3.68 (m, 1H), 3.72-3.82 (m, 1H), 5.12 (dd, *J* = 8.2, 4.9 Hz, 1H), 7.42-7.57 (m, 4H), 7.82 (d, *J* = 7.8 Hz, 1H), 7.89 (dd, *J* = 6.6, 2.9 Hz, 1H), 8.14 (d, *J* = 7.4 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$): δ -74.0. ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.1, 22.7, 28.5, 37.4, 66.3 (q, *J* = 34.4 Hz), 82.2, 123.3, 124.5, 125.6, 125.9, 126.3, 128.6, 129.1, 131.0, 134.1, 136.6. HRMS (EI): $C_{17}H_{19}F_3O$ $[M]^+$ calculated: 296.1388, found: 296.1390.

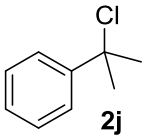
1-Bromo-4-(phenyl(2,2,2-trifluoroethoxy)methyl)benzene (2ia)



2ia

Prepared according to GP5. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a yellow oil (136 mg, 79% yield). IR (neat, cm^{-1}): *v* 3089, 3066, 2938, 1488, 1454, 1278, 1166, 1118, 755, 700. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.76 (q, *J* = 8.6 Hz, 2H), 5.44 (s, 1H), 7.15-7.21 (m, 2H), 7.23-7.34 (m, 5H), 7.39-7.45 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$): δ -73.8. ^{13}C NMR (101 MHz, $CDCl_3$): δ 66.2 (q, *J* = 34.3 Hz), 84.1, 122.2, 124.2 (q, *J* = 278.8 Hz), 127.3, 128.6, 128.8, 129.0, 131.9, 139.9, 140.0. HRMS (EI): $C_{15}H_{12}BrF_3O$ $[M]^+$ calculated: 344.0024, found: 344.0019.

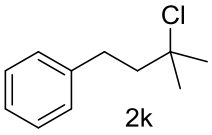
(2-Chloropropan-2-yl)benzene (2j)



2j

Prepared according to GP4-A. ^{1}H NMR yield was determined by adding 1,1,2,2-tetrachloroethane (53 μL, 84 mg, 0.50 mmol, 1.0 equiv) as internal standard (5.92 ppm, 2H) to the crude product redissolved in $CDCl_3$ (85% yield). All analytical data are consistent with those reported in the literature.[20]

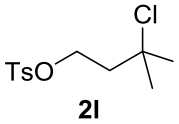
(3-Chloro-3-methylbutyl)benzene (2k)



2k

Prepared according to GP4-A. Styrene (63 μL, 57 mg, 0.55 mmol, 1.1 equiv) was added *via* syringe to quench the reaction. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (27 mg, 30% yield). All analytical data are consistent with those reported in the literature.[21]

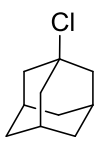
3-Chloro-3-methylbutyl 4-methylbenzenesulfonate (2l)



2l

Prepared according to a modified GP4-A. To an oven-dried 25 mL Schlenk tube containing a stirred solution of the sulfide **1l** (175 mg, 0.5 mmol) in dry CH_2Cl_2 (3 mL) was added *via* syringe a solution of $PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) in dry CH_2Cl_2 (3 mL) rapidly (ca. 5 sec/mL) under N_2 atmosphere. After stirring for 10 s, the reaction was quenched with H_2O (6 mL) and extracted with CH_2Cl_2 (3 x 5 mL). The combined organic layers were washed with H_2O (2 x 5 mL), brine, dried over Na_2SO_4 and the solvent removed *in vacuo*. Purification of the remaining oil by flash column chromatography (silica gel; *n*-hexane/Et_2O, 95:5) afforded the title compound as a yellow oil (80 mg, 58% yield). IR (neat, cm^{-1}): *v* 2923, 2853, 1598, 1456, 1361,1174, 968. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.57 (s, 6H), 2.13 (t, *J* = 6.8 Hz, 2H), 2.46 (s, 3H), 4.26 (t, *J* = 6.8 Hz, 2H), 7.36 (d, *J* = 8.3 Hz, 2H), 7.80 (d, *J* = 8.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 21.8, 33.0, 44.2, 67.6, 68.0, 128.1, 130.1, 133.0, 145.1. HRMS (APCI): $C_{12}H_{16}ClO_3S$ $[M - H]^+$ calculated: 275.0467, found: 275.0439.

1-Chloroadamantane (2m)

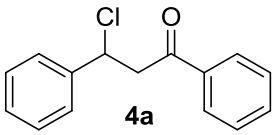


2m

Prepared according to GP4-B. Adamantan-1-yl(phenyl)sulfane[22] (244 mg, 1.0 mmol) was allowed to react with $PhICl_2$ (303 mg, 1.1 mmol, 1.1 equiv) in dry CH_2Cl_2 (6 mL). The reaction mixture was quenched with H_2O (5 mL) and extracted with CH_2Cl_2 (3 x 10 mL). The combined organic extracts were washed with brine, dried over Na_2SO_4 and the solvent was removed *in vacuo*. The title compound was isolated

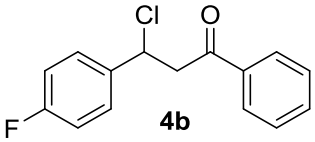
by flash column chromatography (silica gel; *n*-hexane) as a white solid (118 mg, 69% yield). All analytical data are consistent with those reported in the literature.[23]

3-Chloro-1,3-diphenylpropan-1-one (4a)



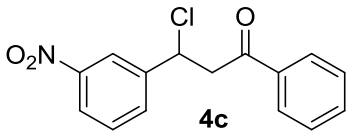
Prepared according to GP4-B. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/Et_2O, 90:10) as a white solid (103 mg, 84% yield). All analytical data are consistent with those reported in the literature.[24]

3-Chloro-3-(4-fluorophenyl)-1-phenylpropan-1-one (4b)



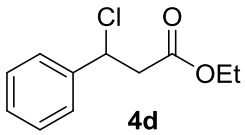
Prepared according to GP4-B. The title compound was isolated by recrystallization (CH_2Cl_2/*n*-hexane, 1:3) as a white solid (96 mg, 73% yield). Mp: 113-115 °C. IR (KBr, cm^{-1}): *v* 2909, 1687, 1605, 1511, 1365, 1225, 839, 765, 689. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.62 (dd, *J* = 17.3, 6.2 Hz, 1H), 3.93 (dd, *J* = 17.3, 7.6 Hz, 1H), 5.60 (dd, *J* = 7.6, 6.2 Hz, 1H), 6.99-7.12 (m, 2H), 7.42-7.54 (m, 4H), 7.54-7.64 (m, 1H), 7.95 (dd, *J* = 8.3, 1.1 Hz, 2H). ^{19}F NMR (376 MHz, $CDCl_3$): δ -113.1. ^{13}C NMR (101 MHz, $CDCl_3$): δ 48.4, 56.8, 115.7 (d, *J* = 21.7 Hz), 128.2, 128.8, 128.9 (d, *J* = 8.9 Hz), 133.7, 136.4, 136.9 (d, *J* = 3.3 Hz), 162.6 (d, *J* = 247.9 Hz), 195.6. HRMS (EI): $C_{15}H_{12}ClFO$ $[M]^+$ calculated: 262.0561, found: 262.0552.

3-Chloro-3-(3-nitrophenyl)-1-phenylpropan-1-one (4c)



Prepared according to GP4-B. The title compound was isolated by recrystallization (CH_2Cl_2/*n*-hexane, 1:3) as a white solid (62 mg, 43% yield). Mp: 111-114 °C. IR (KBr, cm^{-1}): *v* 3069, 2921, 1684, 1530, 1447, 1417, 1350, 713, 685. ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.72 (dd, *J* = 6.8, 17.5 Hz, 1H), 3.98 (dd, *J* = 17.5, 7.0 Hz, 1H), 5.68 (dd, *J* = 7.0, 6.8 Hz, 1H), 7.47-7.61 (m, 4H), 7.84 (d, *J* = 7.7 Hz, 1H), 7.89-8.00 (m, 2H), 8.18 (dd, *J* = 8.2, 2.2 Hz, 1H), 8.39 (t, *J* = 2.0 Hz, 1H).^{13}C NMR (101 MHz, $CDCl_3$): δ 48.3, 56.1, 122.4, 123.6, 128.3, 129.0, 129.9, 133.6, 134.0, 136.2, 143.3, 148.6, 195.2. HRMS (APCI): $C_{15}H_{12}NO_3$ $[M - Cl]^+$ calculated: 254.0817, found: 254.0822.

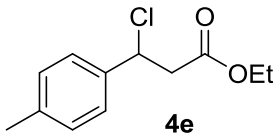
Ethyl 3-chloro-3-phenylpropanoate (4d)



4d

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 80:20) as a yellow oil (87 mg, 82% yield). All analytical data are consistent with those reported in the literature.[25]

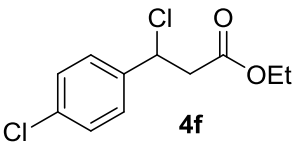
Ethyl 3-chloro-3-(*p*-tolyl)propanoate (4e)



4e

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 80:20 → 70:30) as a colorless oil (96 mg, 85% yield). IR (neat, cm^{-1}): *v* 3027, 2996, 2903, 2861, 1727, 1642, 1514, 1033. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.24 (t, *J* = 7.1 Hz, 3H), 2.35 (s, 3H), 3.01 (dd, *J* = 15.9, 5.9 Hz, 1H), 3.17 (dd, *J* = 15.9, 9.0 Hz, 1H), 4.16 (dq, *J* = 7.1, 2.7 Hz, 2H), 5.33 (dd, *J* = 9.0, 5.9 Hz, 1H), 7.14-7.20 (m, 2H), 7.28-7.33 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.3, 21.3, 45.0, 58.3, 61.1, 127.0, 129.6, 137.6, 138.8, 169.7. HRMS (EI): $C_{12}H_{15}ClO_2$ $[M]^+$ calculated: 226.0761, found: 226.0761.

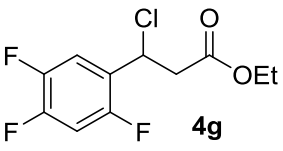
Ethyl 3-chloro-3-(4-chlorophenyl)propanoate (4f)



4f

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 80:20) as a pale yellow oil (99 mg, 80% yield). IR (neat, cm^{-1}): *v* 2984, 1738, 1497, 1095, 1017. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.23 (t, *J* = 7.1 Hz, 3H), 3.00 (dd, *J* = 16.0, 6.3 Hz, 1H), 3.15 (dd, *J* = 16.0, 8.6 Hz, 1H), 3.96-4.31 (m, 2H), 5.31 (dd, *J* = 8.6, 6.3 Hz, 1H), 7.28-7.52 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.2, 44.9, 57.2, 61.2, 128.5, 129.1, 134.6, 138.9, 169.3. HRMS (EI): $C_{11}H_{12}Cl_2O_2$ $[M]^+$ calculated: 246.0214, found: 246.0213.

Ethyl 3-chloro-3-(2,3,5-trifluorophenyl)propanoate (4g)

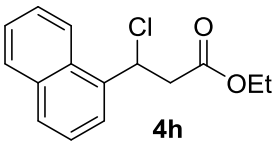


4g

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 90:10 → 70:30) as a colorless oil (96 mg, 72% yield). IR (neat, cm^{-1}): *v* 1737, 1631, 1520, 1431, 882. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.24 (t, *J* = 7.1 Hz, 3H), 3.02 (dd, *J* = 16.2, 6.3 Hz, 1H), 3.13 (dd, *J* = 16.2, 8.5 Hz, 1H), 4.16 (m, 2H), 5.55 (dd, *J* = 8.5, 6.3 Hz, 1H), 6.94 (dt, *J* = 9.7, 6.7 Hz, 1H), 7.32 (ddd, *J* = 10.6, 8.5, 6.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.2, 43.7, 50.1 (d, *J* = 3.0 Hz), 61.4, 106.1 (dd, *J* = 28.0, 21.0 Hz), 116.7

(ddd, *J* = 20.4, 4.5, 1.5 Hz), 124.2 (ddd, *J* = 15.3, 9.6, 4.8 Hz), 147.1 (ddd, *J* = 246.2, 12.7, 3.6 Hz), 150.3 (ddd, *J* = 253.6, 14.4, 12.4 Hz), 154.8 (ddd, *J* = 248.5, 9.5, 2.8 Hz), 168.9. HRMS (EI): $C_{11}H_{10}ClF_3O_2$ $[M]^+$ calculated: 266.0321, found: 266.0314.

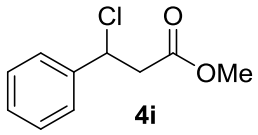
Ethyl 3-chloro-3-(naphthalen-1-yl)propanoate (4h)



4h

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 70:30) as a colorless oil (106 mg, 81% yield). IR (neat, cm^{-1}): *v* 2984, 2939, 1737, 1599, 1512, 1372, 1032, 948, 779, 735. ^1H NMR (400 MHz, $CDCl_3$): δ 1.26 (t, *J* = 7.1 Hz, 3H), 3.26 (dd, *J* = 16.0, 5.0 Hz, 1H), 3.40 (dd, *J* = 16.0, 9.4 Hz, 1H), 4.16-4.29 (m, 2H), 6.22 (dd, *J* = 9.4, 5.0 Hz, 1H), 7.43-7.59 (m, 2H), 7.57-7.66 (m, 1H), 7.69 (d, *J* = 7.2 Hz, 1H), 7.85 (d, *J* = 8.2 Hz, 1H), 7.90 (d, *J* = 8.2 Hz, 1H), 8.24 (d, *J* = 8.5 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 14.2, 43.9, 54.5, 61.2, 123.0, 124.4, 125.4, 126.1, 126.9, 129.2, 129.6, 130.3, 134.0, 135.6, 169.9. HRMS (EI): $C_{15}H_{15}ClO_2$ $[M]^+$ calculated: 262.0761, found: 262.0763.

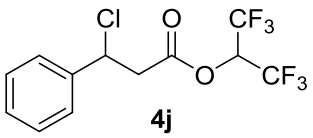
Methyl 3-chloro-3-phenylpropanoate (4i)



4i

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) as a colorless oil (85 mg, 86% yield). All analytical data are consistent with those reported in the literature.[26]

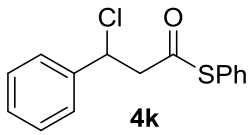
1,1,1,3,3,3-Hexafluoropropan-2-yl 3-chloro-3-phenylpropanoate (4j)



4j

Prepared according to GP4-A. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 80:20) as a colorless oil (125 mg, 75% yield). IR (neat, cm^{-1}): *v* 2971, 1788, 1386, 1358, 1292, 1203, 947, 907, 695. ^1H NMR (400 MHz, $CDCl_3$): δ 3.25 (dd, *J* = 16.3, 5.7 Hz, 1H), 3.40 (dd, *J* = 16.3, 9.2 Hz, 1H), 5.34 (dd, *J* = 9.2, 5.7 Hz, 1H), 5.76 (sept, *J* = 6.1 Hz, 1H), 7.29-7.48 (m, 5H). ^{19}F NMR (376 MHz, $CDCl_3$): δ -73.2, -73.2. ^{13}C NMR (101 MHz, $CDCl_3$): δ 44.09, 57.0, 66.9 (sept, *J* = 35.0 Hz), 126.9, 129.1, 129.3, 139.3, 166.6. HRMS (EI): $C_{12}H_9ClF_6O_2$ $[M]^+$ calculated: 334.0195, found: 334.0205.

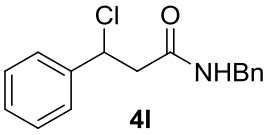
_S_-Phenyl 3-chloro-3-phenylpropanethioate (4k)



4k

Prepared according to GP4-B; the reaction was quenched with styrene (63 μL, 57 mg, 0.55 mmol, 1.1 equiv) prior to evaporation of the solvent. The title compound was isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 80:20) as a pale yellow oil (108 mg, 78% yield). IR (neat, cm^{-1}): *v* 1703, 1478, 1455, 1441, 1175, 979, 747, 697. ^1H NMR (400 MHz, $CDCl_3$): δ 3.31 (dd, *J* = 15.6, 5.9 Hz, 1H), 3.50 (dd, *J* = 15.6, 8.6 Hz, 1H), 5.39 (dd, *J* = 8.6, 5.9 Hz, 1H), 7.26-7.51 (m, 10H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 52.8, 57.7, 127.1, 128.9, 128.9, 129.4, 129.8, 134.5, 140.0, 193.6. HRMS (EI): $C_{15}H_{13}ClOS$ $[M]^+$ calculated: 276.0376, found: 276.0375.

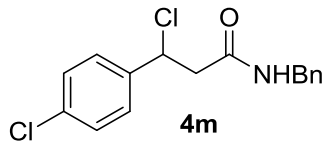
_N_-(3-Chloro-3-phenylpropanoyl)benzamide (4l)



4l

Prepared according to GP4-B. The title compound was isolated by flash column chromatography (silica gel; CH_2Cl_2/EtOAc, 95:5) as a white solid (98 mg, 72% yield). Mp: 125-127 °C. IR (neat, cm^{-1}): *v* 3278, 1635, 1572, 1454, 1424, 1029, 695, 643. ^1H NMR (400 MHz, $CDCl_3$): δ 2.91 (dd, *J* = 14.5, 5.7 Hz, 1H), 2.99 (dd, *J* = 14.5, 8.8 Hz, 1H), 4.44 (d, *J* = 5.7 Hz, 2H), 5.46 (dd, *J* = 8.8, 5.7 Hz, 1H), 5.77 (brs, 1H), 7.13-7.19 (m, 2H), 7.27-7.42 (m, 8H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 43.8, 47.5, 59.2, 127.0, 127.6, 127.8, 128.7, 128.8, 128.9, 137.9, 140.6, 168.8. HRMS (EI): $C_{16}H_{16}ClNO$ $[M]^+$ calculated: 273.0920, found: 273.0927.

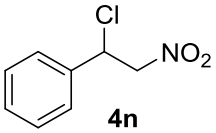
_N_-Benzyl-3-chloro-3-(4-chlorophenyl)propanamide (4m)



4m

Prepared according to GP4-B. The title compound was isolated by flash column chromatography (silica gel; CH_2Cl_2/EtOAc, 95:5) as a white solid (116 mg, 75% yield). Mp: 126-128 °C. IR (neat, cm^{-1}): *v* 3304, 1643, 1557, 1493, 1090, 839. ^1H NMR (400 MHz, $CDCl_3$): δ 2.86 (dd, *J* = 14.5, 6.0 Hz, 1H), 2.98 (dd, *J* = 14.5, 8.6 Hz, 1H), 4.36-4.47 (m, 2H), 5.42 (dd, *J* = 8.6, 6.0 Hz, 1H), 5.82 (brs, 1H), 7.09-7.19 (m, 2H), 7.22-7.42 (m, 7H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 43.9, 47.6, 58.3, 127.8, 128.5, 128.9, 129.1, 134.6, 137.8, 139.2, 168.3. HRMS (EI): $C_{16}H_{15}Cl_2NO$ $[M]^+$ calculated: 307.0531, found: 307.0524.

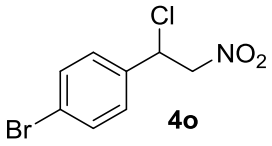
(1-Chloro-2-nitroethyl)benzene (4n)



4n

Prepared according to GP4-A. The title compound was isolated as an inseparable mixture with *trans*-β-nitrostyrene (25%) by flash column chromatography (silica gel; *n*-hexane) as a colorless oil (88 mg, 95% yield based on **4n**). All analytical data are consistent with those reported in the literature.[27]

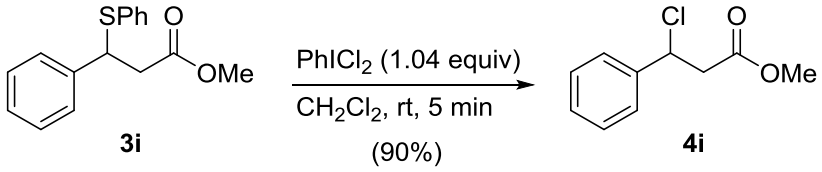
1-Bromo-4-(1-chloro-2-nitroethyl)benzene (4o)



4o

Prepared according to GP4-A. The title compound was isolated by recrystallization (CH_2Cl_2/*n*-hexane, 1:3) as a white solid (73 mg, 55% yield). Mp: 79-81 °C. IR (neat, cm^{-1}): *v* 1552, 1375, 1073, 1012, 825, 717, 519. ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.76 (dd, *J* = 13.5, 6.0 Hz, 1H), 4.89 (dd, *J* = 13.5, 8.8 Hz, 1H), 5.52 (dd, *J* = 8.8, 6.0 Hz, 1H), 7.30-7.33 (m, 2H), 7.51-7.61 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 56.1, 80.6, 124.1, 129.0, 132.7, 135.0. MS (EI): *m/z* (%) 227 (100) $[M - HCl]^+$, 184 (32) $[M - Br]^+$. Anal. Calcd for $C_8H_7BrClNO_2$ (264.50): C, 36.33; H, 2.67; N, 5.30. Found: C, 36.53; H, 2.61; N, 5.07.

5.3. Large scale chloriantion of β-sulfido ester (3i)



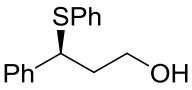
3i **4i**

To an oven-dried 100 mL Schlenk tube containing a stirred solution of sulfide **3i** (1.43 g, 5.0 mmol) in dry CH_2Cl_2 (25 mL) was added $PhICl_2$ (1.43 g, 5.2 mmol, 1.04 equiv) under N_2 atmosphere, which resulted in a color change to orange. After stirring the reaction mixture for 5 min at rt, styrene (630 μL, 572 mg, 5.5 mmol, 1.1 equiv) was added *via* syringe to quench the liberated PhSCl, which led to an immediate fading of the orange color. Evaporation of the solvent *in vacuo* and purification by flash column chromatography (silica gel; *n*-hexane/EtOAc, 99:1) gave chloride **4i** as a colorless oil (893 mg, 90% yield). All analytical data are consistent with those reported in the literature.[26]

6. Desulfurative chlorination of enantioenriched sulfides

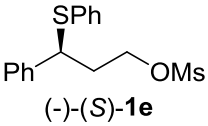
6.1. Synthesis of enantioenriched sulfides

(*S*)-3-Phenyl-3-(phenylthio)propan-1-ol



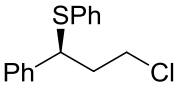
The procedure was similar to that of (±)-3-phenyl-3-(phenylthio)propan-1-ol. (*S*)-**3j** (326 mg, 0.8 mmol) was reacted for 3 h with $LiAlH_4$ (400 μL, 0.4 mmol, 0.5 equiv, 1M solution in THF) in dry THF (2 mL) to give the title compound (195 mg, quantitative yield).[8]

(-)-(*S*)-3-Phenyl-3-(phenylthio)propyl methanesulfonate (-)-(*S*)-1e


(-)-(*S*)-**1e**

The procedure was identical to that of (±)-**1e**. (*S*)-3-Phenyl-3-(phenylthio)propan-1-ol (146 mg, 0.6 mmol) was reacted with methanesulfonyl chloride (62 μL, 92 mg, 0.8 mmol, 1.4 equiv) and triethylamine (111 μL, 81 mg, 0.8 mmol, 1.4 equiv) in CH_2Cl_2 (2 mL) to give the title compound (164 mg, 85% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 85:15, 0.4 mL/min, 210 nm): t_r (major) = 34.3 min; t_r (minor) = 35.9 min: 97% *ee*. $[\alpha]_D^{20}$ = -105.4 (*c* 0.13, $CHCl_3$).

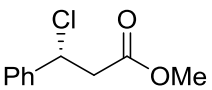
(-)-(*S*)-(3-Chloro-1-phenylpropyl)(phenyl)sulfane (-)-(*S*)-1g


(-)-(*S*)-**1g**

The procedure was identical to that of (±)-**1g**. (*S*)-3-Phenyl-3-(phenylthio)propan-1-ol (326 mg, 0.8 mmol) in CH_2Cl_2 (3 mL) was reacted with TCT (166 mg, 0.9 mmol, 1.1 equiv) in DMF (160 μL) to give the title compound (160 mg, 76% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK OD-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 220 nm): t_r (major) = 15.8 min; t_r (minor) = 17.1 min: 97% *ee*. $[\alpha]_D^{20}$ = -112.0 (*c* 0.10, $CHCl_3$).

6.2. Synthesis of enantioenriched chlorides

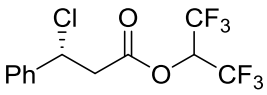
(+)-(*R*)-Methyl 3-chloro-3-phenylpropanoate (+)-(*R*)-4i


(+)-(*R*)-**4i**

$PhICl_2$ (90 mg, 0.33 mmol, 1.1 equiv) was added to a stirred solution of β-sulfido ester (–)-(*S*)-**3i** (82 mg, 0.30 mmol, 97% *ee*) in dry CH_2Cl_2 (3.6 mL) under N_2 atmosphere. The reaction was stirred at rt for 5 min, concentrated *in vacuo* and purified by flash column chromatography (silica gel; *n*-hexane/EtOAc, 98:2) to give the title compound as a colorless oil (50 mg, 84% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK IB-H, *n*-hexane/*i*-

PrOH, 97:3, 0.75 mL/min, 210 nm): t_r (major) = 7.5 min; t_r (minor) = 10.1 min: 84% *ee*. $[\alpha]_D^{20}$ = +66.4 (*c* 2.4, $CHCl_3$).

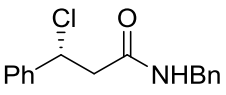
(+)-(*R*)-1,1,1,3,3,3-Hexafluoropropan-2-yl 3-chloro-3-phenylpropanoate (+)-(*R*)-4j



(+)-(*R*)-**4j**

The procedure was identical to that of of (±)-**4j**. (*S*)-**3j** (204 mg, 0.5 mmol) was reacted with $PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) in dry CH_2Cl_2 (6 mL) to give the title compound (135 mg, 81% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 210 nm): t_r (minor) = 12.2 min; t_r (major) = 13.4 min: 86% *ee*. $[\alpha]_D^{20}$ = +46.0 (*c* 0.10, $CHCl_3$).

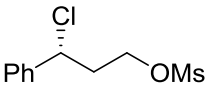
(+)-(*R*)-*N*-Benzyl-3-chloro-3-phenylpropanamide (+)-(*R*)-4l



(+)-(*R*)-**4l**

Dry CH_2Cl_2 (6 mL) was added to a stirred mixture of β-sulfido amide (–)-(*S*)-**3l** (174 mg, 0.50 mmol, 97% *ee*) and $PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) under N_2 atmosphere. The reaction was stirred at rt for 5 min, concentrated *in vacuo* and purified by flash column chromatography (silica gel; CH_2Cl_2/EtOAc, 95:5) to give the title compound as a white solid (98 mg, 72% yield, 89% *ee*). Recrystallization (CH_2Cl_2/*n*-hexane, 1:2, 4.5 mL) afforded racemic crystals with the mother liquor containing enantiomerically enriched (+)-(*R*)-**4l** as a white solid (81 mg, 59% yield). Mp: 94-96 °C. Enantiomeric excess was determined by HPLC analysis (CHIRALPAK IB-H, *n*-hexane/EtOH, 90:10, 0.75 mL/min, 210 nm): t_r (major) = 12.7 min; t_r (minor) = 13.9 min: 94% *ee*. $[\alpha]_D^{20}$ = +60.7 (*c* 1.02, $CHCl_3$).

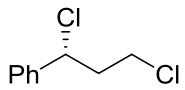
(+)-(*R*)-3-Chloro-3-phenylpropyl methanesulfonate (+)-(*R*)-2e



(+)-(*R*)-**2e**

The procedure was identical to that of (±)-**2e**. (*S*)-**1e** (161 mg, 0.5 mmol) was reacted with $PhICl_2$ (151 mg, 0.55 mmol, 1.1 equiv) in dry CH_2Cl_2 (6 mL) to give the title compound (116 mg, 93% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 90:10, 1.0 mL/min, 210 nm): t_r (major) = 14.4 min; t_r (minor) = 15.5 min: 69% *ee*. $[\alpha]_D^{20}$ = +50.7 (*c* 0.14, $CHCl_3$).

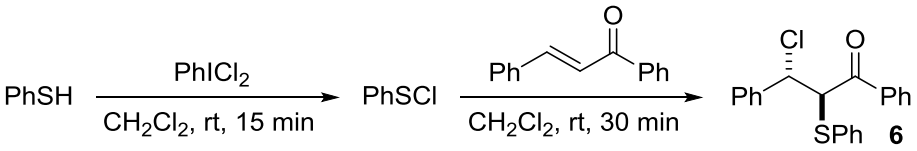
(+)-(*R*)-(1,3-Dichloropropyl)benzene (+)-(*R*)-2g


(+)-(*R*)-**2g**

The procedure was identical to that of of (±)-**2g**. (*S*)-**1g** (144 mg, 0.55 mmol) was reacted with $PhICl_2$ (165 mg, 0.6 mmol, 1.1 equiv) in dry CH_2Cl_2 (6 mL) to give the title compound (87 mg, 84% yield). Enantiomeric excess was determined by HPLC analysis (CHIRALPAK OD-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 220 nm): t_r (minor) = 15.6 min; t_r (major) = 17.2 min: 63% *ee*. $[\alpha]_D^{20}$ = +49.1 (*c* 0.22, $CHCl_3$). Enantioenriched (+)-(*R*)-**2g** has previously been described.[28]

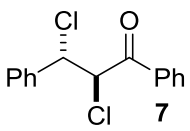
7. Preparation of side products (6), (7) and characterization of (6a)

7.1. Synthesis of *anti*-3-chloro-1,3-diphenyl-2-(phenylthio)propan-1-one (6)



To an oven-dried 50 mL Schlenk tube containing a stirred solution of thiophenol (112 μl, 121 mg, 1.1 mmol, 1.1 equiv) in dry CH_2Cl_2 (6 mL) was added $PhICl_2$ (302 mg, 1.1 mmol, 1.1 equiv) at rt under N_2 atmosphere. After 15 min, *trans*-chalcone (208 mg, 1.0 mmol) was added to the orange solution and the reaction stirred for a further 30 min. The solvent was removed *in vacuo* and the title compound isolated by recrystallization from *n*-hexane (50 mL, –20 °C) as a white solid (205 mg, 58% yield). Mp: 79-81 °C. IR (neat, cm^{-1}): *ν* 1552, 1375, 1073, 1012, 825, 717, 519. ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.04 (d, *J* = 11.1 Hz, 1H), 5.44 (d, *J* = 11.1 Hz, 1H), 6.80-6.90 (m, 2H), 7.05-7.15 (m, 2H), 7.19-7.28 (m, 1H), 7.36-7.40 (m, 3H), 7.43-7.56 (m, 4H), 7.58-7.68 (m, 1H), 7.96-8.08 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 58.5, 61.3, 128.7, 128.8, 128.9, 128.9, 129.0, 129.1, 129.2, 131.5, 133.7, 135.0, 136.3, 138.4, 193.6. HRMS (EI): $C_{21}H_{17}ClOS$ $[M]^+$ calculated: 352.0689, found: 352.0690.

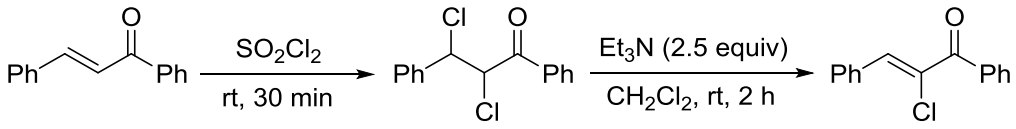
7.2. *anti*-2,3-Dichloro-1,3-diphenylpropan-1-one (7)


7

Isolated from a large scale chlorination of sulfide **3a** (2.5 mmol) by flash column chromatography (silica gel; *n*-hexane/Et_2O 90:10) as a white solid (21 mg, 3% yield). All analytical data are consistent with those reported in the literature.[29]

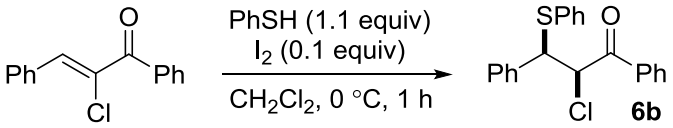
7.3. Synthesis of *syn*-2-chloro-1,3-diphenyl-3-(phenylthio)propan-1-one (6b)

(*Z*)-2-Chloro-1,3-diphenylprop-2-en-1-one



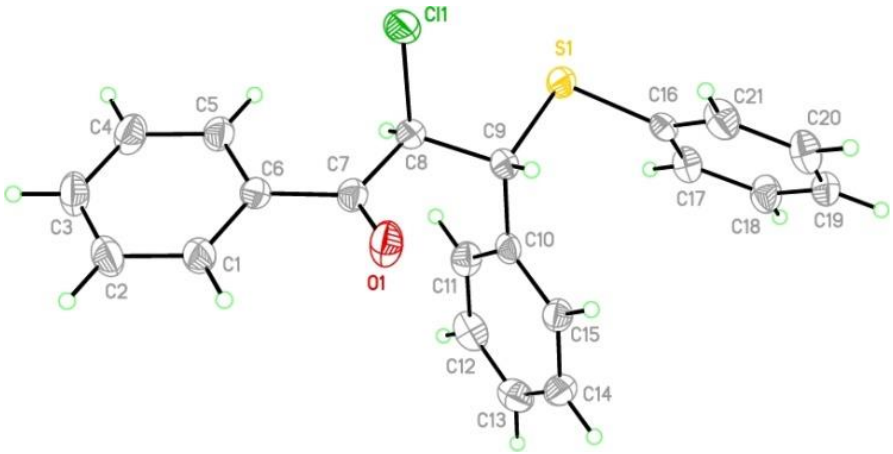
In a 25 mL round-bottom flask, SO_2Cl_2 (10 mL) was added to *trans*-chalcone (1.04 g, 5.0 mmol) and the reaction mixture stirred at rt for 30 min. Concentration *in vacuo* yielded 2,3-dichloro-1,3-diphenylpropan-1-one as crude product. This material was dissolved in CH_2Cl_2 (15 mL), triethylamine (1.73 mL, 1.26 g, 12.5 mmol, 2.5 equiv) was added and the reaction mixture stirred at rt for 2 h. The reaction was quenched with HCl (5%, 10 mL) and extracted with CH_2Cl_2 (2 x 10 mL). The combined organic extracts were washed with H_2O (3 x 10 mL), brine and dried over Na_2SO_4. The solvent was removed *in vacuo* and the title compound isolated by flash column chromatography (silica gel; *n*-hexane/CH_2Cl_2, 3:1) as a pale yellow oil (1.08 g, 89% yield). All analytical data are consistent with those reported in the literature.[30]

***syn*-2-Chloro-1,3-diphenyl-3-(phenylthio)propan-1-one (6b)**



To a stirred solution of (*Z*)-2-chloro-1,3-diphenylprop-2-en-1-one (485 mg, 2.0 mmol) in CH_2Cl_2 (6 mL) were added thiophenol (225 µL, 242 mg, 2.2 mmol, 1.1 equiv) and I_2 (51 mg, 0.2 mmol, 0.1 equiv) at 0 °C and the reaction mixture was stirred at 0 °C for 1 h. The reaction mixture was quenched with sat. aq. $Na_2S_2O_3$ (10 mL) and extracted with CH_2Cl_2 (2 x 10 mL). The combined organic extracts were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to yield the crude product, which contained *syn*-chloro sulfide **6b** as the sole stereoisomeric product. Recrystallization (CH_2Cl_2/*n*-hexane, 1:5) gave the title compound as a white solid (578 mg, 82% yield). *Syn* configuration was confirmed by X-ray analysis of crystals obtained from CH_2Cl_2/*n*-hexane. Mp: 134-136 °C. IR (KBr, cm^{-1}): *v* 3060, 3030, 1686, 1594, 1449, 1273, 974. ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.90 (d, *J* = 10.0 Hz, 1H), 5.54

(d, *J* = 10.0 Hz, 1H), 7.06-7.16 (m, 5H), 7.17-7.24 (m, 3H), 7.27-7.33 (m, 2H), 7.41 (t, *J* = 7.8 Hz, 2H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.81 (d, *J* = 7.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 56.9, 59.3, 127.9, 128.2, 128.4, 128.6, 128.8, 128.9, 128.9, 133.2, 134.0, 134.1, 134.9, 138.7, 192.1. HRMS (APCI): $C_{21}H_{17}OS$ [M - Cl]$^+$ calculated: 317.1000, found: 317.0995.

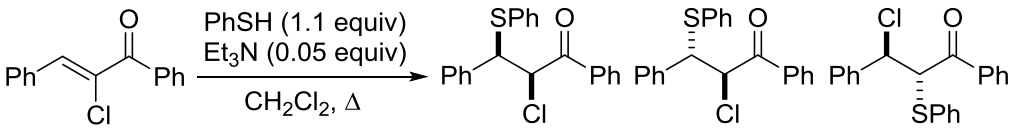


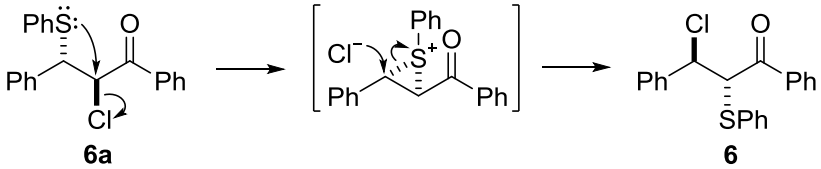
Molecular structure of **6b** with atomic displacement parameters shown at 50% probability.[31]

7.4. ^{1}H NMR characterization of *anti*-3-chloro-1,3-diphenyl-2-(phenylthio)propan-1-one (6a) observed in the chlorination of sulfide (3a) with NCS and SO_2Cl_2

The synthesis of the unstable *anti*-chloro sulfide **6a** was attempted by several methods. Attempted α-chlorination of sulfide **3a** by a deprotonation/chlorination sequence using several bases gave *trans*-chalcone - the product of a retro sulfa-Michael addition.

Triethylamine catalyzed 1,4-addition of PhSH to (*Z*)-2-chloro-1,3-diphenylprop-2-en-1-one gave an insperable mixture of *syn*-chloro sulfide **6b**, *anti*-chloro sulfide **6a** and its rearranged thermodynamically more stable *anti*-chloro sulfide **6**.[32] After stirring at reflux for 16 h, **6b**





and **6** were the only detectable chloro sulfide products.

To a stirred solution of (*Z)*-2-chloro-1,3-diphenylprop-2-en-1-one (121 mg, 0.5 mmol) in CH_2Cl_2 (3 mL) were added thiophenol (56 μL, 61 mg, 0.55 mmol, 1.1 equiv) and triethylamine (3.5 μL, 2.5 mg, 0.025 mmol, 0.05 equiv) and the reaction mixture was stirred at reflux for 16 h. Aliquots (150 μL) were removed *via* syringe at regular intervals for NMR monitoring. The aliquot was concentrated *in vacuo*, 1,1,2,2-tetrachloroethane (50 μL, 0.5 M solution in $CDCl_3$, 0.025 mmol) was added as standard and the mixture dissolved in $CDCl_3$ before recording a ^{1}H NMR spectrum for product ratio analysis. The reaction mixture was concentrated *in vacuo* to afford an inseparable mixture of chloro sulfides **6b** and **6**.

Characteristic signals for **6a**: ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.86 (d, *J* = 11.0 Hz, 1H), 5.53 (d, *J* = 11.0 Hz, 1H).

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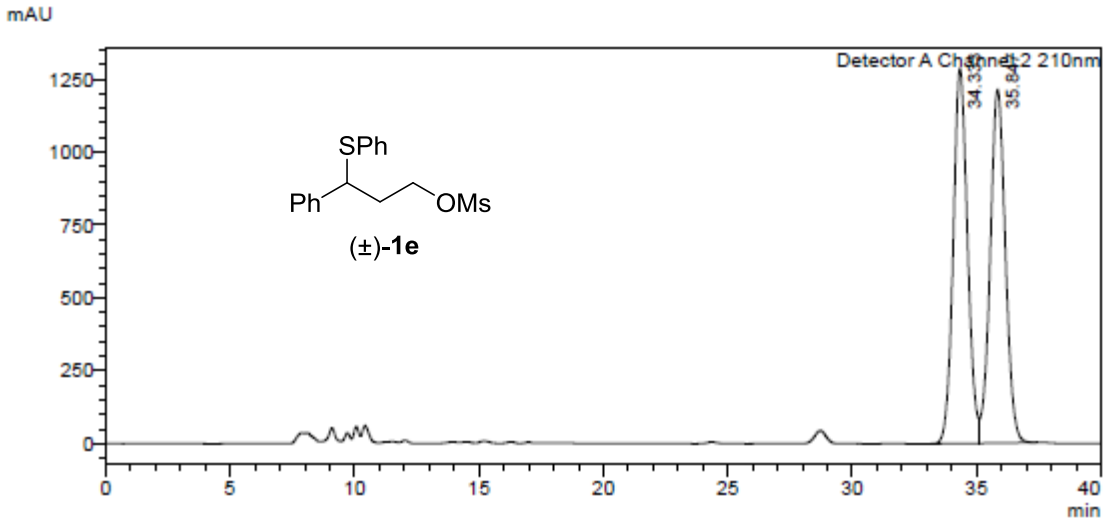
9. HPLC traces of optically active compounds

HPLC traces of (±)-1e and (-)-(*S*)-1e

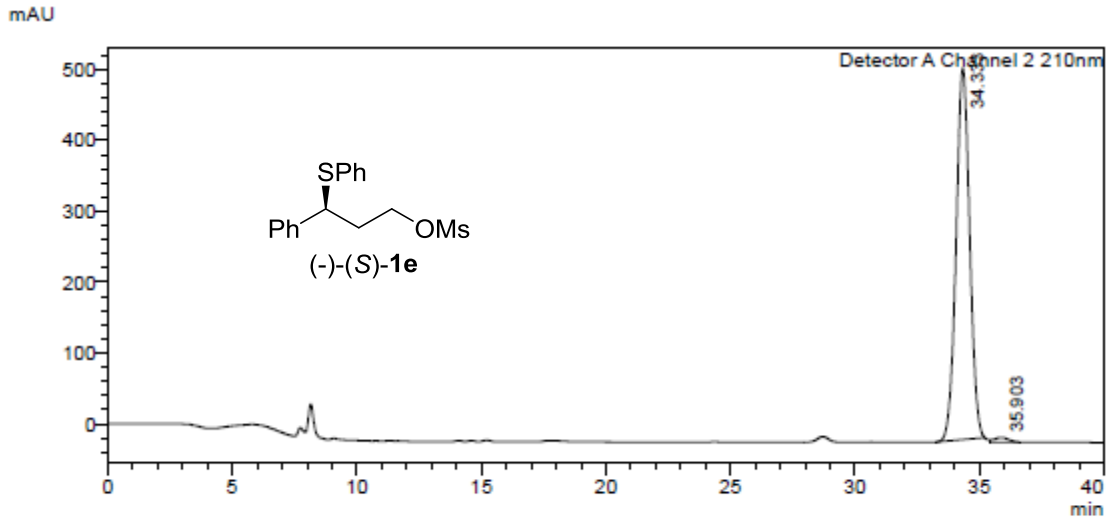
CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 85:15, 0.4 mL/min, 210 nm



<Peak Table>

Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	34.333	51377070	1285699	0.000
2	35.847	51587624	1212870	0.000
Total		102964694	2498569	



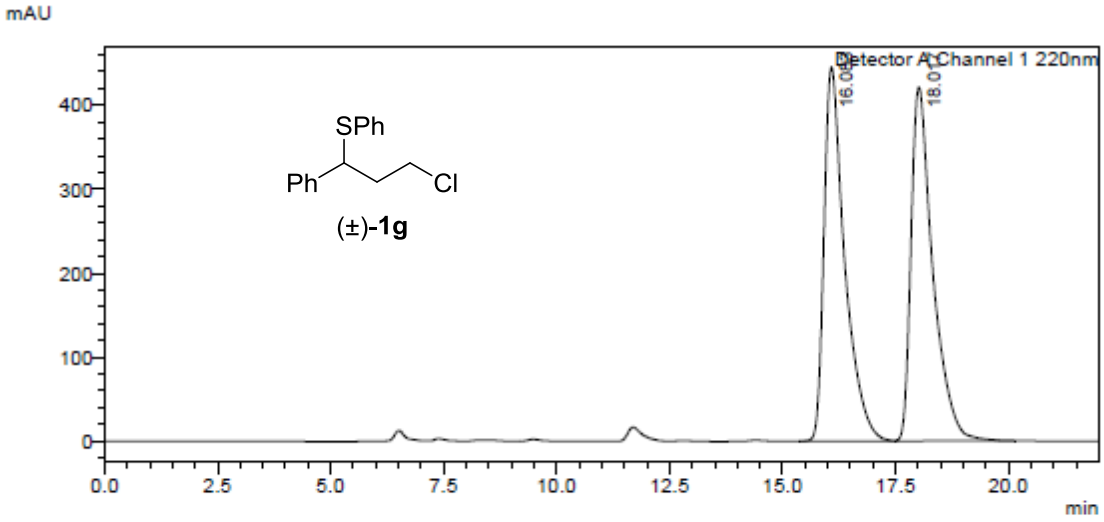
<Peak Table>

Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	34.333	19875117	523820	0.000
2	35.903	263142	6432	0.000
Total		20138259	530252	

HPLC traces of (±)-1g and (-)-(*S*)-1g

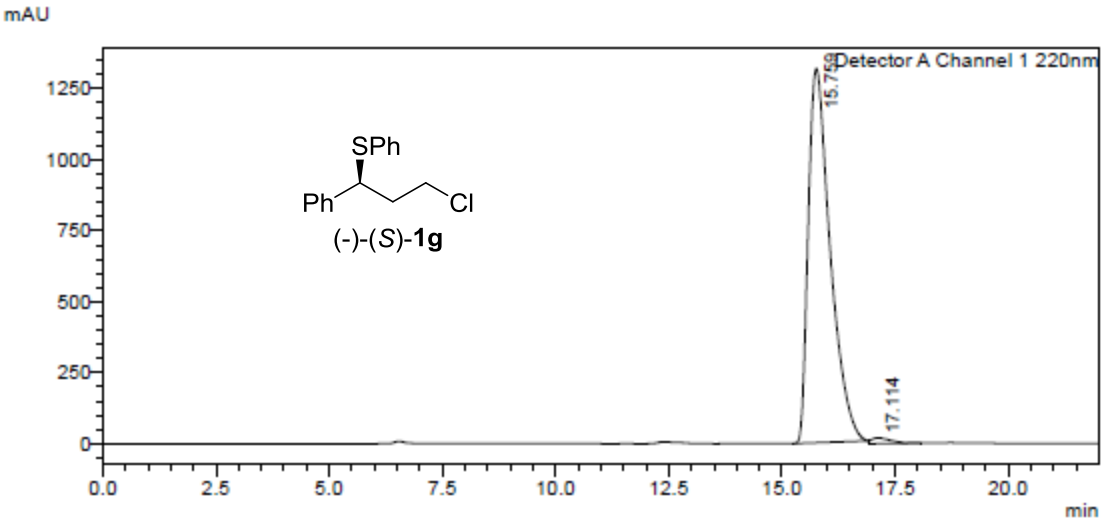
CHIRALPAK OD-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 220 nm



<Peak Table>

Detector A Channel 1 220nm

Peak#	Ret. Time	Area	Height	Conc.
1	16.083	14218557	445219	0.000
2	18.017	14132801	421480	0.000
Total		28351357	866700	



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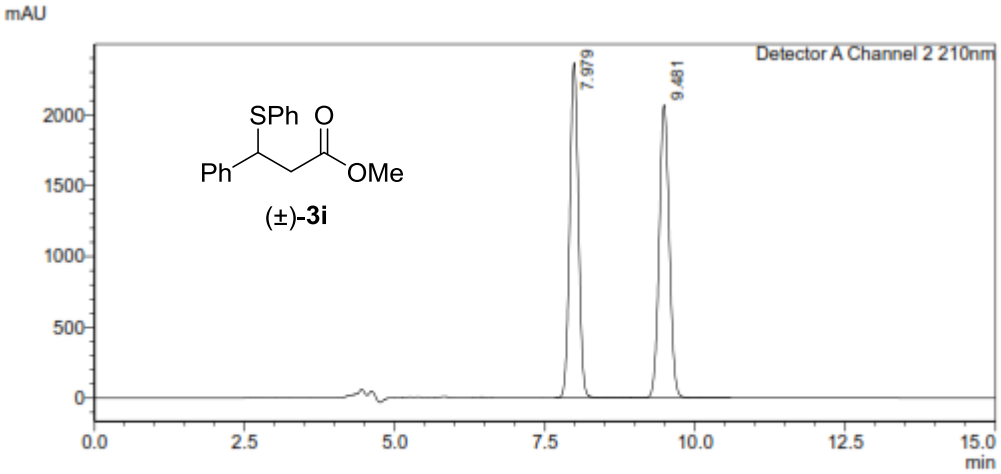
Detector A Channel 1 220nm

Peak#	Ret. Time	Area	Height	Conc.
1	15.759	44373241	1317215	0.000
2	17.114	592667	21029	0.000
Total		44965908	1338244	

HPLC traces of (±)-3i and (-)-(*S*)-3i

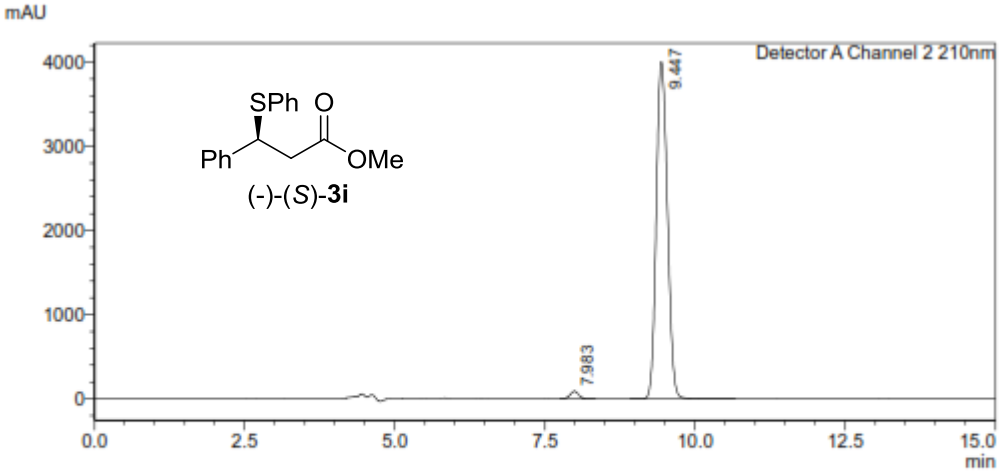
CHIRALPAK IB-H; *n*-hexane/*i*PrOH, 97:3; 0.75 mL/min; 210 nm



<Peak Table>

Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	7.979	23840162	2091084	0.000
2	9.481	24100520	1883139	0.000
Total		47940682	3974223	



<Peak Table>

Detector A Channel 2 210nm

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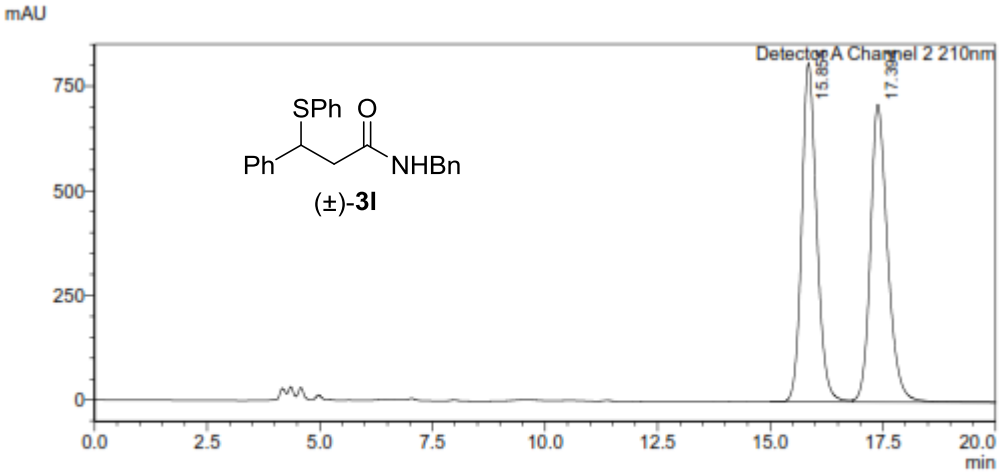
1	7.983	860711	75460	0.000
2	9.447	51658038	3771772	0.000
Total		52518749	3847232	

HPLC traces of (±)-3l and (-)-(*S*)-3l

CHIRALPAK IB-H; *n*-hexane/*i*PrOH, 85:15; 0.75 mL/min; 210 nm



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Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
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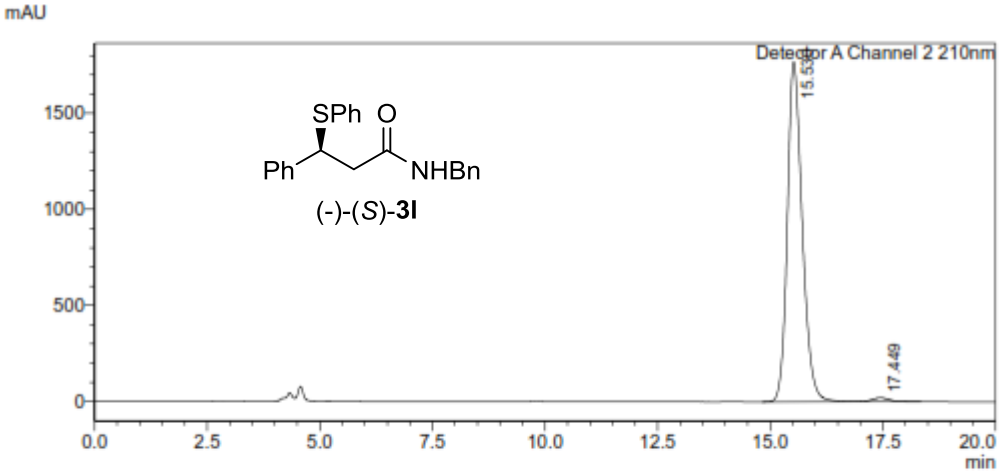
2	17.394	18909962	700557	0.000
Total		37662795	1486700	



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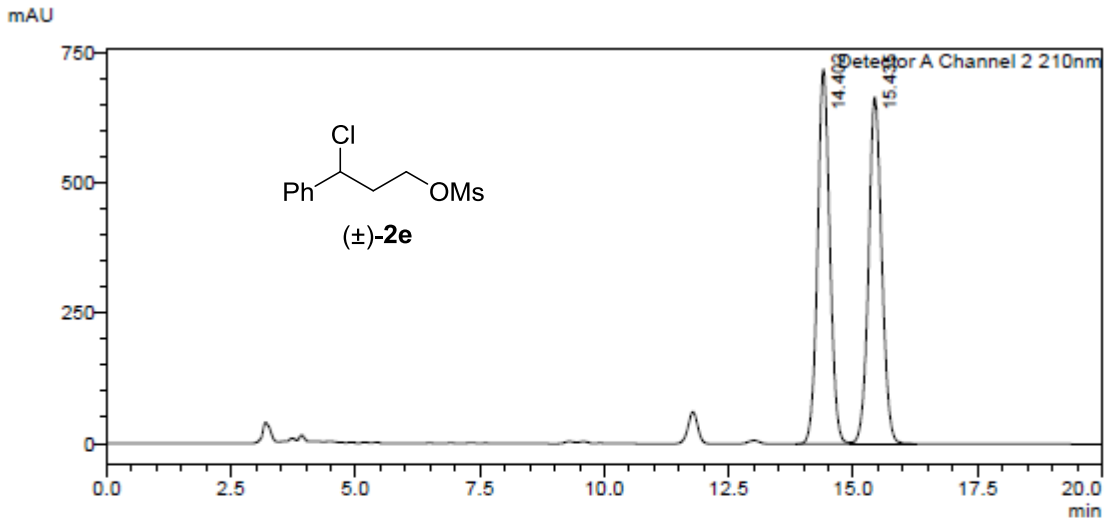
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	15.530	40768598	1726860	0.000
2	17.449	552034	20136	0.000
Total		41320632	1746995	

HPLC traces of (±)-2e and (+)-(*R*)-2e

CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 90:10, 1.0 mL/min, 210 nm



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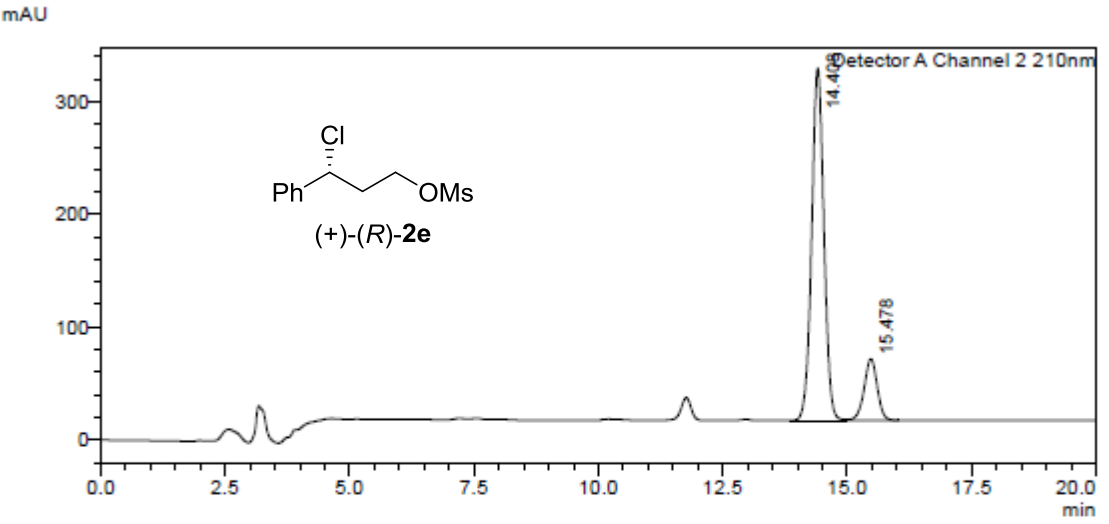
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	14.402	12336717	719294	0.000
2	15.435	12342441	666125	0.000
Total		24679158	1385420	



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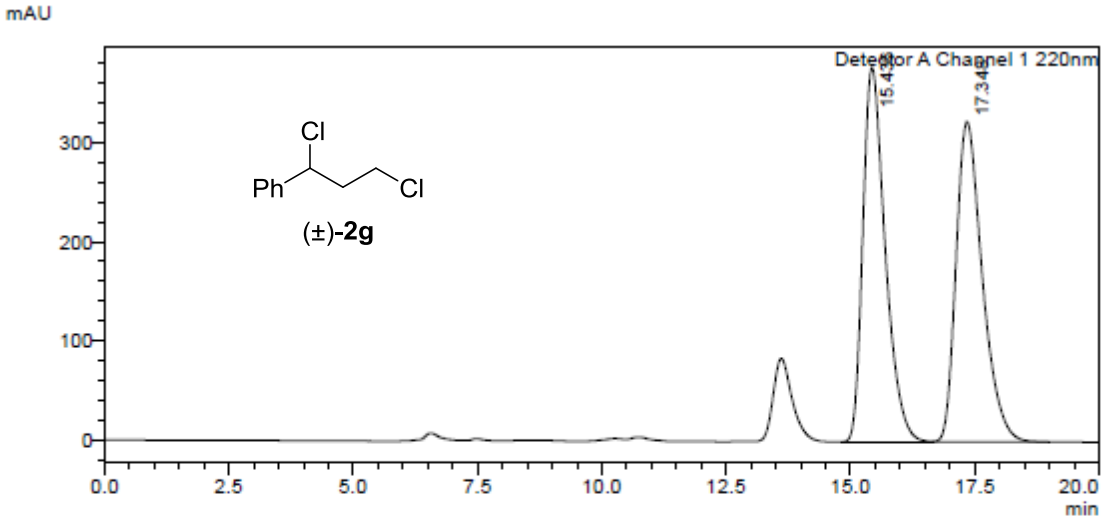
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	14.408	5354557	312112	0.000
2	15.478	997364	54565	0.000
Total		6351921	366677	

HPLC traces of (±)-2g and (+)-(*R*)-2g

CHIRALPAK OD-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 220 nm



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Detector A Channel 1 220nm

Peak#	Ret. Time	Area	Height	Conc.
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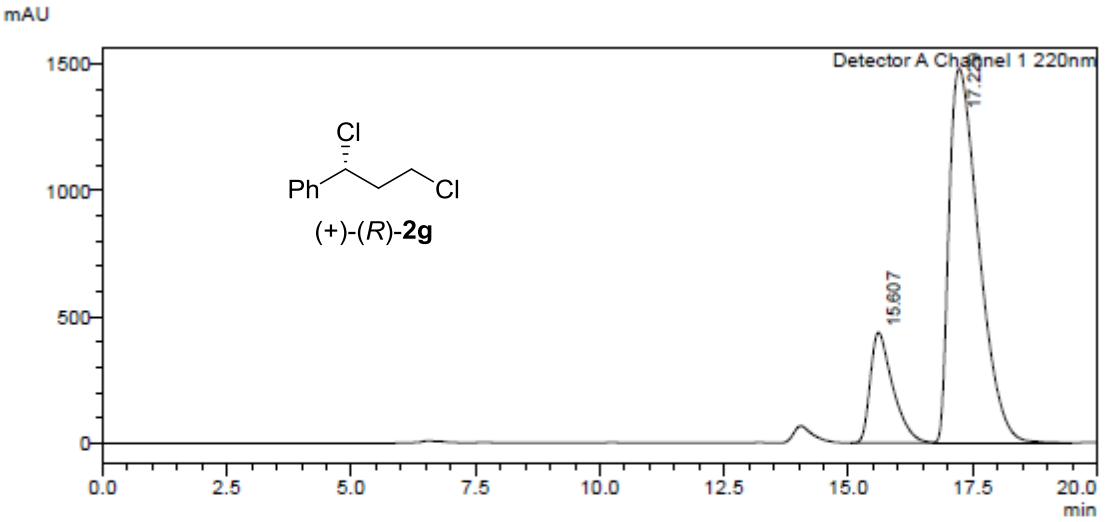
2	17.348	11872088	323000	0.000
Total		23698782	700772	



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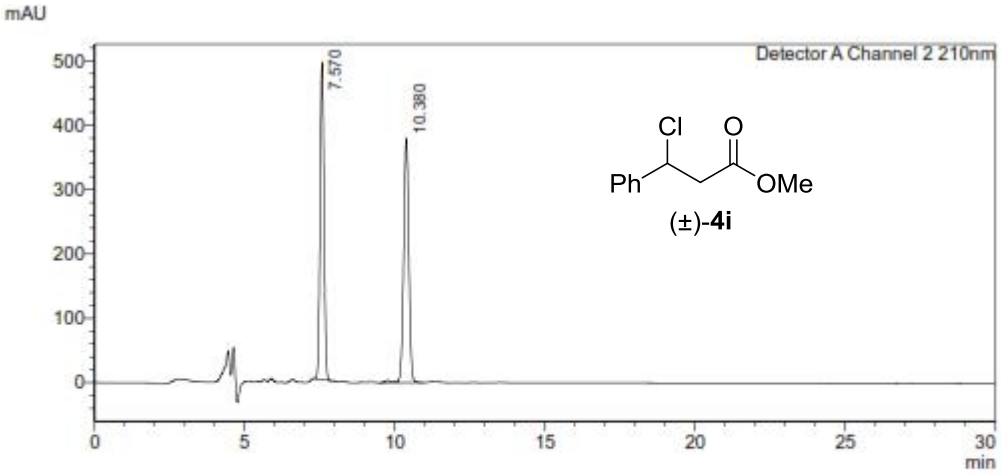
Detector A Channel 1 220nm

Peak#	Ret. Time	Area	Height	Conc.
1	15.607	13818207	437180	18.298
2	17.229	61698910	1482809	81.702
Total		75517117	1919988	

HPLC traces of (±)-4i and (+)-(*R*)-4i

CHIRALPAK IB-H; *n*-hexane/*i*-PrOH, 97:3; 0.75 mL/min; 210 nm



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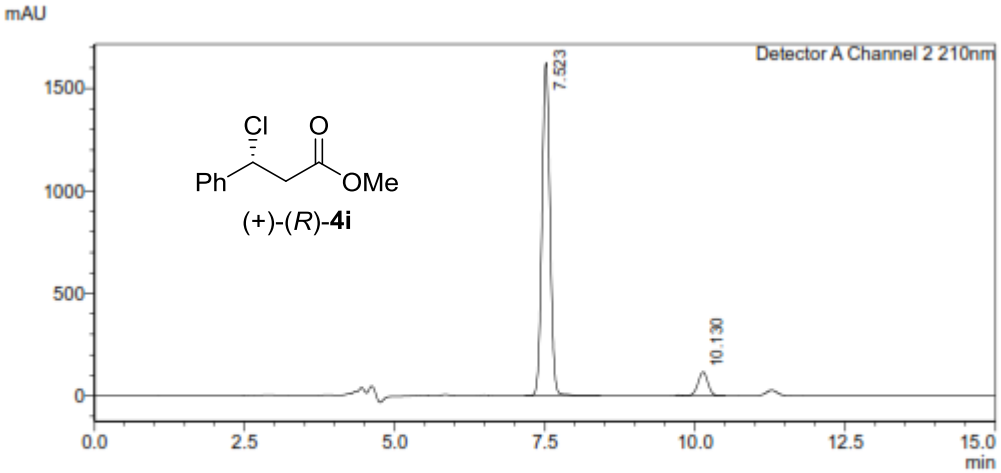
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	7.570	4437558	402456	0.000
2	10.380	4530382	361090	0.000
Total		8967940	763546	



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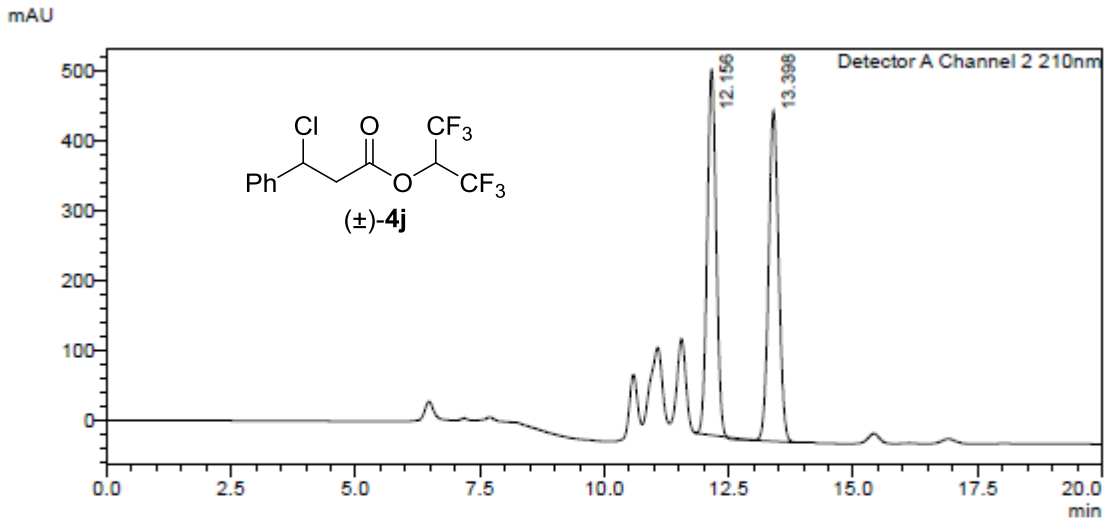
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	7.523	15060226	1383198	0.000
2	10.130	1309328	109250	0.000
Total		16369554	1492448	

HPLC traces of (±)-4j and (+)-(*R*)-4j

CHIRALPAK IB-H, *n*-hexane/*i*-PrOH, 98:2, 0.5 mL/min, 210 nm



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Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
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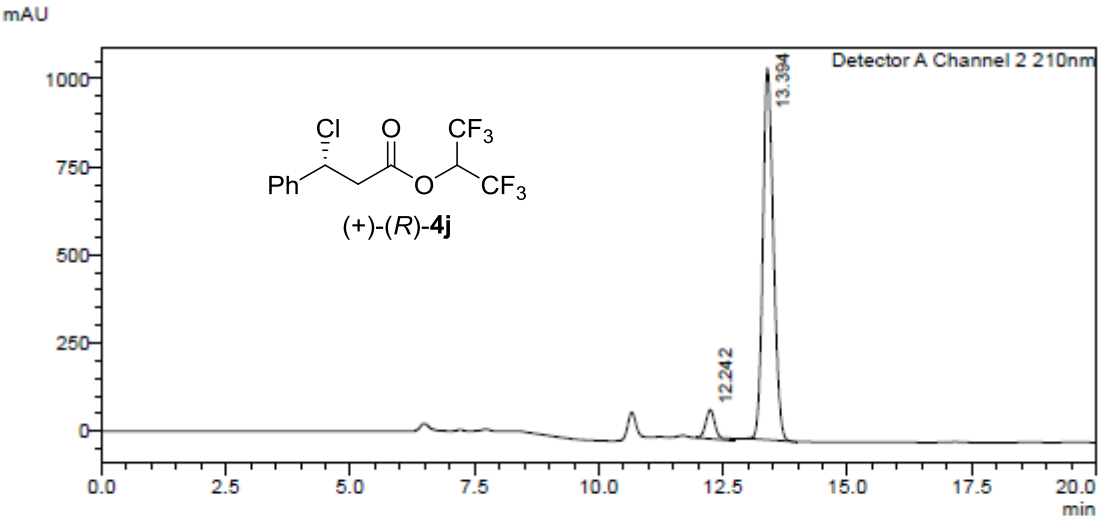
2	13.398	6610216	472764	50.328
Total		13134238	996014	



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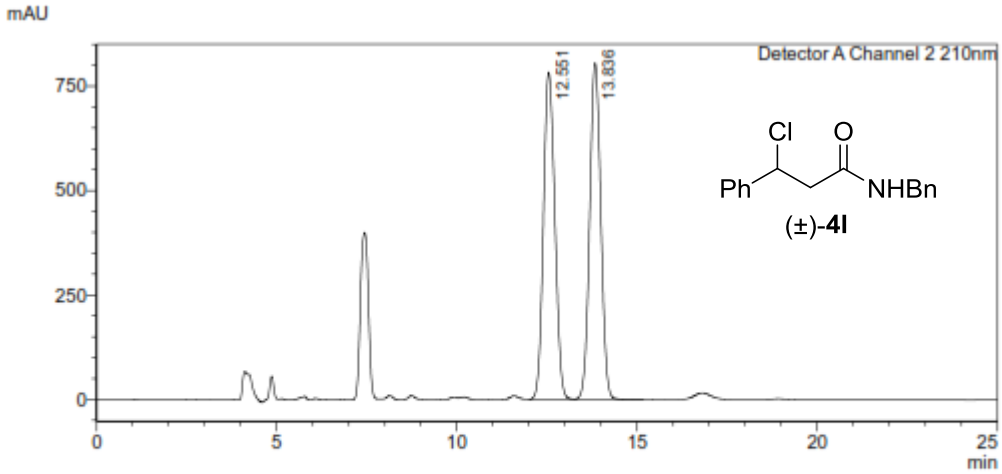
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	12.242	1139453	82666	6.847
2	13.394	15502395	1053761	93.153
Total		16641848	1136427	

HPLC traces of (±)-4l and (+)-(*R*)-4l

CHIRALPAK IB-H; *n*-hexane/EtOH, 90:10; 0.75 mL/min; 210 nm



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Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
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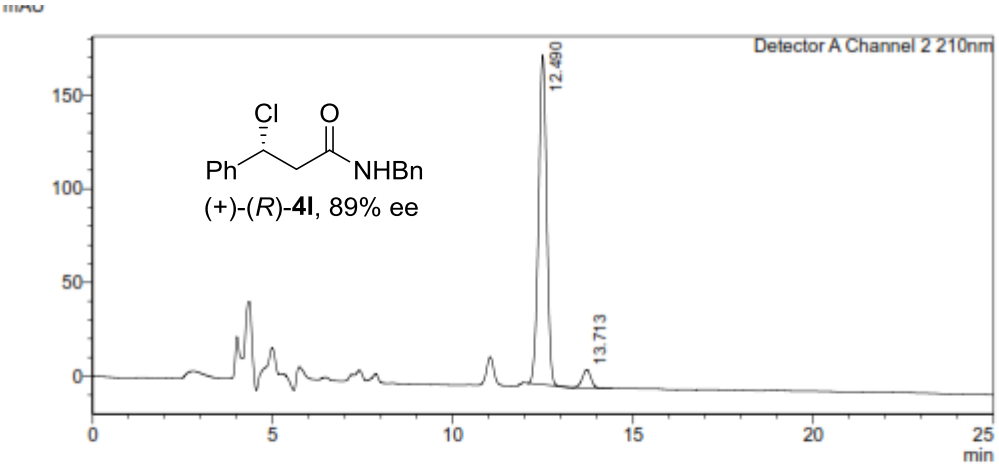
2	13.836	17271150	762287	0.000
Total		34504873	1534195	



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Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
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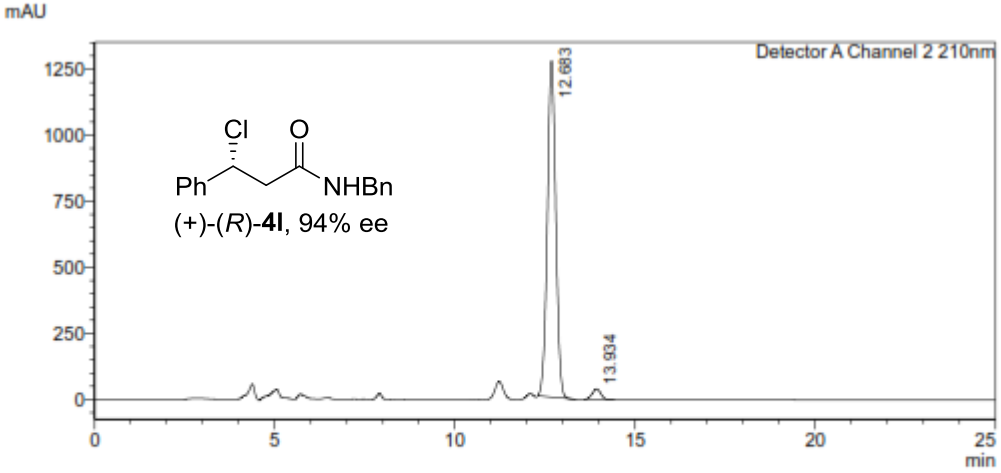
2	13.713	158969	9474	0.000
Total		2887094	172051	

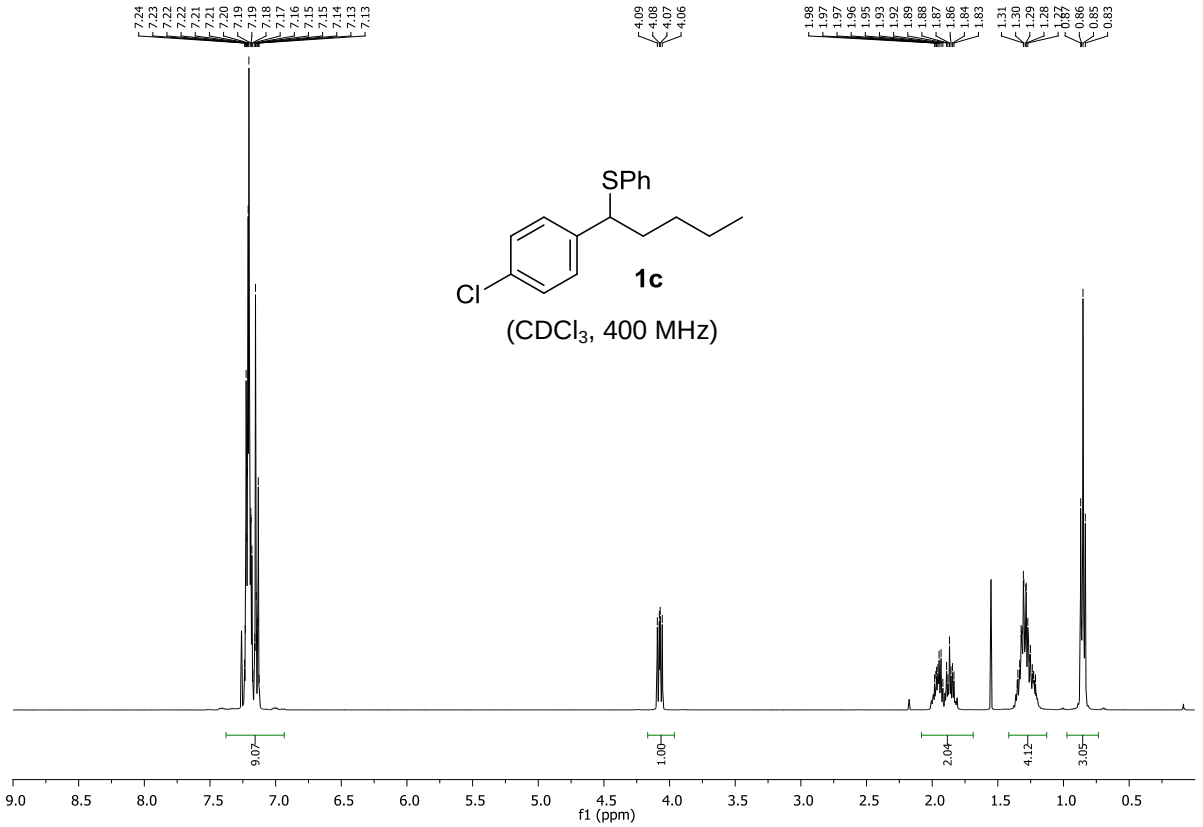


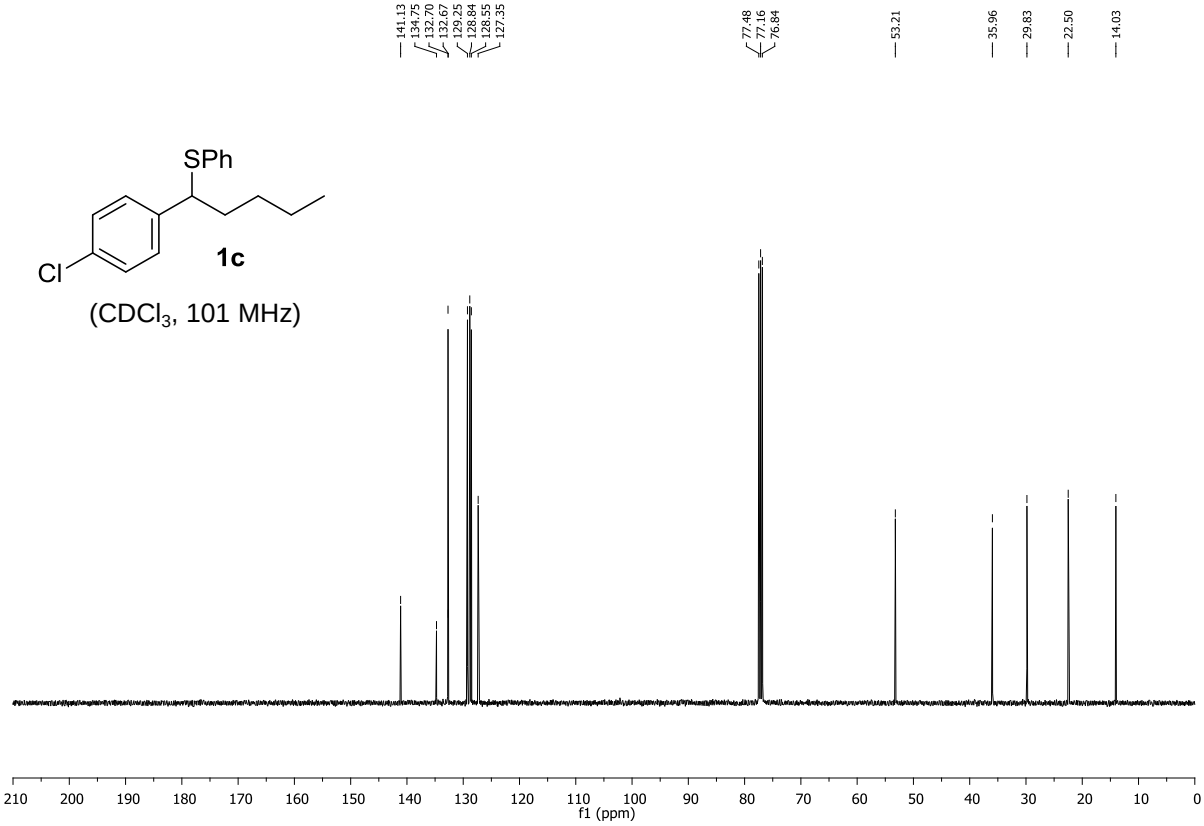
<Peak Table>

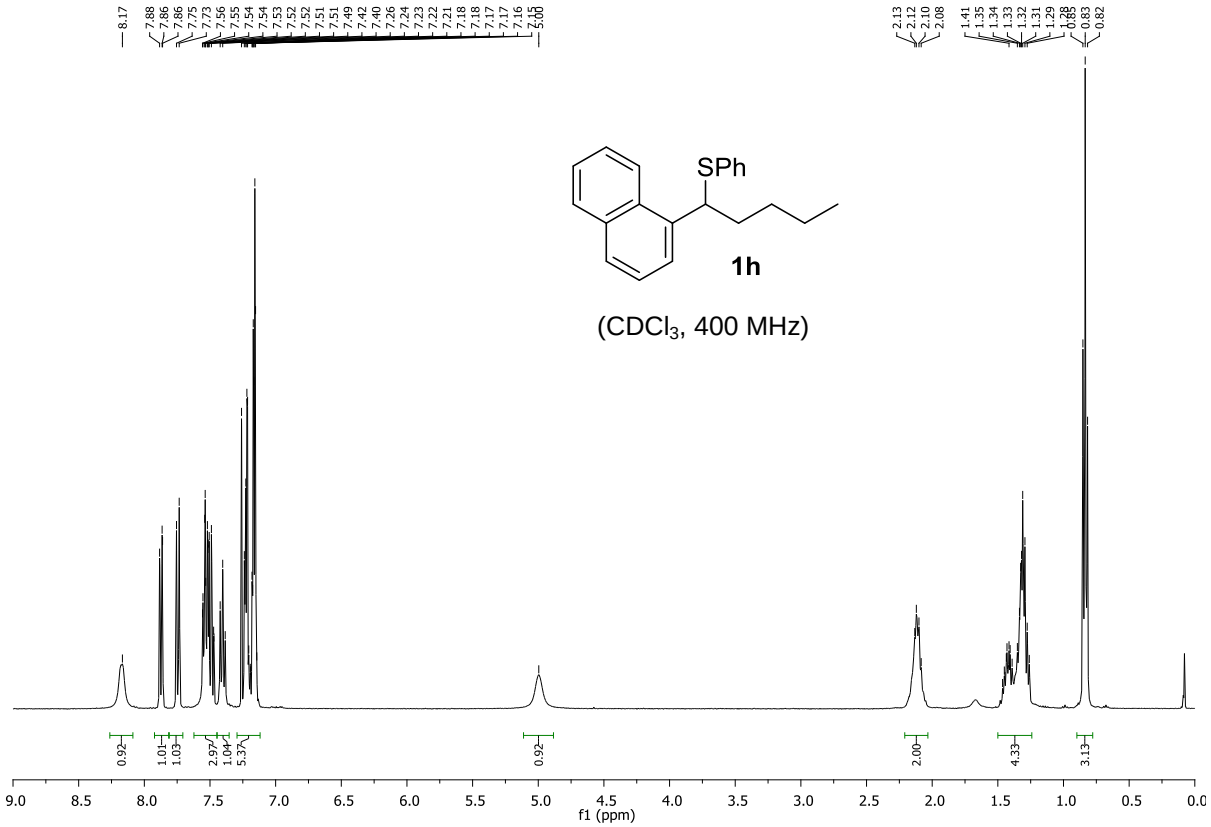
Detector A Channel 2 210nm

Peak#	Ret. Time	Area	Height	Conc.
1	12.683	20655202	1192055	0.000
2	13.934	677996	38229	0.000
Total		21333198	1230284	

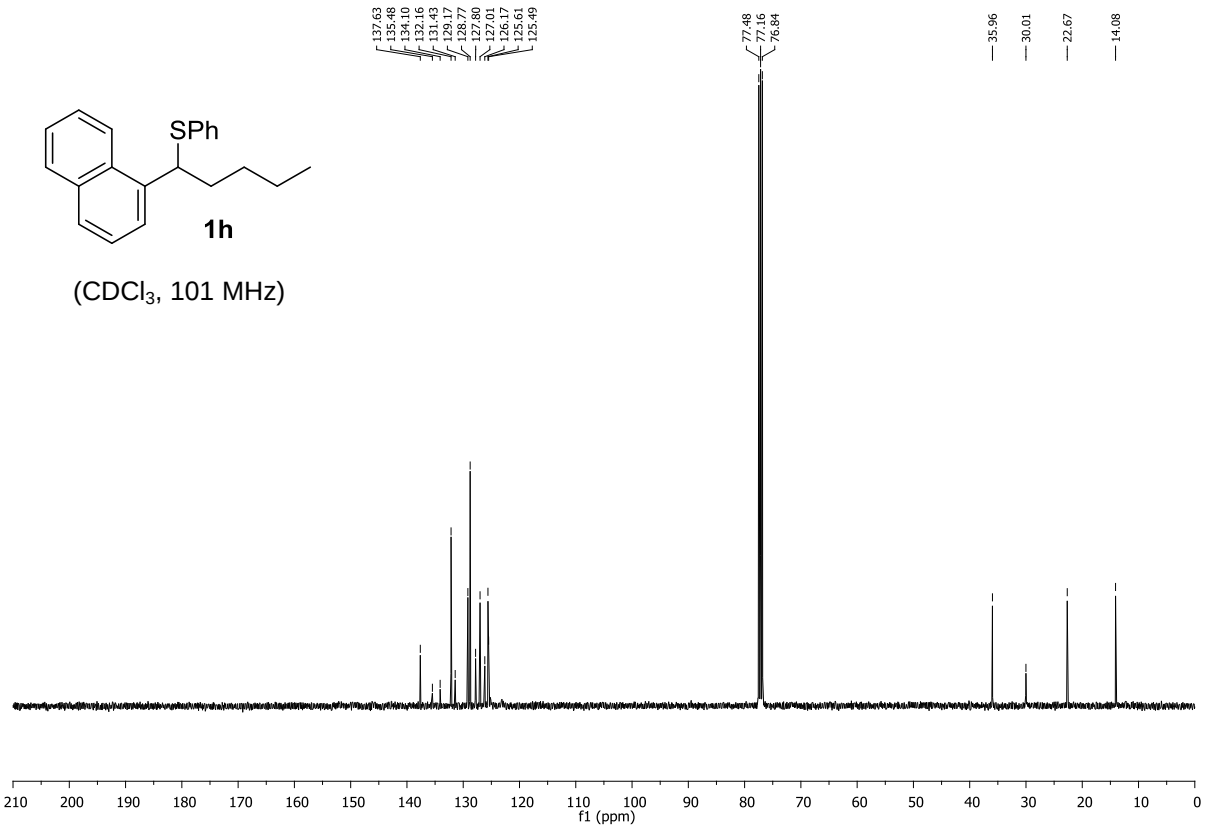
10. Copies of ^{1}H NMR and ^{13}C NMR Spectra



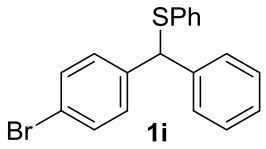




($CDCl_3$, 400 MHz)

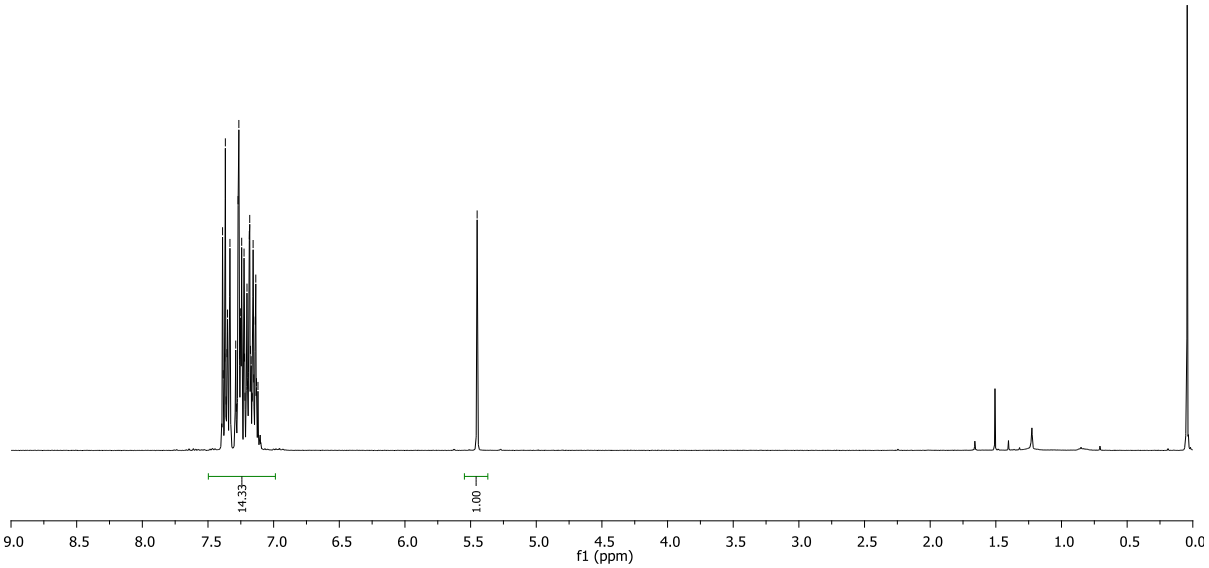


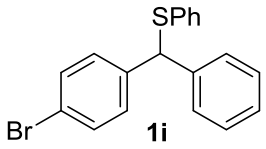
($CDCl_3$, 101 MHz)



1i

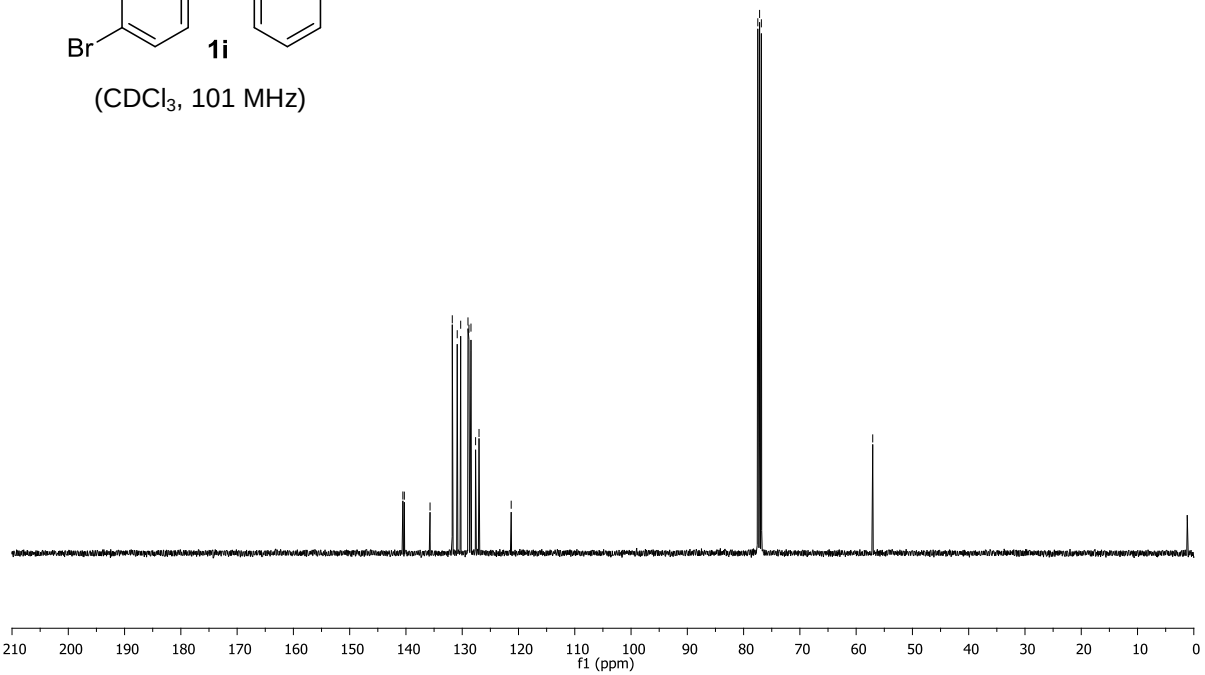
($CDCl_3$, 400 MHz)

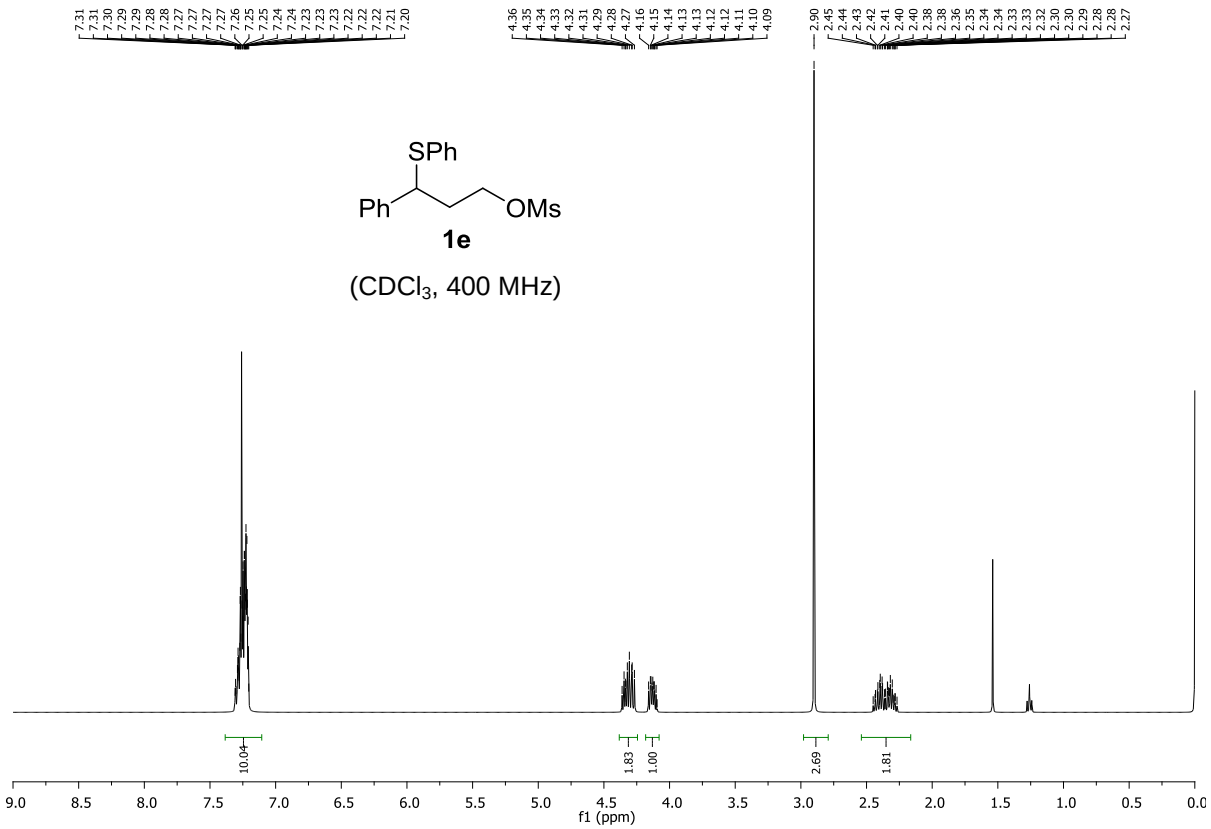


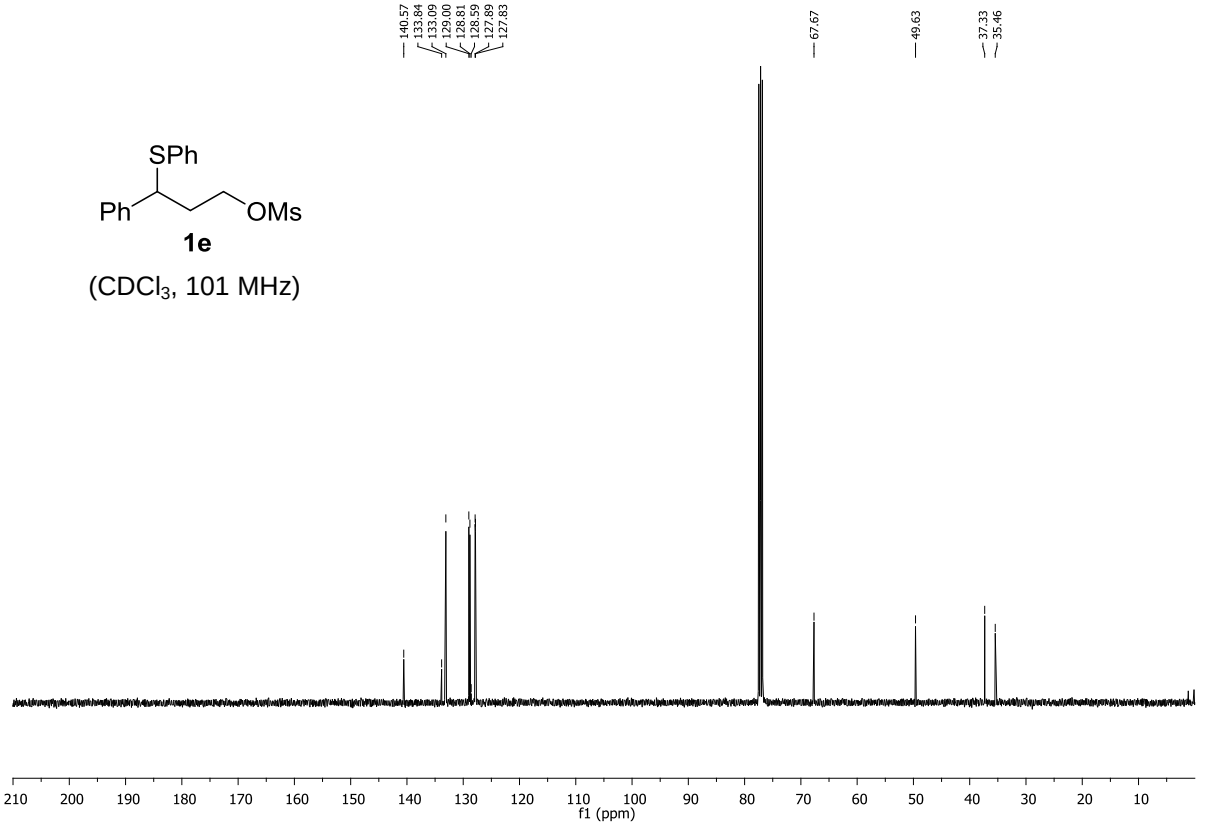


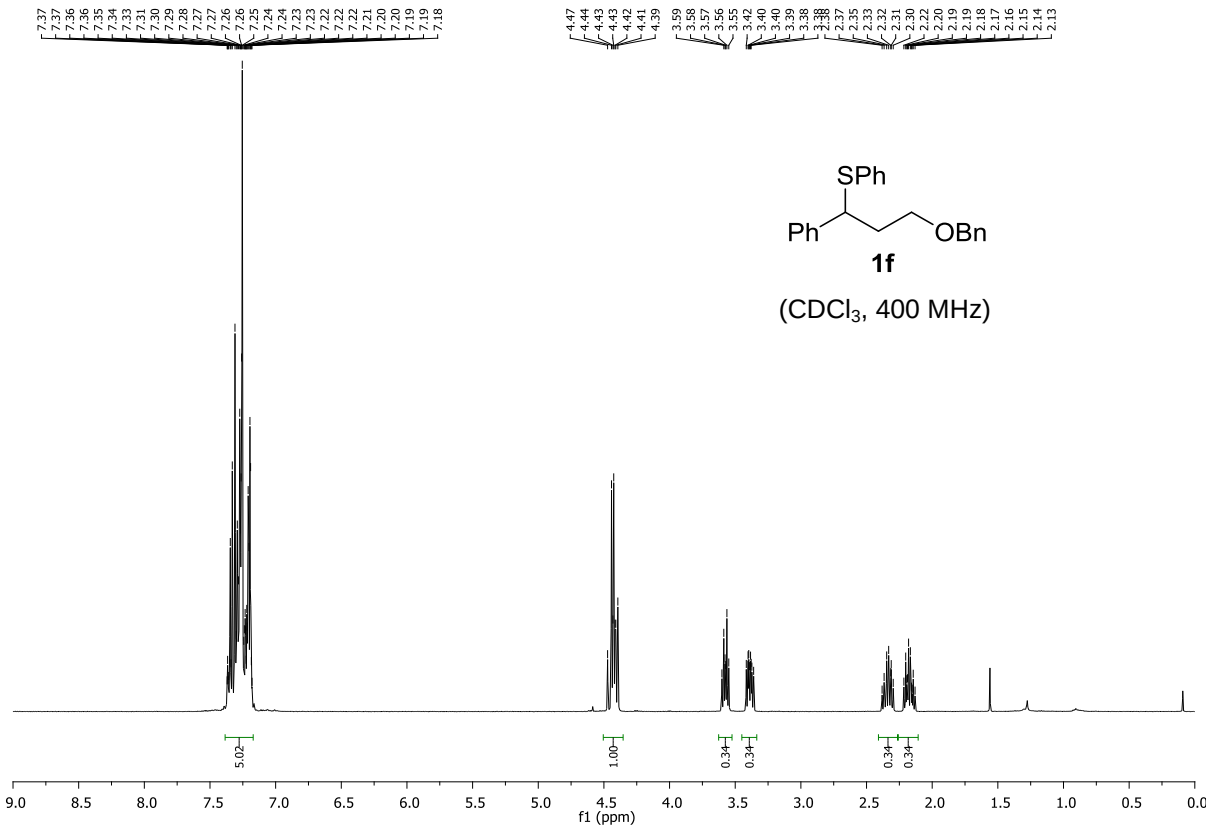
1i

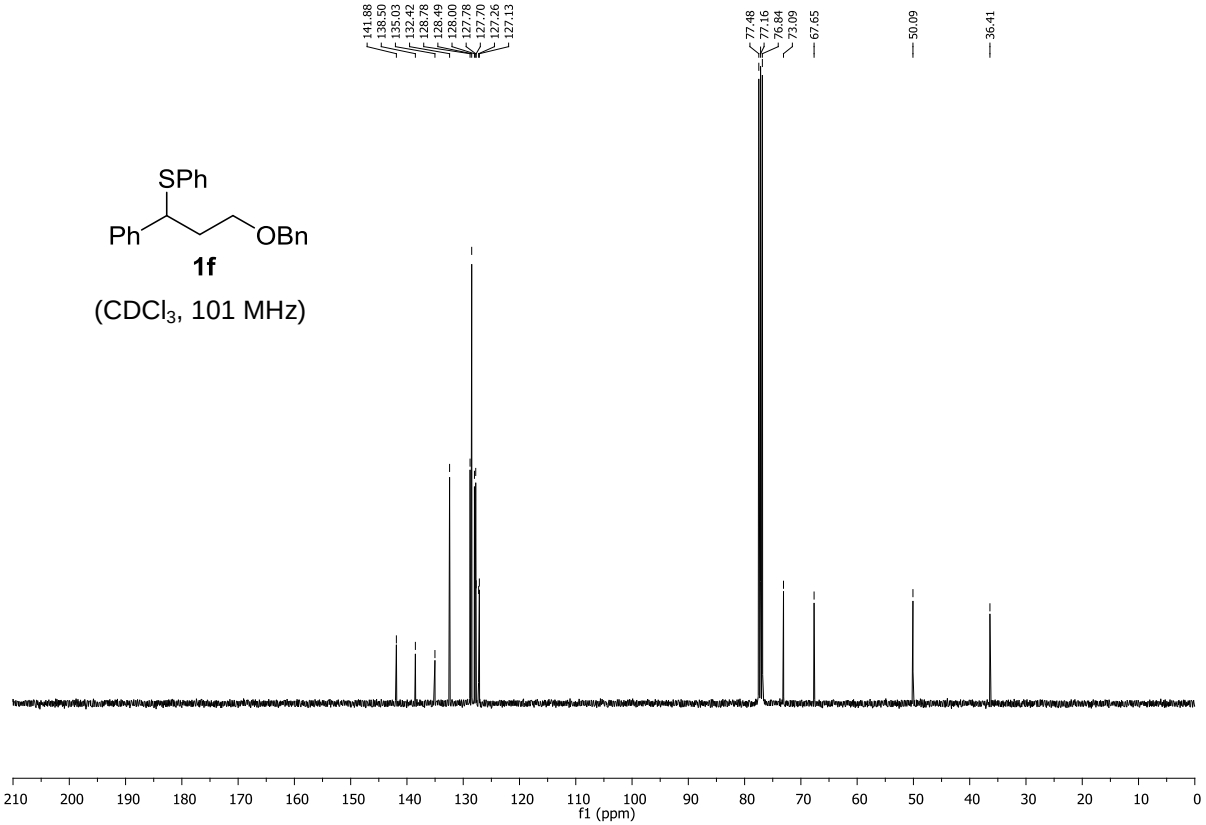
($CDCl_3$, 101 MHz)

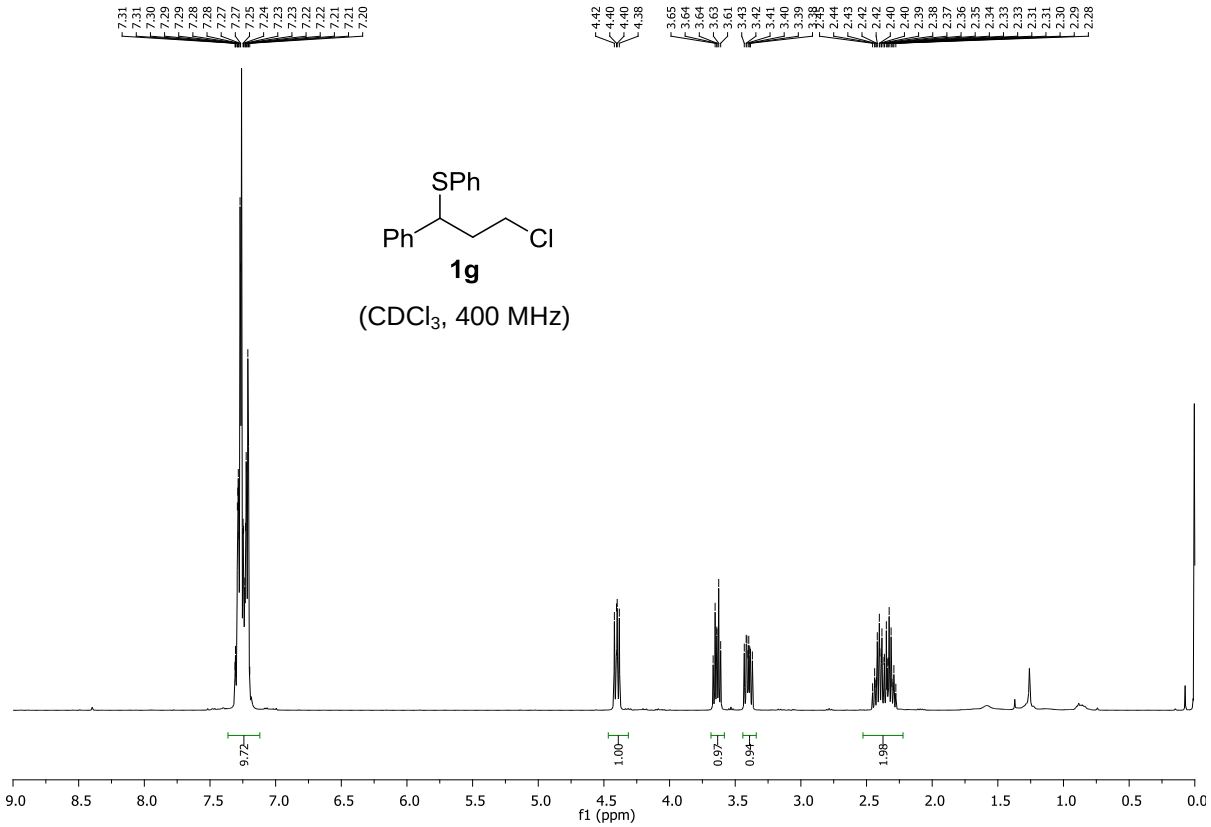


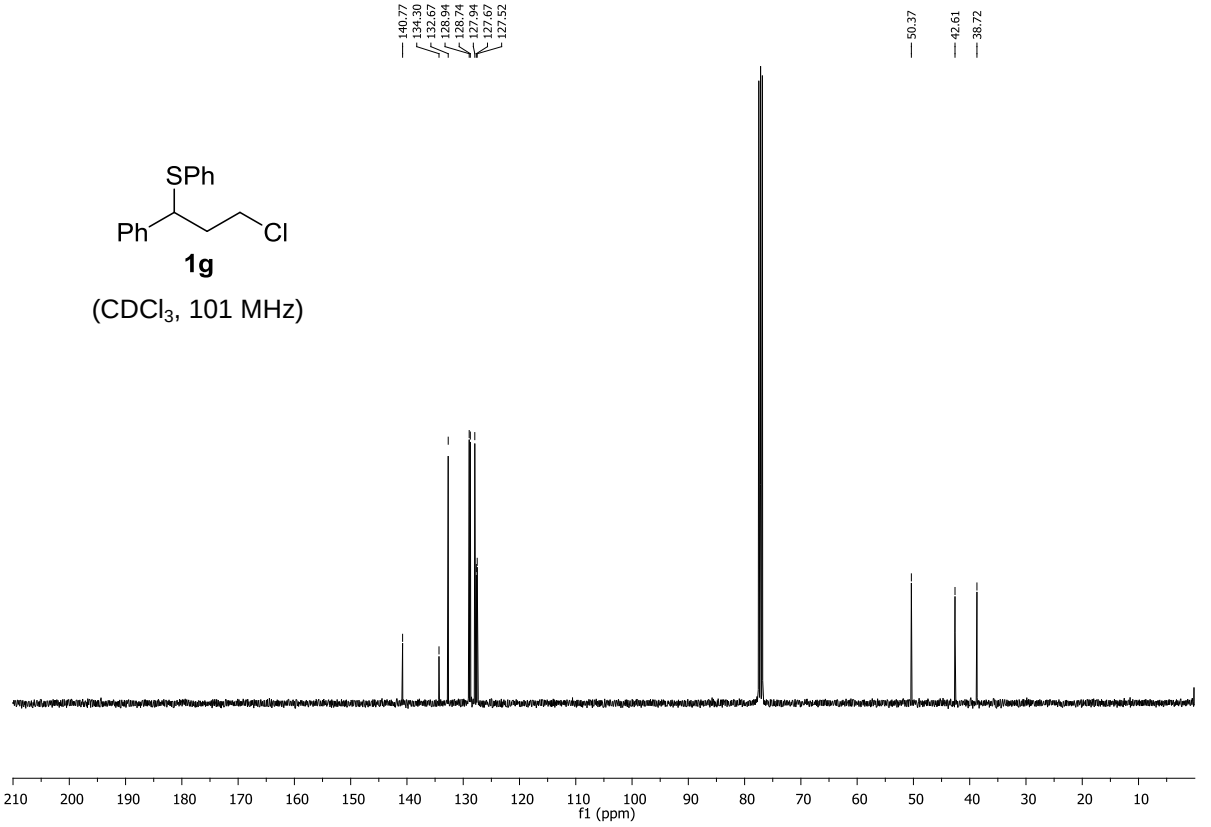

SPh
Ph
OMs
1e
(CDCl3, 400 MHz)
f1 (ppm)

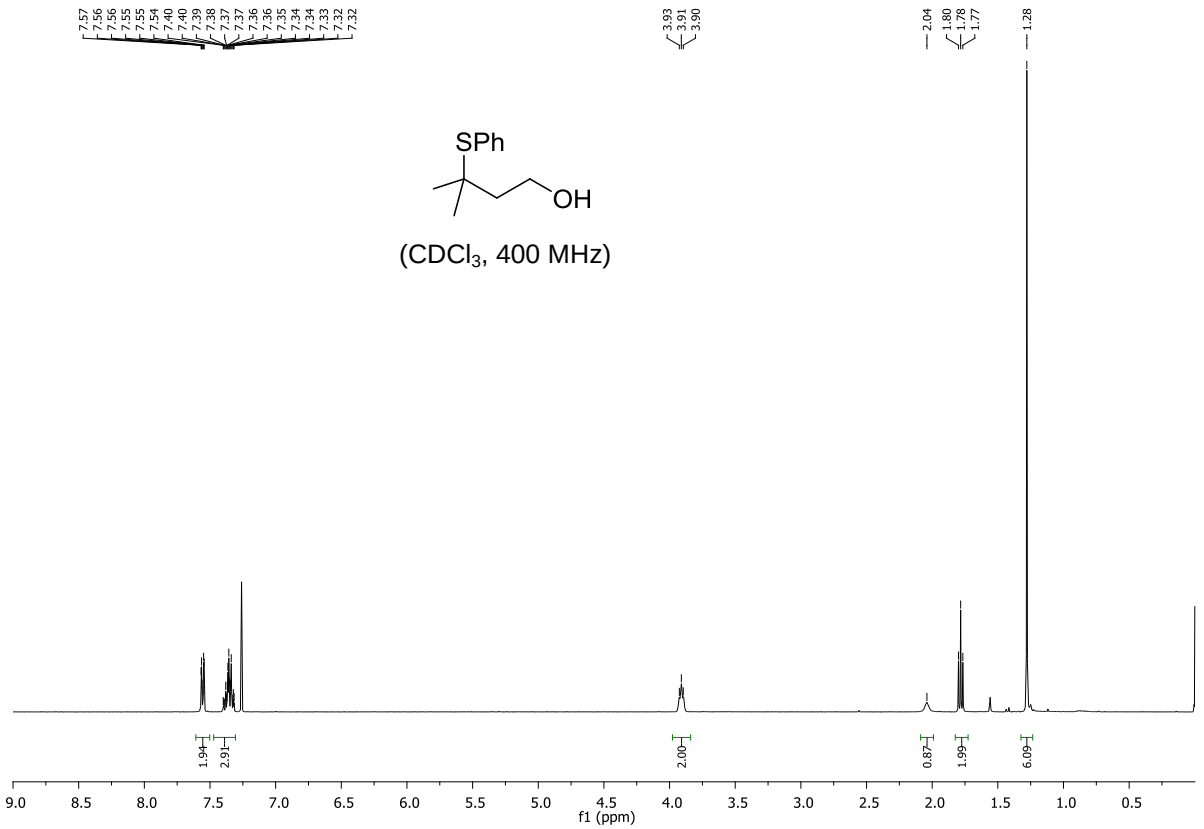

SPh
Ph
OMs
1e
(CDCl3, 101 MHz)
f1 (ppm)


SPh
Ph
OBn
1f
(CDCl3, 400 MHz)
f1 (ppm)

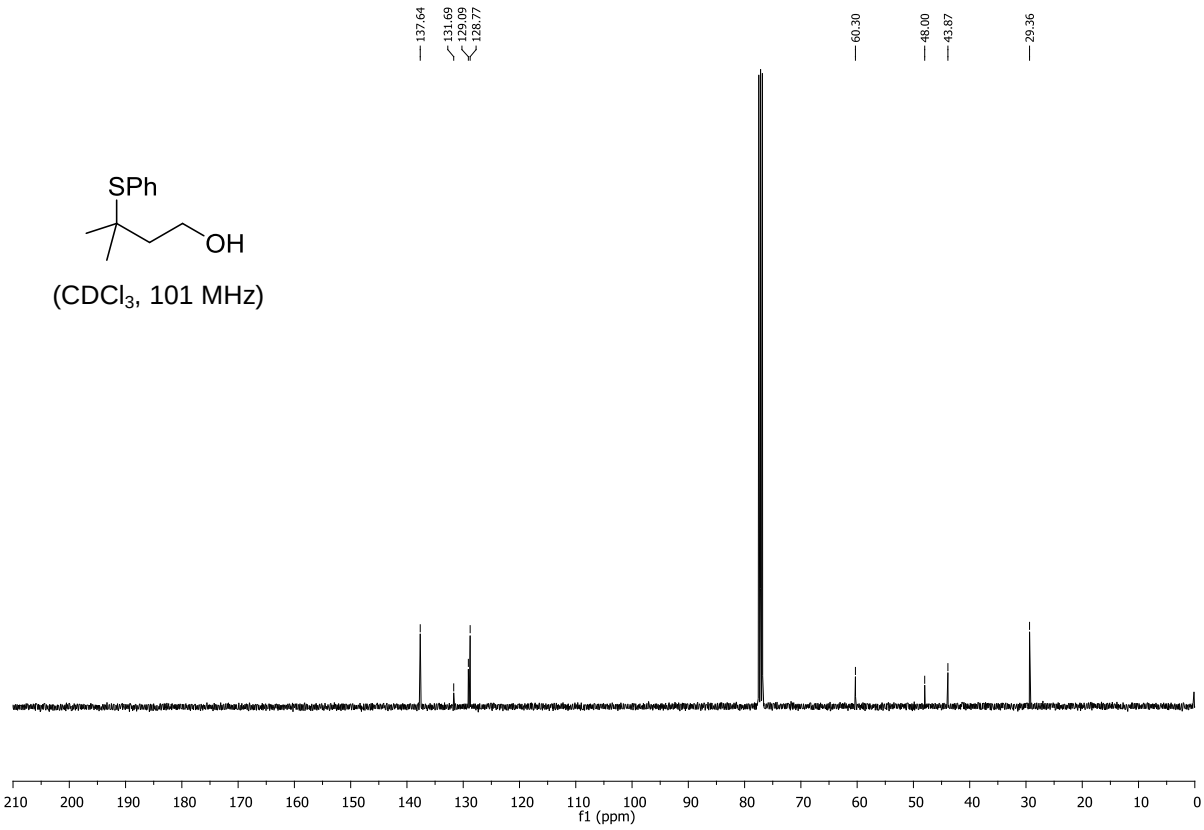

SPh
Ph
OBn
1f
(CDCl3, 101 MHz)
f1 (ppm)


SPh
Ph
Cl
1g
(CDCl3, 400 MHz)
f1 (ppm)

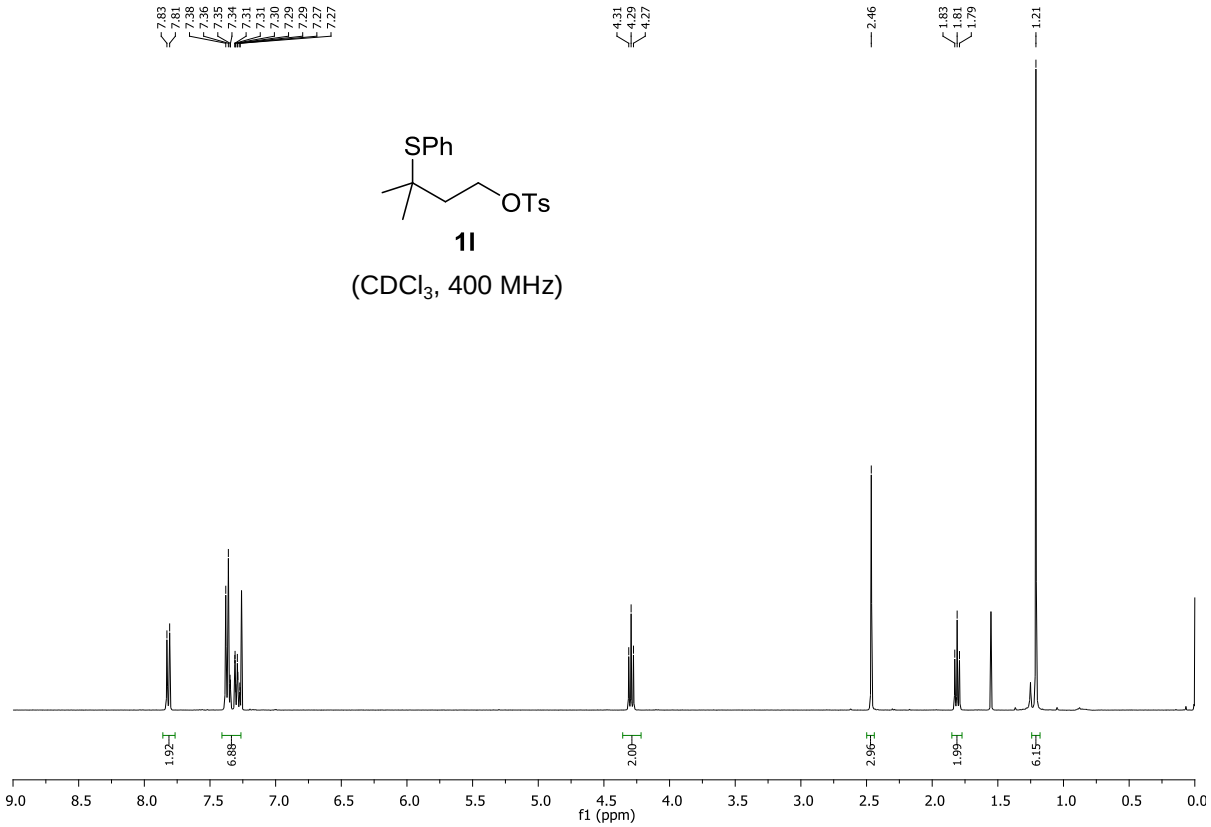

SPh
Ph
Cl
1g
(CDCl3, 101 MHz)
f1 (ppm)



($CDCl_3$, 400 MHz)

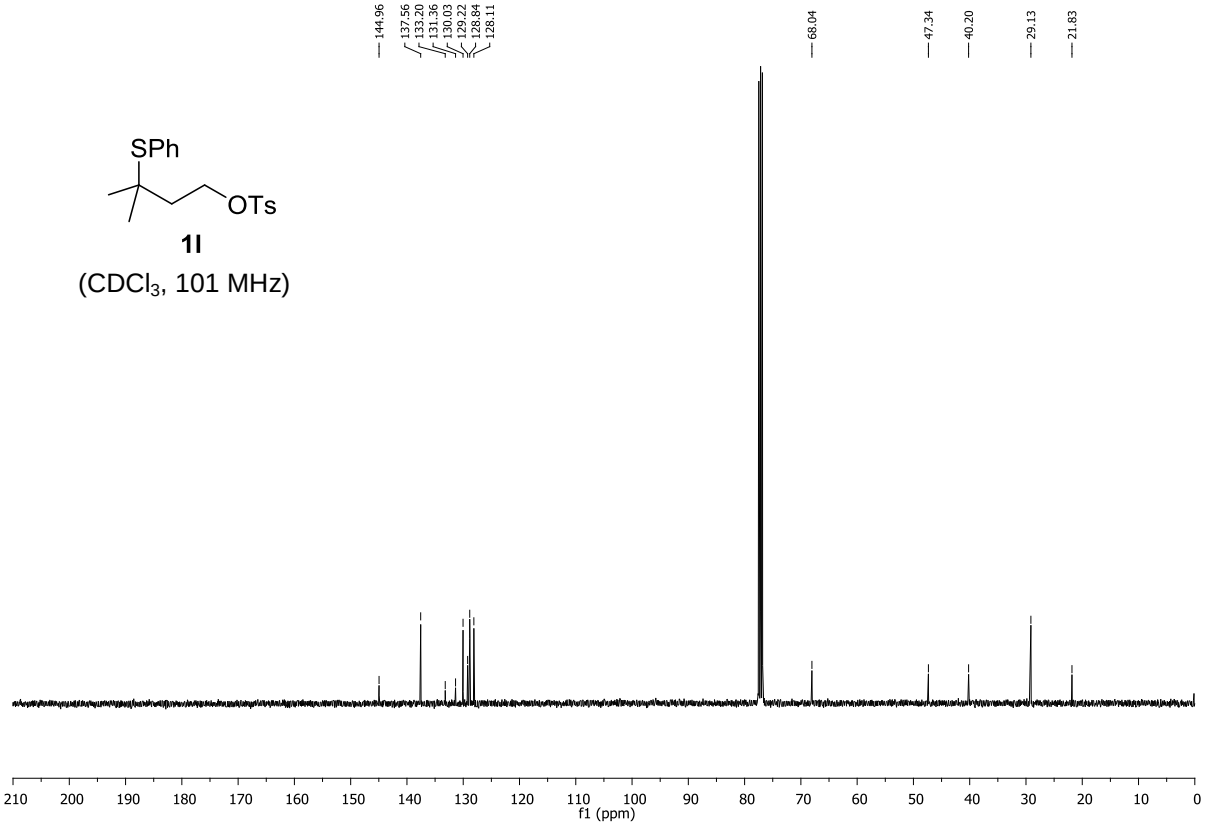


($CDCl_3$, 101 MHz)



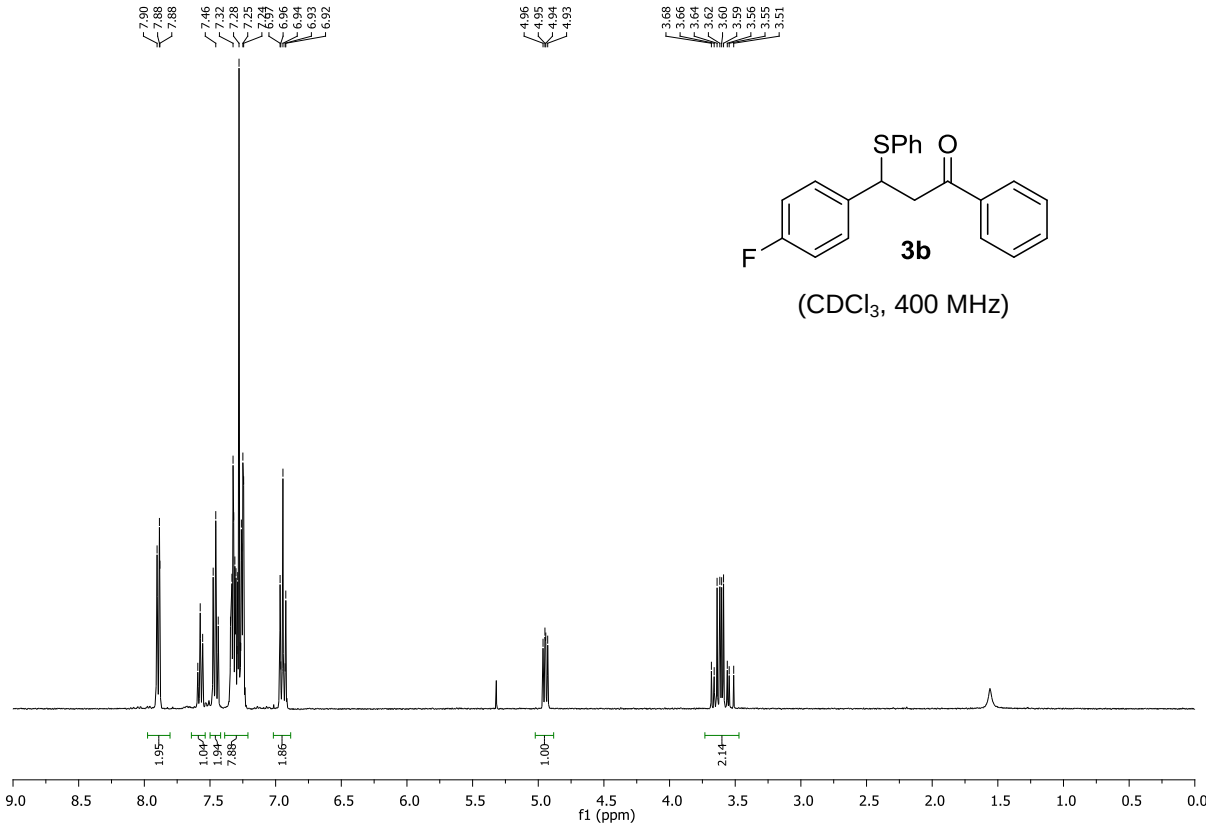
1l

($CDCl_3$, 400 MHz)



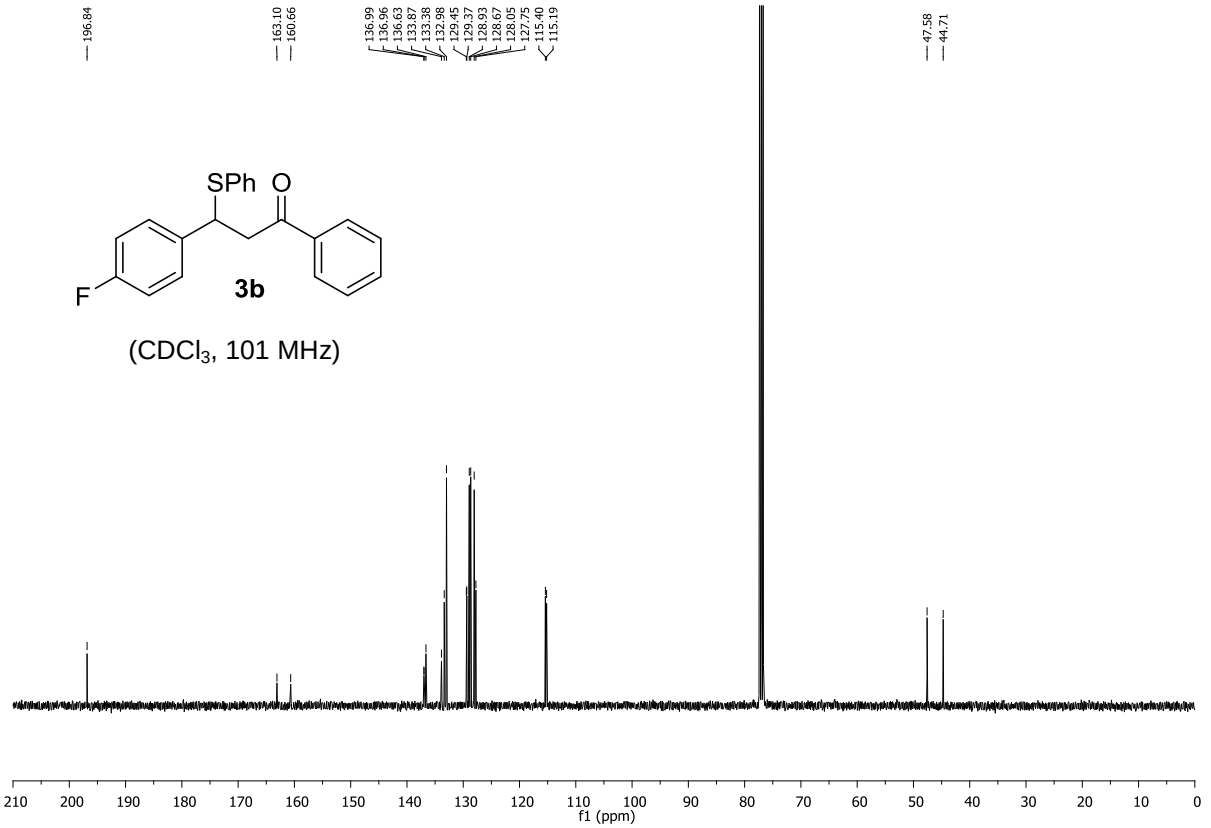
1l

($CDCl_3$, 101 MHz)



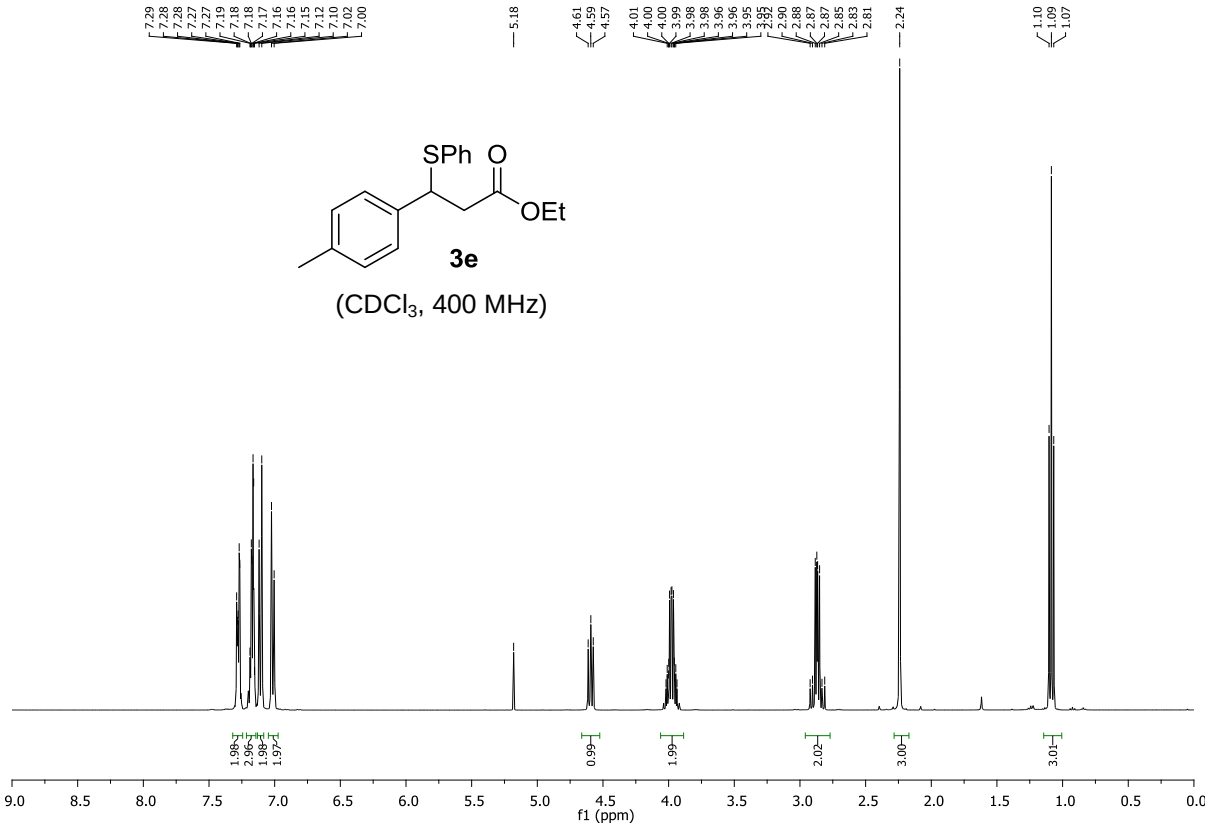
3b

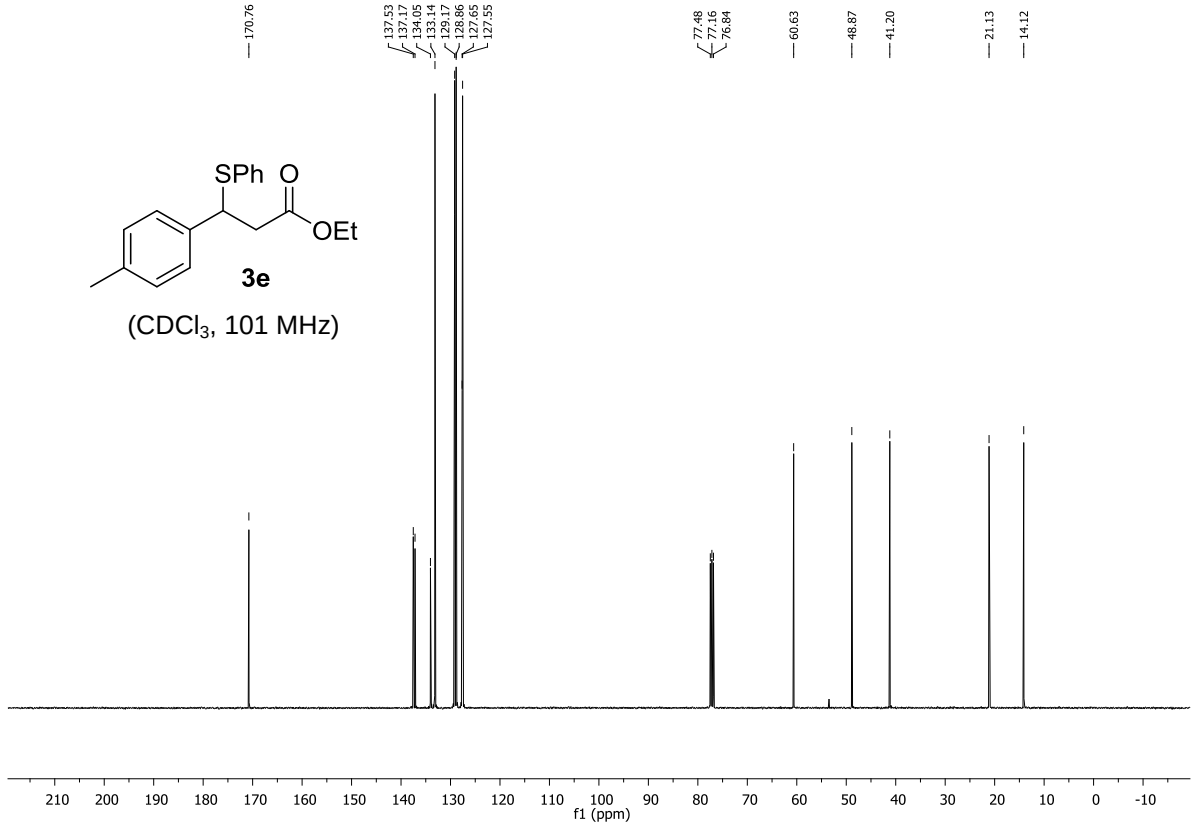
($CDCl_3$, 400 MHz)

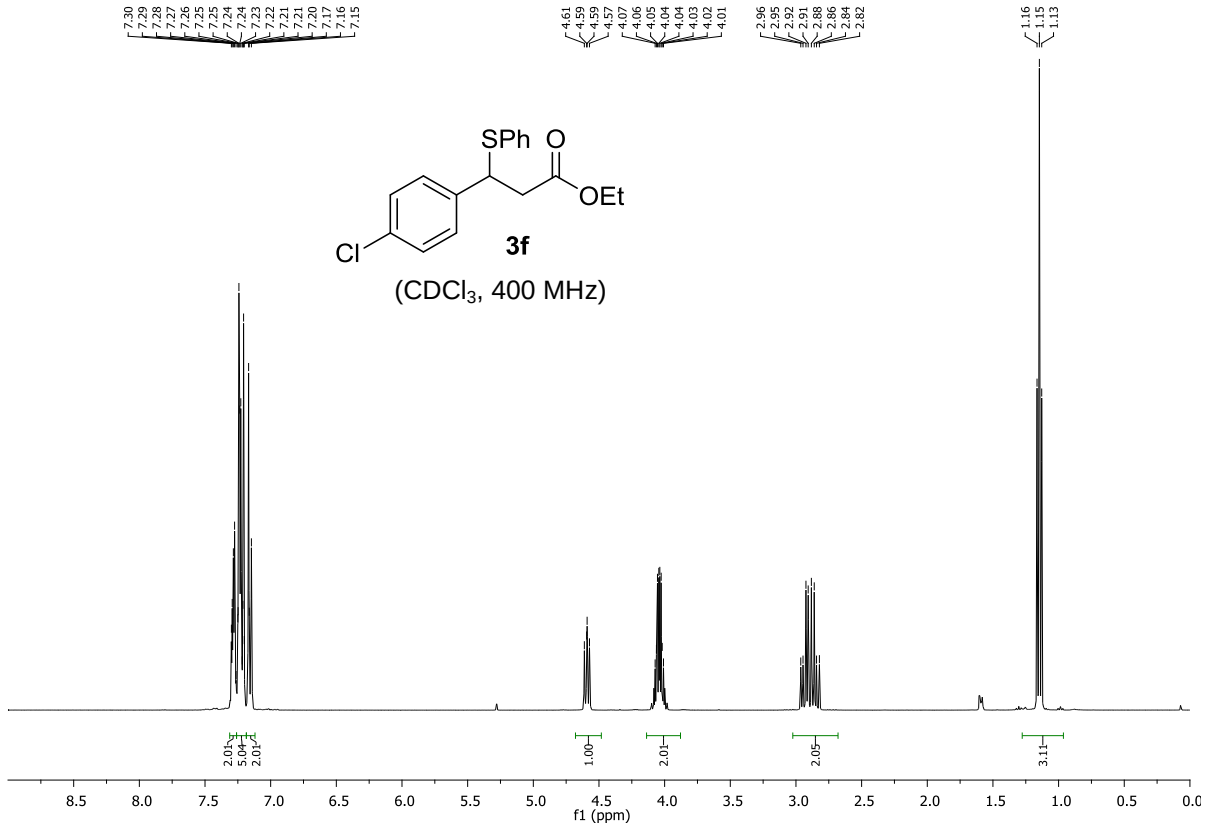


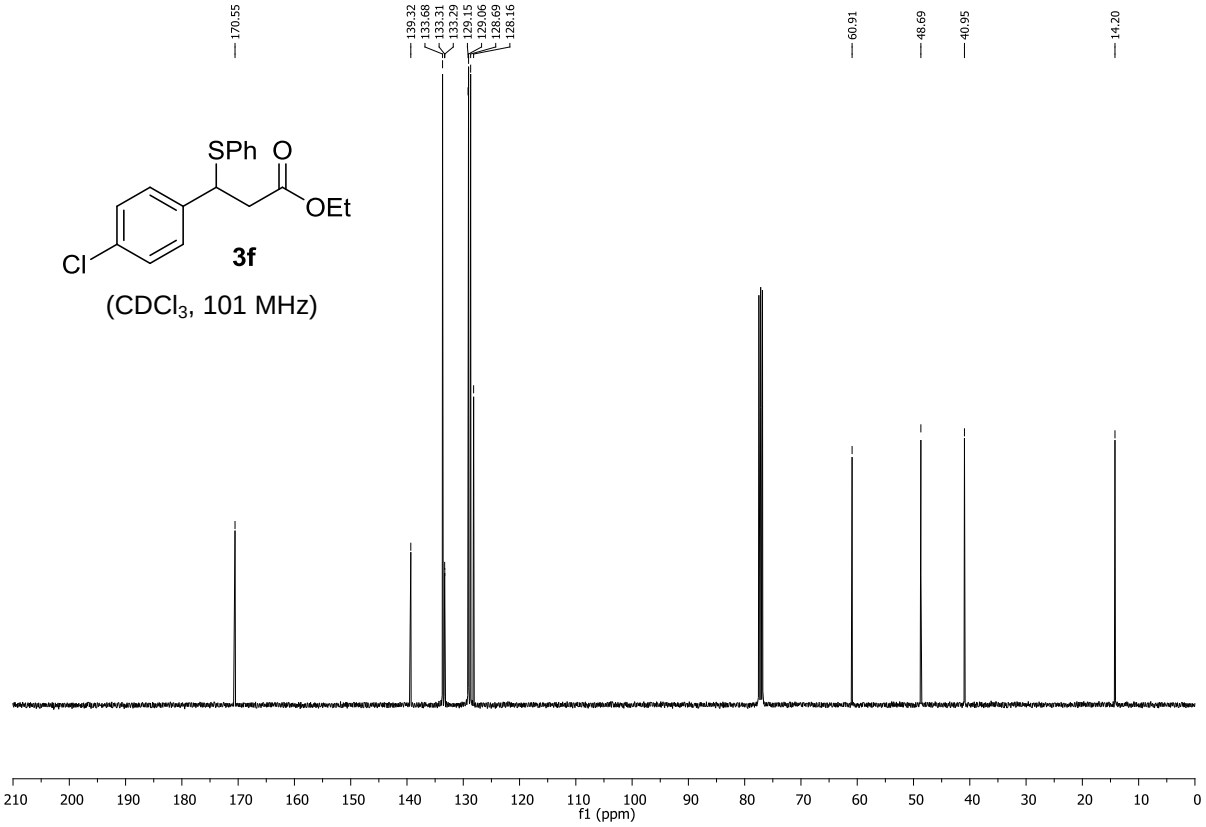
3b

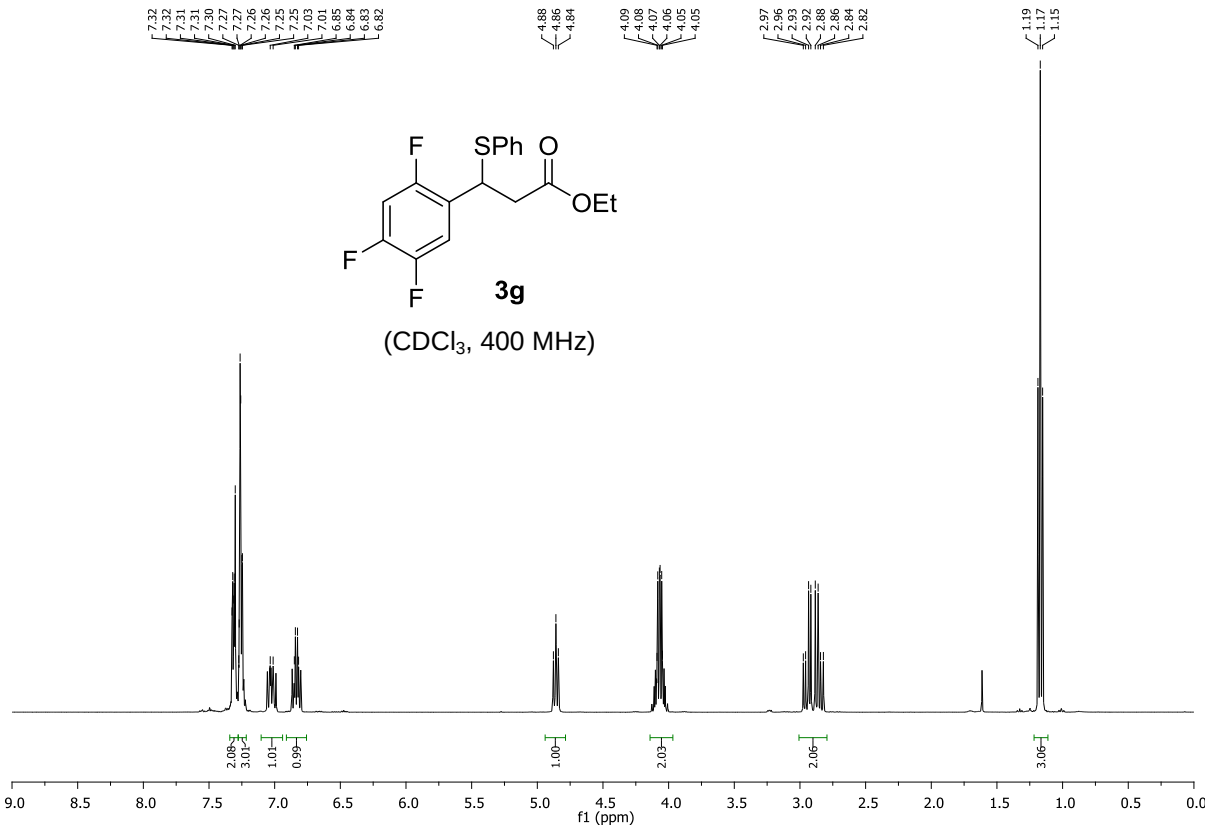
($CDCl_3$, 101 MHz)

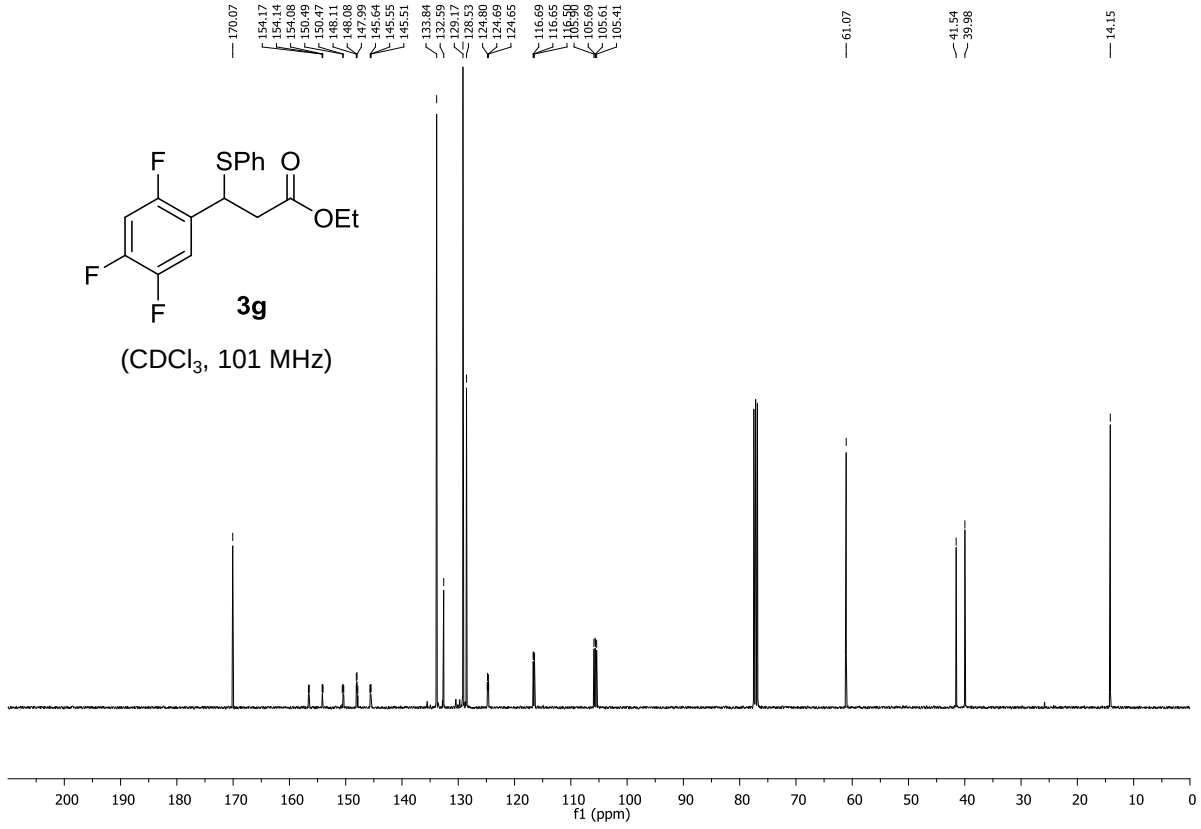

SPh O
OEt
3e
(CDCl3, 400 MHz)
f1 (ppm)

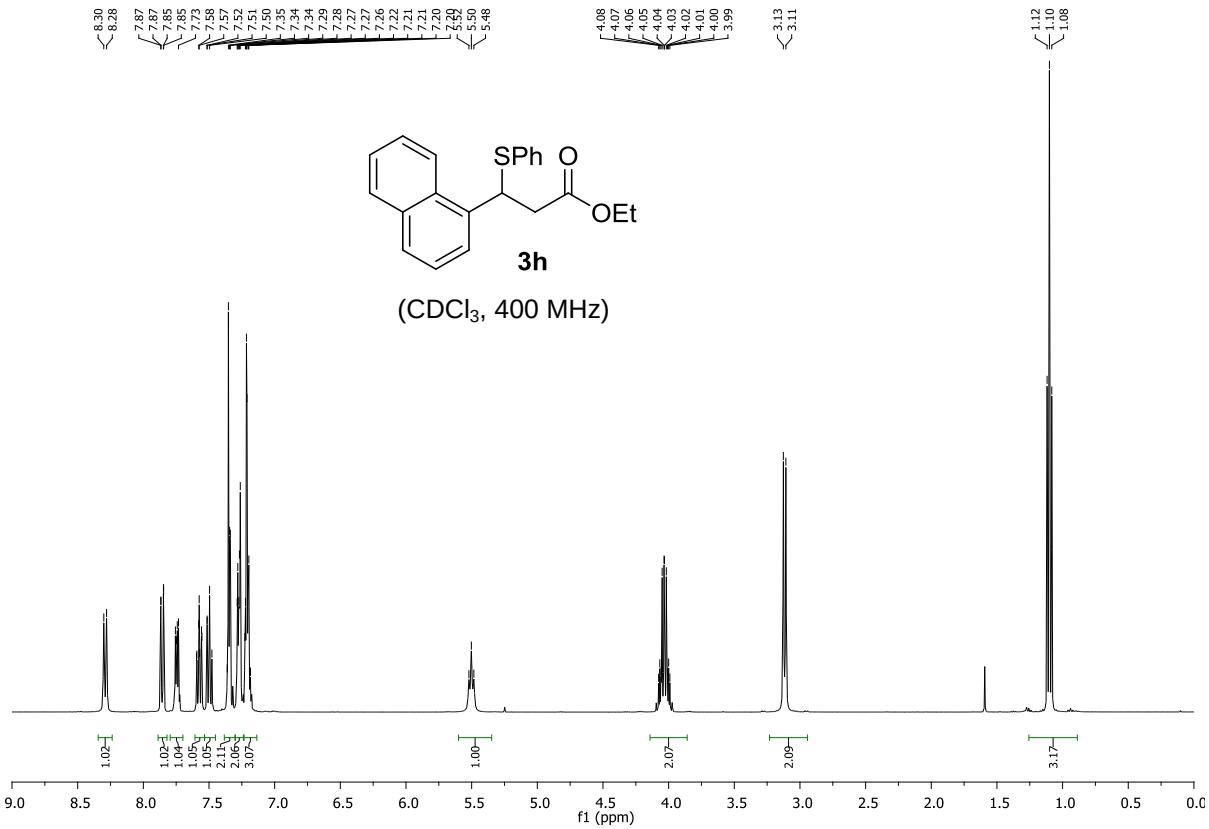

SPh O
OEt
3e
(CDCl3, 101 MHz)
f1 (ppm)

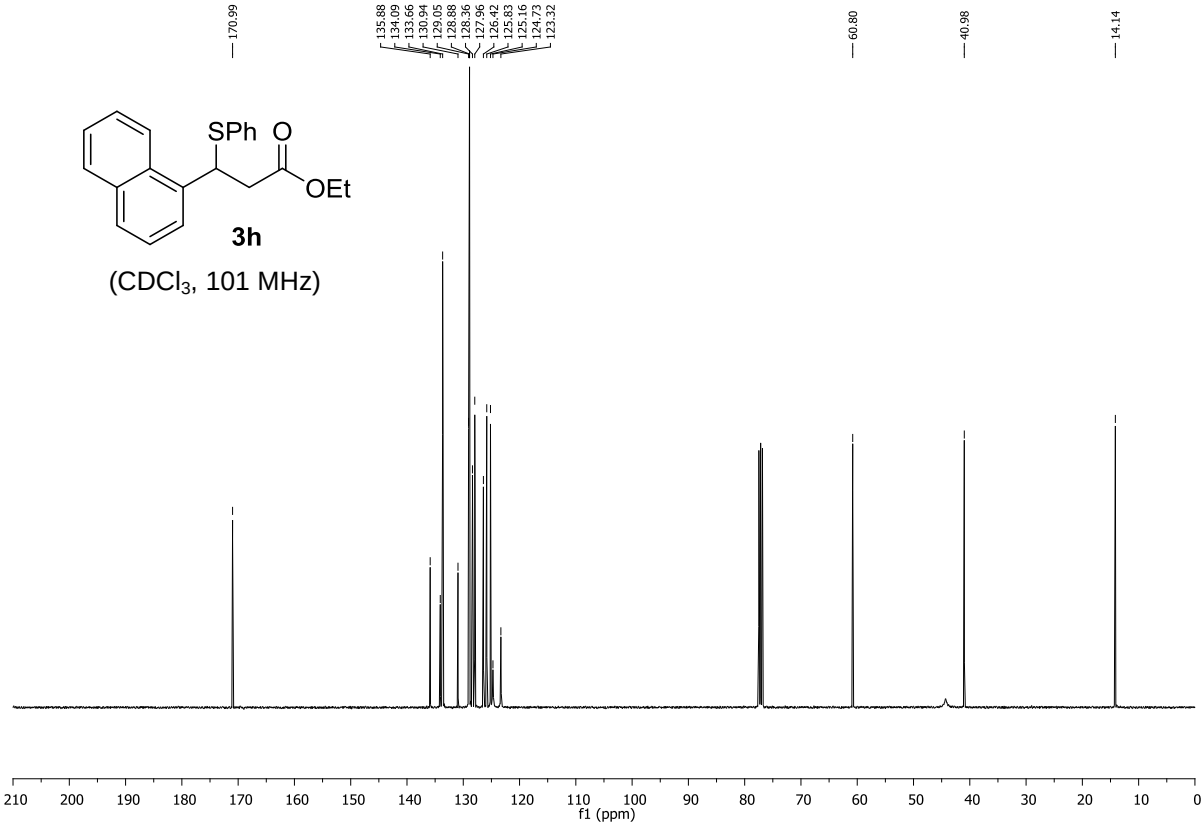

SPh O
OEt
Cl
3f
(CDCl3, 400 MHz)
f1 (ppm)

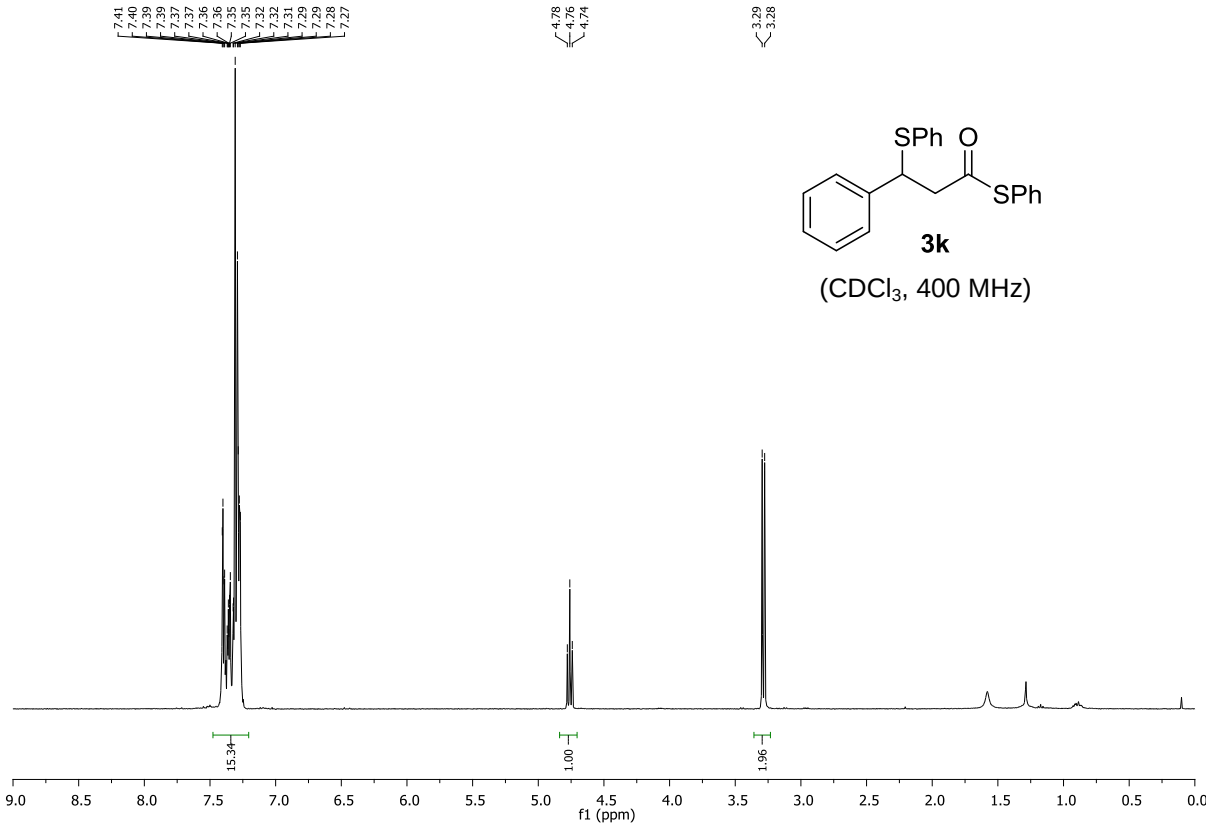

SPh O
OEt
Cl
3f
(CDCl3, 101 MHz)
f1 (ppm)


F
SPh
O
OEt
F
F
3g
(CDCl3, 400 MHz)
f1 (ppm)

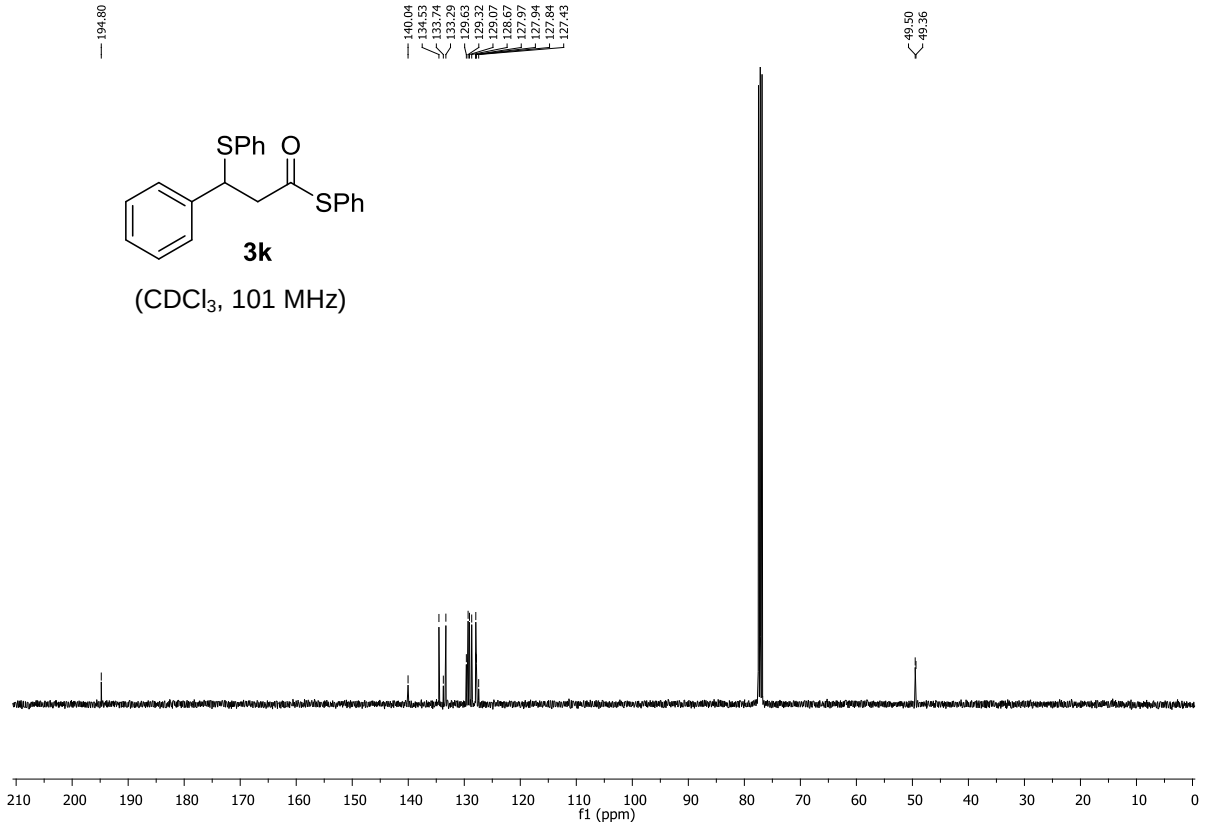

F
SPh
O
OEt
F
F
3g
(CDCl3, 101 MHz)
f1 (ppm)


SPh O
OEt
3h
(CDCl3, 400 MHz)
f1 (ppm)

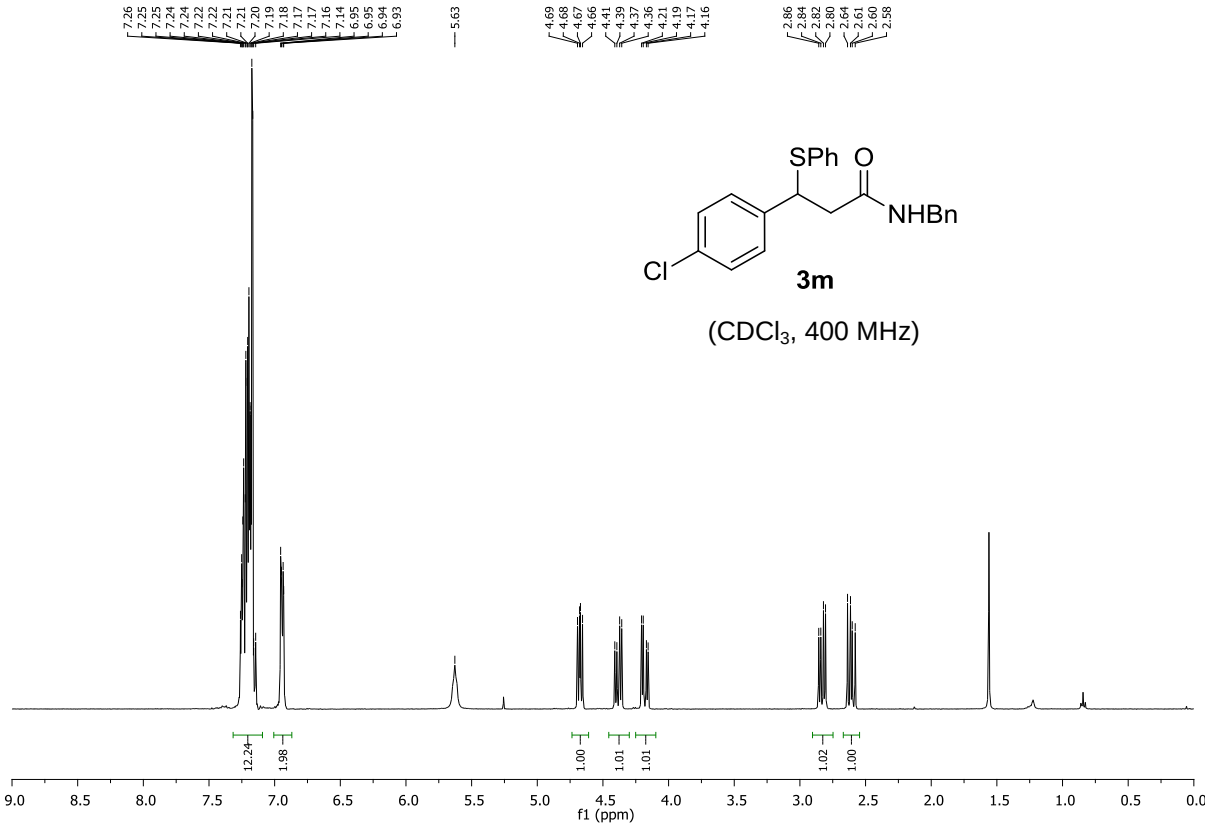

SPh O
OEt
3h
(CDCl3, 101 MHz)
f1 (ppm)



($CDCl_3$, 400 MHz)

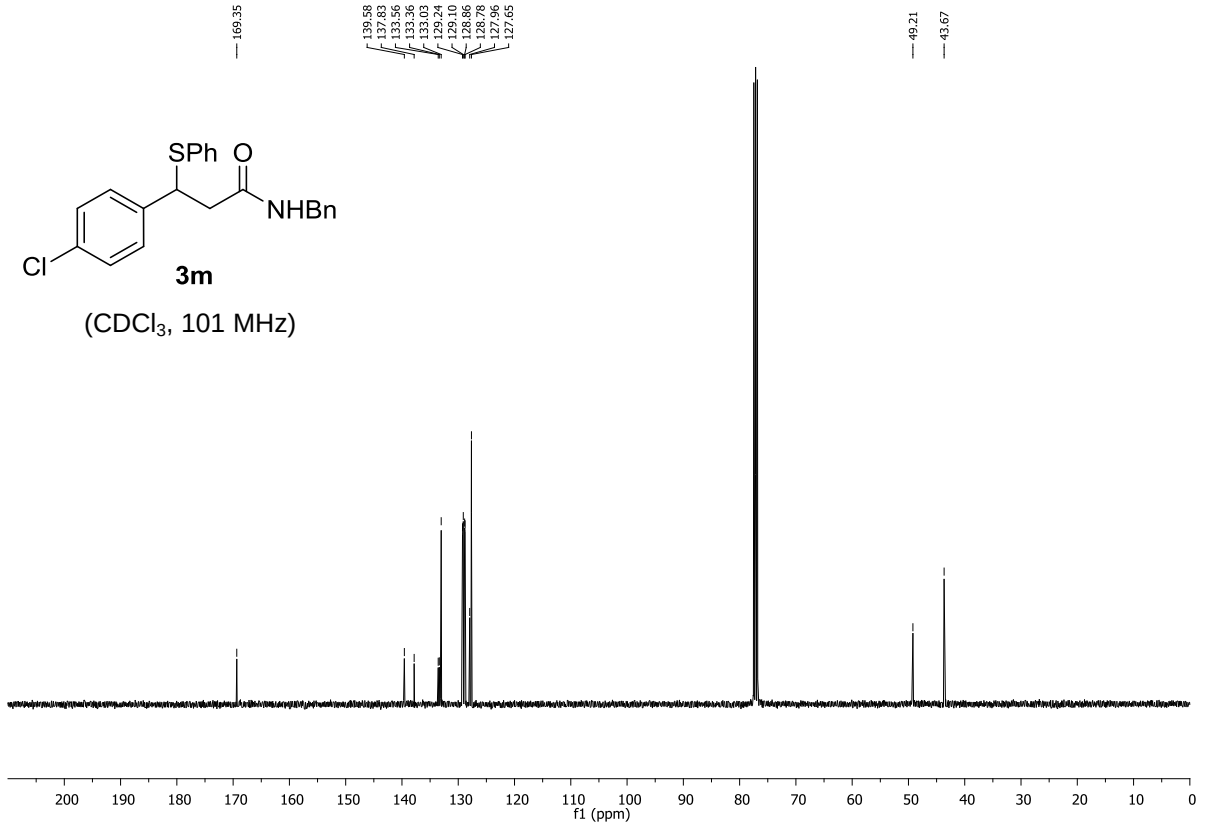


($CDCl_3$, 101 MHz)



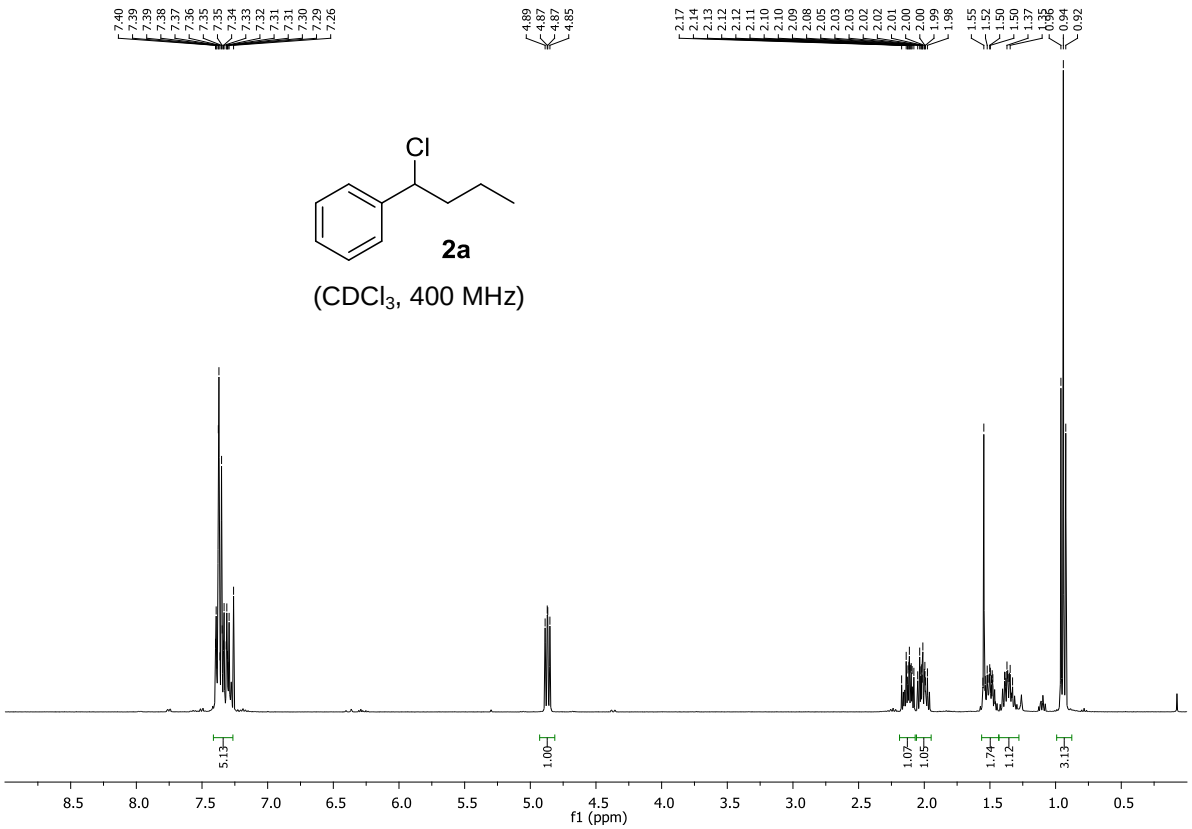
3m

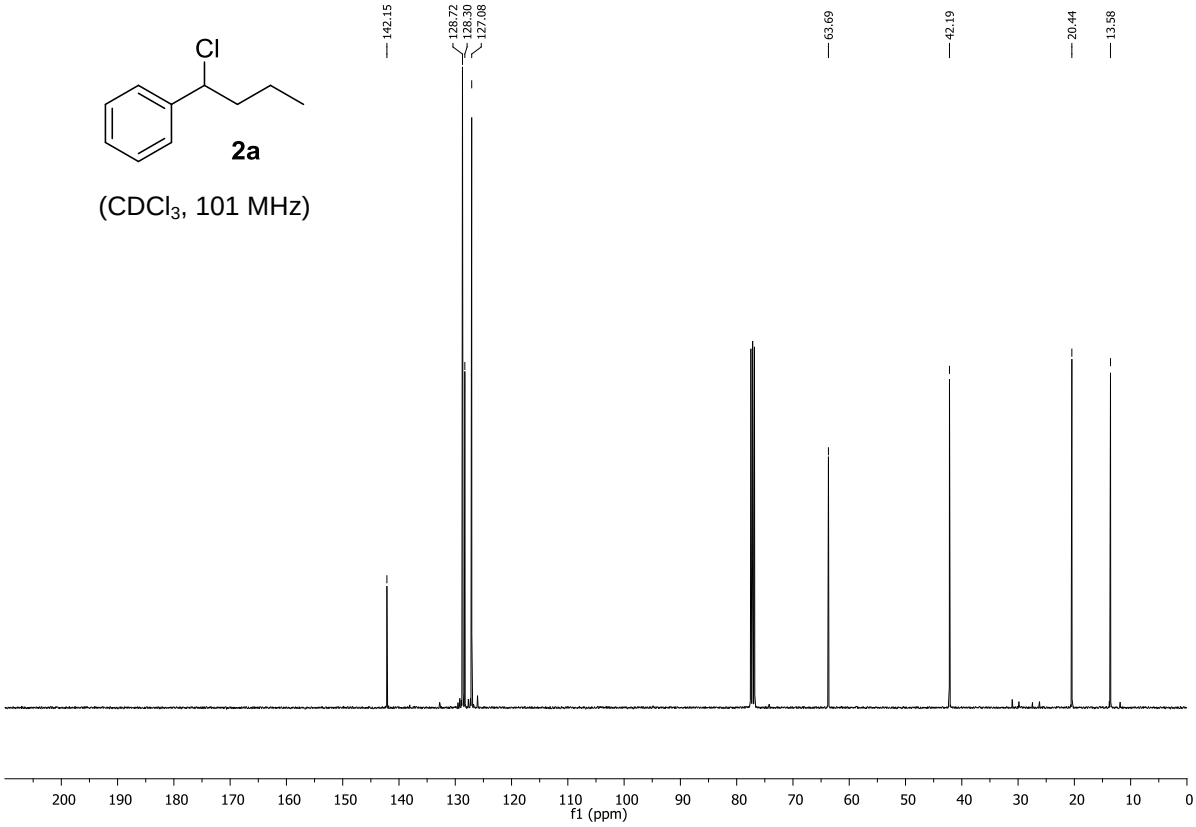
($CDCl_3$, 400 MHz)

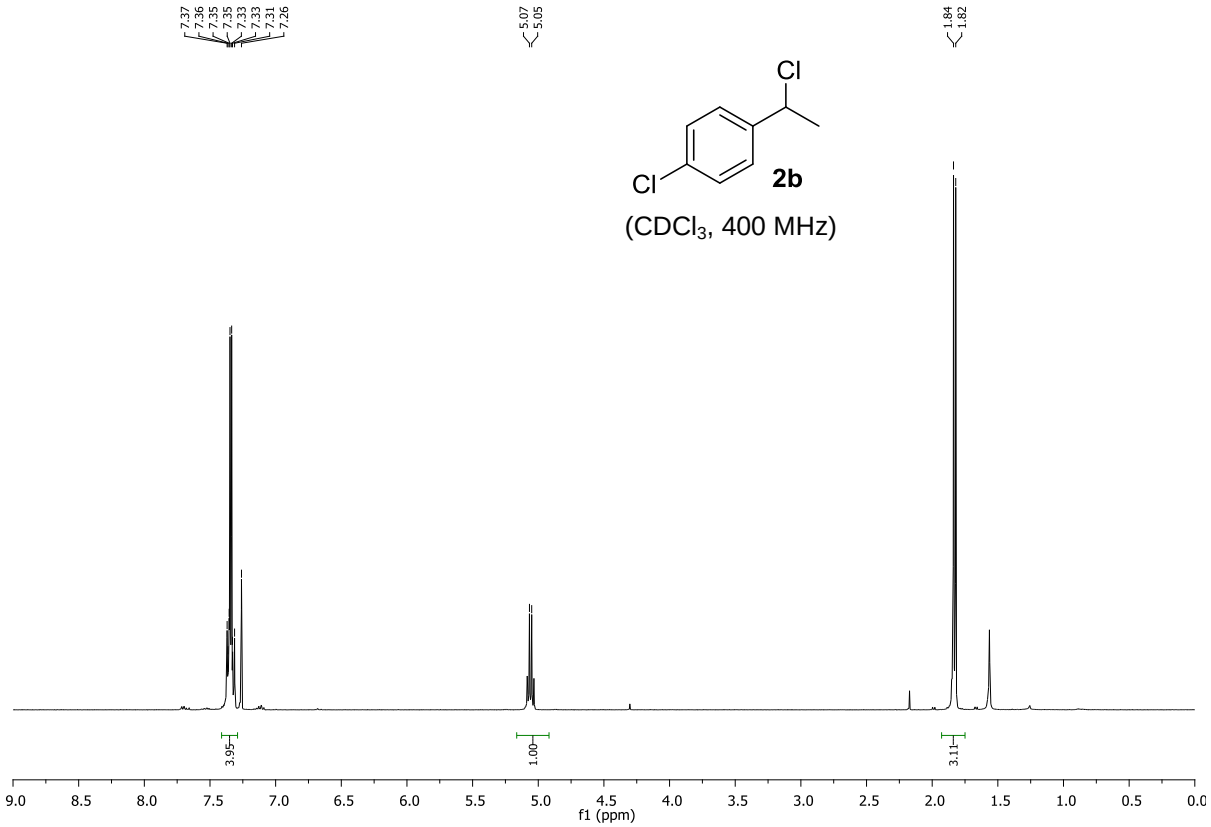


3m

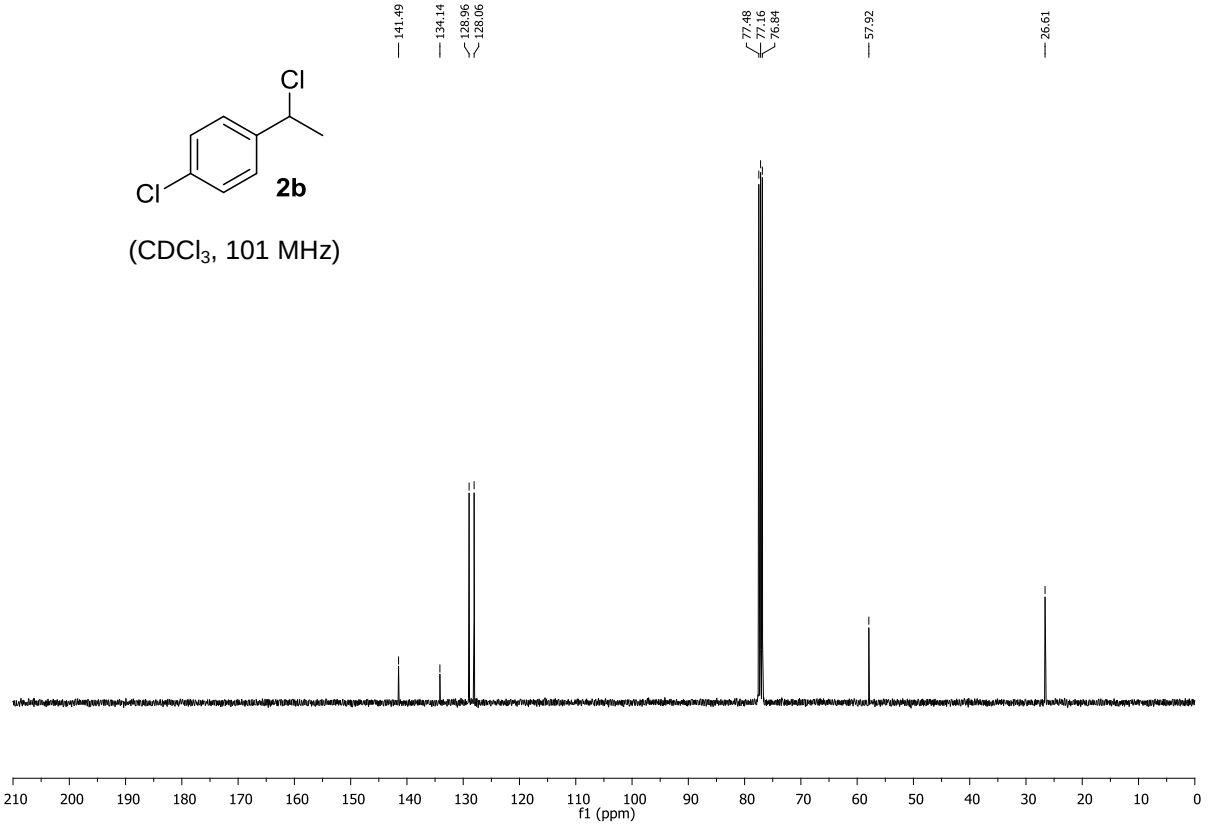
($CDCl_3$, 101 MHz)


Cl
2a
(CDCl3, 400 MHz)
f1 (ppm)

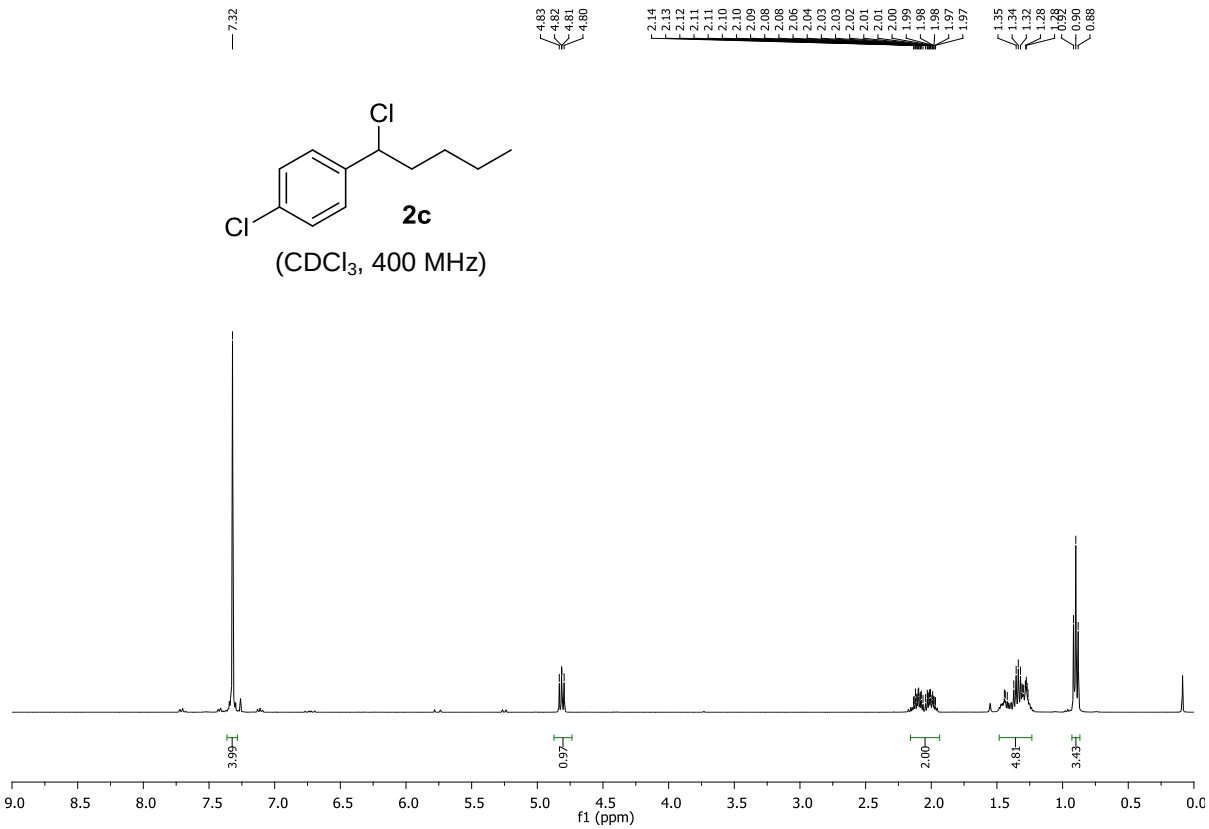

Cl
2a
(CDCl3, 101 MHz)
f1 (ppm)

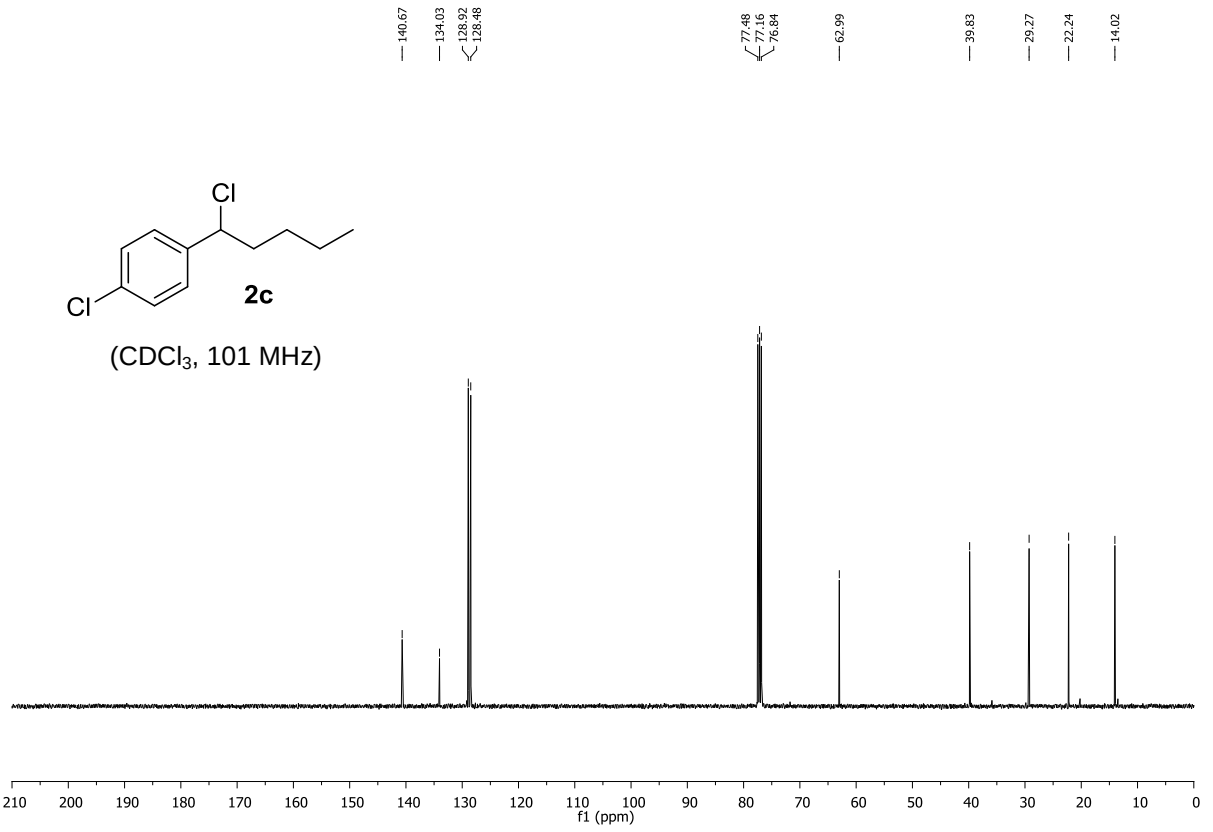


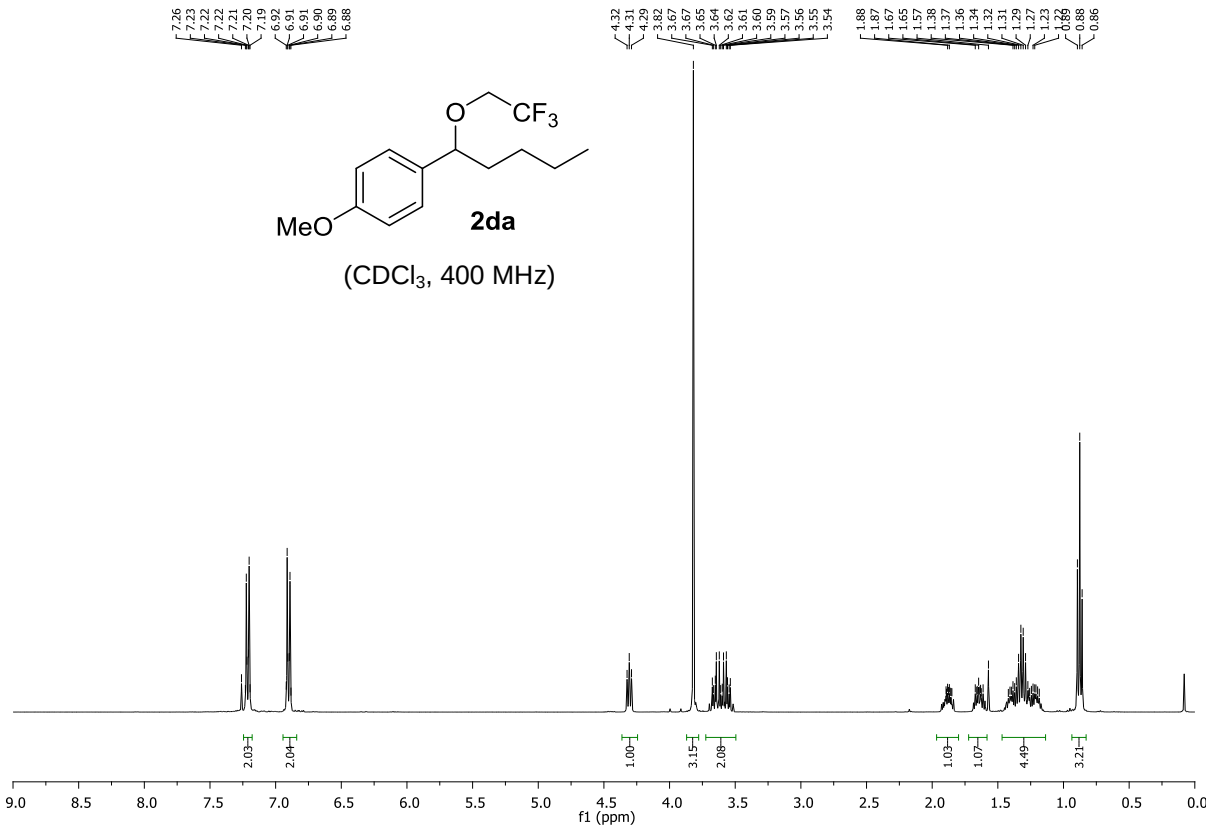
($CDCl_3$, 400 MHz)

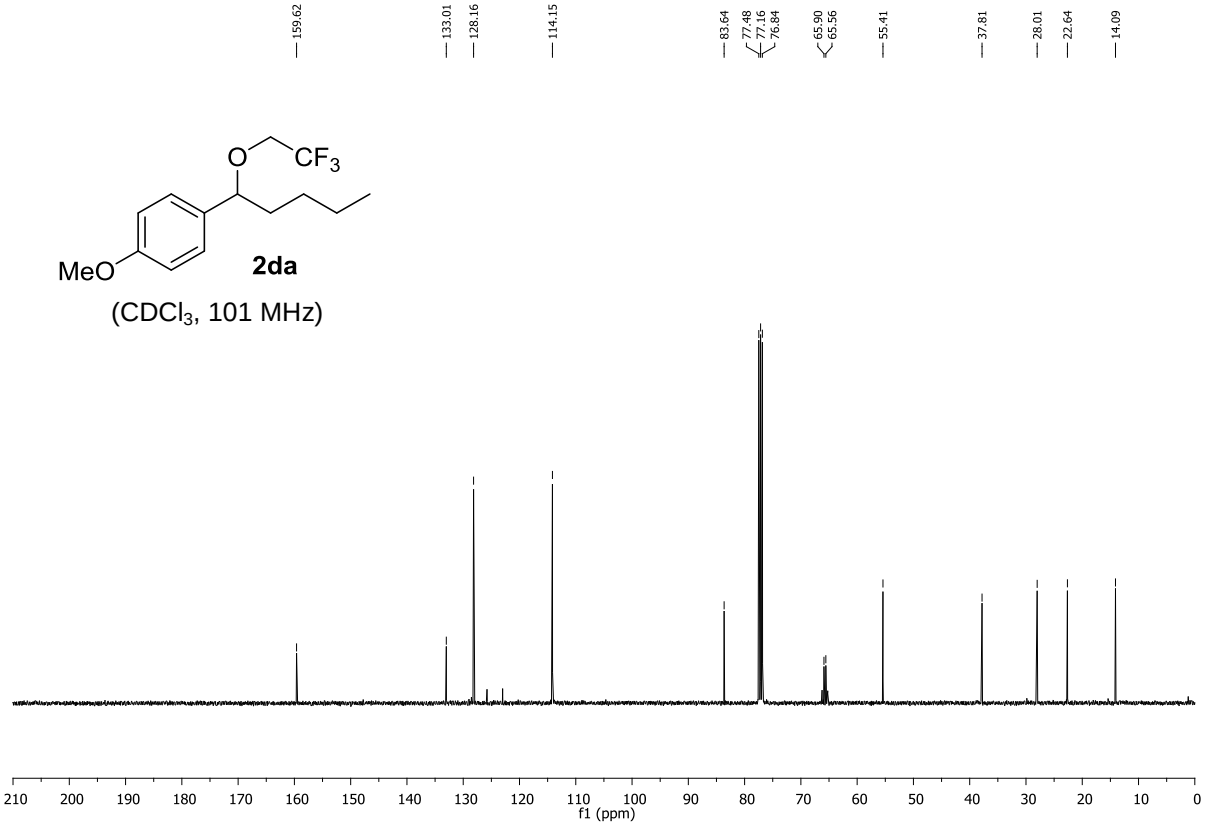


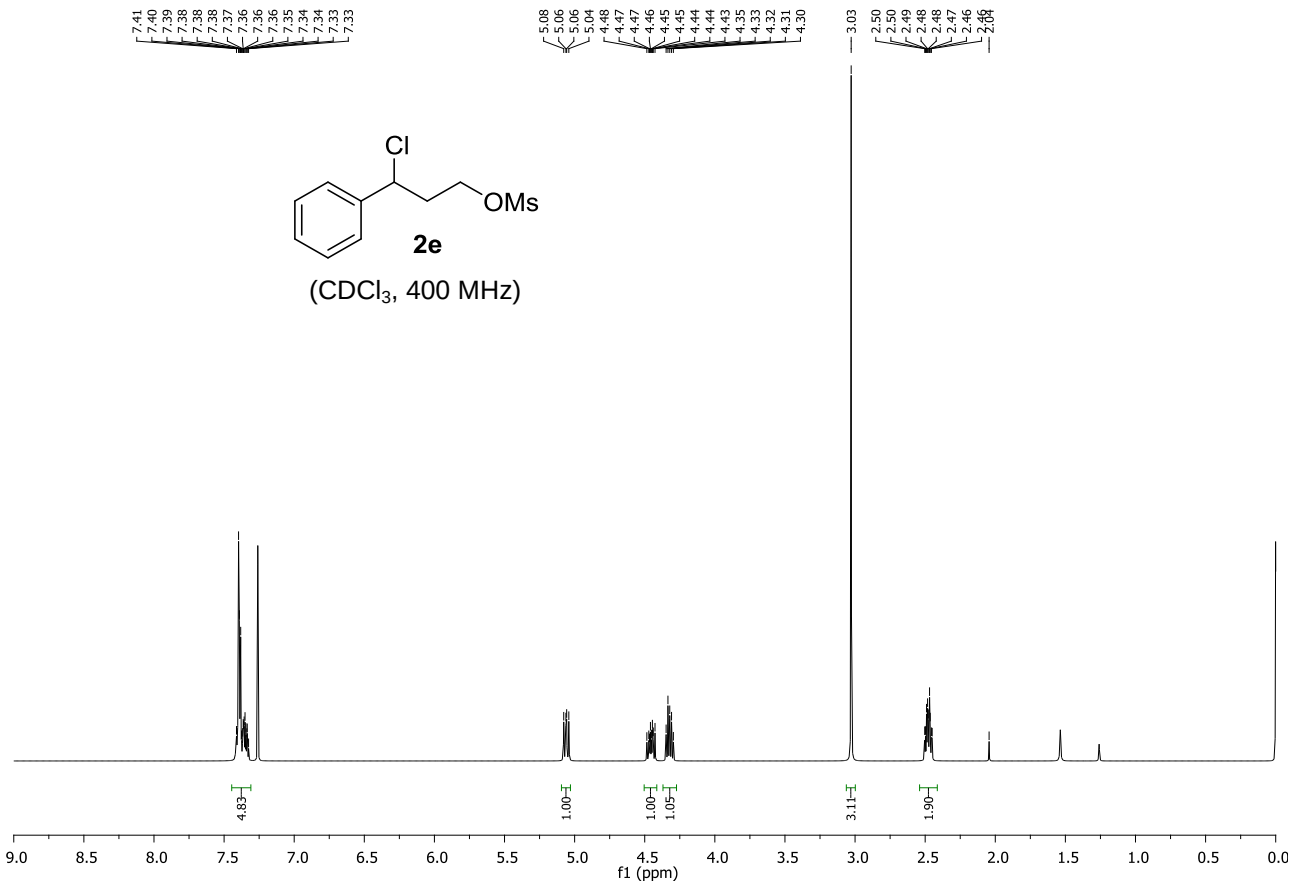
($CDCl_3$, 101 MHz)

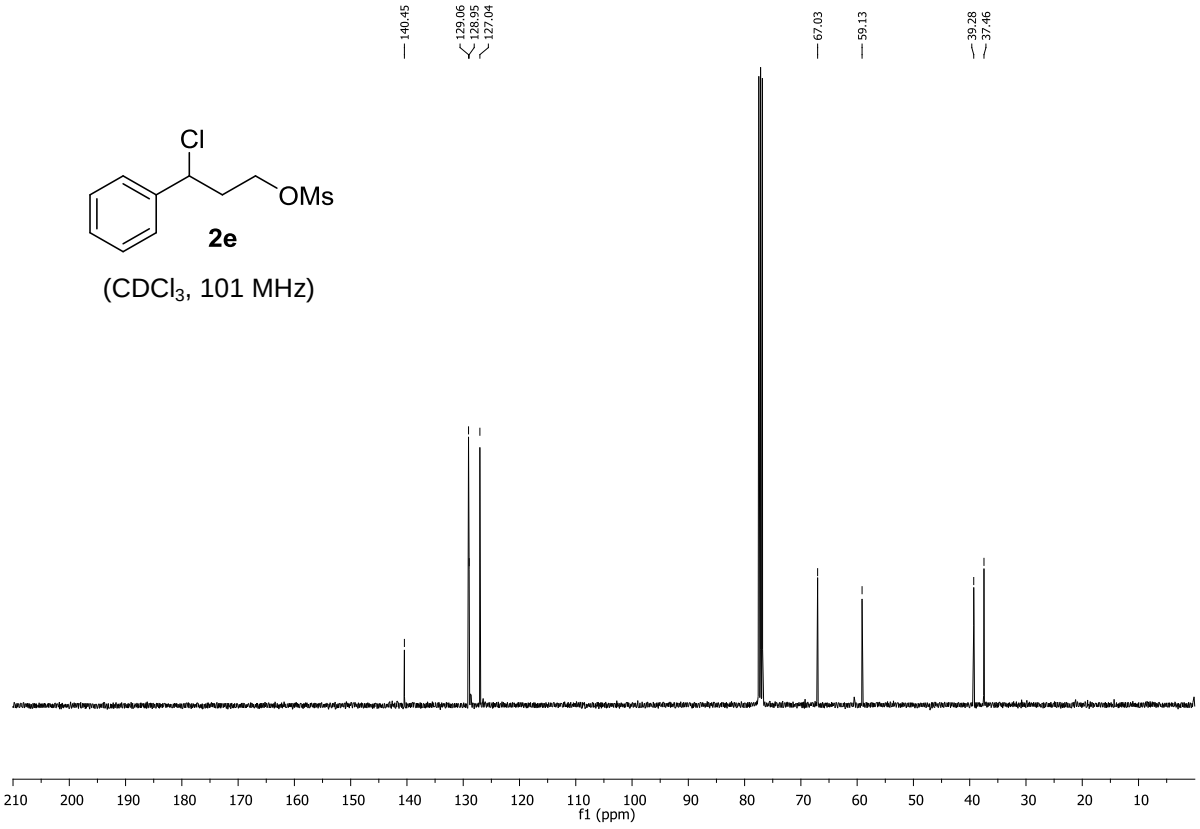

7.32
4.83
4.82
4.81
4.80
2.14
2.13
2.12
2.11
2.10
2.09
2.08
2.06
2.04
2.03
2.02
2.01
2.00
1.99
1.98
1.97
1.35
1.34
1.32
1.28
0.90
0.88
Cl
Cl
2c
(CDCl3, 400 MHz)
3.99
0.97
2.00
4.81
3.43
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

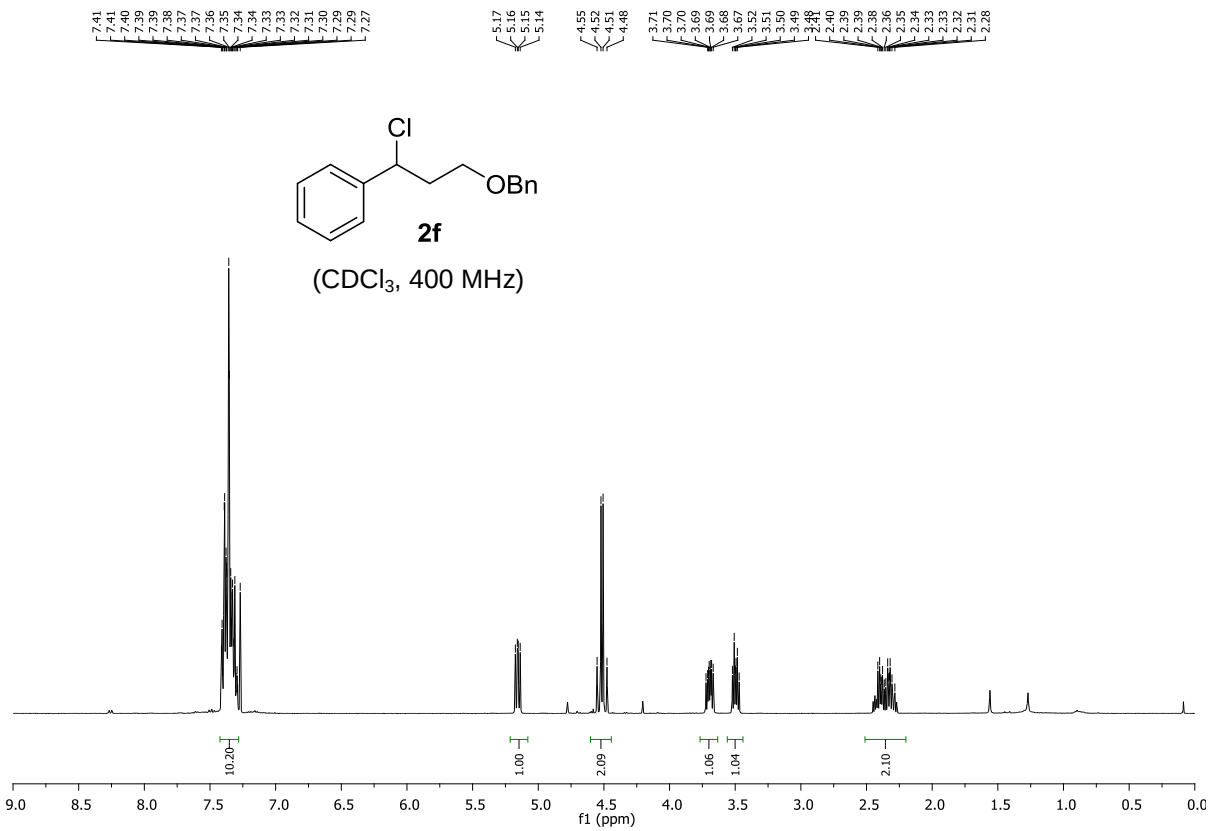

140.67
134.03
128.92
128.48
77.48
77.16
76.84
62.99
39.83
29.27
22.24
14.02
Cl
Cl
2c
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

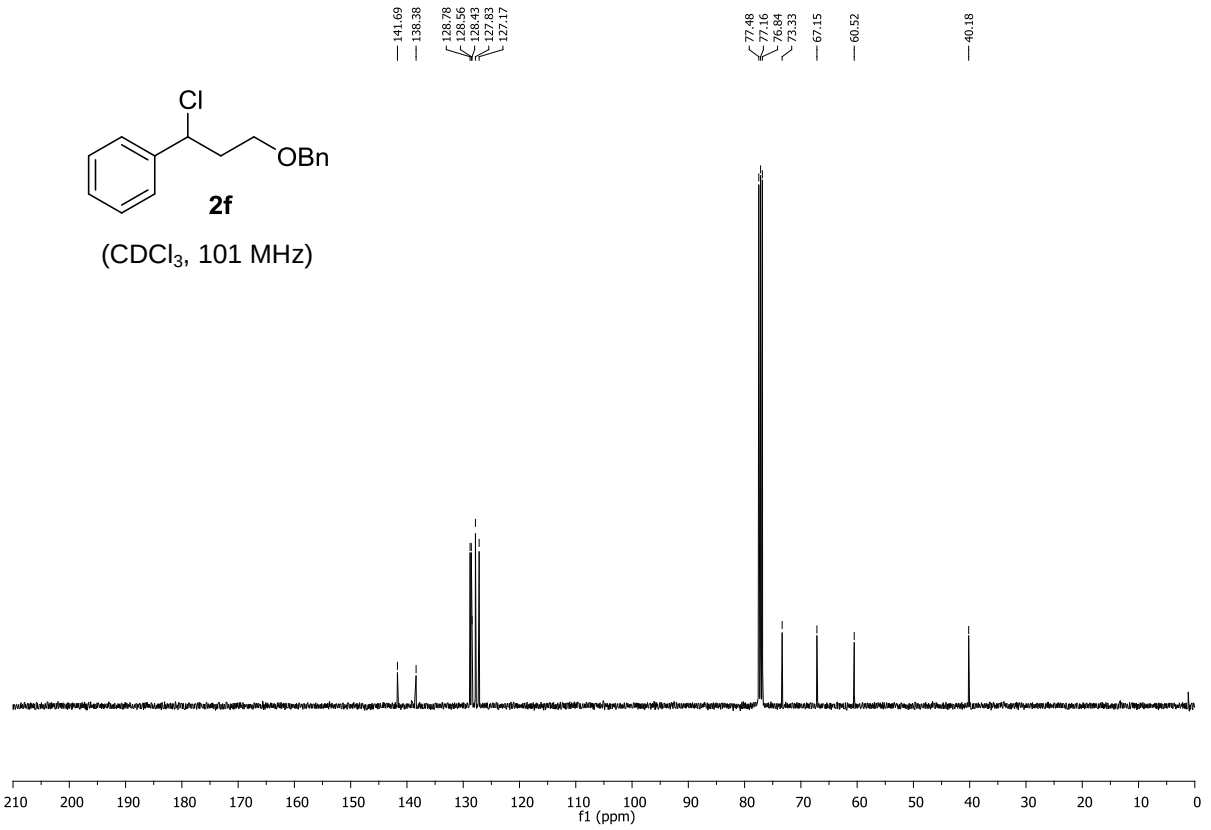

7.26
7.23
7.22
7.22
7.21
7.20
7.19
6.92
6.91
6.91
6.90
6.89
6.88
4.32
4.31
4.29
3.82
3.67
3.67
3.65
3.64
3.62
3.61
3.60
3.59
3.57
3.56
3.55
3.54
1.88
1.87
1.67
1.65
1.57
1.38
1.37
1.36
1.34
1.32
1.31
1.29
1.27
1.23
0.89
0.88
0.86
O
CF3
MeO
2da
(CDCl3, 400 MHz)
2.03
2.04
1.00
3.15
2.08
1.03
1.07
4.49
3.21
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

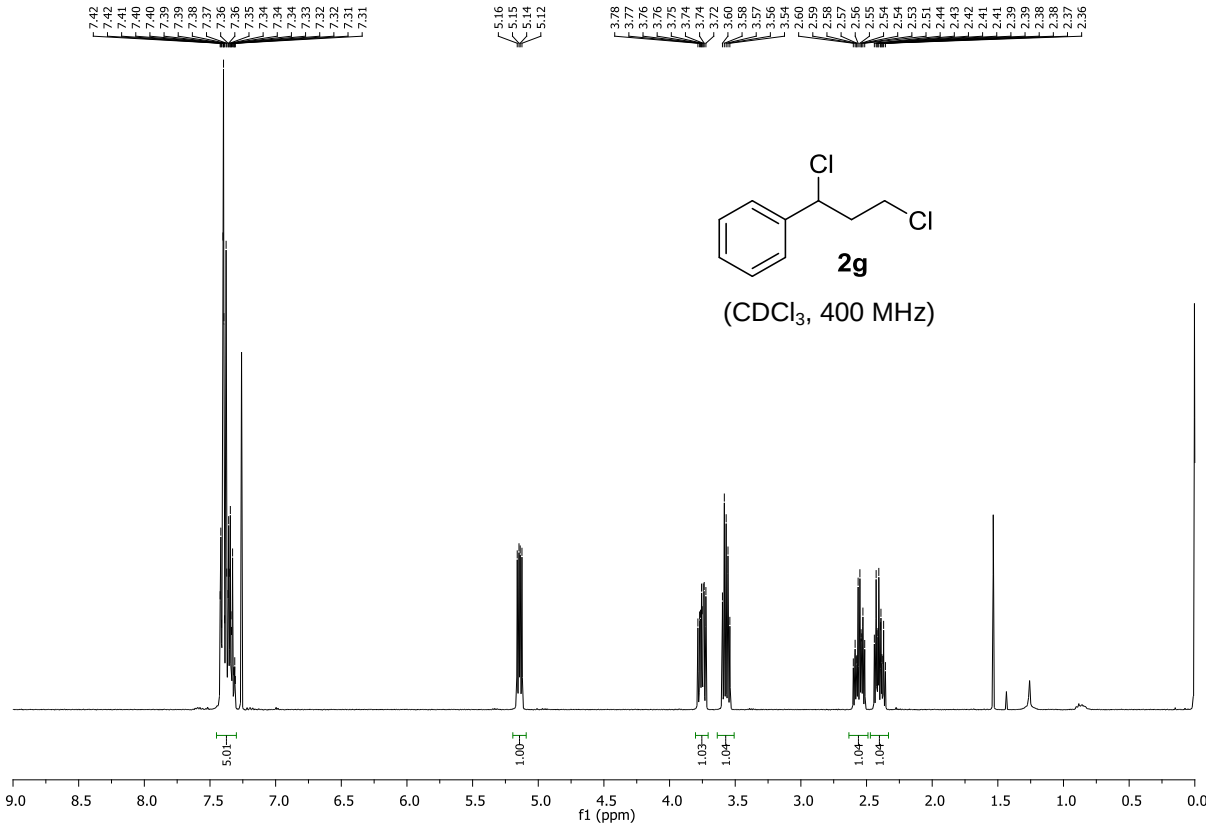

159.62
133.01
128.16
114.15
83.64
77.48
77.16
76.84
65.90
65.56
55.41
37.81
28.01
22.64
14.09
O
CF3
MeO
2da
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

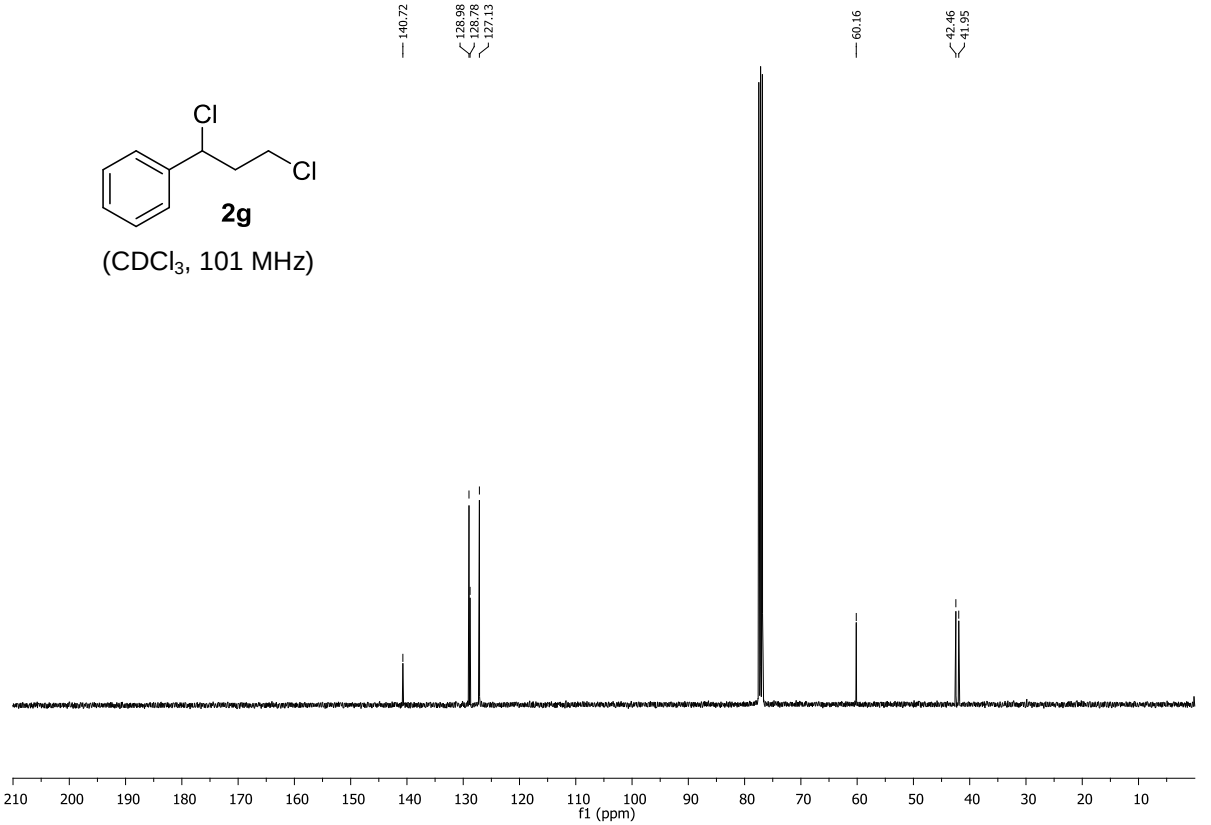

Cl
OMs
2e
(CDCl3, 400 MHz)
f1 (ppm)

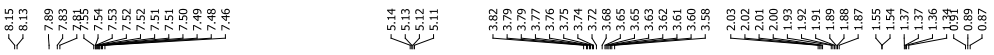

Cl
OMs
2e
(CDCl3, 101 MHz)
f1 (ppm)

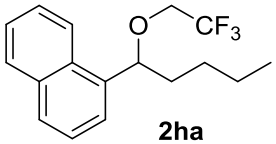

7.41
7.41
7.40
7.39
7.39
7.38
7.37
7.37
7.36
7.35
7.34
7.34
7.33
7.33
7.32
7.31
7.30
7.29
7.29
7.27
5.17
5.16
5.15
5.14
4.55
4.52
4.51
4.48
3.71
3.70
3.70
3.69
3.69
3.68
3.67
3.52
3.51
3.50
3.49
3.48
2.41
2.40
2.39
2.39
2.38
2.36
2.35
2.34
2.33
2.32
2.31
2.28
Cl
OBn
2f
(CDCl3, 400 MHz)
10.20
1.00
2.09
1.06
1.04
2.10
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


141.69
138.38
128.78
128.56
128.43
127.83
127.17
77.48
77.16
76.84
73.33
67.15
60.52
40.18
Cl
OBn
2f
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Cl
Cl
2g
(CDCl3, 400 MHz)
f1 (ppm)

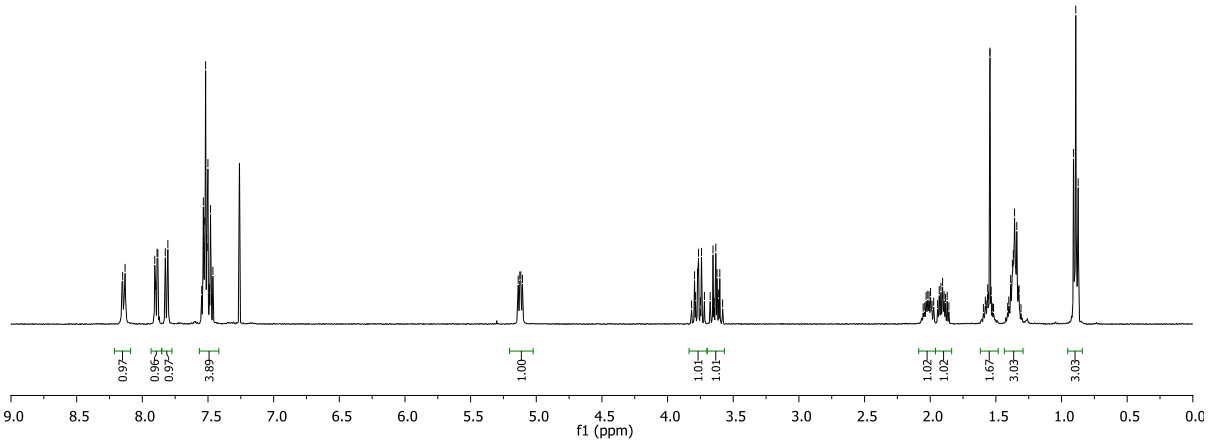

Cl
Cl
2g
(CDCl3, 101 MHz)
f1 (ppm)

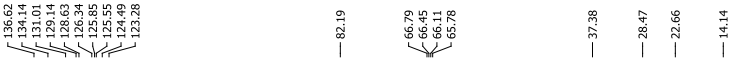


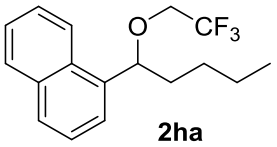


2ha

($CDCl_3$, 400 MHz)

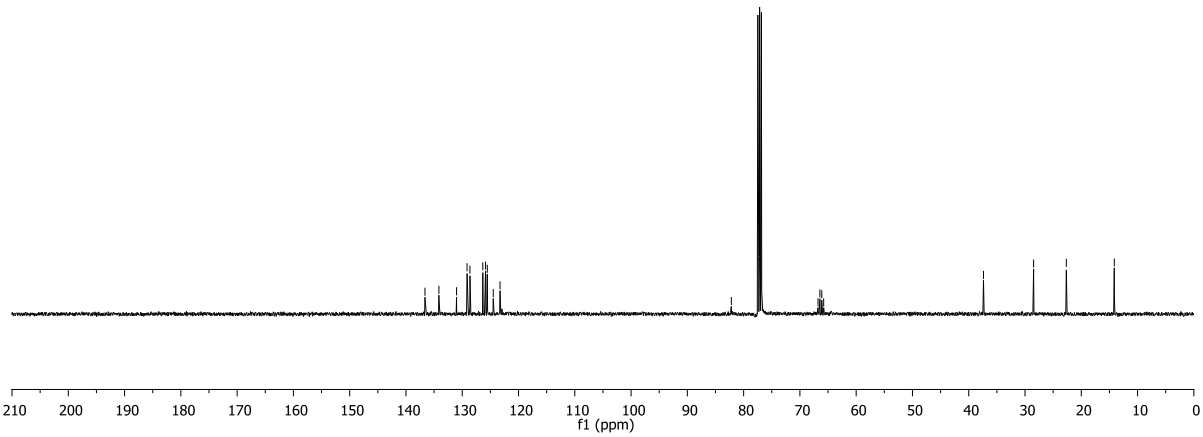


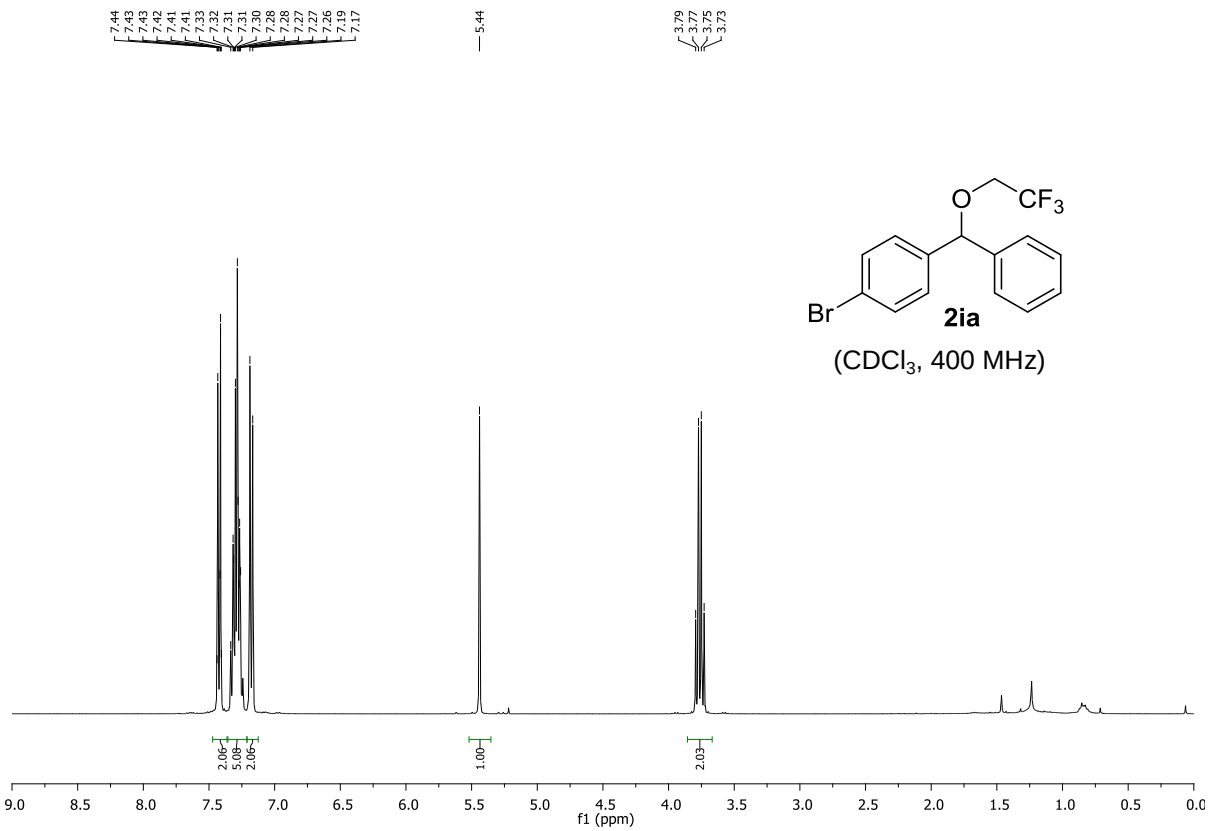


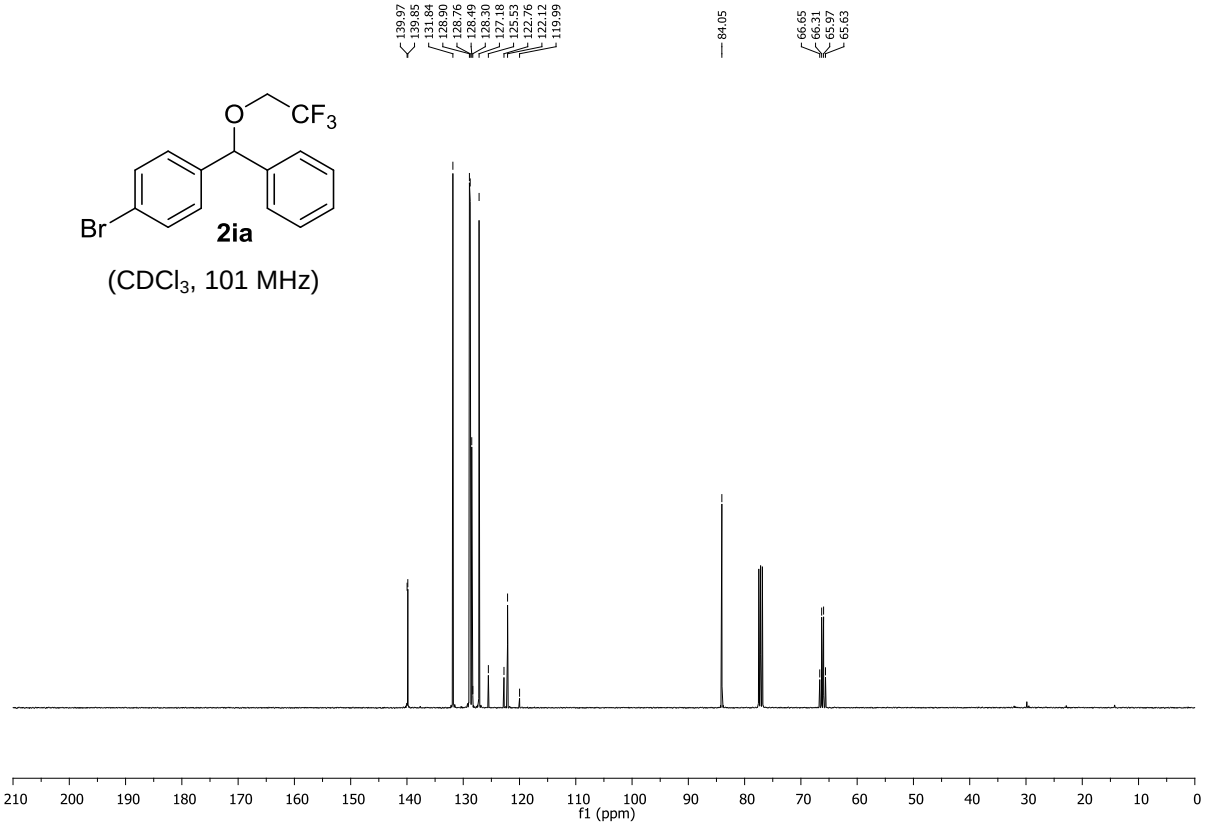


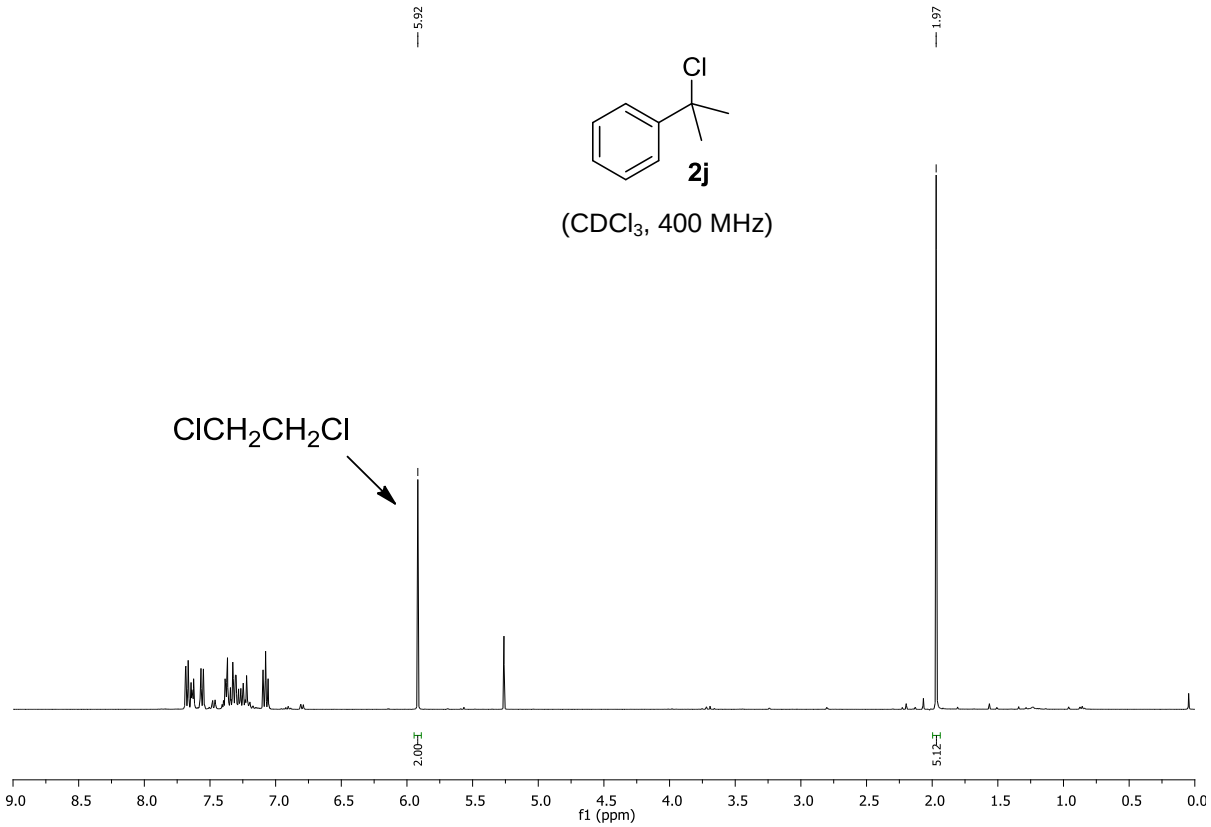
2ha

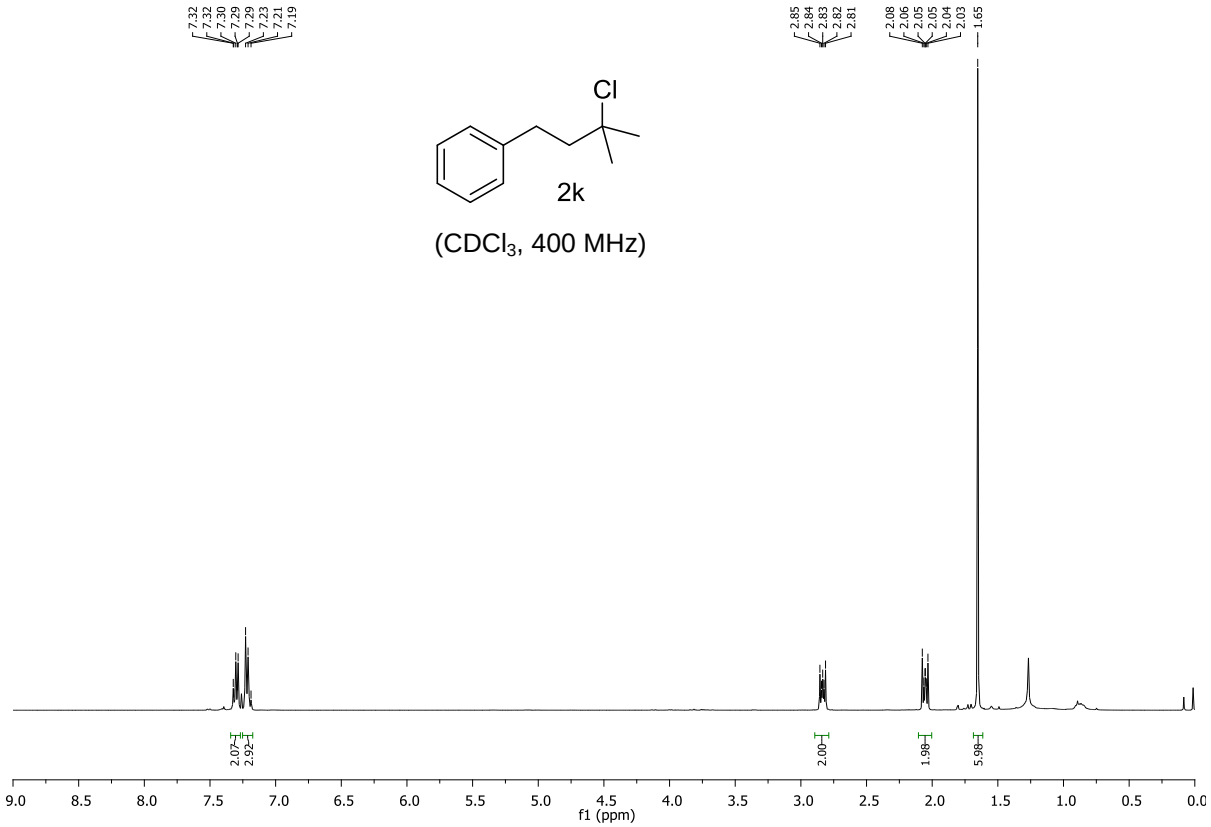
($CDCl_3$, 101 MHz)

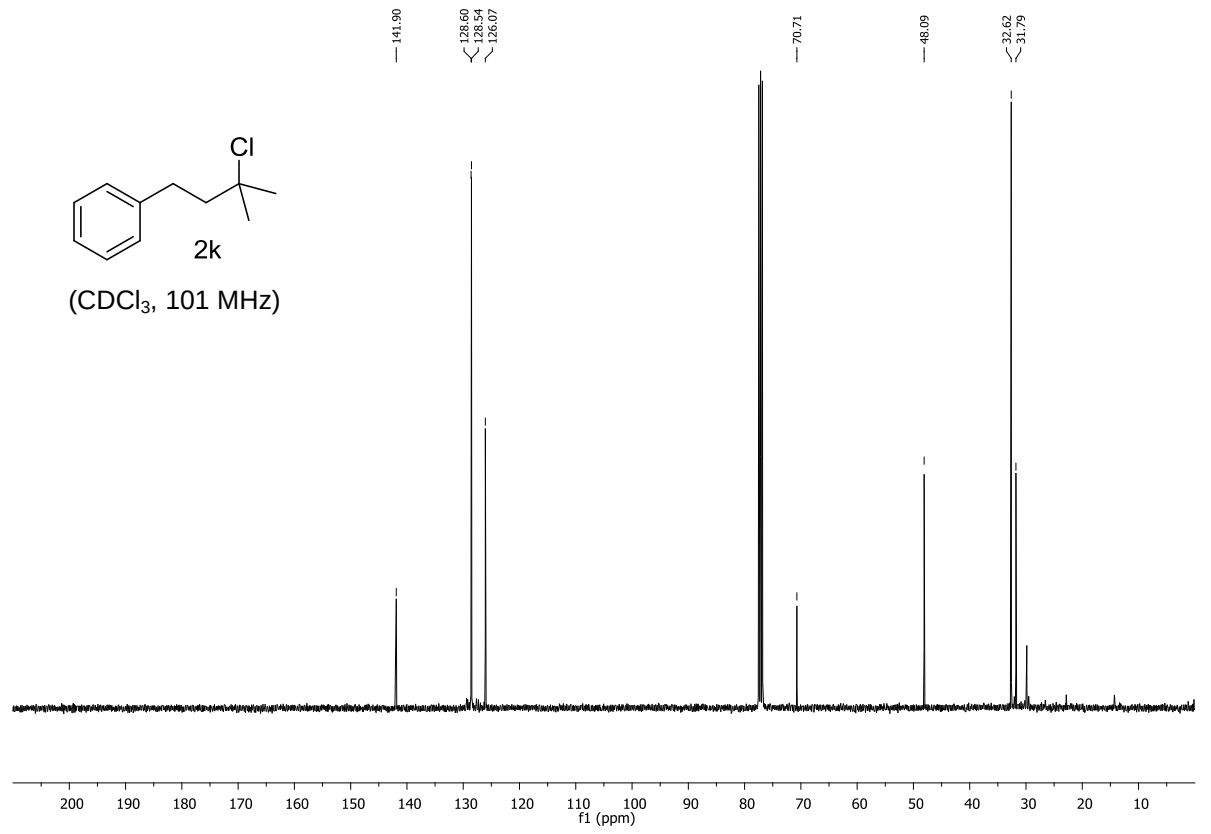


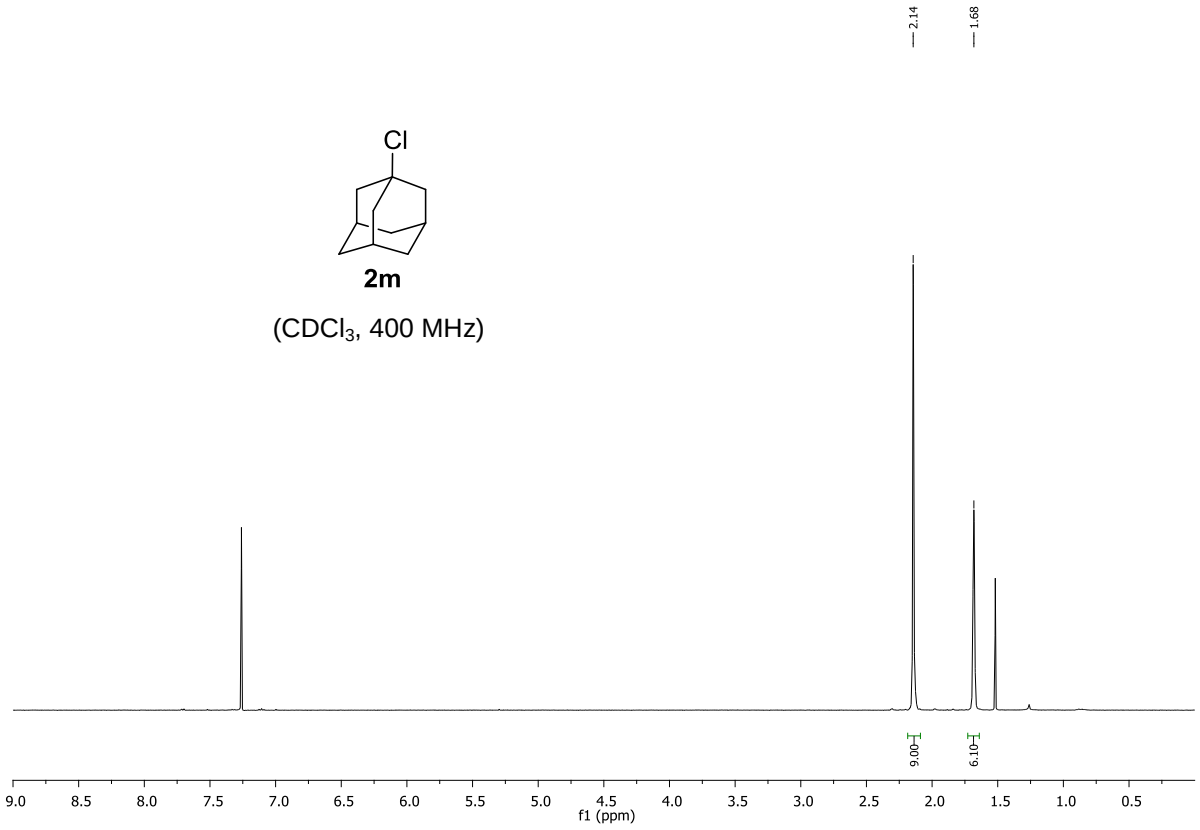

7.44
7.43
7.43
7.42
7.41
7.41
7.33
7.32
7.31
7.31
7.30
7.28
7.27
7.27
7.26
7.19
7.17
5.44
3.79
3.77
3.75
3.73
O
CF3
Br
2ia
(CDCl3, 400 MHz)
2.06
5.08
2.06
1.00
2.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

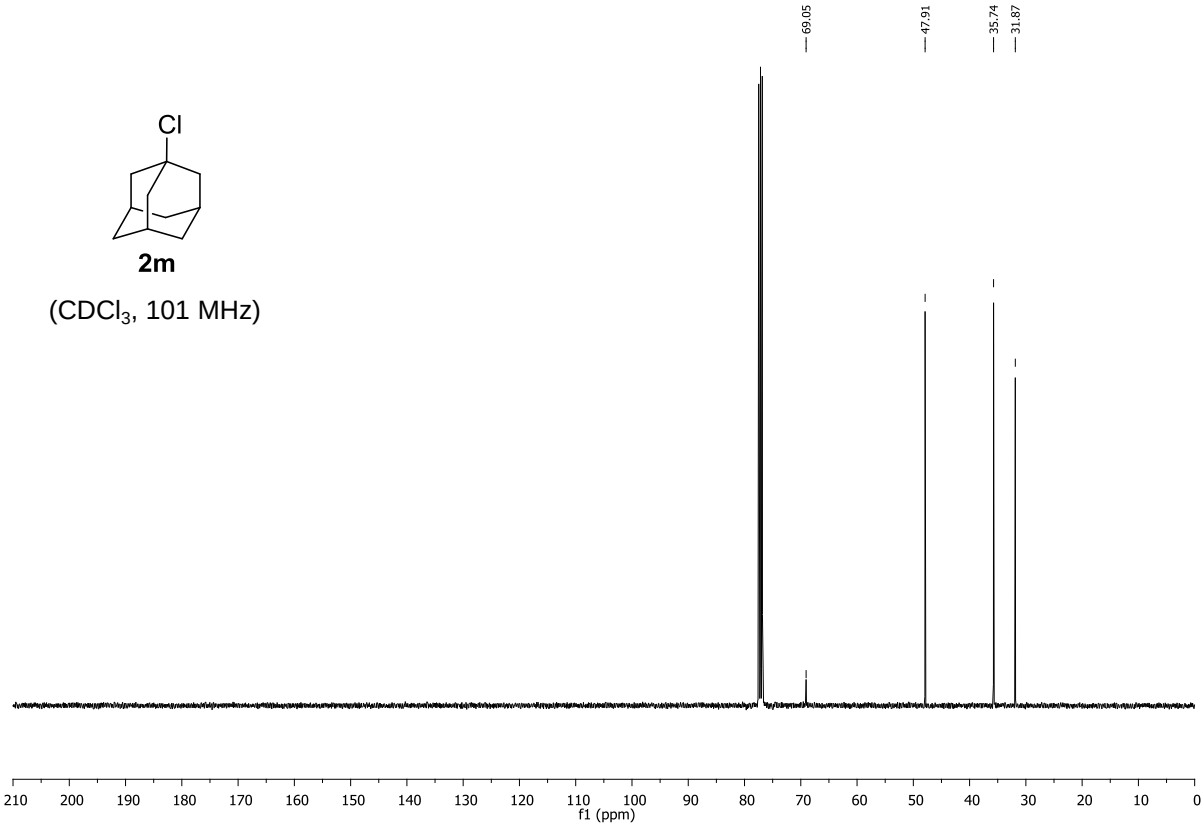

139.97
139.85
131.84
128.90
128.76
128.49
128.30
127.18
125.53
122.76
122.12
119.99
84.05
66.65
66.31
65.97
65.63
O
CF3
Br
2ia
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

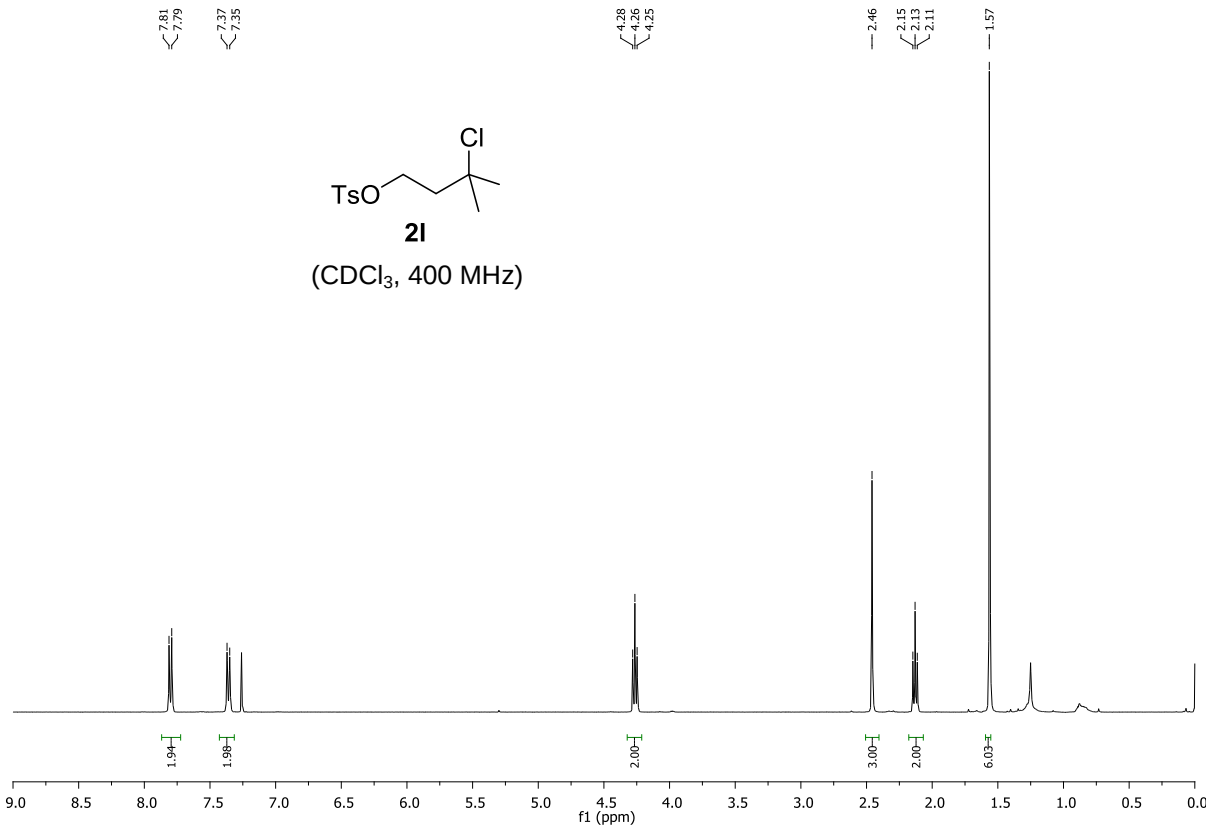

5.92
1.97
Cl
2j
(CDCl3, 400 MHz)
ClCH2CH2Cl
2.00
5.12
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


7.32
7.32
7.30
7.29
7.29
7.23
7.21
7.19
2.85
2.84
2.83
2.82
2.81
2.08
2.06
2.05
2.05
2.04
2.03
1.65
Cl
2k
(CDCl3, 400 MHz)
2.07
2.92
2.00
1.98
5.98
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


141.90
128.60
128.54
126.07
70.71
48.09
32.62
31.79
Cl
2k
(CDCl3, 101 MHz)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

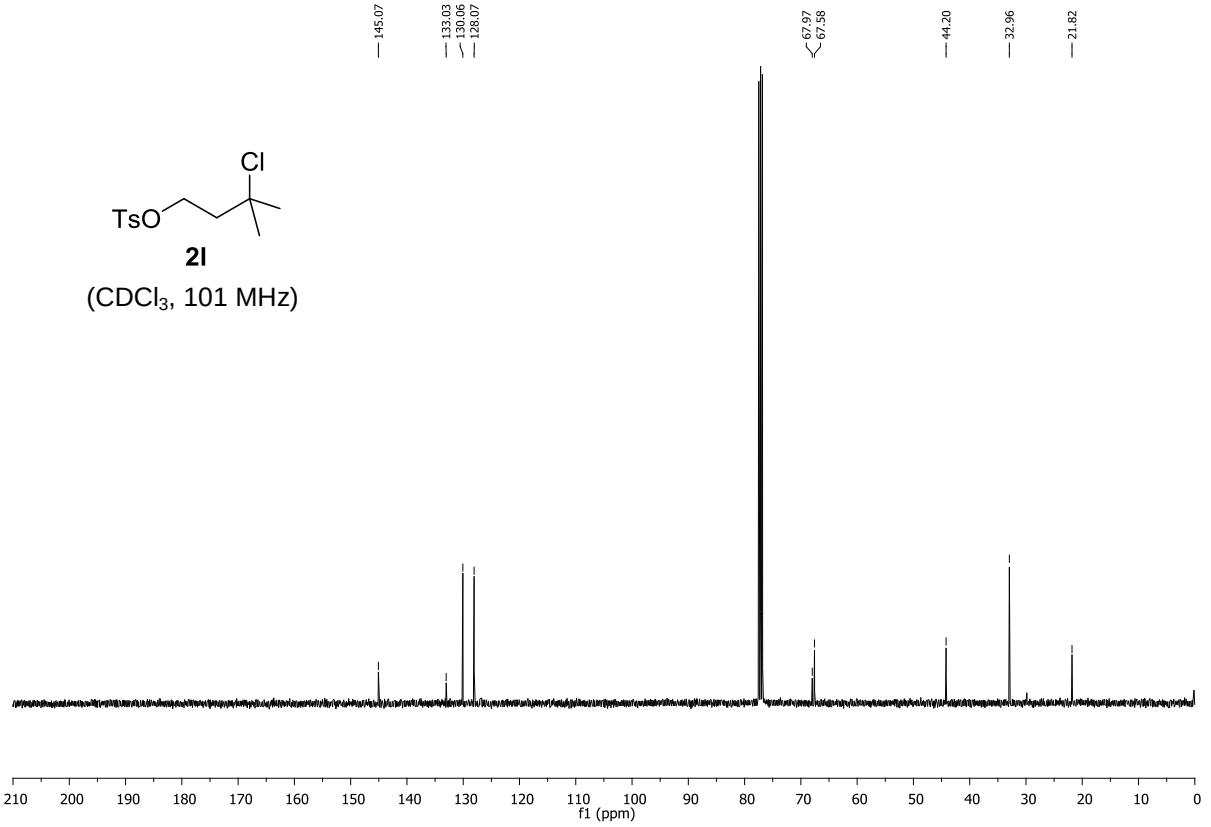

Cl
2m
(CDCl3, 400 MHz)
2.14
1.68
9.00
6.10
f1 (ppm)


Cl
2m
(CDCl3, 101 MHz)
69.05
47.91
35.74
31.87
f1 (ppm)



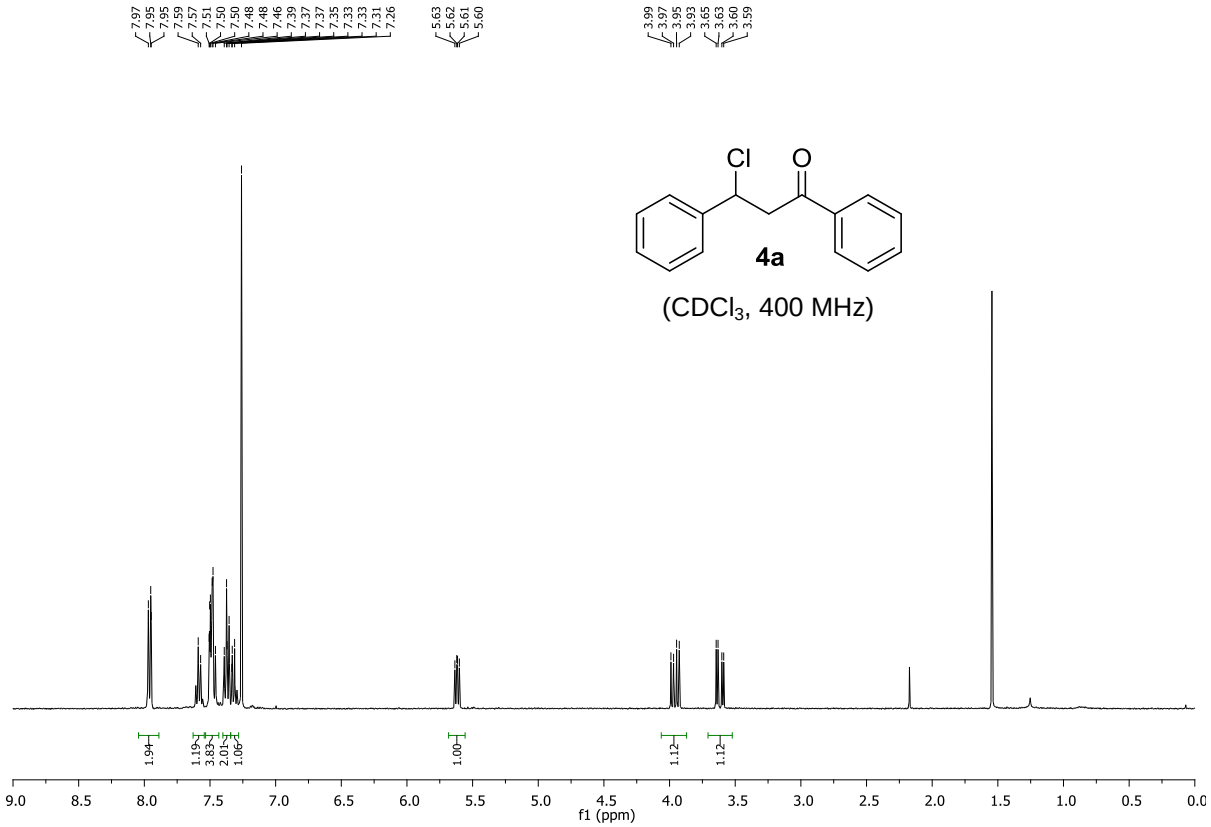
2l

($CDCl_3$, 400 MHz)

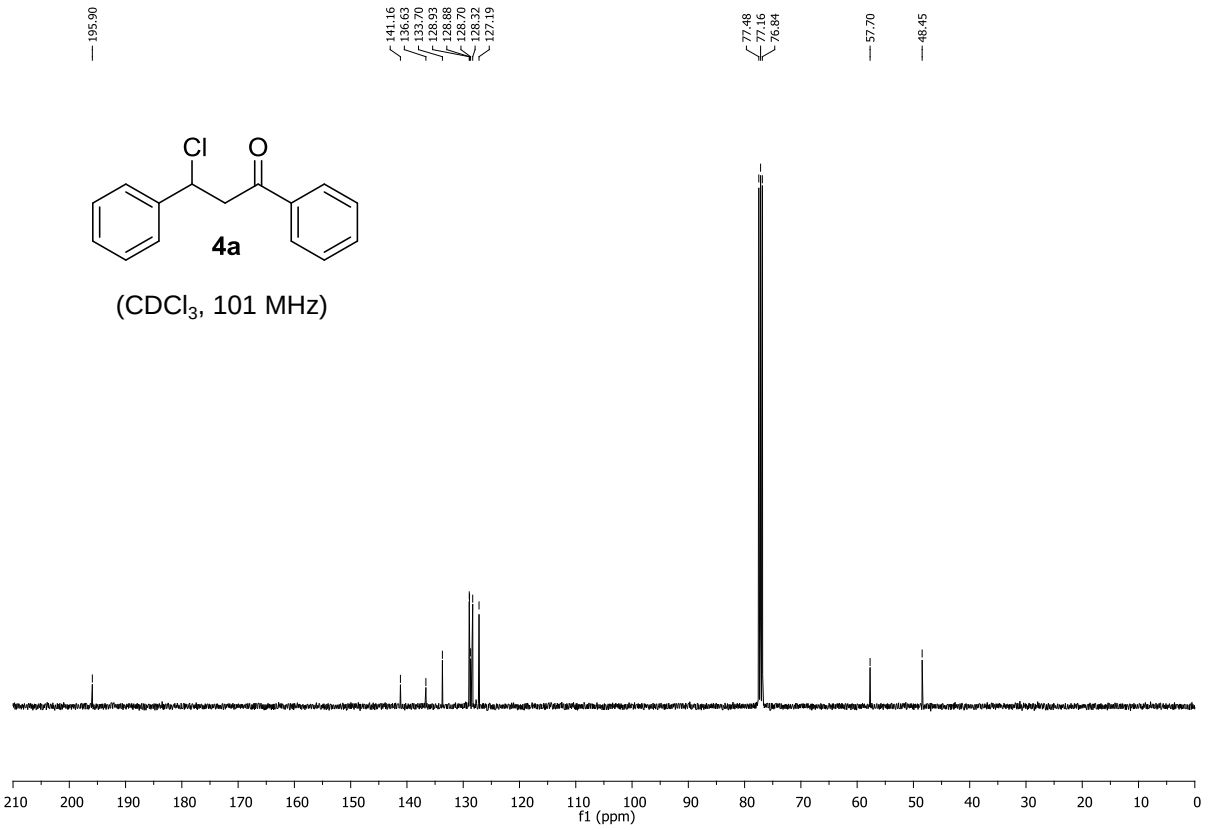


2l

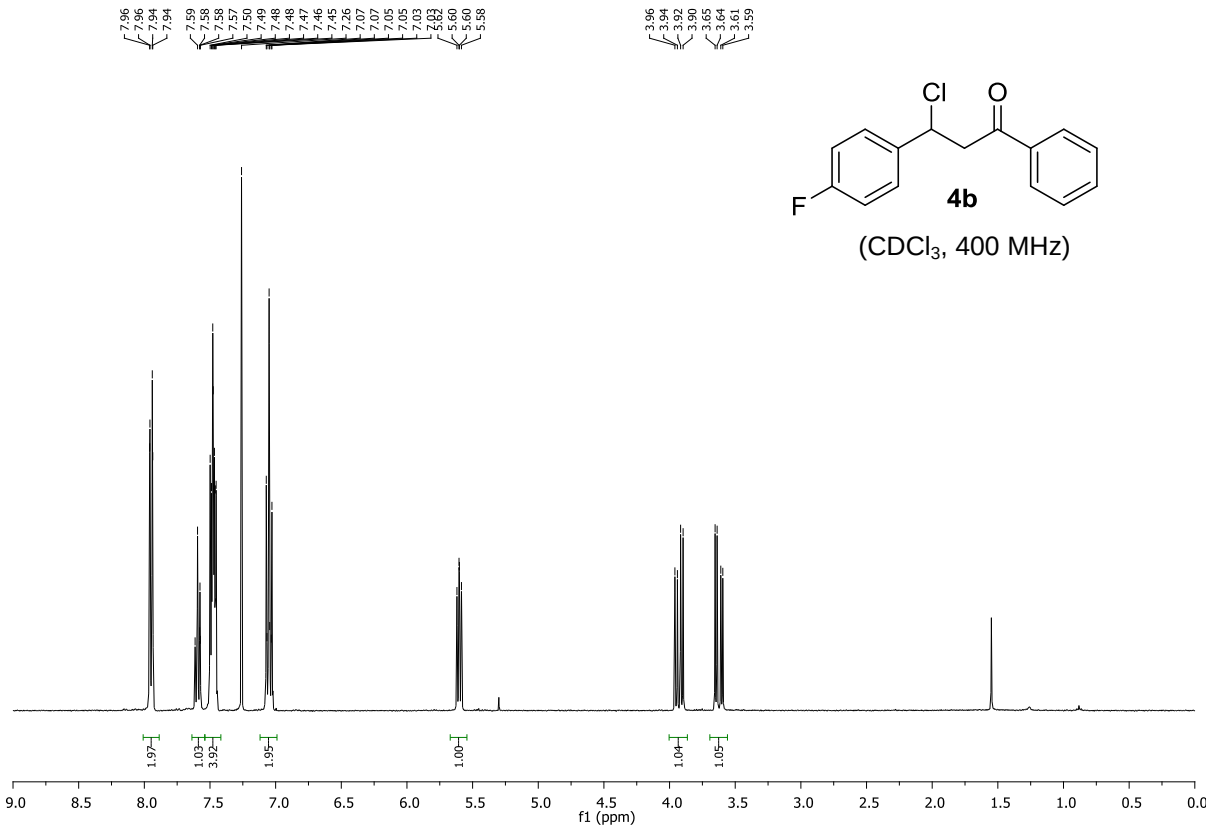
($CDCl_3$, 101 MHz)



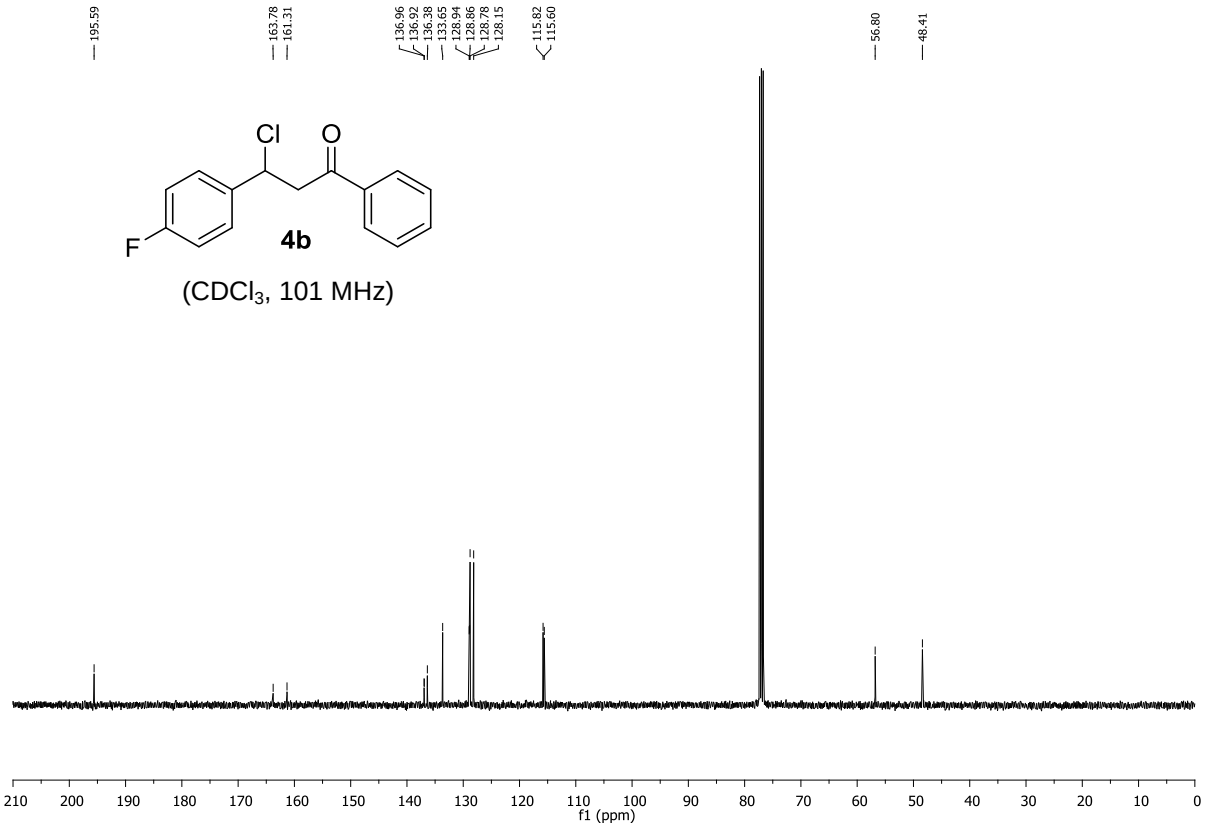
($CDCl_3$, 400 MHz)



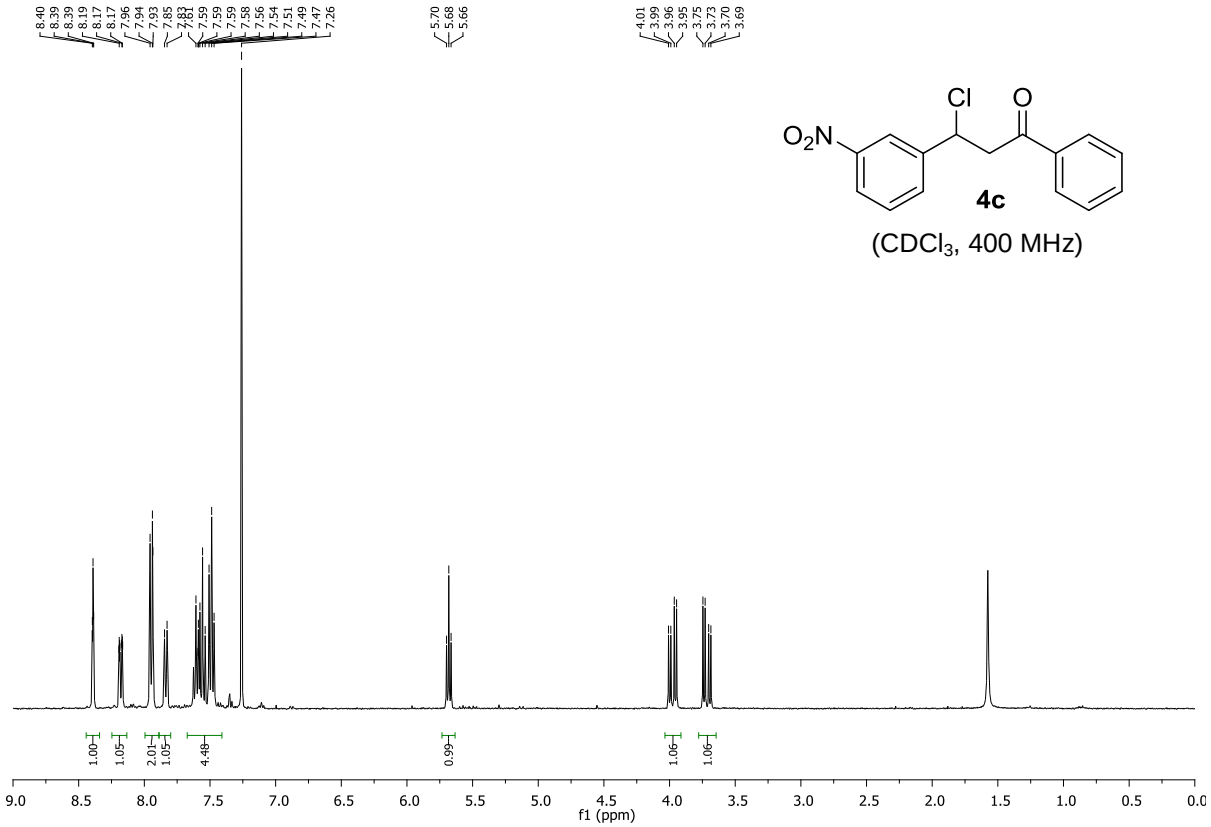
($CDCl_3$, 101 MHz)



($CDCl_3$, 400 MHz)

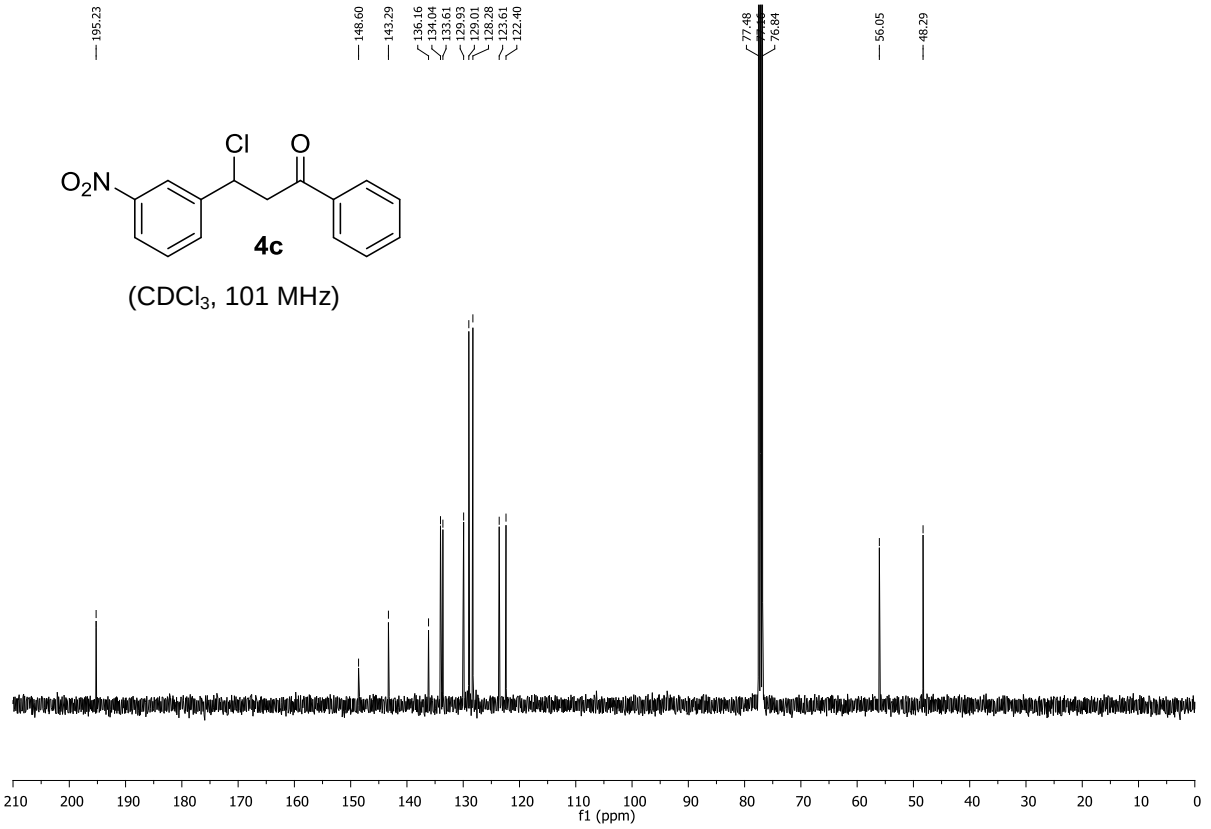


($CDCl_3$, 101 MHz)



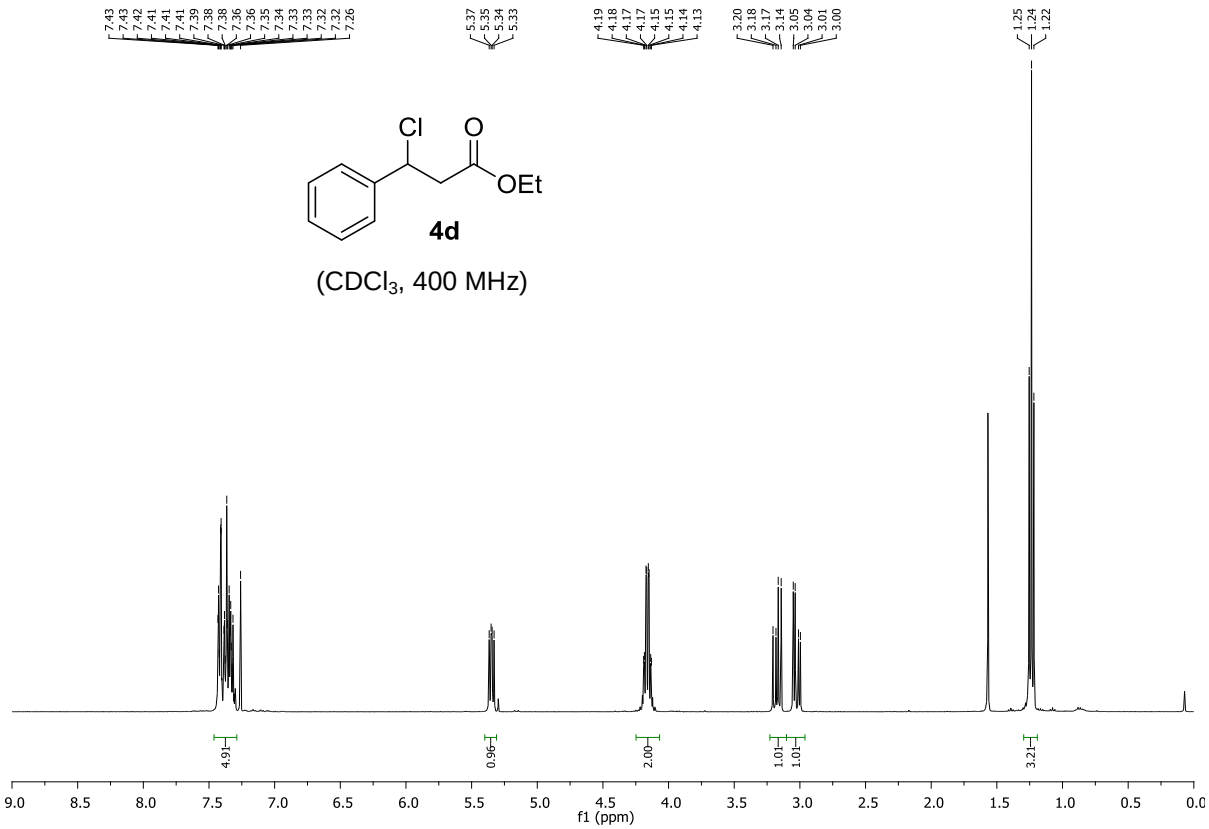
4c

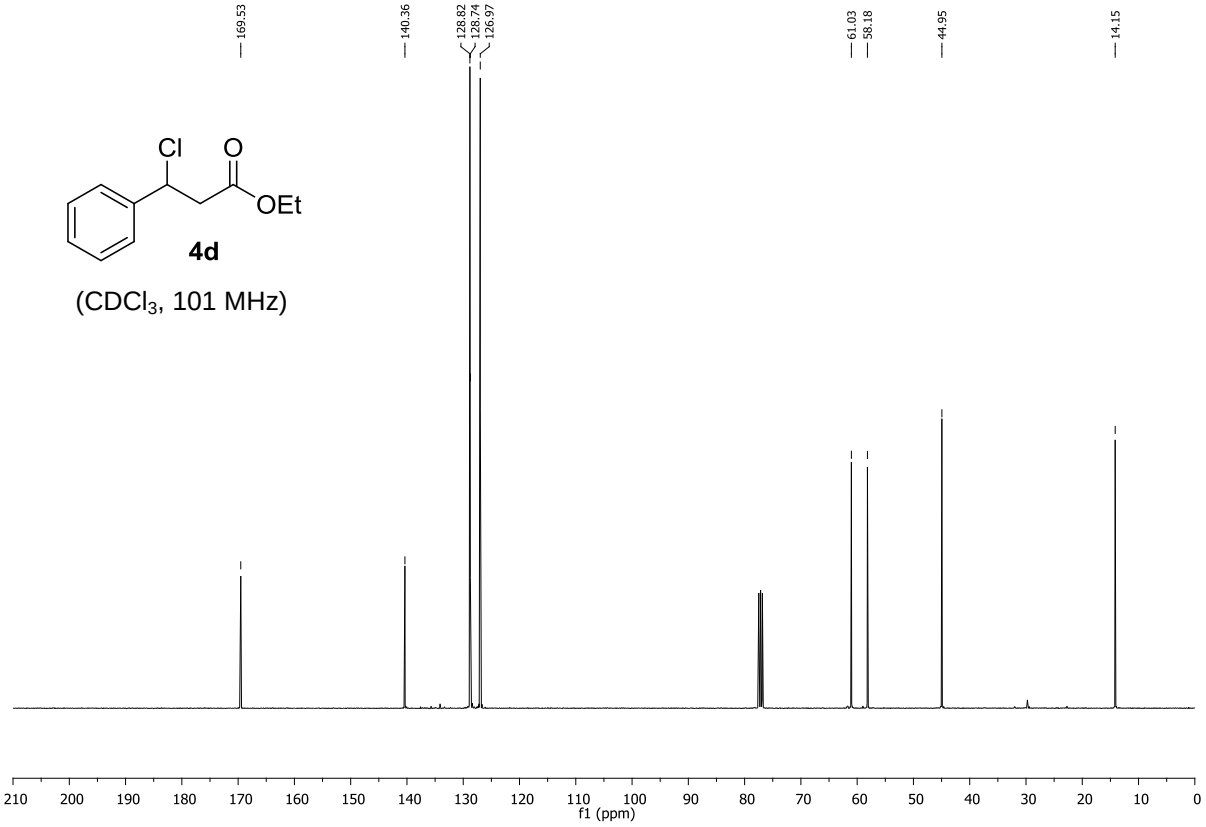
($CDCl_3$, 400 MHz)

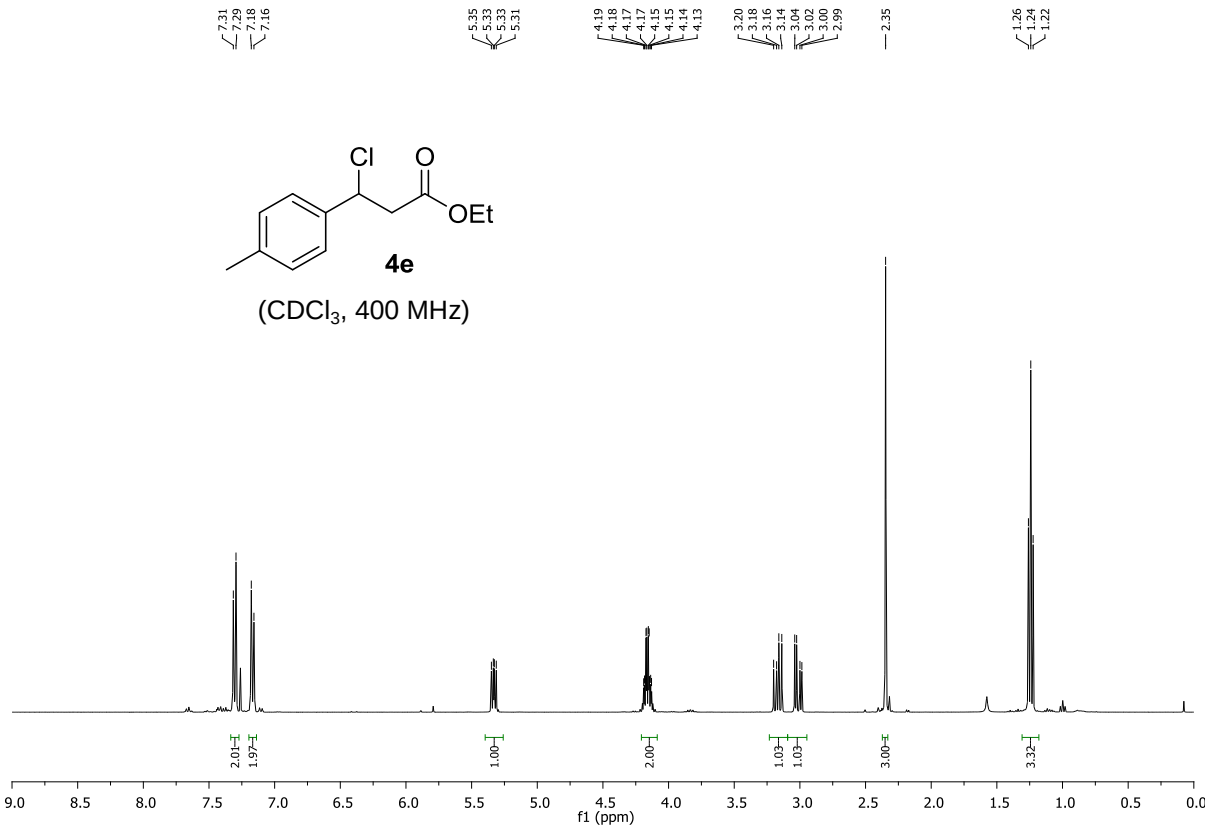


4c

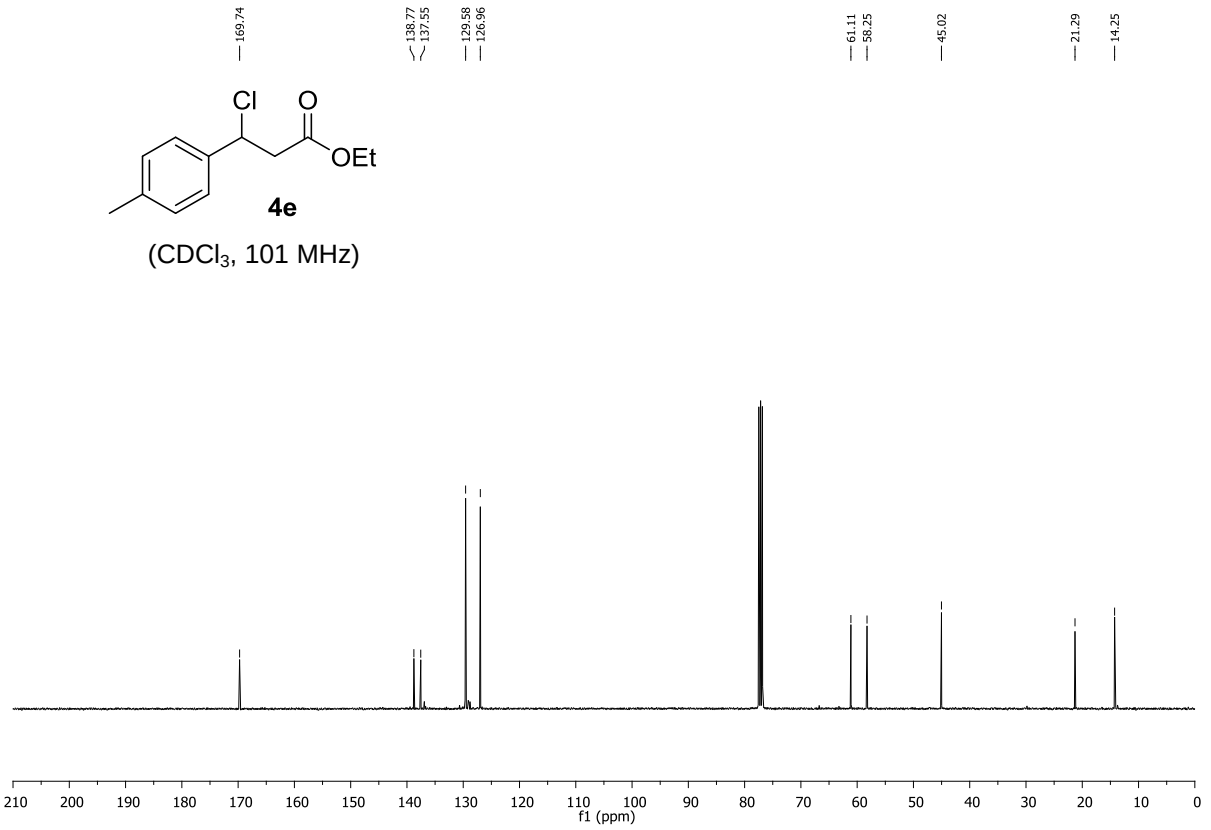
($CDCl_3$, 101 MHz)


7.43
7.43
7.42
7.41
7.41
7.41
7.39
7.38
7.38
7.36
7.36
7.35
7.34
7.33
7.33
7.32
7.32
7.26
5.37
5.35
5.34
5.33
4.19
4.18
4.17
4.17
4.15
4.15
4.14
4.13
3.20
3.18
3.17
3.14
3.05
3.04
3.01
3.00
1.25
1.24
1.22
Cl
O
OEt
4d
(CDCl3, 400 MHz)
4.91
0.96
2.00
1.01
1.01
3.21
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

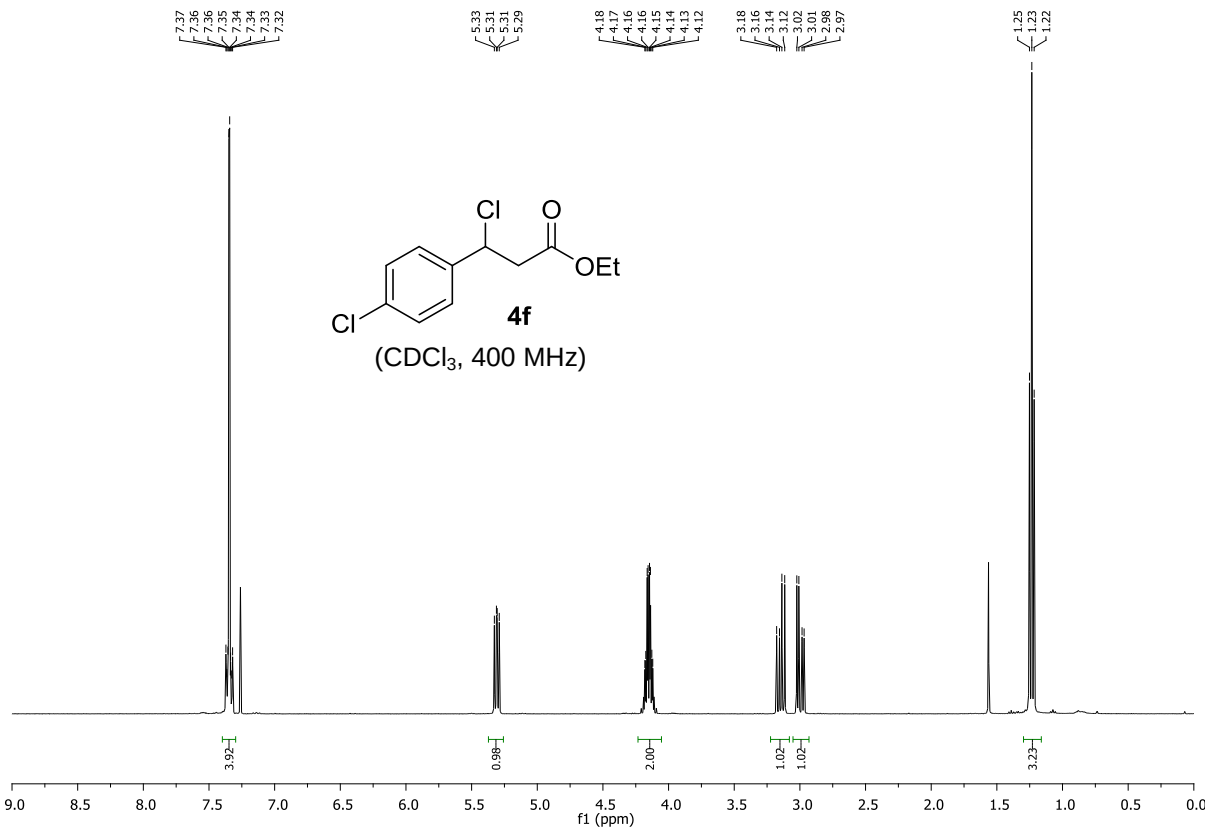

169.53
140.36
128.82
128.74
126.97
61.03
58.18
44.95
14.15
Cl
O
OEt
4d
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

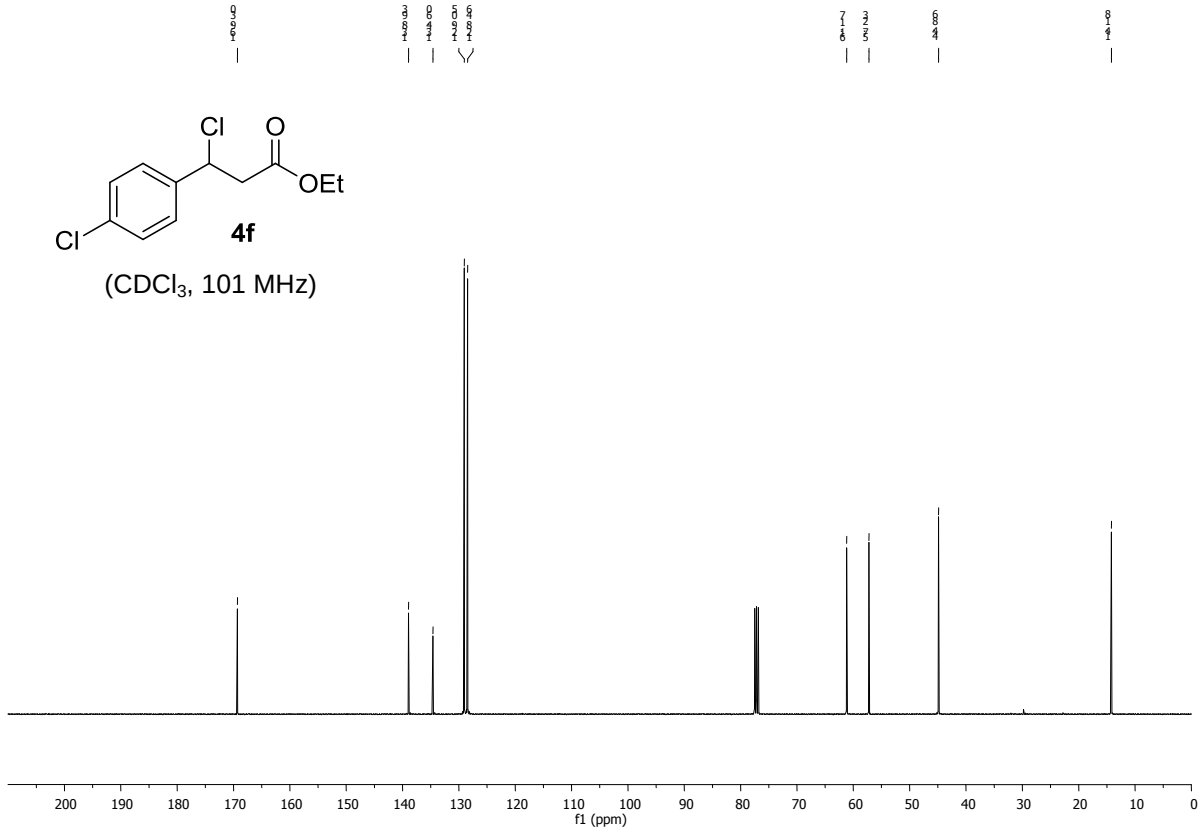


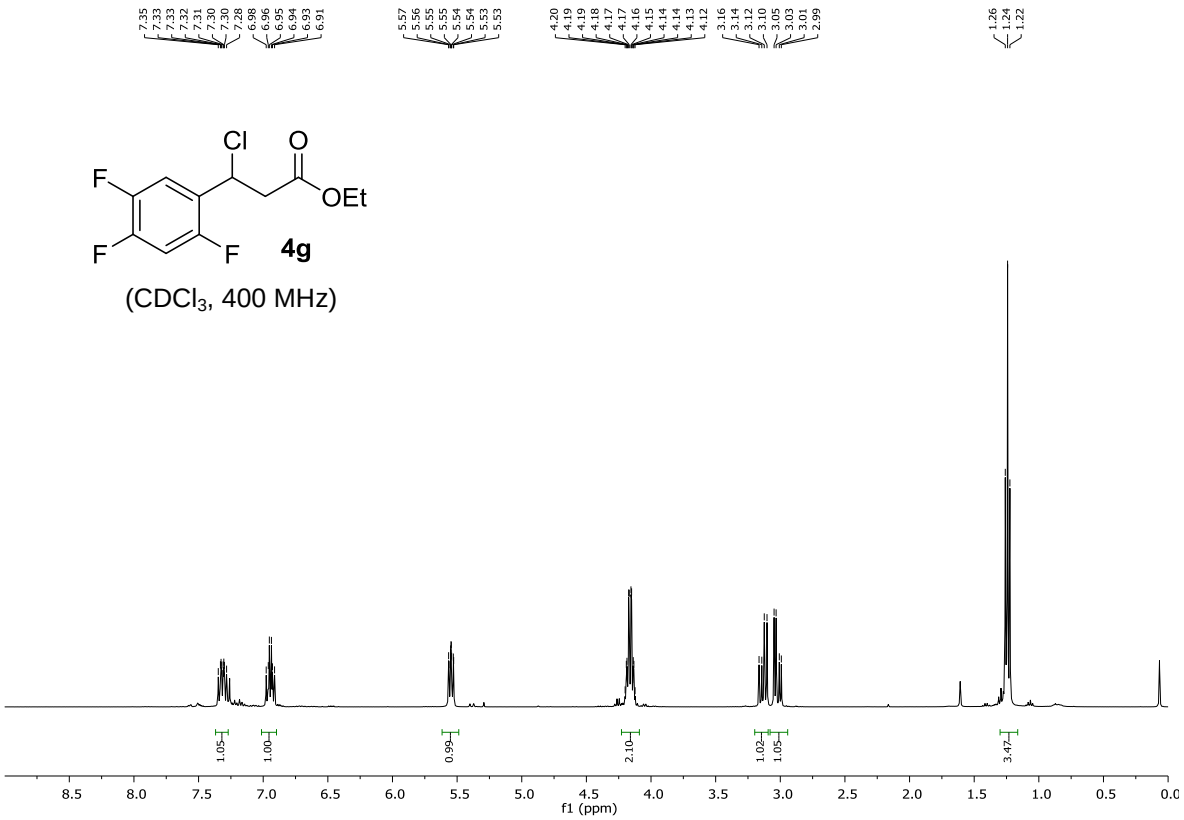
($CDCl_3$, 400 MHz)

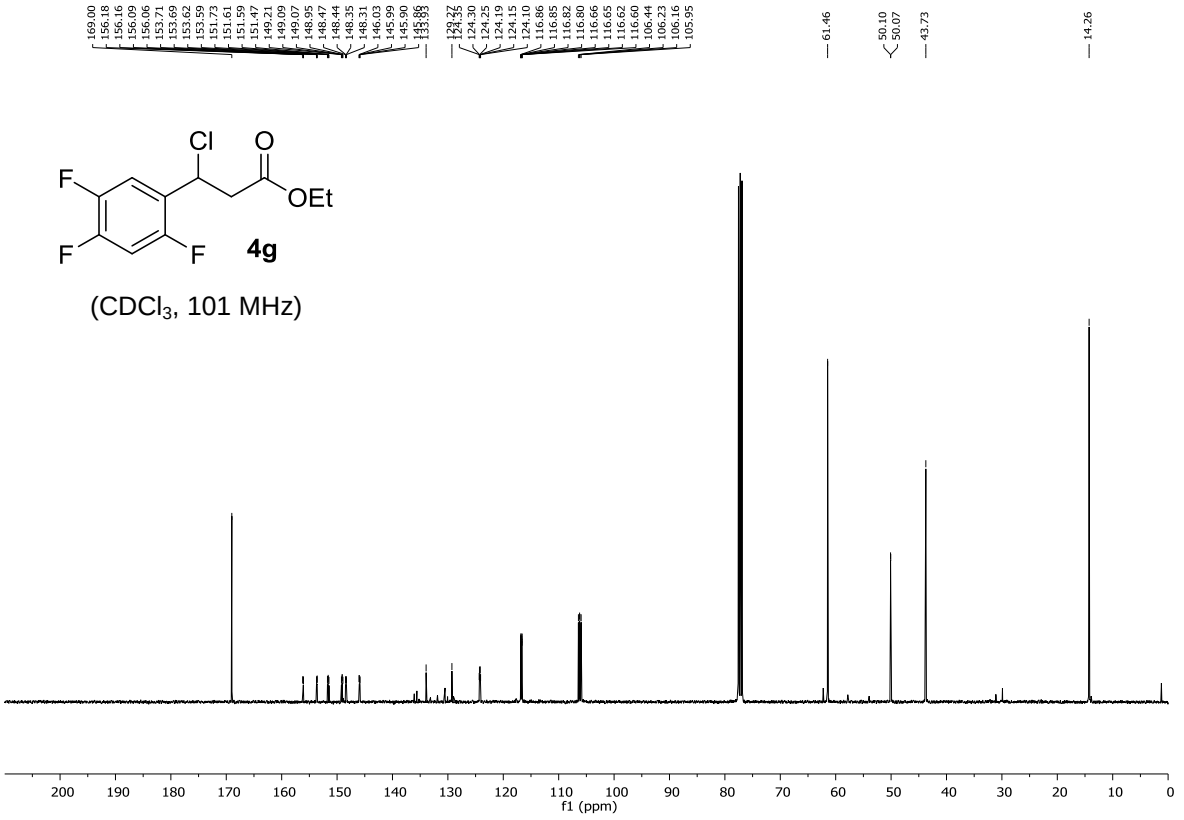


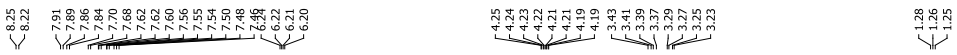
($CDCl_3$, 101 MHz)

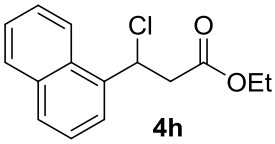

Cl
O
OEt
Cl
4f
(CDCl3, 400 MHz)
f1 (ppm)


Cl
O
OEt
Cl
4f
(CDCl3, 101 MHz)
f1 (ppm)


7.35 7.33 7.33 7.32 7.31 7.30 7.30 7.28 6.98 6.96 6.95 6.94 6.93 6.91
5.57 5.56 5.55 5.55 5.54 5.54 5.53 5.53
4.20 4.19 4.19 4.18 4.17 4.17 4.16 4.15 4.14 4.14 4.13 4.12
3.16 3.14 3.12 3.10 3.05 3.03 3.01 2.99
1.26 1.24 1.22
Cl
O
OEt
F
F
F
4g
(CDCl3, 400 MHz)
1.05
1.00
0.99
2.10
1.02
1.05
3.47
f1 (ppm)

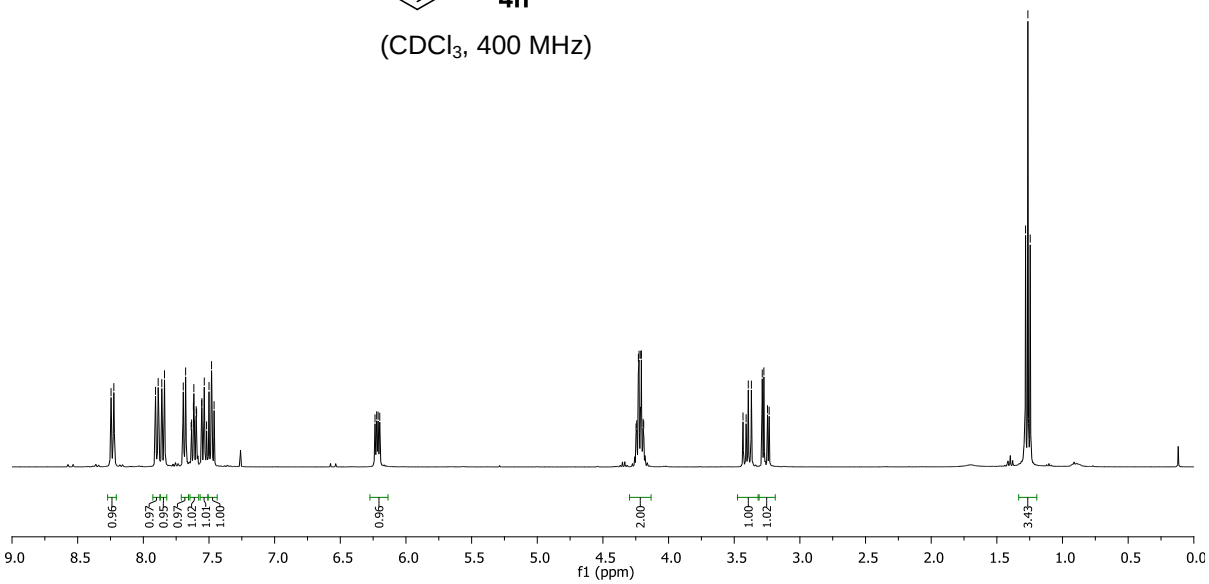

169.00 156.18 156.16 156.09 156.06 153.71 153.69 153.62 153.59 151.73 151.61 151.59 151.47 149.21 149.09 149.07 148.95 148.47 148.44 148.35 148.31 146.03 145.99 145.90
124.37 124.35 124.30 124.25 124.19 124.15 124.10 116.86 116.85 116.82 116.80 116.66 116.65 116.62 116.60 106.44 106.23 106.16 105.95
61.46
50.10 50.07
43.73
14.26
Cl
O
OEt
F
F
F
4g
(CDCl3, 101 MHz)
f1 (ppm)

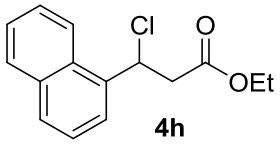




4h

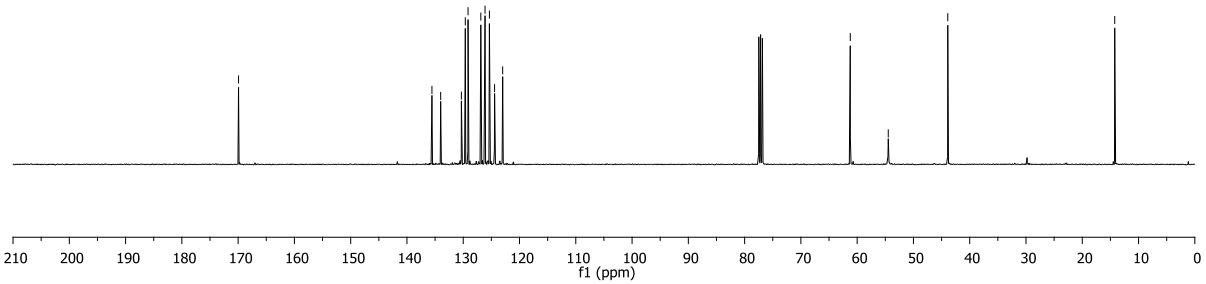
($CDCl_3$, 400 MHz)

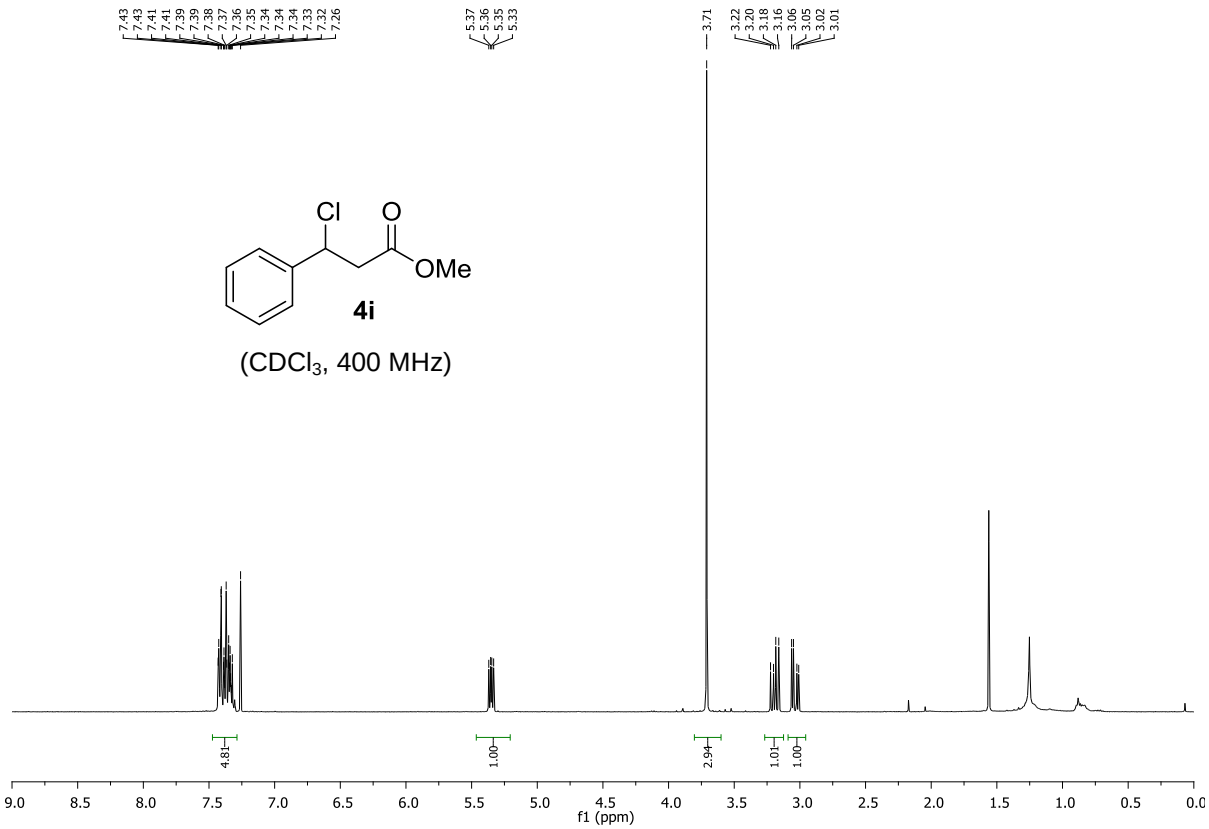




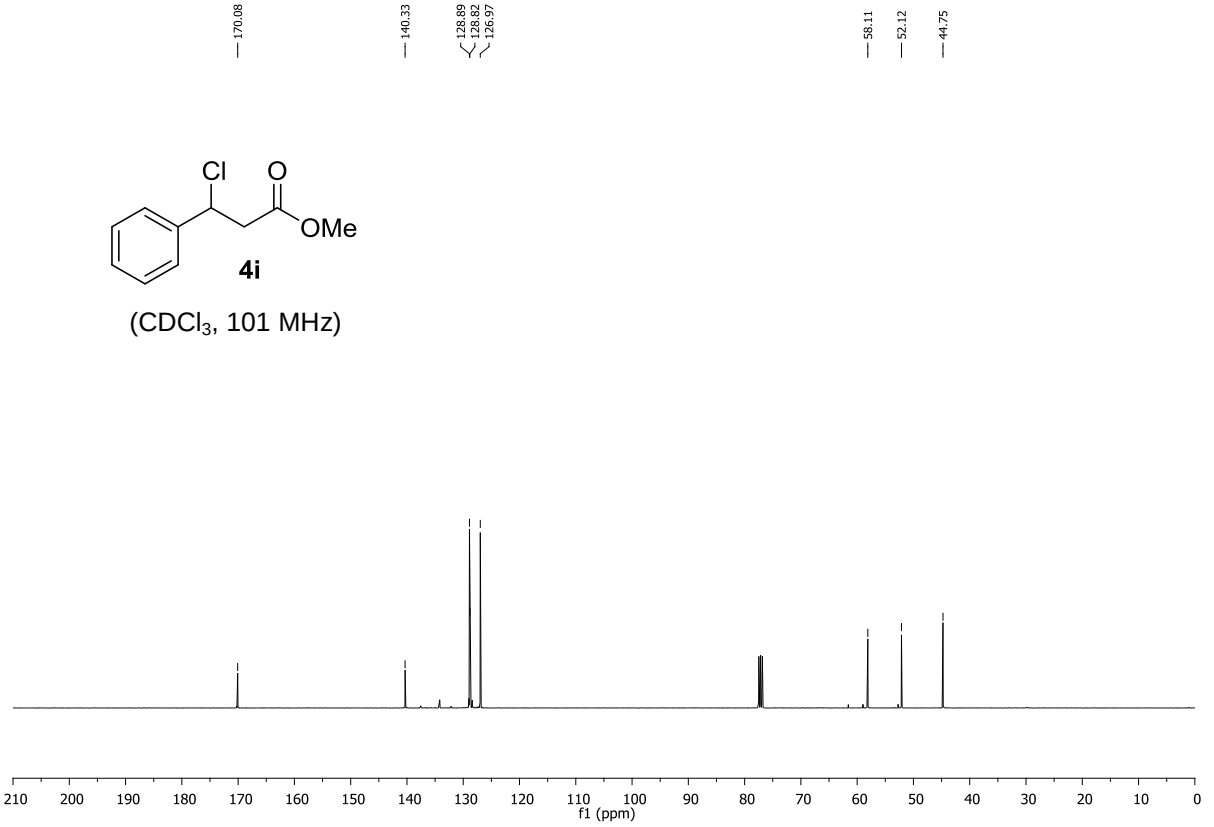
4h

($CDCl_3$, 101 MHz)

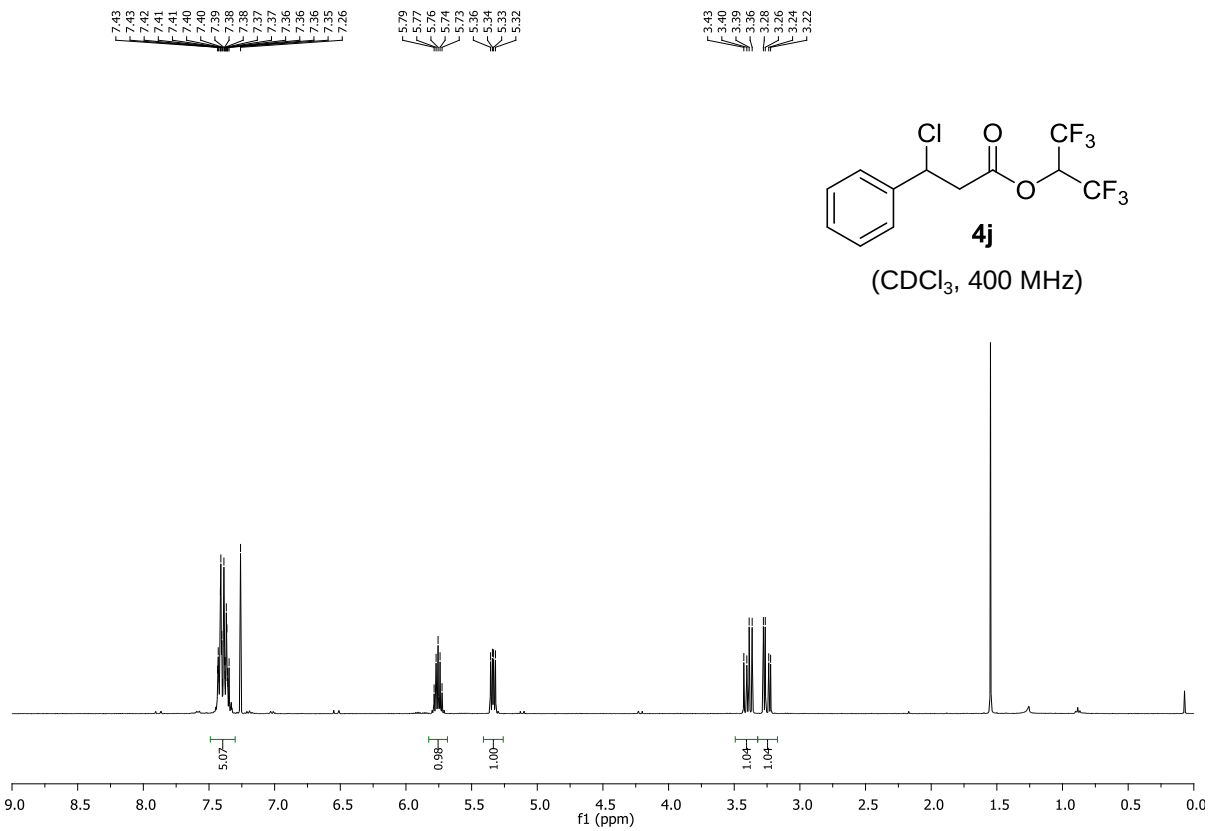


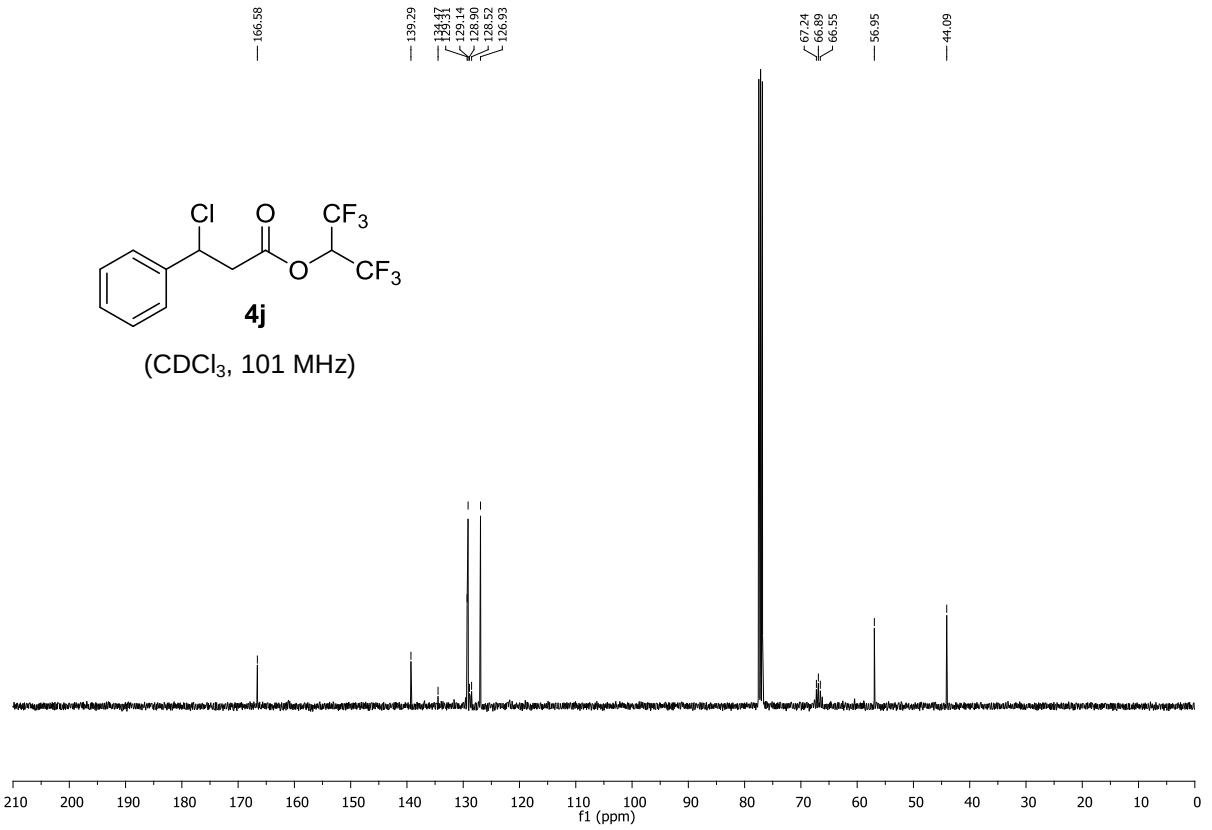


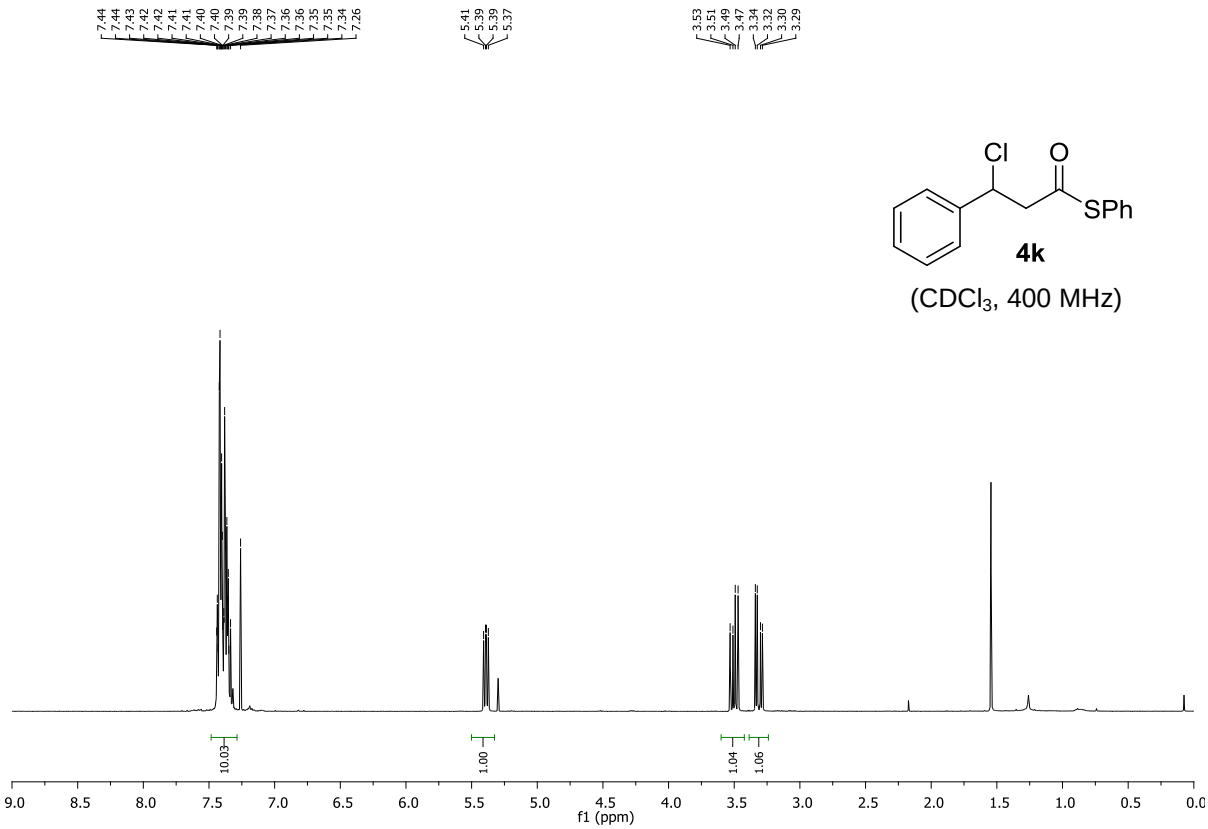
(CDCl$_3$, 400 MHz)

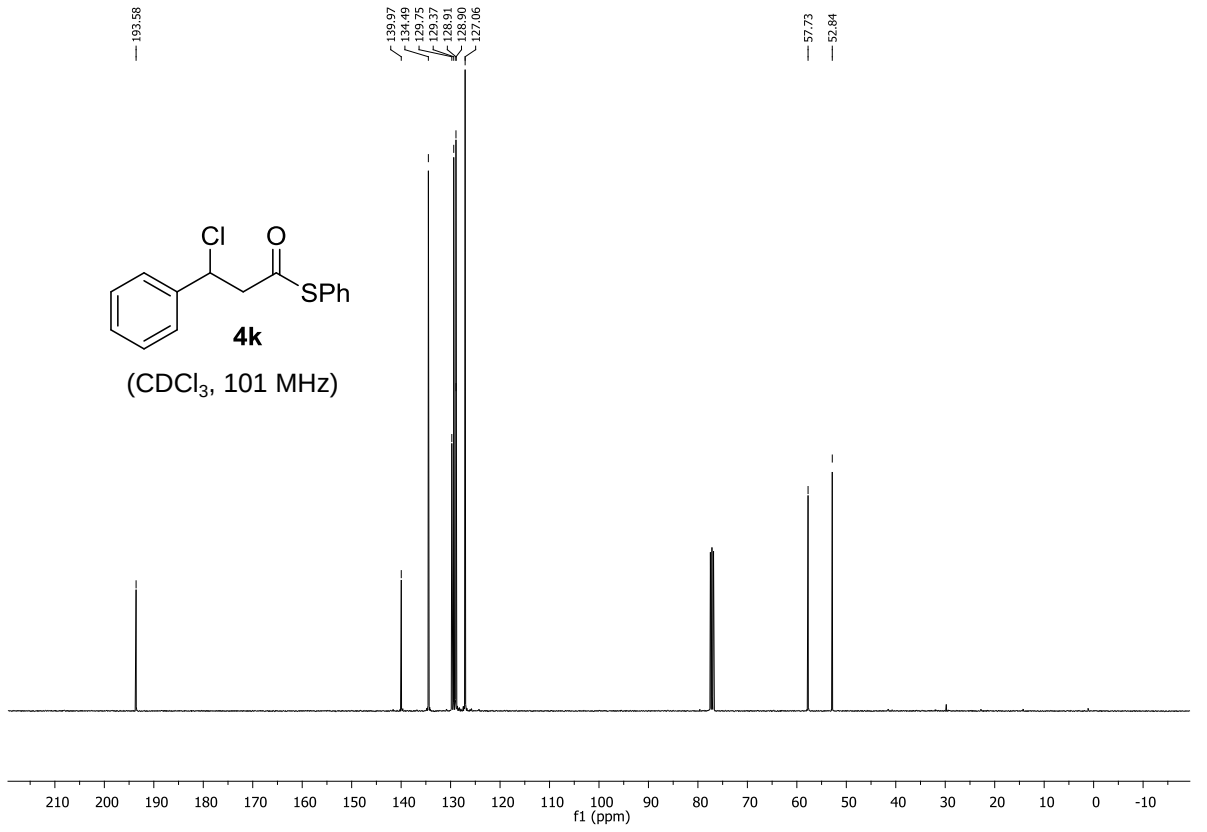


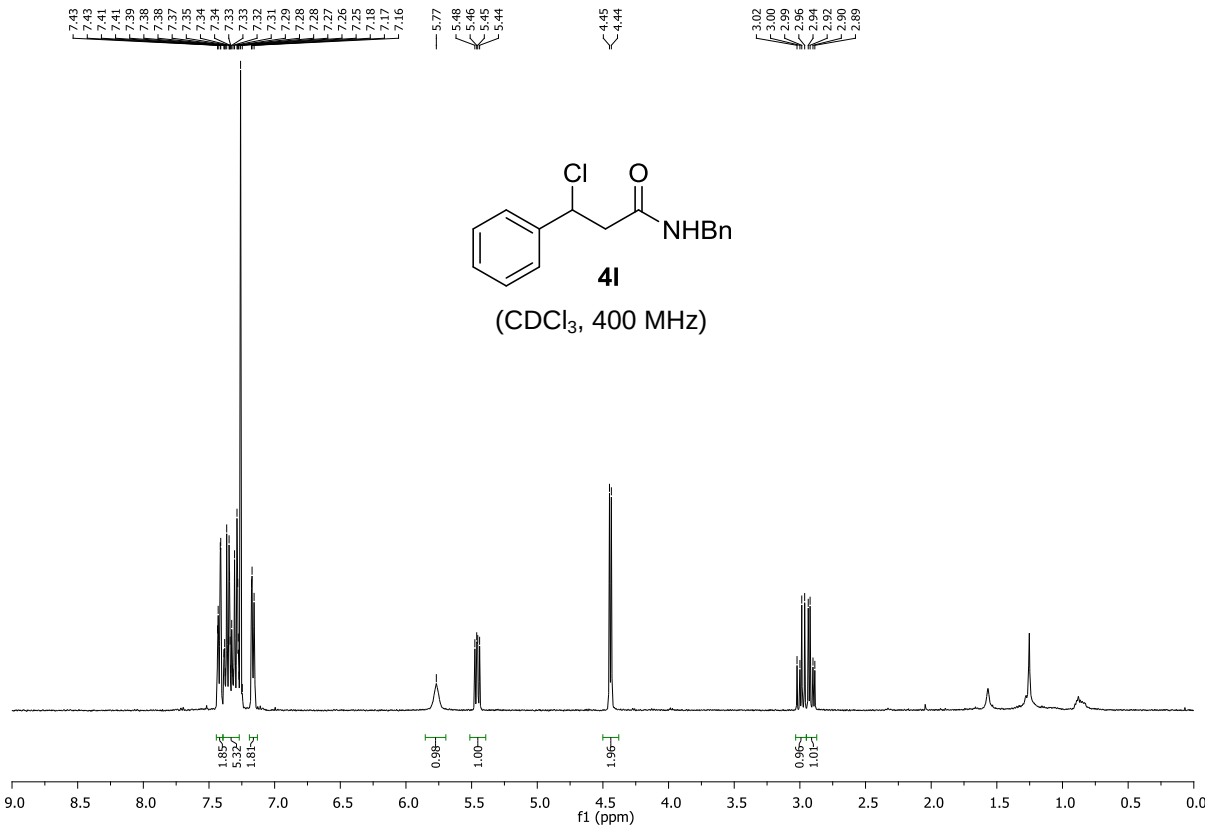
(CDCl$_3$, 101 MHz)

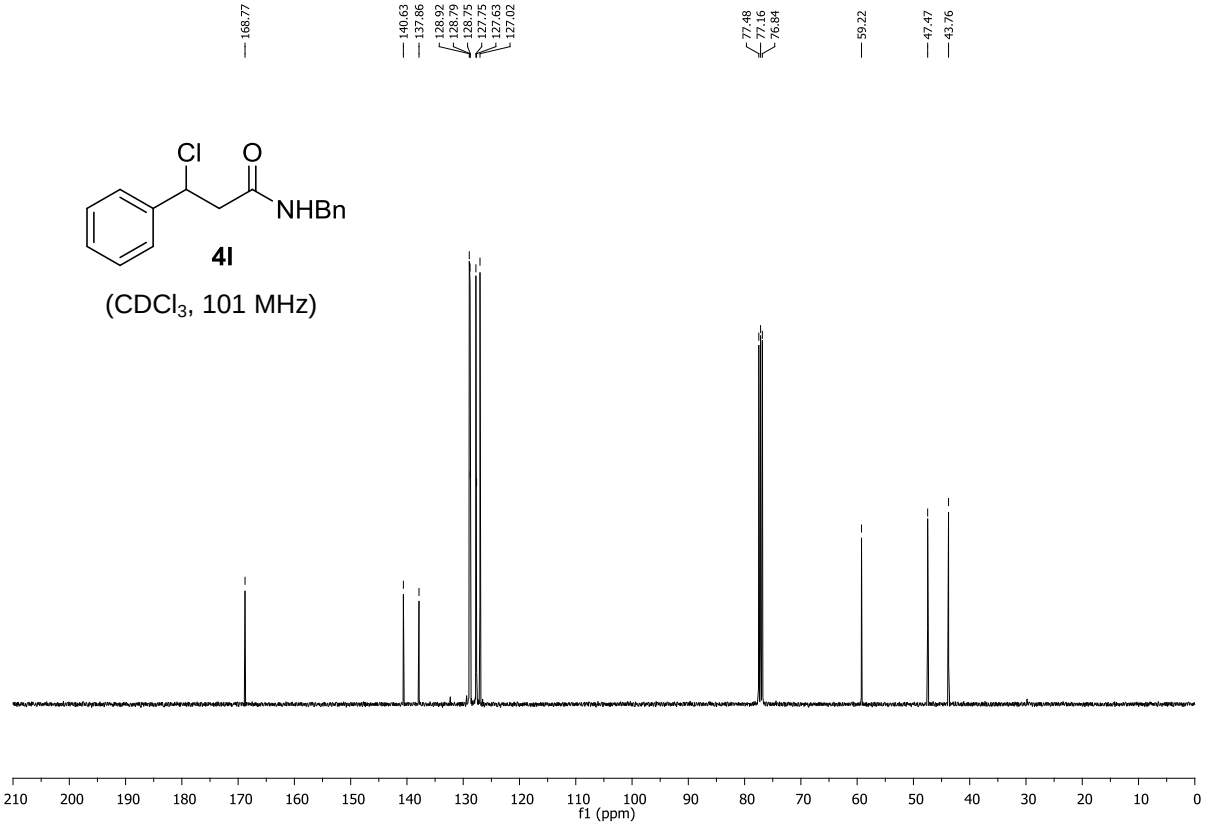

7.43
7.43
7.42
7.41
7.41
7.40
7.40
7.39
7.38
7.38
7.37
7.37
7.36
7.36
7.36
7.35
7.26
5.79
5.77
5.76
5.74
5.73
5.36
5.34
5.33
5.32
3.43
3.40
3.39
3.36
3.28
3.26
3.24
3.22
Cl
O
CF3
O
CF3
4j
(CDCl3, 400 MHz)
5.07
0.98
1.00
1.04
1.04
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

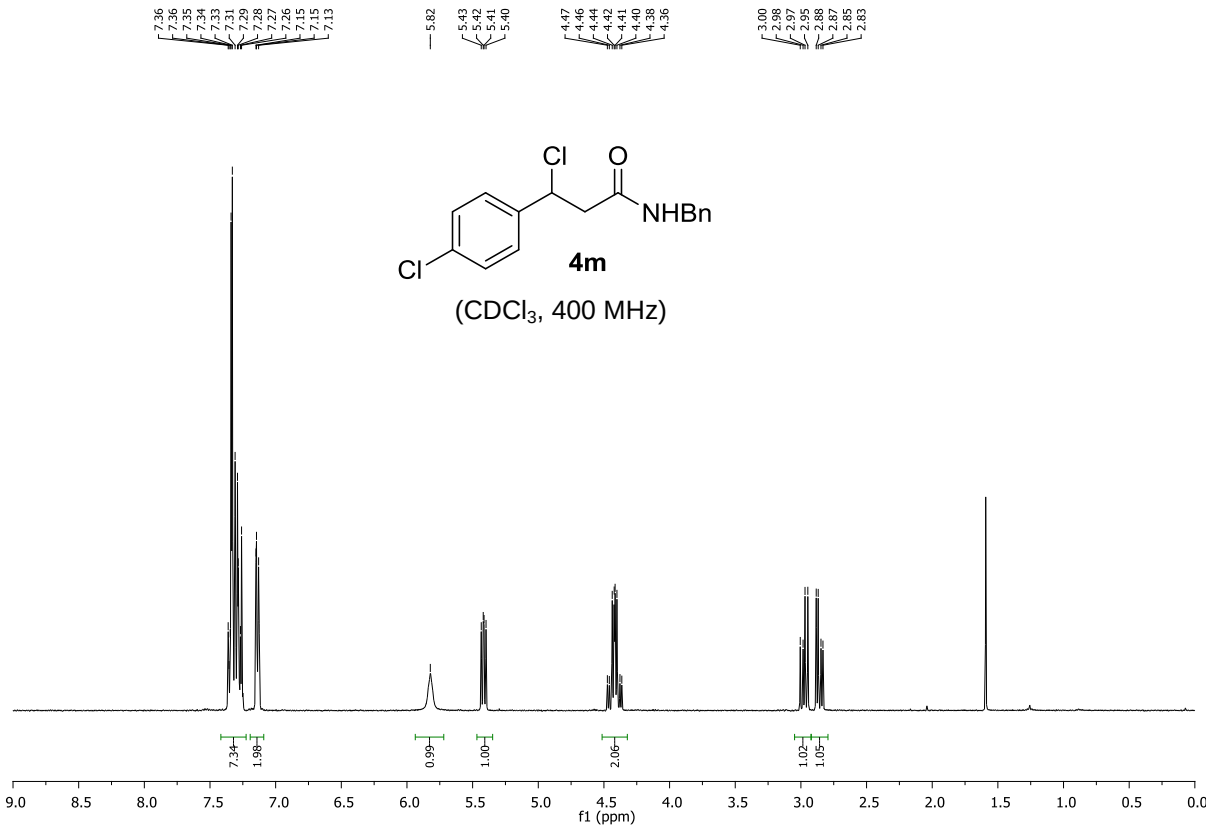

166.58
139.29
134.47
130.31
129.14
128.90
128.52
126.93
67.24
66.89
66.55
56.95
44.09
Cl
O
CF3
O
CF3
4j
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

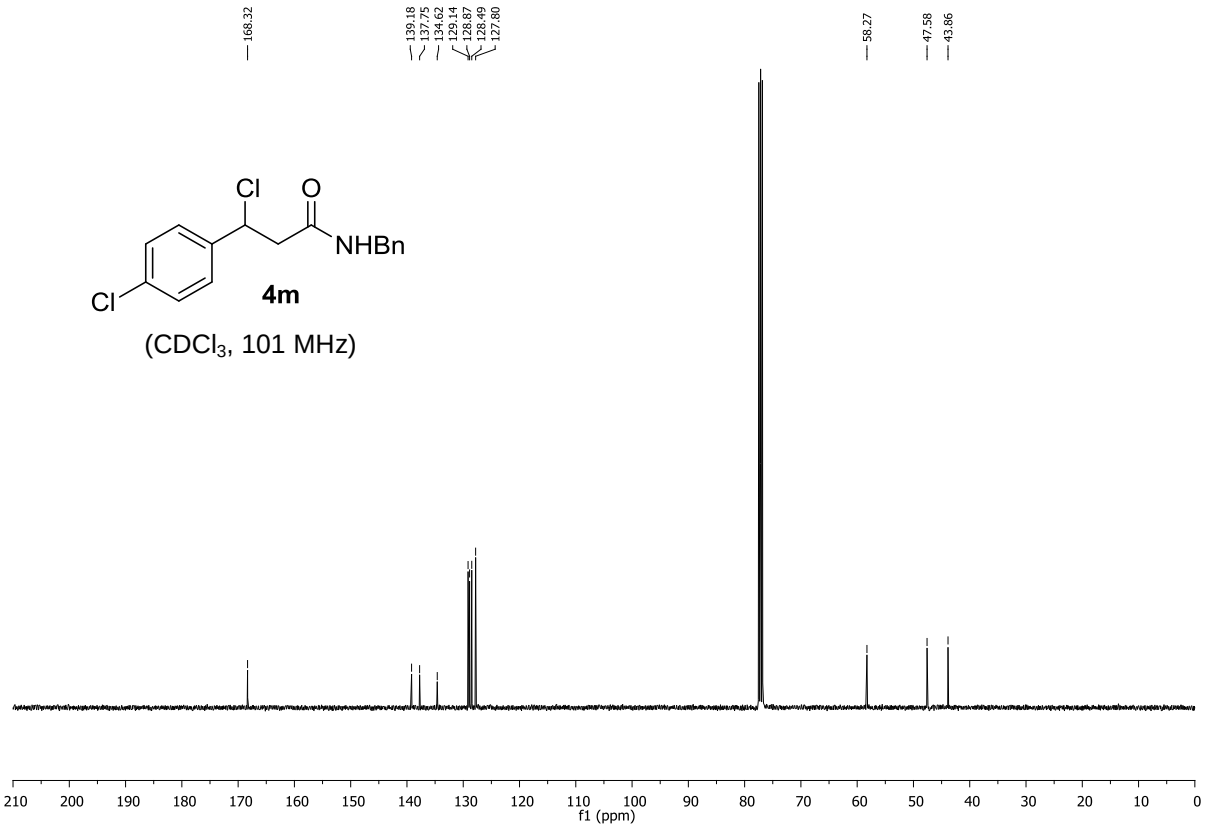

7.44
7.44
7.43
7.42
7.42
7.41
7.41
7.40
7.40
7.39
7.39
7.38
7.37
7.36
7.36
7.35
7.35
7.34
7.26
5.41
5.39
5.39
5.37
3.53
3.51
3.49
3.47
3.34
3.32
3.30
3.29
Cl
O
SPh
4k
(CDCl3, 400 MHz)
10.03
1.00
1.04
1.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

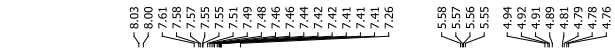

193.58
139.97
134.49
129.75
129.37
128.91
128.90
127.06
57.73
52.84
Cl
O
SPh
4k
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

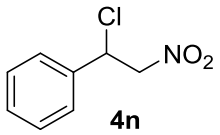

7.43
7.43
7.41
7.41
7.39
7.38
7.38
7.37
7.35
7.34
7.34
7.33
7.33
7.32
7.31
7.29
7.28
7.28
7.27
7.26
7.25
7.18
7.17
7.16
5.77
5.48
5.46
5.45
5.44
4.45
4.44
3.02
3.00
2.99
2.96
2.94
2.92
2.90
2.89
Cl
O
NHBn
4l
(CDCl3, 400 MHz)
1.85
5.32
1.81
0.98
1.00
1.96
0.96
1.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


168.77
140.63
137.86
128.92
128.79
128.75
127.75
127.63
127.02
77.48
77.16
76.84
59.22
47.47
43.76
Cl
O
NHBn
4l
(CDCl3, 101 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.36
7.36
7.35
7.34
7.33
7.31
7.29
7.28
7.27
7.26
7.15
7.15
7.13
5.82
5.43
5.42
5.41
5.40
4.47
4.46
4.44
4.42
4.41
4.40
4.38
4.36
3.00
2.98
2.97
2.95
2.88
2.87
2.85
2.83
Cl
O
NHBn
Cl
4m
(CDCl3, 400 MHz)
7.34
1.98
0.99
1.00
2.06
1.02
1.05
f1 (ppm)

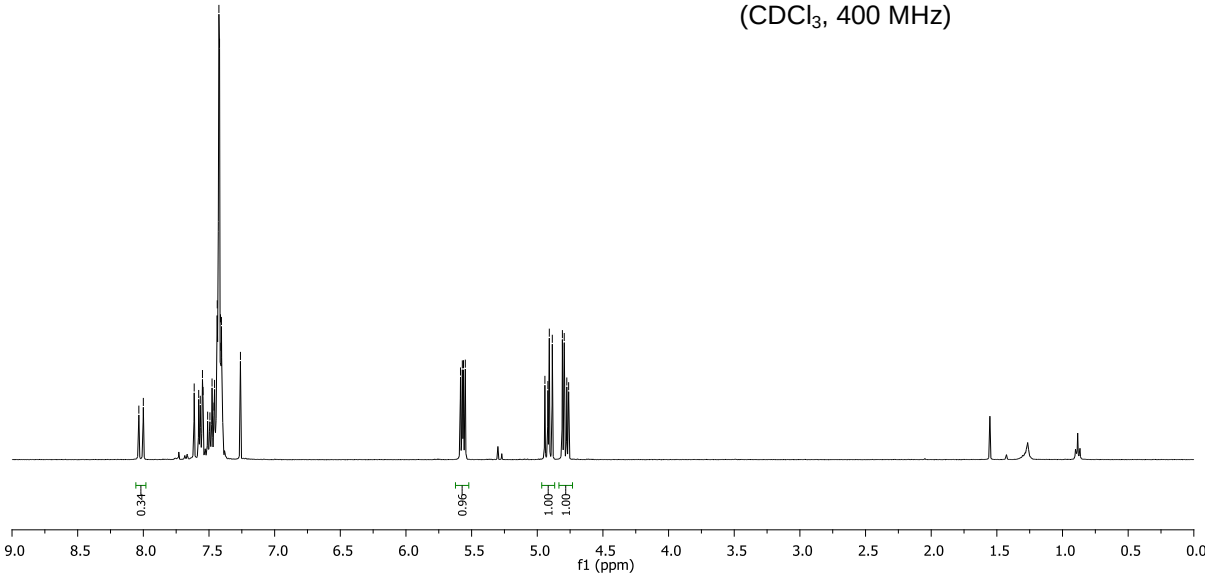

168.32
139.18
137.75
134.62
129.14
128.87
128.49
127.80
58.27
47.58
43.86
Cl
O
NHBn
Cl
4m
(CDCl3, 101 MHz)
f1 (ppm)

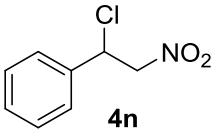




4n

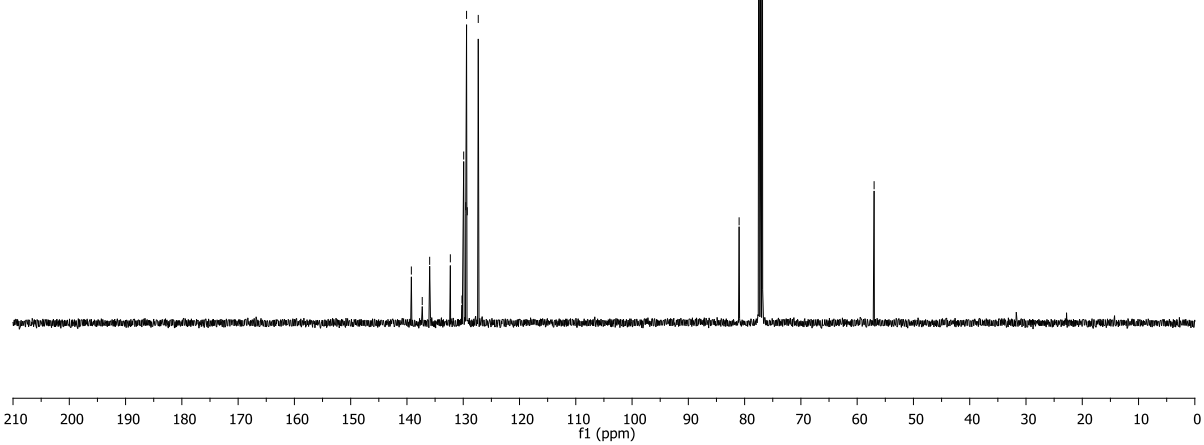
($CDCl_3$, 400 MHz)

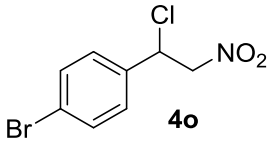




4n

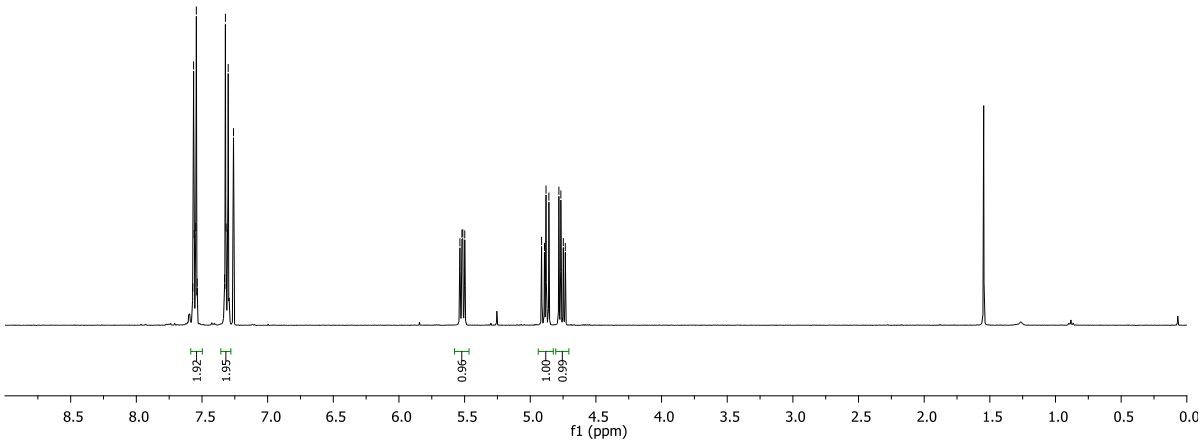
($CDCl_3$, 101 MHz)

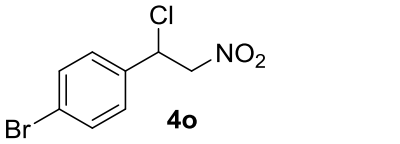




4o

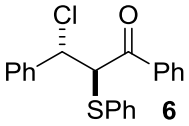
($CDCl_3$, 400 MHz)





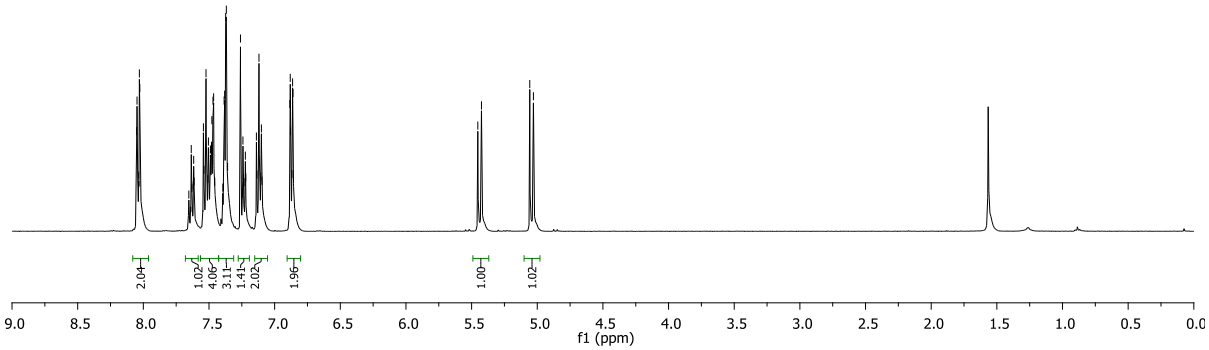
4o

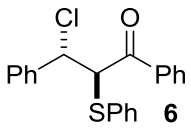
($CDCl_3$, 101 MHz)



6

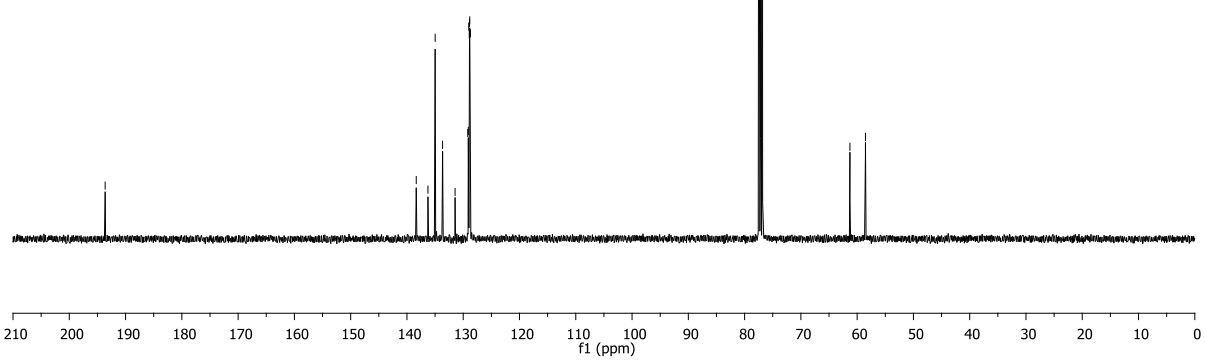
($CDCl_3$, 400 MHz)

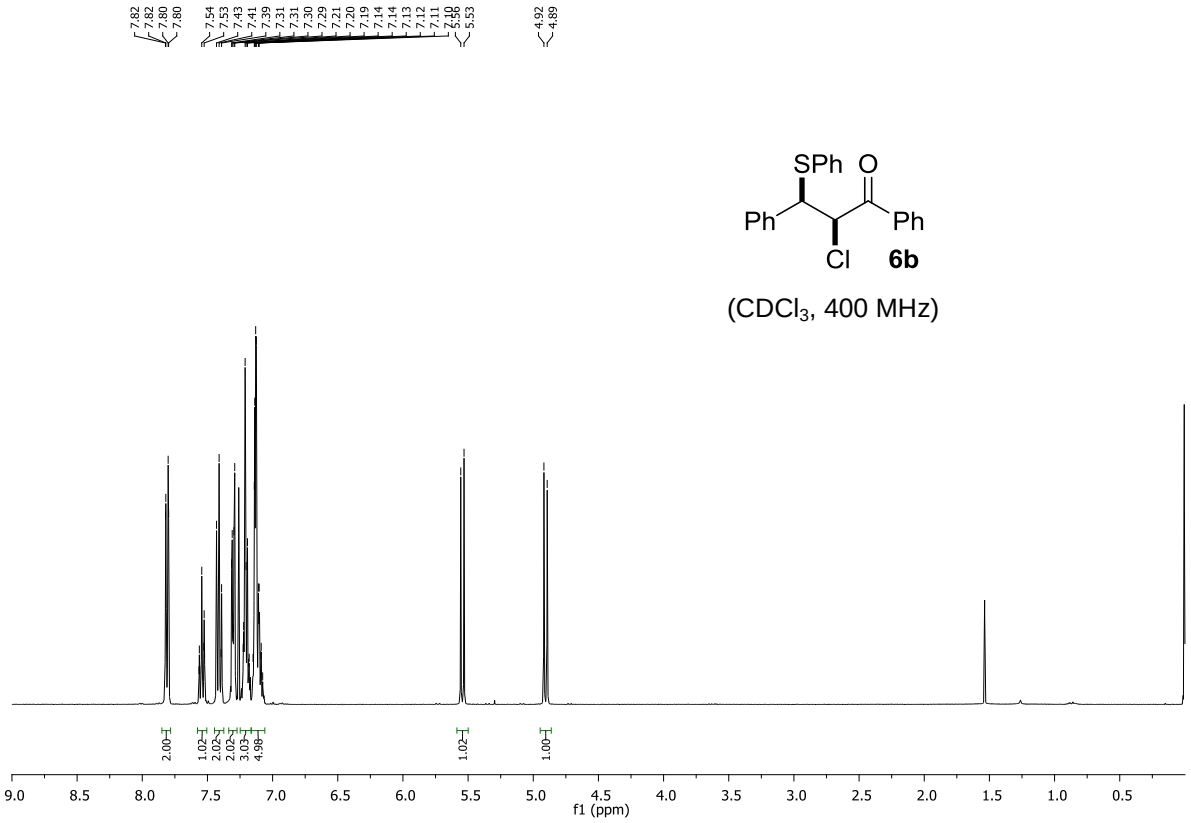


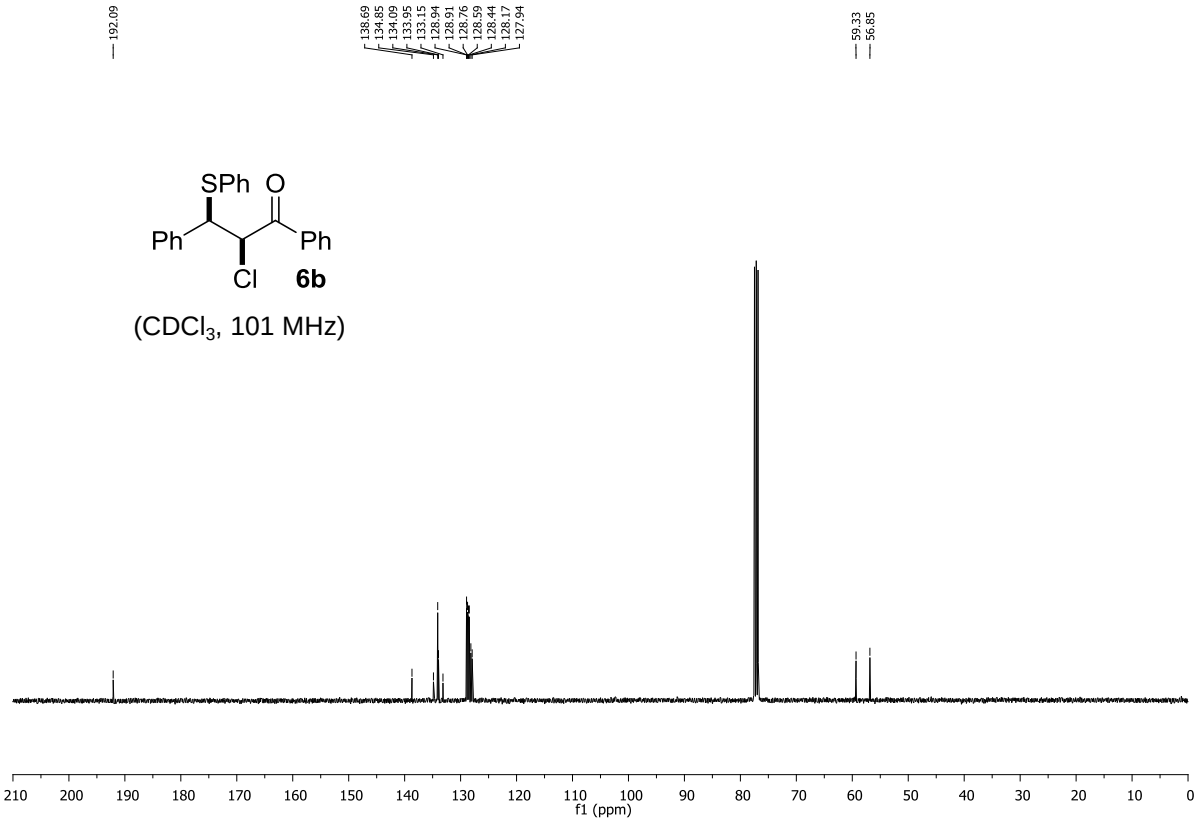


6

($CDCl_3$, 101 MHz)




7.82
7.82
7.80
7.80
7.54
7.53
7.43
7.41
7.39
7.31
7.31
7.30
7.29
7.21
7.20
7.19
7.14
7.13
7.12
7.11
5.58
5.53
4.92
4.89
SPh O
Ph
Ph
Cl
6b
(CDCl3, 400 MHz)
2.00
1.02
2.02
2.02
3.03
4.98
1.02
1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


192.09
138.69
134.85
134.09
133.95
133.15
128.94
128.91
128.76
128.59
128.44
128.17
127.94
59.33
56.85
SPh O
Ph
Ph
Cl
6b
(CDCl3, 101 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)