Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting information

Visible-Light Photoredox-Catalyzed Aryl Radical *in situ* SO_2-capture Reactions

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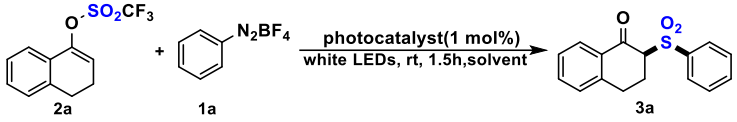
1. General Information

Unless otherwise mentioned, all commercial reagents and solvents were used without further purification. Thin layer chromatography (TLC) was performed on pre-coated silica gel GF254 plates. Visualization of TLC was achieved by the use of UV light (254 nm). Column chromatography was performed on silica gel (300-400 mesh) using a proper eluent. ^{1}H NMR was recorded on FT AM 400 (400 MHz). Chemical shifts were reported in parts per million (ppm) referenced to the appropriate solvent peak or 0.0 ppm for tetramethylsilane or chloroform-d ($CDCl_3$) at 7.26 ppm. The following abbreviations were used to describe peak splitting patterns: brs = broad, s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublet, td = triplet of doublet, ddd = doublet of doublet of doublet, m = multiplet. Coupling constants, *J*, were reported in hertz (Hz). The fully decoupled ^{13}C NMR was recorded on FT AM 400 (101 MHz). Chemical shifts were reported in ppm referenced to the center of a triplet at 77.36 ppm of chloroform-d. Infrared (IR) spectra were recorded neat in KBr cell. Frequencies are given in centimeter inverse (cm^{-1}) and only selected absorbance is reported. High resolution mass spectra were obtained by using the UHD Accurate-Mass Q-TOF. Vinyl triflates[1], arenediazonium salts[2], propylene triflones[3], acetylenic triflones[4] were prepared from the corresponding materials according to previously reported methods.

2. Detailed Optimization of Reaction Conditions

2.1 Table S1: Screen of the reaction condition for synthesis of 3a

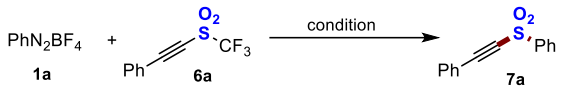


Entry	1a:2a	photocatalyst	solvent	c/mol.L^{-1}	yield
1	1:1	$Ir(ppy)_2(dtbbpy)PF_6$	DMF	0.05	10%
2	1:1	$Ru(bpy)_3$	DMF	0.05	15%
3	1:1	$Ru(bpy)_3Cl_2$	DMF	0.05	26%
4	1:1	Acridine•HCl	DMF	0.05	0%
5	1:1	$Ir(dFMeppy)_2(bpy)•PF_6$	DMF	0.05	15%
6	1:1	$Ir(ppy)_3$	DMF	0.05	0%
7	1:1.5	$Ru(bpy)_3Cl_2$	1,4-dioxane	0.05	38%
8	1:1.5	$Ru(bpy)_3Cl_2$	1,4-dioxane	0.10	63%
9	1:1.5	$Ru(bpy)_3Cl_2$	1,4-dioxane	0.20	59%
10[b]	**1:2.0**	**$Ru(bpy)_3Cl_2$**	**1,4-dioxane**	**0.10**	**75%**
11	1:2.0	$Ru(bpy)_3Cl_2$(0.5 mol%)	1,4-dioxane	0.20	61%
12	1:2.0	--	1,4-dioxane	0.20	18%
13[c]	1:2.0	$Ru(bpy)_3Cl_2$	1,4-dioxane	0.20	trace

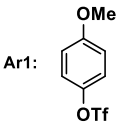
[a] A 10 mL Schlenk tube filled with argon, **1a**(0.2 mmol), **4a**(0.4 mmol), photocatalyst(1 mol%) and solvent were added under argon atmosphere. Irradiated by white LEDs(24 W) and stirred for 1 hour. Isolated yield.[b] With **1a**(0.4 mmol), **4a**(0.8 mmol). [c] The reaction was stirred in dark.

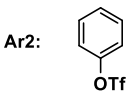
As shown in Table S1, among the conditions tested, when under the **condition A** (entry 10), the reaction gave the best result, and we confirmed the condition for the further substrates scope exploration.

2.2 Table S2: Screen of the reaction condition for synthesis of 7a



Entry	1a:6a	photocatalyst	solvent	Additive1	Additive2	yield
1	1:1.5	$Ru(bpy)_3Cl_2$	dioxane	--	--	21%
2	1:1.5	$Ru(bpy)_3Cl_2$	DMF	--	--	11%
3	1:1	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(0.5 eq.)	--	31%
4	1:1	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(1.0 eq.)	--	30%
5	1:1	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(2.0 eq.)	--	32%
6	1:1	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(4.0 eq.)		36%
7	1.5	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(8.0 eq.)		35%
8	1.5	$Ru(bpy)_3Cl_2$	DMF	Mesitylene(4.0 eq.)		30%
9	1.5	$Ru(bpy)_3Cl_2$	MeCN	Mesitylene(4.0 eq.)		trace
10	1.5	$Ru(bpy)_3Cl_2$	DMSO	Mesitylene(4.0 eq.)		--
11	1.5	$Ru(bpy)_3Cl_2$	dioxane	Ar1(4.0 eq.)		mess
12	1.5	$Ru(bpy)_3Cl_2$	dioxane	Ar2(4.0 eq.)		mess
13	1:1.5	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(4.0 eq.)	MS4Å	39%
14	1:2.0	$Ru(bpy)_3Cl_2$	dioxane	Mesitylene(4.0 eq.)	MS4Å	43%
15[c]	**1:2.0**	**$Ru(bpy)_3Cl_2$**	**dioxane**	**Mesitylene(4.0 eq.)**	**MS4Å**	**47%**



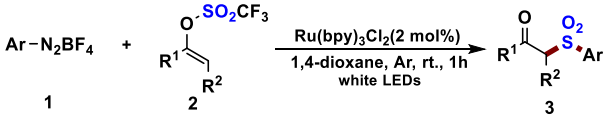


[a] A 10 mL Schlenk tube filled with argon, **1a**, **6a**, photocatalyst(1 mol%), additive, solvent were added under argon atmosphere. Irradiated by white LEDs(24 W) and stirred for 2 hours. Isolated yield. [b] With activated MS4Å (100 mg) [c] With 0.5 mol% $Ru(bpy)_3Cl_2$, and stirred for 12 h.

As shown in Table S2, among the conditions tested, when under the **condition** (entry 15), the reaction gave the best result, and we confirmed the condition for the further substrates scope exploration.

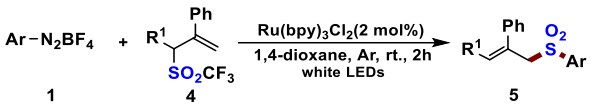
3. General Procedures for *in situ* SO2 Capture Reaction

3.1 General procedures for synthesis *β*-ketone sulfones 3



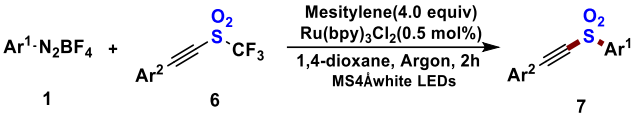
Condition A: Under Argon atmosphere, **1**(0.4 mmol), **2**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane (4 mL). After that, the solution was stirred under irritation of white LEDs for 1 hour. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products.

3.2 General procedures for synthesis allyl sulfones 5



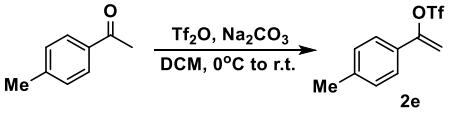
Condition B: Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane (4 mL). After that, the solution was stirred under irritation of white LEDs for 2 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5**.

3.3 General procedures for synthesis alkynyl sulfones 7



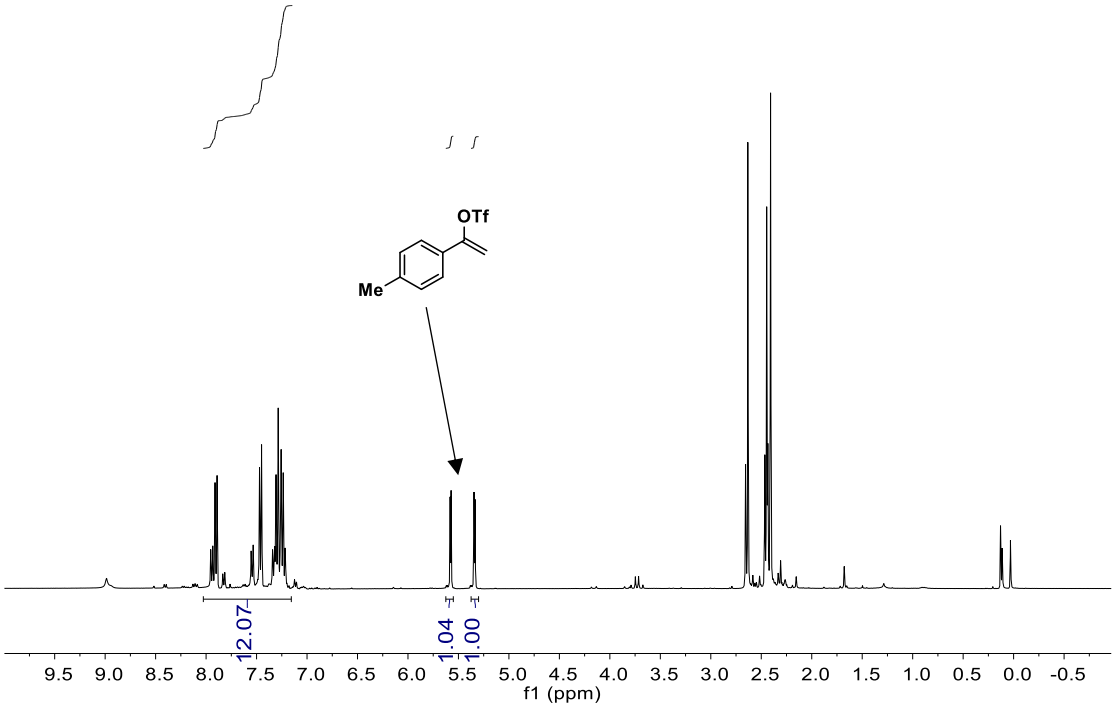
Condition C: Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), Mesitylene(0.8 mmol), activated MS4Å(100 mg), ($Ru(bpy)_3Cl_2$(0.5 mol%) were dissolved in 1,4-dioxane (1 mL). After that, the solution was stirred under irritation of white LEDs(24 W) for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/DCM 2:1~1:1) to afford the aim products **7**.

3.4 Synthesis of 2e

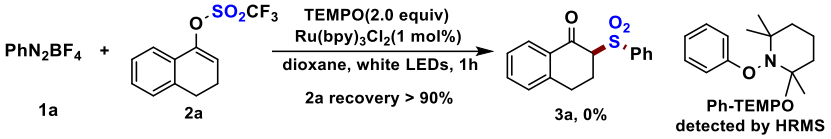


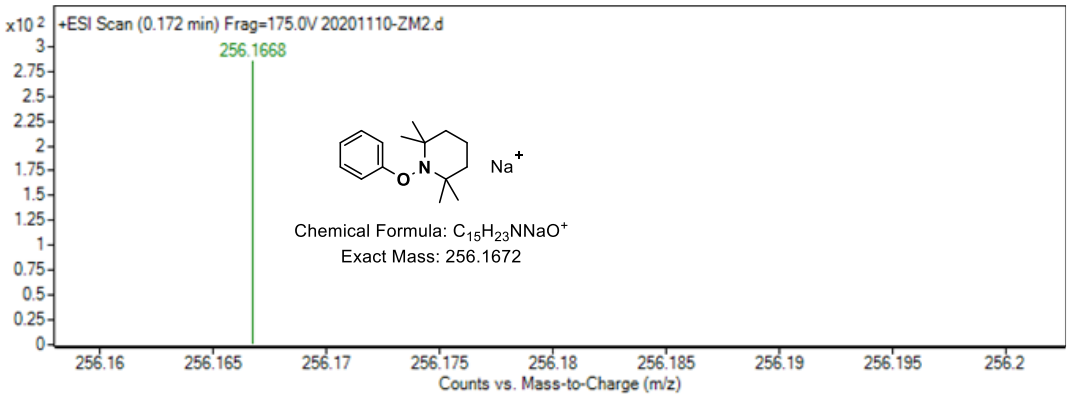
To a solution of 1-(*p*-tolyl)ethan-1-one (10 mmol, 1.34 g) and Na_2CO_3 (20 mmol, 2.12g) in DCM (15 ml) was cooled to 0 ºC, Tf_2O(15 mmol, 4.23g, dissolved in 10 mL DCM) was added dropwise to the solution. The mixture was warmed to room temperature and stirred for another 12 h. $NaHCO_3$(sat. 50 mL) $NaHCO_3$ (sat. 50 mL) was poured to the solution, and petroleum(100 mL) was added. The organic layer was separate and washed with more $NaHCO_3$ (sat. aq. 50 mL), brine (sat. 50 mL), and dried over Na2SO4, the solvent was removed under reduced pressure and afford the crude product 2j (mix with1-(*p*-tolyl)ethan-1-one, 4:8, about 50 wt.%). The mixture was used in the synthesis of beta-ketone sulfone reaction without further purification.

Crude **^{1}H NMR** for the mixture.

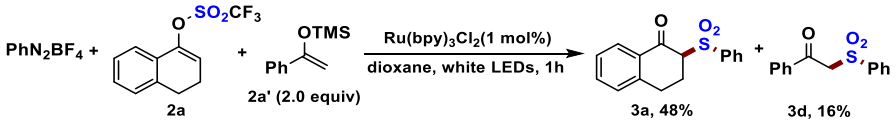


3.5 General procedures for control experiments

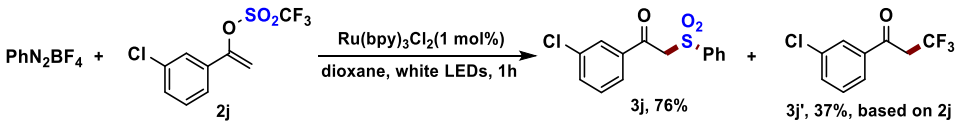




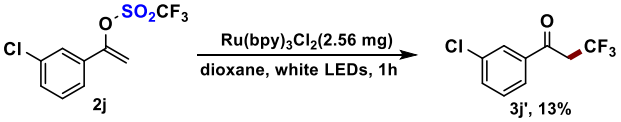
Under the standard condition, TEMPO(2.0 eq.) was added to the reaction, TLC and ^{1}H NMR spectrum showed that the generation of **3aa** was inhabited completely, and the phenyl-TEMPO adduct could be detected by HRMS analysis, this result suggested that the phenyl radical was generated in the reaction.



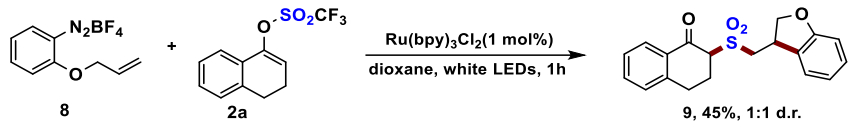
Under the standard condition, silyl enol ether **2a'**(2.0 eq.) was added to the reaction. Besides the product **3a** was detected in 48% yield and the product **3d** could also be detected in 16% yield by ^{1}H NMR (use CH_2Br_2 as internal standard), this result suggested that the product is generate via intermolecular addition other than an intramolecular sulfonyl shift process.



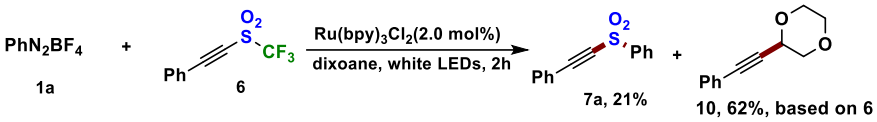
Under the standard condition, besides the product **3j** was obtained in 76% yield and the byproduct **3j'** could also be isolated in 37% yield, this result suggested that part of enol triflates could serve as SO_2 source in the reaction.



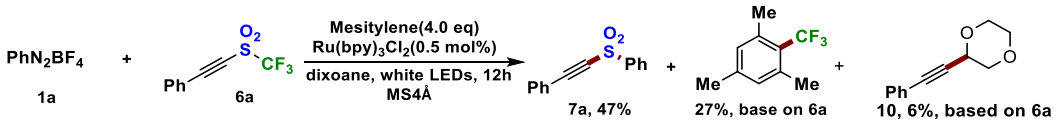
Under the standard condition, **2j** could transform into **3j`** directly under standard condition, which reveal how the iniatial SO_2 come into being.



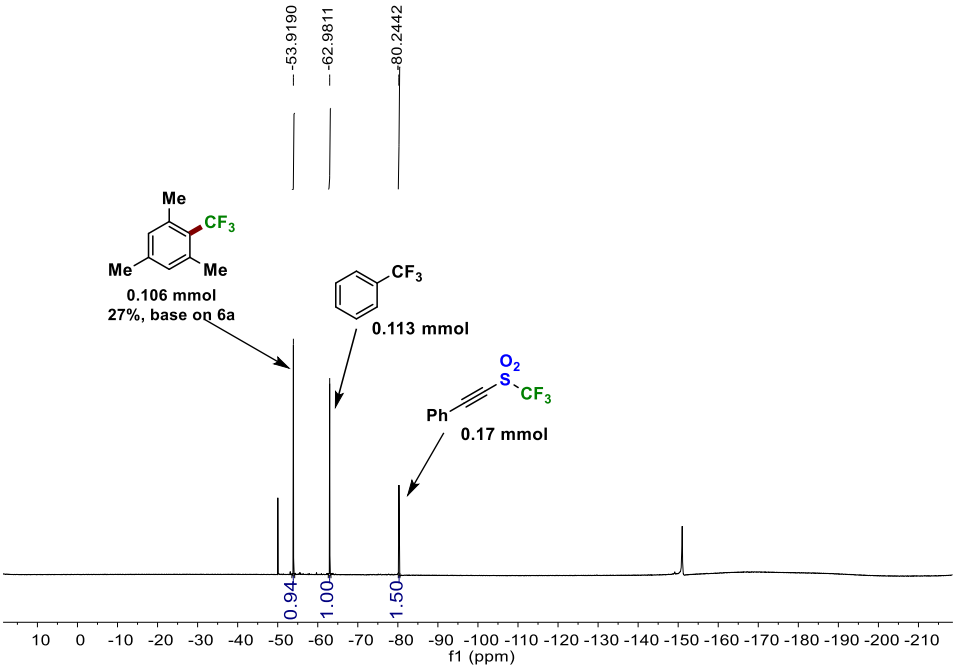
Under the standard condition, applied aryl diazo compound **8** (0.2 mmol) and enol triflate **2a** (0.4 mmol) as substrates, the product **9** could isolated in 45% yield. This result indicated that initiate from the aryl diazo compound.



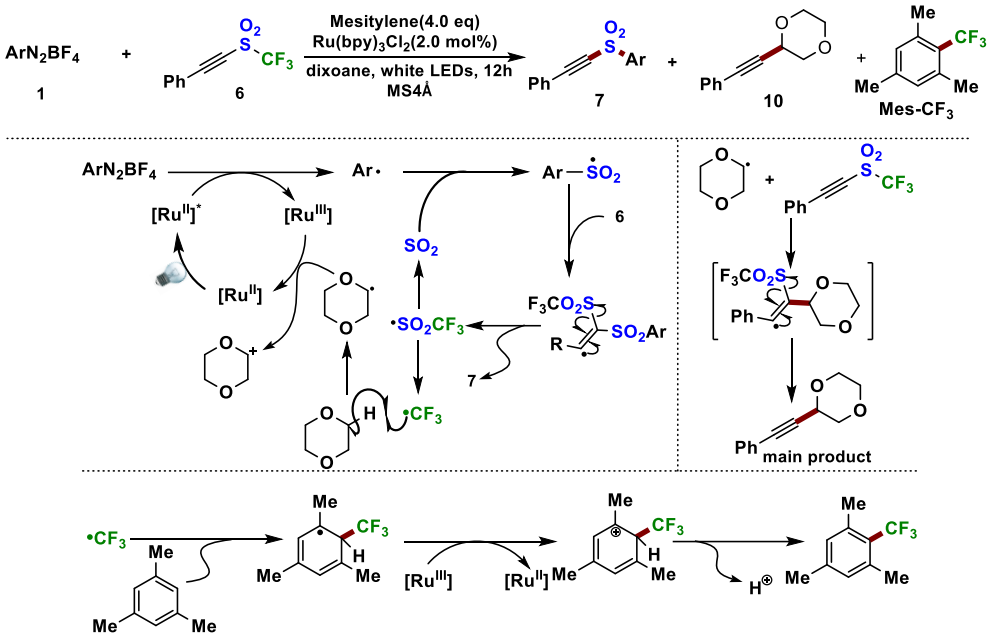
Under initial condition of *de*-CF_3 arylation reaction, the side product **10** could be isolated in 32% yield, this result suggested that solvent have a great influence in target product yield.



Under standard condition of *de*-CF_3 arylation reaction, the side product Mes-CF_3 could be detected in 0.106 mmol(27%, based on **1a,** determined by ^{19}F NMR), this result suggested that the mesitylene could combine with trifluoromethyl radical to complete the catalytic cycle.

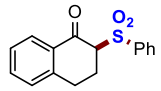


4. Proposed Mechanism for Synthesis of alkynyl arylsulfones



5. Spectroscopic Data

2-(phenylsulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3a)[5]

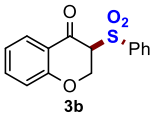


3a

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 85.7 mg, yield: 75%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.90 (m, 3H), 7.68 (dd, *J* = 9.1, 5.7 Hz, 1H), 7.63 – 7.48 (m, 3H), 7.37 – 7.24 (m, 2H), 4.14 (t, *J* = 5.8 Hz, 1H), 3.50 (ddt, *J* = 16.5, 10.6, 5.6 Hz, 1H), 3.01 (dt, *J* = 17.1, 5.3 Hz, 1H), 2.91 – 2.79 (m, 1H), 2.67 (ddt, *J* = 14.3, 9.7, 4.8 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.6, 143.6, 139.0, 134.5, 134.0, 131.7, 129.1, 129.0, 129.0, 127.9, 127.9, 127.1, 69.6, 26.6, 23.6. Spectroscopic data matched with the reported data in the literature.

3-(phenylsulfonyl)chroman-4-one (3b)

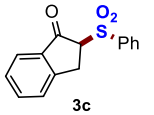


3b

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 4:1); white solid, 98.2 mg, yield: 85%; M.p. = 155~157 ºC.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (dd, *J* = 12.4, 7.9 Hz, 3H), 7.59 (t, *J* = 7.5 Hz, 1H), 7.47 (t, *J* = 7.2 Hz, 3H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.88 (d, *J* = 8.4 Hz, 1H), 5.29 (dd, *J* = 12.9, 2.6 Hz, 1H), 4.73 (dd, *J* = 12.9, 4.1 Hz, 1H), 4.06 (d, *J* = 3.5 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 182.5, 160.8, 137.9, 137.0, 134.4, 129.3, 128.9, 127.5, 122.1, 120.5, 118.1, 68.7, 66.0. **IR** (KBr, cm^{-1}): 1686, 1605, 1477, 1465, 1308, 1275, 1148, 751, 725, 686, 590, 504. **HRMS** m/z (ESI) calcd. for $C_{15}H_{12}NaO_4S^+$ $(M + Na)^+$ 311.0349, found 311.0351.

2-(phenylsulfonyl)-2,3-dihydro-1H-inden-1-one (3c)[6]

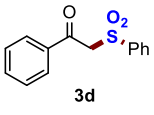


3c

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 82.6 mg, yield: 76%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.6, 1.6 Hz, 2H), 7.71 – 7.52 (m, 5H), 7.48 (d, *J* = 7.7 Hz, 1H), 7.37 (t, *J* = 7.5 Hz, 1H), 4.31 (dd, *J* = 8.4, 3.4 Hz, 1H), 3.79 (dd, *J* = 18.3, 3.4 Hz, 1H), 3.53 (dd, *J* = 18.3, 8.4 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 194.5, 151.9, 137.6, 136.0, 135.8, 134.2, 129.2, 129.1, 128.2, 126.5, 124.8, 68.7, 28.2. Spectroscopic data matched with the reported data in the literature.

1-phenyl-2-(phenylsulfonyl)ethan-1-one (3d)[7]

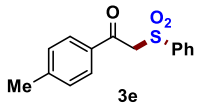


3d

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); White solid, 82.4 mg, yield: 79%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (t, *J* = 8.3 Hz, 4H), 7.62 (dt, *J* = 18.1, 7.4 Hz, 2H), 7.49 (dt, *J* = 29.1, 7.7 Hz, 4H), 4.77 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.1, 138.8, 135.7, 134.4, 134.2, 129.3, 129.2, 128.9, 128.5, 63.4. Spectroscopic data matched with the reported data in the literature.

2-(phenylsulfonyl)-1-(p-tolyl)ethan-1-one (3e)[8]



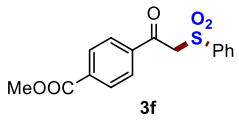
3e

Due to the purification of enol triflates 2e was failed(decomposed both in silica gel and Al_2O_3 column), we used a mixture of ketone and enol triflate **2e** (about 8:4, 50 wt%)(425 mg) as the substrate. According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); White solid, 50.6 mg, yield: 46%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.98 – 7.78 (m, 4H), 7.65 (d, *J* = 7.4 Hz, 1H), 7.54 (t, *J* = 7.8 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 4.74 (s, 2H), 2.42 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 187.55, 145.64, 138.76, 134.22, 133.28, 129.58, 129.46, 129.21, 128.56, 63.33, 21.82.

Spectroscopic data matched with the reported data in the literature.

methyl 4-(2-(phenylsulfonyl)acetyl)benzoate (3f)[8]

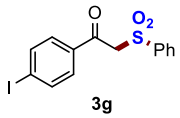


3f

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 88.6 mg, yield: 69%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 – 8.09 (m, 2H), 8.03 – 7.96 (m, 2H), 7.94 – 7.86 (m, 2H), 7.73 – 7.64 (m, 1H), 7.56 (dd, *J* = 8.4, 7.2 Hz, 2H), 4.79 (s, 2H), 3.96 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 187.7, 165.9, 138.7, 138.6, 134.9, 134.4, 130.0, 129.3, 129.2, 128.5, 63.7, 52.6. Spectroscopic data matched with the reported data in the literature.

1-(4-iodophenyl)-2-(phenylsulfonyl)ethan-1-one (3g)[9]



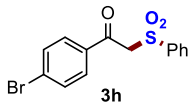
3g

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 121.4 mg, yield: 79%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.83 (m, 4H), 7.72 – 7.64 (m, 3H), 7.57 (t, *J* = 7.7 Hz, 2H), 4.71 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 187.4, 138.6, 138.2, 135.0, 134.4, 130.5, 129.3, 128.5, 103.1, 63.5. Spectroscopic data matched with the reported data in the literature.

1-(4-bromophenyl)-2-(phenylsulfonyl)ethan-1-one (3h)[9]

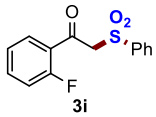
According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 88.4 mg, yield: 67%.



3h

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.85 (m, 2H), 7.82 (d, *J* = 8.6 Hz, 2H), 7.73 – 7.52 (m, 5H), 4.73 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 187.1, 138.6, 134.5, 134.4, 132.2, 130.8, 130.0, 129.3, 128.5, 63.5. Spectroscopic data matched with the reported data in the literature.

1-(2-fluorophenyl)-2-(phenylsulfonyl)ethan-1-one (3i)[10]

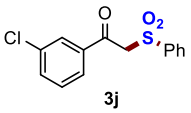


3i

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 83.2 mg, yield: 74%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 – 7.86 (m, 2H), 7.79 (td, *J* = 7.7, 1.9 Hz, 1H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.53 (q, *J* = 8.0 Hz, 3H), 7.22 (d, *J* = 7.6 Hz, 1H), 7.09 (dd, *J* = 11.6, 8.3 Hz, 1H), 4.81 (s, 2H). **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 185.9 (d, *J* = 3.1 Hz), 161.8 (d, *J* = 255.3 Hz), 139.1, 136.1 (d, *J* = 9.5 Hz), 134.1, 131.1 (d, *J* = 1.6 Hz), 129.2, 128.5, 124.8 (d, *J* = 3.4 Hz), 124.5 (d, *J* = 11.0 Hz), 116.8 (d, *J* = 23.6 Hz), 67.0 (d, *J* = 8.7 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -108.65. Spectroscopic data matched with the reported data in the literature.

1-(3-chlorophenyl)-2-(phenylsulfonyl)ethan-1-one (3j)[11]

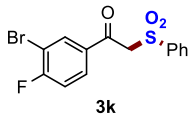


3j

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 95.0 mg, yield: 82%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.81 (m, 4H), 7.68 (t, *J* = 7.5 Hz, 1H), 7.57 (q, *J* = 8.1, 6.3 Hz, 3H), 7.43 (t, *J* = 7.9 Hz, 1H), 4.74 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 187.0, 138.6, 137.2, 135.2, 134.4, 134.3, 130.2, 129.3, 129.1, 128.5, 127.5, 63.5. Spectroscopic data matched with the reported data in the literature.

1-(3-bromo-4-fluorophenyl)-2-(phenylsulfonyl)ethan-1-one (3k)

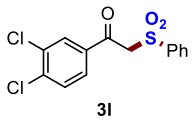


3k

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 92.4 mg, yield: 65%; M.p. = 138~140 ºC.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dd, *J* = 6.5, 2.3 Hz, 1H), 7.95 (ddd, *J* = 8.6, 4.6, 2.3 Hz, 1H), 7.92 – 7.85 (m, 2H), 7.72 – 7.65 (m, 1H), 7.57 (t, *J* = 7.8 Hz, 2H), 7.22 (t, *J* = 8.3 Hz, 1H), 4.73 (s, 2H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 185.6, 162.7 (d, *J* = 258.1 Hz), 138.5, 135.2 (d, *J* = 2.1 Hz), 134.5, 133.2 (d, *J* = 3.5 Hz), 130.9 (d, *J* = 8.9 Hz), 129.4, 128.5, 117.0 (d, *J* = 23.2 Hz), 110.2 (d, *J* = 21.9 Hz), 63.5. **IR** (KBr, cm^{-1}): 1681, 1587, 1489, 1322, 1275, 1261, 1154, 1084, 763, 749, 686, 556. **HRMS** m/z (ESI) calcd. for $C_{14}H_{10}BrFNaO_3S^+$ $(M + Na)^+$ 378.9410, found 378.9408.

1-(3,4-dichlorophenyl)-2-(phenylsulfonyl)ethan-1-one (3l)[12]

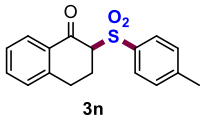


3l

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 99.6 mg, yield: 68%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 2.2 Hz, 1H), 7.93 – 7.86 (m, 2H), 7.82 (dd, *J* = 8.4, 2.2 Hz, 1H), 7.71 (t, *J* = 7.4 Hz, 1H), 7.59 (dt, *J* = 7.8, 3.5 Hz, 3H), 4.71 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 186.0, 139.3, 138.5, 135.2, 134.5, 133.7, 131.1, 131.0, 129.4, 128.5, 128.4, 63.6. Spectroscopic data matched with the reported data in the literature.

2-tosyl-3,4-dihydronaphthalen-1(2H)-one (3n)[13]

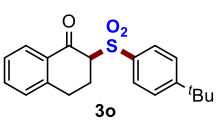


3n

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 98.4 mg, yield: 82%.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.85 – 7.77 (m, 2H), 7.53 (td, *J* = 7.5, 1.4 Hz, 1H), 7.41 – 7.25 (m, 4H), 4.11 (t, *J* = 5.7 Hz, 1H), 3.53 (ddd, *J* = 17.0, 9.7, 4.7 Hz, 1H), 3.00 (dt, *J* = 17.0, 5.5 Hz, 1H), 2.87 (dq, *J* = 17.0, 5.6 Hz, 1H), 2.67 (dq, *J* = 9.5, 4.8 Hz, 1H), 2.47 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.8, 145.1, 143.6, 136.0, 134.5, 131.8, 129.7, 129.1, 128.9, 127.9, 127.0, 69.7, 26.6, 23.7, 21.7. Spectroscopic data matched with the reported data in the literature.

2-((4-(tert-butyl)phenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3o)



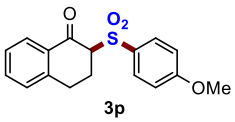
3o

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 83.4 mg, yield: 71%; M.p. = 122~124ºC.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.91 – 7.79 (m, 2H), 7.62 – 7.46 (m, 3H), 7.28 (dt, *J* = 14.6, 7.9 Hz, 2H), 4.13 (dd, *J* = 6.3, 5.3 Hz, 1H), 3.48 (ddd, *J* = 16.9, 9.5, 4.7 Hz, 1H), 2.98 (dt, *J* = 17.0, 5.5 Hz, 1H), 2.82 (dtd, *J* = 14.1, 6.2, 4.7 Hz, 1H), 2.64 (ddt, *J* = 14.4, 9.9, 5.1 Hz, 1H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.8, 157.9, 143.6, 136.0, 134.4, 131.8, 129.0, 128.9, 127.9, 127.0, 126.0, 69.7, 35.3, 31.1, 26.6, 23.8. **IR** (KBr, cm^{-1}): 1681, 1595, 1455, 1399, 1316, 1274, 1107, 764, 659, 577,557, 486. **HRMS** m/z (ESI) calcd. for $C_{20}H_{22}NaO_3S^+$ $(M + Na)^+$ 365.1182, found 365.1190.

2-((4-methoxyphenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3p)

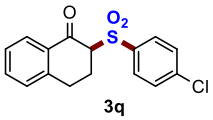
According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); yellow solid, 55.8 mg, yield: 44%; M.p. = 133~135°C.



3p

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.9 Hz, 1H), 7.84 (d, *J* = 8.6 Hz, 2H), 7.51 (t, *J* = 7.5 Hz, 1H), 7.34 – 7.24 (m, 2H), 7.02 (d, *J* = 8.6 Hz, 2H), 4.09 (t, *J* = 5.8 Hz, 1H), 3.88 (s, 3H), 3.56 – 3.43 (m, 1H), 2.98 (dt, *J* = 17.1, 5.6 Hz, 1H), 2.83 (dq, *J* = 17.3, 5.6 Hz, 1H), 2.65 (tt, *J* = 9.6, 5.1 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 189.0, 164.0, 143.6, 134.4, 131.8, 131.4, 130.4, 129.0, 127.9, 127.0, 114.2, 69.9, 55.7, 26.6, 23.8. **IR** (KBr, cm^{-1}): 1681, 1594, 1578, 1497, 1298, 1262, 1113, 748, 679, 581, 536. **HRMS** m/z (ESI) calcd. for $C_{17}H_{16}NaO_4S^+$ $(M + Na)^+$ 339.0662, found 339.0666.

2-((4-chlorophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3q)

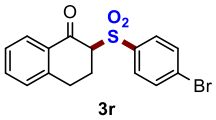


3q

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 70.8 mg, yield: 55%; M.p. = 123~125°C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 7.9 Hz, 1H), 7.87 (d, *J* = 8.3 Hz, 2H), 7.54 (d, *J* = 8.0 Hz, 3H), 7.35 – 7.26 (m, 2H), 4.13 (t, *J* = 6.1 Hz, 1H), 3.46 (ddd, *J* = 17.0, 9.1, 4.7 Hz, 1H), 3.01 (dt, *J* = 17.1, 5.8 Hz, 1H), 2.88 – 2.76 (m, 1H), 2.68 (ddt, *J* = 14.2, 9.8, 5.2 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.6, 143.5, 140.8, 137.5, 134.7, 131.6, 130.7, 129.3, 129.0, 127.9, 127.1, 69.7, 26.7, 23.5. **IR** (KBr, cm^{-1}): 1682, 1598, 1476, 1316, 1145, 1086, 1047, 1024, 758, 627, 539, 485. **HRMS** m/z (ESI) calcd. for $C_{16}H_{13}ClNaO_3S^+$ $(M + Na)^+$ 343.0166, found 343.0165.

2-((4-bromophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one(3r)

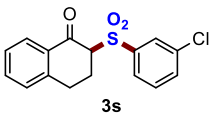


3r

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 76.0 mg, yield: 52%; M.p. = 130~132°C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.84 – 7.77 (m, 2H), 7.75 – 7.67 (m, 2H), 7.54 (td, *J* = 7.5, 1.5 Hz, 1H), 7.37 – 7.27 (m, 2H), 4.12 (dd, *J* = 6.7, 5.3 Hz, 1H), 3.47 (ddd, *J* = 17.0, 9.1, 4.7 Hz, 1H), 3.02 (dt, *J* = 17.0, 5.7 Hz, 1H), 2.84 (dtd, *J* = 13.5, 6.6, 4.7 Hz, 1H), 2.69 (ddt, *J* = 14.2, 9.1, 5.1 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.5, 143.5, 138.0, 134.6, 132.3, 131.6, 130.7, 129.5, 129.0, 127.9, 127.2, 69.7, 26.7, 23.5. **IR** (KBr, cm^{-1}): 1681, 1598, 1573, 1316, 1143, 1082, 1023, 743, 650, 553. **HRMS** m/z (ESI) calcd. for $C_{16}H_{13}BrNaO_3S^+$ $(M + Na)^+$ 386.9661, found 386.9663.

2-((3-chlorophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one(3s)

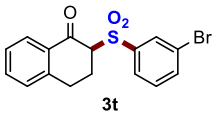


3s

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 72.0 mg, yield: 56%; M.p. = 123~125°C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 – 7.91 (m, 2H), 7.84 (dt, *J* = 7.9, 1.4 Hz, 1H), 7.65 (ddd, *J* = 8.1, 2.0, 1.0 Hz, 1H), 7.59 – 7.50 (m, 2H), 7.37 – 7.28 (m, 2H), 4.16 (dd, *J* = 6.7, 5.3 Hz, 1H), 3.48 (ddd, *J* = 17.0, 9.1, 4.7 Hz, 1H), 3.03 (dt, *J* = 17.0, 5.7 Hz, 1H), 2.85 (dtd, *J* = 13.6, 6.7, 4.7 Hz, 1H), 2.70 (ddt, *J* = 14.2, 9.1, 5.1 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.4, 143.5, 140.8, 135.2, 134.7, 134.1, 131.6, 130.3, 129.1, 129.0, 128.0, 127.4, 127.2, 69.7, 26.7, 23.5. **IR** (KBr, cm^{-1}): 1682, 1599, 1456, 1297, 1110, 1077, 681, 595, 561, 489, 444. **HRMS** m/z (ESI) calcd. for $C_{16}H_{13}ClNaO_3S^+$ $(M + Na)^+$ 343.0166, found 343.0168.

2-((3-bromophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3t)

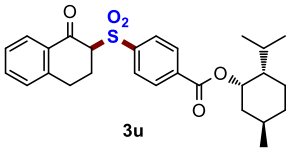


3t

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 93.4 mg, yield: 64%; M.p. = 128~130 °C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (s, 1H), 7.98 (d, *J* = 7.9 Hz, 1H), 7.88 (d, *J* = 7.9 Hz, 1H), 7.79 (d, *J* = 7.9 Hz, 1H), 7.54 (t, *J* = 7.5 Hz, 1H), 7.46 (t, *J* = 7.9 Hz, 1H), 7.36 – 7.27 (m, 2H), 4.16 (t, *J* = 6.1 Hz, 1H), 3.46 (ddd, *J* = 17.0, 9.0, 4.7 Hz, 1H), 3.02 (dt, *J* = 17.1, 5.8 Hz, 1H), 2.83 (dtd, *J* = 13.6, 6.7, 4.6 Hz, 1H), 2.69 (ddt, *J* = 14.2, 9.7, 5.1 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.4, 143.5, 140.9, 137.0, 134.6, 131.8, 131.6, 130.5, 129.0, 128.0, 127.9, 127.2, 122.9, 69.7, 26.7, 23.5. **IR** (KBr, cm^{-1}): 1703, 1646, 1569, 1354, 1145, 1081, 1023, 764, 594, 561, 484. **HRMS** m/z (ESI) calcd. for $C_{16}H_{13}BrNaO_3S^+$ $(M + Na)^+$ 386.9661, found 386.9662.

Product 3u

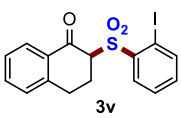


3u

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 125.4 mg, yield: 67%, 1:1 d.r.; M.p = 75~78 °C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 8.2 Hz, 2H), 7.99 (ddd, *J* = 11.6, 8.2, 1.6 Hz, 3H), 7.54 (td, *J* = 7.5, 1.4 Hz, 1H), 7.36 – 7.28 (m, 2H), 4.99 (td, *J* = 10.9, 4.4 Hz, 1H), 4.17 (ddd, *J* = 7.1, 5.5, 2.4 Hz, 1H), 3.50 (ddd, *J* = 16.8, 9.2, 4.7 Hz, 1H), 3.03 (dt, *J* = 17.1, 5.7 Hz, 1H), 2.88 (ddd, *J* = 14.2, 6.8, 5.0 Hz, 1H), 2.78 – 2.66 (m, 1H), 2.14 (dd, *J* = 12.1, 4.1 Hz, 1H), 1.96 (ddq, *J* = 13.5, 6.8, 3.5, 2.9 Hz, 1H), 1.79 – 1.72 (m, 2H), 1.66 – 1.54 (m, 2H), 1.21 – 1.10 (m, 2H), 1.00 – 0.90 (m, 7H), 0.81 (dd, *J* = 7.0, 1.3 Hz, 3H).**^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.5, 188.4, 164.5, 164.5, 143.5, 142.7, 142.6, 135.7, 134.7, 131.6, 130.1, 129.2, 129.0, 128.0, 127.2, 75.9, 69.6, 47.2, 40.9, 40.9, 34.2, 31.5, 26.7, 26.7, 26.5, 26.4, 23.6, 23.5, 23.4, 22.0, 20.8, 20.8, 16.5, 16.4. **IR** (KBr, cm^{-1}):2955, 1715, 1682, 1485, 1270, 1240, 1115, 738, 619, 538. **HRMS** m/z (ESI) calcd. for $C_{27}H_{32}NaO_5S^+$ $(M + Na)^+$ 491.1863, found 491.1861.

2-((2-iodophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3v)



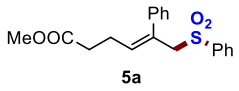
3v

According to the condition A, purification of the reaction mixture using column chromatography (petroleum ether/ethyl acetate = 5:1); white solid, 40.9 mg, yield: 25%; M.p. = 132~136°C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dd, *J* = 8.0, 1.6 Hz, 2H), 7.97 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.64 – 7.52 (m, 2H), 7.38 – 7.30 (m, 3H), 4.83 (t, *J* = 5.8 Hz, 1H), 3.51 (ddt, *J* = 17.5, 7.8, 4.7

Hz, 1H), 3.11 – 2.95 (m, 2H), 2.82 – 2.70 (m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.5, 143.6, 142.5, 141.6, 134.6, 134.6, 132.9, 131.7, 129.0, 128.6, 127.9, 127.1, 92.9, 66.2, 26.8, 22.7. **IR** (KBr, cm^{-1}): 1679, 1599, 1454, 1315, 1275, 1260, 1146, 1120, 1010, 755, 591, 488, 446. **HRMS** m/z (ESI) calcd. for $C^{16}H^{13}INaO^3S^+$ $(M + Na)^+$ 434.9522, found 434.9525.

methyl (E)-5-phenyl-6-(phenylsulfonyl)hex-4-enoate (5a)

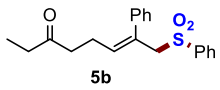


5a

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5aa**. Colorless oil, 84.2 mg, yield: 61%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.72 (m, 2H), 7.53 (t, *J* = 7.5 Hz, 1H), 7.41 (t, *J* = 7.7 Hz, 2H), 7.26 – 7.16 (m, 5H), 6.03 – 5.94 (m, 1H), 4.43 (s, 2H), 3.69 (s, 3H), 2.51 – 2.39 (m, 4H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 173.1, 140.6, 139.1, 136.1, 133.5, 129.3, 128.9, 128.4, 128.3, 127.4, 126.4, 57.6, 51.7, 33.2, 24.8. **IR** (KBr, cm^{-1}): 1732, 1446, 1307, 1276, 1163, 1136, 1084, 1024, 906, 764, 688, 530. **HRMS** m/z (ESI) calcd. for $C_{19}H_{20}NaO_4S^+$ $(M + Na)^+$ 367.0975, found 369.0977. The *E*-conformation was assigned by 2D NOE experiment.

(E)-7-phenyl-8-(phenylsulfonyl)oct-6-en-3-one (5b)

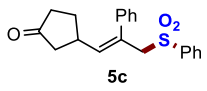


5b

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5ab**. Colorless oil, 82.2 mg, yield: 60%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.74 (m, 2H), 7.58 – 7.49 (m, 1H), 7.42 (dd, *J* = 8.4, 7.1 Hz, 2H), 7.26 – 7.14 (m, 5H), 5.96 (t, *J* = 7.6 Hz, 1H), 4.44 (s, 2H), 2.55 (t, *J* = 7.0 Hz, 2H), 2.42 (dt, *J* = 14.7, 7.3 Hz, 4H), 1.07 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 173.1, 140.6, 139.1, 136.1, 133.5, 129.3, 128.9, 128.4, 128.3, 127.4, 126.4, 57.6, 51.7, 33.2, 24.8. **IR** (KBr, cm^{-1}): 2977, 1712, 1446, 1306, 1135, 1804, 912, 764, 748, 688, 590, 530. **HRMS** m/z (ESI) calcd. for $C_{20}H_{22}NaO_3S^+$ $(M + Na)^+$ 365.1182, found 365.1185. The *E*-conformation was assigned by 2D NOE experiment.

(E)-3-(2-phenyl-3-(phenylsulfonyl)prop-1-en-1-yl)cyclohexan-1-one (5c)



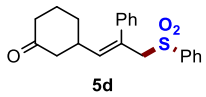
5c

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5ac**. Yellow oil, 99.2 mg, yield: 73%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.7 Hz, 2H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.22 – 7.10 (m, 5H), 5.89 (d, *J* = 10.1 Hz, 1H), 4.40 (s, 2H), 3.17 (dddd, *J* = 16.8, 13.1, 8.5, 5.1 Hz, 1H), 2.42 – 2.16 (m, 4H), 1.95 (dd, *J* = 18.3, 10.5 Hz, 1H), 1.84 – 1.64 (m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 217.9, 140.4, 140.3, 139.0, 133.7, 128.9, 128.5, 128.4, 128.3, 127.5, 126.4, 57.8, 44.8, 38.1, 37.4, 29.8. **IR** (KBr, cm^{-1}): 3058, 2932, 1740, 1446, 1307, 1135, 1084, 914, 743, 688, 610, 528. **HRMS** m/z (ESI) calcd. for $C_{20}H_{20}NaO_3S^+$ $(M + Na)^+$ 363.1025, found 363.1026. The *E*-conformation was assigned by 2D

NOE experiment.

(E)-3-(2-phenyl-3-(phenylsulfonyl)prop-1-en-1-yl)cyclohexan-1-one (5d)

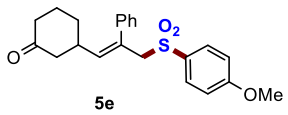


5d

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5ad**. Yellow oil, 106.1 mg, yield: 75%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, *J* = 7.5 Hz, 2H), 7.53 (t, *J* = 7.5 Hz, 1H), 7.40 (t, *J* = 7.6 Hz, 2H), 7.25 – 7.14 (m, 5H), 5.82 (d, *J* = 10.1 Hz, 1H), 4.36 (d, *J* = 3.0 Hz, 2H), 2.77 (qt, *J* = 10.6, 4.0 Hz, 1H), 2.45 – 2.34 (m, 1H), 2.34 – 2.21 (m, 2H), 2.20 – 2.02 (m, 2H), 1.86 – 1.66 (m, 2H), 1.52 (dtd, *J* = 13.4, 11.3, 3.5 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.8, 140.3, 140.1, 139.0, 133.7, 129.0, 128.4, 127.7, 127.6, 126.6, 57.5, 46.8, 41.1, 39.3, 31.0, 25.1. **IR** (KBr, cm^{-1}): 3032, 2930, 1741, 1442, 1280, 1130, 880, 721, 671, 586. **HRMS** m/z (ESI) calcd. for $C_{21}H_{22}NaO_3S^+$ $(M + Na)^+$ 377.1182, found 377.1184. The *E*-conformation was assigned by 2D NOE experiment.

(E)-3-(3-((4-methoxyphenyl)sulfonyl)-2-phenylprop-1-en-1-yl)cyclohexan-1-one (5e)

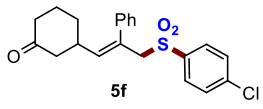


5e

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **4 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5bd**. Yellow oil, 93.6 mg, yield: 61%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.6 Hz, 2H), 7.27 – 7.12 (m, 5H), 6.84 (d, *J* = 8.6 Hz, 2H), 5.80 (d, *J* = 10.1 Hz, 1H), 4.33 (d, *J* = 3.2 Hz, 2H), 3.84 (s, 3H), 2.74 (qt, *J* = 10.7, 4.1 Hz, 1H), 2.47 – 2.35 (m, 1H), 2.26 (ddd, *J* = 21.9, 8.8, 4.2 Hz, 2H), 2.17 – 2.02 (m, 2H), 1.84 (dd, *J* = 13.3, 4.2 Hz, 1H), 1.70 (tt, *J* = 12.8, 4.2 Hz, 1H), 1.51 (dtd, *J* = 13.5, 11.4, 3.5 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.9, 163.7, 140.4, 139.8, 130.5, 130.3, 128.3, 128.1, 127.5, 126.6, 114.2, 57.7, 55.7, 46.9, 41.1, 39.3, 31.0, 25.1. **IR** (KBr, cm^{-1}): 2709, 1564, 1545, 1423, 1376, 1115, 1083, 949, 761, 669, 625, 556. **HRMS** m/z (ESI) calcd. for $C_{22}H_{24}NaO_4S^+$ $(M + Na)^+$ 407.1288, found 407.1288. The *E*-conformation was assigned by 2D NOE experiment.

(E)-3-(3-((4-chlorophenyl)sulfonyl)-2-phenylprop-1-en-1-yl)cyclohexan-1-one (5f)



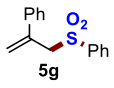
5f

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5g**. Yellow oil, 71.6 mg, yield: 46%, E/Z > 20:1.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.54 (m, 2H), 7.33 – 7.27 (m, 2H), 7.18 (dd, *J* = 5.0, 2.0 Hz, 3H), 7.13 – 7.04 (m, 2H), 5.83 (d, *J* = 10.1 Hz, 1H), 4.35 (d, *J* = 2.6 Hz, 2H), 2.84 (qt, *J* = 10.6, 4.0 Hz, 1H), 2.46 – 2.23 (m, 3H), 2.23 – 2.06 (m, 2H), 1.94 – 1.83 (m, 1H), 1.82 – 1.70 (m, 1H), 1.62 – 1.53 (m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.7, 140.4, 140.3, 140.1, 137.3, 129.9, 129.7, 128.4, 127.6, 127.5, 126.5, 57.7, 46.9, 41.1, 39.3, 31.0, 25.0. **IR** (KBr, cm^{-1}): 1709, 1507, 1445, 1323, 1276, 1135, 1083, 909,

764, 699, 615, 555. **HRMS** m/z (ESI) calcd. for $C_{21}H_{21}ClNaO_3S^+$ $(M + Na)^+$ 411.0792, found 411.0796. The *E*-conformation was assigned by 2D NOE experiment.

((2-phenylallyl)sulfonyl)benzene(5g)

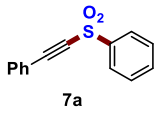


5g

Under Argon atmosphere, **1**(0.4 mmol), **4**(0.8 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(4 mL). After that, the solution was stirred under irritation of white LEDs for **4 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **5e**. Yellow oil, 42.4 mg, yield: 41%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.86 – 7.76 (m, 2H), 7.57 (t, *J* = 7.5 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 7.32 – 7.23 (m, 5H), 5.62 (s, 1H), 5.25 (s, 1H), 4.30 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 138.8, 138.4, 136.5, 133.6, 128.9, 128.7, 128.4, 128.1, 126.2, 121.9, 62.1. Spectroscopic data matched with the reported data in the literature.

((phenylethynyl)sulfonyl)benzene(7a)

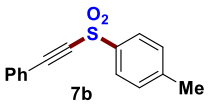


7a

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 10:1) to afford the aim products **7a**. Light yellow oil, 21.4 mg, yield: 43%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.19 – 8.08 (m, 2H), 7.76 – 7.69 (m, 1H), 7.63 (t, *J* = 7.7 Hz, 2H), 7.59 – 7.53 (m, 2H), 7.53 – 7.46 (m, 1H), 7.40 (t, *J* = 7.6 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.81, 134.18, 132.77, 131.60, 129.39, 128.71, 127.42, 117.88, 93.51, 85.34. Spectroscopic data matched with the reported data in the literature.

1-methyl-4-((phenylethynyl)sulfonyl)benzene(7b)[14]

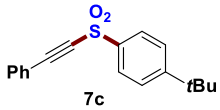


7b

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 10:1) to afford the aim products **7b**. Yellow soild, 21.1 mg, yield: 41%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06 – 7.95 (m, 2H), 7.58 – 7.46 (m, 3H), 7.40 (dt, *J* = 8.5, 7.1 Hz, 4H), 2.49 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 145.4, 139.0, 132.7, 131.4, 130.0, 128.7, 127.5, 118.04, 93.0, 85.6, 21.7. Spectroscopic data matched with the reported data in the literature.

1-(tert-butyl)-4-((phenylethynyl)sulfonyl)benzene(7c)[14]



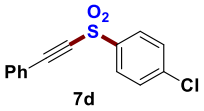
7c

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/DCM 1:1) to afford the aim products **7c**. Yellow soild, 30.4 mg, yield: 51%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.05 – 7.98 (m, 2H), 7.63 (d, *J* = 1.9 Hz, 1H), 7.62 – 7.44 (m, 4H), 7.43 – 7.34 (m, 2H), 1.39 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.3, 138.8, 132.8, 131.4, 128.7,

127.3, 126.4, 118.1, 93.0, 85.6, 35.4, 31.0. Spectroscopic data matched with the reported data in the literature.

1-chloro-4-((phenylethynyl)sulfonyl)benzene(7d)[14]

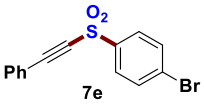


7d

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/DCM 1:1) to afford the aim products **7c**. Yellow soild, 27.6 mg, yield: 50%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.15 – 8.07 (m, 2H), 7.75 – 7.68 (m, 1H), 7.66 – 7.59 (m, 2H), 7.57 – 7.53 (m, 2H), 7.53 – 7.45 (m, 1H), 7.40 (t, *J* = 7.5 Hz, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 141.9, 134.1, 132.8, 131.6, 129.4, 128.7, 127.4, 117.9, 93.5, 85.4. Spectroscopic data matched with the reported data in the literature.

1-bromo-4-((phenylethynyl)sulfonyl)benzene(7e)[14]

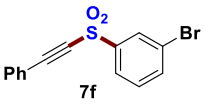


7e

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/DCM 1:1) to afford the aim products **7e**. Yellow soild, 36.0 mg, yield: 50%. Spectroscopic data matched with the reported data in the literature.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.08 – 8.00 (m, 2H), 7.64 – 7.57 (m, 2H), 7.57 – 7.47 (m, 3H), 7.45 – 7.36 (m, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 141.0, 140.3, 132.8, 131.7, 129.7, 128.9, 128.7, 117.7, 94.0, 85.1.

1-bromo-3-((phenylethynyl)sulfonyl)benzene(7f)[14]

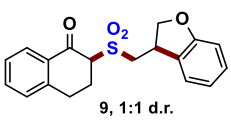


7f

Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), mesitylene(0.8 mmol), activated MS4Å(100 mg), $Ru(bpy)_3Cl_2$ (0.5 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 12 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/DCM 1:1) to afford the aim products **7f**. Yellow soild, 19.3 mg, yield: 30%. Spectroscopic data matched with the reported data in the literature.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.24 (t, *J* = 1.9 Hz, 1H), 8.04 (ddd, *J* = 7.9, 1.8, 1.0 Hz, 1H), 7.83 (ddd, *J* = 8.1, 2.0, 1.0 Hz, 1H), 7.62 – 7.46 (m, 4H), 7.42 (dd, *J* = 8.2, 6.9 Hz, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 143.6, 137.2, 132.9, 131.8, 130.9, 130.3, 128.8, 126.0, 123.3, 117.6, 94.4, 84.9.

Compound 9

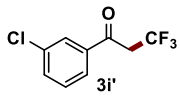


9, 1:1 d.r.

Under Argon atmosphere, **8**(0.2 mmol), **1**(0.4 mmol), $Ru(bpy)_3Cl_2$(1 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for **2 hours**. The crude products were purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 5:1~2:1) to afford the aim products **9**. Yellow oil, 35.8 mg, yield: 45%, 1:1 d.r..

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.09 (dd, *J* = 8.4, 3.0 Hz, 1H), 7.62 – 7.54 (m, 1H), 7.39 (t, *J* = 7.7 Hz, 1H), 7.34 – 7.27 (m, 2H), 7.21 (td, *J* = 8.0, 2.6 Hz, 1H), 6.94 (td, *J* = 7.5, 2.6 Hz, 1H), 6.86 (dd, *J* = 8.0, 2.1 Hz, 1H), 4.79 (q, *J* = 9.5 Hz, 1H), 4.61 (ddd, *J* = 16.1, 9.7, 6.3 Hz, 1H), 4.26 – 4.13 (m, 1H), 4.13 – 4.02 (m, 1H), 3.98 (dd, *J* = 7.2, 5.5 Hz, 1H), 3.82 – 3.73 (m, 1H), 3.42 (ddd, *J* = 13.6, 9.7, 4.5 Hz, 2H), 3.02 (ddd, *J* = 17.0, 7.1, 4.9 Hz, 1H), 2.85 (ddtd, *J* = 11.6, 8.9, 7.1, 4.5 Hz, 1H), 2.69 (tt, *J* = 14.1, 5.2 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 189.6, 189.5, 159.8, 159.7, 143.8, 135.0, 131.4, 129.4, 129.3, 129.0, 128.2, 127.3, 127.0, 126.9, 124.6, 124.4, 121.0, 120.9, 110.1, 110.0, 76.0, 76.0, 68.1, 66.8, 58.4, 58.0, 36.2, 35.8, 26.8, 26.72, 22.0, 21.8. **IR** (KBr, cm^{-1}): 1678, 1598, 1482, 1458, 1304, 1235, 1129, 1017, 966, 913, 748. **HRMS** m/z (ESI) calcd. for $C19H18NaO4S^+$ $(M + Na)^+$ 365.0818, found 365.0816.

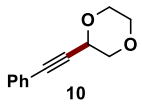
1-(3-chlorophenyl)-3,3,3-trifluoropropan-1-one[15]



Under Argon atmosphere, **3i** (0.8 mmol), $Ru(bpy)_3Cl_2$ (2.56 mg) were dissolved in 1,4-dioxane (4 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 1 hour. The crude products were purified by flash chromatography on silica gel (petroleum ether/EA 20:1) to afford the aim products **3i'**. Colorless oil, 65.7 mg, yield: 37%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.91 (t, *J* = 1.9 Hz, 1H), 7.82 (dt, *J* = 7.8, 1.3 Hz, 1H), 7.62 (ddd, *J* = 8.0, 2.1, 1.0 Hz, 1H), 7.48 (t, *J* = 7.9 Hz, 1H), 3.81 (q, *J* = 9.9 Hz, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.6, 188.6, 134.2, 130.3, 128.4, 126.4, 123.8 (q, *J* = 277.0 Hz), 42.2 (q, *J* = 28.5 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.09.

Compound 10[16]



Under Argon atmosphere, **1**(0.2 mmol), **6**(0.4 mmol), $Ru(bpy)_3Cl_2$ (2 mol%) were dissolved in 1,4-dioxane(1 mL). After that, the solution was stirred under irritation of white LEDs at room temperature for 2 hours. The crude products were purified by flash chromatography on silica gel (petroleum ether/EA 20:1) to afford the aim products **10**. Colorless oil, 24 mg, yield: 32%.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.48 (dd, *J* = 7.4, 2.1 Hz, 2H), 7.33 (d, *J* = 6.6 Hz, 3H), 4.59 (dd, *J* = 8.5, 2.9 Hz, 1H), 3.96 (dt, *J* = 11.5, 3.4 Hz, 2H), 3.80 – 3.68 (m, 4H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 131.9, 128.7, 128.3, 122.1, 86.6, 84.3, 70.4, 66.5, 66.4, 65.8. Spectroscopic data matched with the reported data in the literature.

6. Reference

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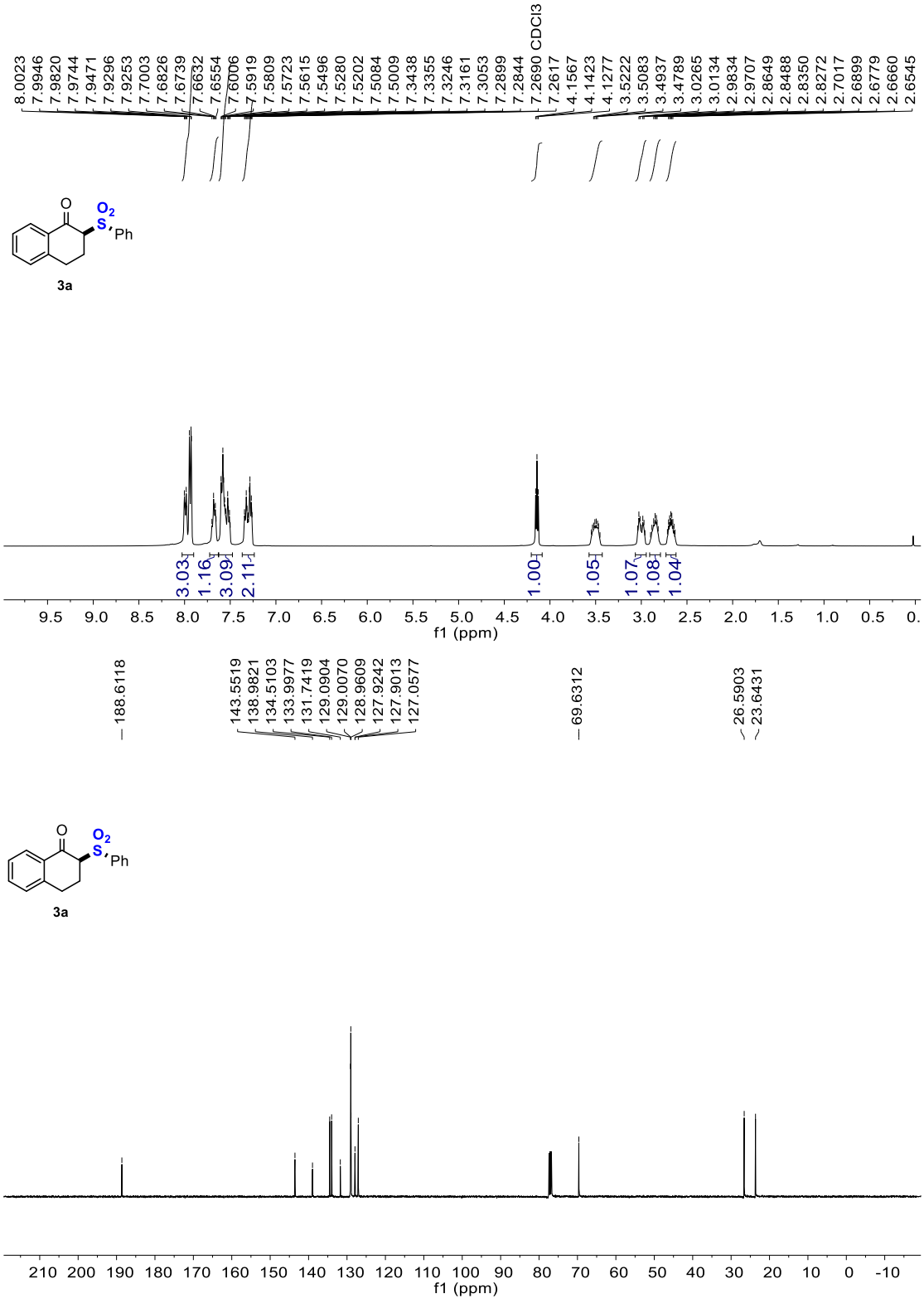
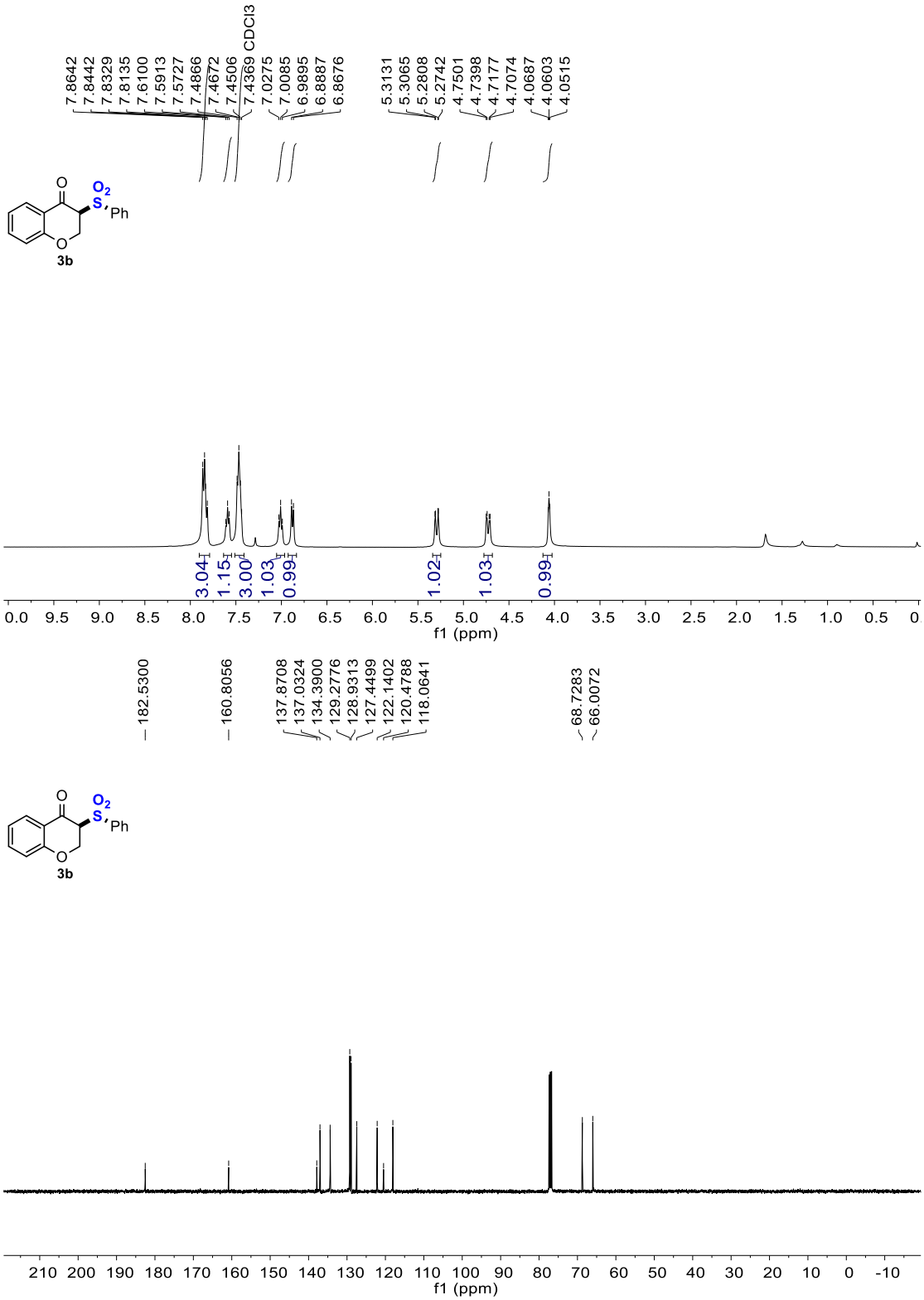
7. Copies of NMR spectra

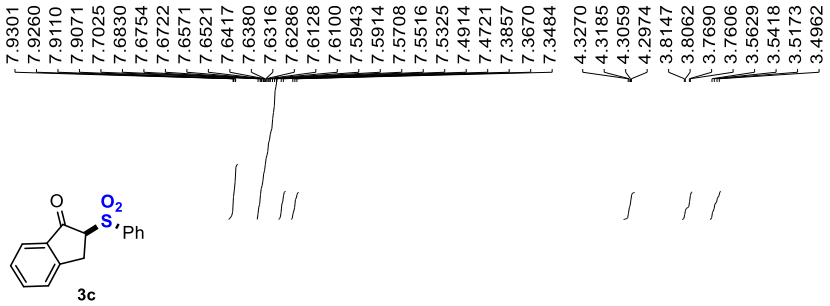
2-(phenylsulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3a)

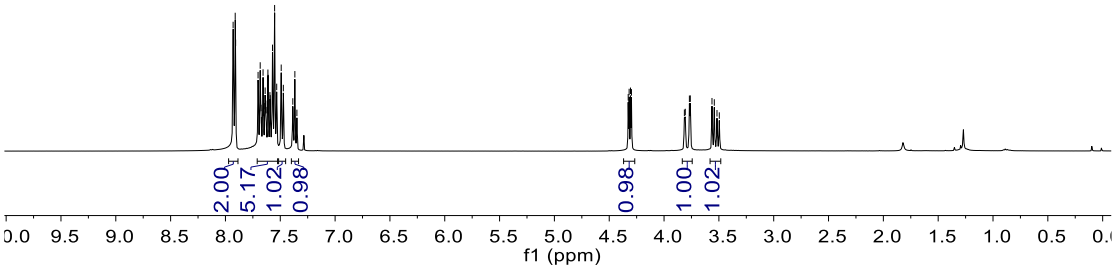


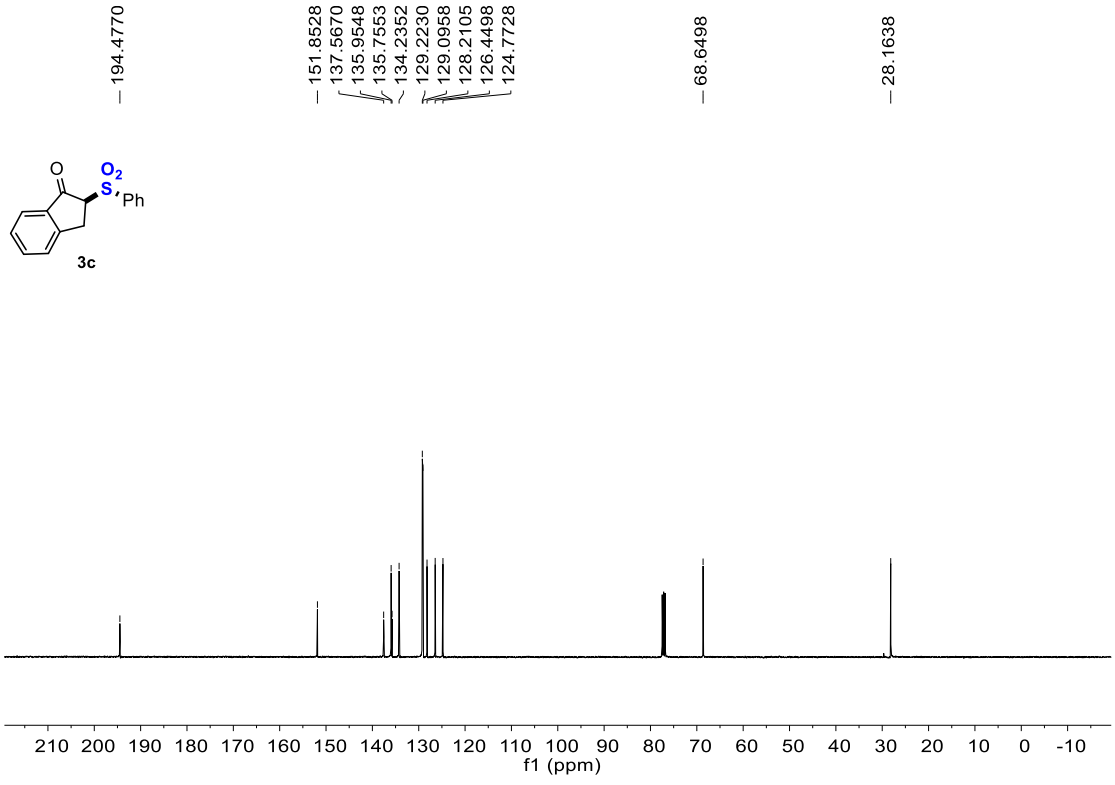
3-(phenylsulfonyl)chroman-4-one (3b)



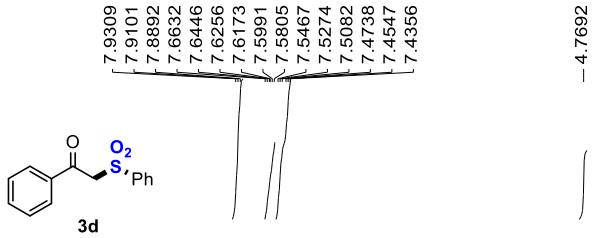
2-(phenylsulfonyl)-2,3-dihydro-1H-inden-1-one (3c)

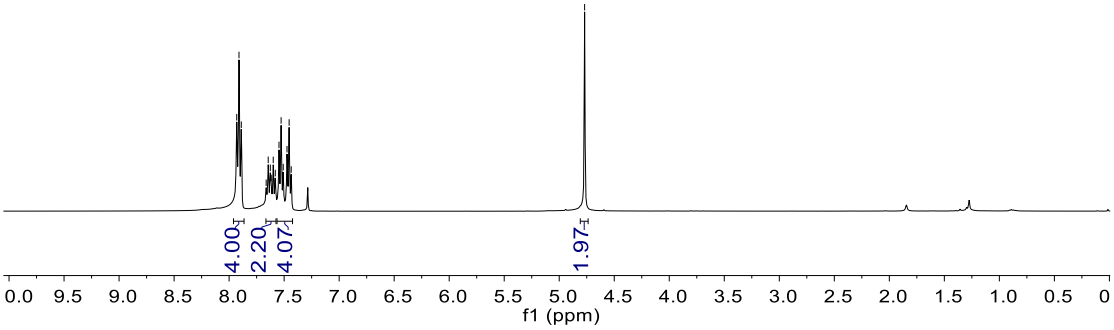


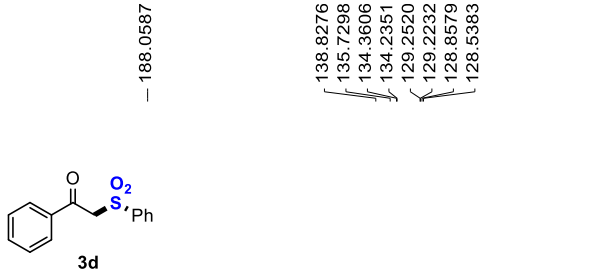


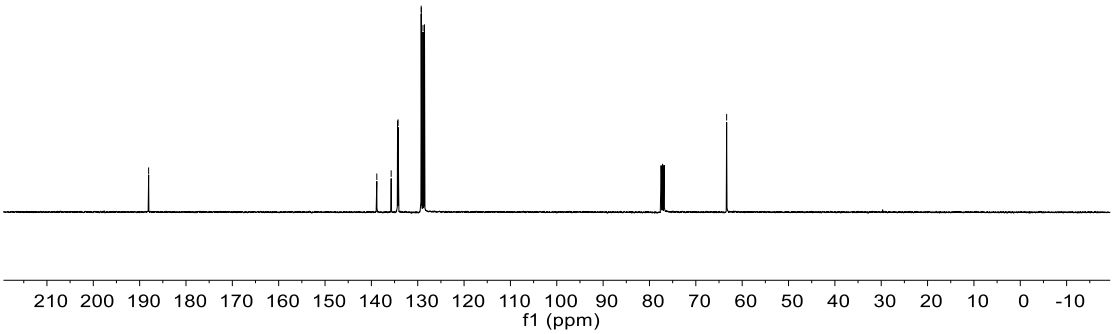


1-phenyl-2-(phenylsulfonyl)ethan-1-one (3d)

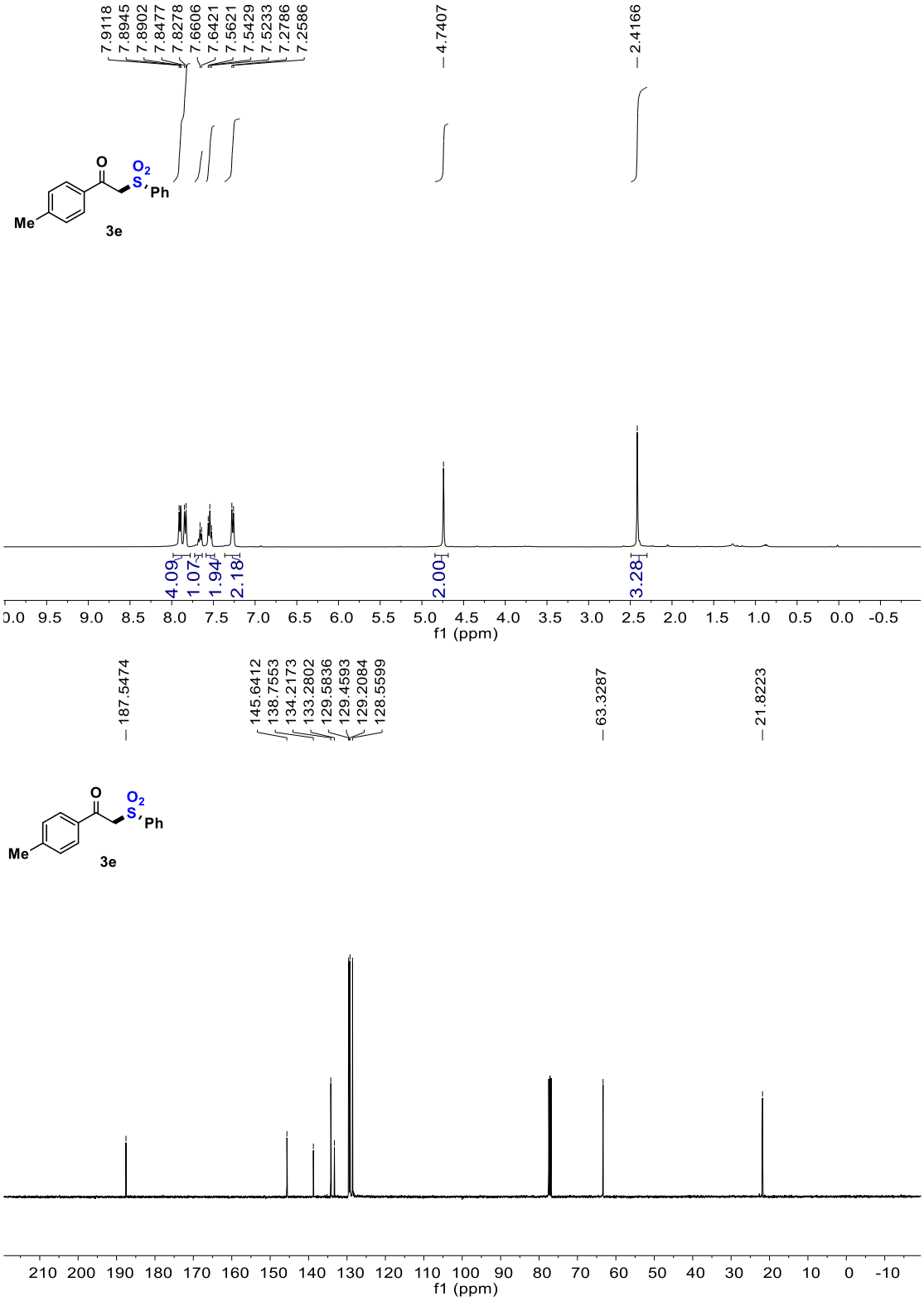




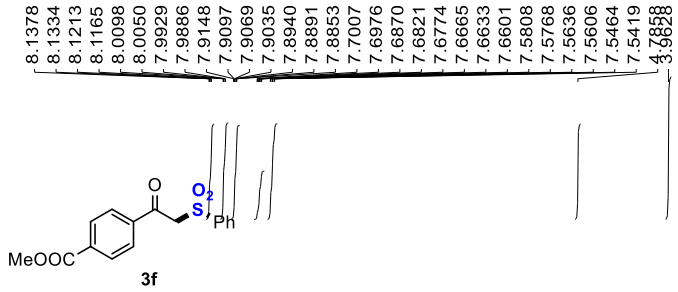




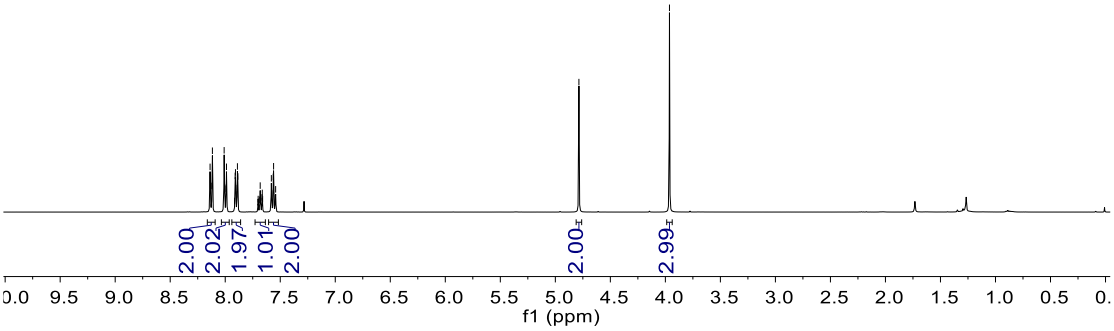
2-(phenylsulfonyl)-1-(p-tolyl)ethan-1-one (3e)

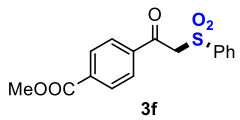


methyl 4-(2-(phenylsulfonyl)acetyl)benzoate (3f)



3f





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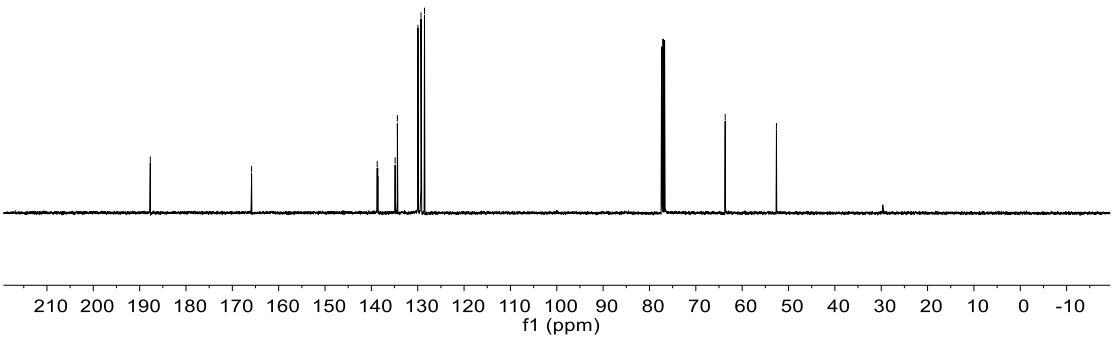
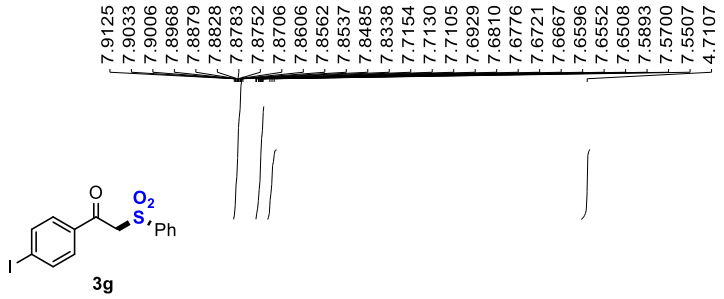
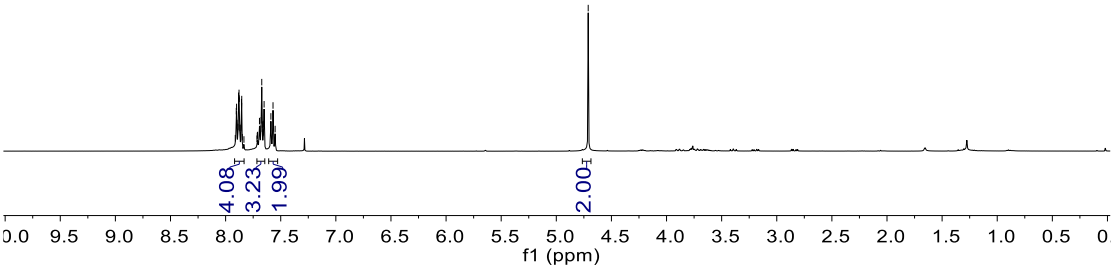
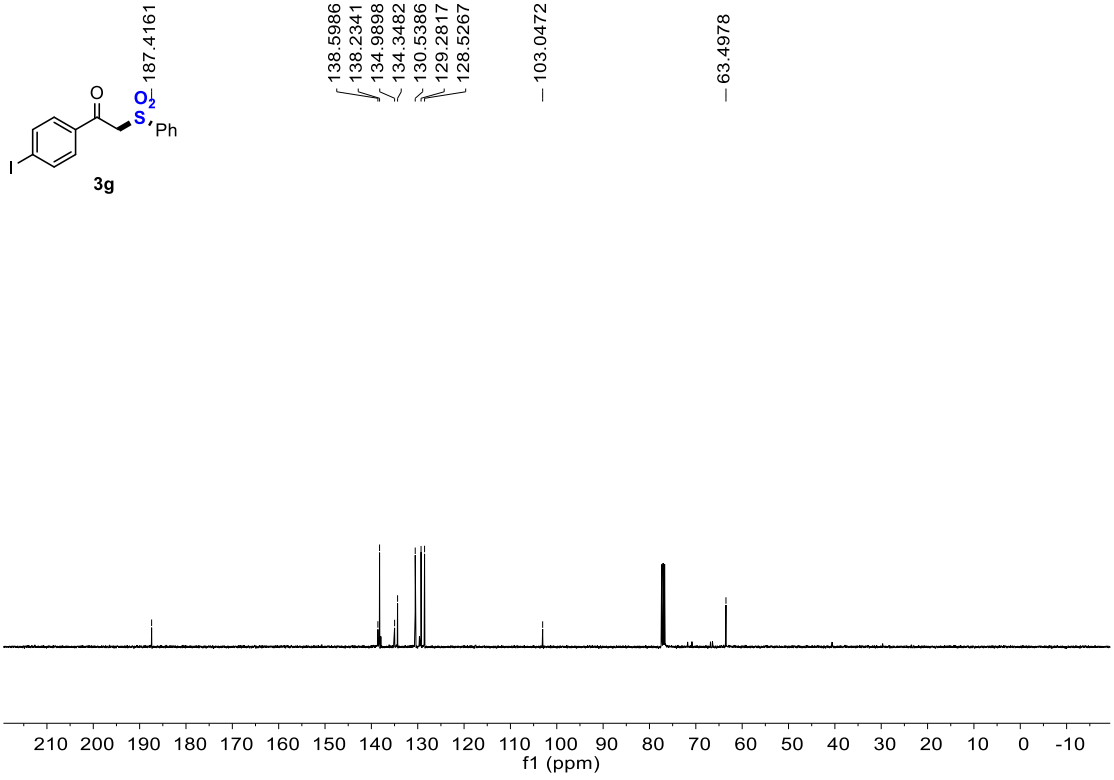


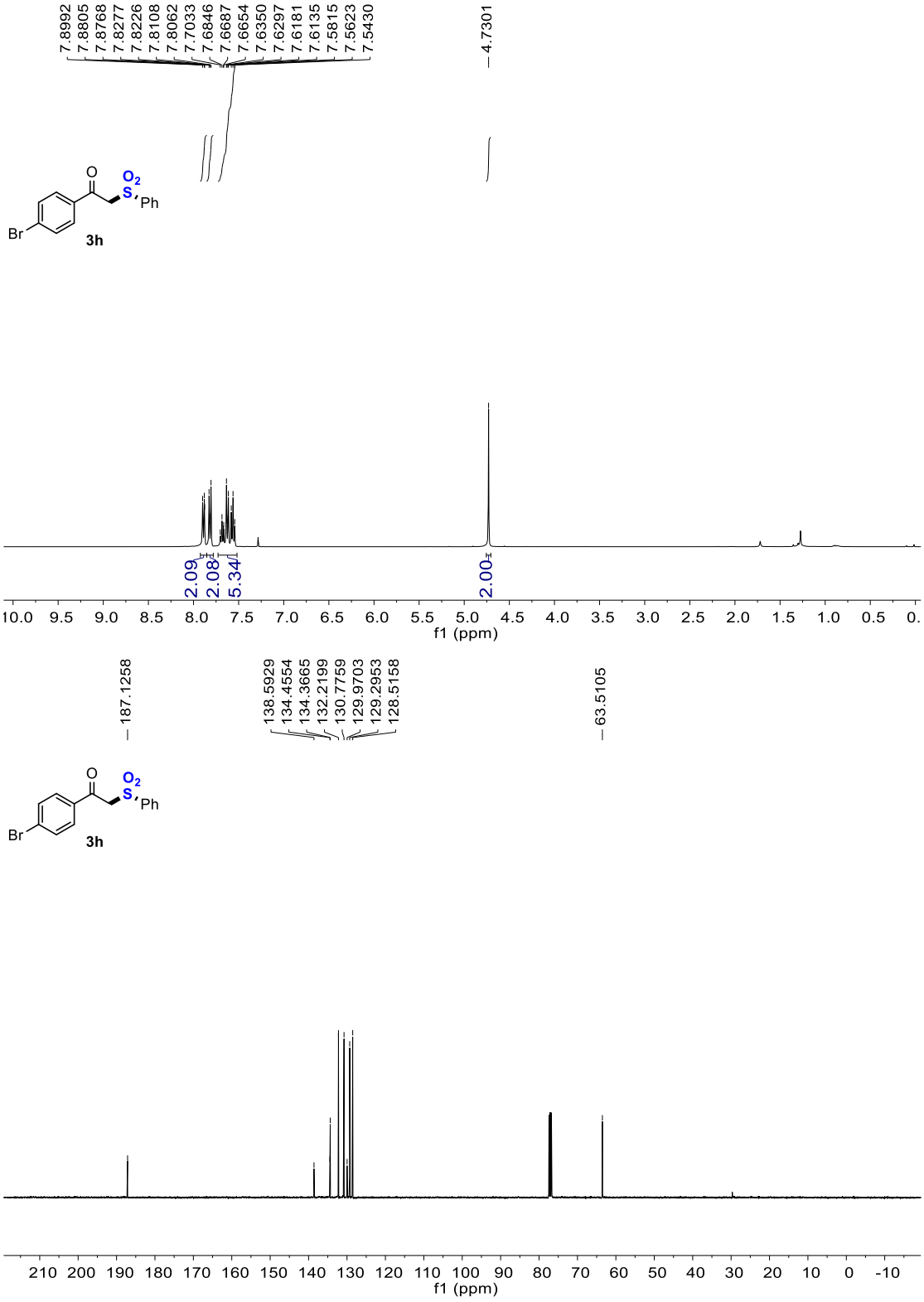
1-(4-iodophenyl)-2-(phenylsulfonyl)ethan-1-one (3g)



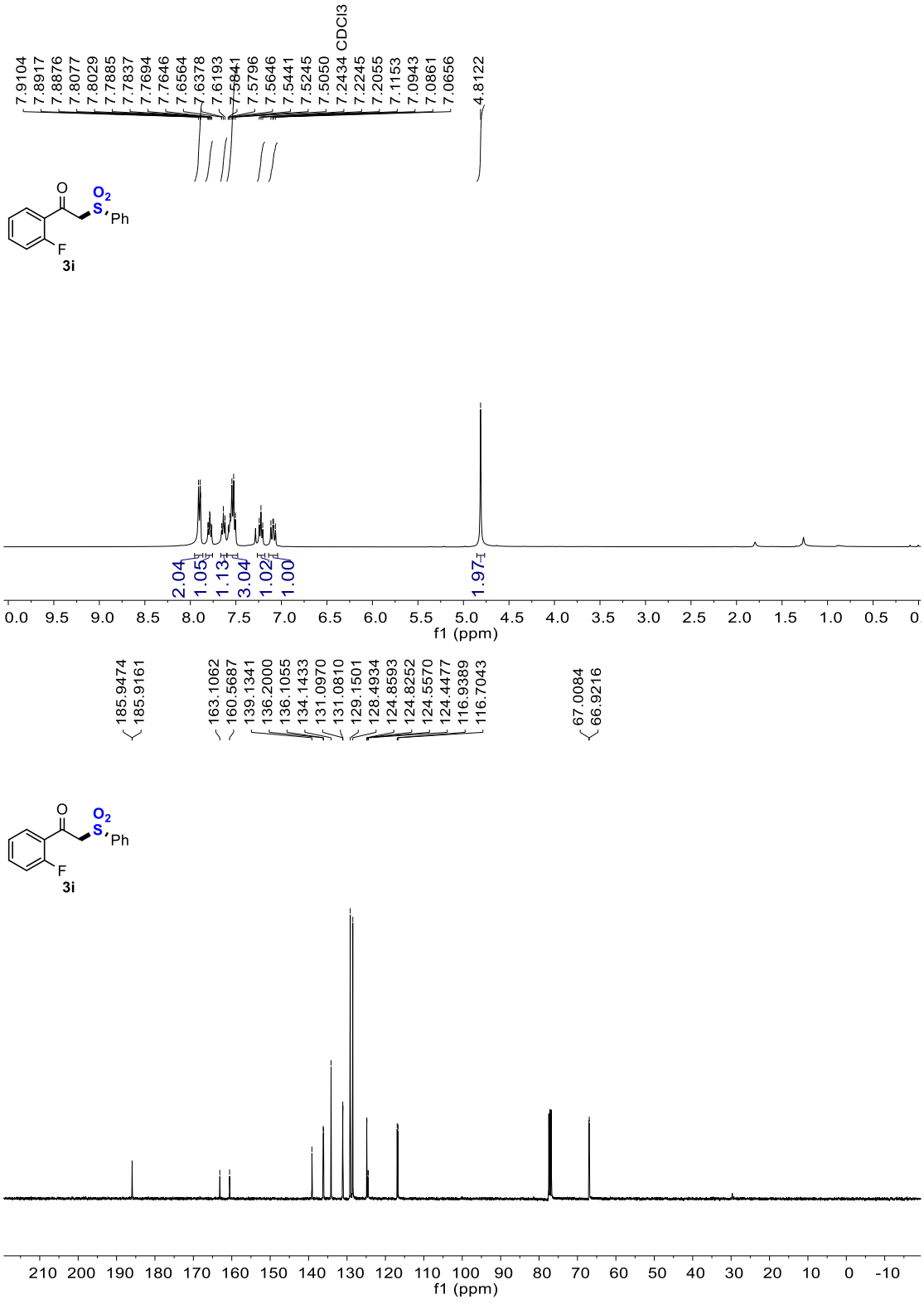


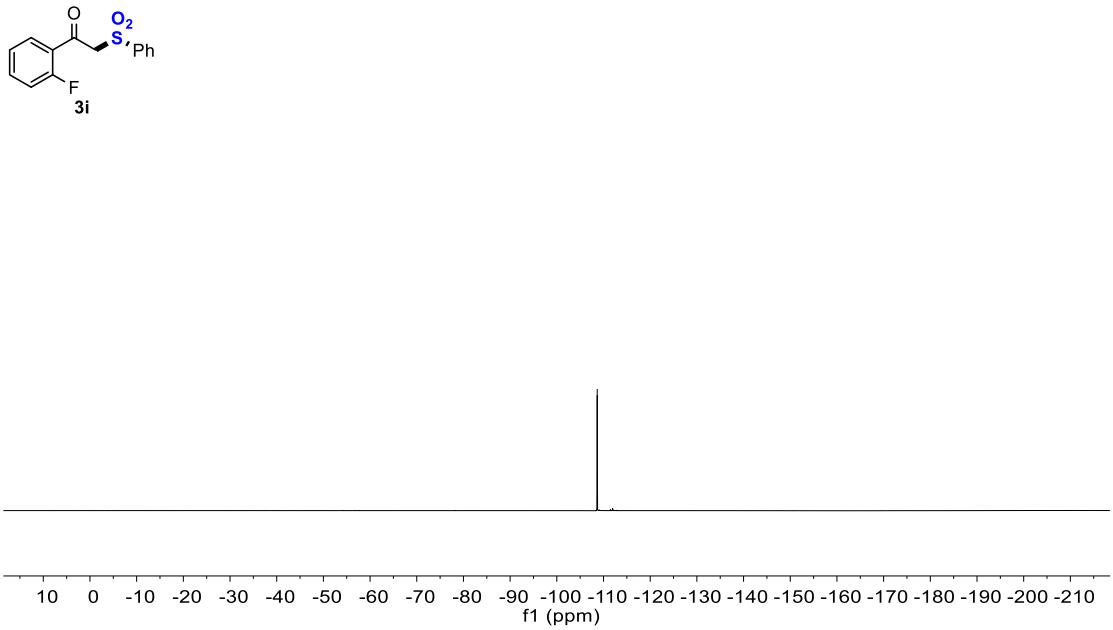


1-(4-bromophenyl)-2-(phenylsulfonyl)ethan-1-one (3h)

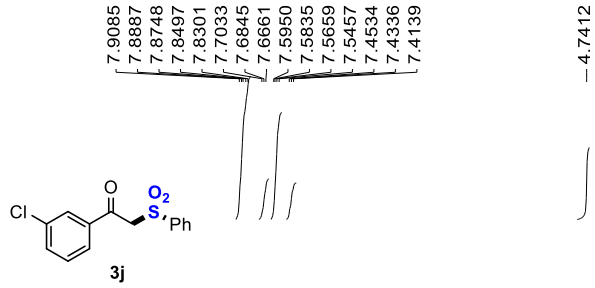


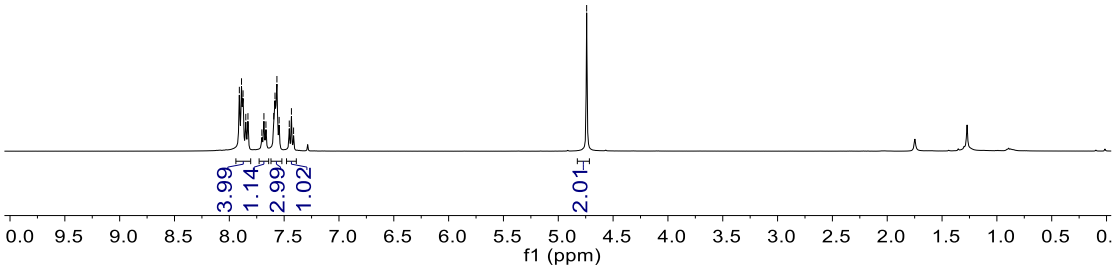
1-(2-fluorophenyl)-2-(phenylsulfonyl)ethan-1-one (3i)

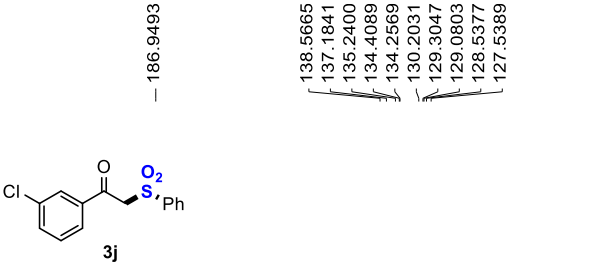


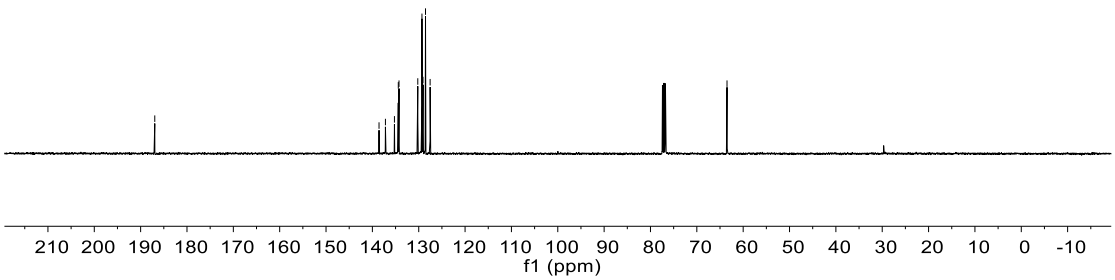

-108.6515
O
O2
S
Ph
F
3i
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

1-(3-chlorophenyl)-2-(phenylsulfonyl)ethan-1-one (3j)

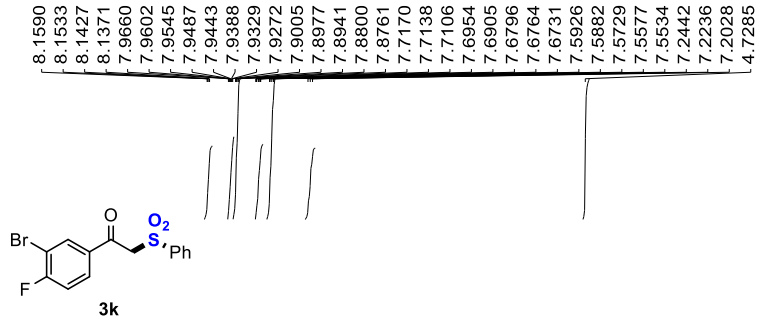


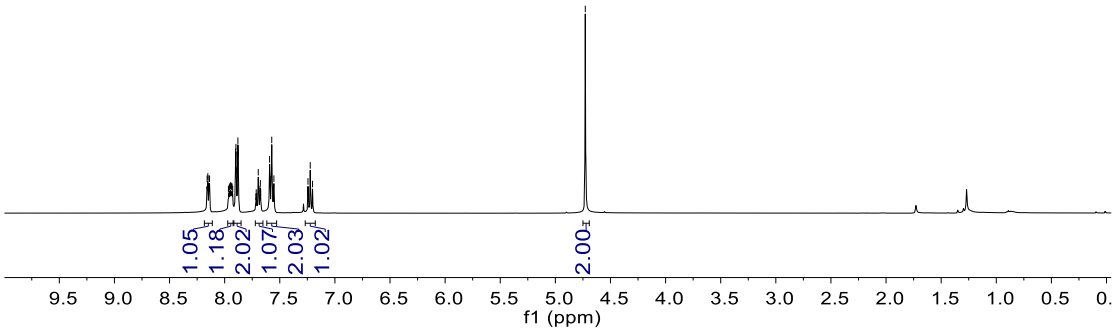


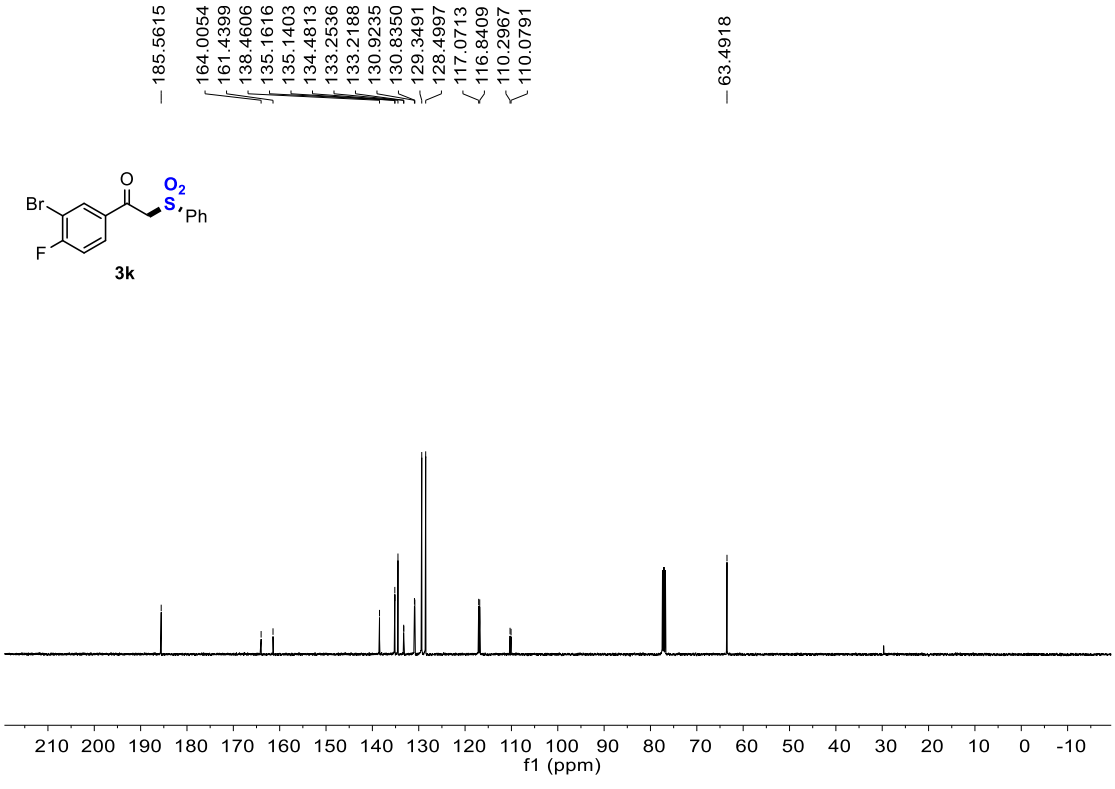


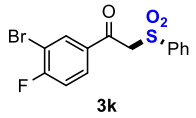


1-(3-bromo-4-fluorophenyl)-2-(phenylsulfonyl)ethan-1-one (3k)





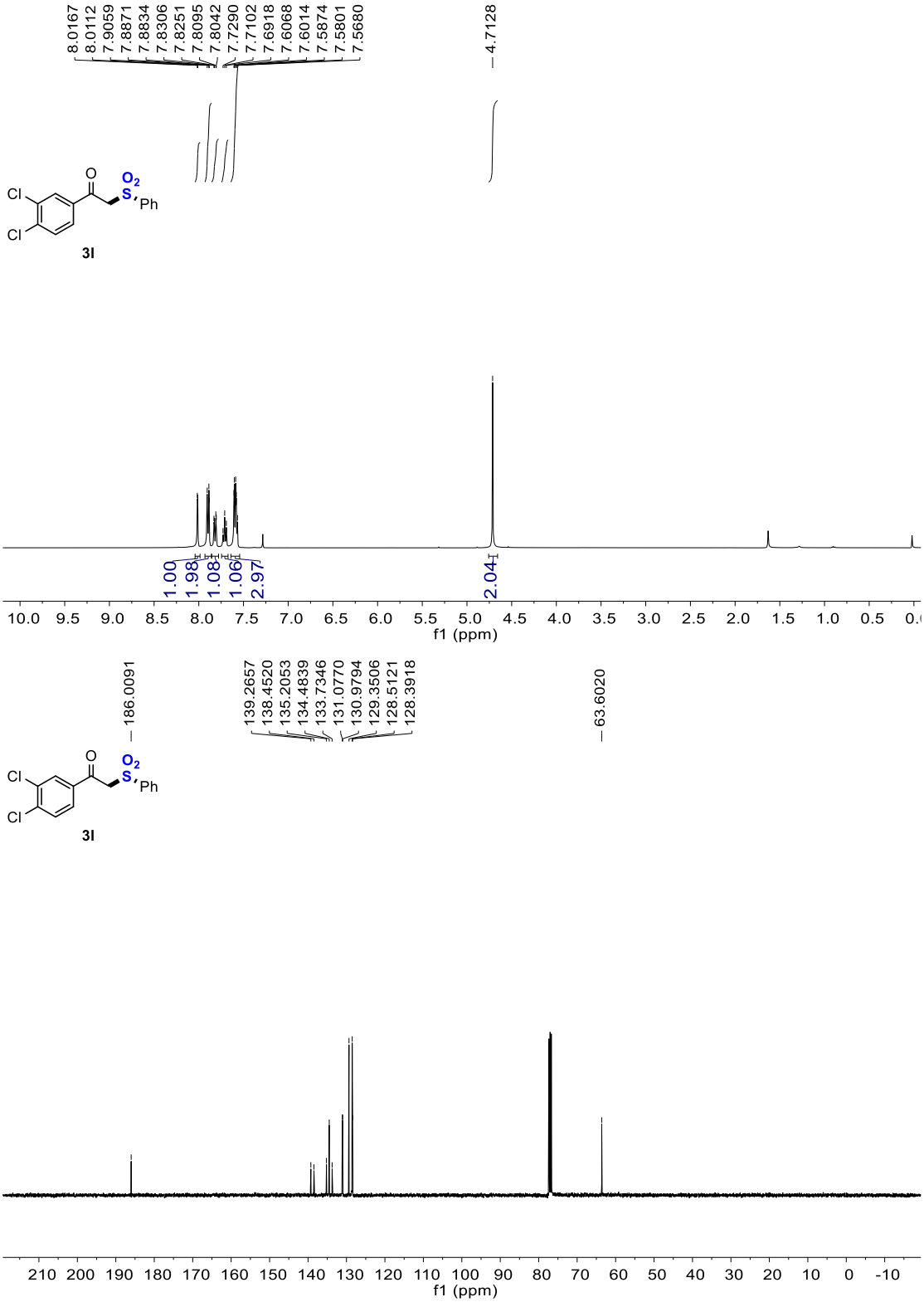



O
O2
S
Ph
Br
F

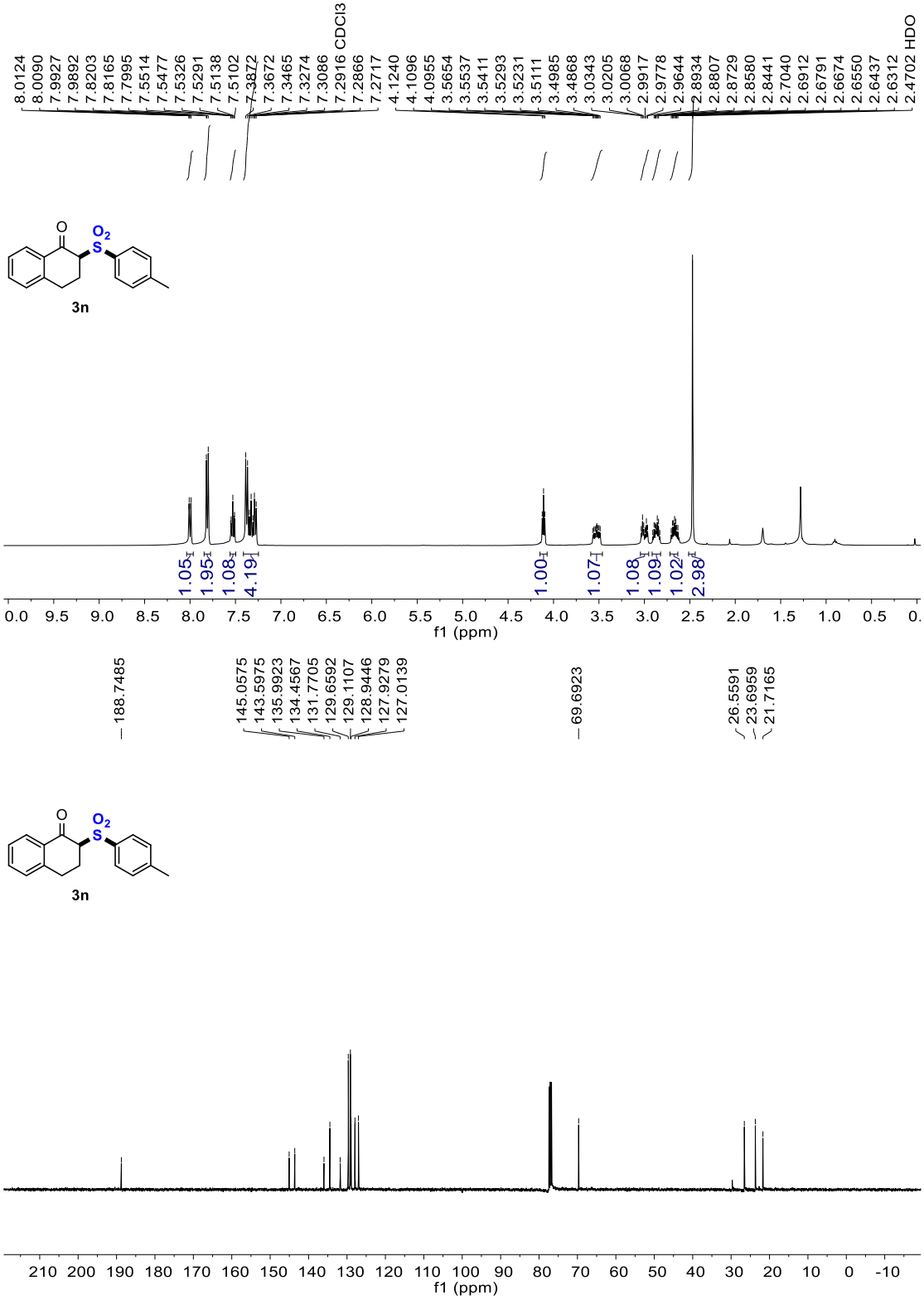
3k

-96.7602
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

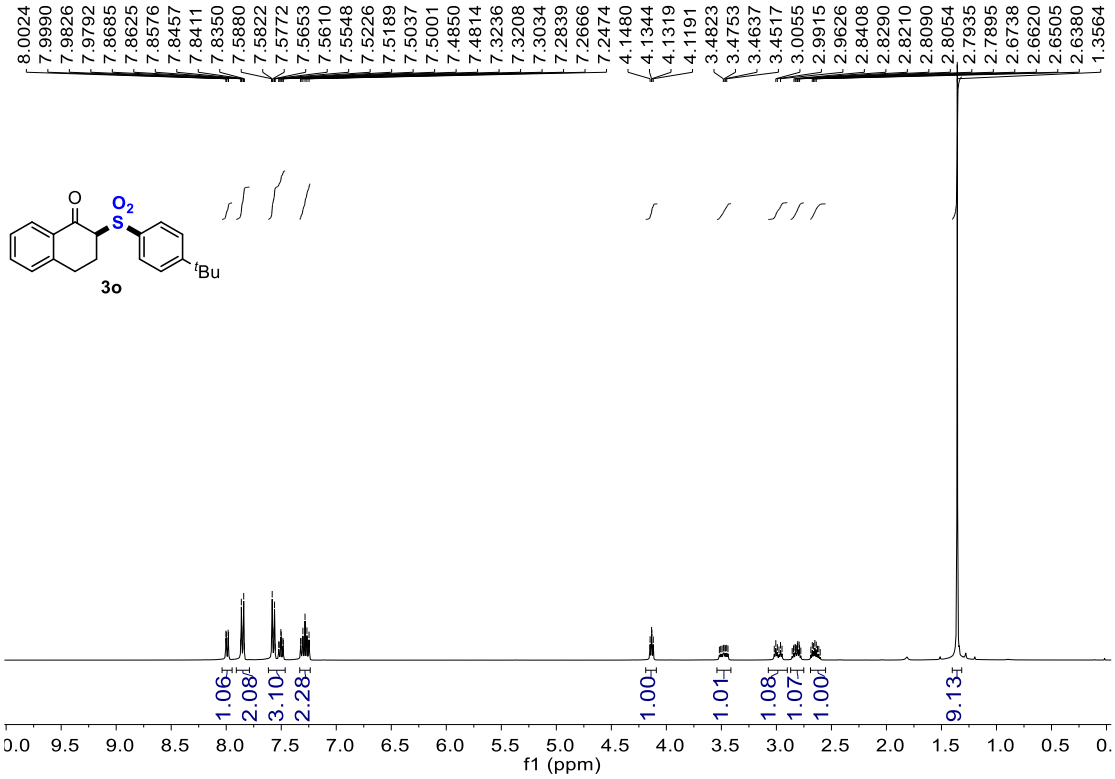
1-(3,4-dichlorophenyl)-2-(phenylsulfonyl)ethan-1-one (3l)

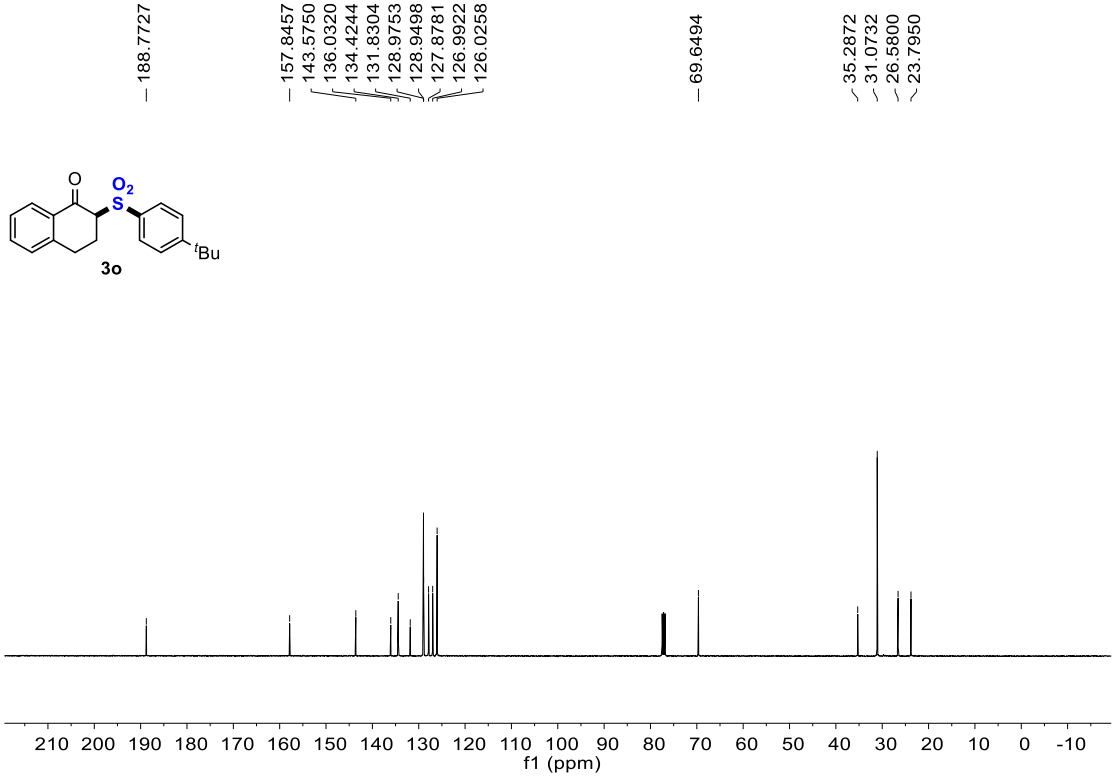


2-tosyl-3,4-dihydronaphthalen-1(2H)-one (3n)

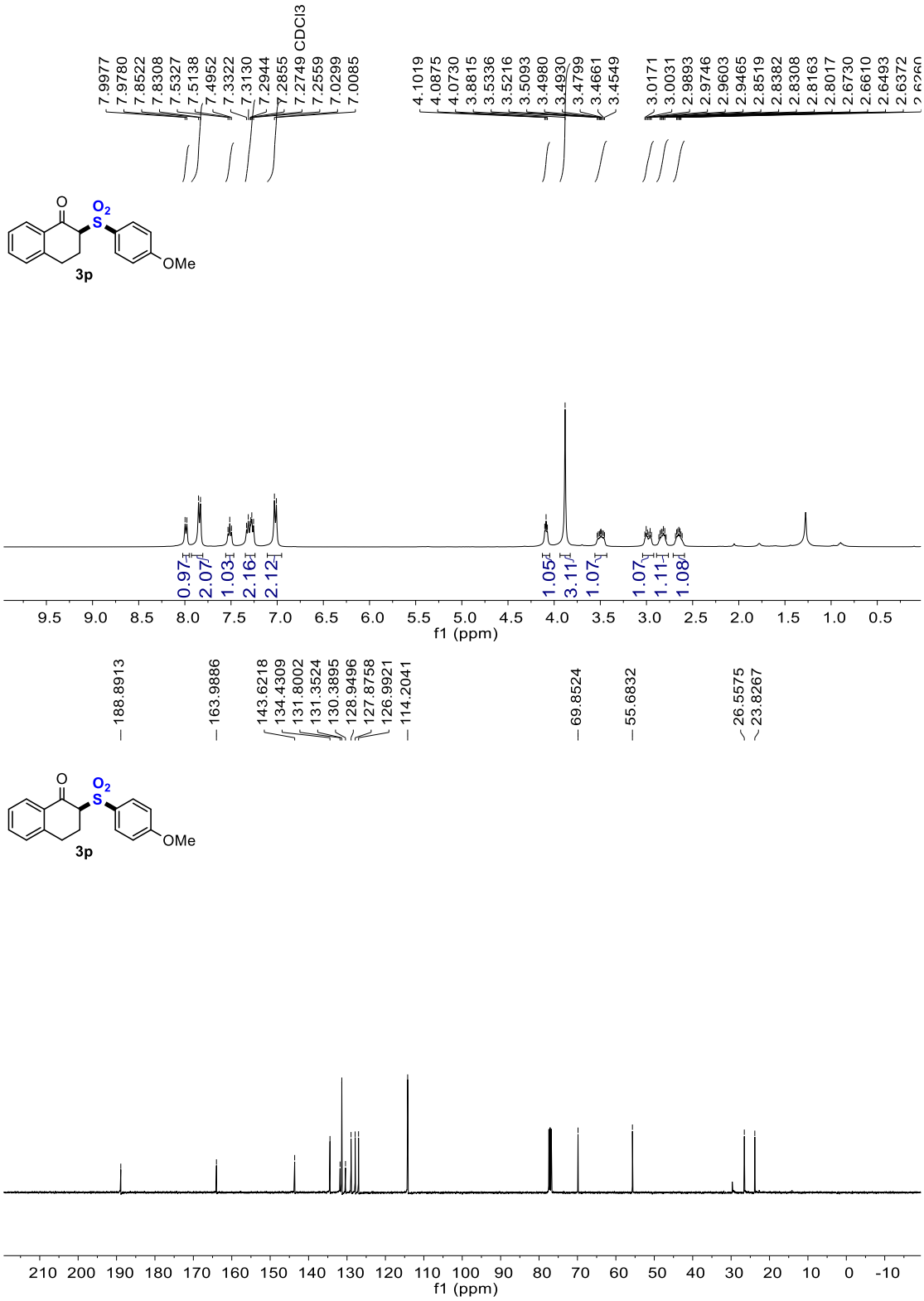


2-((4-(tert-butyl)phenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3o)

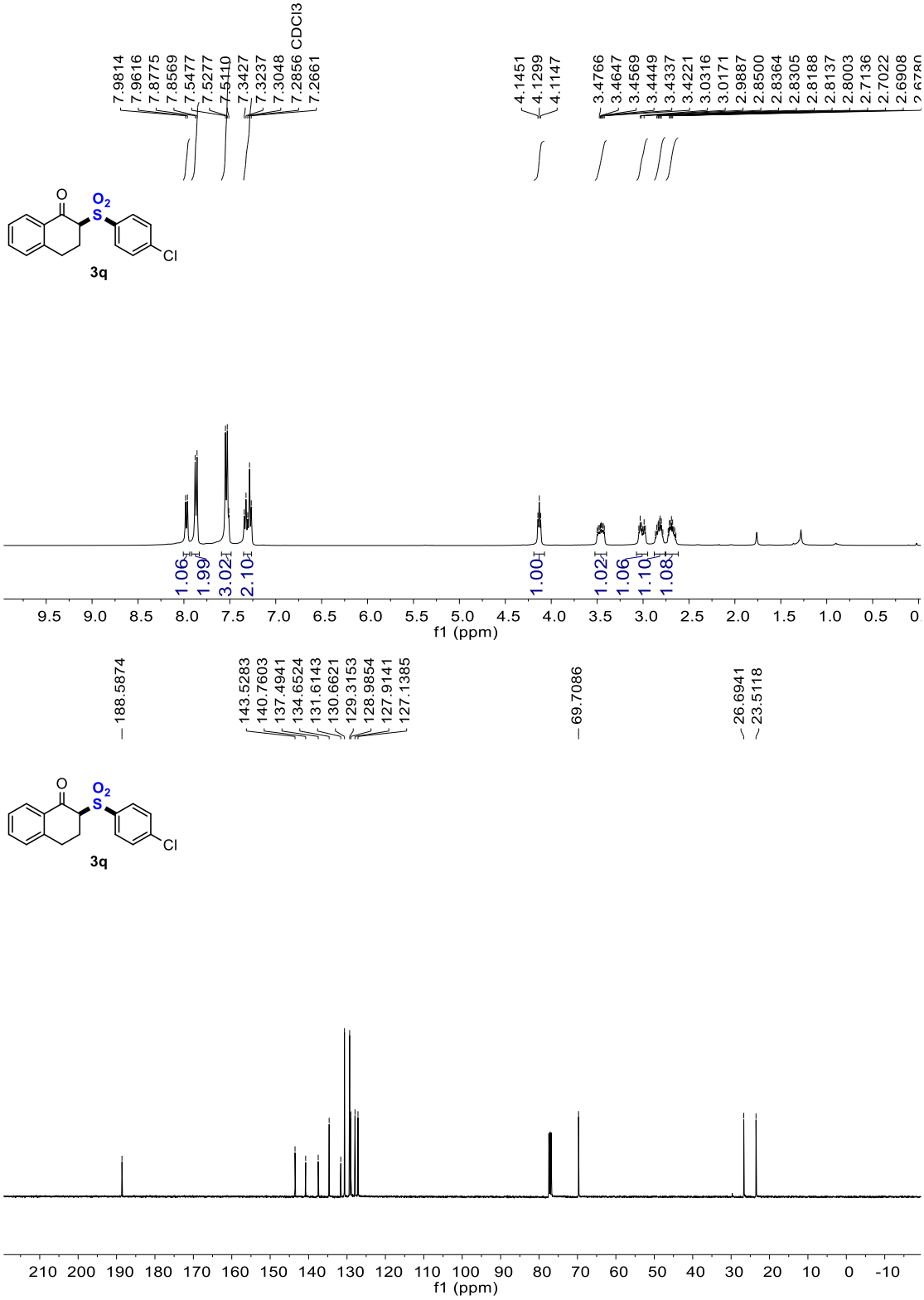




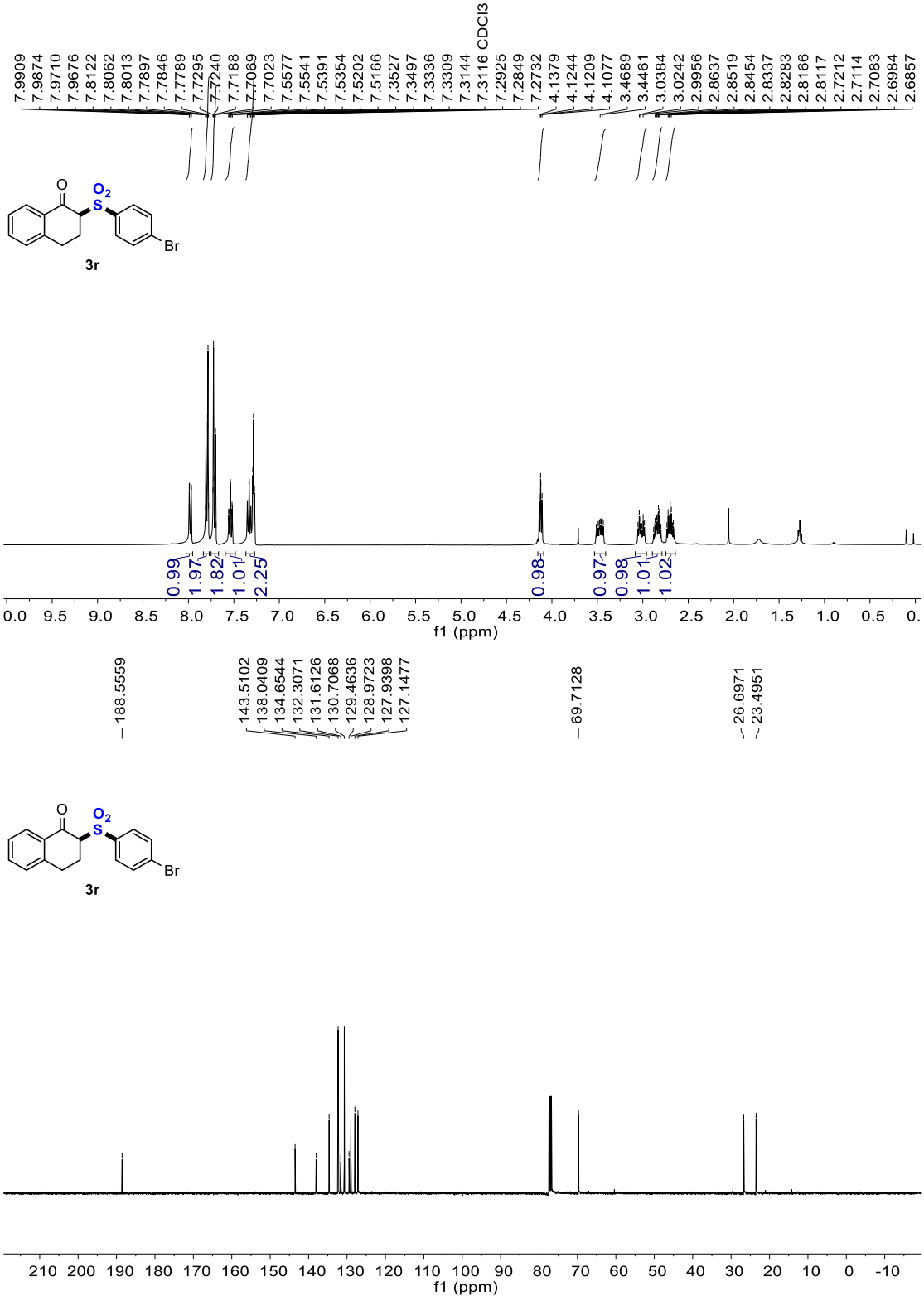
2-((4-methoxyphenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3p)



2-((4-chlorophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3q)



2-((4-bromophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one(3r)



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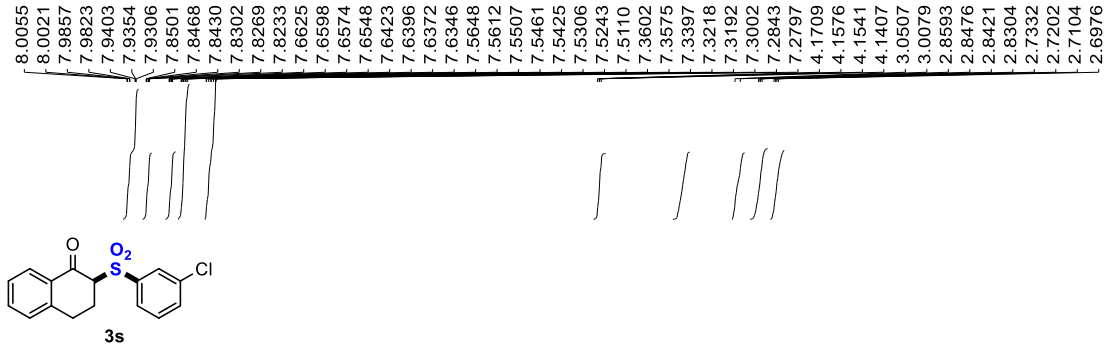
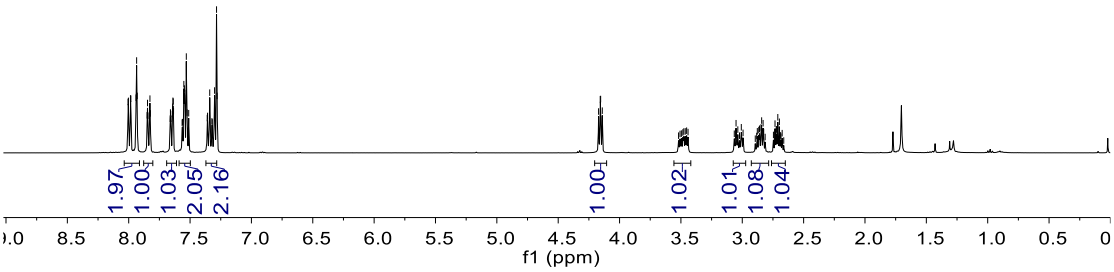
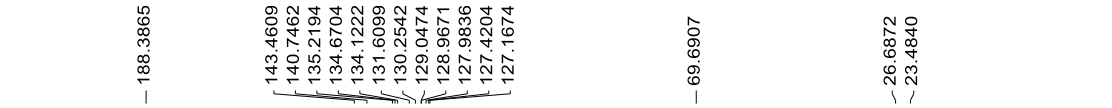
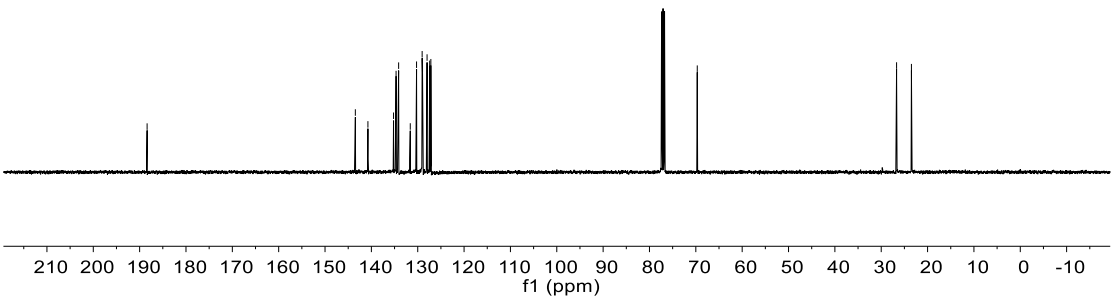
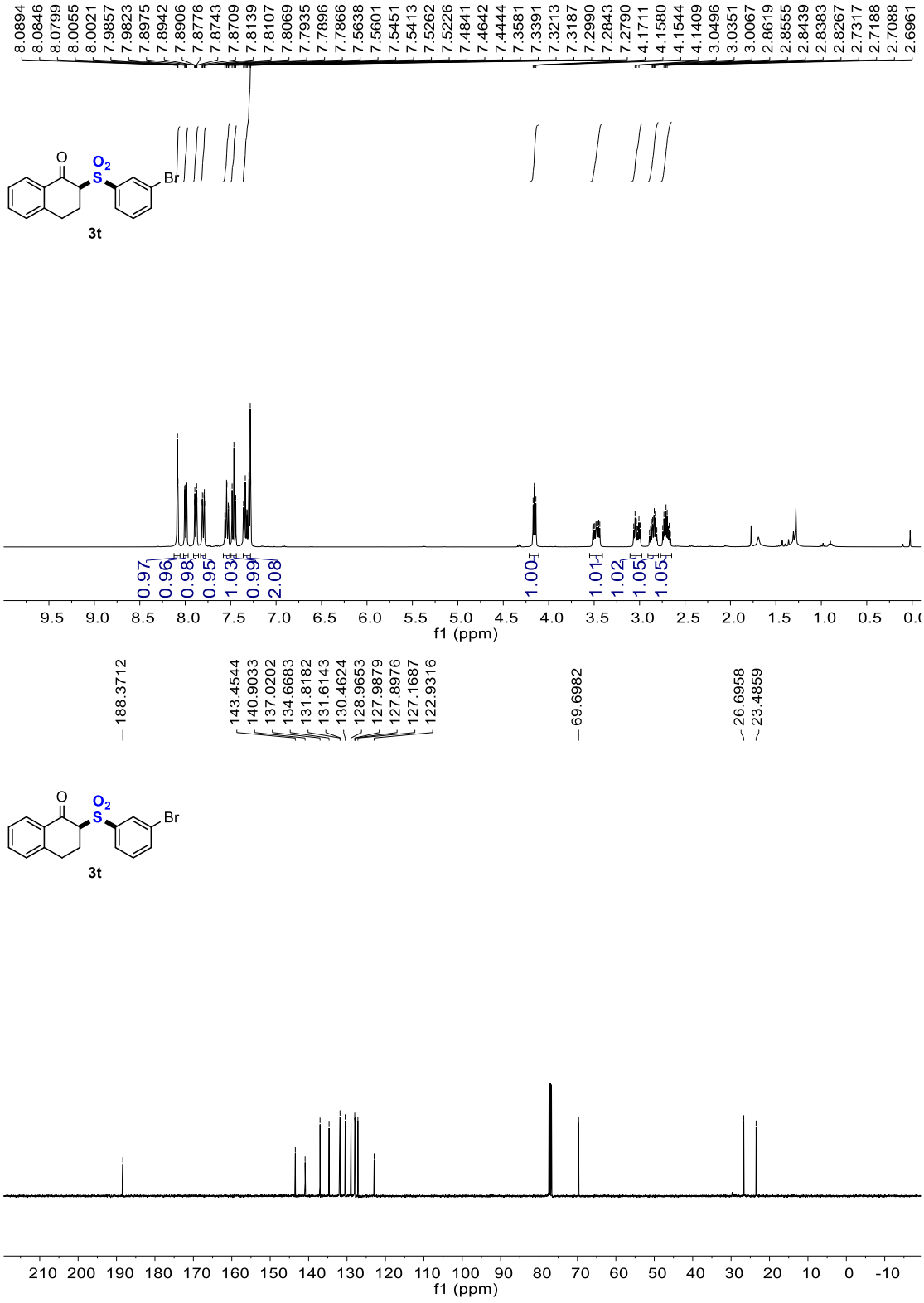




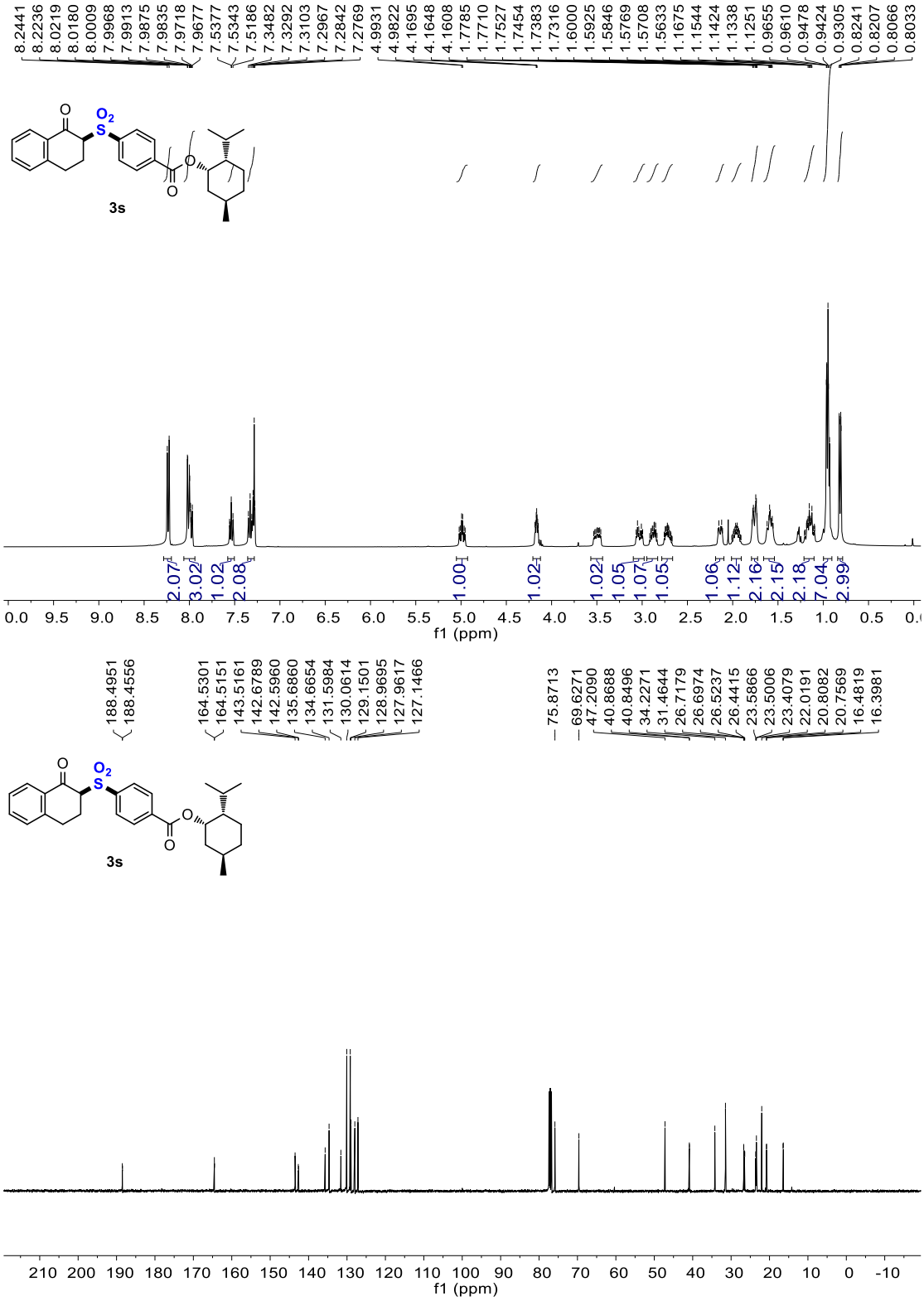




2-((3-bromophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3t)



Product 3u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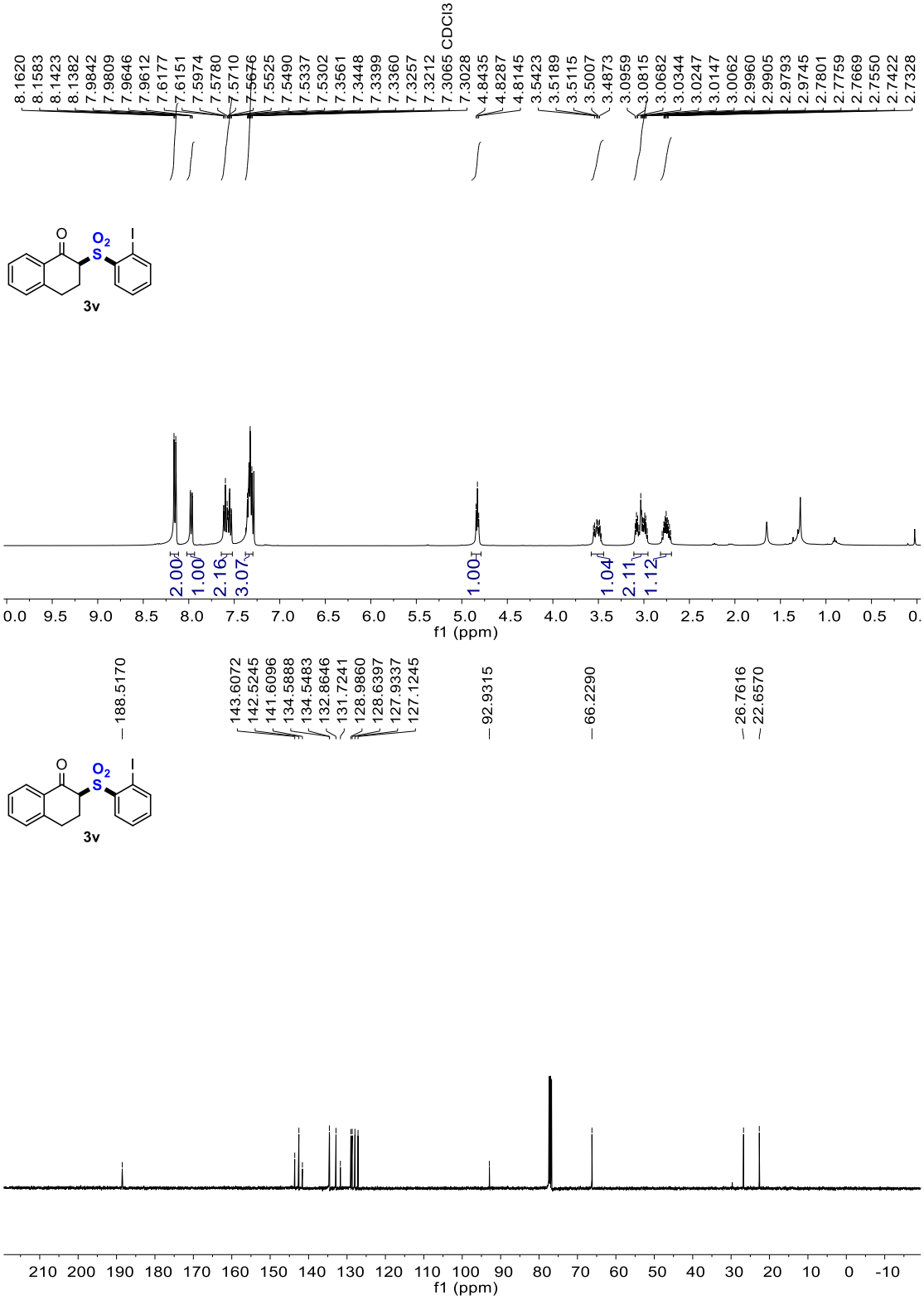
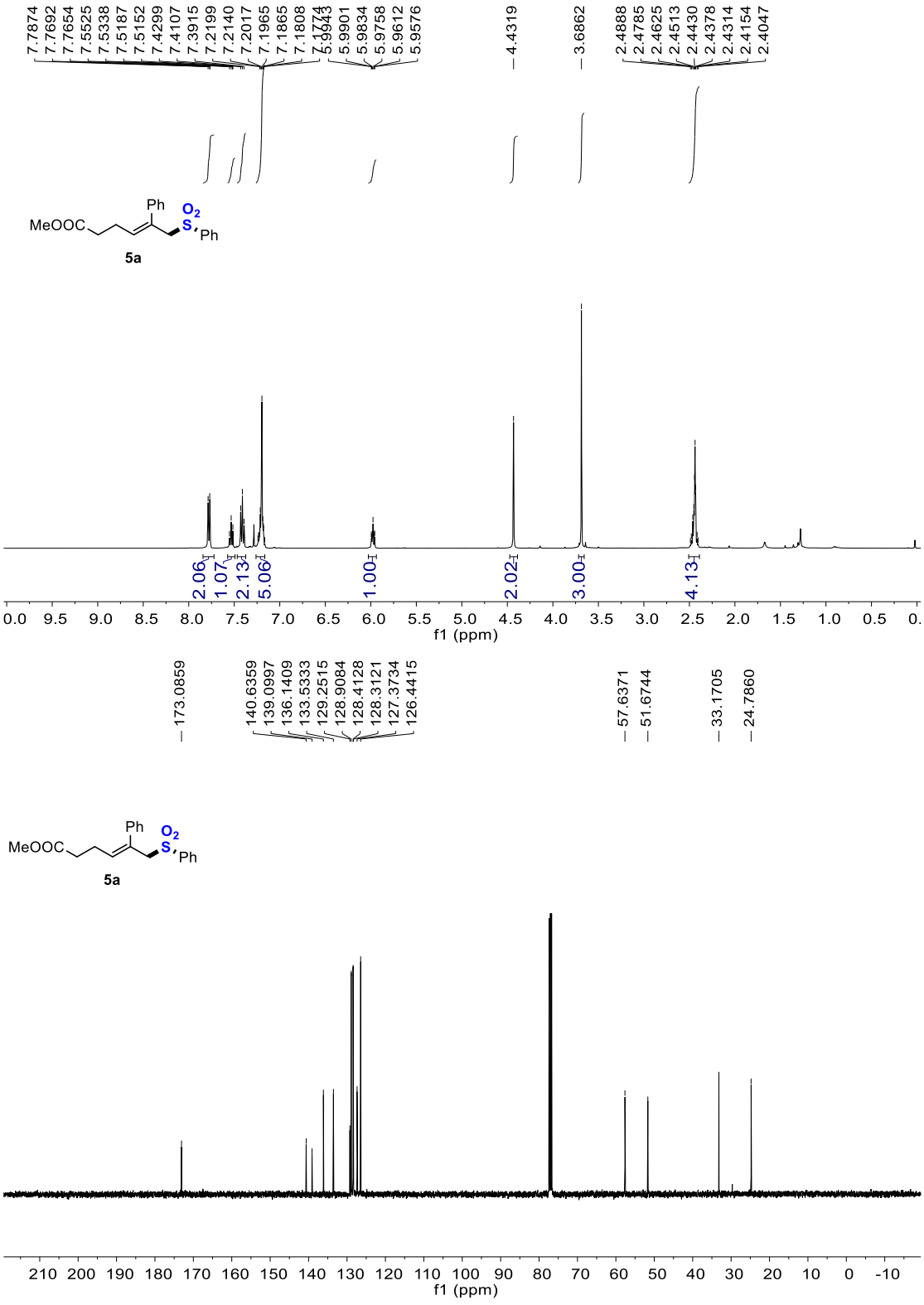
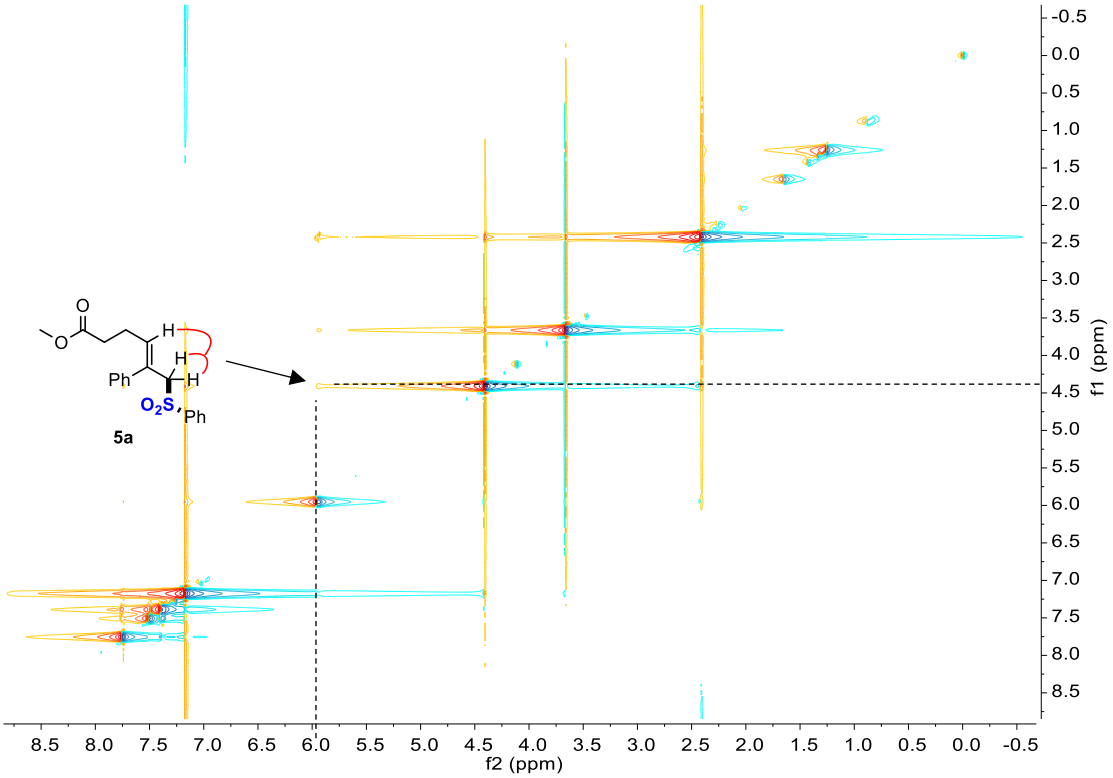
8.2236
8.0219
8.0180
8.0009
7.9968
7.9913
7.9875
7.9835
7.9718
7.9677
7.5377
7.5343
7.5186
7.3482
7.3292
7.3103
7.2967
7.2842
7.2769
4.9931
4.9822
4.1695
4.1648
4.1608
1.7785
1.7710
1.7527
1.7454
1.7383
1.7316
1.6000
1.5925
1.5846
1.5769
1.5708
1.5633
1.1675
1.1544
1.1424
1.1338
1.1251
0.9655
0.9610
0.9478
0.9424
0.9305
0.8241
0.8207
0.8066
0.8033
O
O2
S
O
O
3s
2.07
3.02
1.02
2.08
1.00
1.02
1.02
1.05
1.07
1.05
1.06
1.12
2.16
2.15
2.18
7.04
2.99
f1 (ppm)
188.4951
188.4556
164.5301
164.5151
143.5161
142.6789
142.5960
135.6860
134.6654
131.5984
130.0614
129.1501
128.9695
127.9617
127.1466
75.8713
69.6271
47.2090
40.8688
40.8496
34.2271
31.4644
26.7179
26.6974
26.5237
26.4415
23.5866
23.5006
23.4079
22.0191
20.8082
20.7569
16.4819
16.3981
f1 (ppm)

2-((2-iodophenyl)sulfonyl)-3,4-dihydronaphthalen-1(2H)-one (3v)

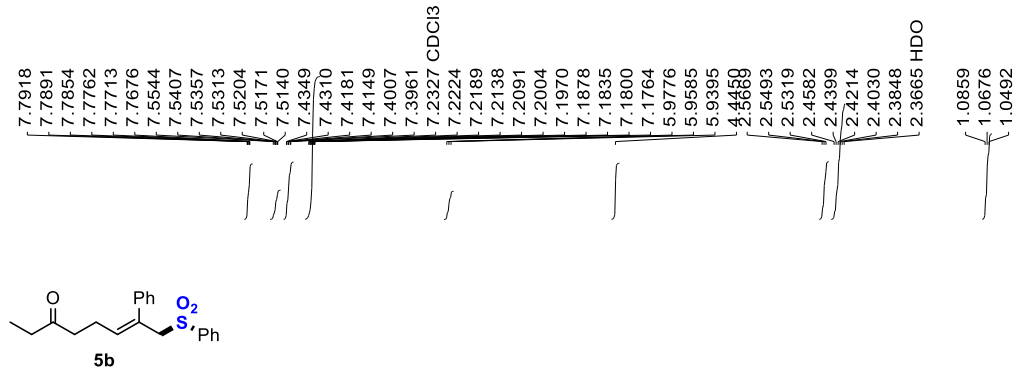


methyl (E)-5-phenyl-6-(phenylsulfonyl)hex-4-enoate (5a)

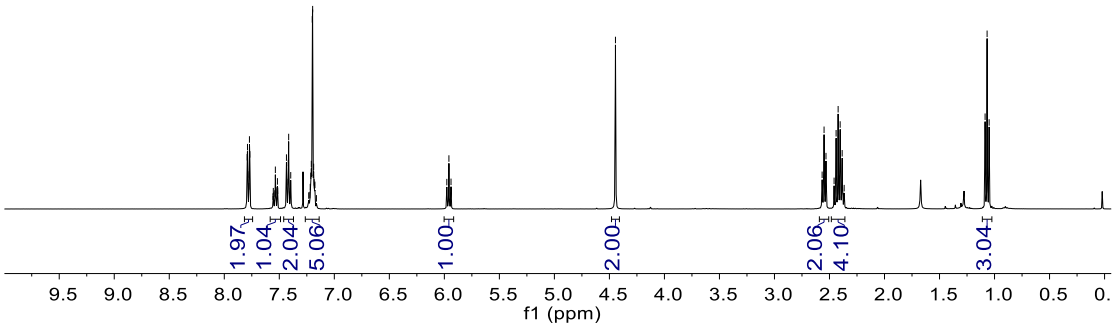


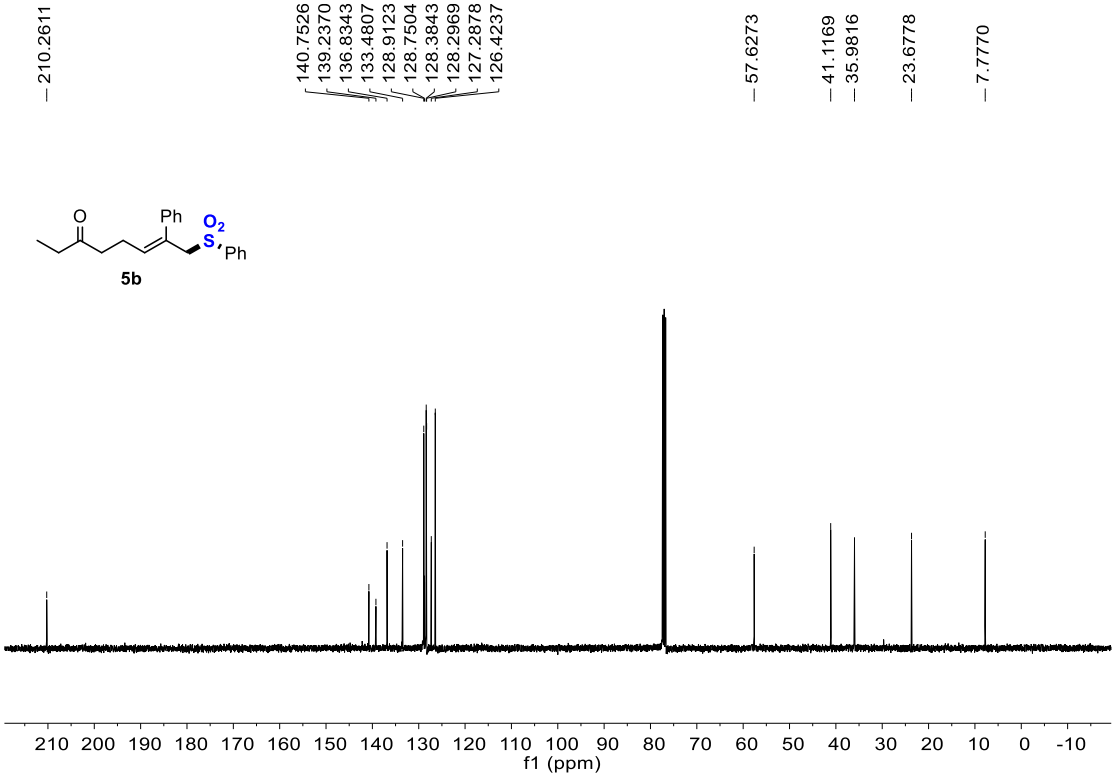

O
O
H
H
Ph
H
O2S
Ph
5a
f2 (ppm)
f1 (ppm)

(E)-7-phenyl-8-(phenylsulfonyl)oct-6-en-3-one (5b)

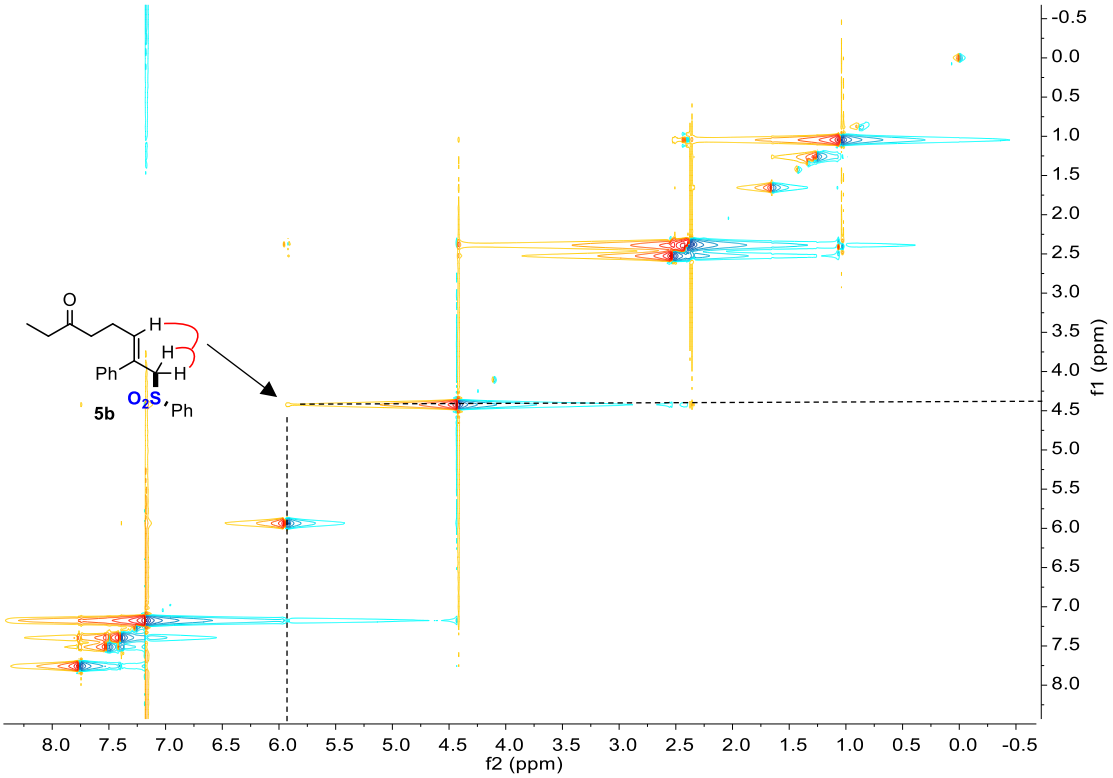


5b

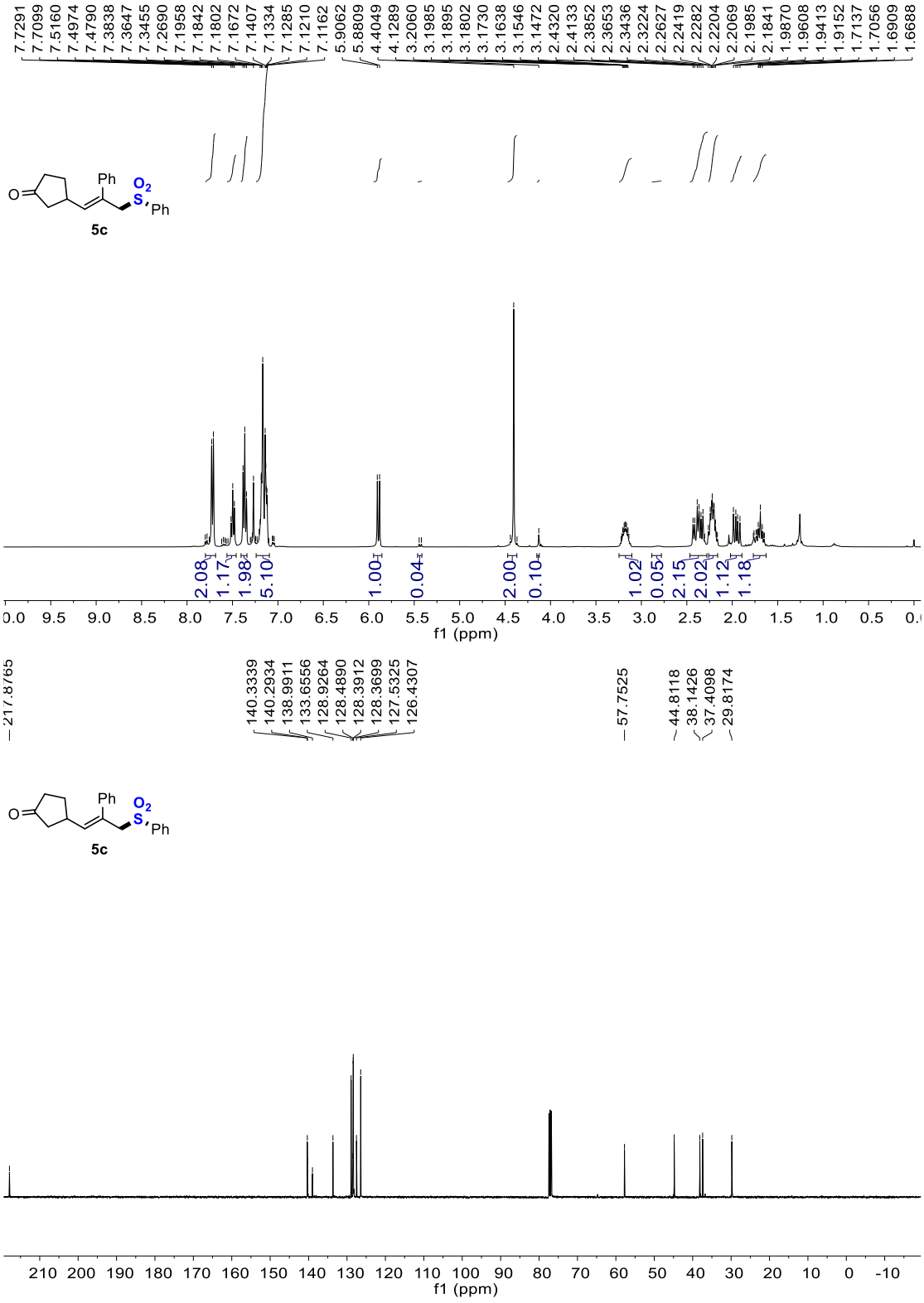


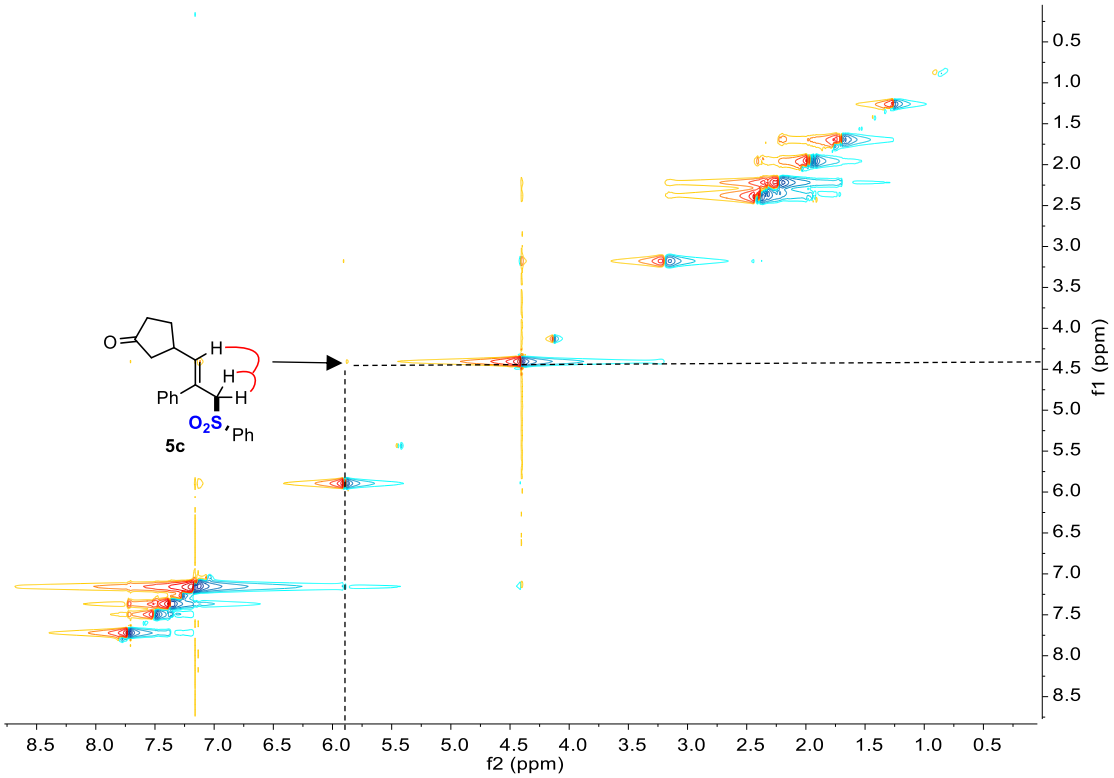


5b

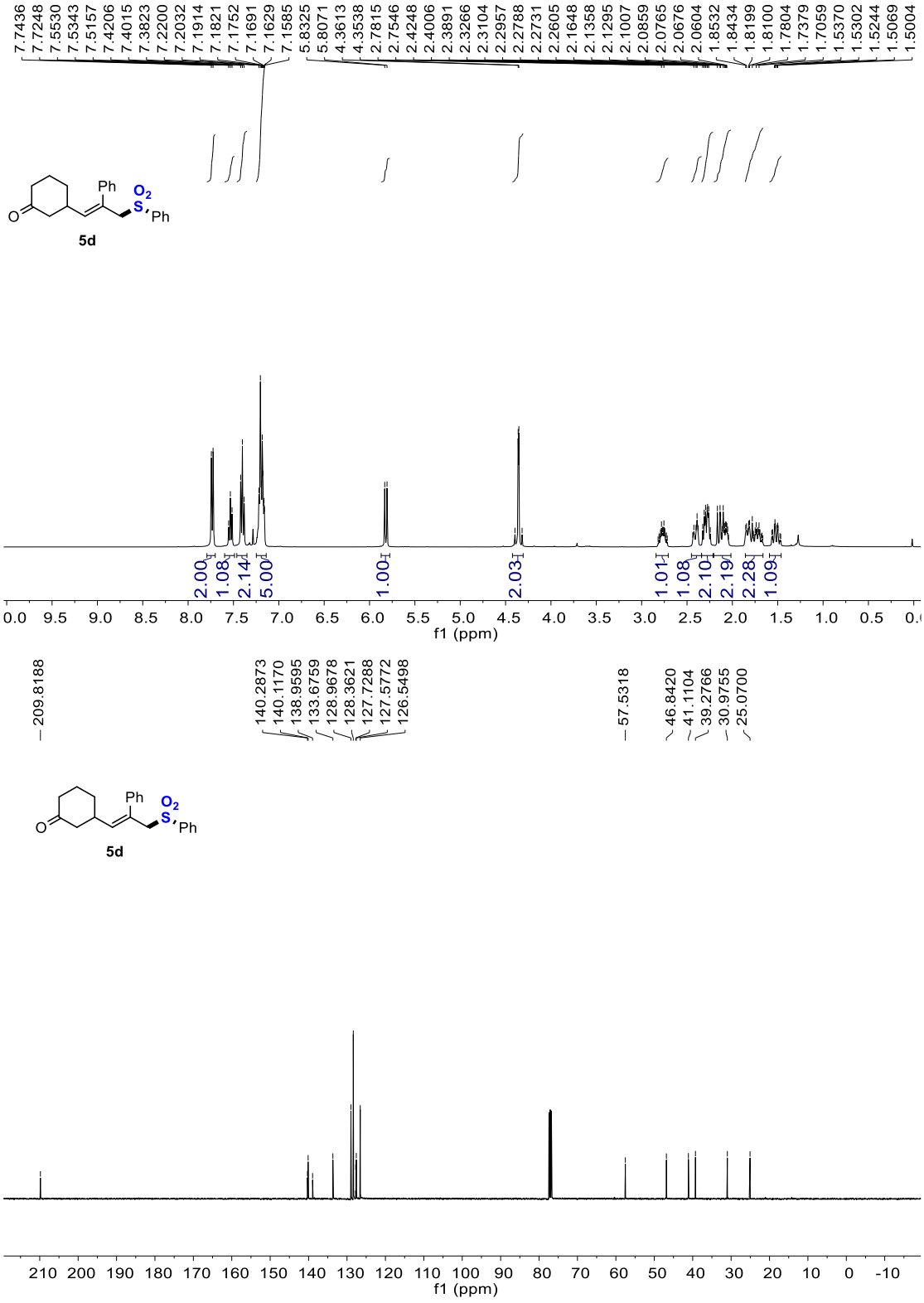

O
H
H
Ph
H
O2S
Ph
5b
f2 (ppm)
f1 (ppm)

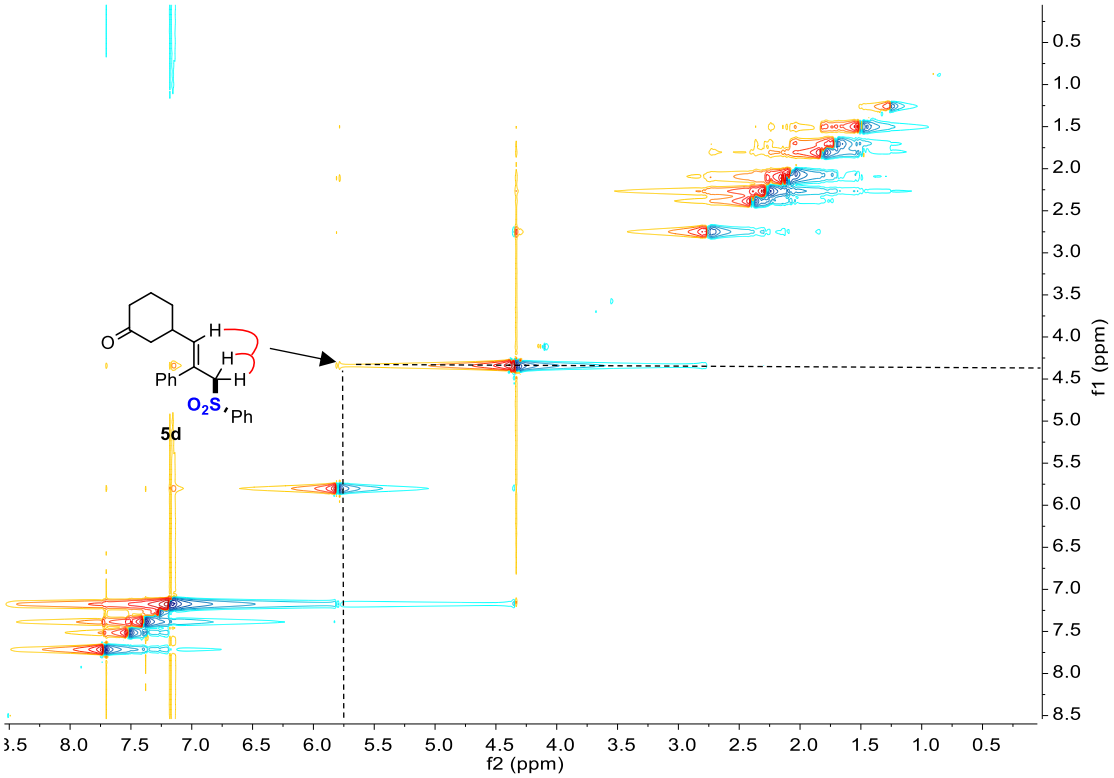
(E)-3-(2-phenyl-3-(phenylsulfonyl)prop-1-en-1-yl)cyclohexan-1-one (5c)



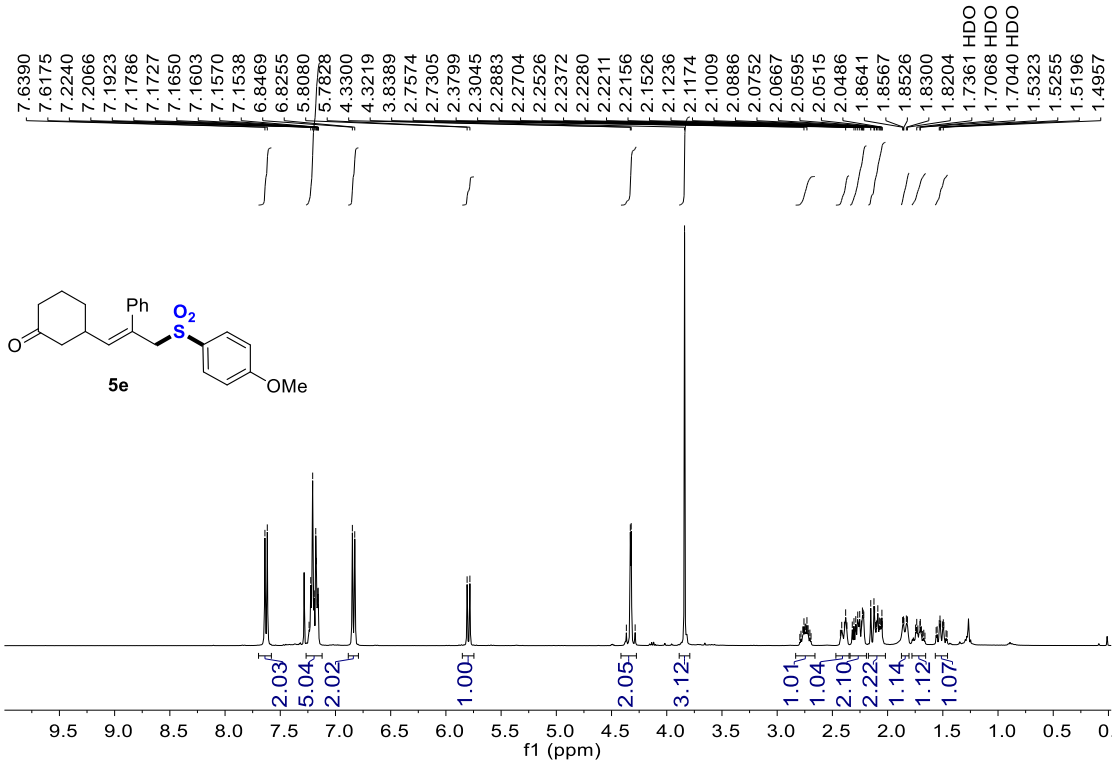

O
H
H
H
Ph
O2S
Ph
5c
f2 (ppm)
f1 (ppm)

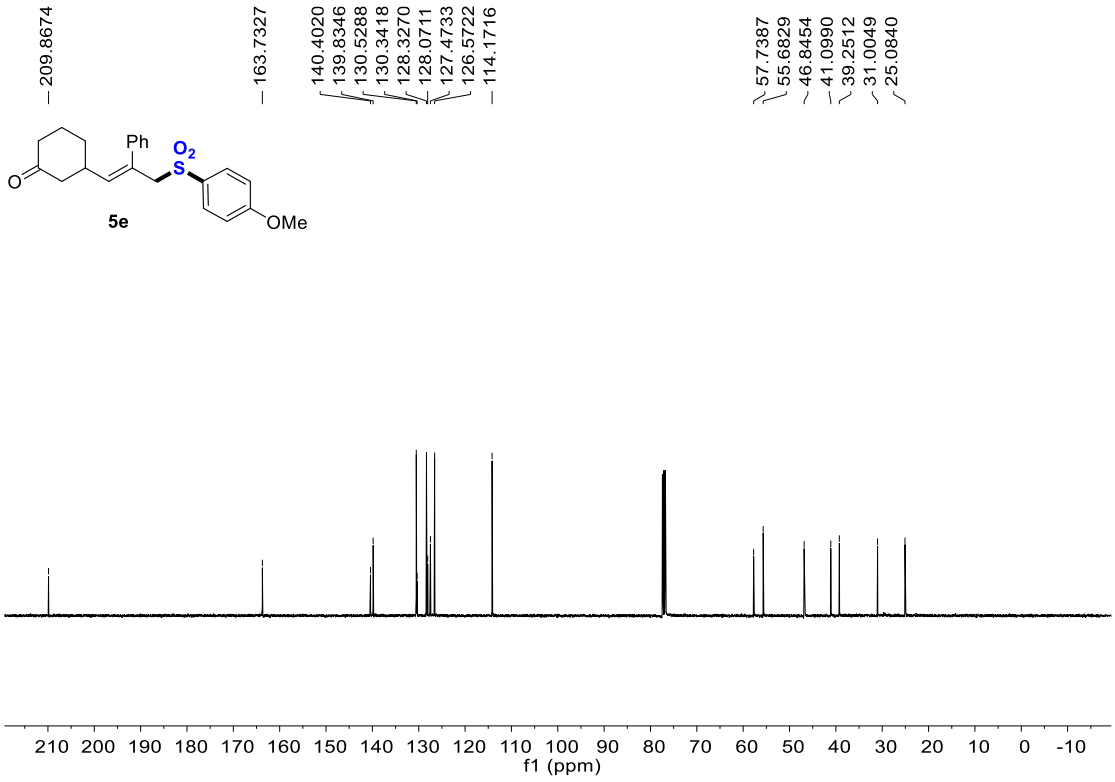
(E)-3-(2-phenyl-3-(phenylsulfonyl)prop-1-en-1-yl)cyclohexan-1-one (5d)

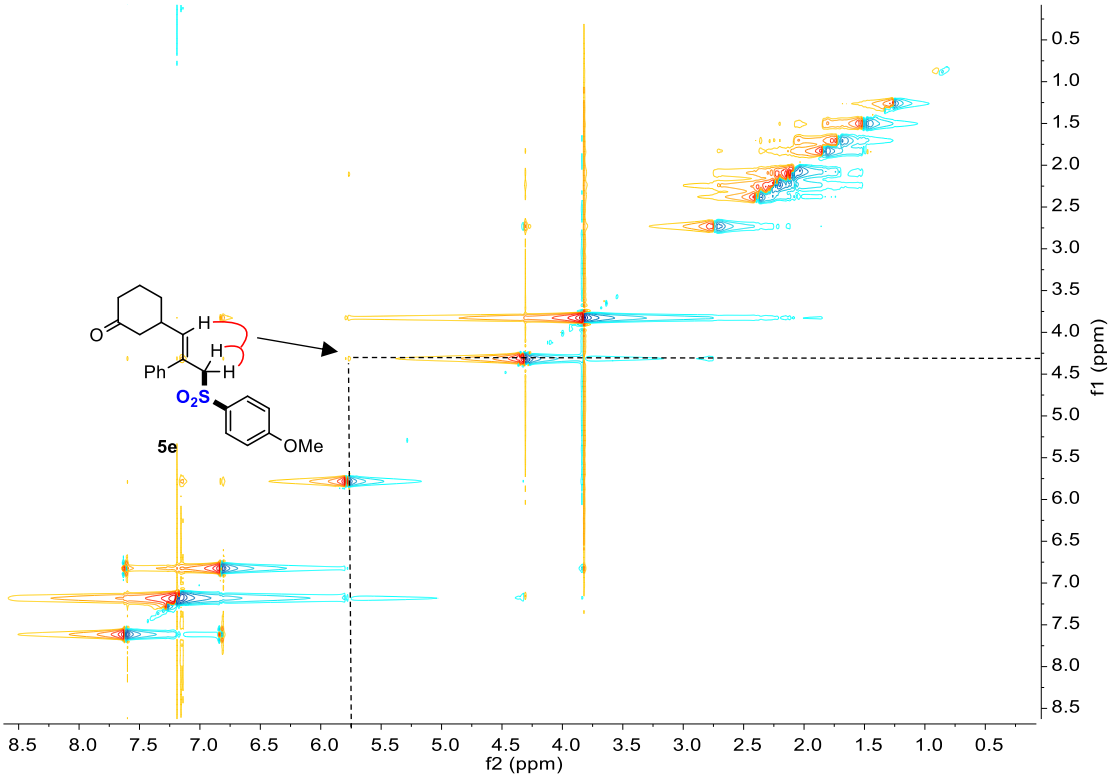



O
H
H
H
Ph
O2S
Ph
5d
f1 (ppm)
f2 (ppm)

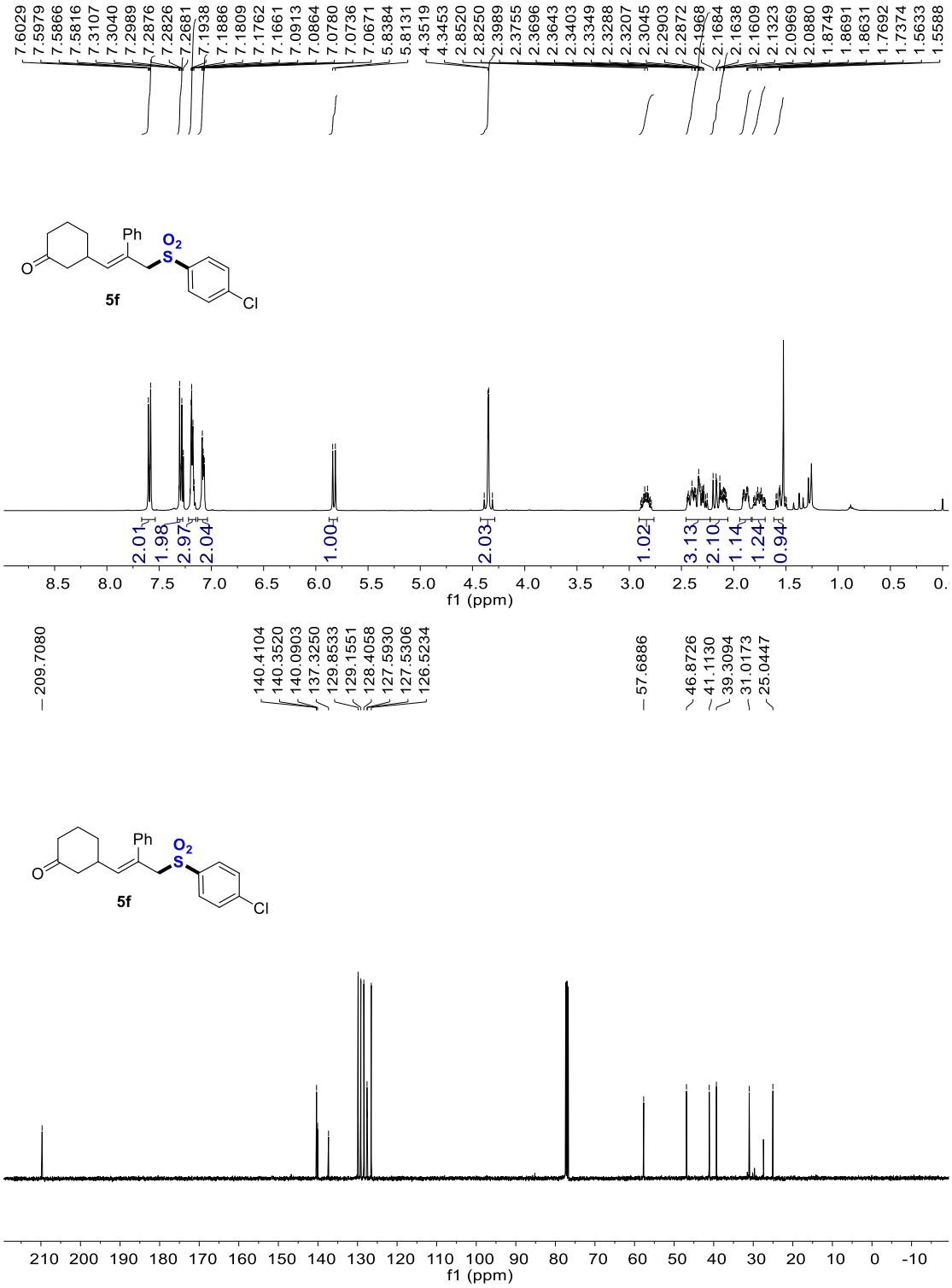
(E)-3-(3-((4-methoxyphenyl)sulfonyl)-2-phenylprop-1-en-1-yl)cyclohexan-1-one (5e)

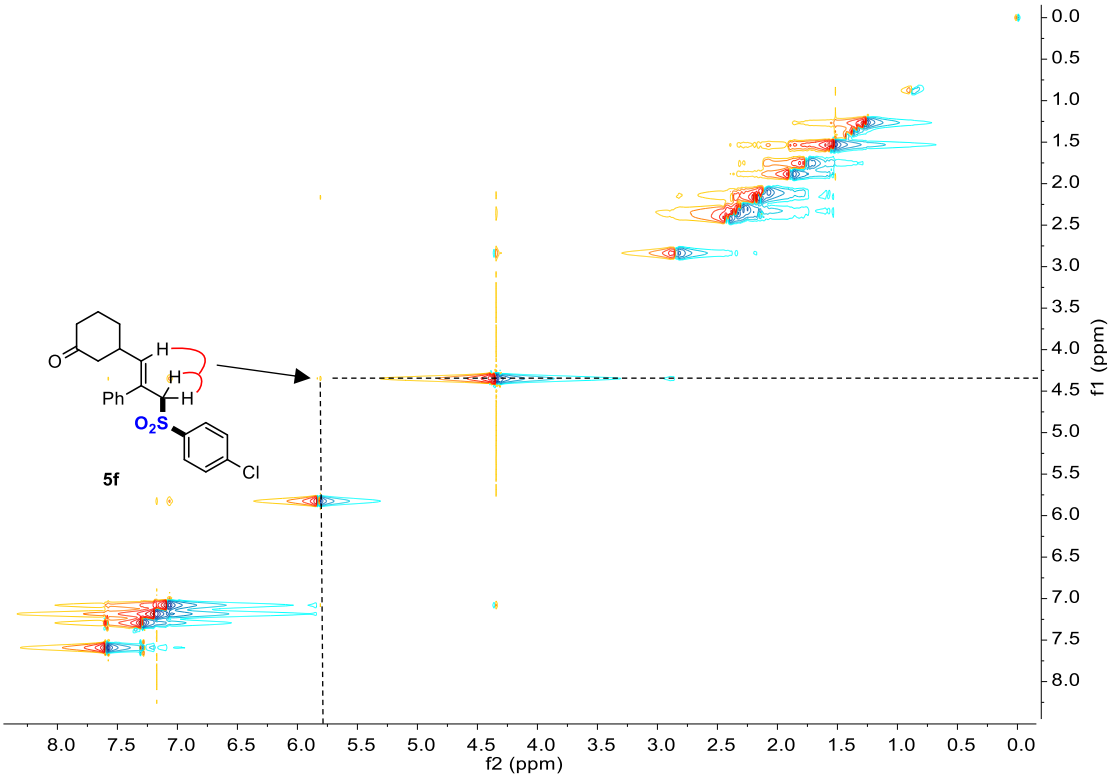




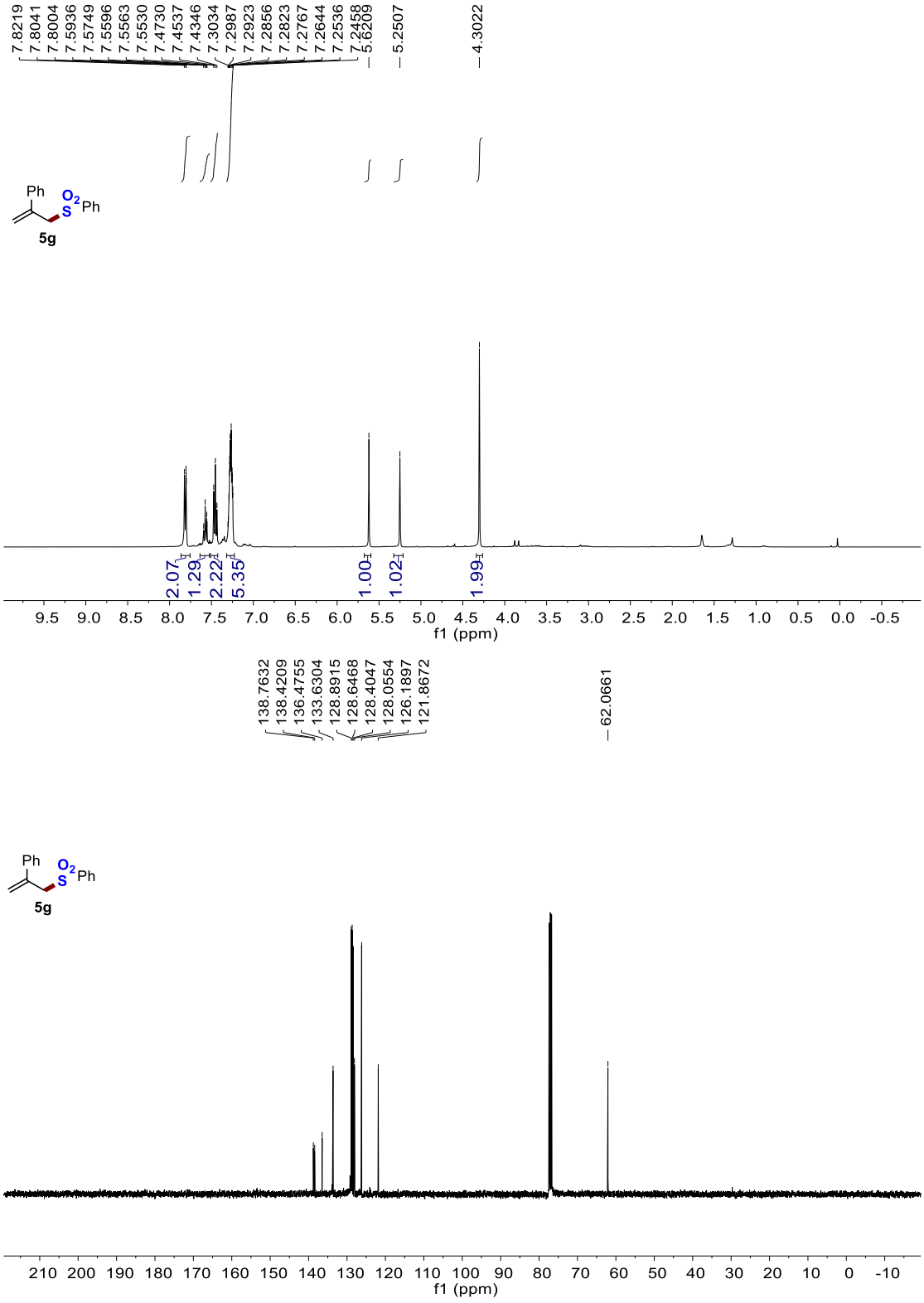

O
H
H
Ph
H
O2S
OMe
5e
f2 (ppm)
f1 (ppm)

(E)-3-(3-((4-chlorophenyl)sulfonyl)-2-phenylprop-1-en-1-yl)cyclohexan-1-one (5f)

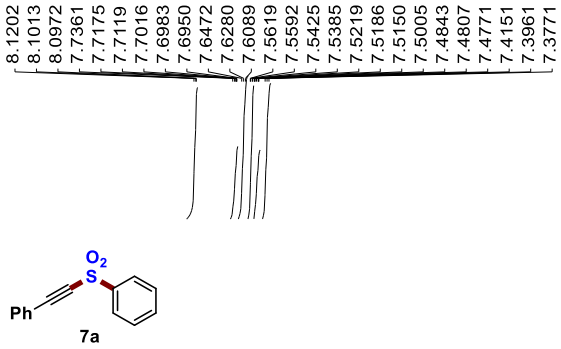


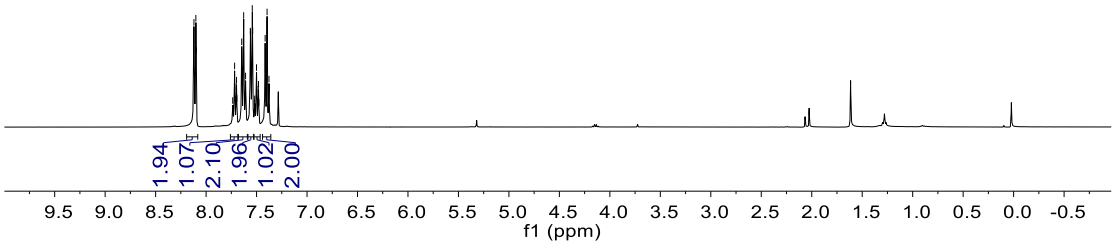

O
H
H
Ph
H
O2S
Cl
5f
f2 (ppm)
f1 (ppm)

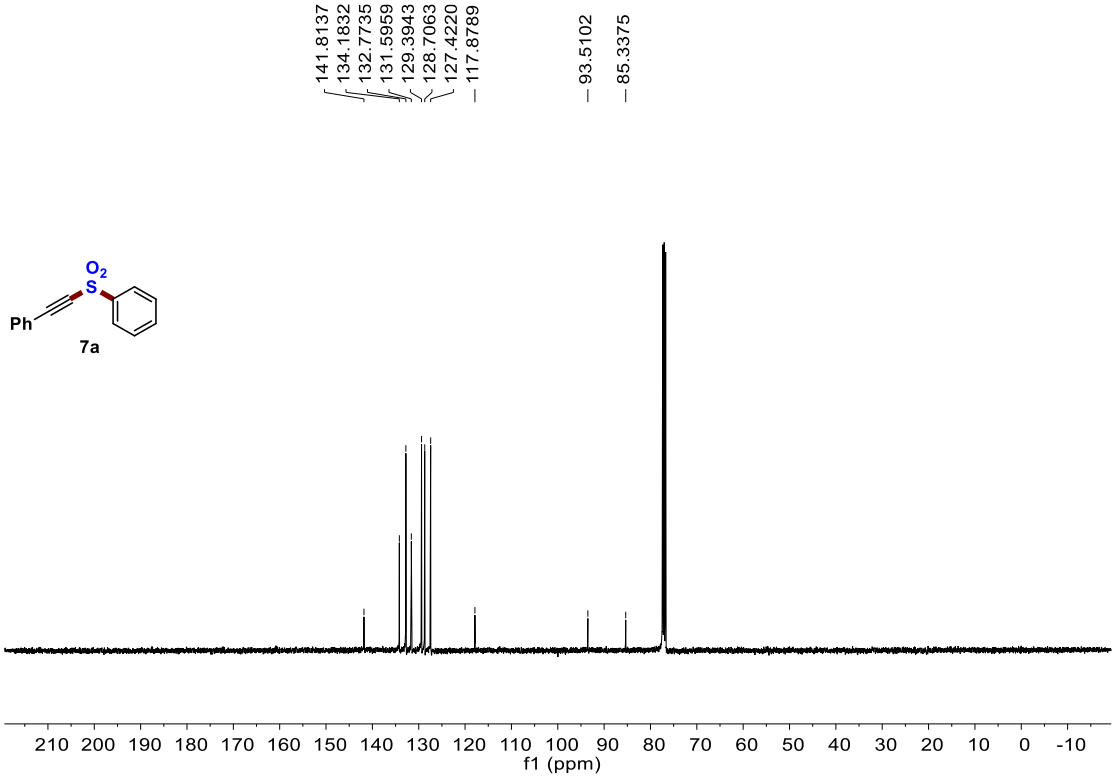
((2-phenylallyl)sulfonyl)benzene(5g)



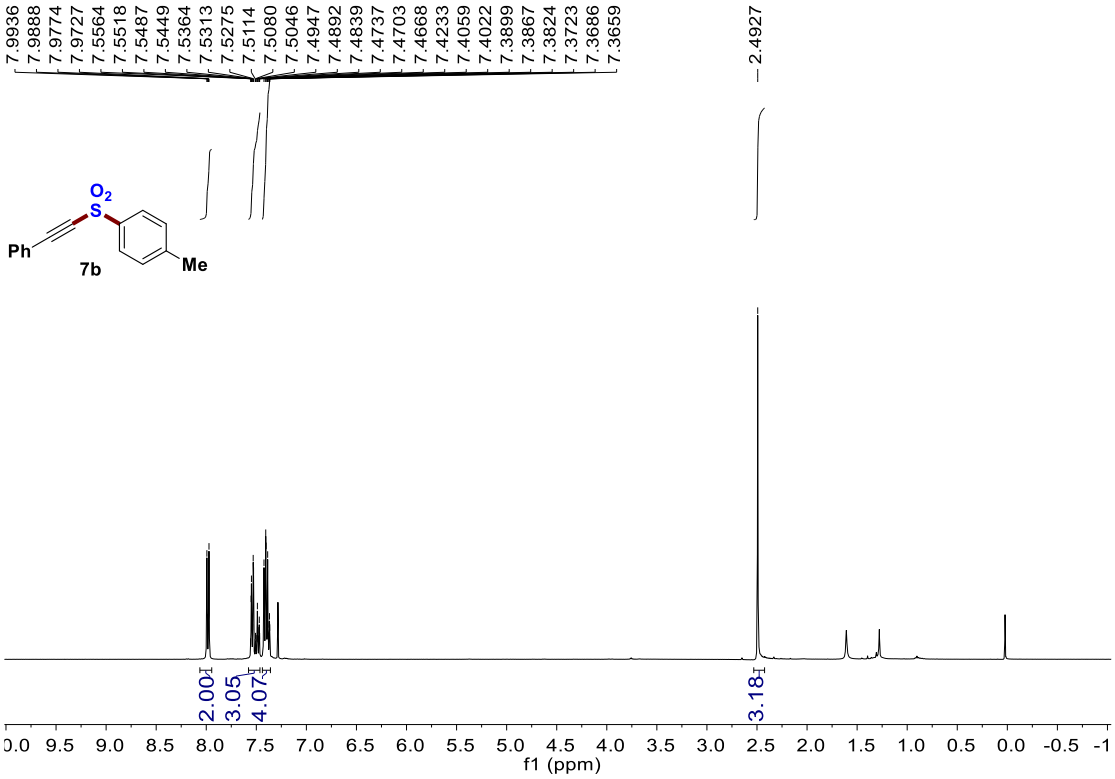
((phenylethynyl)sulfonyl)benzene(7a)

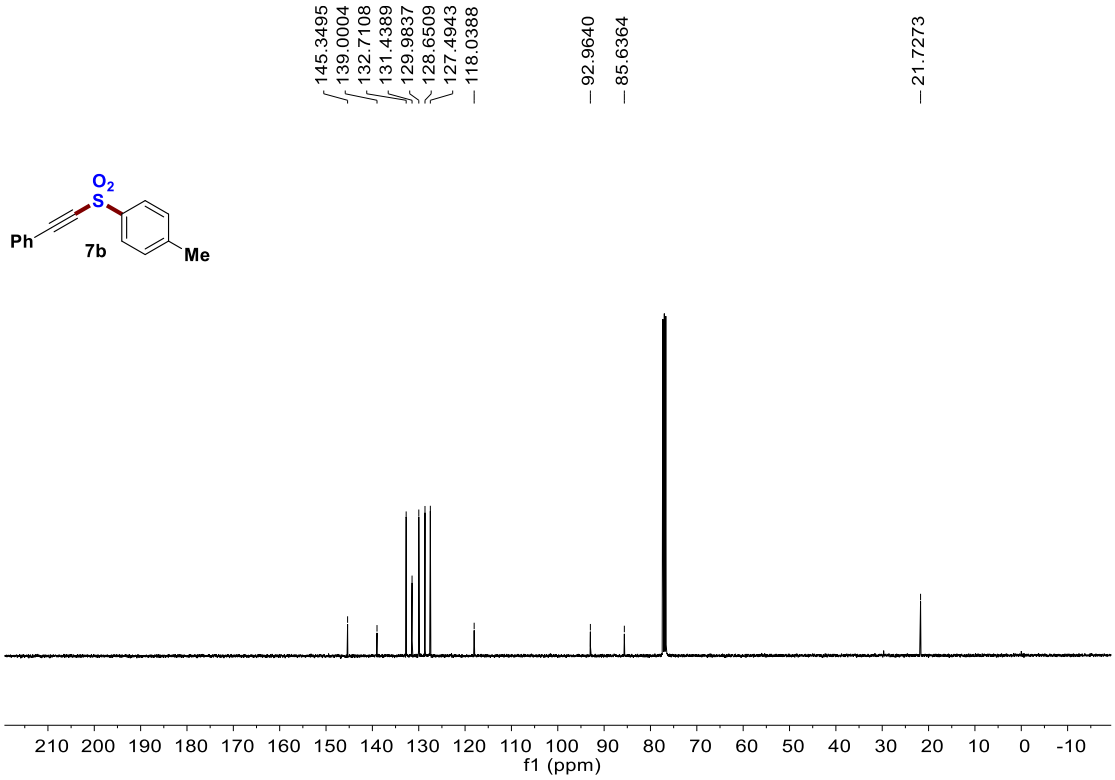




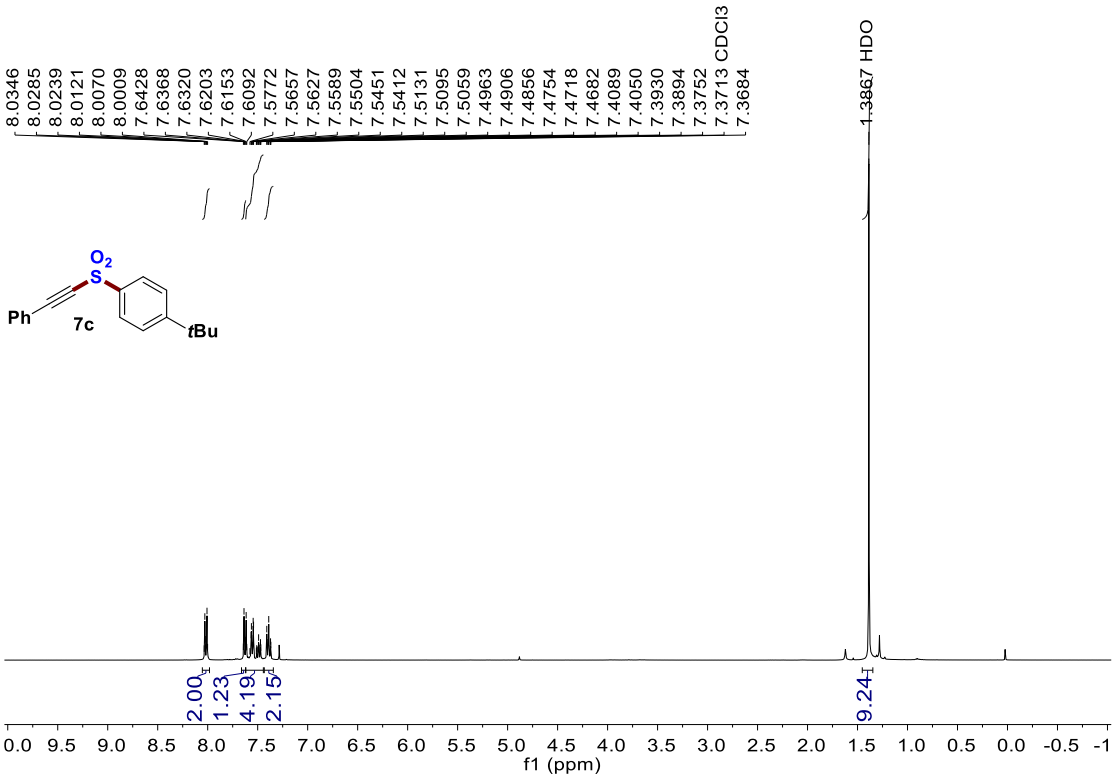


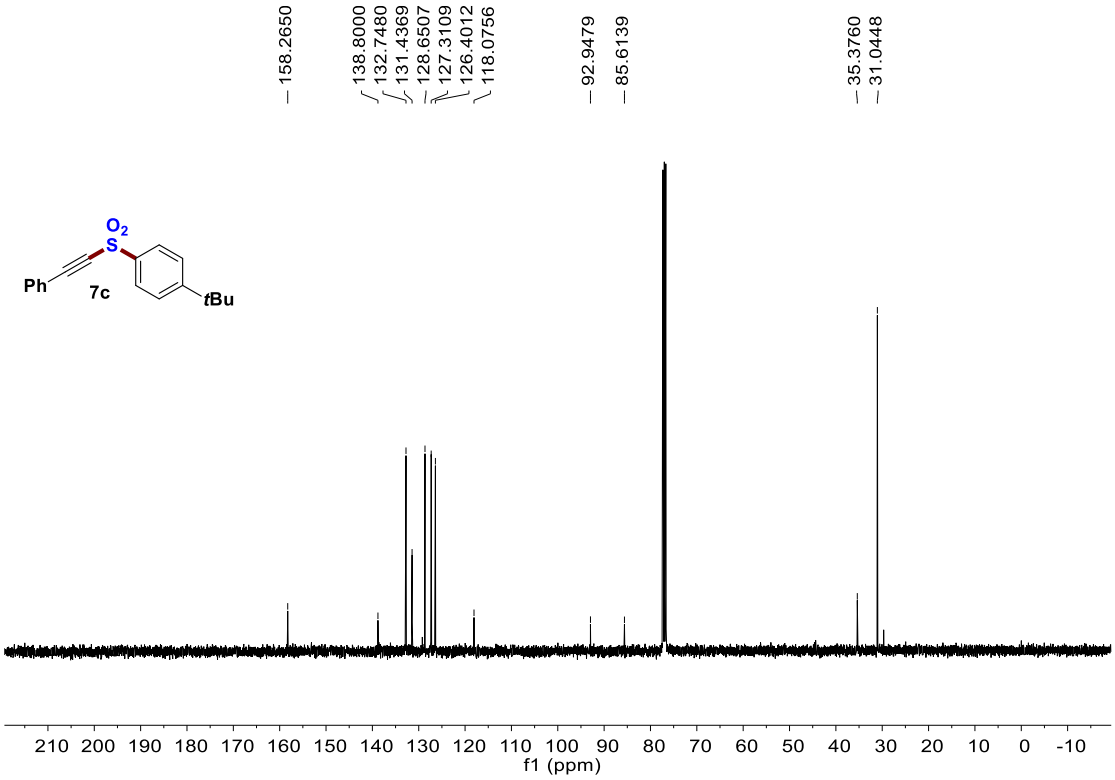
1-methyl-4-((phenylethynyl)sulfonyl)benzene(7b)



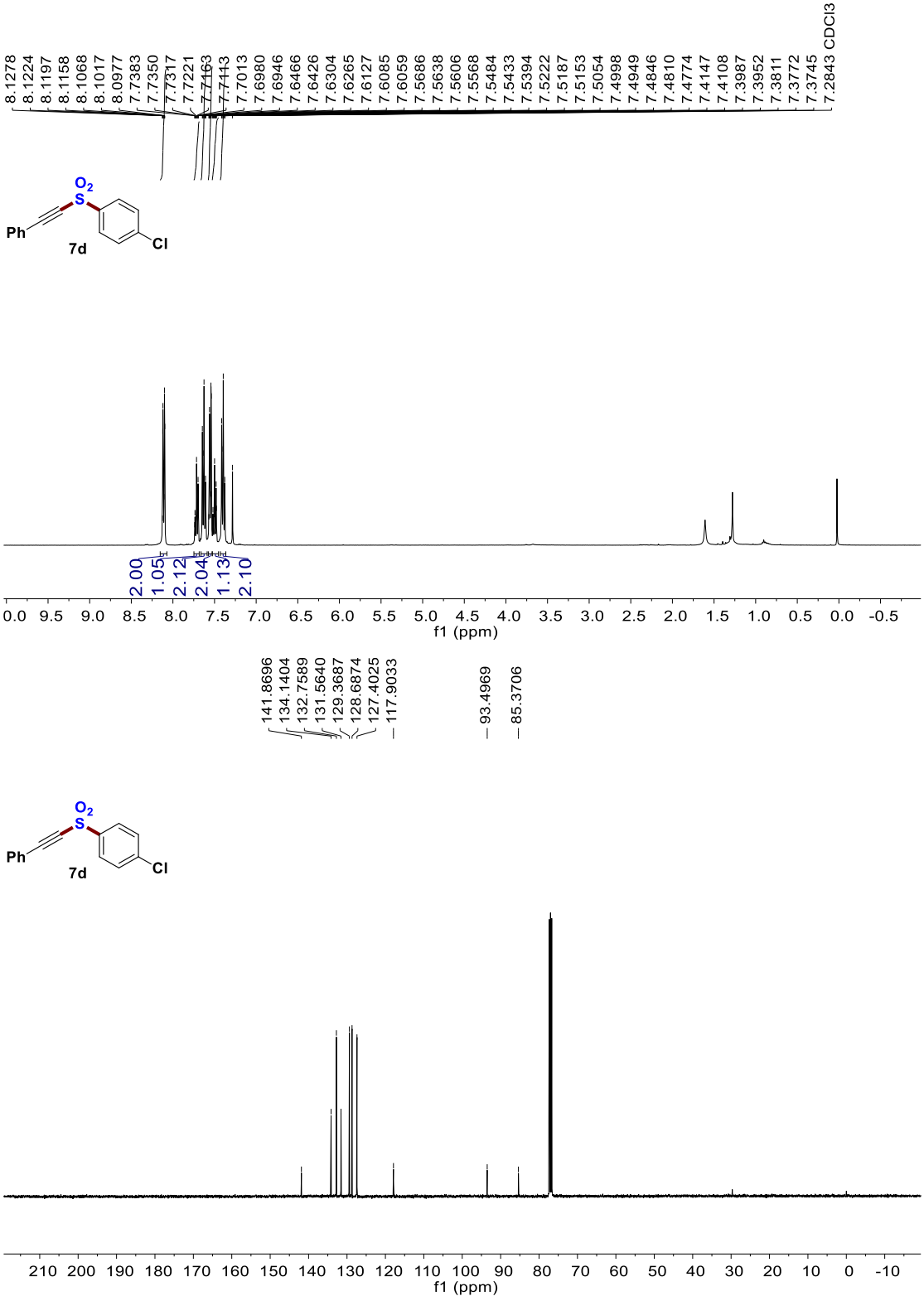


1-(tert-butyl)-4-((phenylethynyl)sulfonyl)benzene(7c)

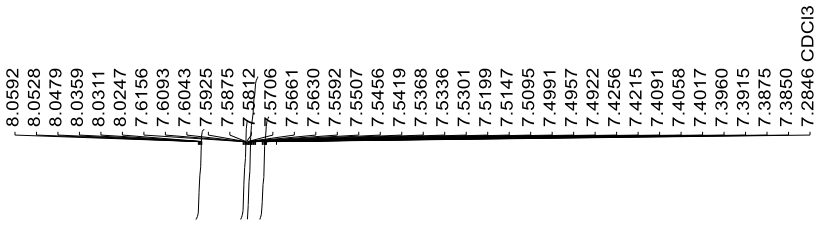


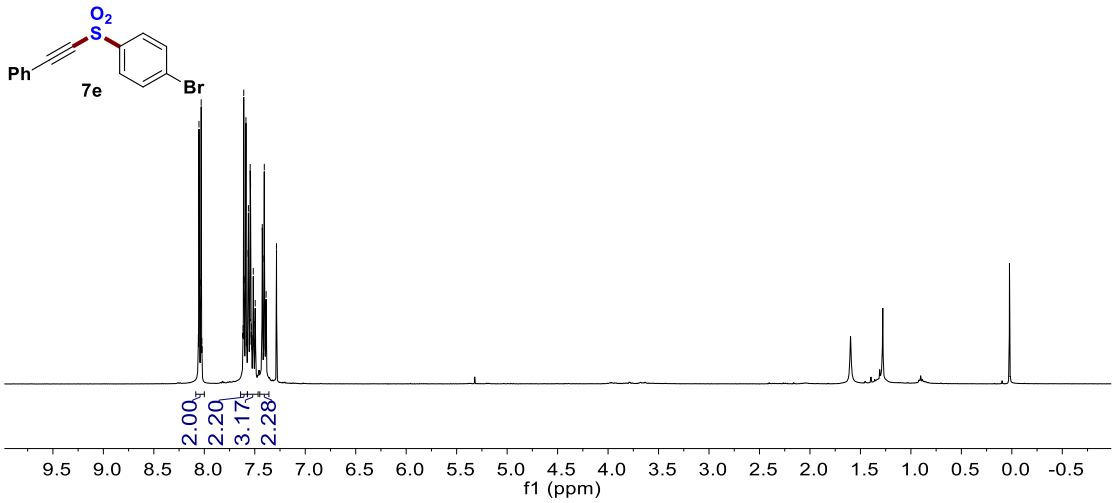


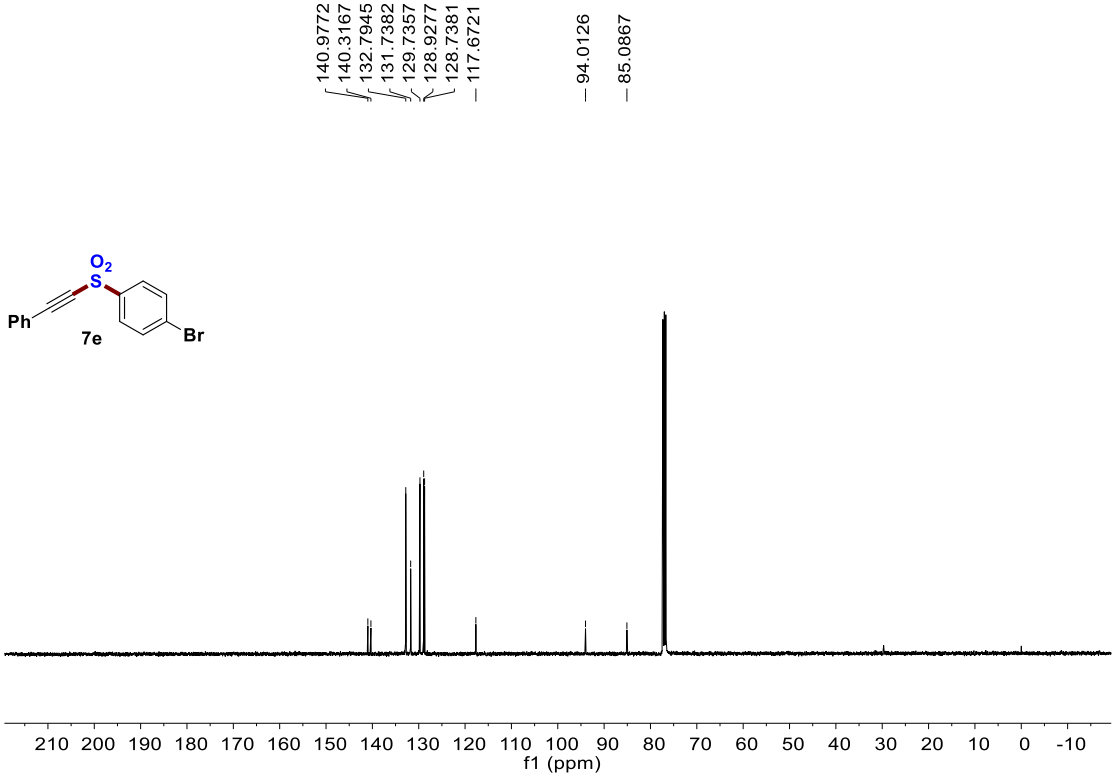
1-chloro-4-((phenylethynyl)sulfonyl)benzene(7d)



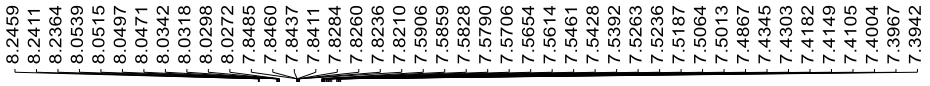
1-bromo-4-((phenylethynyl)sulfonyl)benzene(7e)

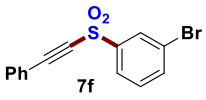


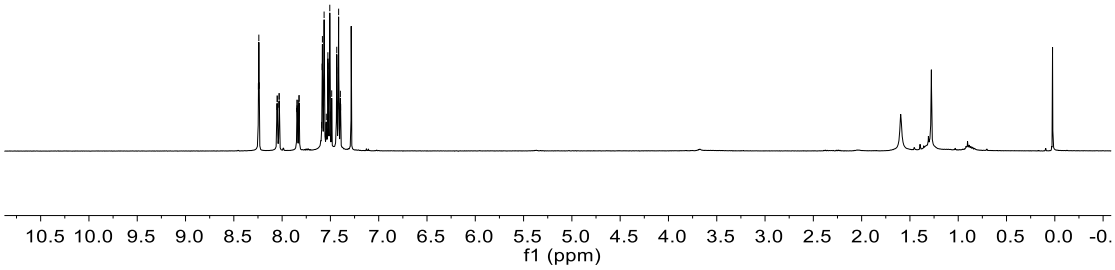


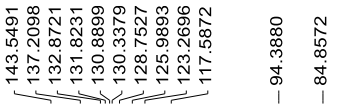


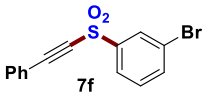
1-bromo-3-((phenylethynyl)sulfonyl)benzene(7f)

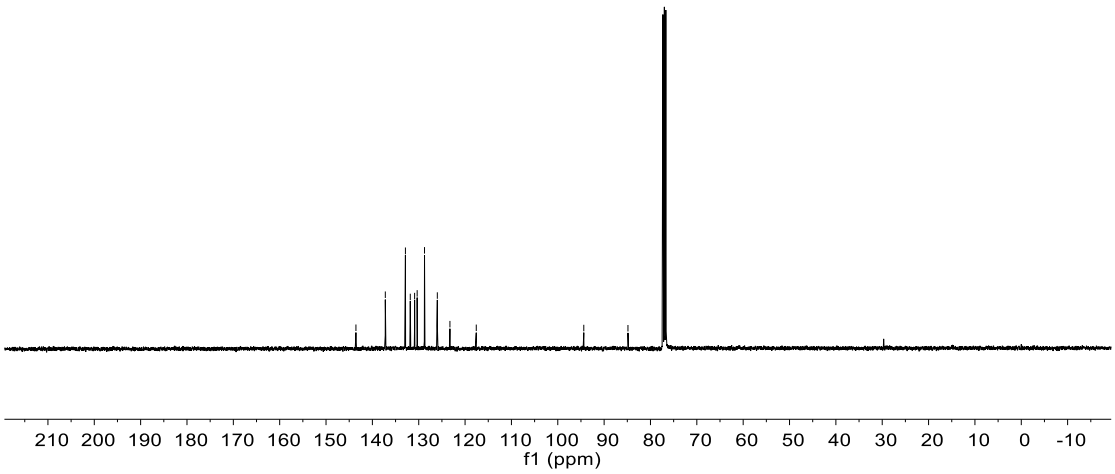




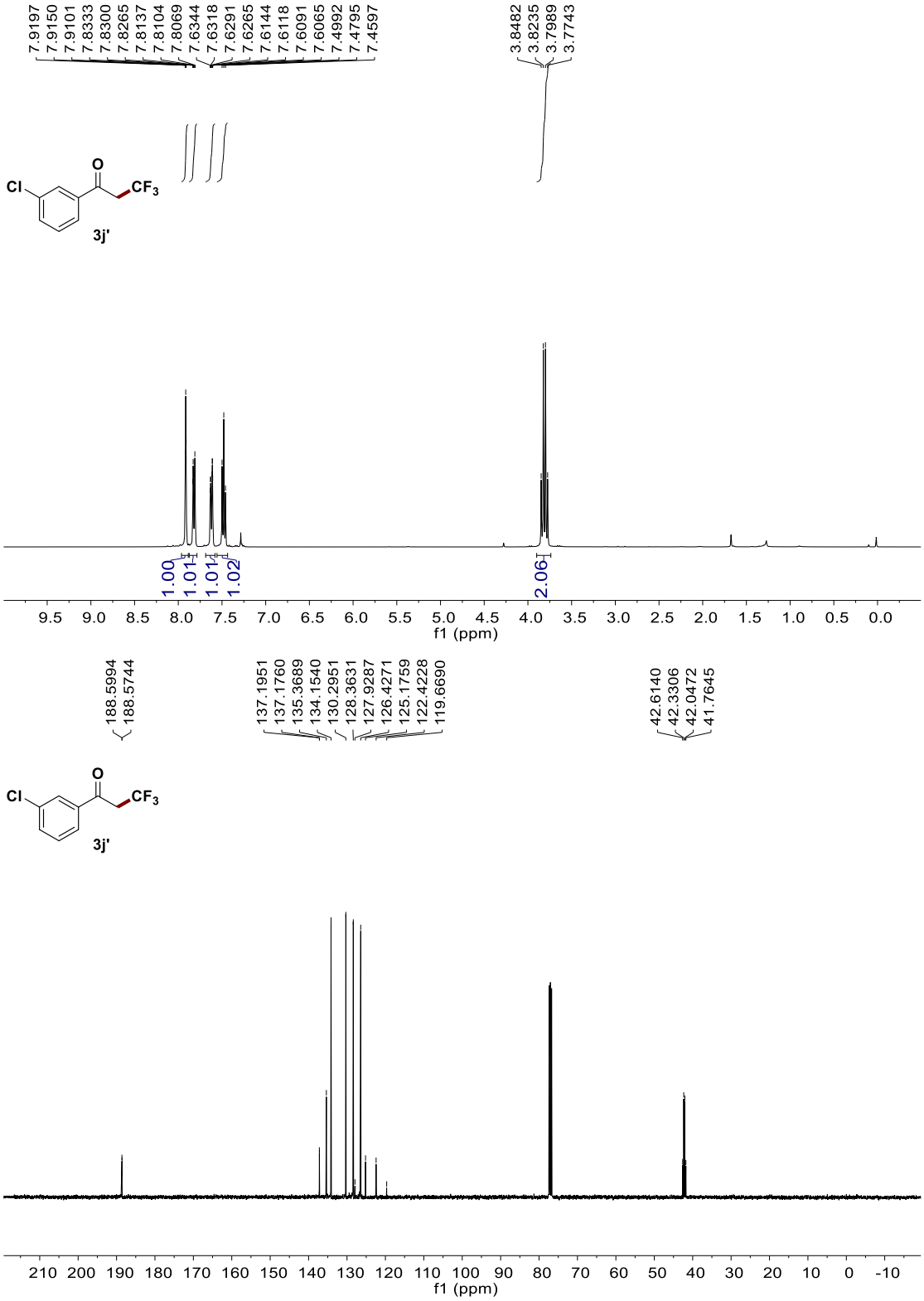


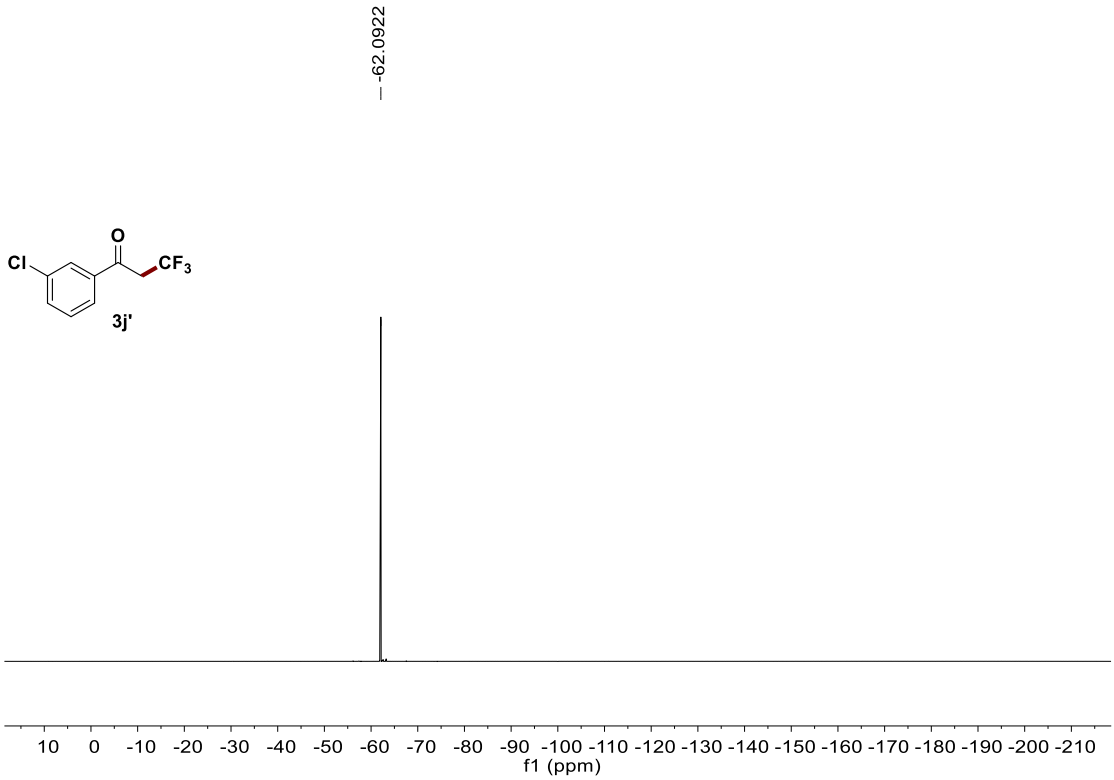




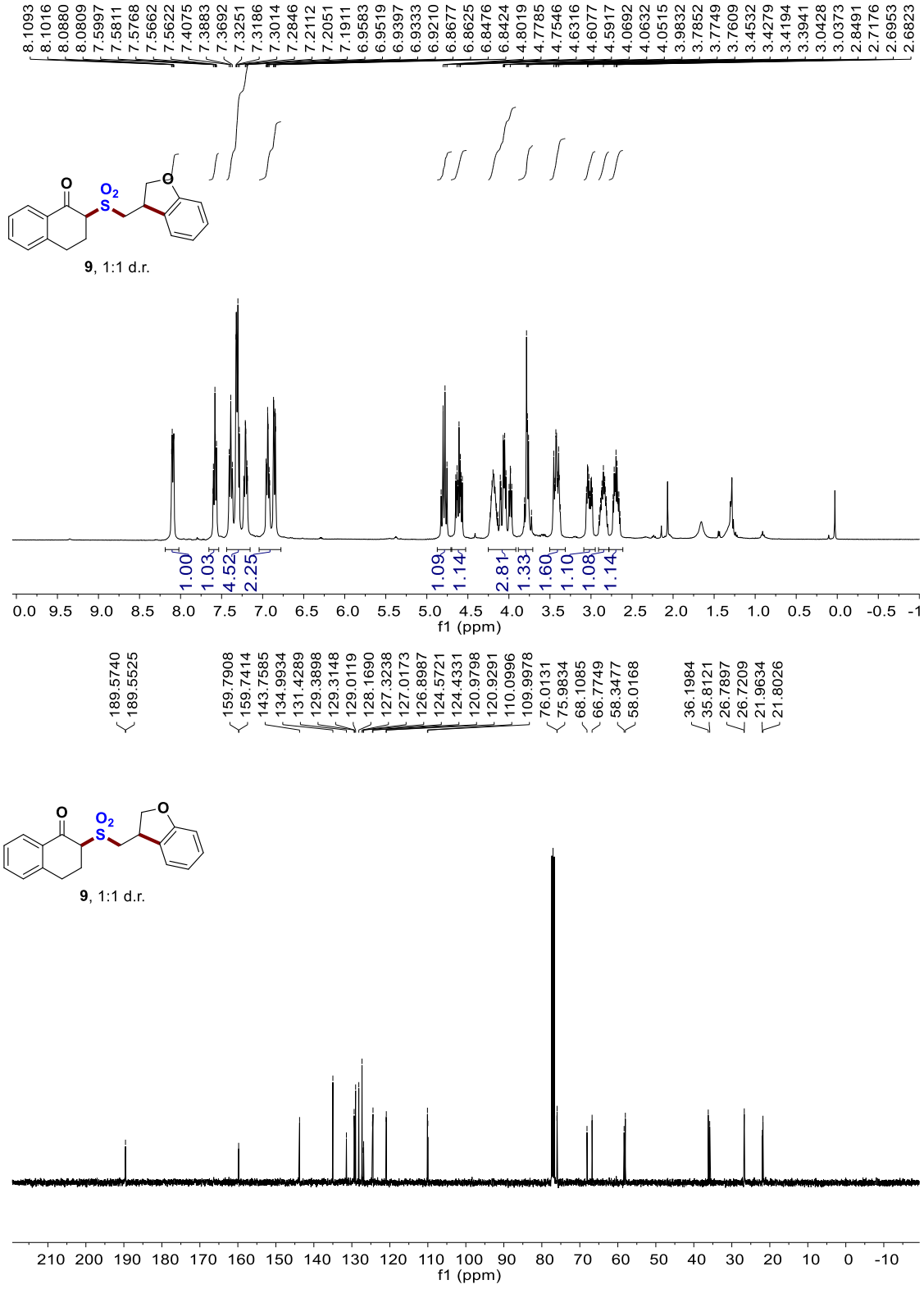


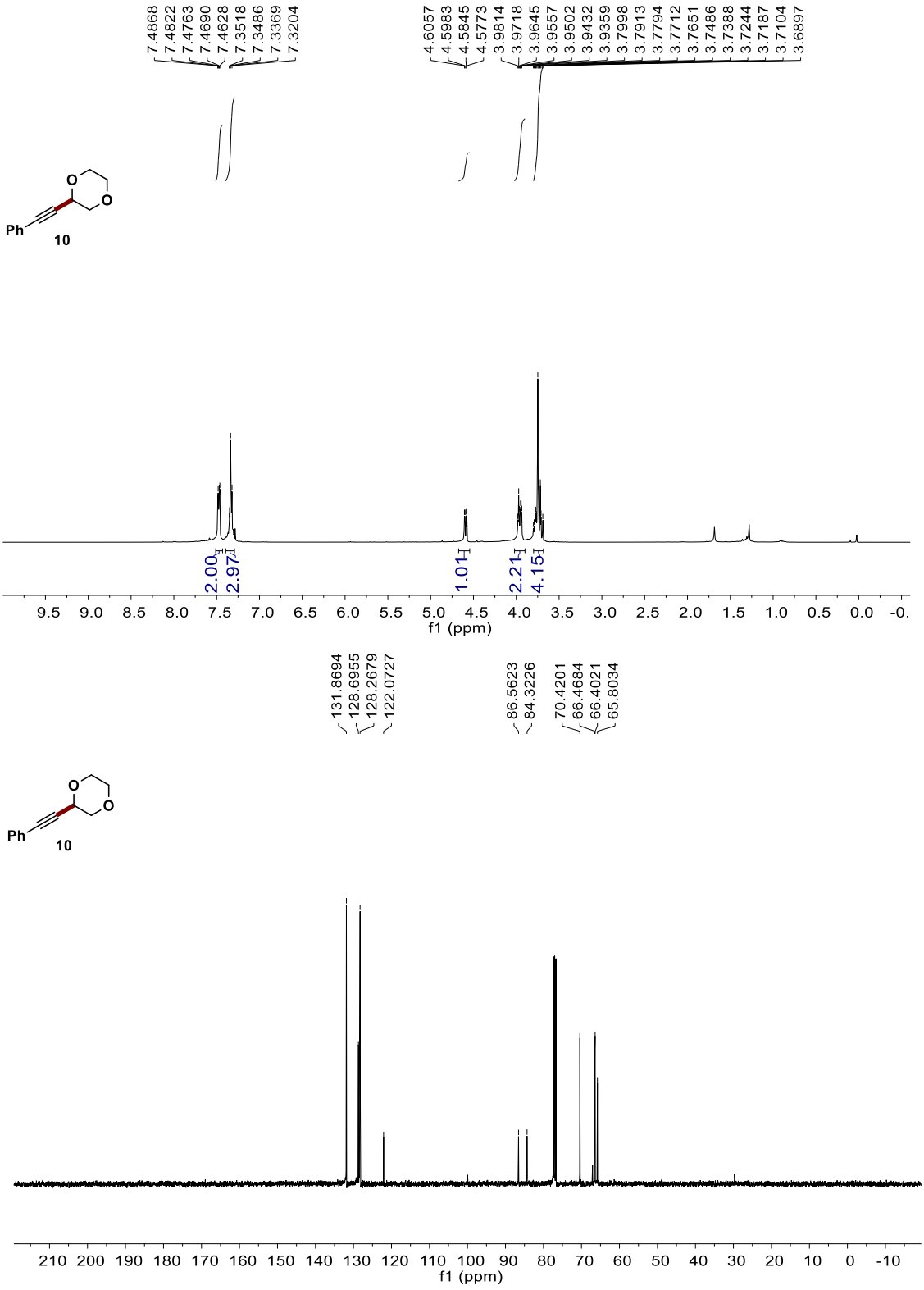
1-(3-chlorophenyl)-3,3,3-trifluoropropan-1-one (3j')




-62.0922
O
Cl
CF3
3j'
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

Compound 9


8.1093
8.1016
8.0880
8.0809
7.5997
7.5811
7.5768
7.5662
7.5622
7.4075
7.3883
7.3692
7.3251
7.3186
7.3014
7.2846
7.2112
7.2051
7.1911
6.9583
6.9519
6.9397
6.9333
6.9210
6.8677
6.8625
6.8476
6.8424
4.8019
4.7785
4.7546
4.6316
4.6077
4.5917
4.0692
4.0632
4.0515
3.9832
3.7852
3.7749
3.7609
3.4532
3.4279
3.4194
3.3941
3.0428
3.0373
2.8491
2.7176
2.6953
2.6823
O
O2
S
O
9, 1:1 d.r.
1.00
1.03
4.52
2.25
1.09
1.14
2.81
1.33
1.60
1.10
1.08
1.14
0.0 9.5 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 -0.5 -1
f1 (ppm)
189.5740
189.5525
159.7908
159.7414
143.7585
134.9934
131.4289
129.3898
129.3148
129.0119
128.1690
127.3238
127.0173
126.8987
124.5721
124.4331
120.9798
120.9291
110.0996
109.9978
76.0131
75.9834
68.1085
66.7749
58.3477
58.0168
36.1984
35.8121
26.7897
26.7209
21.9634
21.8026
O
O2
S
O
9, 1:1 d.r.
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)


7.4868
7.4822
7.4763
7.4690
7.4628
7.3518
7.3486
7.3369
7.3204
4.6057
4.5983
4.5845
4.5773
3.9814
3.9718
3.9645
3.9557
3.9502
3.9432
3.9359
3.7998
3.7913
3.7794
3.7712
3.7651
3.7486
3.7388
3.7244
3.7187
3.7104
3.6897
O
O
Ph
10
2.00
2.97
1.01
2.21
4.15
9.5 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 -0.
f1 (ppm)
131.8694
128.6955
128.2679
122.0727
86.5623
84.3226
70.4201
66.4684
66.4021
65.8034
O
O
Ph
10
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)