Supplementary Materials

Enantioselective 1,1-diarylation of allyl sulfones catalyzed by palladium with a chiral phosphoric acid

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1. General considerations

Unless otherwise noted, all reactions were carried out under an atmosphere of argon, using over-dried or flame-dried glassware equipped with a magnetic stir bar. All chemicals were purchased from commercial suppliers and used without further purification. In addition to commercially available extra dry solvents, all solvents were purified by standard operating methods. Thin-layer chromatography was performed with EMD silica gel 60 F_{254} plates eluting with solvents indicated, visualized by a 254 nm UV lamp and stained with phosphomolybdic acid (PMA). **^{1}H NMR**, **^{13}C NMR** and **^{19}F NMR** spectra were obtained on Bruker AM-400 and Bruker AM-700. Chemical shifts (δ) were quoted in ppm relative to tetramethylsilane or deuterated solvent as internal standard (Chloroform-*d*: 7.26 ppm for **^{1}H NMR**; Chloroform-*d*: 77.16 ppm for **^{13}C NMR**), multiplicities are as indicated: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet. High-resolution mass spectral analysis (**HRMS**) data were measured on a Buker impact II (Q-TOF) mass spectrum by means of the ESI technique and a Fourier Transform Ion Cyclotron (Solarix 7.0T). Crystallographic data were obtained from a Bruker D8 VENTURE diffractometer. Melting points were measured on a melting point apparatus and were uncorrected. Optical rotations were measured on a Rudolph Research Analytical. $[\alpha]_D$ values are reported in degrees and concentration (c) is in g/100 mL. Er values were measured on the supercritical fluid chromatography (SFC, ACQUITY UPC^2 system of Waters) and HPLC analysis employing Daicel Chiralpak IC-3, OD-3, IG-3, Trefoil CEL1 and Trefoil CEL2 column.

2. General procedure for preparing substrates

2.1 All of the used alkenes are known compounds except **2t** and **2u**. Compounds **2b-2j**[1], **2k**[2], **2l**[1], **2m**[2], **2n-2o**[3], **2p**[4], **2s**[1], **2t**[5], **2u**[6], **6b**[7] were prepared according to the reported literatures, and other alkenes were purchased from commercial suppliers (Energy Chemical) and used without further purification.

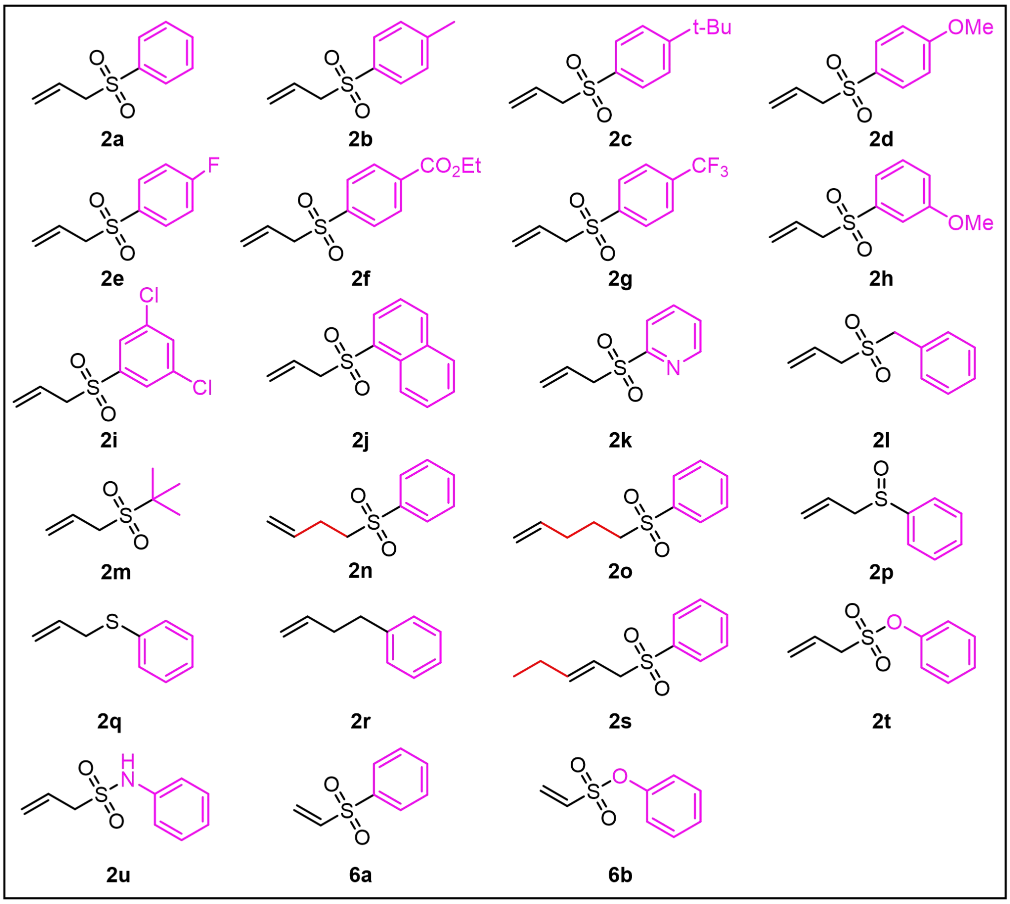
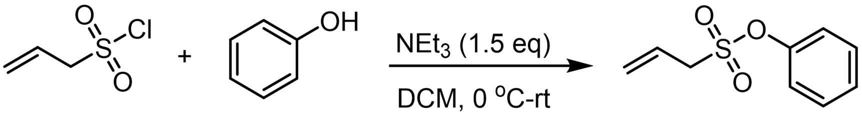


Figure S1. Substrate scope of known alkenes

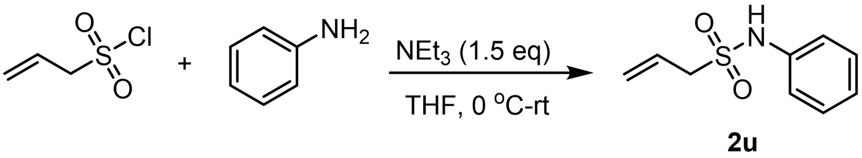
Synthesis of new substrates 2t and 2u



2t

Phenyl prop-2-ene-1-sulfonate (2t): Following a modified procedure:[5] prop-2-ene-1-sulfonyl chloride (3.56 mmol, 500 mg, 1.2 eq) and Et_3N (618 μL, 4.45 mmol, 1.5 eq) were added to a stirred solution of phenol (2.96 mmol, 279 mg, 1.0 eq) in DCM (5 mL) at 0 °C. The reaction mixture was stirred overnight (20 h) at room temperature. Water (10 ml) was added, the reaction mixture was extracted with EtOAc (3 × 10 ml), combined organic extracts were washed with brine (2 × 10 ml), dried over Na_2SO_4, filtered and the solvent was driven off in a vacuum. The crude product was purified by column chromatography (SiO_2, PE/EA = 15:1, v/v) in 36%

yield (210 mg) as a yellow oil. **^{1}H NMR** (400 MHz, Chloroform-d) δ 7.5 – 7.4 (m, 2H), 7.3 – 7.2 (m, 3H), 6.1 – 5.9 (m, 1H), 5.6 – 5.4 (m, 2H), 4.0 (d, *J* = 7.2 Hz, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 149.3, 130.0, 127.3, 125.2, 124.0, 122.1, 54.6. **HRMS (ESI)** calcd for $C_9H_{10}NaO_3S$ $[M+Na]^+$ *m/z* 221.0243, found 221.0245.



N-phenylprop-2-ene-1-sulfonamide (2u): Following a modified procedure:[6] Et_3N (618 μL, 4.45 mmol, 1.5 eq) was added to a stirred solution of aniline (2.96 mmol, 270 μL, 1.0 eq) in THF (3 mL) at 0 °C. Then prop-2-ene-1-sulfonyl chloride (3.56 mmol, 500 mg, 1.2 eq) in THF (2 mL) was slowly added dropwise to the solution at 0 °C. The resulting mixture was stirred for 1 h while the temperature was gradually warmed to room temperature. Additional Et_3N (618 μL, 4.45 mmol, 1.5 eq) was added to the reaction mixture and the resultant solution was stirred for 0.5 h. $NaHCO_3$ (aq) was added, the reaction mixture was extracted with EtOAc (3×10 mL), combined organic extracts were washed with brine (2×10 mL), dried over Na_2SO_4, filtered and the solvent was driven off in a vacuum. The crude product was purified by column chromatography (SiO_2, PE/EA = 15:1~8:1, v/v) in 94% yield (550 mg) as a yellow oil. **^{1}H NMR** (500 MHz, Chloroform-d) δ 7.44 (s, 1H), 7.37 – 7.30 (m, 2H), 7.31 – 7.22 (m, 2H), 7.16 (t, J = 7.3 Hz, 1H), 5.88 (ddt, J = 17.4, 10.1, 7.3 Hz, 1H), 5.45 – 5.39 (m, 1H), 5.33 – 5.26 (m, 1H), 3.83 (d, J = 7.4 Hz, 2H); **^{13}C NMR** (126 MHz, CDCl3) δ 136.89, 129.62, 125.18, 125.02, 124.83, 120.78, 55.53. **HRMS (ESI)** calcd for $C_9H_{11}NNaO_2S$ $[M+Na]^+$ *m/z* 220.0399, found 220.0403.

2.2 All of the used aryldiazonium salts are known compounds. Compounds **3a-3e**[8], **3f**[8-9] were prepared according to the reported literatures.

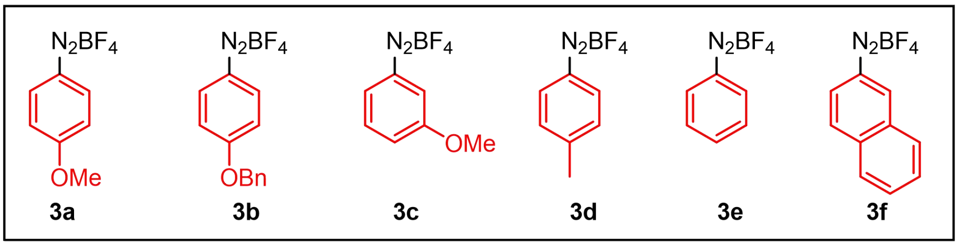


Figure S2. The scope of aryldiazonium salts

Caution: All aryldiazonium salts need to be recrystallized from anhydrous Et_2O/Acetone several times to get pure and dry white crystals; low purity and high water content of aryldiazonium salts might lead to low yields and er values of targeting diarylation products.

Our analytical data (**^{1}H NMR**, **^{13}C NMR** and **^{19}F NMR**) match with the literatures[1-4, 8-9]. (**Figure S1** and **Figure S2)**.

2.3 All of the arylboronic acids were purchased from commercial suppliers (*Energy Chemical* and *TCI company*) and used without further purification, Rb_2CO_3 was purchased from commercial suppliers (*Adamas-beta*) and used without further purification, Pd_2dba_3 was purchased from commercial suppliers (*Strem Chemicals*) and used without further purification, (*R*)-**1a** was purchased from commercial suppliers (*DAICEL CHIRAL TECHNOLOGIES*) and purified according to reported literature[10].

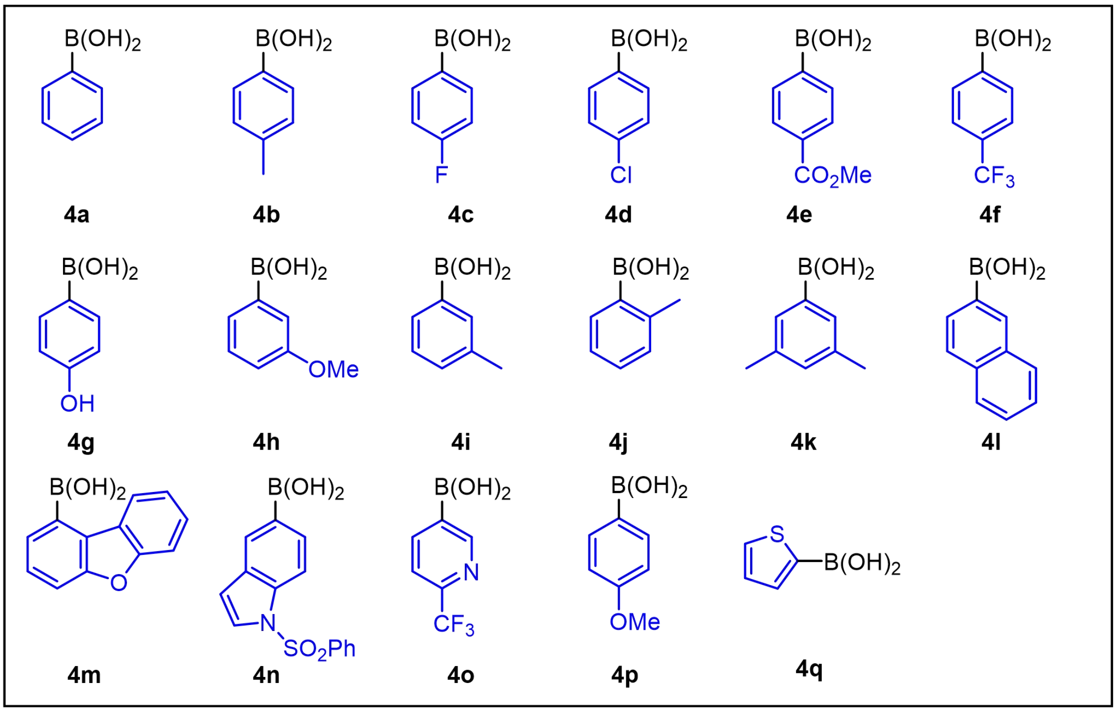
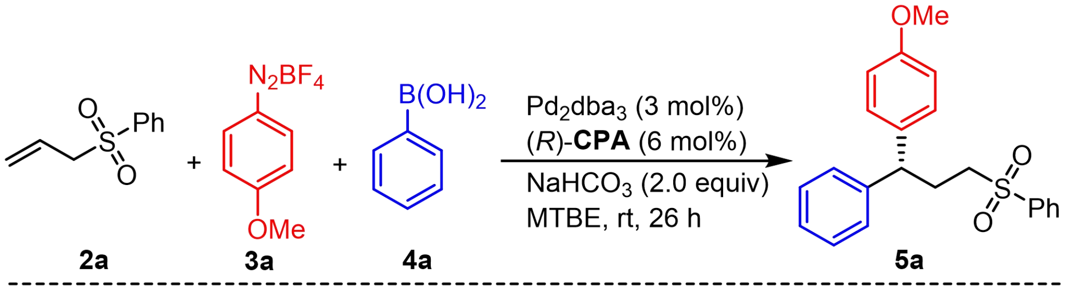
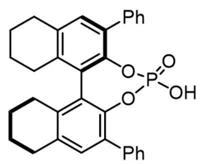


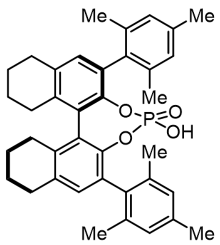
Figure S3. The scope of arylboronic acids

3. Reaction optimization

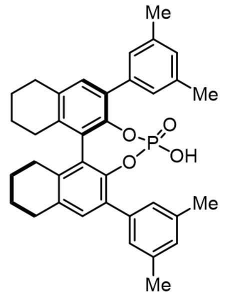




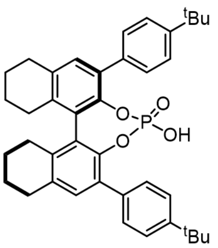
(*R*)-**1f,** 44%, 68:32 er



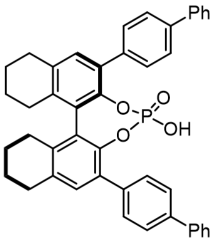
19%, 52:48 er



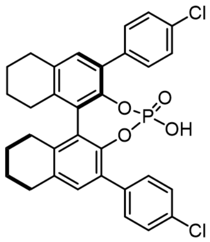
41%, 64:36 er



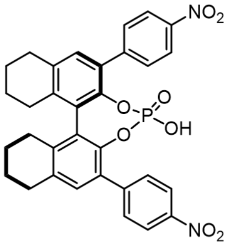
46%, 70:30 er



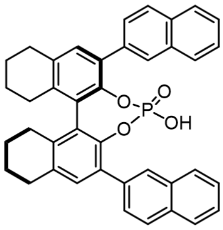
65%, 36:64 er



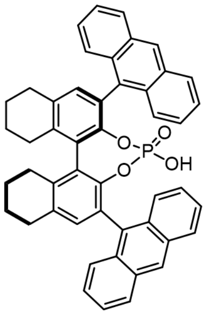
54%, 63:37 er



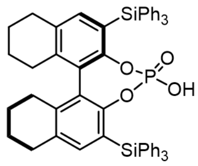
36%, 58:42 er



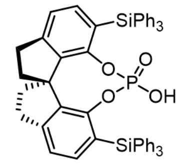
47%, 62 :38 er



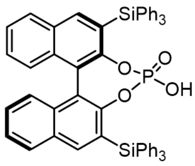
18%, 46:54 er



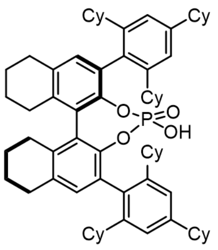
(*R*)-**1e**, 25%, 38 :63 er



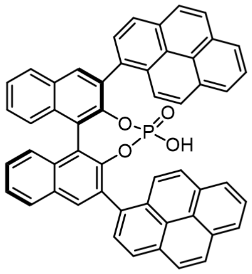
(*R*)-**1a**, 56%, 75:25 er



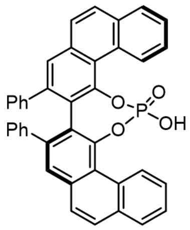
(*R*)-**1c**, 31%, 22:78 er



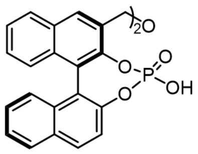
50%, 54:46 er



47%, 46:54 er



59%, 53:47 er



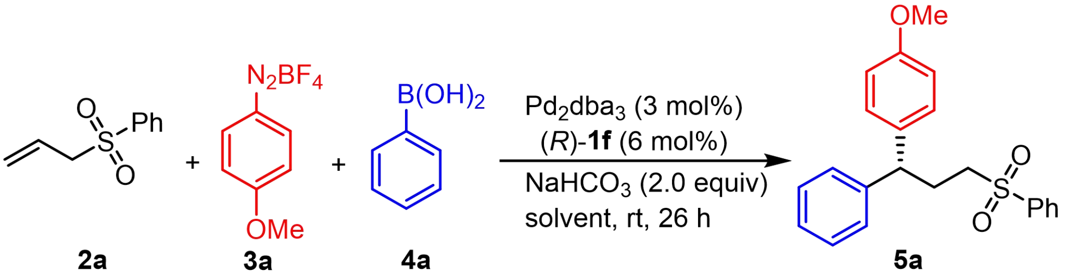
NR

Table S1. The effects of CPAs[a]

[a]Unless otherwise noted, the reaction was conducted with **2a** (0.1 mmol), **3a** (0.12

mmol), **4a** (0.15 mmol), $NaHCO_3$ (0.2 mmol), (*R*)-**CPA** (0.006 mmol) and Pd_2dba_3 (0.003 mmol) in MTBE (2 mL) at rt for 26 h under Ar. Isolated yields are shown. The er values were determined by SFC.

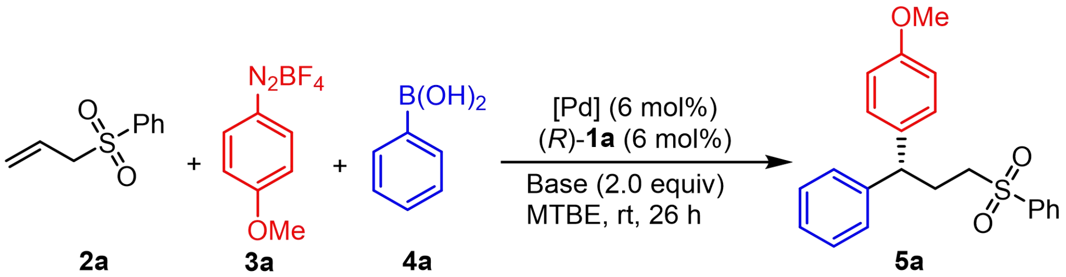
Table S2. The effects of solvent[a]



Entry	Solvent	Volume	Yield (%)[b]	er (%)[c]
1	MTBE	2 mL	44	68:32
2	Et_2O	2 mL	42	62:38
3	$^iPr_2O$	2 mL	19	66:34
4	Toluene	2 mL	12	67:33
5	Hexane	2 mL	NR	-
6[d]	MTBE	2 mL	56	75:25
7[d]	MTBE	1 mL	30	72:28
8[d]	MTBE	3 mL	32	73:27

[a] Unless otherwise noted, the reaction was conducted with **2a** (0.1 mmol), **3a** (0.12 mmol), **4a** (0.15 mmol), $NaHCO_3$ (0.2 mmol), (*R*)-**1f** (0.006 mmol) and Pd_2dba_3 (0.003 mmol) in solvent (2 mL) at rt for 26 h under Ar. [b] Isolated yields are shown. [c] The er values were determined by SFC. [d] Replaced (*R*)-**1f** with (*R*)-**1a** (0.006 mmol).

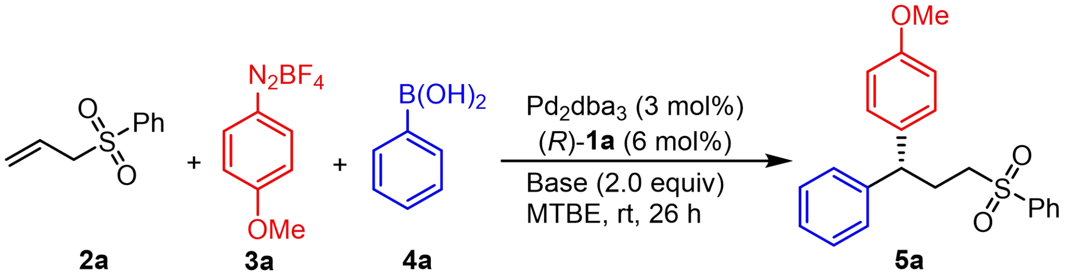
Table S3. The effects of [Pd] source[a]



Entry	[Pd] source	Yield (%)[b]	er (%)[c]
1	Pd_2dba_3	56	75:25
2	Pd_2(3,3',5,5'-OMe-dba)$_3$	56	75:25
3	$Pddba_2$	54	75:25
4	$Pd_2dba_3 \cdot CHCl_3$	55	75:25
5	$Pd(OAc)_2$	28	73:27
6	Buchwald precatalyst	40	70:30

[a] Unless otherwise noted, the reaction was conducted with **2a** (0.1 mmol), **3a** (0.12 mmol), **4a** (0.15 mmol), $NaHCO_3$ (0.2 mmol), (*R*)-**1a** (0.006 mmol) and [Pd] (0.006 mmol) in MTBE (2 mL) at rt for 26 h under Ar. [b] Isolated yields are shown. [c] The er values were determined by SFC.

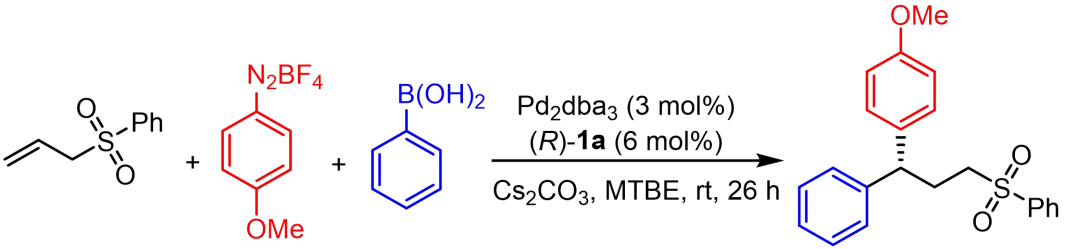
Table S4. The effects of base[a]



Entry	Base	Yield (%)[b]	er (%)[c]
1	$NaHCO_3$	44	68:32
2	Na_2CO_3	44	78:22
3	Na_2HPO_4	26	73:27
4	Na_3PO_4	60	74:26
5	Li_2CO_3	40	71:29
6	K_2CO_3	60	80:20
7	$KHCO_3$	33	75:25
8	K_2HPO_4	50	73:27
9	K_3PO_4	44	76:24
10	Cs_2CO_3	51	83:17
11	$MgCO_3$	31	76:24

[a]Unless otherwise noted, the reaction was conducted with **2a** (0.1 mmol), **3a** (0.12 mmol), **4a** (0.15 mmol), Base (0.2 mmol), (*R*)-**1a** (0.006 mmol) and Pd_2dba_3 (0.003 mmol) in MTBE (2 mL) at rt for 26 h under Ar. [b]Isolated yields are shown. [c]The er values were determined by SFC.

Table S5. The effects of substrates ratio[a]

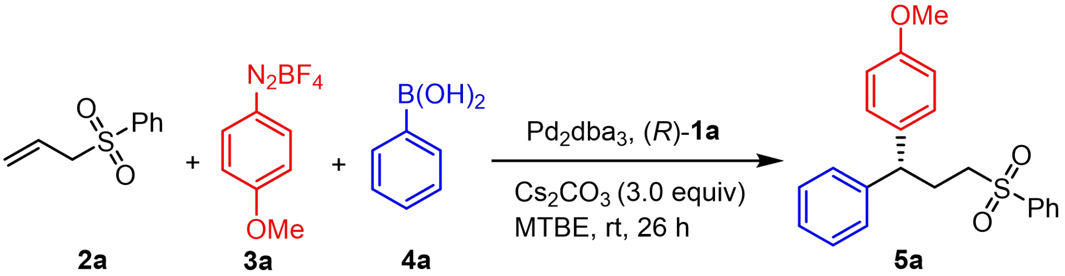


2a **3a** **4a** **5a**

Entry	2a (equiv)	3a (equiv)	4a (equiv)	Cs_2CO_3 (equiv)	Yield (%)[b]	er (%)[c]
1	1.0	1.0	1.0	2.0	37	85:15
2	1.0	1.5	1.5	2.0	46	82:18
3	1.0	1.2	2.0	2.0	48	79:21
4	1.2	1.2	1.0	2.0	44	87:13
5	1.2	1.0	1.5	2.0	43	83:17
6	1.5	1.2	1.0	2.0	30	87:13
7	2.0	1.2	1.0	2.0	27	89:11
8	2.0	2.0	1.0	2.0	37	88:12
9	1.2	1.2	1.0	1.2	27	87:13
10	1.2	1.2	1.0	3.0	55	86:14
11	2.0	2.0	1.0	3.0	43	88:12

[a]Unless otherwise noted, the reaction was conducted with **2a**, **3a**, **4a**, Cs_2CO_3, (*R*)-**1a** (0.006 mmol) and Pd_2dba_3 (0.003 mmol) in MTBE (2 mL) at rt for 26 h under Ar. [b]Isolated yields are shown. [c]The er values were determined by SFC.

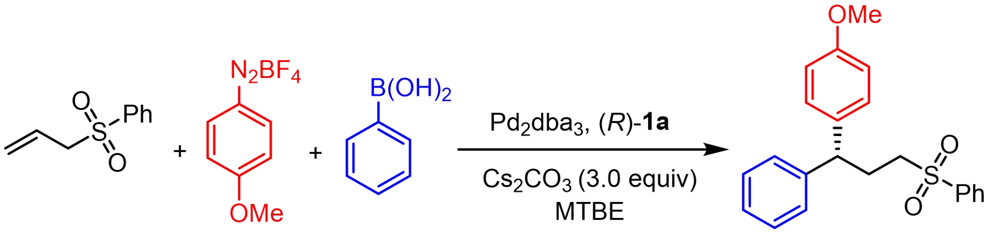
Table S6. The effects of catalyst ratio[a]



Entry	Pd_2dba_3 (equiv)	1a (equiv)	Yield (%)[b]	er (%)[c]
1	0.03	0.06	43	88:12
2	0.04	0.08	30	91:9
3	0.05	0.10	60	91:9
4	0.03	0.12	51	91:9
5	0.04	0.12	55	92:8

[a] Unless otherwise noted, the reaction was conducted with **2a** (0.2 mmol), **3a** (0.2 mmol), **4a** (0.1 mmol), Cs_2CO_3 (0.3 mmol), (*R*)-**1a** and Pd_2dba_3 in MTBE (2 mL) at rt for 26 h under Ar. [b] Isolated yields are shown. [c] The er values were determined by SFC.

Table S7. The effects of temperature and other adjustments[a]

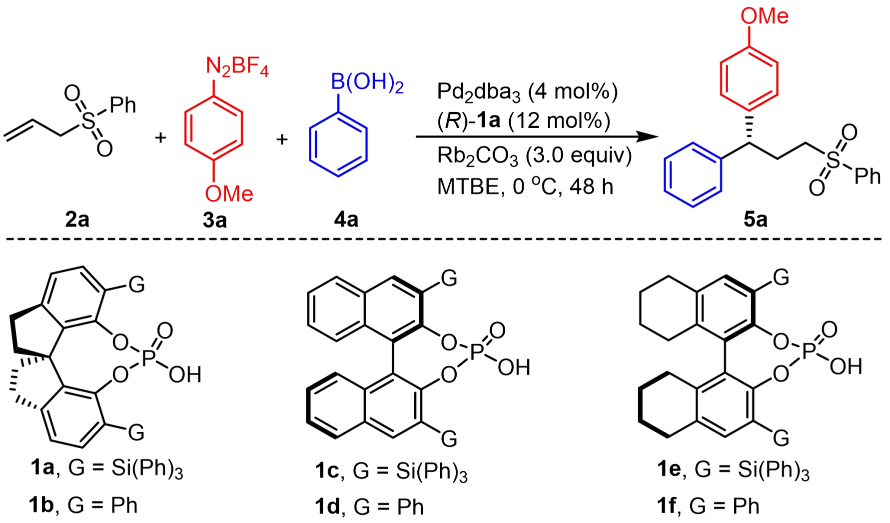


2a **3a** **4a** **5a**

Entry	Temperature	Time	Yield (%)[b]	er (%)[c]
1	rt	26 h	55	92:8
2	10°C	48 h	61	92:8
3	0°C	48 h	60	94:6
4	0°C	72 h	58	94:6
5[d]	0°C	48 h	51	96:4
6[d,e]	0°C	48 h	64	96:4

[a] Unless otherwise noted, the reaction was conducted with **2a** (0.2 mmol), **3a** (0.2 mmol), **4a** (0.1 mmol), Cs_2CO_3 (0.3 mmol), (*R*)-**1a** and Pd_2dba_3 in MTBE (2 mL) at rt for 26 h under Ar. [b] Isolated yields are shown. [c] The er values were determined by SFC. [d] (*R*)-**1a** was recrystallized from 2.0 M HCl and methanol followed by reported literature[10]. [e] Replaced Cs_2CO_3 with Rb_2CO_3 (0.3 mmol).

Table S8. Adjustments from optimized reaction condition[a]



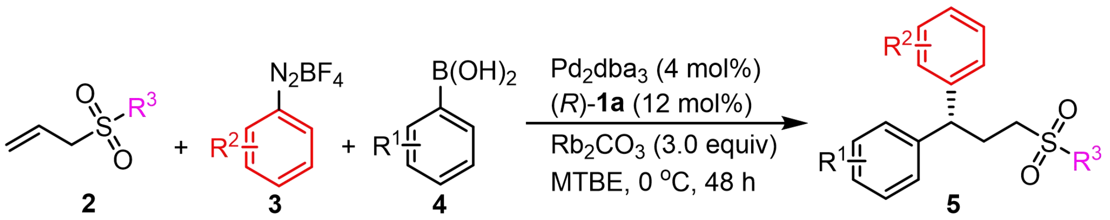
Entry	Change from the "standard conditions"	Yield (%)[b]	er (%)[c]
1	none	64	96:4
2	(*R*)-**1b** instead of (*R*)-**1a**	11	71:29
3	(*R*)-**1c** instead of (*R*)-**1a**	10	13:87
4	(*R*)-**1d** instead of (*R*)-**1a**	12	65:35
5	(*R*)-**1e** instead of (*R*)-**1a**	24	12:88
6	(*R*)-**1f** instead of (*R*)-**1a**	27	71:29
7	Cs_2CO_3 instead of Rb_2CO_3	51	96:4
8	K_2CO_3 instead of Rb_2CO_3	62	95:5
9	Na_2CO_3 instead of Rb_2CO_3	44	94:6
10	Et_2O instead of MTBE	66	90:10
11	toluene instead of MTBE	trace	-

12	rt instead of 0 ºC	21	88:12
13	$Pd(OAc)_2$ instead of Pd_2dba_3	29	96:4
14	$Pd(CH_3CN)_4(BF_4)_2$ instead of Pd_2dba_3	25	89:11
15	Buchwald precatalyst instead of Pd_2dba_3	27	96:4

[a]Unless otherwise noted, the reaction was conducted with **2a** (0.2 mmol), **3a** (0.2 mmol), **4a** (0.1 mmol), Rb_2CO_3 (0.3 mmol), (*R*)-**1a** (0.012 mmol) and Pd_2dba_3 (0.004 mmol) in MTBE (2 mL) at 0 ºC for 48 h under Ar. [b]Isolated yields were shown. [c]The er values were determined by SFC.

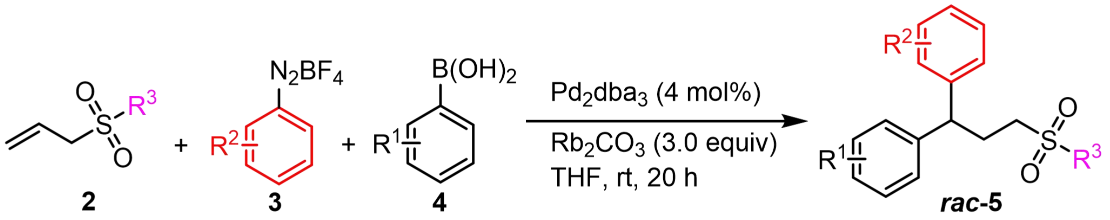
4. General procedure for the synthesis of products 5 and 7.

4.1 General procedure **A**: asymmetric reactions for the synthesis of **5** using allylic sulfone substrates.

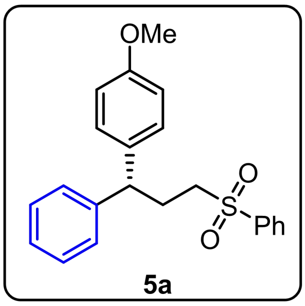


In glovebox, **2** (0.2 mmol), **3** (0.2 mmol), **4** (0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol), anhydrous MTBE (2.0 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours at 0 °C. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. An external standard (Dibromomethane) was added to the system for determining NMR yields. Product **5** was obtained by PTLC.

4.2 General procedure **B**: Racemic reactions for the synthesis of ***rac*-5** using allylic sulfone substrates.

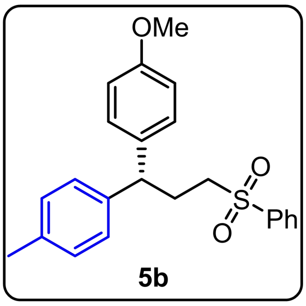


Under Ar atmosphere, **2** (0.2 mmol), **3** (0.2 mmol), **4** (0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol), anhydrous THF (2.0 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and stirred for 20 hours in an argon atmosphere at room temperature. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. The racemic product **5** was obtained by PTLC.



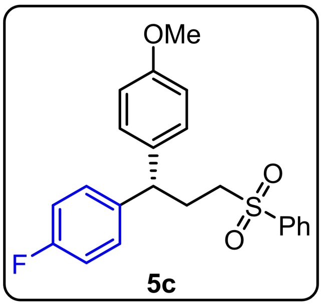
5a

(*R*)-1-methoxy-4-(1-phenyl-3-(phenylsulfonyl)propyl)benzene (5a): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5a** (23.4 mg, 64%) as a colorless oil, Rf =0.39 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.84 (m, 2H), 7.70 – 7.61 (m, 1H), 7.60 – 7.51 (m, 2H), 7.30 – 7.22 (m, *2*H), 7.21 – 7.09 (m, 3H), 7.08 – 6.99 (m, 2H), 6.84 – 6.75 (m, 2H), 3.89 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.09 – 2.97 (m, 2H), 2.49 – 2.34 (m, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.5, 143.4, 139.3, 135.1, 133.8, 129.5, 128.9, 128.7, 128.2, 127.6,126.8, 114.3, 55.4, 55.0, 49.0, 28.6. $[\alpha]_D^{20}$ = -1.9 (c = 2.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 92:8, 0.8 mL/min, 212.1 nm): t_R (major) = 18.915 min, t_R (minor) = 25.697 min, 96:4 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_3S$ $[M+Na]^+$ *m/z* 389.1182, found 389.1186.



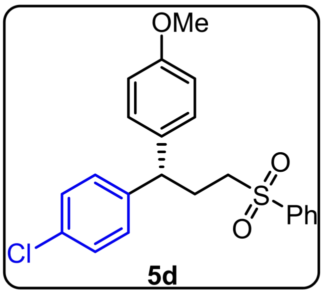
5b

(*R*)-1-methoxy-4-(3-(phenylsulfonyl)-1-(p-tolyl)propyl)benzene (5b): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4b** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 8:1, twice, v/v) to afford **5b** (24.3 mg, 64%) as a colorless oil, Rf =0.32 (silica gel, PE:EA = 8:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.90 – 7.83 (m, 2H), 7.70 – 7.61 (m, 1H), 7.59 – 7.51 (m, 2H), 7.09 – 6.97 (m, 6H), 6.82 – 6.76 (m, 2H), 3.84 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.06 – 2.98 (m, 2H), 2.45 – 2.34 (m, 2H), 2.28 (s, 3H). **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.39, 140.38, 139.26, 136.37, 135.35, 133.80, 129.54, 129.43, 128.64, 128.17, 127.50, 114.23, 55.37, 55.01, 48.62, 28.60, 21.08. $[\alpha]_D^{20}$ = -0.6 (c = 1.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (major) = 10.899 min, t_R (minor) = 13.915 min, 96:4 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1337.



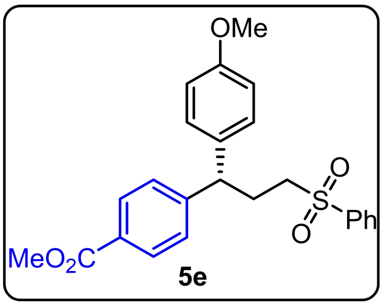
5c

(*S*)-1-fluoro-4-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)benzene (5c): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4c** (14.0 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5c** (25.4 mg, 66%) as a colorless oil, Rf =0.50 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ7.90 – 7.83 (m, 2H), 7.69 – 7.62 (m, 1H), 7.56 (dd, *J* = 8.3, 7.0 Hz, 2H), 7.13 – 6.99 (m, 4H), 6.98 – 6.90 (m, 2H), 6.86 – 6.76 (m, 2H), 3.90 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.06 – 2.95 (m, 2H), 2.46 – 2.35 (m, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 161.7 (d, *J* = 246.0 Hz), 158.5, 139.3, 139.2, 134.8, 133.9, 129.5, 129.1 (d, *J* = 7.8 Hz), 128.6, 128.1, 115.7 (d, *J* = 21.6 Hz), 114.3, 55.4, 54.8, 48.2, 28.7; ^{19}**F NMR** (376 MHz, CDCl$_3$) δ -116.22. $[\alpha]_D^{20}$ = -0.8 (c = 1.0, CHCl$_3$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 225.0 nm): t$_R$ (major) = 8.950 min, t$_R$ (minor) = 13.054 min, 95:5 er. **HRMS (ESI)** calcd for $C_{22}H_{21}FNaO_3S$ [M+Na]$^+$ *m/z* 407.1088, found 407.1092.



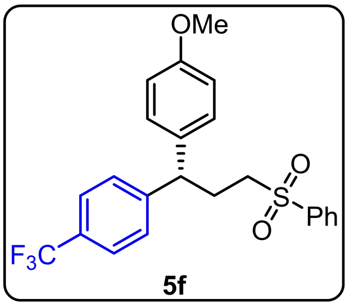
5d

(*S*)-1-chloro-4-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)benzene (5d): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4d** (15.6 mg, 0.1 mmol), Pd$_2$dba$_3$ (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5d** (19.2 mg, 48%) as a colorless oil, Rf =0.37 (silica gel, Tol:EA = 30:1, twice, v/v); ^{1}**H NMR** (400 MHz, Chloroform-*d*) δ 7.90 – 7.83 (m, 2H), 7.71 – 7.62 (m, 1H), 7.60 – 7.52 (m, 2H), 7.23 (d, *J* = 8.5 Hz, 2H), 7.04 (dd, *J* = 14.1, 8.6 Hz, 4H), 6.81 (d, *J* = 8.7 Hz, 2H), 3.89 (t, *J* = 8.1 Hz, 1H), 3.77 (s, 3H), 3.11 – 2.94 (m, 2H), 2.50 – 2.28 (m, 2H); ^{13}**C NMR** (101 MHz, Chloroform-*d*) δ 158.6, 142.0, 139.2, 134.5, 133.9, 132.6, 129.5, 129.0, 128.7, 128.2, 114.4, 55.4, 54.8, 48.3, 28.4. $[\alpha]_D^{20}$ = +1.7 (c = 0.6, CHCl$_3$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 92:8, 0.7 mL/min, 228.0 nm): t$_R$ (major) = 32.333 min, t$_R$ (minor) = 45.222 min, 94:6 er. **HRMS (ESI)** calcd for $C_{22}H_{21}ClNaO_3S$ [M+Na]$^+$ *m/z* 423.0792, found 423.0791.



5e

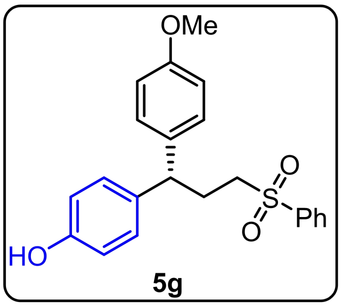
methyl (*R*)-4-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)benzoate (5e): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4e** (18.0 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5e** (23.7 mg, 56%) as a colorless oil, Rf =0.20 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.97 – 7.81 (m, 4H), 7.68 – 7.62 (m, 1H), 7.60 – 7.52 (m, 2H), 7.20 (d, *J* = 8.3 Hz, 2H), 7.04 (d, *J* = 8.7 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 3.98 (t, J = 8.0 Hz, 1H), 3.88 (s, 3H), 3.76 (s, 3H), 3.06 – 2.92 (m, 2H), 2.49 – 2.38 (m, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 166.9, 158.7, 148.7, 139.2, 134.1, 133.9, 130.2, 129.5, 128.8, 128.8, 128.1, 127.7, 114.4, 55.4, 54.7, 52.2, 48.9, 28.3. $[\alpha]_D^{20}$ = +2.5 (c = 1.5, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 11.163 min, t_R (major) = 19.276 min, 93.5:6.5 er. **HRMS (ESI)** calcd for $C_{24}H_{24}NaO_5S$ $[M+Na]^+$ *m/z* 447.1237, found 447.1243.



5f

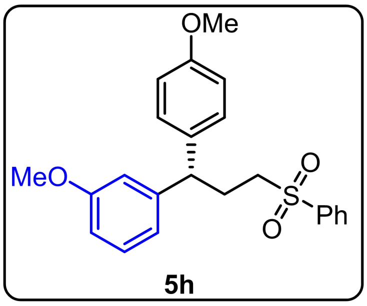
(*R*)-1-methoxy-4-(3-(phenylsulfonyl)-1-(4-(trifluoromethyl)phenyl)propyl)benzene (5f): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4f** (19.0 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5f** (20.0 mg, 46%) as a colorless oil, Rf =0.45 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.82 (m, 2H), 7.70 – 7.62 (m, 1H), 7.60 – 7.47 (m, 4H), 7.04 (d, *J* = 8.7 Hz, 2H), 6.82 (d, *J* = 8.7 Hz, 2H), 3.99 (t, *J* = 8.1 Hz, 1H), 3.77 (s, 3H), 3.02 (td, *J* = 6.9, 2.4 Hz, 2H), 2.45 (ddd, *J* = 9.5, 8.2, 6.7 Hz, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.8, 147.7, 139.2, 134.0, 133.9, 129.5, 129.1

(q, *J* = 32.3 Hz), 128.8, 128.2, 128.0, 125.8 (q, *J* = 3.7 Hz), 124.2 (q, *J* = 268.9 Hz), 114.5, 55.4, 54.7, 48.7, 28.3; **^{19}F NMR** (376 MHz, CDCl$_3$) δ -62.48. $[\alpha]_D^{20}$ = -1.8 (c = 0.8, CHCl$_3$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 5.508 min, t$_R$ (minor) = 7.480 min, 93.5:6.5 er. **HRMS (ESI)** calcd for $C_{23}H_{21}F_3NaO_3S$ [M+Na]$^+$ *m/z* 457.1056, found 457.1058.



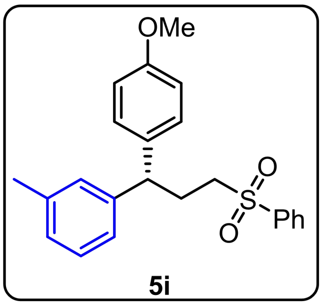
5g

(*R*)-4-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)phenol (5g): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4g** (13.8 mg, 0.1 mmol), Pd$_2$dba$_3$ (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 2:1, twice, v/v) to afford **5g** (10.3 mg, 27%) as a colorless oil, Rf =0.27 (silica gel, PE:EA = 2:1, twice, v/v); **^{1}H NMR** (700 MHz, Chloroform-*d*) δ 7.88 – 7.85 (m, 2H), 7.67 – 7.63 (m, 1H), 7.58 – 7.49 (m, 2H), 7.04 – 7.00 (m, 2H), 6.97 (dd, *J* = 8.6, 2.4 Hz, 2H), 6.79 (dd, *J* = 8.7, 2.4 Hz, 2H), 6.74 – 6.70 (m, 2H), 3.82 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.04 – 2.99 (m, 2H), 2.41 – 2.32 (m, 2H); **^{13}C NMR** (176 MHz, CDCl$_3$) δ 159.1, 149.6, 142.6, 139.1, 136.2, 134.1, 132.4, 129.6, 128.8, 128.1, 120.6, 114.8, 55.5, 54.4, 46.3, 28.1. $[\alpha]_D^{20}$ = -1.2 (c = 0.2, CH$_2$Cl$_2$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 85:15, 1 mL/min, 220.0 nm): t$_R$ (minor) = 14.800 min, t$_R$ (major) = 18.475 min, 96.5:3.5 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_4S$ [M+Na]$^+$ *m/z* 405.1131, found 405.1126.



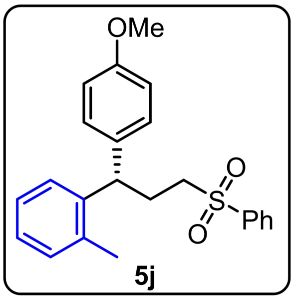
5h

(*S*)-1-methoxy-3-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)benzene(5h): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4h** (15.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 8:1, three times, v/v) to afford **5h** (17.4 mg, 44%) as a colorless oil, Rf =0.27 (silica gel, PE:EA = 8:1, three times, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.90 – 7.82 (m, 2H), 7.70 – 7.61 (m, 1H), 7.55 (t, *J* = 7.6 Hz, 2H), 7.18 (t, *J* = 7.9 Hz, 1H), 7.06 (d, *J* = 8.7 Hz, 2H), 6.83 – 6.61 (m, 5H), 3.86 (t, *J* = 8.0 Hz, 1H), 3.76 (s, 3H), 3.75 (s, 3H), 3.08 – 2.96 (m, 2H), 2.46 – 2.32 (m, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 160.0, 158.5, 145.1, 139.3, 134.9, 133.8, 129.9, 129.5, 128.7, 128.2, 120.0, 114.3, 113.9, 111.7, 55.4, 55.3, 55.0, 49.0, 28.5. $[\alpha]_D^{20}$ = -3.2 (c = 1.5, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 5.176 min, t_R (minor) = 6.594 min, 95:5 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_4S$ $[M+Na]^+$ *m/z* 419.1288, found 419.1288.



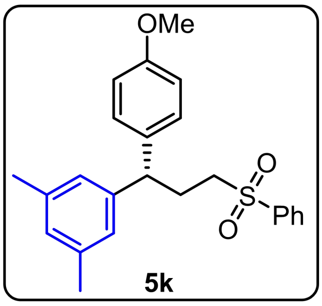
5i

(*S*)-1-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)-3-methylbenzene (5i): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4i** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5i** (23.2 mg, 61%) as a colorless oil, Rf =0.45 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.83 (m, 2H), 7.68 – 7.62 (m, 1H), 7.56 (dd, *J* = 8.3, 6.9 Hz, 2H), 7.14 (t, *J* = 7.8 Hz, 1H), 7.09 – 6.89 (m, 5H), 6.80 (d, *J* = 8.7 Hz, 2H), 3.84 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.10 – 2.96 (m, 2H), 2.46 – 2.35 (m, 2H), 2.28 (s, 3H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.4, 143.3, 139.3, 138.47, 135.2, 133.8, 129.4, 128.7, 128.7, 128.4, 128.2, 127.6, 124.6, 114.2, 55.4, 55.0, 49.0, 28.6, 21.6. $[\alpha]_{\mathrm{D}}^{20}$ = -2.0 (c = 0.5, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 229.0 nm): t_R (major) = 4.069 min, t_R (minor) = 5.516 min, 95.5:4.5 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1338.



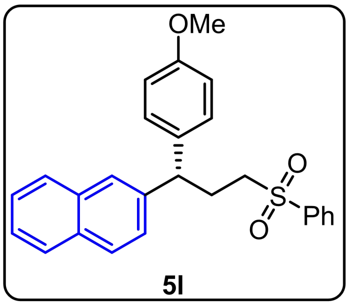
5j

(*S*)-1-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)-2-methylbenzene (5j): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4j** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 8:1, twice, v/v) to afford **5j** (23.5 mg, 62%) as a colorless oil, Rf =0.32 (silica gel, PE:EA = 8:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.84 (m, 2H), 7.68 – 7.61 (m, 1H), 7.56 (t, *J* = 7.6 Hz, 2H), 7.18 – 7.07 (m, 4H), 7.00 (d, *J* = 8.6 Hz, 2H), 6.78 (d, *J* = 8.7 Hz, 2H), 4.09 (t, *J* = 7.9 Hz, 1H), 3.75 (s, 3H), 3.15 – 2.97 (m, 2H), 2.39 (q, *J* = 7.9 Hz, 2H), 2.19 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.3, 140.9, 139.3, 136.5, 134.7, 133.8, 131.0, 129.5, 129.1, 128.2, 126.7, 126.4, 126.1, 114.2, 55.4, 54.9, 44.7, 28.8, 19.9. $[\alpha]_{\mathrm{D}}^{20}$ = +33.5 (c = 0.8, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (major) = 11.061 min, t_R (minor) = 21.236 min, 96:4 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1340.



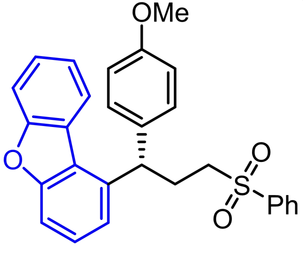
5k

(*S*)-1-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)-3,5-dimethylbenzene(5k): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4k** (15.0 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5k** (13.8 mg, 35%) as a colorless oil, Rf =0.39 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.82 (m, 2H), 7.69 – 7.60 (m, 1H), 7.56 (dd, *J* = 8.3, 6.9 Hz, 2H), 7.05 (d, *J* = 8.7 Hz, 2H), 6.85 – 6.68 (m, 5H), 3.82 – 3.72 (m, 4H), 3.13 – 2.95 (m, 2H), 2.44 – 2.33 (m, 2H), 2.24 (s,6H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.4, 143.2, 139.3, 138.3, 135.4, 133.8, 129.4, 128.7, 128.5, 128.2, 125.4, 114.2, 55.4, 55.1, 49.0, 28.6, 21.5. $[\alpha]_D^{20}$ = -0.2 (c = 1.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 232.0 nm): t_R (major) = 8.386 min, t_R (minor) = 14.587 min, 95:5 er. **HRMS (ESI)** calcd for $C_{24}H_{26}NaO_3S$ $[M+Na]^+$ *m/z* 417.1495, found 417.1492.



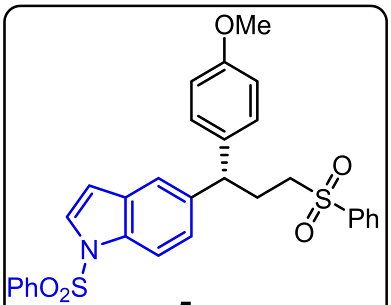
5l

(*S*)-2-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)naphthalene (5l): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4l** (17.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5l** (22.0 mg, 53%) as a colorless oil, Rf =0.53 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.83 (m, 2H), 7.79 – 7.61 (m, 4H), 7.60 – 7.38 (m, 5H), 7.22 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.10 (d, *J* = 8.7 Hz, 2H), 6.86 – 6.75 (m, 2H), 4.07 (t, *J* = 8.0 Hz, 1H), 3.76 (s, 3H), 3.07 (td, *J* = 8.1, 1.7 Hz, 2H), 2.60 – 2.48 (m, 2H); **^{13}C NMR** (101 MHz, Chloroform-*d*) δ 158.5, 140.8, 139.3, 135.0, 133.9, 129.5, 128.9, 128.7, 128.2, 127.9, 127.7, 126.4, 126.3, 125.9, 125.8, 114.3, 55.4, 55.0, 49.0, 28.3. $[\alpha]_D^{20}$ = +10.0 (c = 1.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 220.0 nm): t_R (major) = 9.977 min, t_R (minor) = 13.725 min, 95.5:4.5 er. **HRMS (ESI)** calcd for $C_{26}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 439.1338, found 439.1341.



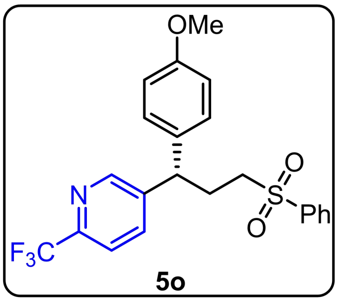
5m

(*S*)-2-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)naphthalene (5m): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4m** (21.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5m** (26.8 mg, 60%) as a colorless oil, Rf =0.44 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.93 – 7.81 (m, 3H), 7.65 – 7.36 (m, 7H), 7.30 – 7.24 (m, 1H), 7.16 (d, *J* = 8.7 Hz, 2H), 7.12 – 7.07 (m, 1H), 6.80 (d, *J* = 8.7 Hz, 2H), 4.83 (t, *J* = 7.9 Hz, 1H), 3.74 (s, 3H), 3.24 – 3.07 (m, 2H), 2.70 – 2.48 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.6, 156.6, 156.2, 139.1, 138.5, 133.9, 133.7, 129.4, 129.1, 128.1, 127.4, 127.0, 123.7, 122.9, 122.7, 122.6, 121.0, 114.3, 111.9, 110.3, 55.4, 54.9, 45.3, 28.7. $[\alpha]_D^{20}$ = -48.6 (c = 2.0, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 13.282 min, t_R (minor) = 14.826 min, 86.5:13.5 er. **HRMS (ESI)** calcd for $C_{28}H_{24}NaO_4S$ $[M+Na]^+$ *m/z* 479.1288, found 479.1294.



5n

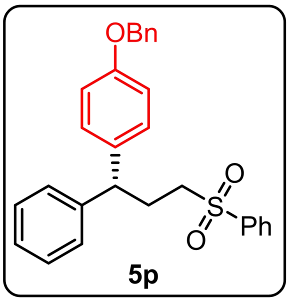
(*S*)-5-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)-1-(phenylsulfonyl)-1H-indole (5n): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4n** (30.1 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 4:1, v/v) to afford **5n** (21.3 mg, 39%) as a colorless oil, Rf =0.15 (silica gel, PE:EA = 4:1, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 8.3 Hz, 1H), 7.88 – 7.82 (m, 4H), 7.69 – 7.64 (m, 1H), 7.60 – 7.51 (m, 3H), 7.44 (t, *J* = 7.8 Hz, 2H), 7.36 (s, 1H), 7.29 – 7.22 (m, 1H), 7.20 – 7.14 (m, 1H), 7.13 – 7.05 (m, 1H), 7.02 (d, *J* = 8.6 Hz, 2H), 6.77 (d, *J* = 8.7 Hz, 2H), 4.15 – 4.04 (m, 1H), 3.76 (s, 3H), 3.15 – 2.94 (m, 2H), 2.60 – 2.50 (m, 1H), 2.38 – 2.24 (m, 1H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.8, 139.2, 138.2, 135.7, 134.0, 133.9, 133.1, 130.1, 129.5, 129.4, 128.8, 128.1, 126.8, 125.7, 125.1, 123.5, 122.6, 120.2, 114.4, 113.9, 55.4, 54.5, 40.5, 28.3. $[\alpha]_D^{20}$ = +22.8 (c = 0.8, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 70:30, 1 mL/min, 215.0 nm): t_R (major) = 8.245 min, t_R (minor) = 10.146 min, 88.5:11.5 er. **HRMS (ESI)** calcd for $C_{30}H_{27}NNaO_5S_2$ $[M+Na]^+$ *m/z* 568.1223, found 568.1222.



5o

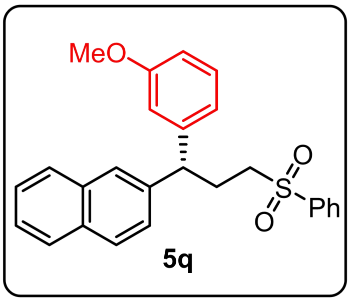
(*S*)-5-(1-(4-methoxyphenyl)-3-(phenylsulfonyl)propyl)-2-(trifluoromethyl)pyridine (5o): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4o** (19.1 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 2:1, v/v) to afford **5o** (5.2 mg, 12%) as a colorless oil, Rf =0.35 (silica gel, PE:EA = 2:1, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.55 (s, 1H), 7.88 (d, *J* = 7.0 Hz, 2H), 7.71 – 7.53 (m, 5H), 7.05 (d, *J* = 8.7 Hz, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 4.13 – 4.04 (m, 1H), 3.78 (s, 3H) 3.06 – 2.99

(m, 2H), 2.56 – 2.40 (m, 2H); **^{13}C NMR** (176 MHz, $CDCl_3$) δ 158.39, 154.47, 139.23, 135.5 (q, *J* = 19.1 Hz), 133.86, 130.04 (q, *J* = 51.4 Hz), 129.47, 128.81, 128.67, 128.62, 128.61(q, *J* = 220.1 Hz), 128.17, 115.69, 114.24, 55.39, 55.01, 48.17, 28.72. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -67.84. $[\alpha]_D^{20}$ = -7.8 (c = 0.13, CH_2Cl_2). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 10.736 min, t_R (minor) = 12.774 min, 91.5:8.5 er. **HRMS (ESI)** calcd for $C_{22}H_{20}F_3NNaO_3S$ $[M+Na]^+$ *m/z* 458.1008, found 458.1011.



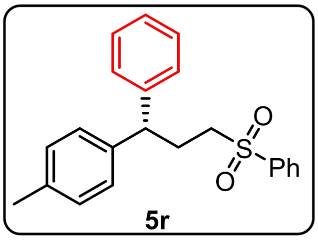
5p

(*R*)-1-(benzyloxy)-4-(1-phenyl-3-(phenylsulfonyl)propyl)benzene (5p): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3b** (56.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5p** (26.5 mg, 60%) as a colorless oil, Rf =0.52 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 7.0 Hz, 2H), 7.69 – 7.62 (m, 1H), 7.56 (t, *J* = 7.6 Hz, 2H), 7.45 – 7.32 (m, 5H), 7.30 – 7.23 (m, 2H), 7.21 – 7.11 (m, 3H), 7.06 (d, *J* = 8.7 Hz, 2H), 6.88 (d, *J* = 8.7 Hz, 2H), 5.02 (s, 2H), 3.90 (t, *J* = 8.0 Hz, 1H), 3.09 – 2.97 (m, 2H), 2.50 – 2.35 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 157.7, 143.4, 139.2, 137.1, 135.3, 133.8, 129.5, 128.9, 128.7, 128.7, 128.2, 128.1, 127.7, 127.6, 126.8, 115.2, 70.2, 54.9, 49.0, 28.6. $[\alpha]_D^{20}$ = -2.8 (c = 1.2, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 9.028 min, t_R (minor) = 13.727 min, 96:4 er. **HRMS (ESI)** calcd for $C_{28}H_{26}NaO_3S$ $[M+Na]^+$ *m/z* 465.1495, found 465.1496.



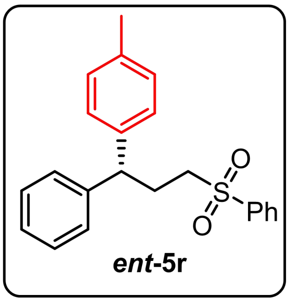
5q

(*R*)-2-(1-(3-methoxyphenyl)-3-(phenylsulfonyl)propyl)naphthalene (5q): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3c** (44.4 mg, 0.2 mmol), **4l** (17.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5q** (16.6 mg, 40%) as a colorless oil, Rf =0.50 (silica gel, Tol:EA = 30:1, twice, v/v); ^{1}**H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.85 (m, 2H), 7.81 – 7.70 (m, 3H), 7.68 – 7.60 (m, 2H), 7.55 (t, *J* = 7.7 Hz, 2H), 7.45 (ddd, *J* = 7.3, 5.3, 1.6 Hz, 2H), 7.28 – 7.15 (m, 2H), 6.84 – 6.67 (m, 3H), 4.09 (t, *J* = 8.0 Hz, 1H), 3.75 (s, 3H), 3.14 – 3.02 (m, 2H), 2.56 (q, *J* = 8.0 Hz, 2H); ^{13}**C NMR** (101 MHz, $CDCl_3$) δ 160.0, 144.5, 140.2, 139.2, 133.9, 133.6, 132.5, 129.9, 129.5, 128.7, 128.2, 127.9, 127.7, 126.4, 126.2, 126.0, 120.2, 114.1, 111.9, 55.3, 54.9, 49.8, 28.1. $[\alpha]_D^{20}$ = +15.4 (c = 1.0, $CHCl_3$). **SFC** (IC-3, CO_2/MeOH = 80:20, 1 mL/min, 272.0 nm): t_R (major) = 18.584 min, t_R (minor) = 23.934 min, 95.5:4.5 er. **HRMS (ESI)** calcd for $C_{26}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 439.1338, found 439.1341.



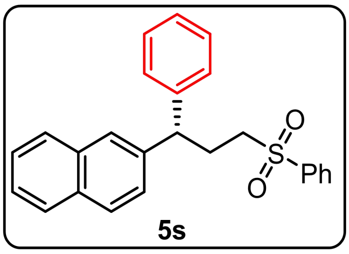
5r

(*S*)-1-methyl-4-(1-phenyl-3-(phenylsulfonyl)propyl)benzene (5r): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3e** (38.4 mg, 0.2 mmol), **4b** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5r** (8.8 mg, 25%) as a colorless oil, Rf =0.45 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.87 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.70 – 7.62 (m, 1H), 7.60 – 7.51 (m, 2H), 7.29 – 7.22 (m, 2H), 7.21 – 7.11 (m, 3H), 7.10 – 6.99 (m, 4H), 3.90 (t, *J* = 8.0 Hz, 1H), 3.08 – 2.98 (m, 2H), 2.49 – 2.38 (m, 2H), 2.29 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 143.3, 140.0, 139.2, 136.5, 133.8, 129.6, 129.5, 128.9, 128.2, 127.7, 127.6, 126.8, 55.0, 49.4, 28.4, 21.1. $[\alpha]_D^{20}$ = +2.2 (c = 0.7, $CHCl_3$). **SFC** (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 9.904 min, t_R (minor) = 10.875 min, 96.5:3.5 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_2S$ [M+Na]$^+$ *m/z* 373.1233, found 373.1235.



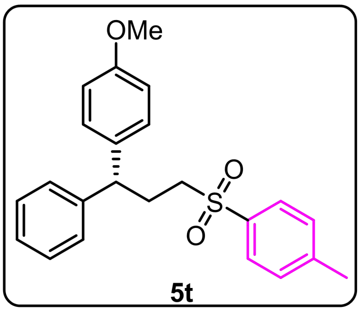
***ent*-5r**

(*R*)-1-methyl-4-(1-phenyl-3-(phenylsulfonyl)propyl)benzene (*ent*-5r): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3d** (41.2 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford ***ent*-5r** (14.0 mg, 40%) as a colorless oil, Rf =0.45 (silica gel, Tol:EA = 30:1, twice, v/v); $[\alpha]_D^{20}$ = -2.0 (c = 0.7, $CHCl_3$). **SFC** (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (minor) = 10.330 min, t_R (major) = 11.136 min, 89:11 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_2S$ [M+Na]$^+$ *m/z* 373.1233, found 373.1235.



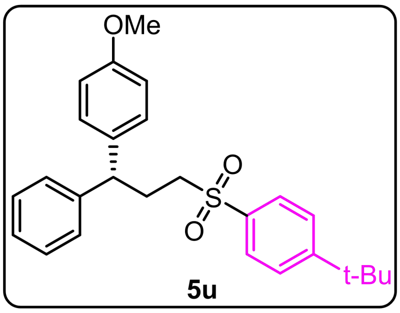
5s

(*S*)-2-(1-phenyl-3-(phenylsulfonyl)propyl)naphthalene (5s): According to the general procedure **A**, **2a** (30.6 ul, 0.2 mmol), **3e** (38.4 mg, 0.2 mmol), **4l** (17.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5s** (12.4 mg, 32%) as a colorless oil, Rf =0.47 (silica gel, Tol:EA = 30:1, twice, v/v); ^{1}**H NMR** (400 MHz, Chloroform-*d*) δ 7.91 – 7.84 (m, 2H), 7.81 – 7.70 (m, 3H), 7.69 – 7.59 (m, 2H), 7.55 (t, *J* = 7.7 Hz, 2H), 7.50 – 7.40 (m, 2H), 7.32 – 7.15 (m, 6H), 4.12 (t, *J* = 8.0 Hz, 1H), 3.15 – 3.00 (m, 2H), 2.63 – 2.47 (m, 2H); ^{13}**C NMR** (101 MHz, $CDCl_3$) δ 142.9, 140.4, 139.3, 133.9, 133.6, 132.5, 129.5, 128.9, 128.7, 128.2, 127.9, 127.7, 127.0, 126.4, 126.3, 126.0, 126.0, 55.0, 49.8, 28.2. $[\alpha]_D^{20}$ = +11.3 (c = 0.9, $CHCl_3$). **SFC** (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 223.0 nm): t_R (major) = 31.934 min, t_R (minor) = 34.425 min, 95.5:4.5 er. **HRMS (ESI)** calcd for $C_{25}H_{22}NaO_2S$ $[M+Na]^+$ *m/z* 409.1233, found 409.1234.



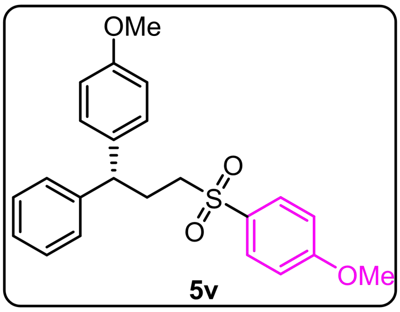
5t

(*R*)-1-methoxy-4-(1-phenyl-3-tosylpropyl)benzene (5t): According to the general procedure **A**, **2b** (39.3 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5t** (25.8 mg, 68%) as a colorless oil, Rf =0.44 (silica gel, Tol:EA = 30:1, twice, v/v); ^{1}**H NMR** (400 MHz, Chloroform-*d*) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.30 – 7.21 (m, 2H), 7.21 – 7.03 (m, 3H), 6.80 (d, *J* = 8.7 Hz, 2H), 3.89 (t, *J* = 8.1 Hz, 2H), 3.76 (s, 1H), 3.05 – 2.96 (m, 2H), 2.48 – 2.33 (m, 5H); ^{13}**C NMR** (101 MHz, $CDCl_3$) δ 158.4, 144.8, 143.5, 136.3, 135.1, 130.1, 128.8, 128.7, 128.2, 127.6, 126.8, 114.2, 55.4, 55.1, 49.0, 28.6, 21.8. $[\alpha]_D^{20}$ = -2.4 (c = 1.5, $CHCl_3$). **SFC** (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (minor) = 17.043 min, t_R (major) = 18.110 min, 95:5 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1344.



5u

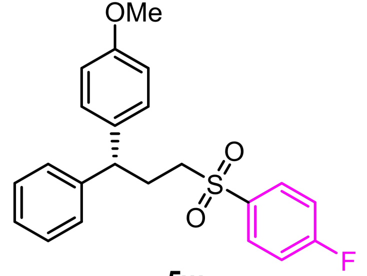
(*R*)-1-(tert-butyl)-4-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzene(5u): According to the general procedure **A**, **2c** (23.8 mg, 0.1 mmol), **3a** (22.2 mg, 0.1 mmol), **4a** (6.1 mg, 0.05 mmol), Pd_2dba_3 (1.8 mg, 0.002 mmol), (*R*)-**1a** (5.0 mg, 0.06 mmol), Rb_2CO_3 (34.7 mg, 0.15 mmol) was stirred for 48 h at 10 °C, the crude product was purified by PTLC (silica gel, PE:EA = 6:1, twice, v/v) to afford **5u** (11.6 mg, 55%) as a colorless oil, Rf =0.40 (silica gel, PE:EA = 6:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.78 (d, *J* = 8.6 Hz, 2H), 7.55 (d, *J* = 8.5 Hz, 2H), 7.28 – 7.22 (m, 2H), 7.21 – 7.11 (m, 3H), 7.06 (d, *J* = 8.6 Hz, 2H), 6.82 – 6.77 (m, 2H), 3.89 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.05 – 2.95 (m, 2H), 2.49 – 2.39 (m, 2H), 1.35 (s, 9H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.4, 157.8, 143.5, 136.3, 135.2, 128.9, 128.7, 128.0, 127.7, 126.8, 126.5, 114.2, 55.4, 55.0, 49.0, 35.4, 31.2, 28.5. $[\alpha]_D^{20}$ = -1.3 (c = 1.1, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 11.267 min, t_R (minor) = 16.226 min, 95:5 er. **HRMS (ESI)** calcd for $C_{26}H_{30}NaO_3S$ $[M+Na]^+$ *m/z* 445.1808, found 445.1809.



5v

(*R*)-1-methoxy-4-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzene(5v): According to the general procedure **A**, **2d** (42.5 mg, 0.2 mmol), **3a** (44.4 mg, 0.2

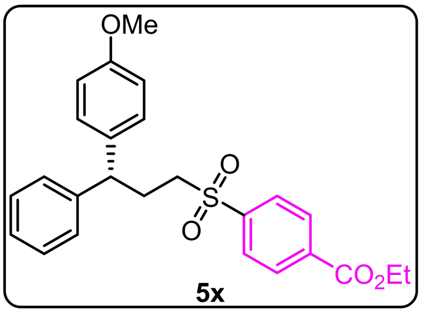
mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5v** (20.6 mg, 52%) as a colorless oil, Rf =0.48 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.81 (d, *J* = 8.9 Hz, 2H), 7.31 – 7.24 (m, 2H), 7.23 – 7.12 (m, 3H), 7.10 – 6.99 (m, 4H), 6.82 (d, *J* = 8.7 Hz, 2H), 3.94 – 3.85 (m, 4H), 3.78 (s, 3H), 3.07 – 2.95 (m, 2H), 2.48 – 2.37 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 163.9, 158.4, 143.5, 135.2, 130.8, 130.3, 128.9, 128.7, 127.7, 126.8, 114.6, 114.2, 55.8, 55.4, 55.3, 49.0, 28.7. $[\alpha]_{\mathrm{D}}^{20}$ = -2.2 (c = 1.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 19.168 min, t_R (minor) = 25.047 min, 94:6 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_4S$ $[M+Na]^+$ *m/z* 419.1288, found 419.1290.



5w

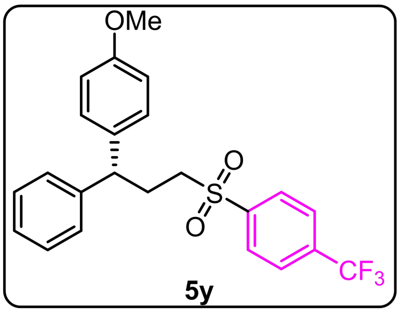
(*R*)-1-fluoro-4-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzene (5w): According to the general procedure **A**, **2e** (40.0 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5w** (18.0 mg, 47%) as a colorless oil, Rf =0.52 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.96 – 7.87 (m, 2H), 7.34 – 7.19 (m, 5H), 7.19 – 7.14 (m, 2H), 7.10 (d, *J* = 8.7 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 3.93 (t, *J* = 8.1 Hz, 1H), 3.80 (s, 3H), 3.11 – 2.96 (m, 2H), 2.51 – 2.37 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.2, 164.7, 158.5, 143.3, 135.3 (d, *J* = 3.3 Hz), 135.0, 131.4 (d, *J* = 9.6 Hz), 128.8 (d, *J* = 22.7 Hz), 127.6, 126.9, 116.8 (d, *J* = 22.8 Hz), 114.3, 55.4, 55.1, 49.0, 28.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -103.43. $[\alpha]_{\mathrm{D}}^{20}$ = -2.0 (c = 1.2, $CHCl_3$).

SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 220.0 nm): t_R (major) = 6.682 min, t_R (minor) = 9.315 min, 93:7 er. **HRMS (ESI)** calcd for $C_{22}H_{21}FNaO_3S$ $[M+Na]^+$ *m/z* 407.1088, found 407.1094.



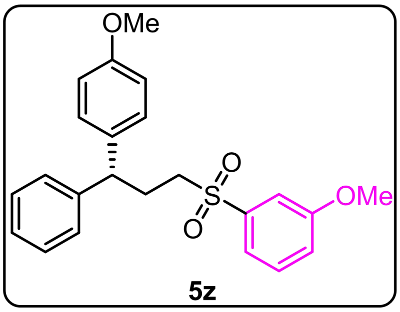
5x

ethyl (*R*)-4-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzoate (5x): According to the general procedure **A**, **2f** (25.4 mg, 0.2 mmol), **3a** (22.2 mg, 0.1 mmol), **4a** (6.1 mg, 0.05 mmol), Pd_2dba_3 (1.8 mg, 0.002 mmol), (*R*)-**1a** (5.0 mg, 0.06 mmol), Rb_2CO_3 (34.7 mg, 0.15 mmol) was stirred for 48 h at 10 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5x** (10.7mg, 49%) as a colorless oil, Rf =0.38 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.21 (d, *J* = 8.5 Hz, 2H), 7.94 (d, *J* = 8.5 Hz, 2H), 7.25 (d, *J* = 7.9 Hz, 2H), 7.21 – 7.09 (m, 3H), 7.05 (d, *J* = 8.7 Hz, 2H), 6.80 (d, *J* = 8.7 Hz, 2H), 4.43 (q, *J* = 7.1 Hz, 2H), 3.89 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.11 – 2.97 (m, 2H), 2.47 – 2.35 (m, 2H), 1.42 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 165.1, 158.5, 143.2, 142.9, 135.4, 134.9, 130.5, 128.9, 128.7, 128.2, 127.6, 126.9, 114.3, 62.0, 55.4, 54.9, 49.0, 28.5, 14.4. $[\alpha]_D^{20}$ = -2.6 (c = 1.0, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 12.857 min, t_R (minor) = 17.521 min, 92:8 er. **HRMS (ESI)** calcd for $C_{25}H_{26}NaO_5S$ $[M+Na]^+$ *m/z* 461.1393, found 461.1393.



5y

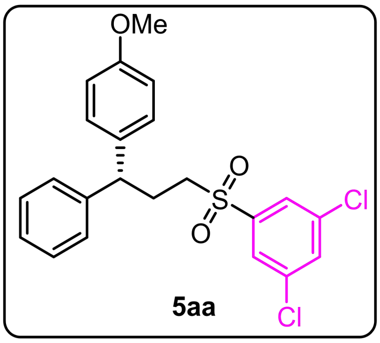
(*R*)-1-methoxy-4-(1-phenyl-3-((4-(trifluoromethyl)phenyl)sulfonyl)propyl)benzene (5y): According to the general procedure **A**, **2g** (50.0 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5y** (20.4 mg, 47%) as a colorless oil, Rf =0.42 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.00 (d, *J* = 8.3 Hz, 2H), 7.82 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.22 (m, 2H), 7.21 – 7.10 (m, 3H), 7.06 (d, *J* = 8.7 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 3.90 (t, *J* = 8.1 Hz, 1H), 3.76 (s, 3H), 3.11 – 3.01 (m, 2H), 2.50 – 2.37 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.57, 143.18, 135.61 (q, *J* = 33.7 Hz), 134.81, 128.95, 128.92, 128.84, 128.69, 127.61, 126.94, 126.63 (q, *J* = 3.7 Hz), 123.3 (q, J = 271.9 Hz), 114.34, 55.39, 54.90, 49.00, 28.43; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -63.20. $[\alpha]_D^{20}$ = -2.0 (c = 1.2, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 3.506 min, t_R (minor) = 5.310 min, 95:5 er. **HRMS (ESI)** calcd for $C_{23}H_{21}F_3NaO_3S$ $[M+Na]^+$ *m/z* 457.1056, found 457.1053.



5z

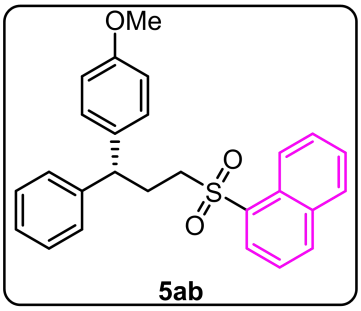
(*R*)-1-methoxy-3-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzene(5z): According to the general procedure **A**, **2h** (42.5 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5z** (18.6 mg, 47%) as a colorless oil, Rf =0.47 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.50 – 7.39 (m, 2H), 7.36 – 7.32 (m, 1H), 7.29 – 7.22 (m, 2H), 7.20 – 7.09 (m, 4H), 7.05 (d, *J* = 8.6 Hz, 2H), 6.80 (d, *J* = 8.7 Hz, 2H), 3.89 (t, *J* = 8.1 Hz, 1H), 3.84 (s, 3H), 3.76 (s, 3H), 3.08 – 2.99 (m, 2H), 2.48 – 2.38

(m, 2H); **^{13}C NMR** (101 MHz, CDCl$_3$) δ 160.2, 158.5, 143.4, 140.4, 135.1, 130.5, 128.9, 128.7, 127.7, 126.8, 120.4, 120.3, 114.3, 112.5, 55.9, 55.4, 54.9, 49.0, 28.6. $[\alpha]_D^{20}$ = -1.4 (c = 1.0, CHCl$_3$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 12.035 min, t$_R$ (minor) = 16.532 min, 93.5:6.5 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_4S$ [M+Na]$^+$ *m/z* 419.1288, found 419.1292.



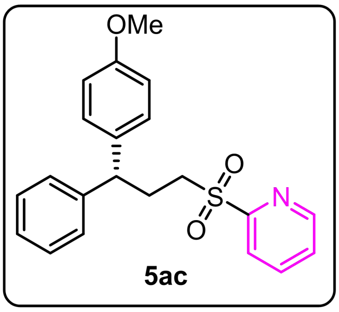
5aa

(*R*)-1,3-dichloro-5-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)benzene(5aa): According to the general procedure **A**, **2i** (50.2 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd$_2$dba$_3$ (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5aa** (20.8 mg, 48%) as a colorless oil, Rf =0.59 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 1.8 Hz, 2H), 7.62 (t, *J* = 1.9 Hz, 1H), 7.31 – 7.25 (m, 2H), 7.23 – 7.12 (m, 3H), 7.07 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 8.7 Hz, 2H), 3.91 (t, *J* = 8.1 Hz, 1H), 3.77 (s, 3H), 3.13 – 2.97 (m, 2H), 2.50 – 2.35 (m, 2H); **^{13}C NMR** (101 MHz, CDCl$_3$) δ 158.6, 143.1, 142.2, 136.6, 134.7, 133.9, 129.0, 128.7, 127.6, 127.0, 126.6, 114.4, 55.4, 54.9, 49.0, 28.3. $[\alpha]_D^{20}$ = -0.7 (c = 1.5, CHCl$_3$). **SFC** (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 8.963 min, t$_R$ (minor) = 14.771 min, 94:6 er. **HRMS (ESI)** calcd for $C_{22}H_{20}Cl_2NaO_3S$ [M+Na]$^+$ *m/z* 457.0402, found 457.0404.



5ab

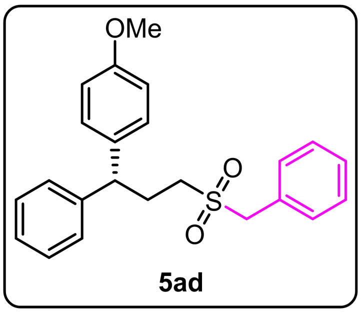
(*R*)-1-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)naphthalene (5ab): According to the general procedure **A**, **2j** (46.5 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5ab** (17.1 mg, 41%) as a colorless oil, Rf =0.49 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.56 (dd, *J* = 6.3, 3.5 Hz, 1H), 8.31 (dd, *J* = 7.4, 1.3 Hz, 1H), 8.13 (d, *J* = 8.2 Hz, 1H), 7.97 (dd, *J* = 6.3, 3.3 Hz, 1H), 7.69 – 7.49 (m, 3H), 7.23 – 7.10 (m, 3H), 7.07 – 7.01 (m, 2H), 6.96 (d, *J* = 8.7 Hz, 2H), 6.72 (d, *J* = 8.7 Hz, 2H), 3.84 (t, *J* = 8.1 Hz, 1H), 3.74 (s, 3H), 3.33 – 3.14 (m, 2H), 2.48 – 2.33 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.4, 143.4, 135.3, 135.0, 134.4, 134.1, 130.8, 129.4, 129.0, 128.8, 128.8, 128.7, 127.6, 127.2, 126.7, 124.6, 124.1, 114.2, 55.3, 54.3, 48.8, 28.7. $[\boldsymbol{\alpha}]_{\mathbf{D}}^{\mathbf{20}}$ = +4.0 (c = 0.8, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 27.867 min, t_R (minor) = 37.462 min, 93:7 er. **HRMS (ESI)** calcd for $C_{26}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 439.1338, found 439.1340.



5ac

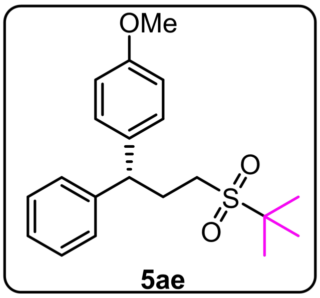
(*R*)-2-((3-(4-methoxyphenyl)-3-phenylpropyl)sulfonyl)pyridine (5ac): According to the general procedure **A**, **2k** (36.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol),

Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, **^{1}H NMR** showed that there were no **5ac** obtained.



5ad

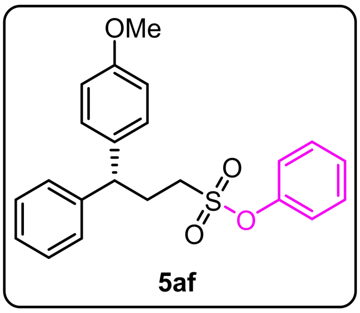
(*R*)-1-(3-(benzylsulfonyl)-1-phenylpropyl)-4-methoxybenzene (5ad): According to the general procedure **A**, **2l** (39.3 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 10 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5ad** (17.1 mg, 45%) as a colorless oil, Rf =0.49 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.41 – 7.34 (m, 3H), 7.33 – 7.25 (m, 4H), 7.23 – 7.14 (m, 3H), 7.09 (d, *J* = 8.7 Hz, 2H), 6.82 (d, *J* = 8.6 Hz, 2H), 4.17 (s, 2H), 3.90 (t, *J* = 8.0 Hz, 1H), 3.77 (s, 3H), 2.89 – 2.66 (m, 2H), 2.56 – 2.32 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.5, 143.4, 135.1, 130.6, 129.2, 129.2, 128.9, 128.8, 128.1, 127.7, 126.8, 114.3, 59.6, 55.4, 45.0, 49.1, 28.1. $[\alpha]_D^{20}$ = +0.8 (c = 0.5, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 12.251 min, t_R (minor) = 16.168 min, 80:20 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1339.



5ae

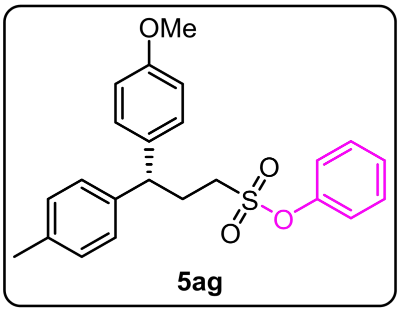
(*R*)-1-(3-(benzylsulfonyl)-1-phenylpropyl)-4-methoxybenzene (5ae): According to the general procedure **A**, **2l** (39.3 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol),

Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 8:1, twice, v/v) to afford **5ae** (14.4 mg, 38%) as a colorless oil, Rf =0.42 (silica gel, PE:EA = 8:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.32 – 7.27 (m, 2H), 7.25 – 7.13 (m, 5H), 6.84 (d, J = 8.6 Hz, 2H), 4.02 (t, J = 8.0 Hz, 1H), 3.77 (s, 3H), 2.89 – 2.79 (m, 2H), 2.65 – 2.53 (m, 2H), 1.34 (s, 9H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.4, 143.7, 135.4, 128.9, 127.8, 126.8, 114.3, 59.2, 55.4, 49.4, 44.4, 26.6, 23.6. $[\alpha]_D^{20}$ = -1.5 (c = 0.4, $CHCl_3$). **SFC** (IC-3, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (minor) = 14.812 min, t_R (major) = 18.985 min, 69:31 er. **HRMS (ESI)** calcd for $C_{20}H_{26}NaO_3S$ $[M+Na]^+$ *m/z* 369.1495, found 369.1496.



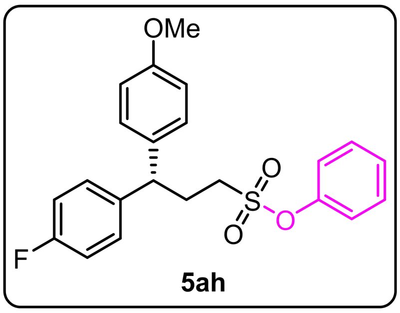
5af

Phenyl (*R*)-3-(4-methoxyphenyl)-3-phenylpropane-1-sulfonate (5af): According to the general procedure **A**, **2t** (19.8 mg, 0.1 mmol), **3a** (22.2 mg, 0.1 mmol), **4a** (6.1 mg, 0.05 mmol), Pd_2dba_3 (1.8 mg, 0.002 mmol), (*R*)-**1a** (5.0 mg, 0.06 mmol), Cs_2CO_3 (48.9 mg, 0.15 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 10:1) to afford **5af** (10.3 mg, 48%) as a colorless oil, Rf =0.26 (silica gel, PE:EA = 10:1); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.40 – 7.27 (m, 5H), 7.26 – 7.12 (m, 7H), 6.90 – 6.78 (m, 2H), 4.02 (t, J = 8.0 Hz, 1H), 3.79 (s, 3H), 3.27 – 3.11 (m, 2H), 2.73 – 2.62 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.59, 149.18, 143.24, 134.90, 130.07, 128.98, 128.81, 127.72, 127.34, 126.97, 122.12, 114.37, 55.41, 49.23, 48.82, 29.62. $[\alpha]_D^{20}$ = -60 (c = 0.1, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 4.986 min, t_R (minor) = 6.883 min, 95.5:4.5 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_4S$ $[M+Na]^+$ *m/z* 405.1131, found 405.1131.



5ag

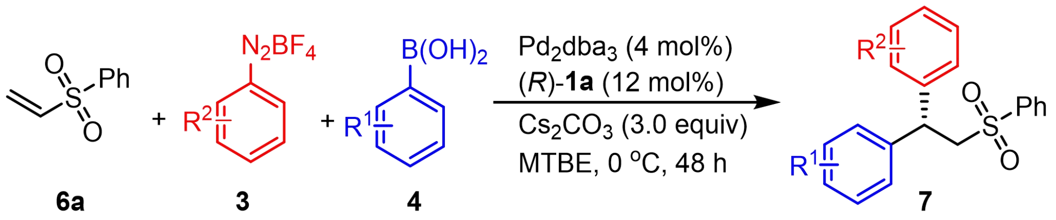
(*R*)-3-(4-methoxyphenyl)-N,3-diphenylpropane-1-sulfonamide (5ag): According to the general procedure **A**, **2t** (39.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 60:1, then PE:DCM = 2:1, twice, v/v) to afford **5ag** (15.7 mg, 40%) as a colorless oil, Rf =0.57 (silica gel, Tol:EA = 60:1); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.40 – 7.33 (m, 2H), 7.32 – 7.27 (m, 1H), 7.19 – 7.09 (m, 8H), 6.88 – 6.80 (m, 2H), 3.97 (t, J = 8.0 Hz, 1H), 3.78 (s, 3H), 3.24 – 3.11 (m, 2H), 2.74 – 2.57 (m, 2H), 2.31 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.52, 149.18, 140.21, 136.56, 135.20, 130.06, 129.65, 128.73, 127.59, 127.33, 122.14, 114.33, 55.41, 49.26, 48.44, 29.65, 21.12. $[\alpha]_D^{20}$ = -27 (c = 0.2, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 11.283 min, t_R (minor) = 17.102 min, 93:7 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_4S$ $[M+Na]^+$ *m/z* 419.1288, found 419.1287.



5ah

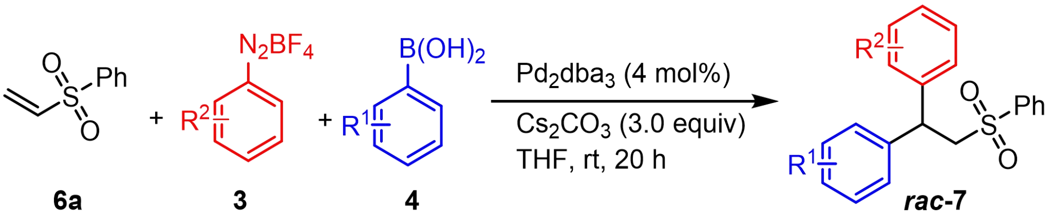
Phenyl (*S*)-3-(4-fluorophenyl)-3-(4-methoxyphenyl)propane-1-sulfonate (5ah): According to the general procedure **A**, **2t** (39.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 60:1, then PE:DCM = 2:1, twice, v/v) to afford **5ah** (18.3 mg, 46%) as a colorless oil, Rf =0.61 (silica gel, Tol:EA = 60:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.42 – 7.27 (m, 3H), 7.23 – 7.07 (m, 6H), 7.03 – 6.95 (m, 2H), 6.90 – 6.81 (m, 2H), 4.01 (t, J = 8.0 Hz, 1H), 3.79 (s, 3H), 3.21 – 3.13 (m, 2H), 2.69 – 2.60 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 161.76 (d, *J* = 245.43 Hz), 158.68, 149.13, 139.08 (d, *J* = 3.2 Hz), 134.59, 130.10, 129.17 (d, *J* = 7.9 Hz), 128.74, 127.40, 122.10, 115.78 (d, *J* = 21.3 Hz), 114.45, 55.42, 49.09, 48.01, 29.74; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -115.99. $[\alpha]_D^{20}$ = -52 (c = 0.1, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 9.190 min, t_R (minor) = 14.619 min, 96.5:3.5 er. **HRMS (ESI)** calcd for $C_{22}H_{21}FNaO_4S$ $[M+Na]^+$ *m/z* 423.1037, found 423.1037.

4.3 General procedure **C**: Asymmetric reactions for the synthesis of **7** using alkenyl sulfone substrates.

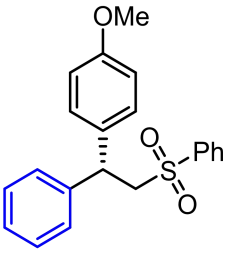


In glovebox, **6a** (33.6 mg, 0.2 mmol), **3** (0.2 mmol), **4** (0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol), anhydrous MTBE (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours at 0 °C. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. An external standard (Dibromomethane) was added to the system for determining NMR yields. Product **7** was obtained by PTLC.

4.4 General procedure **D**: Racemic reactions for the synthesis of rac-**7** using alkenyl sulfone substrates.



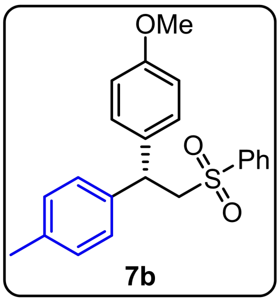
Under Ar atmosphere, **6a** (33.6 mg, 0.2 mmol), **3** (0.2 mmol), **4** (0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol), anhydrous THF (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and stirred for 20 hours in an argon atmosphere at room temperature. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. The racemic product **7** was obtained by PTLC.



7a

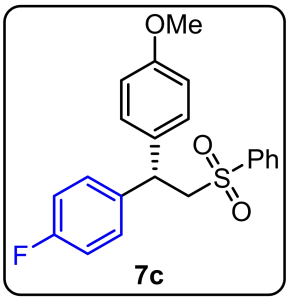
(*R*)-1-methoxy-4-(1-phenyl-2-(phenylsulfonyl)ethyl)benzene (7a): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7a** (23.6 mg, 67%) as a white solid, Rf =0.40 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.68 – 7.60 (m, 2H), 7.52 – 7.45 (m, 1H), 7.38 – 7.31 (m, 2H), 7.22 – 7.09 (m, 5H), 7.04 (d, *J* = 8.7 Hz, 2H), 6.76 – 6.67 (m, 2H), 4.59 (t, *J* = 7.2 Hz, 1H), 3.89 (d, *J* = 7.1 Hz, 2H), 3.73 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.6, 141.9, 139.9, 133.5, 133.3, 129.0, 128.9, 128.8, 128.1, 127.6, 127.0, 114.2, 61.8, 55.4, 45.5.

$[\alpha]_D^{20}$ = -2.0 (c = 0.4, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 240.0 nm): t_R (minor) = 6.186 min, t_R (major) = 6.616 min, 95:5 er. **HRMS (ESI)** calcd for $C_{21}H_{20}NaO_3S$ $[M+Na]^+$ *m/z* 375.1025, found 375.1024.



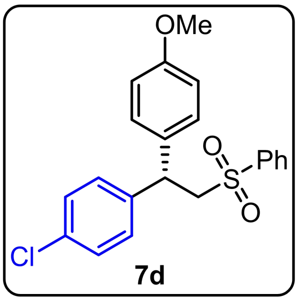
7b

(R) **-1-methoxy-4-(2-(phenylsulfonyl)-1-(p-tolyl)ethyl)benzene (7b):** According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4b** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7b** (21.2 mg, 58%) as a white solid, Rf =0.39 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.71 – 7.59 (m, 2H), 7.54 – 7.44 (m, 1H), 7.34 (t, *J* = 7.8 Hz, 2H), 7.06 – 6.95 (m, 6H), 6.70 (d, *J* = 8.8 Hz, 2H), 4.55 (t, *J* = 7.2 Hz, 1H), 3.87 (d, *J* = 7.2 Hz, 2H), 3.73 (s, 3H), 2.25 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.5, 139.9, 138.9, 136.6, 133.7, 133.2, 129.5, 129.0, 128.7, 128.1, 127.5, 114.2, 61.9, 55.4, 45.1, 21.1. $[\alpha]_D^{20}$ = +1.3 (c = 1.2, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 85:15, 1 mL/min, 235.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 94:6 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_3S$ $[M+Na]^+$ *m/z* 389.1182, found 389.1181.



7c

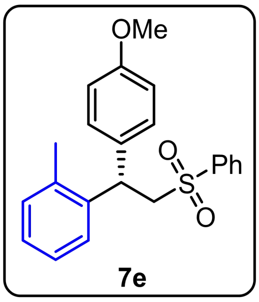
(*S*)-1-fluoro-4-(1-(4-methoxyphenyl)-2-(phenylsulfonyl)ethyl)benzene (7c): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4c** (14.0 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7c** (16.7 mg, 45%) as a white solid, Rf =0.37 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.68 – 7.60 (m, 2H), 7.56 – 7.46 (m, 1H), 7.37 (t, *J* = 8.0 Hz, 2H), 7.15 – 6.97 (m, 4H), 6.91 – 6.77 (m, 2H), 7.75 – 6.66 (m, 2H), 4.59 (t, *J* = 7.2 Hz, 1H), 3.85 (d, *J* = 7.3 Hz, 2H), 3.73 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 161.9 (d, *J* = 244.9 Hz), 158.7, 141.9, 139.8, 133.4, 133.4, 129.2 (d, *J* = 7.9 Hz), 129.1, 128.6, 128.1, 115.7 (d, *J* = 21.3 Hz), 114.3, 61.9, 55.4, 44.8; **^{19}F NMR** (376 MHz, CDCl3) δ -115.80; $[\alpha]_D^{20}$ = -2.2 (c = 0.8, CH_2Cl_2); **SFC** (AD-3, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 13.410 min, t_R (minor) = 14.689 min, 93:7 er. **HRMS (ESI)** calcd for $C_{21}H_{19}FNaO_3S$ $[M+Na]^+$ *m/z* 393.0932, found 393.0928.



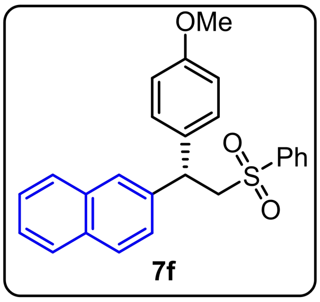
7d

(*S*)-1-chloro-4-(1-(4-methoxyphenyl)-2-(phenylsulfonyl)ethyl)benzene (7d): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4d** (15.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7d** (20.5 mg, 53%) as a white solid, Rf =0.40 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.63 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.58 – 7.48 (m, 1H), 7.37 (t, *J* = 7.8 Hz, 2H), 7.14 (d, *J* = 8.5 Hz, 2H), 7.08 – 6.93 (m, 4H), 6.78 – 6.68 (m, 2H), 4.57 (t, *J* = 7.2 Hz, 1H), 3.84 (dd, *J* = 7.3, 2.1 Hz, 2H), 3.74 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.7, 140.2, 139.8, 133.4, 133.1, 132.9, 129.1, 129.1, 128.9, 128.6, 128.0, 114.4, 61.7, 55.4, 44.9. $[\alpha]_D^{20}$ = +3.6 (c = 1.0, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 85:15, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) =

10.629 min, 95:5 er. **HRMS (ESI)** calcd for $C_{21}H_{19}ClNaO_3S$ $[M+Na]^+$ *m/z* 409.0636, found 409.0643.

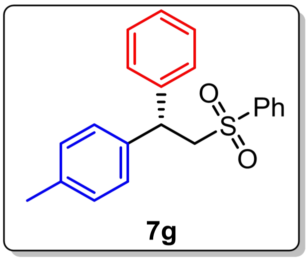

7e

(*S*)-1-(1-(4-methoxyphenyl)-2-(phenylsulfonyl)ethyl)-2-methylbenzene (7e): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4j** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7e** (16.5 mg, 45%) as a white solid, Rf =0.40 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.73 – 7.60 (m, 2H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.35 (t, *J* = 7.7 Hz, 2H), 7.10 – 6.96 (m, 6H), 6.72 (d, *J* = 8.5 Hz, 2H), 4.83 (t, *J* = 7.1 Hz, 1H), 3.84 (d, *J* = 7.4 Hz, 2H), 3.73 (s, 3H), 2.30 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.5, 139.9, 139.5, 136.0, 133.4, 133.0, 131.0, 129.2, 129.0, 128.0, 126.9, 126.6, 126.3, 114.1, 61.9, 55.4, 41.0, 19.9. $[\alpha]_D^{20}$ = +14.0 (c = 0.6, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 85:15, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 96:4 er. **HRMS (ESI)** calcd for $C_{22}H_{22}NaO_3S$ $[M+Na]^+$ *m/z* 389.1182, found 389.1182.

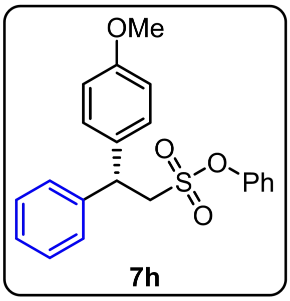

7f

(*S*)-2-(1-(4-methoxyphenyl)-2-(phenylsulfonyl)ethyl)naphthalene (7f): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4l** (17.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol),

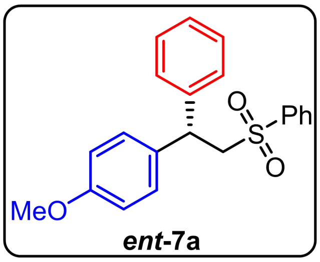
Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7f** (36.5 mg, 66%) as a white solid, Rf =0.38 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.75 – 7.67 (m, 2H), 7.66 – 7.59 (m, 3H), 7.54 (d, *J* = 1.9 Hz, 1H), 7.46 – 7.33 (m, 3H), 7.27 – 7.16 (m, 3H), 7.12 – 7.06 (m, 2H), 6.77 – 6.68 (m, 2H), 4.76 (t, *J* = 7.2 Hz, 1H), 4.07 – 3.87 (m, 2H), 3.74 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.6, 139.8, 139.0, 133.4, 133.2, 132.4, 128.9, 128.9, 128.7, 128.0, 127.9, 127.6, 126.4, 126.2, 126.0, 125.9, 114.3, 61.7, 55.4, 45.6. $[\alpha]_D^{20}$ = +23.5 (c = 1.5, $CHCl_3$). **SFC** (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 96:4 er. **HRMS (ESI)** calcd for $C_{25}H_{22}NaO_3S$ $[M+Na]^+$ *m/z* 425.1182, found 425.1178.



(*S*)-1-methyl-4-(1-phenyl-2-(phenylsulfonyl)ethyl)benzene (7g): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3e** (38.2 mg, 0.2 mmol), **4b** (13.6 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **7g** (15.1 mg, 45%) as a white solid, Rf =0.42 (silica gel, Tol:EA = 30:1, twice, v/v); compound **7g** is a known compound.[11] $[\alpha]_D^{20}$ = +1.3 (c = 0.3, $CHCl_3$). The absolute configuration of (*S*)-**7g** was determined by comparison with optical rotation data for the reported literature.[11] **SFC** (Trefoir CEL1, CO_2/MeOH = 90:10, 1 mL/min, 232.0 nm): t_R (major) = 4.340 min, t_R (minor) = 4.787 min, 93.5:6.5 er. **HRMS (ESI)** calcd for $C_{26}H_{28}NaO_4S$ $[M+Na]^+$ *m/z* 359.1076, found 359.1078.



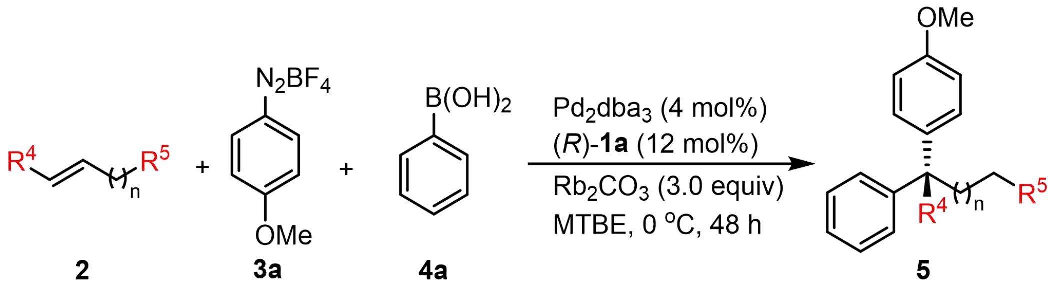
Phenyl (*R*)-2-(4-methoxyphenyl)-2-phenylethane-1-sulfonate (7h): According to the general procedure **C**, **6b** (36.9 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 60:1, then PE:DCM = 2:1, twice, v/v) to afford **7h** (10.8 mg, 30%) as a white solid, Rf =0.54 (silica gel, Tol:EA = 60:1); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.37 – 7.18 (m, 10H), 7.02 – 6.91 (m, 2H), 6.90 – 6.80 (m, 2H), 4.72 (t, J = 7.1 Hz, 1H), 3.99 (dd, J = 7.1, 1.0 Hz, 2H), 3.77 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.85, 149.03, 141.77, 133.46, 129.96, 129.04, 128.91, 127.77, 127.38, 127.20, 121.99, 114.39, 56.34, 55.41, 45.85. $[\alpha]_D^{20}$ = -21.33 (c = 0.3, $CHCl_3$). **SFC** (Trefoir CEL1, CO_2/MeOH = 97:3, 1 mL/min, 232.0 nm): t_R (minor) = 17.231 min, t_R (major) = 19.696 min, 96:4 er. **HRMS (ESI)** calcd for $C_{21}H_{20}NaO_4S$ $[M+Na]^+$ *m/z* 391.0975, found 391.0977.



(*S*)-1-methoxy-4-(1-phenyl-2-(phenylsulfonyl)ethyl)benzene (*ent*-7a): According to the general procedure **C**, **6a** (33.6 mg, 0.2 mmol), **3e** (38.2 mg, 0.2 mmol), **4p** (15.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Cs_2CO_3 (97.7 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford ***ent*-7a** (15.8 mg, 45%) as a white solid, Rf =0.40 (silica gel, Tol:EA = 30:1, twice, v/v); $[\alpha]_D^{20}$ = +2.5 (c = 1.2, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 240.0 nm): t_R (major) = 6.206 min, t_R (minor) = 6.764 min, 90:10 er. **HRMS (ESI)** calcd for $C_{21}H_{20}NaO_3S$ $[M+Na]^+$ *m/z* 375.1025, found 375.1024.

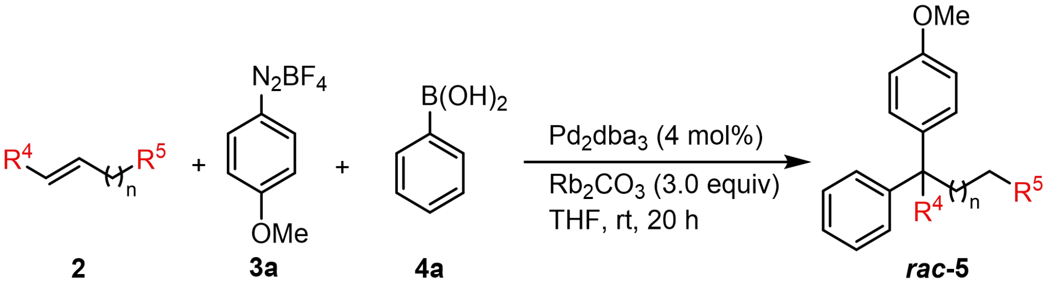
5. Control experiments

5.1 General procedure **E**: Asymmetric reactions for the synthesis of **5** using various different alkene substrates.

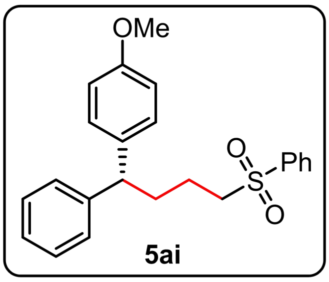


In glovebox, **2** (0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol), anhydrous MTBE (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours at 0 °C. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. An external standard (Dibromomethane) was added to the crude for determining NMR yields. Product **5** was obtained by PTLC.

5.2 General procedure **F**: Racemic reactions for the synthesis of rac-**5** using various different alkene substrates.

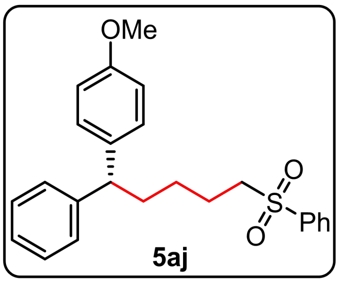


In an argon atmosphere, **2** (0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol), anhydrous THF (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and stirred for 20 hours in an argon atmosphere at room temperature. After the reaction was completed (monitored by TLC), the crude reaction mixture was filtered through a short silica column with PE: EA = 1:2, and the solvent was removed in vacuo. The racemic product ***rac*-5** was obtained by PTLC.



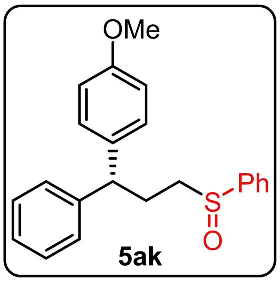
5ai

(R) **-1-methoxy-4-(1-phenyl-4-(phenylsulfonyl)butyl)benzene (5ai):** According to the general procedure **E**, **2n** (39.3 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 4:1, v/v) to afford the mixture of **5ai** and its Heck by-product, added the mixture to 2 ml DCM and *m*-CPBA (34.6 mg, 0.2 mmol) and stirred for 2 h at room temperature, and the solvent was removed in vacuo. The pure product **5ai** (6.0 mg, 16%) was obtained by PTLC as a colorless oil, Rf =0.37 (silica gel, PE:EA = 4:1, v/v); ^{1}**H NMR** (400 MHz, Chloroform-*d*) δ 7.89 – 7.76 (m, 2H), 7.65 – 7.59 (m, 1H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.29 – 7.20 (m, 2H), 7.19 – 7.11 (m, 3H), 7.10 – 7.04 (m, 2H), 6.79 (d, *J* = 8.8 Hz, 2H), 3.79 – 3.74 (m, 4H), 3.11 – 3.02 (m, 2H), 2.09 (q, *J* = 7.8 Hz, 2H), 1.75 – 1.64 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.2, 144.5, 139.2, 136.3, 133.7, 129.4, 128.7, 128.7, 128.2, 127.7, 126.5, 114.1, 56.2, 55.4, 50.2, 34.4, 21.5. **$[\alpha]_D^{20}$** = -1.3 (c = 0.3, $CHCl_3$). **SFC** (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 10.743 min, t_R (major) = 12.949 min, 69.5:30.5 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO_3S$ $[M+Na]^+$ *m/z* 403.1338, found 403.1337.



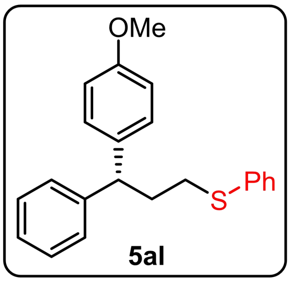
5aj

(*R*)-1-methoxy-4-(1-phenyl-5-(phenylsulfonyl)pentyl)benzene (5aj): According to the general procedure **E**, **2o** (42.1 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, PE:EA = 4:1, v/v) to afford the mixture of **5aj** and its Heck by-product, added the mixture to 2 ml DCM and *m*-CPBA (34.6 mg, 0.2 mmol) and stirred for 2 h at room temperature, and the solvent was removed in vacuo. The pure product **5aj** (13.2 mg, 33%) was obtained by PTLC as a colorless oil, Rf =0.36 (silica gel, PE:EA = 4:1, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.94 – 7.83 (m, 2H), 7.71 – 7.60 (m, 1H), 7.55 (t, *J* = 7.6 Hz, 2H), 7.28 – 7.21 (m, 2H), 7.18 – 7.12 (m, 3H), 7.12 – 7.05 (m, 2H), 6.84 – 6.77 (m, 2H), 3.82 – 3.68 (m, 4H), 3.12 – 2.96 (m, 2H), 2.01 – 1.90 (m, 2H), 1.78 – 1.68 (m, 2H), 1.36 – 1.22 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.1, 145.1, 139.3, 136.9, 133.8, 129.4, 128.8, 128.6, 128.2, 127.8, 126.3, 114.0, 56.3, 55.4, 50.3, 35.4, 26.9, 22.8. **$[\alpha]_D^{20}$** = -2.0 (c = 0.8, $CHCl_3$). **SFC** (Trefoir CEL1, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 4.556 min, t_R (major) = 5.478 min, 82.5:17.5 er. **HRMS (ESI)** calcd for $C_{24}H_{26}NaO_3S$ $[M+Na]^+$ *m/z* 417.1495, found 417.1493.



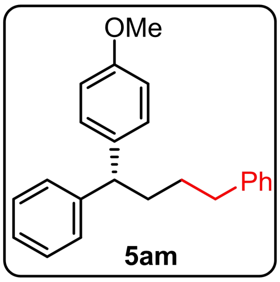
5ak

1-methoxy-4-((1*R*)-1-phenyl-3-(phenylsulfinyl)propyl)benzene (5ak): According to the general procedure **E**, **2p** (33.2 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, **^{1}H NMR** showed that trace **5ak** (< 5%) was detected.



5al

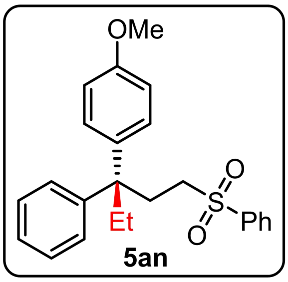
(*R*)-(3-(4-methoxyphenyl)-3-phenylpropyl)(phenyl)sulfane (5al): According to the general procedure **E**, **2q** (30.0 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, **^{1}H NMR** showed that trace **5al** (< 5%) was detected.



5am

(*R*)-(1-(4-methoxyphenyl)butane-1,4-diyl)dibenzene (5am): According to the general procedure **E**, **2r** (30.1 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by

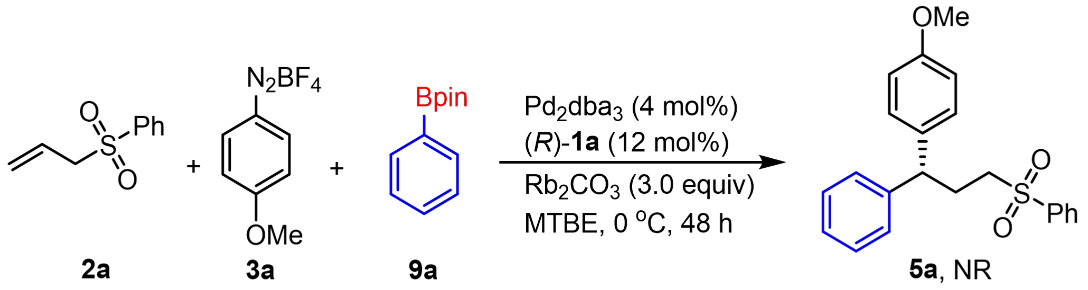
PTLC (silica gel, PE:EA = 20:1, twice, v/v) to afford **5am** (5.0 mg, 17%) as a colorless oil, Rf =0.51 (silica gel, PE:EA = 20:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.35 – 7.27 (m, 7H), 7.25 – 7.15 (m, 5H), 6.91 – 6.83 (m, 2H), 3.92 (t, *J* = 7.8 Hz, 1H), 3.82 (s, 3H), 2.69 (t, *J* = 7.7 Hz, 2H), 2.11 (dd, *J* = 15.1, 8.3 Hz, 2H), 1.71 – 1.61 (m, 2H); **^{13}C NMR** (101 MHz, CDCl$_3$) δ 158.0, 145.6, 142.5, 137.4, 128.9, 128.6, 128.5, 128.4, 127.9, 126.1, 125.8, 113.9, 55.4, 50.5, 36.0, 35.6, 29.9. $[\alpha]_D^{20}$ = -1.6 (c = 0.5, CHCl$_3$). **SFC** (OD-3, CO$_2$/MeOH = 95:5, 1 mL/min, 235.0 nm): t$_R$ (minor) = 7.634 min, t$_R$ (major) = 8.266 min, 72:28 er. **HRMS (ESI)** calcd for $C_{23}H_{24}NaO$ [M+Na]$^+$ *m/z* 339.1719, found 339.1720.



5an

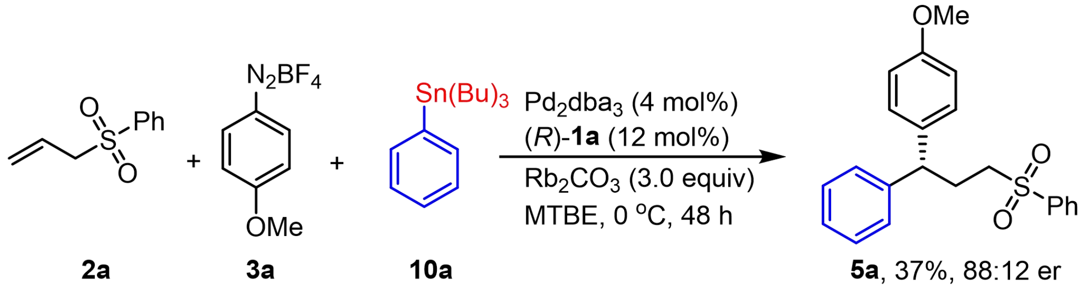
(*R*)-1-methoxy-4-(3-phenyl-1-(phenylsulfonyl)pentan-3-yl)benzene (5an): According to the general procedure **E**, **2s** (42.1 mg, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd$_2$dba$_3$ (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol) was stirred for 48 h at 0 °C, the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5an** (8.0 mg, 20%) as a colorless oil, Rf =0.32 (silica gel, Tol:EA = 30:1, twice, v/v); **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 7.84 – 7.77 (m, 2H), 7.66 – 7.59 (m, 1H), 7.53 (ddd, *J* = 8.2, 6.6, 1.2 Hz, 2H), 7.25 – 7.10 (m, 3H), 7.08 – 7.01 (m, 2H), 6.98 – 6.88 (m, 2H), 6.80 – 6.69 (m, 2H), 3.77 (s, 3H), 2.80 – 2.68 (m, 2H), 2.41 (ddd, *J* = 10.8, 5.4, 1.7 Hz, 2H), 1.99 (q, *J* = 7.4 Hz, 2H), 0.56 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (101 MHz, CDCl$_3$) δ 157.9, 146.6, 139.0, 138.4, 133.7, 129.4, 128.8, 128.3, 128.1, 127.8, 126.3, 113.6, 55.3, 52.4, 48.5, 30.8, 30.1, 8.4. $[\alpha]_D^{20}$ = -1.5 (c = 0.4, CHCl$_3$). **SFC** (IG-3, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 9.560 min, t$_R$ (minor) = 10.340 min, 63.5:36.5 er. **HRMS (ESI)** calcd for $C_{24}H_{26}NaO_3S$ [M+Na]$^+$ *m/z* 417.1495, found 417.1500.

5.3 Asymmetric reactions for the synthesis of **5a** using esterified phenylboronic acid **9a**.



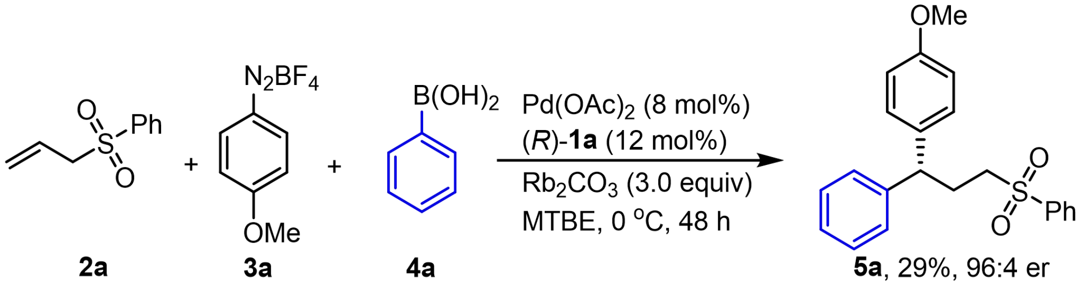
In glovebox, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **9a** (20.4 mg, 0.1 mmol), Pd_2dba_3 (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb_2CO_3 (69.3 mg, 0.3 mmol), anhydrous MTBE (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours in an argon atmosphere at 0 °C. ^1H NMR showed that no desired product **5a** was detected.

5.4 Asymmetric reactions for the synthesis of **5a** using tributyl(phenyl)stannane **10a**.



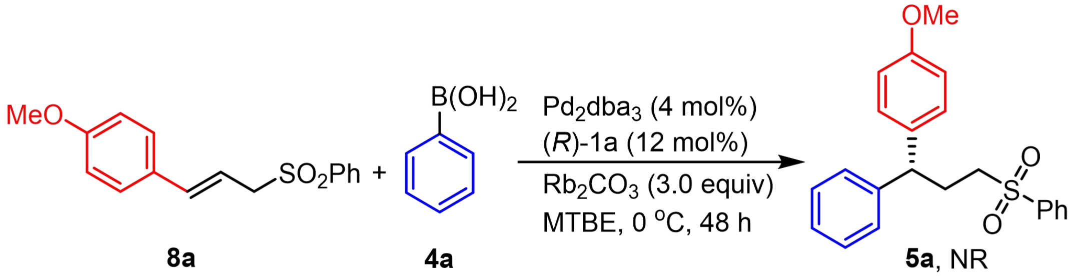
In glovebox, **2a** (16 μL, 0.1 mmol), **3a** (22.2 mg, 0.1 mmol), **10a** (16.4 μL, 0.05 mmol), Pd_2dba_3 (1.8 mg, 0.002 mmol), (*R*)-**1a** (5.0 mg, 0.06 mmol), Rb_2CO_3 (34.7 mg, 0.15 mmol), anhydrous MTBE (1 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours in an argon atmosphere at 0 °C, and the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5a** (6.7 mg, 37%) with 88:12 er.

5.5 Asymmetric reactions for the synthesis of **5a** using Pd(OAc)$_2$.



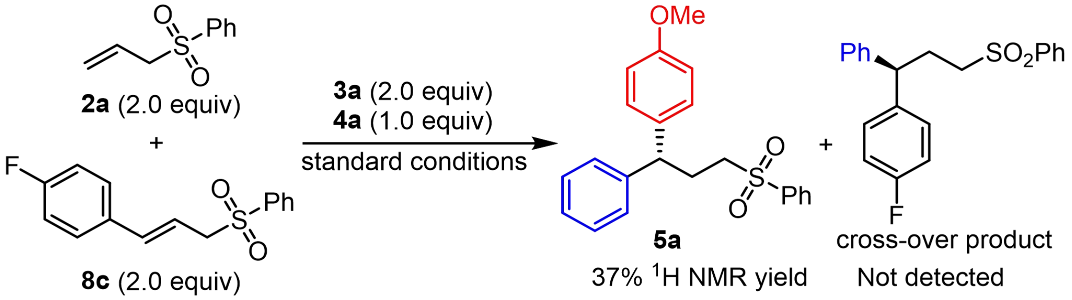
In glovebox, **2a** (30.6 ul, 0.2 mmol), **3a** (44.4 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd(OAc)$_2$ (1.8 mg, 0.008 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol), anhydrous MTBE (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours in an argon atmosphere at 0 °C, and the crude product was purified by PTLC (silica gel, Tol:EA = 30:1, twice, v/v) to afford **5a** (10.6 mg, 29%) with 96:4 er.

5.6 Asymmetric reactions for the synthesis of **5a** using Heck by-product **8a**.

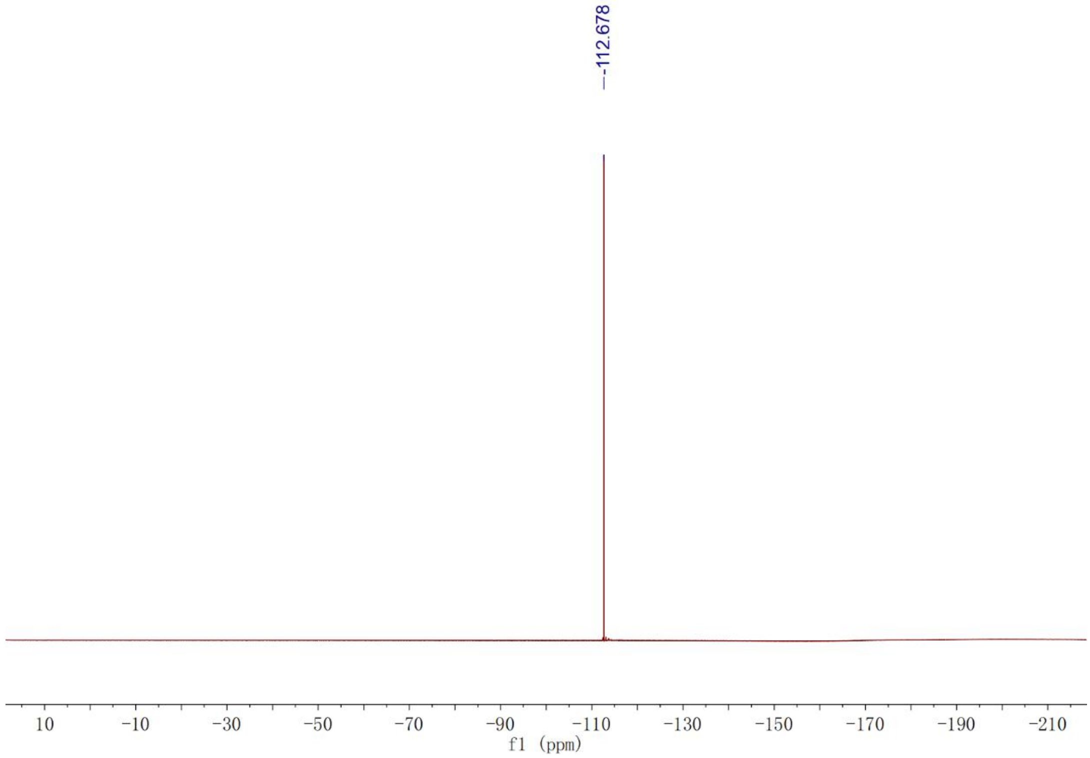


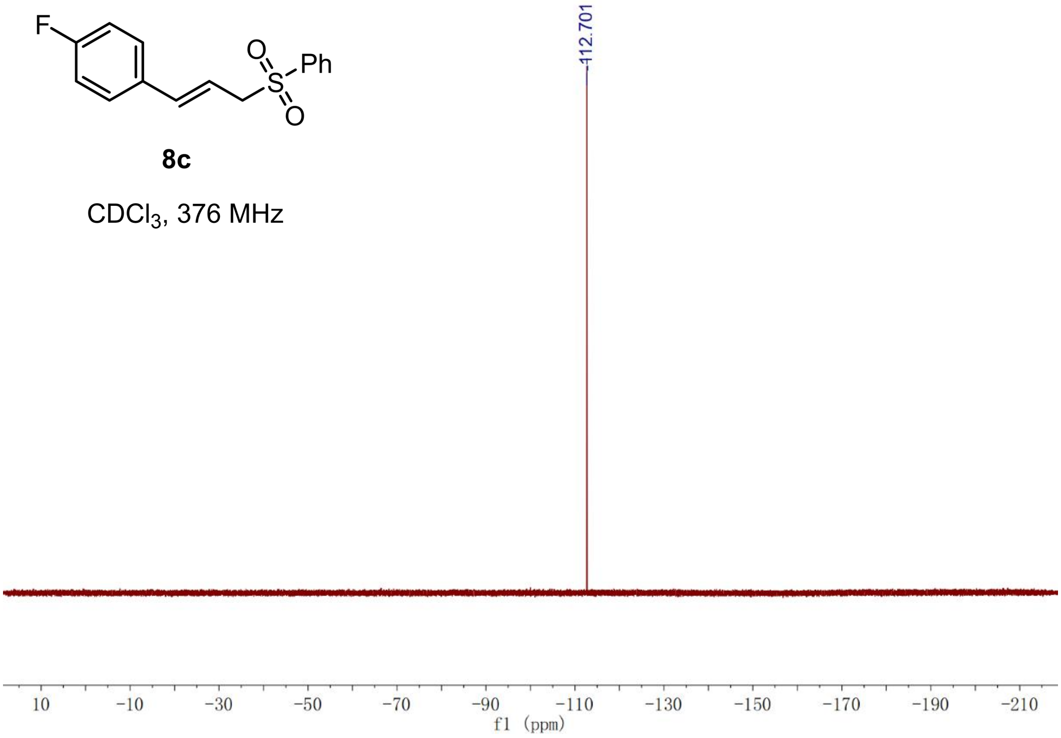
In glovebox, **8a** (57.6 mg, 0.2 mmol), **4a** (12.2 mg, 0.1 mmol), Pd$_2$dba$_3$ (3.7 mg, 0.004 mmol), (*R*)-**1a** (10.0 mg, 0.012 mmol), Rb$_2$CO$_3$ (69.3 mg, 0.3 mmol), anhydrous MTBE (2 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours in an argon atmosphere at 0 °C. ^{1}H NMR showed that no desired product **5a** was detected.

5.7 Cross-over experiment using **8c**.

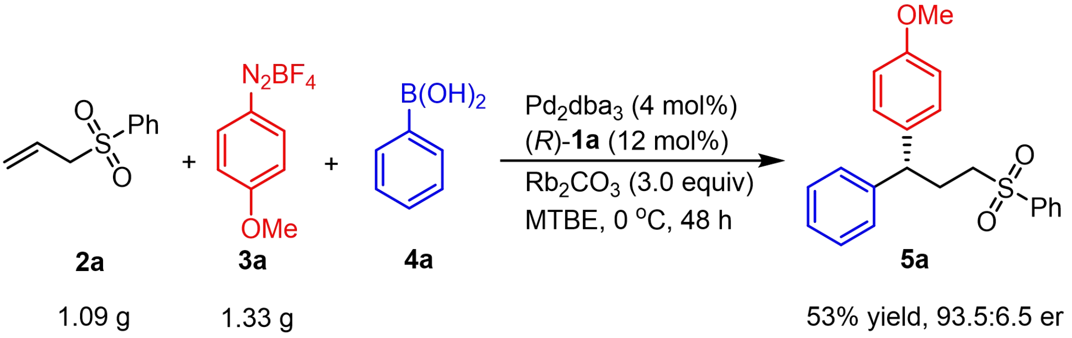


In glovebox, **8c** (27.6 mg, 0.1 mmol), **2a** (16 µl, 0.1 mmol), **3a** (22.2 mg, 0.2 mmol), **4a** (6.1 mg, 0.05 mmol), Pd_2dba_3 (1.8 mg, 0.002 mmol), (*R*)-**1a** (5.0 mg, 0.06 mmol), Rb_2CO_3 (34.7 mg, 0.15 mmol), anhydrous MTBE (1 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 48 hours in an argon atmosphere at 0 °C. ^{1}F NMR showed that no desired cross-over product was detected.





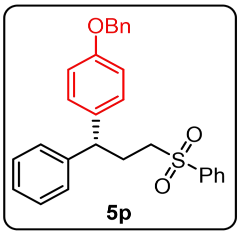
5.8 Gram-scale reaction.

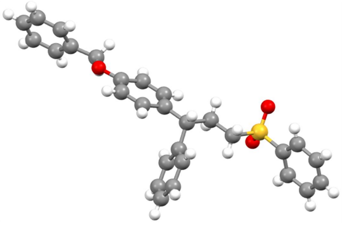


In glovebox, **2a** (1.09 g, 6.0 mmol), **3a** (1.33 mg, 6.0 mmol), **4a** (365.8 mg, 3.0 mmol), Pd_2dba_3 (109.8 mg, 0.12 mmol), (*R*)-**1a** (299.1 mg, 0.36 mmol), Rb_2CO_3 (2.08 g, 9.0 mmol), anhydrous MTBE (60 mL) were added into an oven-dried tube (10 mL) charged with a stir bar, sealed the flask with its septum and then removed from the glovebox. The system was stirred for 60 hours in an argon atmosphere at 0 °C, and the crude product was purified by SepaBean preparative rapid liquid chromatograph machine to afford **5a** (582.8 mg, 53%) with 93.5:6.5 er.

6. Crystal Data

6.1 Crystal Data of **5p**





CCDC: 2152365

Procedure for the recrystallization of **5p**: methanol (3 mL) was added to a 5 mL vial containing **5p** (5 mg) to form a clear solution. The solution was kept aside 2 days at room temperature to obtain crystals.

5.2 Crystal data and structure refinement for **5p**:

Identification code	**5p**
Empirical formula	$C_{28}H_{26}O_3S$
Formula weight	442.55
Temperature/K	293(2)
Crystal system	monoclinic
Space group	$P2_1$
a/Å	5.7414(3)
b/Å	33.3513(13)
c/Å	12.4948(7)
α/°	90
β/°	97.762(5)
γ/°	90
Volume/Å^3	2370.62(19)
Z	4
ρ_{calc}g/cm^3	1.240

μ/mm^{-1}	1.420
F(000)	936.0
Crystal size/mm^3	0.05 × 0.02 × 0.02
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	5.3 to 117.866
Index ranges	$-6 \leq h \leq 6$, $-33 \leq k \leq 37$, $-13 \leq l \leq 13$
Reflections collected	86175
Independent reflections	6647 [R_{int} = 0.2181, R_{sigma} = 0.0640]
Data/restraints/parameters	6647/1/565
Goodness-of-fit on F^2	1.063
Final R indexes [I>=2σ (I)]	R_1 = 0.0682, wR_2 = 0.1807
Final R indexes [all data]	R_1 = 0.1013, wR_2 = 0.2079
Largest diff. peak/hole / e Å^{-3}	0.42/-0.17
Flack parameter	0.01(3)

7. References

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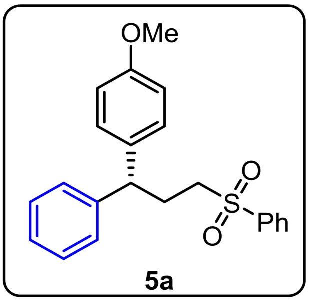
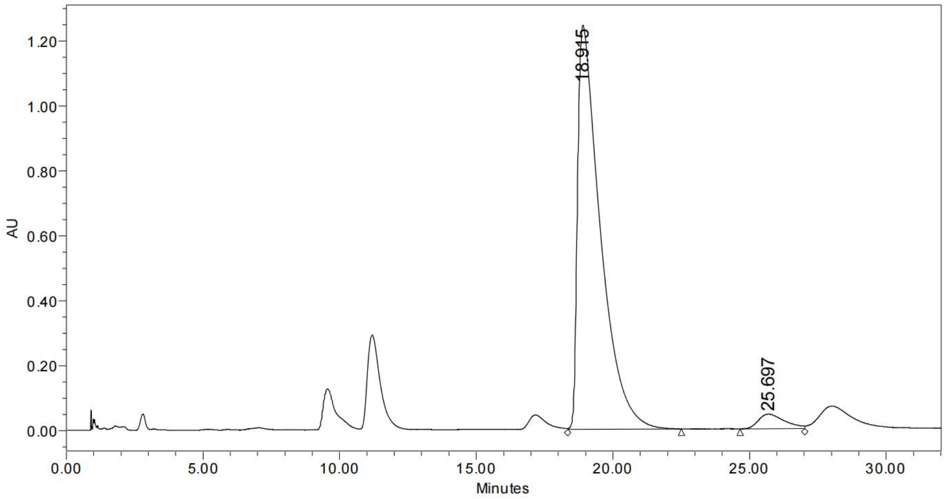
hydrogenation. *J. Am. Chem. Soc.* 2019; 141: 1749-1756. [DOI: 10.1021/jacs.8b12657]

8. SFC spectra

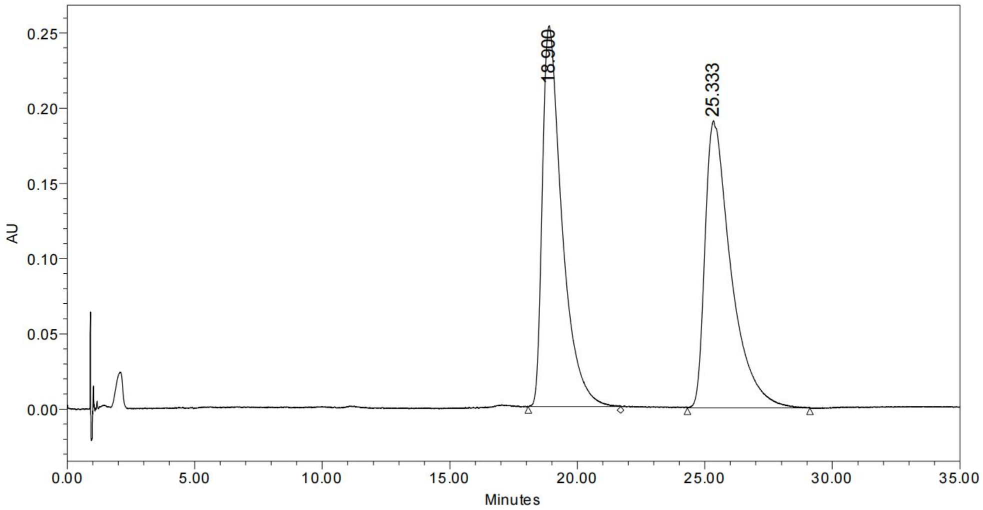


5a

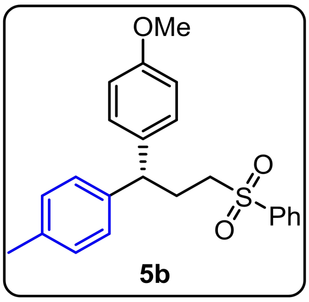
SFC (Trefoir CEL2, CO_2/MeOH = 92:8, 0.8 mL/min, 212.1 nm): t_R (major) = 18.915 min, t_R (minor) = 25.697 min, 96:4 er.



	RT	Area	% Area	Height
1	18.915	72133161	96.06	1244323
2	25.697	2959856	3.94	44719

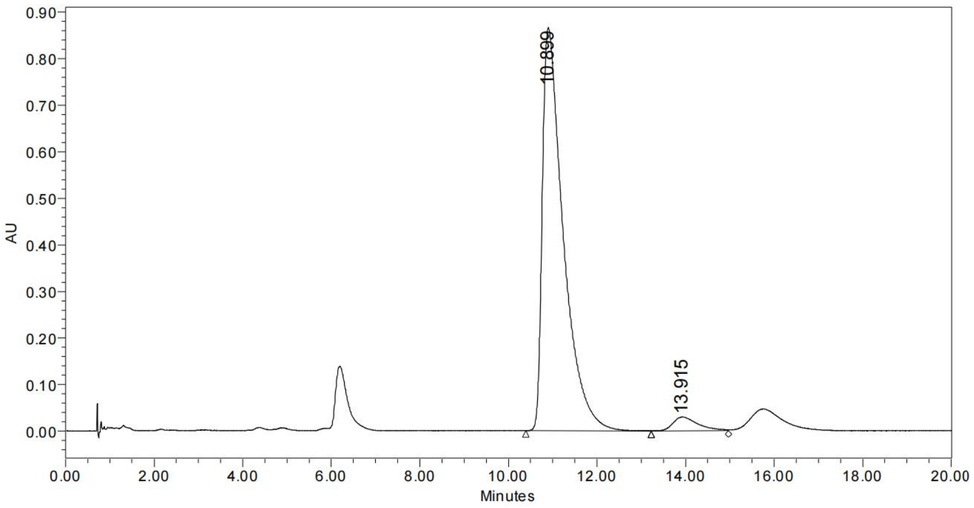


	RT	Area	% Area	Height
1	18.900	13550311	50.08	253126
2	25.333	13505371	49.92	190837

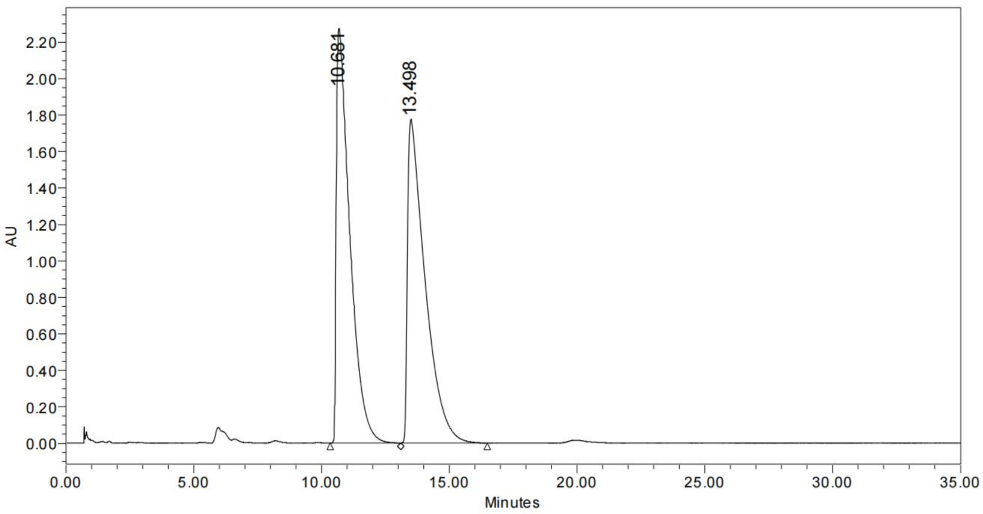


5b

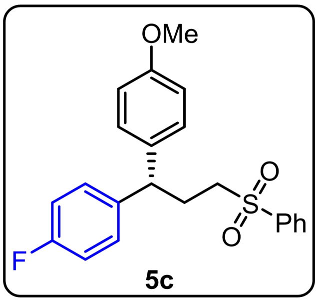
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (major) = 10.899 min, t_R (minor) = 13.915 min, 96:4 er.



	RT	Area	% Area	Height
1	10.899	28491723	95.98	865745
2	13.915	1191801	4.02	29993

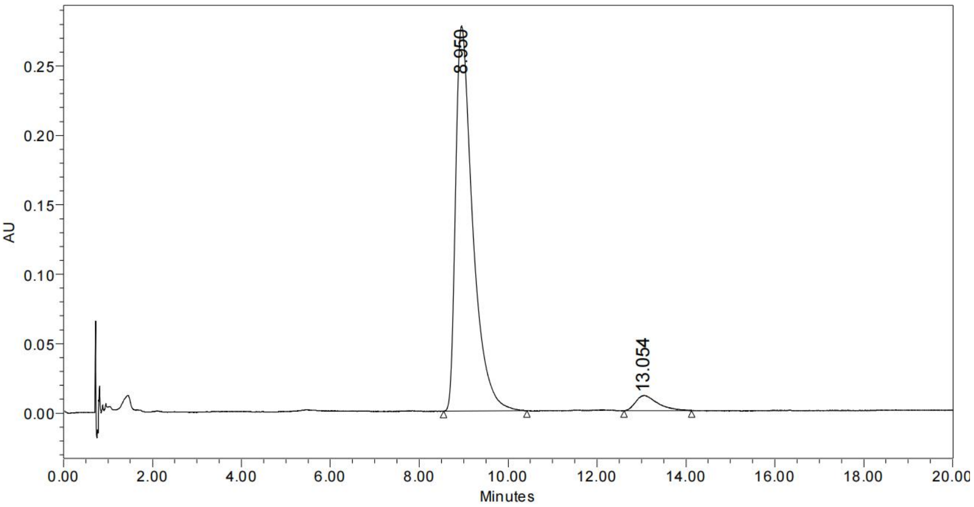


	RT	Area	% Area	Height
1	10.681	83803796	49.76	2273129
2	13.498	84619334	50.24	1775681

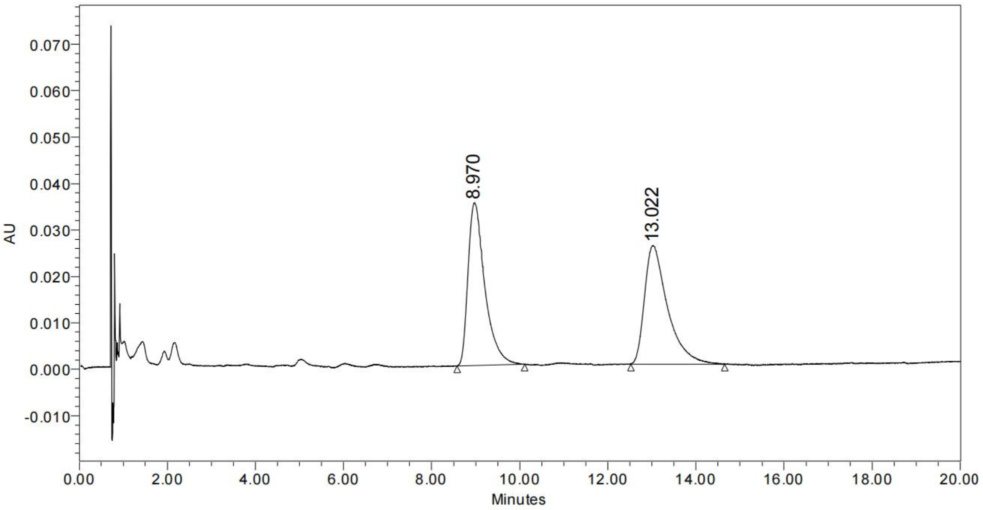


5c

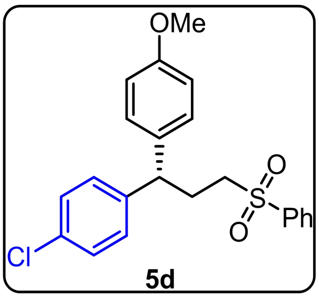
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (major) = 8.950 min, t_R (minor) = 13.054 min, 95:5 er.



	RT	Area	% Area	Height
1	8.950	7416280	95.19	277302
2	13.054	374714	4.81	10882

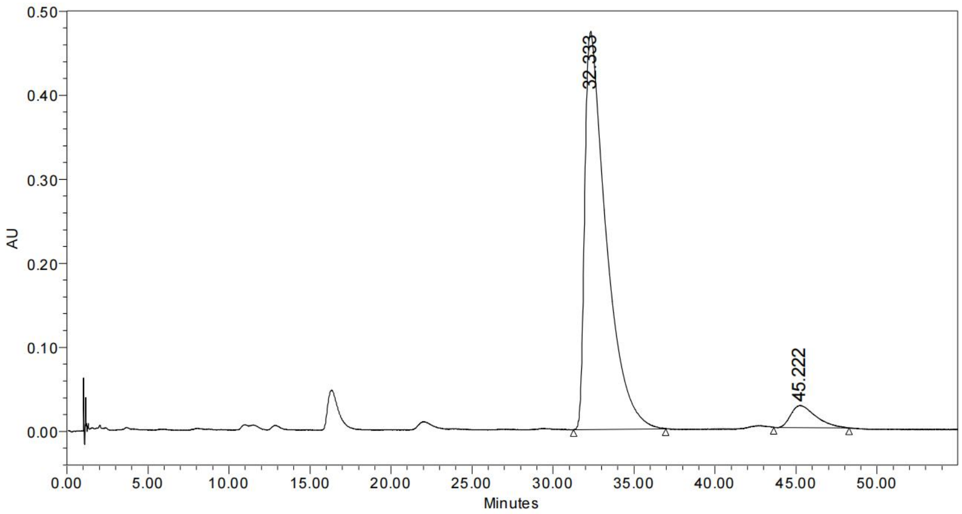


	RT	Area	% Area	Height
1	8.970	932013	50.11	35046
2	13.022	928103	49.89	25541

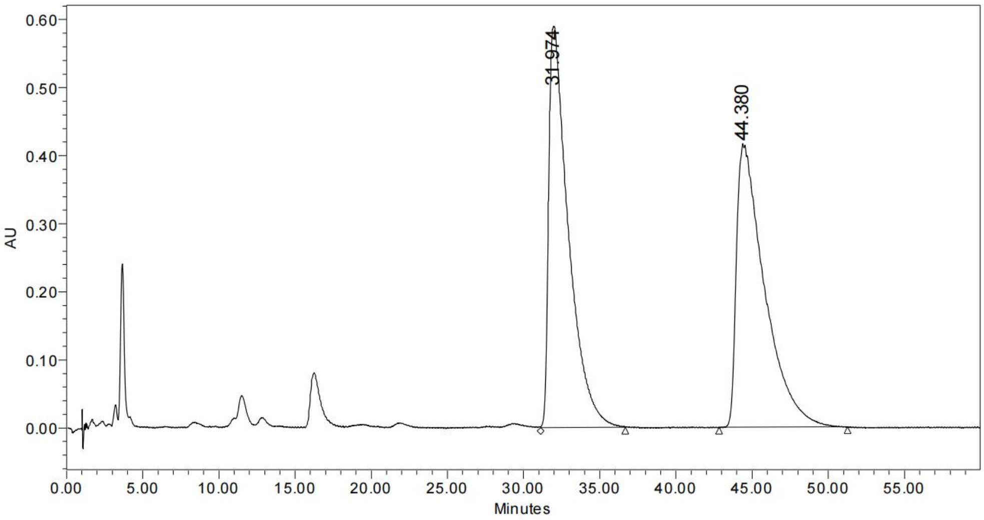


5d

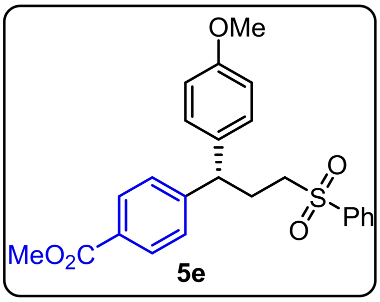
SFC (Trefoir CEL2, CO_2/MeOH = 92:8, 0.7 mL/min, 228.0 nm): t_R (major) = 32.333 min, t_R (minor) = 45.222 min, 94:6 er.



	RT	Area	% Area	Height
1	32.333	43590242	93.96	473410
2	45.222	2804529	6.04	26146

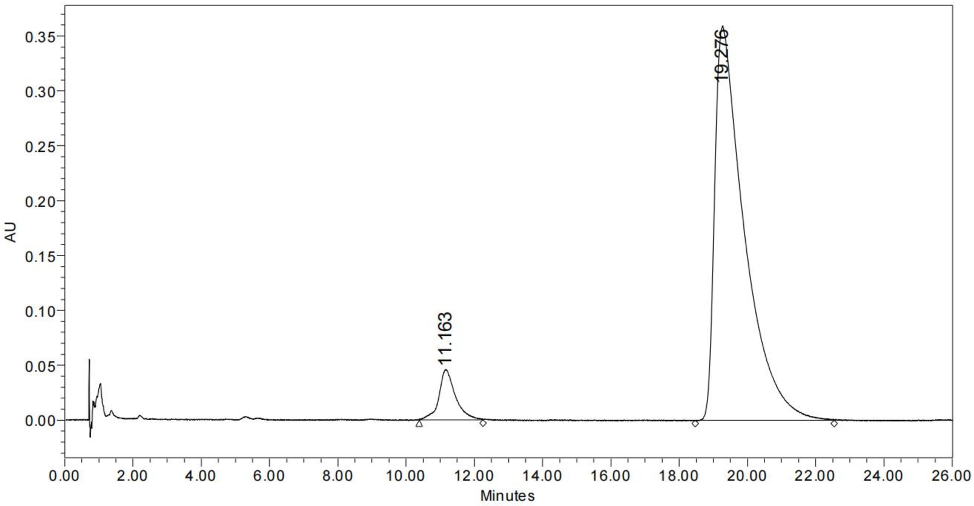


	RT	Area	% Area	Height
1	31.974	53122734	49.91	588941
2	44.380	53315733	50.09	416191

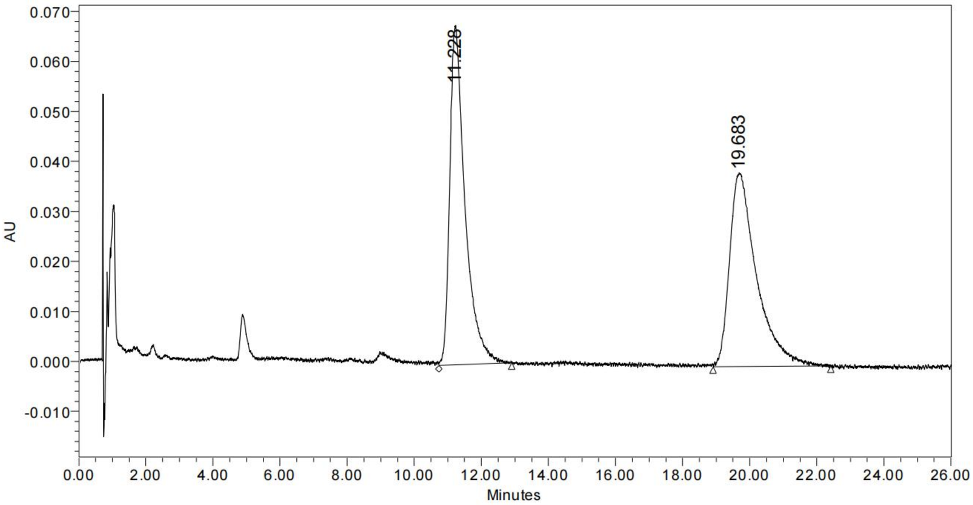


5e

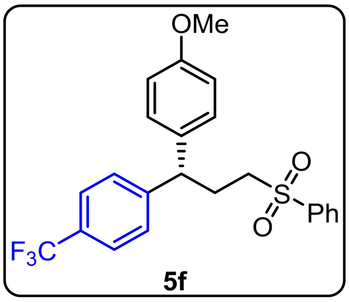
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 11.163 min, t_R (major) = 19.276 min, 93.5:6.5 er.



	RT	Area	% Area	Height
1	11.163	1526610	6.60	45679
2	19.276	21591691	93.40	359050

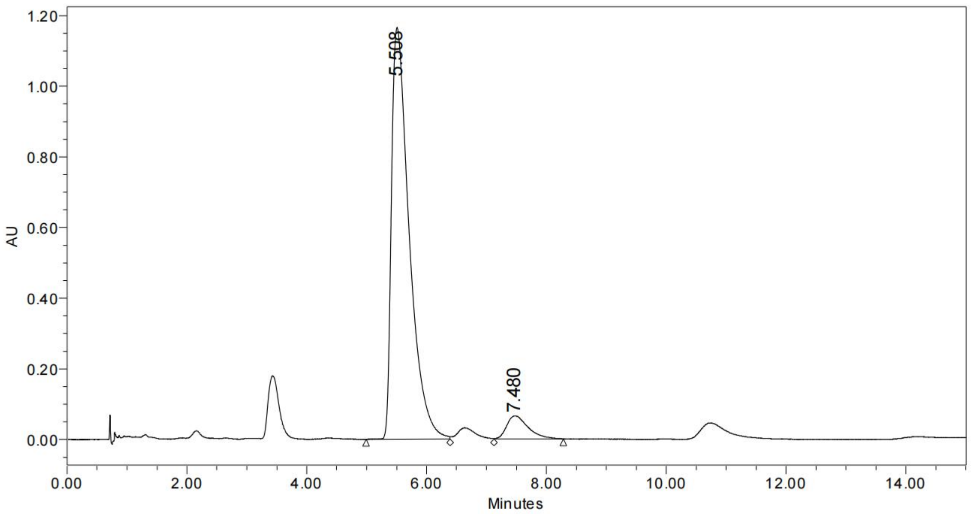


	RT	Area	% Area	Height
1	11.228	2160861	49.96	67809
2	19.683	2163964	50.04	38788

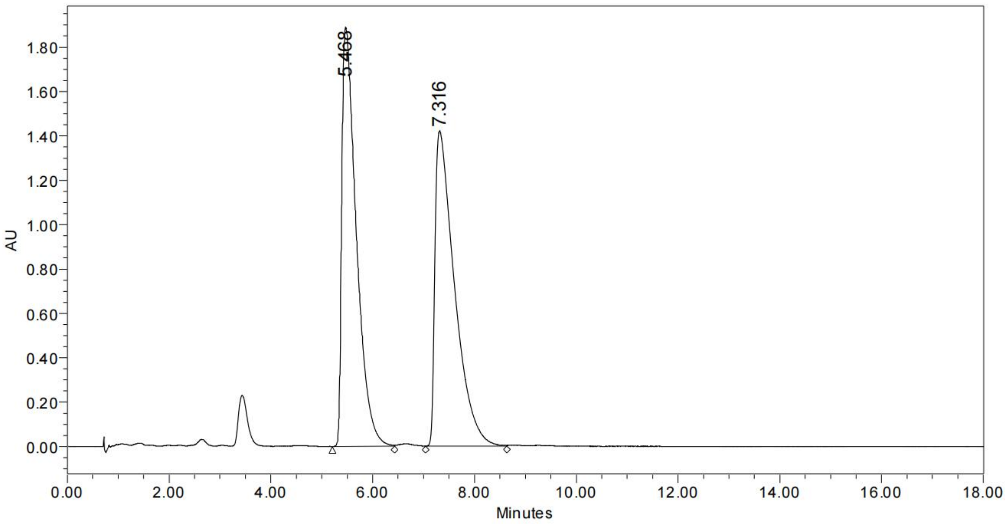


5f

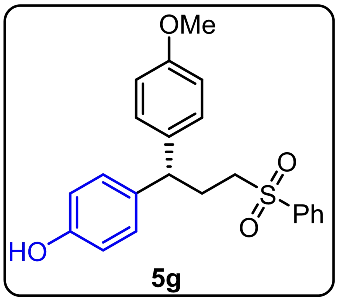
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 5.508 min, t_R (minor) = 7.480 min, 93.5:6.5 er.



	RT	Area	% Area	Height
1	5.508	23880335	93.60	1164732
2	7.480	1632739	6.40	65629

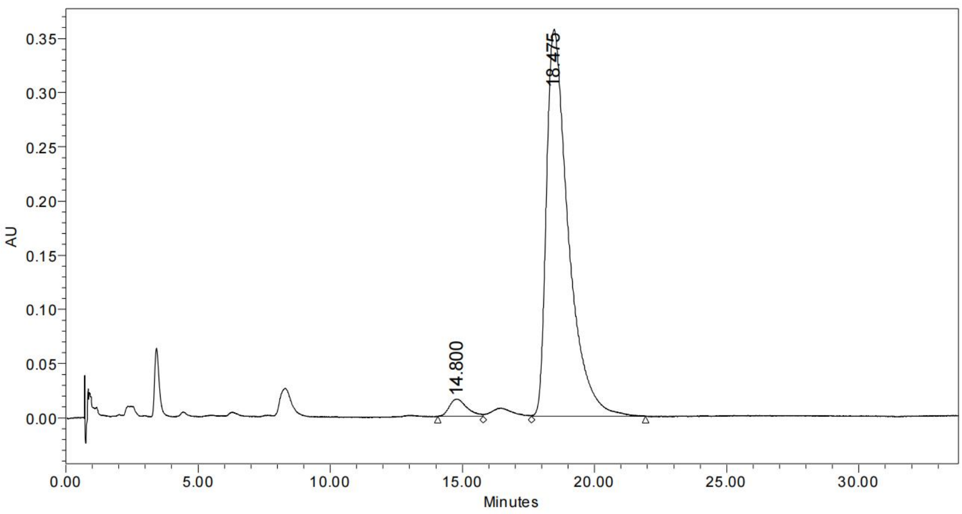


	RT	Area	% Area	Height
1	5.468	37573404	49.84	1888204
2	7.316	37820704	50.16	1422152

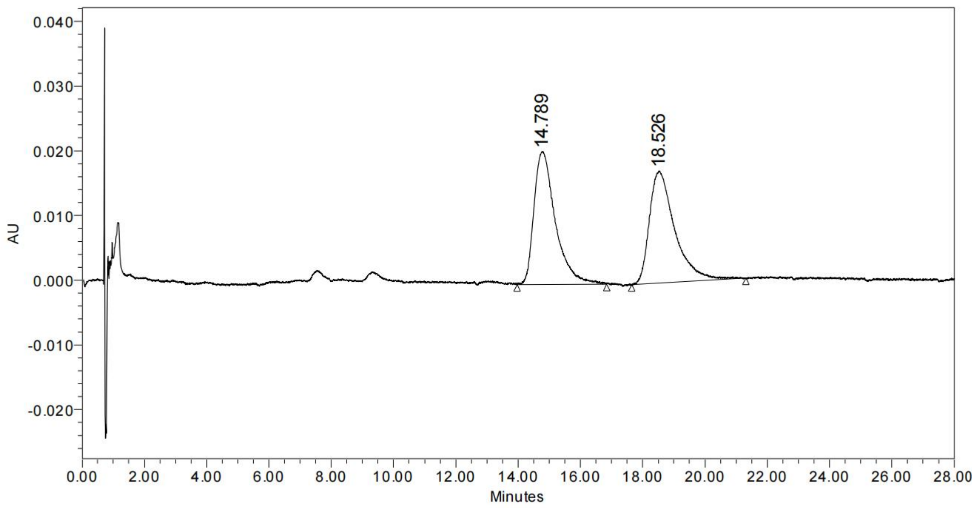


5g

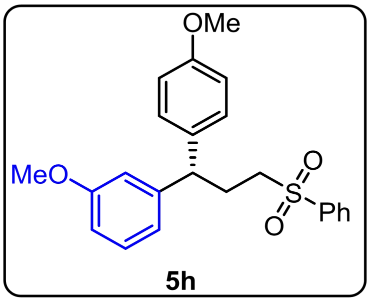
SFC (Trefoir CEL2, CO_2/MeOH = 85:15, 1 mL/min, 220.0 nm): t_R (minor) = 14.800 min, t_R (major) = 18.475 min, 96.5:3.5 er.



	RT	Area	% Area	Height
1	14.800	741734	3.48	15963
2	18.475	20590399	96.52	356890

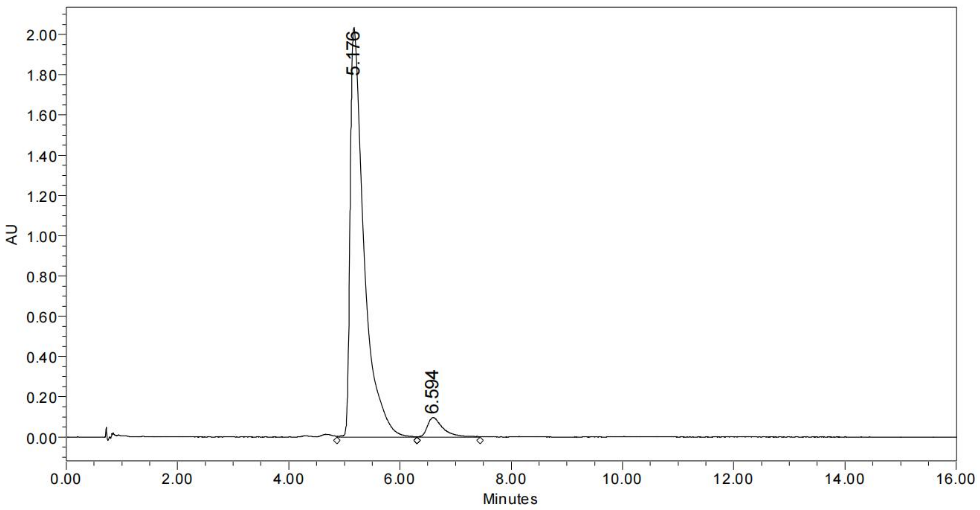


	RT	Area	% Area	Height
1	14.789	978583	49.97	20586
2	18.526	979916	50.03	17365

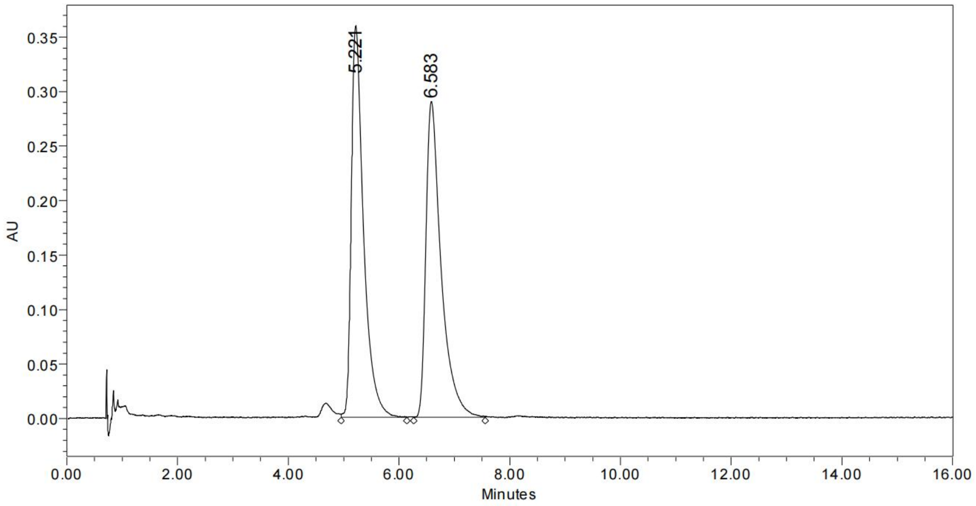


5h

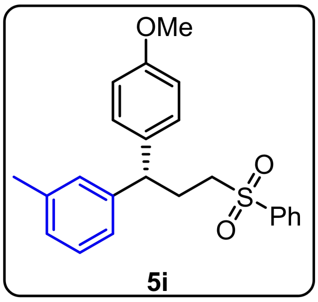
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 5.176 min, t_R (minor) = 6.594 min, 95:5 er.



	RT	Area	% Area	Height
1	5.176	35186282	94.88	2032404
2	6.594	1900445	5.12	96497

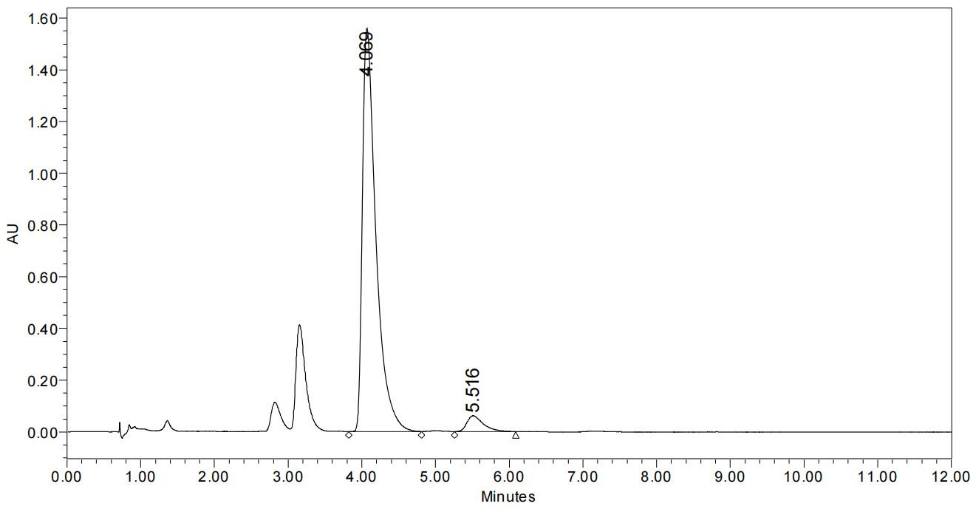


	RT	Area	% Area	Height
1	5.221	5536504	50.03	359227
2	6.583	5528795	49.97	289691

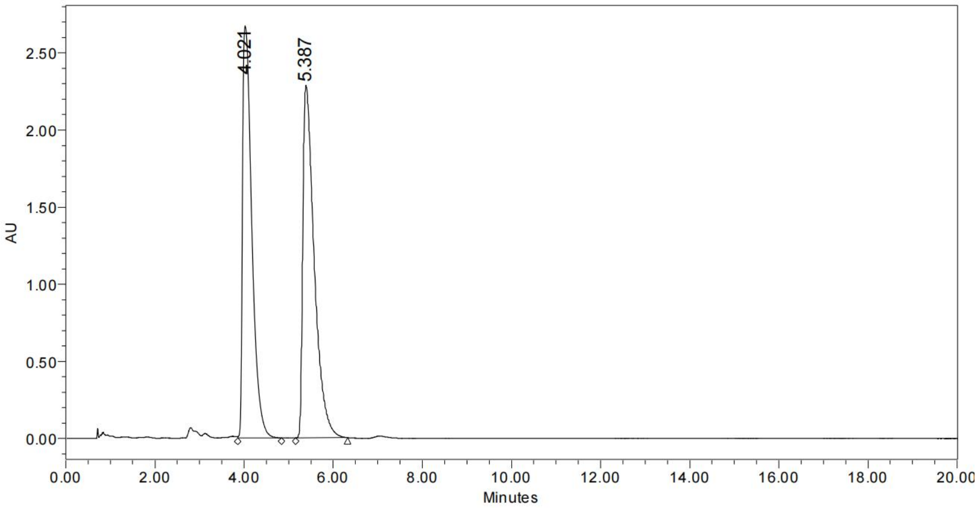


5i

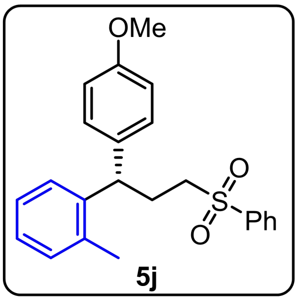
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 229.0 nm): t_R (major) = 4.069 min, t_R (minor) = 5.516 min, 95.5:4.5 er.



	RT	Area	% Area	Height
1	4.069	19959241	95.45	1559188
2	5.516	952279	4.55	61040

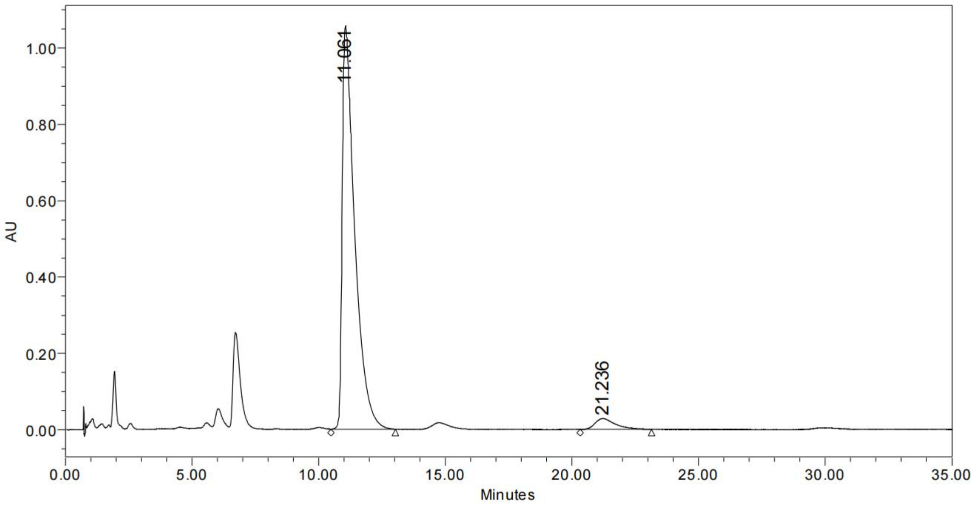


	RT	Area	% Area	Height
1	4.021	38531001	48.68	2669510
2	5.387	40618574	51.32	2283796

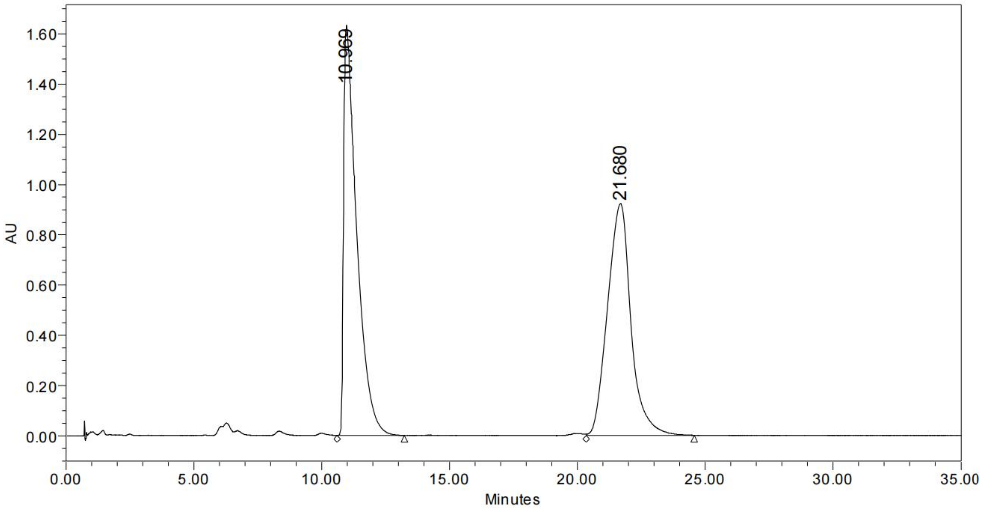


5j

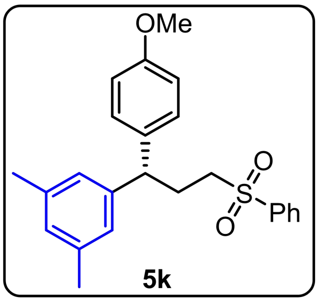
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (major) = 11.061 min, t_R (minor) = 21.236 min, 96:4 er.



	RT	Area	% Area	Height
1	11.061	36387567	95.78	1055885
2	21.236	1602793	4.22	28458

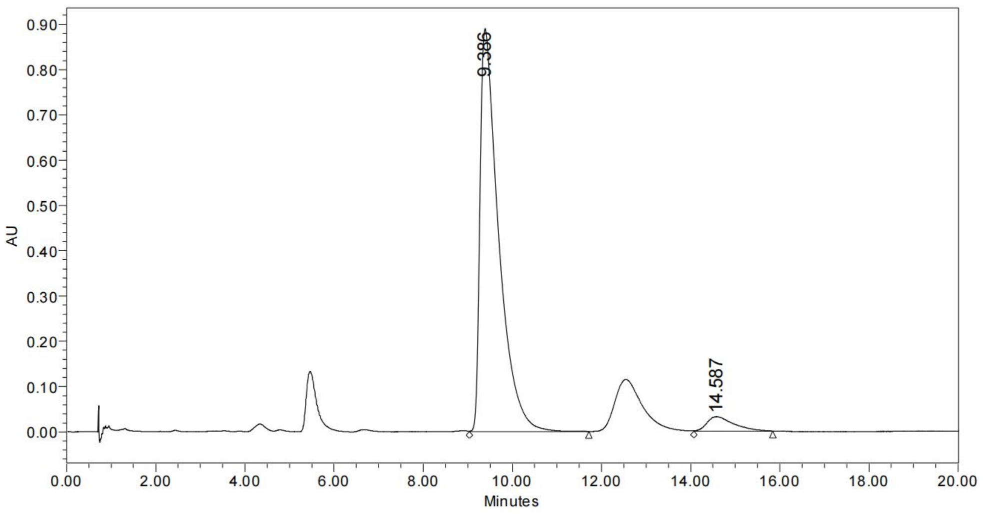


	RT	Area	% Area	Height
1	10.969	58474504	49.99	1630660
2	21.680	58509462	50.01	921989

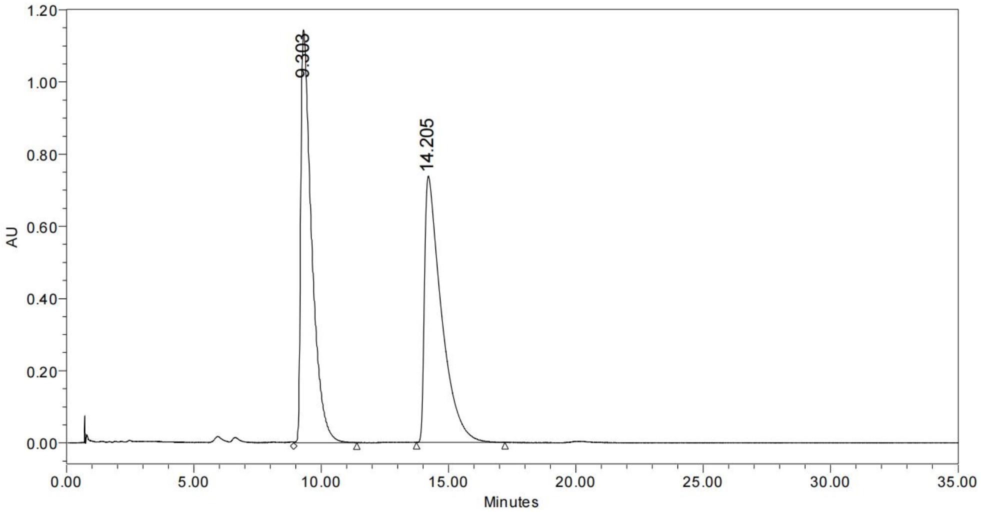


5k

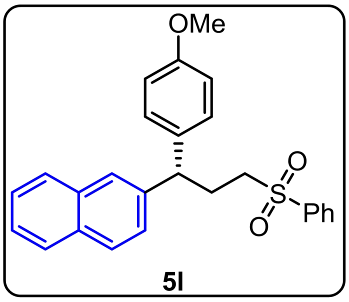
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 232.0 nm): t_R (major) = 8.386 min, t_R (minor) = 14.587 min, 95:5 er.



	RT	Area	% Area	Height
1	9.386	25762721	95.07	889492
2	14.587	1335595	4.93	32068

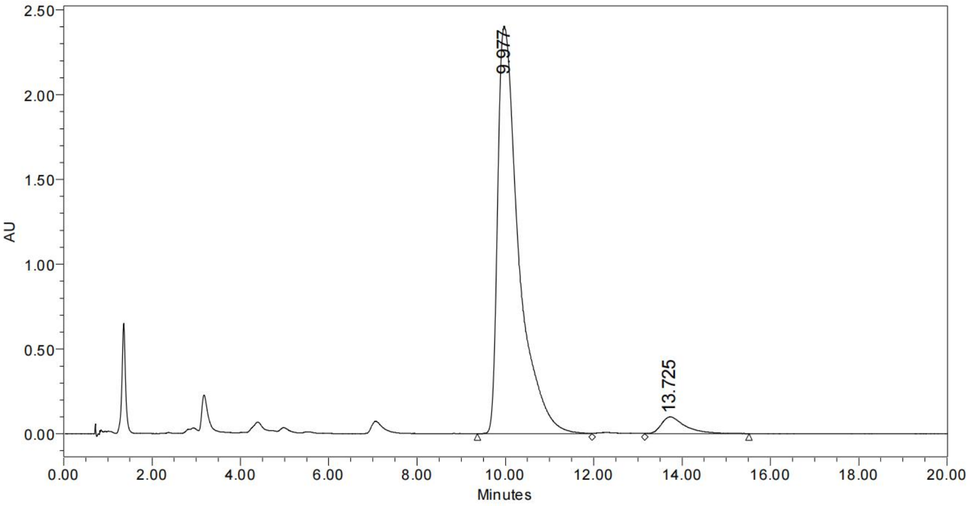


	RT	Area	% Area	Height
1	9.303	34036388	50.10	1142338
2	14.205	33905767	49.90	737803

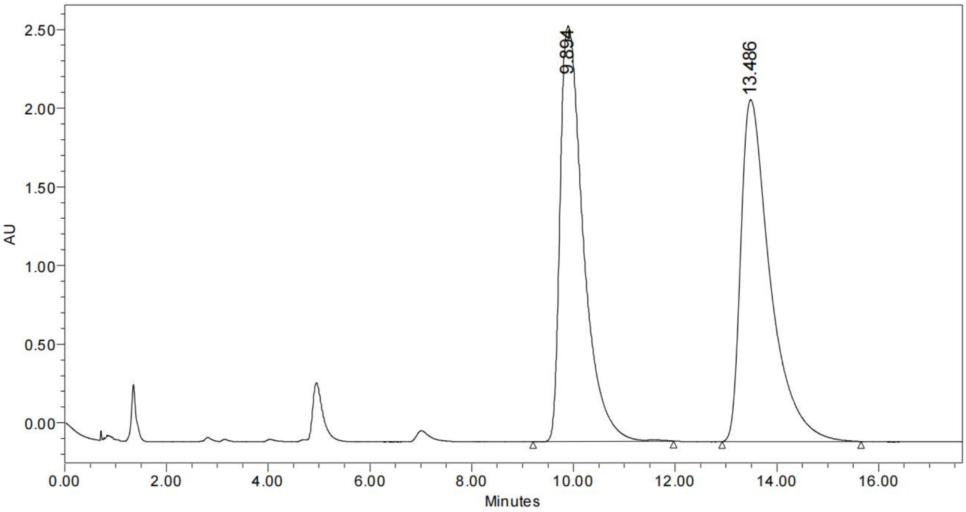


5l

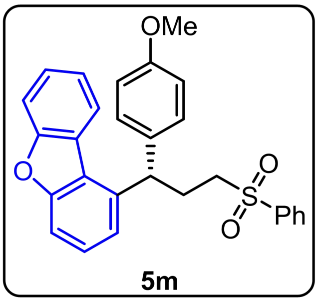
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 220.0 nm): t_R (major) = 9.977 min, t_R (minor) = 13.725 min, 95.5:4.5 er.



	RT	Area	% Area	Height
1	9.977	78890604	95.51	2400076
2	13.725	3711528	4.49	98704

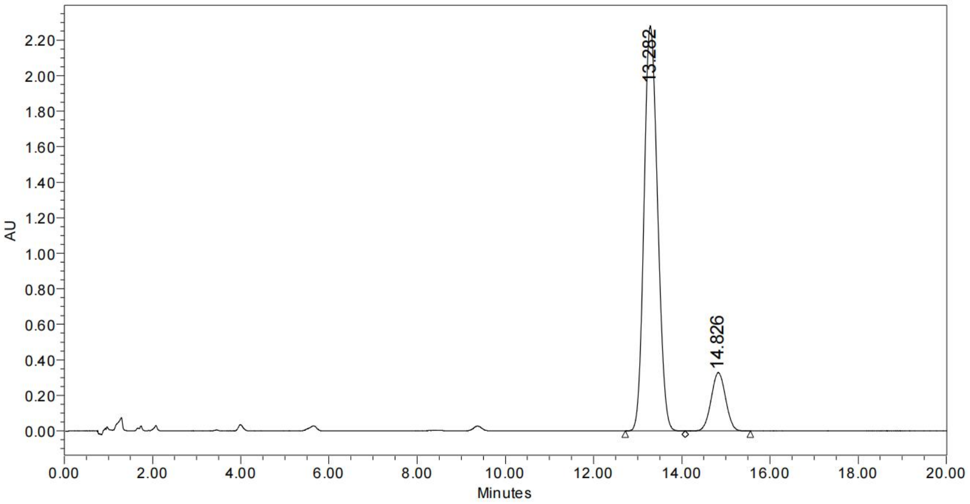


	RT	Area	% Area	Height
1	9.894	83775223	49.02	2641204
2	13.486	87134208	50.98	2173698

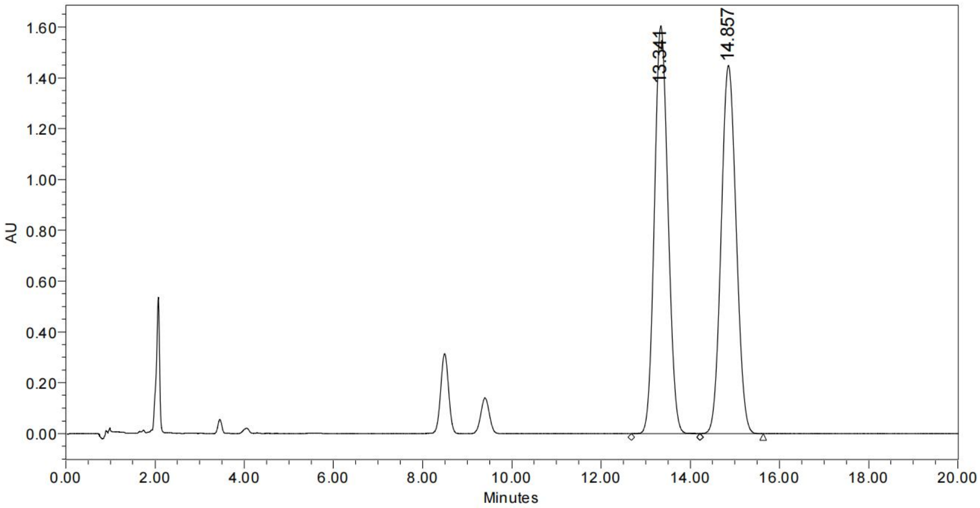


5m

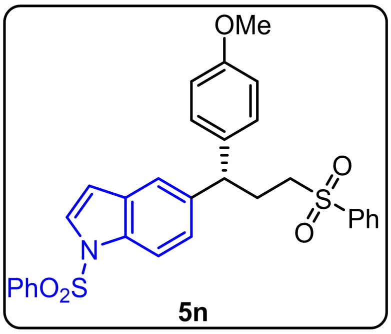
SFC (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 13.282 min, t_R (minor) = 14.826 min, 86.5:13.5 er.



	RT	Area	% Area	Height
1	13.282	48491558	86.67	2279978
2	14.826	7460532	13.33	328714

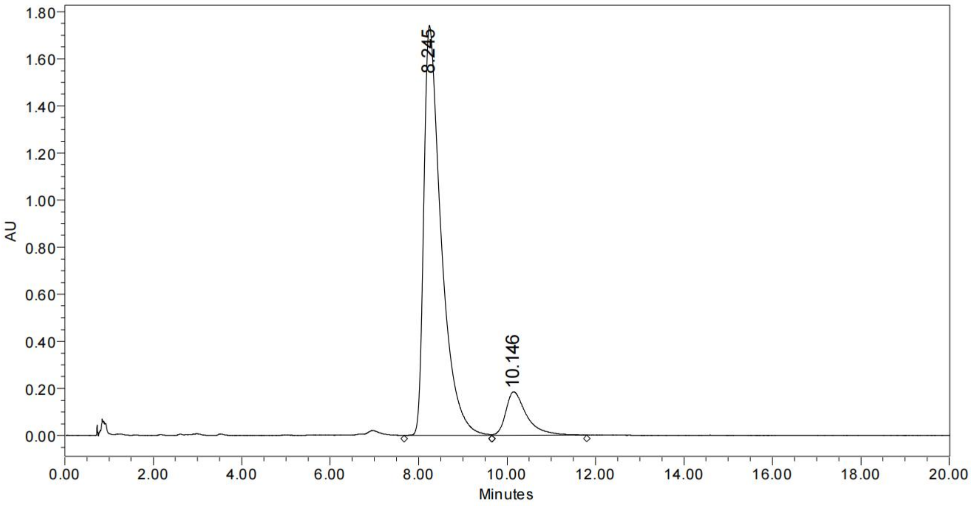


	RT	Area	% Area	Height
1	13.341	33807140	49.94	1604708
2	14.857	33889167	50.06	1449061

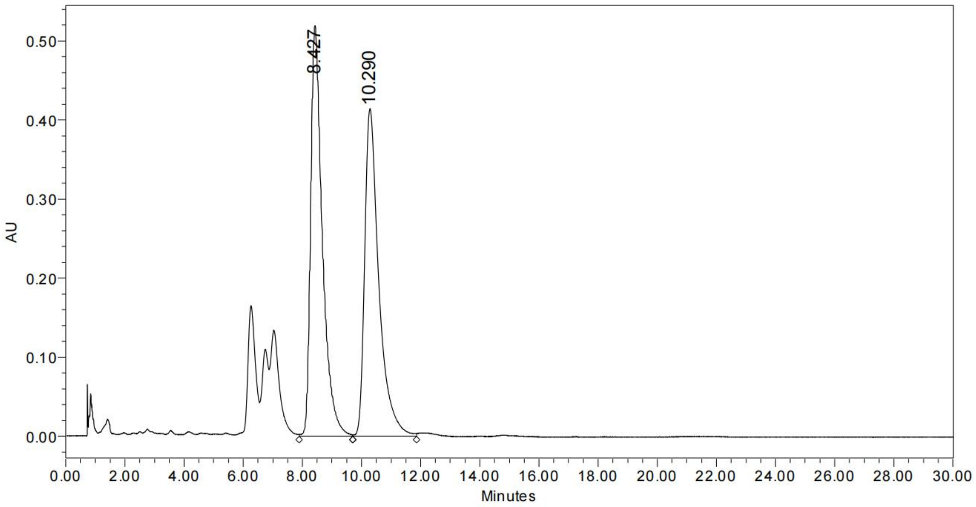


5n

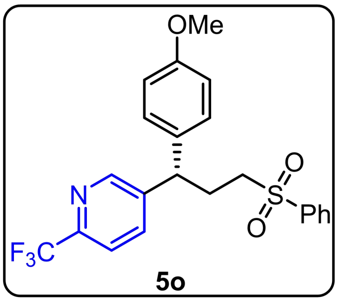
SFC (Trefoir CEL2, CO$_2$/MeOH = 70:30, 1 mL/min, 215.0 nm): t$_R$ (major) = 8.245 min, t$_R$ (minor) = 10.146 min, 88.5:11.5 er.



	RT	Area	% Area	Height
1	8.245	47388022	88.74	1739590
2	10.146	6012960	11.26	184107

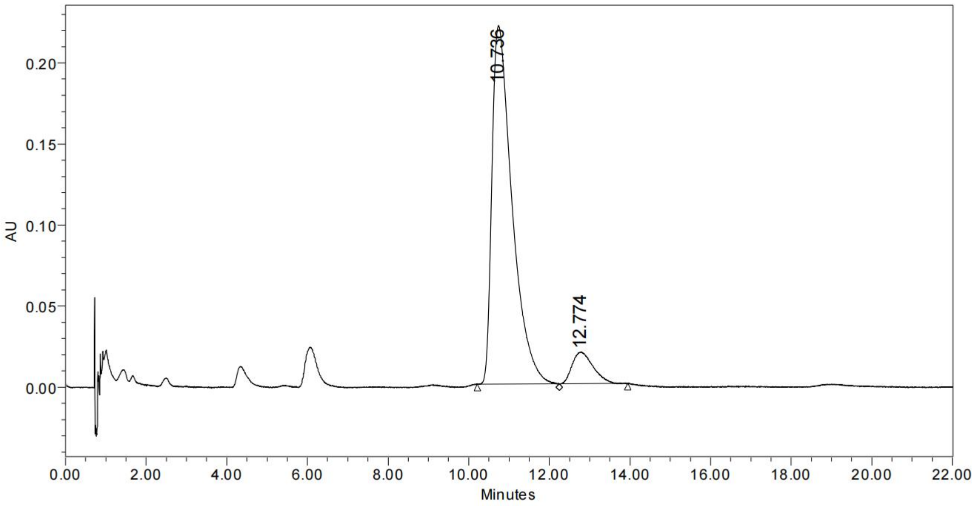


	RT	Area	% Area	Height
1	8.427	14272524	50.98	518500
2	10.290	13726220	49.02	414054

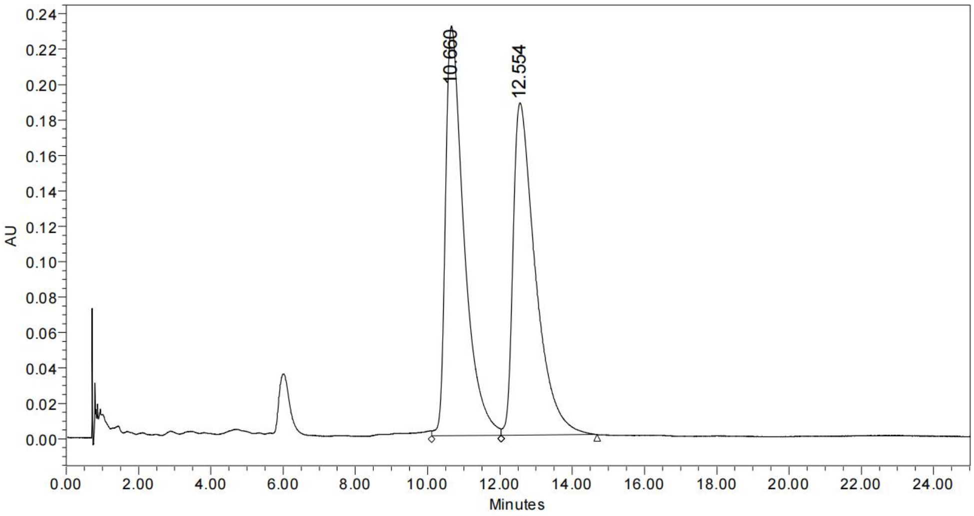


5o

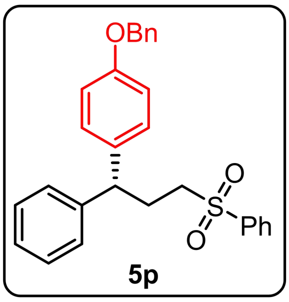
SFC (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 10.736 min, t$_R$ (minor) = 12.774 min, 91.5:8.5 er.



	RT	Area	% Area	Height
1	10.736	7669579	91.53	221074
2	12.774	709958	8.47	19590

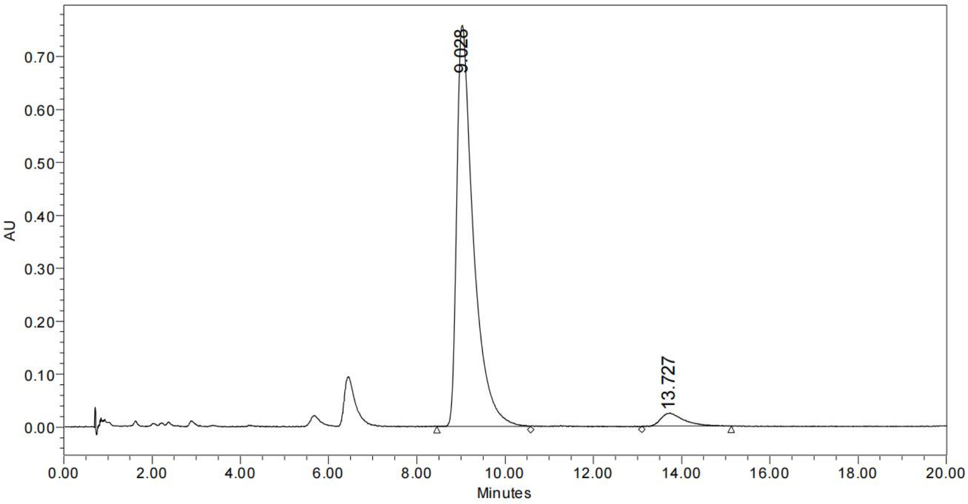


	RT	Area	% Area	Height
1	10.660	8229539	50.57	231182
2	12.554	8044308	49.43	187546

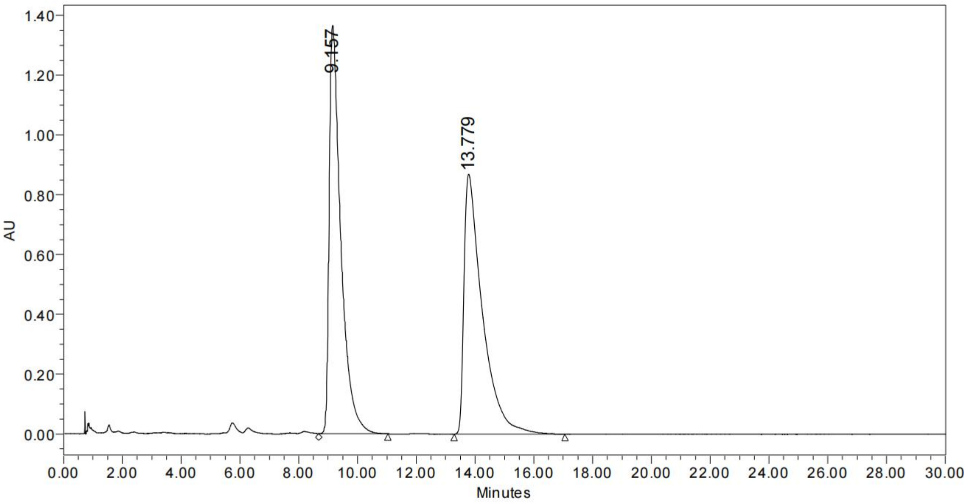


5p

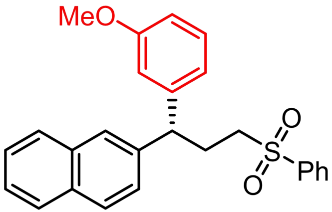
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (major) = 9.028 min, t_R (minor) = 13.727 min, 96:4 er.



	RT	Area	% Area	Height
1	9.028	19777905	95.80	756877
2	13.727	867576	4.20	24108

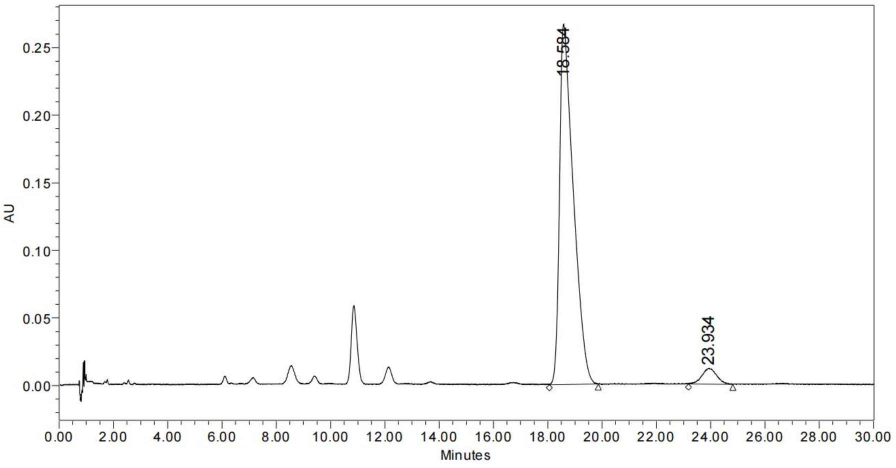


	RT	Area	% Area	Height
1	9.157	37631276	50.02	1365272
2	13.779	37597907	49.98	869772

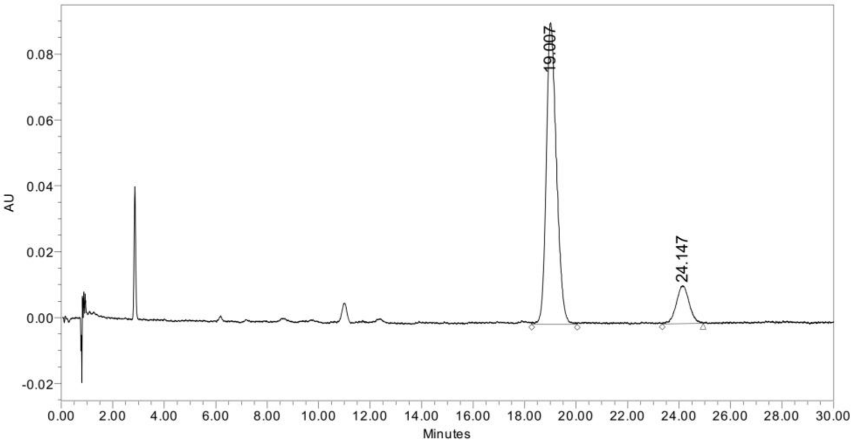


5q

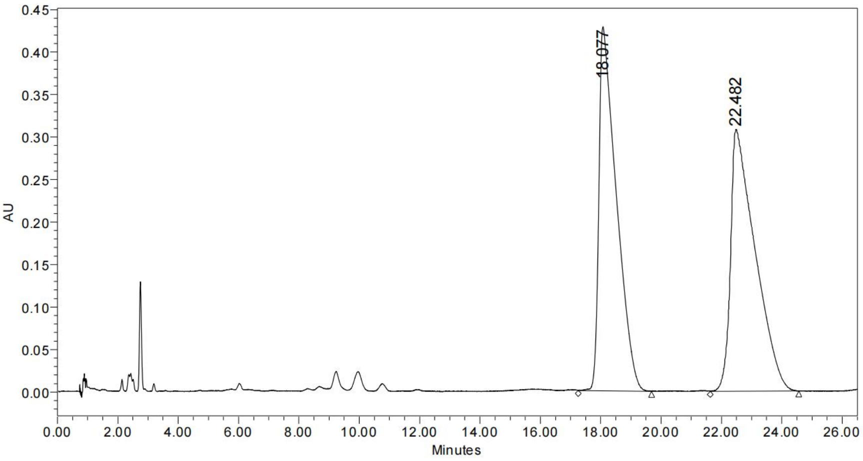
SFC (IC-3, CO_2/MeOH = 85:15, 1 mL/min, 272.0 nm): t_R (major) = 18.584 min, t_R (minor) = 23.934 min, 95.5:4.5 er.



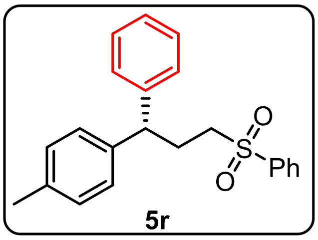
	RT	Area	% Area	Height
1	18.584	9380343	95.50	266493
2	23.934	442468	4.50	11668



	RT	Area	% Area	Height
1	19.007	2532435	86.40	91507
2	24.147	398660	13.60	11533

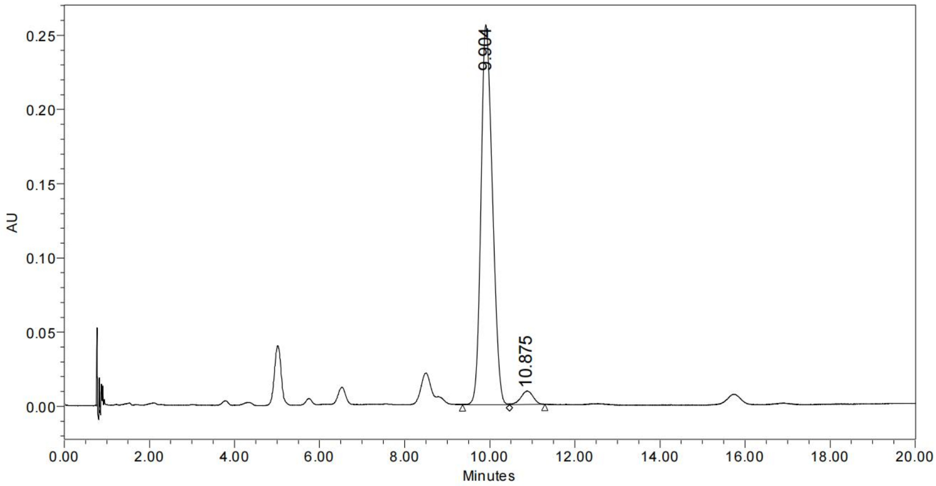


	RT	Area	% Area	Height
1	18.077	17209233	49.51	428214
2	22.482	17550042	50.49	308327

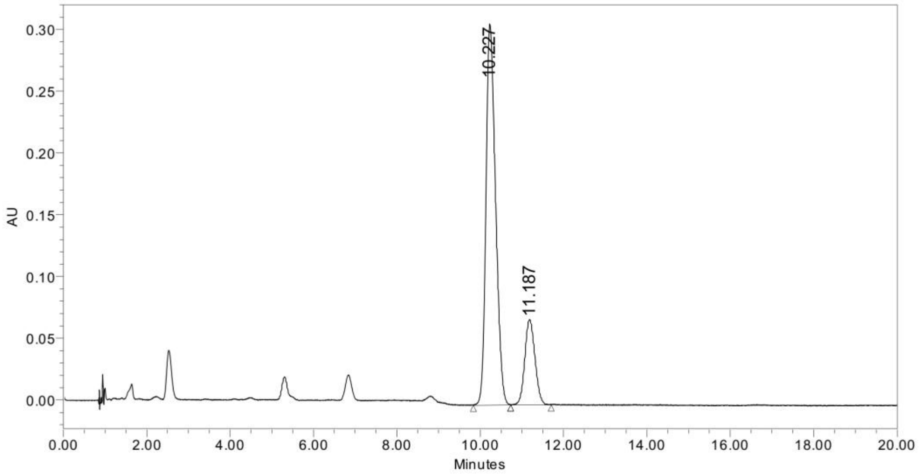


5r

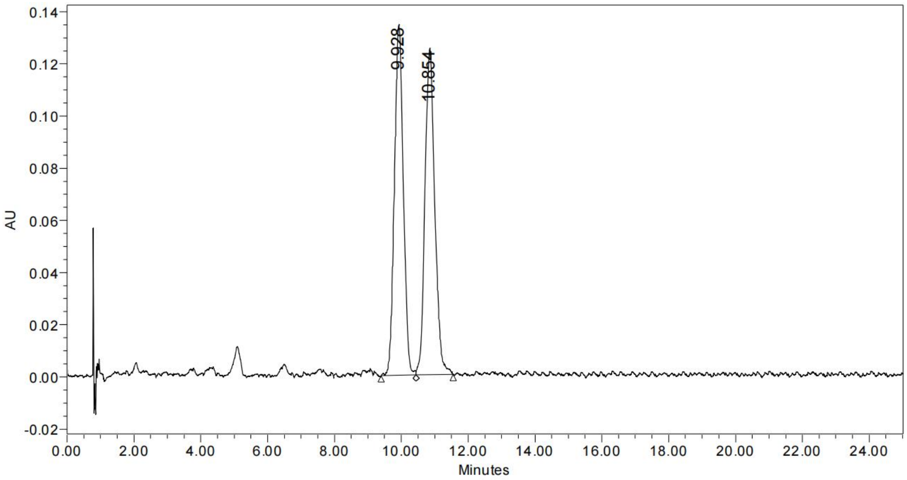
SFC (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 9.904 min, t_R (minor) = 10.875 min, 96.5:3.5 er.



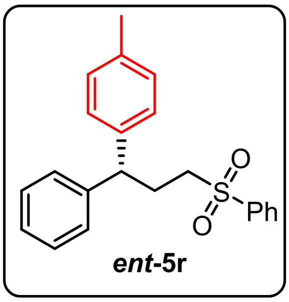
	RT	Area	% Area	Height
1	9.904	4753901	96.34	255783
2	10.875	180610	3.66	9001



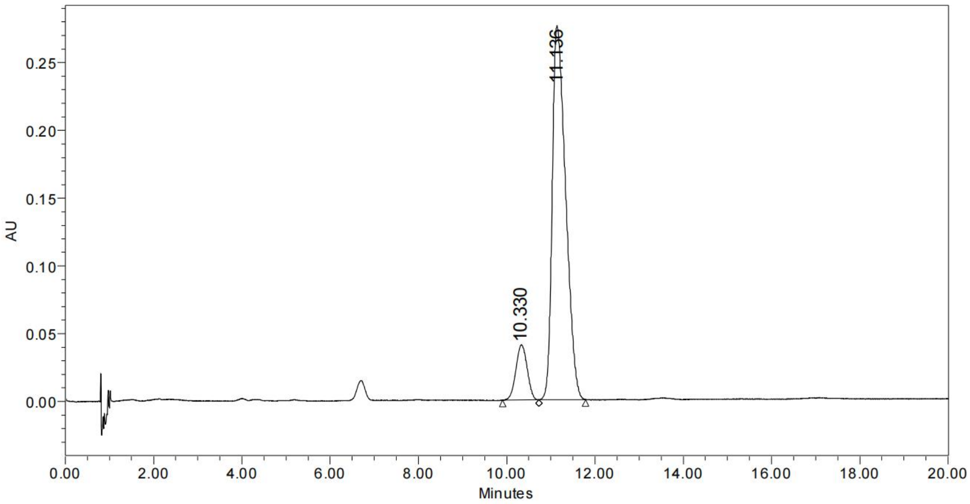
	RT	Area	% Area	Height
1	10.227	4933855	80.78	308428
2	11.187	1174087	19.22	69115



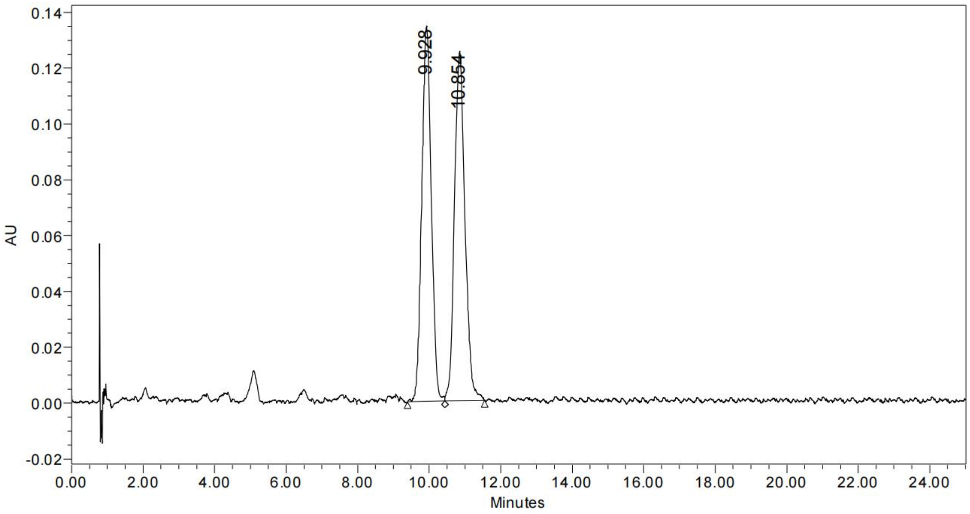
	RT	Area	% Area	Height
1	9.928	2500350	49.67	134418
2	10.854	2533546	50.33	125266



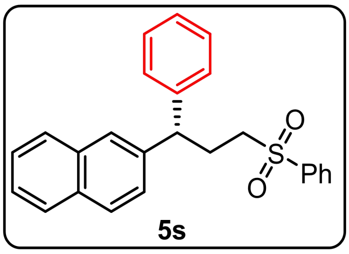
SFC (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (minor) = 10.330 min, t_R (major) = 11.136 min, 89:11 er.



	RT	Area	% Area	Height
1	10.330	730204	11.08	40823
2	11.136	5859863	88.92	275836

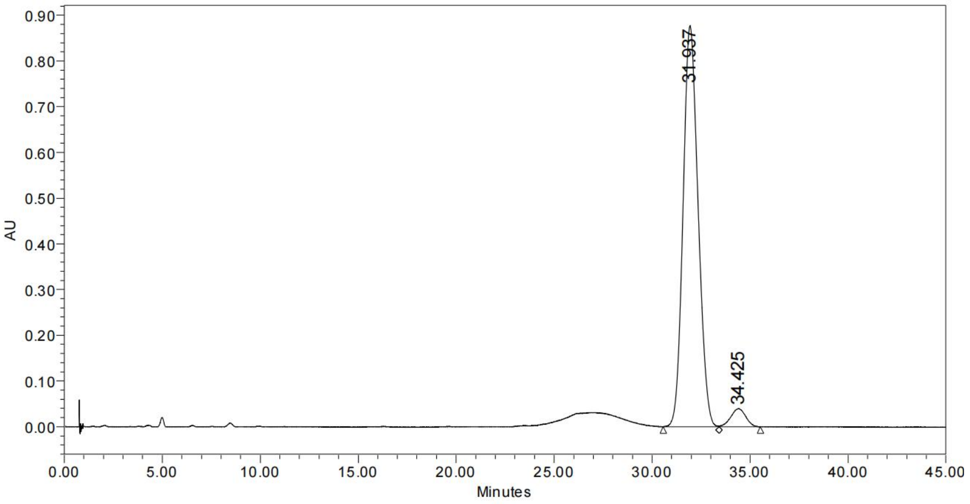


	RT	Area	% Area	Height
1	9.928	2500350	49.67	134418
2	10.854	2533546	50.33	125266

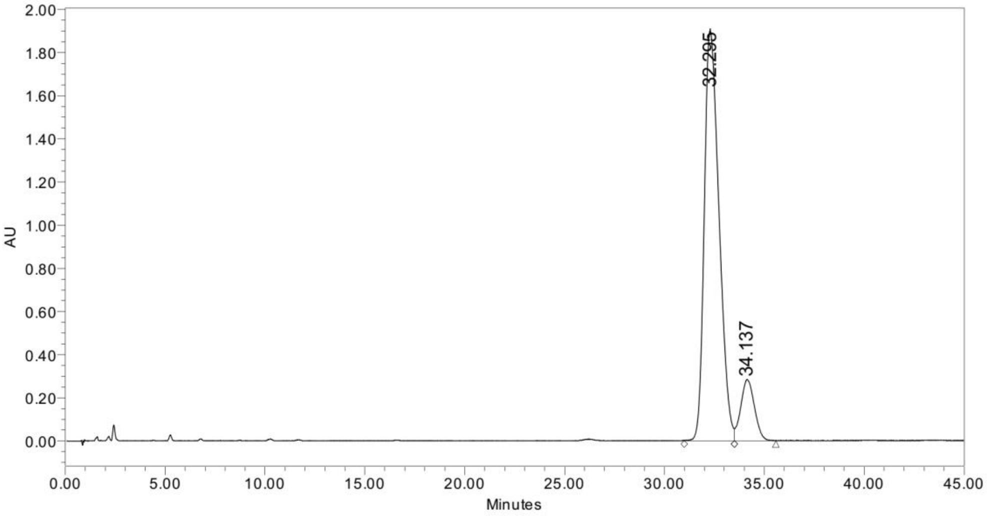


5s

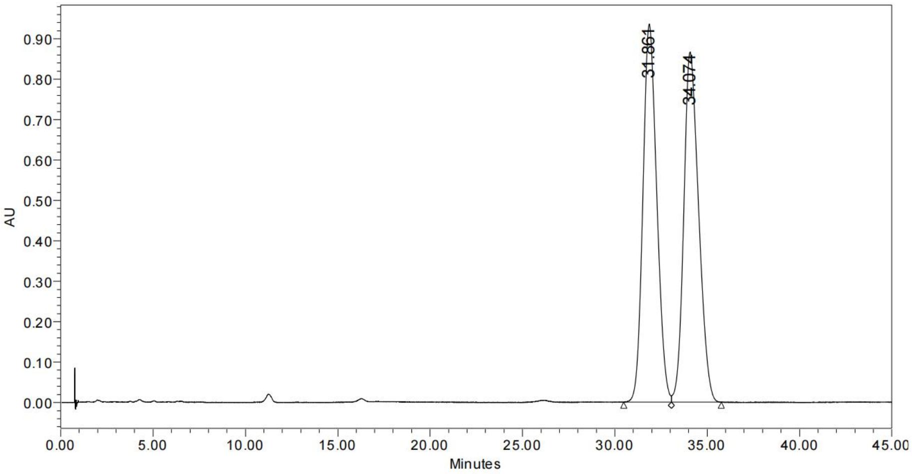
SFC (OD-3, CO$_2$/MeOH = 95:5, 1 mL/min, 223.0 nm): t$_R$ (major) = 31.934 min, t$_R$ (minor) = 34.425 min, 95.5:4.5 er.



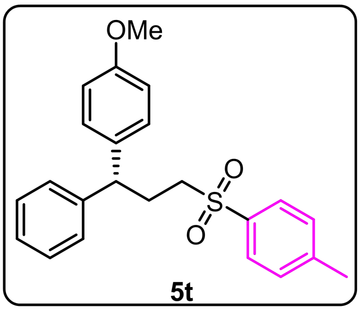
	RT	Area	% Area	Height
1	31.937	46632956	95.70	876792
2	34.425	2097003	4.30	39572



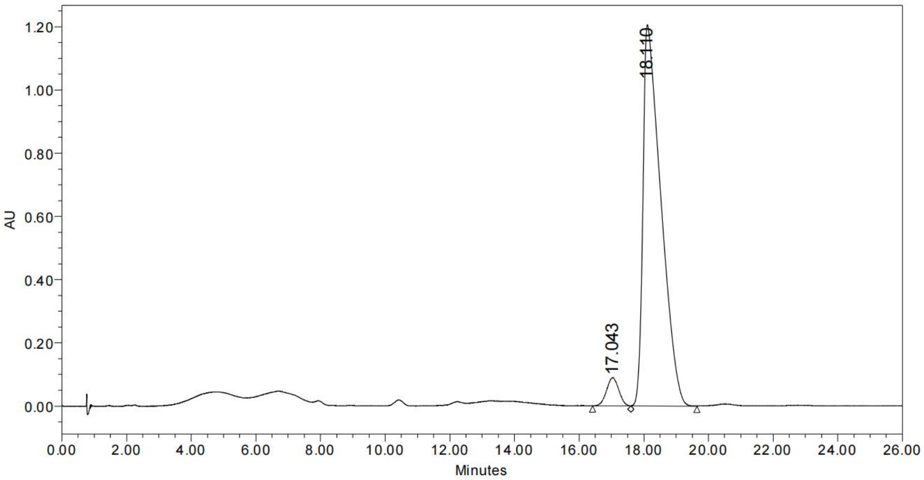
	RT	Area	% Area	Height
1	32.295	97400713	87.88	1907527
2	34.137	13435293	12.12	282309



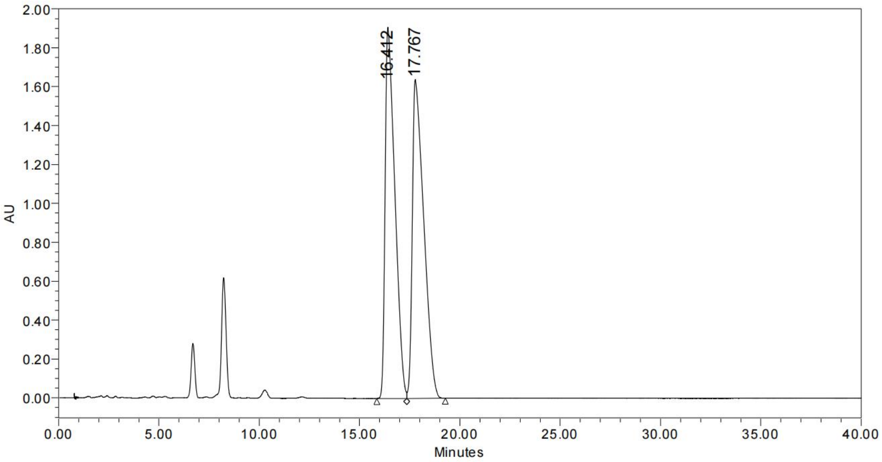
	RT	Area	% Area	Height
1	31.861	48559969	50.01	934533
2	34.074	48535501	49.99	866296



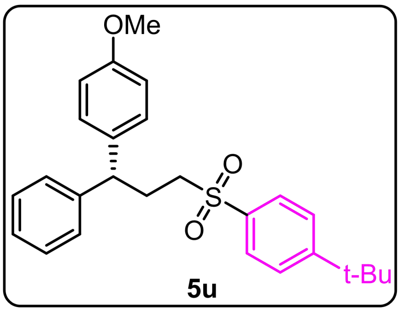
SFC (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (minor) = 17.043 min, t_R (major) = 18.110 min, 95:5 er.



	RT	Area	% Area	Height
1	17.043	2357110	4.84	89192
2	18.110	46382252	95.16	1205307

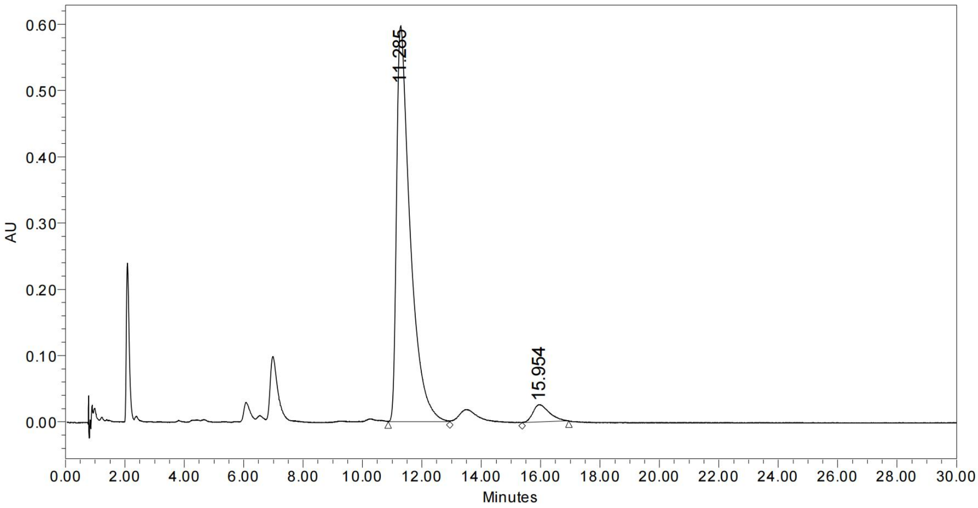


	RT	Area	% Area	Height
1	16.412	64252533	49.75	1906777
2	17.767	64906169	50.25	1638324

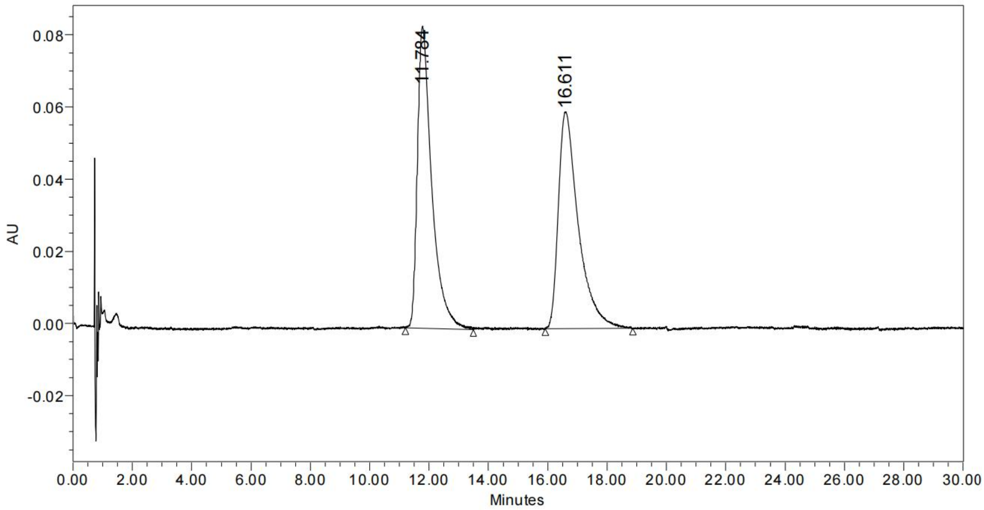


5u

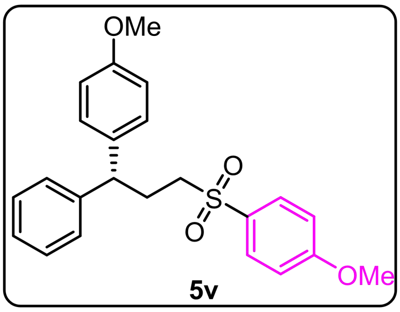
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 11.285 min, t_R (minor) = 15.954 min, 95:5 er.



	RT	Area	% Area	Height
1	11.285	19007823	95.01	597291
2	15.954	997497	4.99	26085

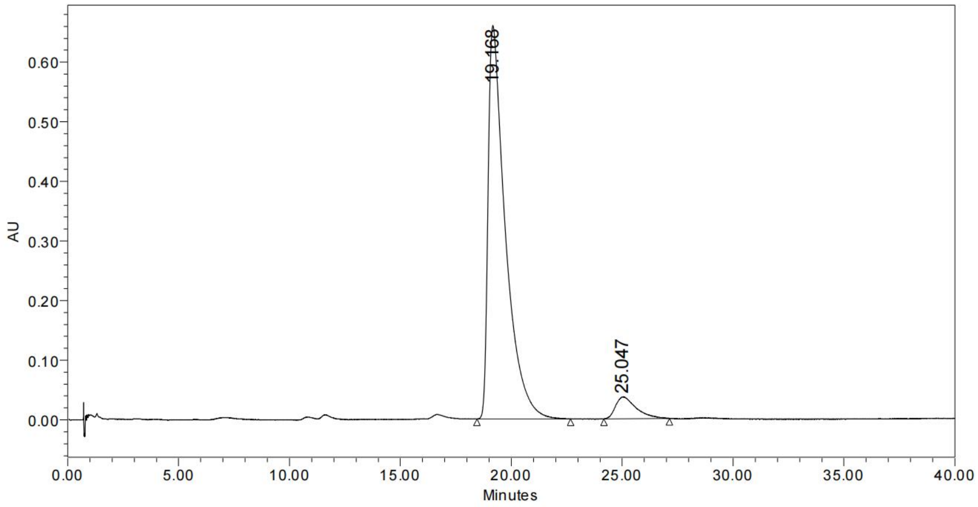


	RT	Area	% Area	Height
1	11.784	2825155	50.12	83683
2	16.611	2811880	49.88	60159

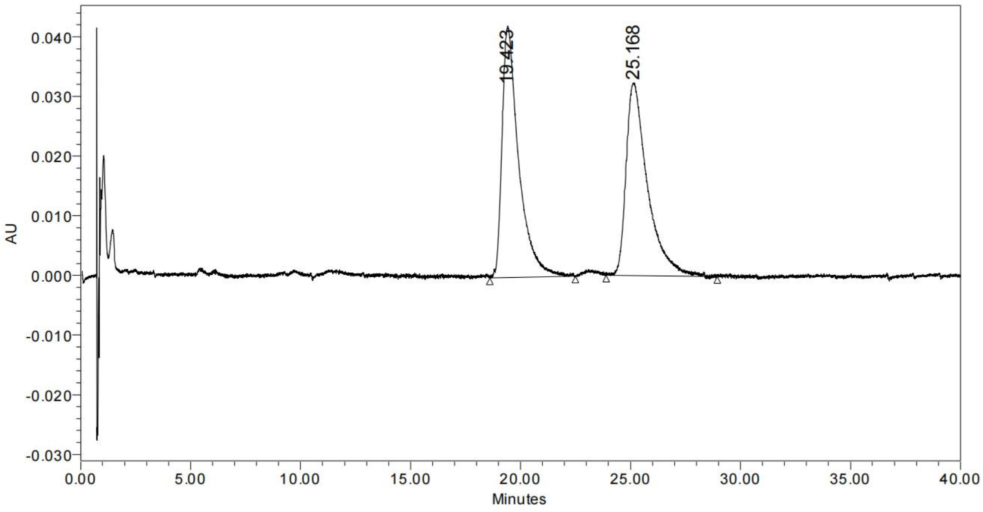


5v

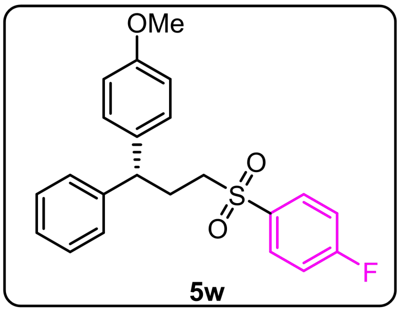
SFC (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 19.168 min, t$_R$ (minor) = 25.047 min, 94:6 er.



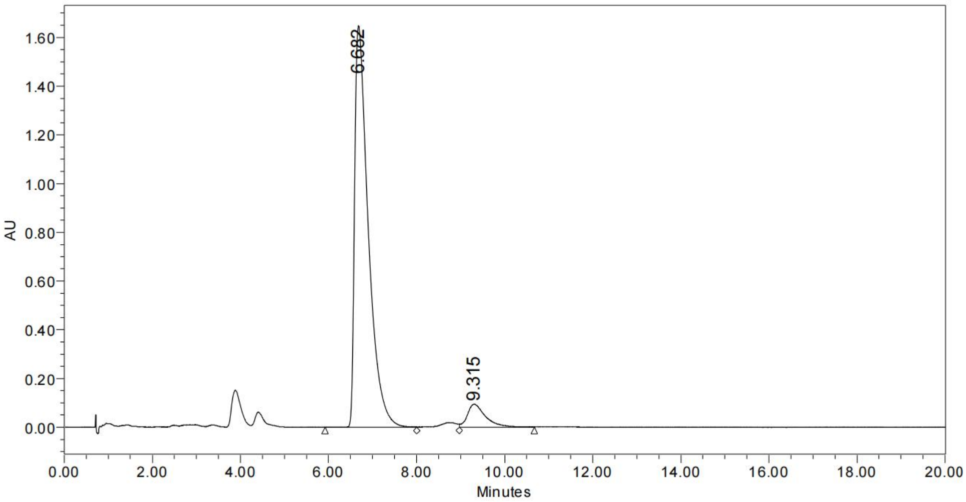
	RT	Area	% Area	Height
1	19.168	35604569	93.79	659528
2	25.047	2356647	6.21	36825



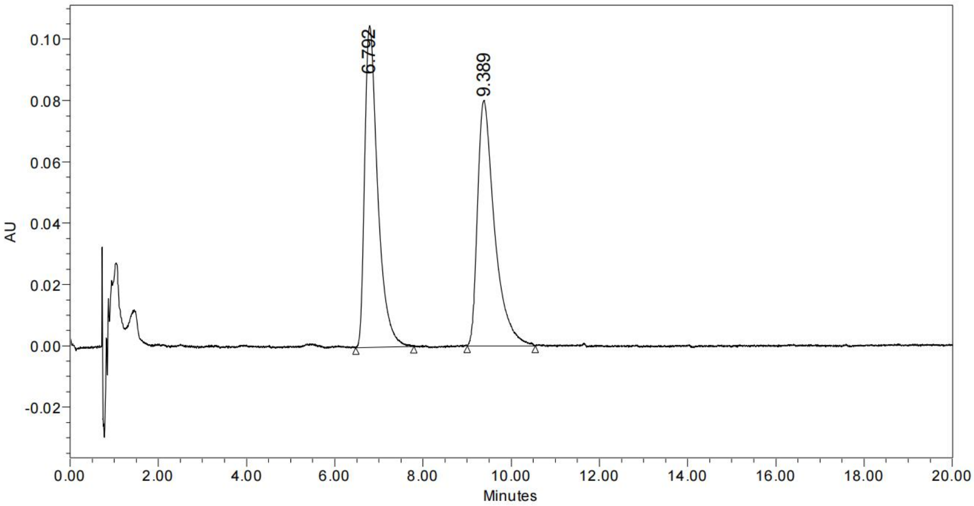
	RT	Area	% Area	Height
1	19.423	2232291	50.37	42150
2	25.168	2199354	49.63	32291



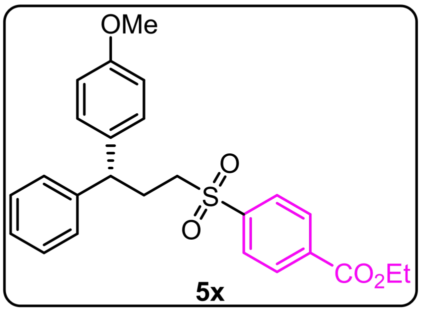
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 220.0 nm): t_R (major) = 6.682 min, t_R (minor) = 9.315 min, 93:7 er.



	RT	Area	% Area	Height
1	6.682	35305685	92.92	1647154
2	9.315	2691888	7.08	93910

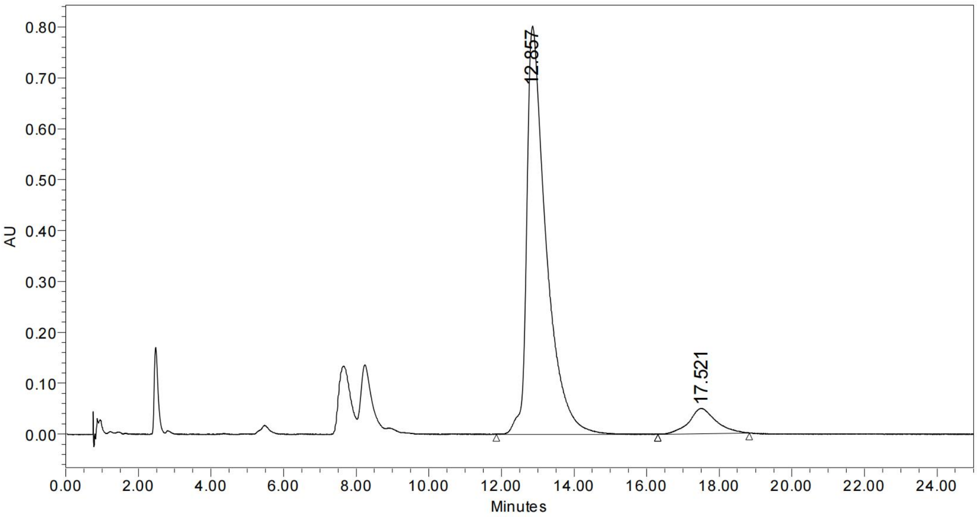


	RT	Area	% Area	Height
1	6.792	2142340	50.03	104932
2	9.389	2139863	49.97	80171

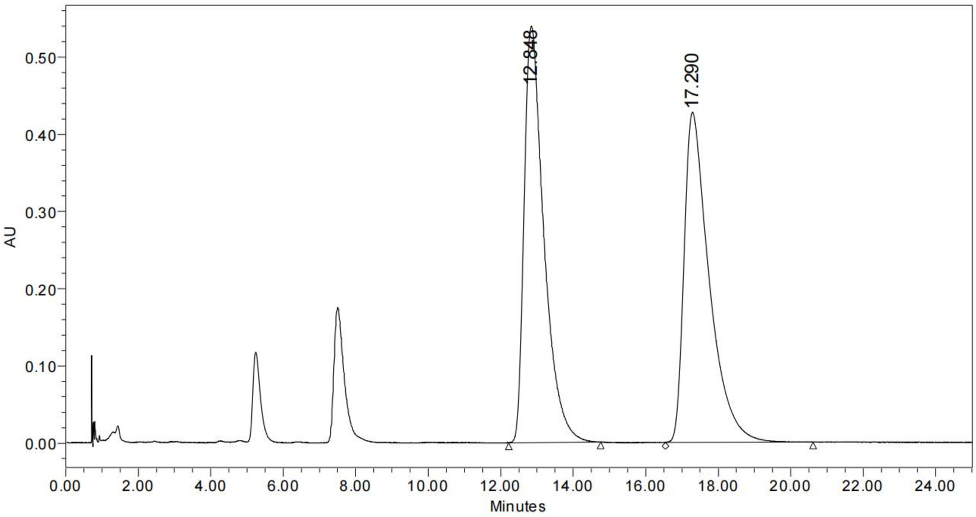


5x

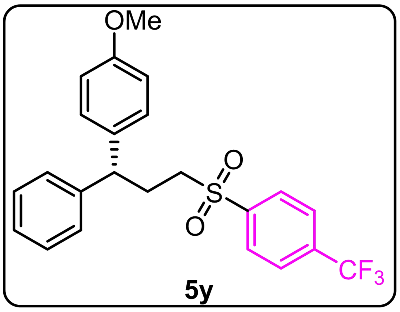
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 12.857 min, t_R (minor) = 17.521 min, 92:8 er.



	RT	Area	% Area	Height
1	12.857	29648054	92.03	801781
2	17.521	2566392	7.97	49479

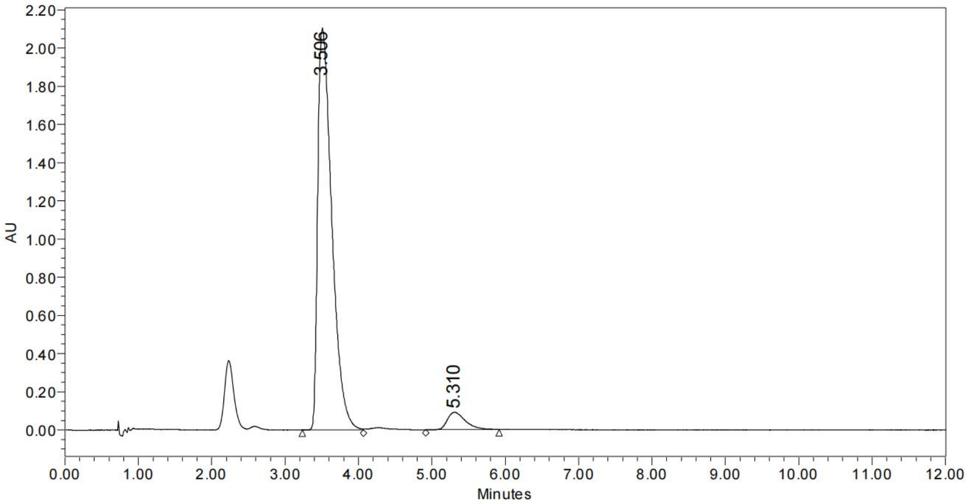


	RT	Area	% Area	Height
1	12.848	20493180	49.87	539098
2	17.290	20598916	50.13	427607

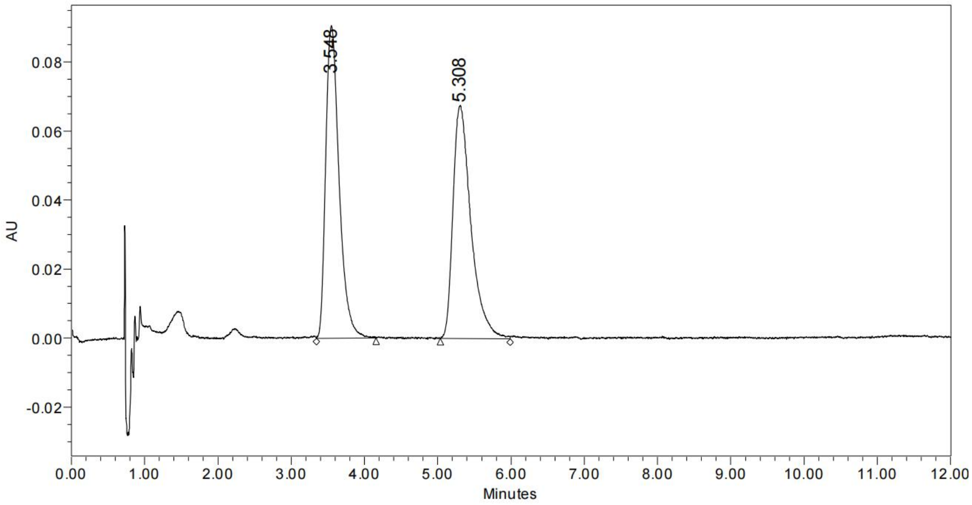


5y

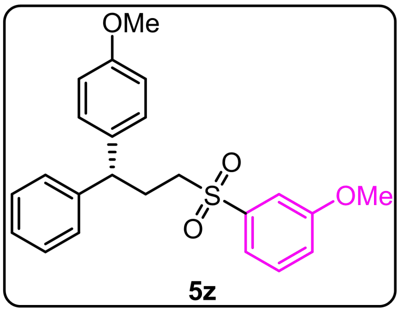
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 3.506 min, t_R (minor) = 5.310 min, 95:5 er.



	RT	Area	% Area	Height
1	3.506	28027012	94.76	2102606
2	5.310	1548761	5.24	90543

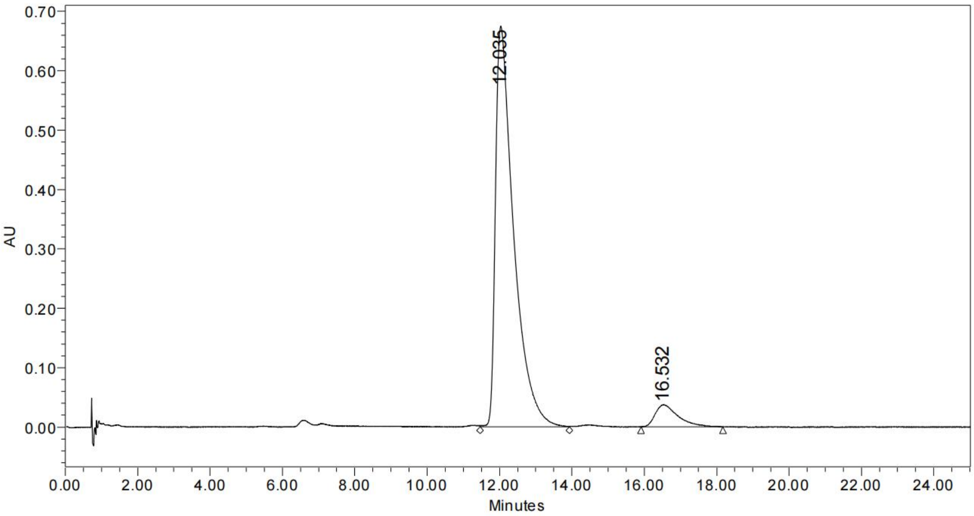


	RT	Area	% Area	Height
1	3.548	1143611	49.64	90579
2	5.308	1160156	50.36	67570

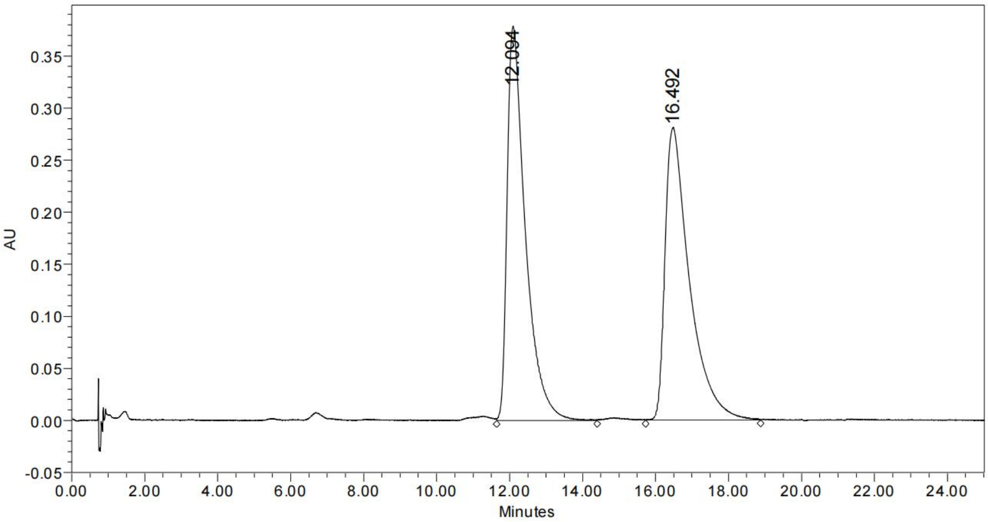


5z

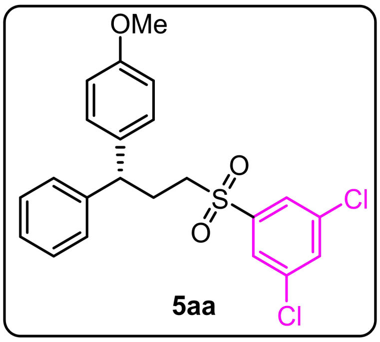
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 12.035 min, t_R (minor) = 16.532 min, 93.5:6.5 er.



	RT	Area	% Area	Height
1	12.035	23509393	93.42	674205
2	16.532	1655438	6.58	37294

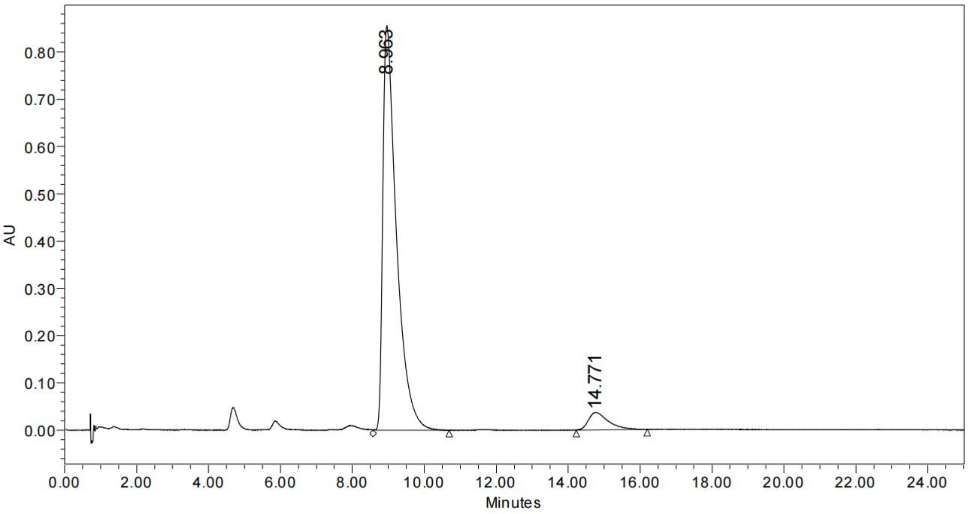


	RT	Area	% Area	Height
1	12.094	13064668	50.12	378676
2	16.492	13003317	49.88	281155

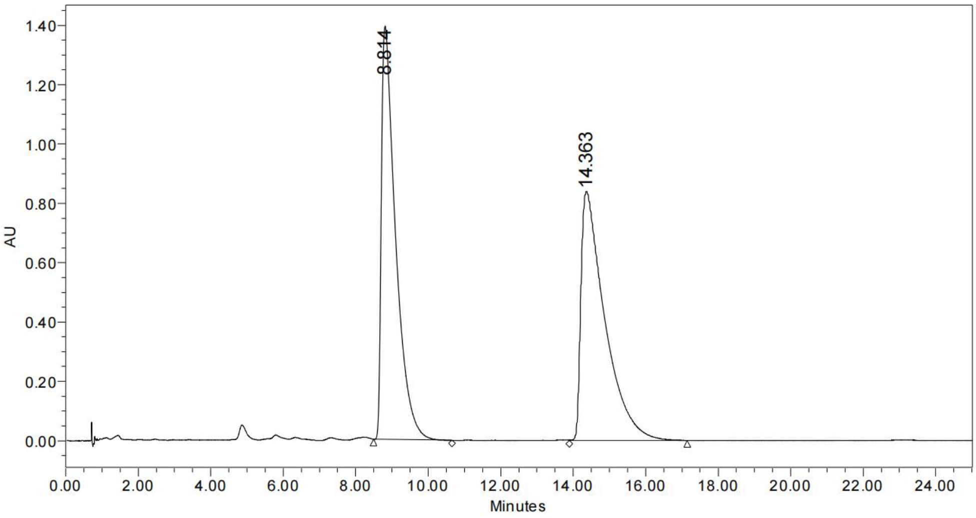


5aa

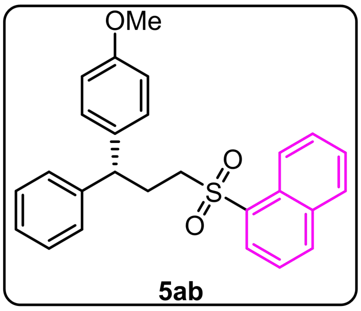
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 8.963 min, t_R (minor) = 14.771 min, 94:6 er.



	RT	Area	% Area	Height
1	8.963	22482067	94.05	855113
2	14.771	1421708	5.95	36703

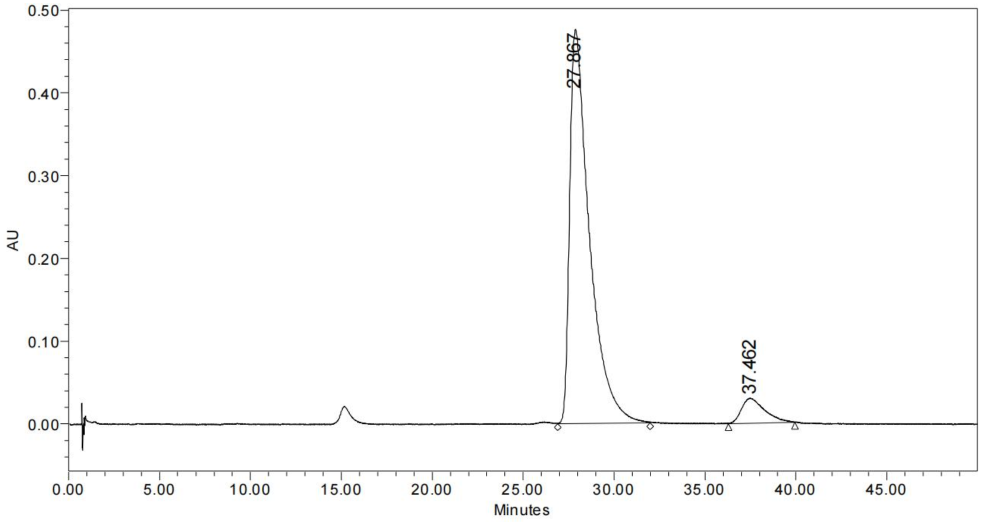


	RT	Area	% Area	Height
1	8.814	37741944	49.63	1392362
2	14.363	38312326	50.37	838701

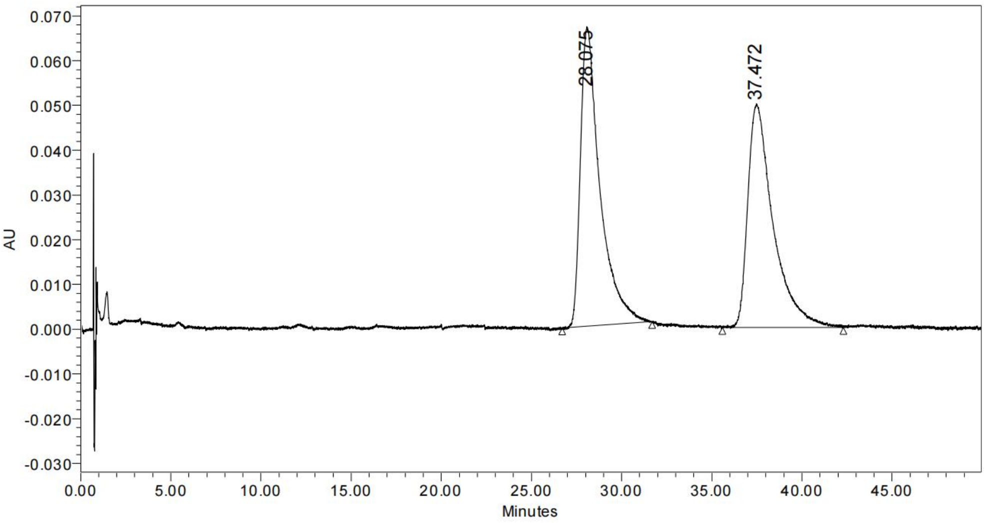


5ab

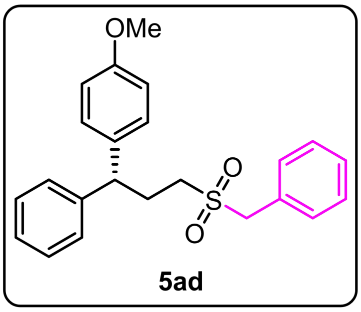
SFC (Trefoir CEL2, CO$_2$/MeOH = 90:10, 1 mL/min, 230.0 nm): t$_R$ (major) = 27.867 min, t$_R$ (minor) = 37.462 min, 93:7 er.



	RT	Area	% Area	Height
1	27.867	36045029	93.04	475955
2	37.462	2695665	6.96	30314

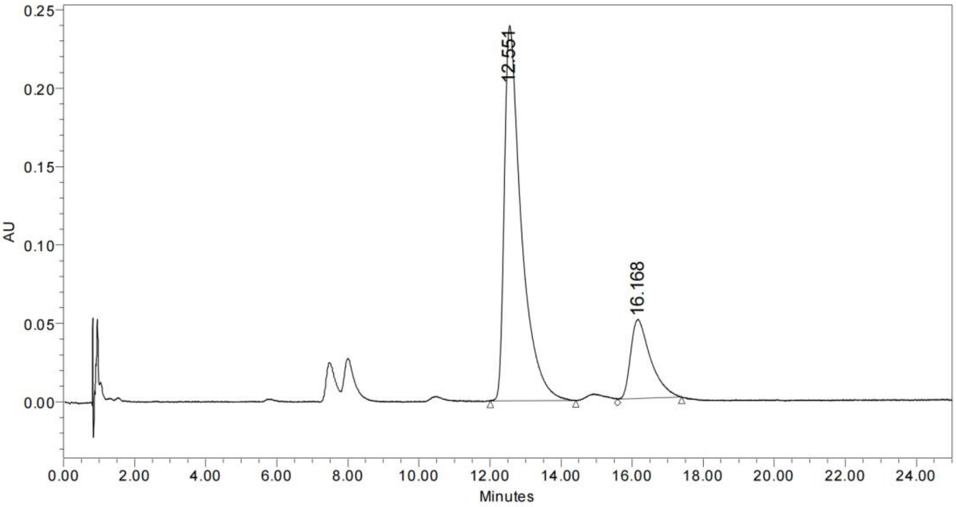


	RT	Area	% Area	Height
1	28.075	5041429	50.87	66894
2	37.472	4869899	49.13	49927

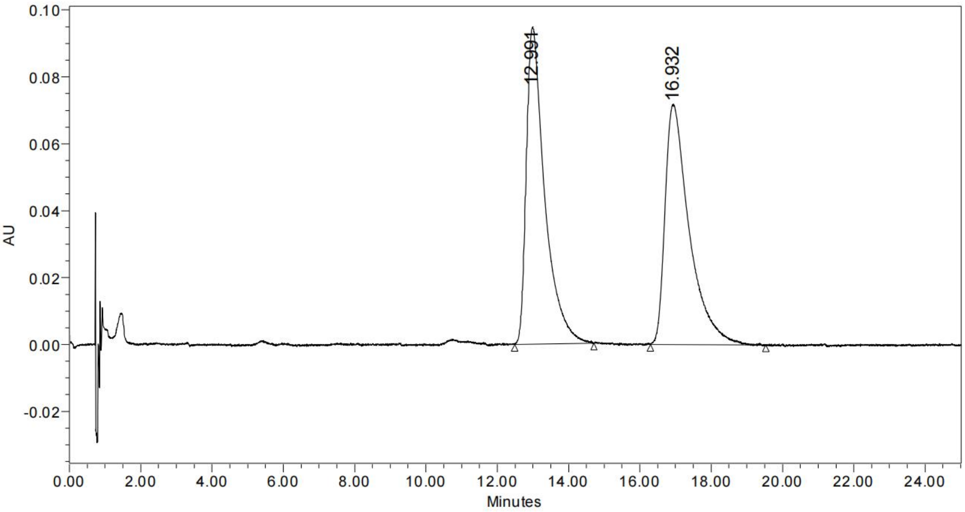


5ad

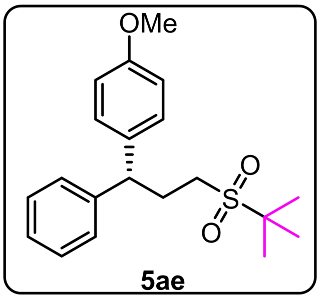
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 12.251 min, t_R (minor) = 16.168 min, 80:20 er.



	RT	Area	% Area	Height
1	12.551	7971915	80.24	239337
2	16.168	1963529	19.76	50403

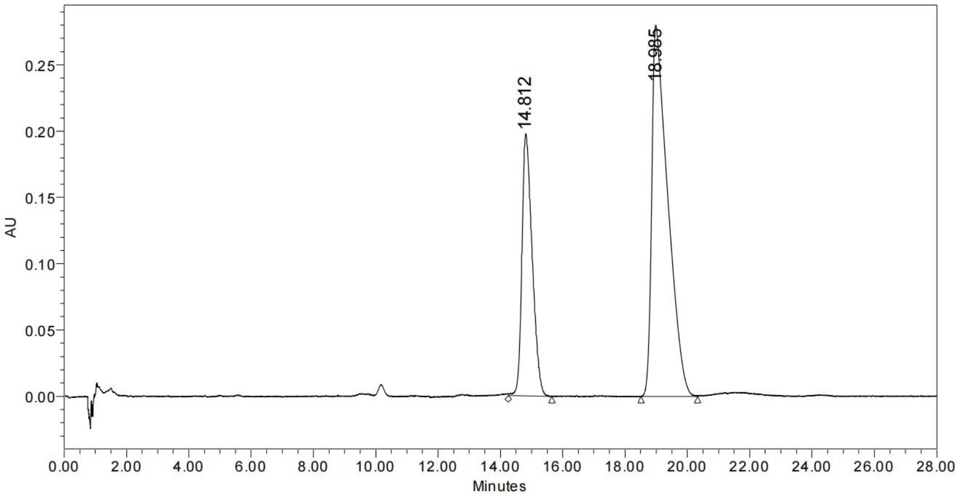


	RT	Area	% Area	Height
1	12.991	3410632	50.22	94803
2	16.932	3380111	49.78	71867

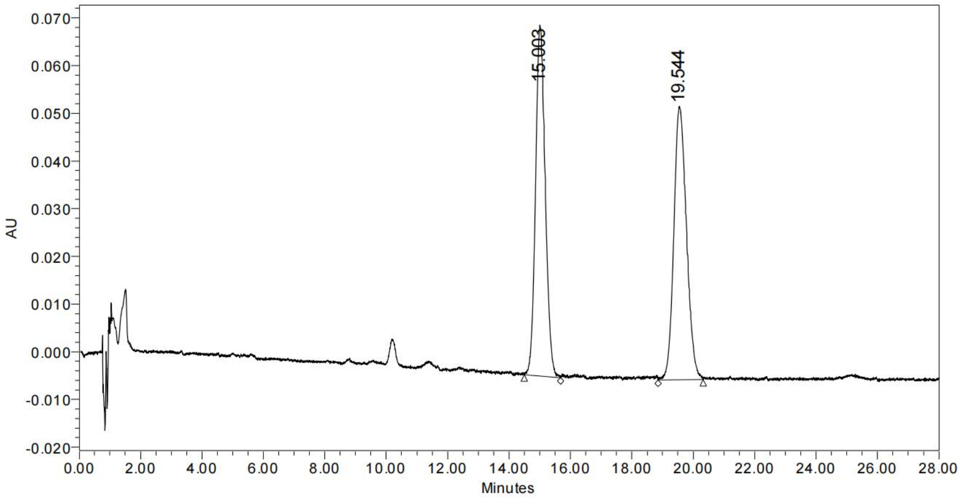


5ae

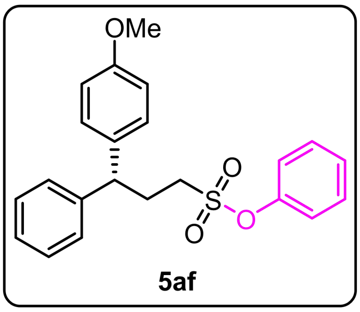
SFC (IC-3, CO_2/MeOH = 90:10, 1 mL/min, 225.0 nm): t_R (minor) = 14.812 min, t_R (major) = 18.985 min, 69:31 er.



	RT	Area	% Area	Height
1	14.812	4533376	31.21	197947
2	18.985	9994237	68.79	280080

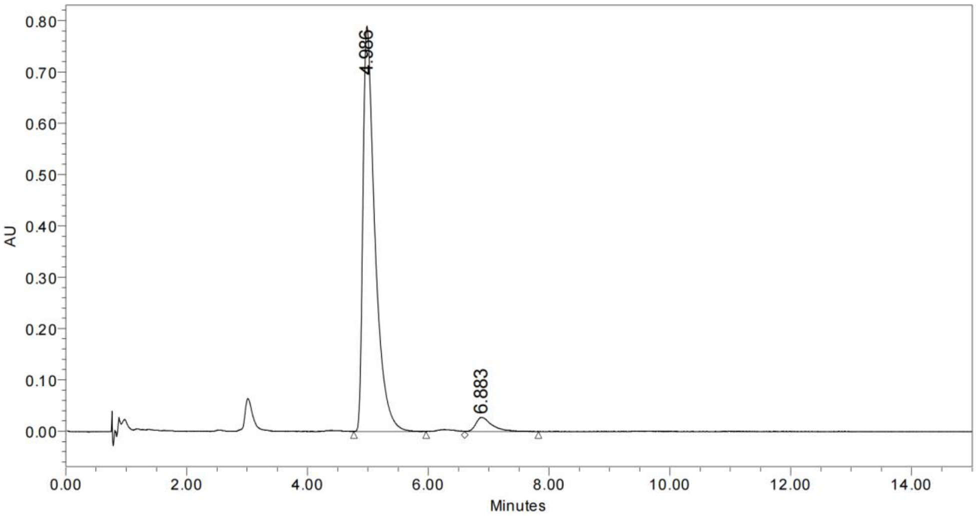


	RT	Area	% Area	Height
1	15.003	1629756	49.85	73498
2	19.544	1639262	50.15	57352

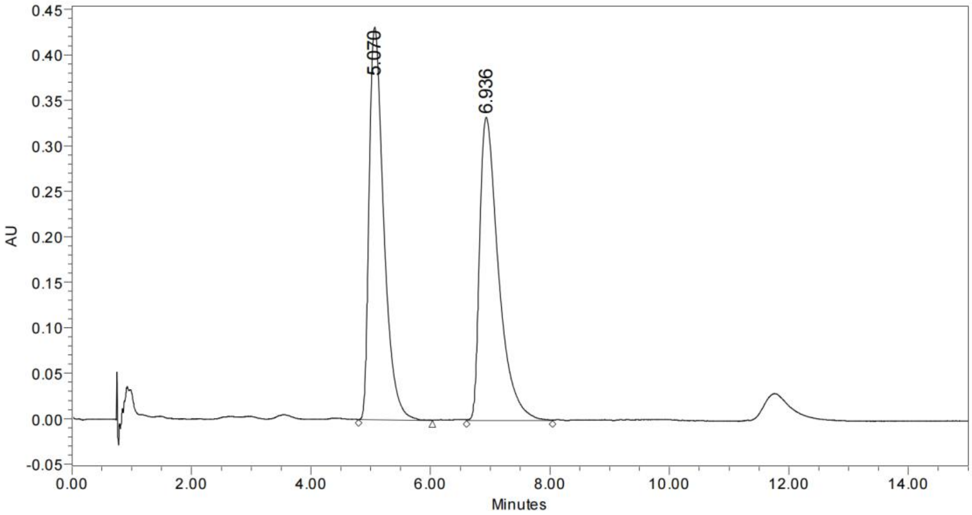


5af

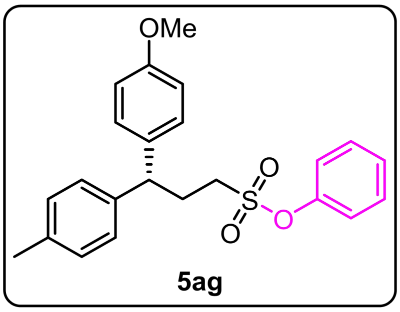
SFC (Trefoir CEL2, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 4.986 min, t_R (minor) = 6.883 min, 95.5:4.5 er.



	RT	Area	% Area	Height
1	4.986	10885587	95.46	789487
2	6.883	517827	4.54	27459

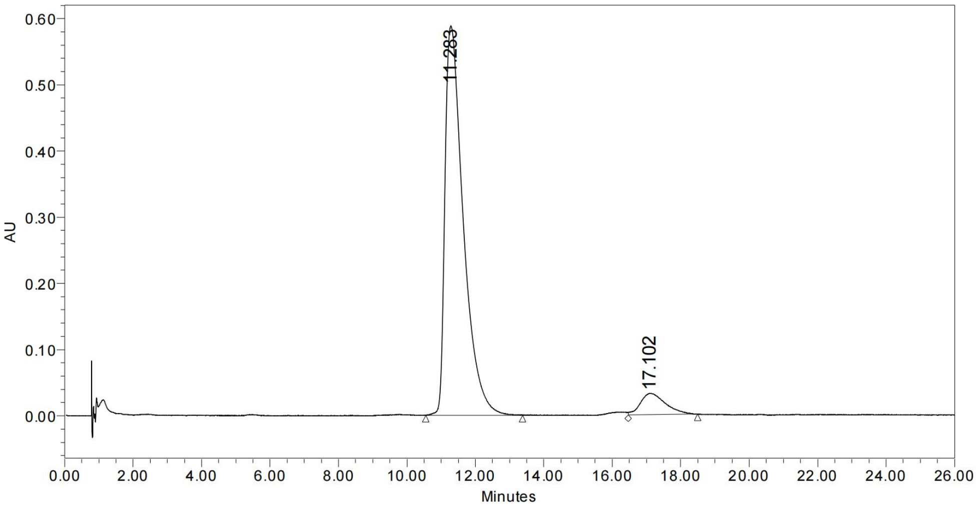


	RT	Area	% Area	Height
1	5.070	7278544	49.82	431640
2	6.936	7330742	50.18	333456

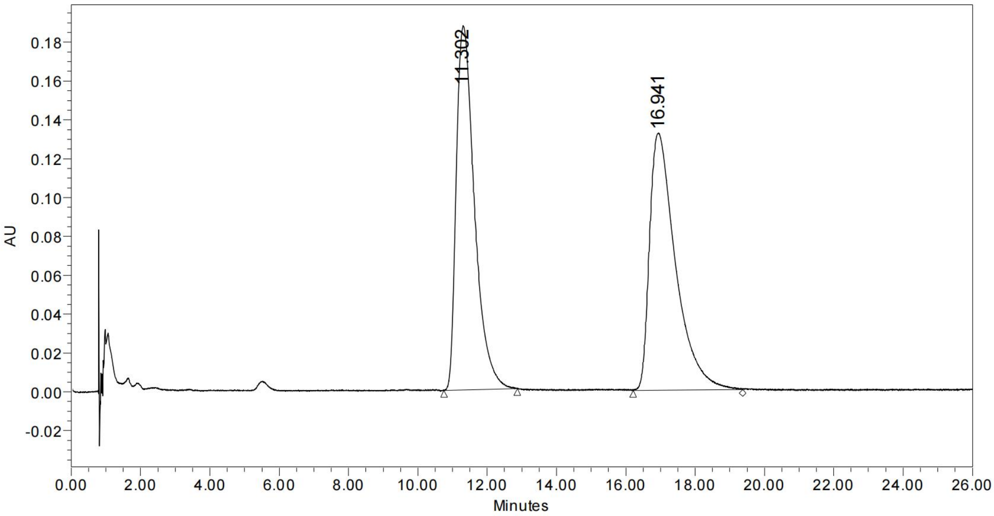


5ag

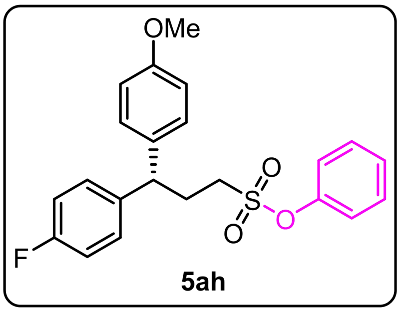
SFC (Trefoir CEL2, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 11.283 min, t_R (minor) = 17.102 min, 93:7 er.



	RT	Area	% Area	Height
1	11.283	21792069	93.02	588250
2	17.102	1634873	6.98	32188

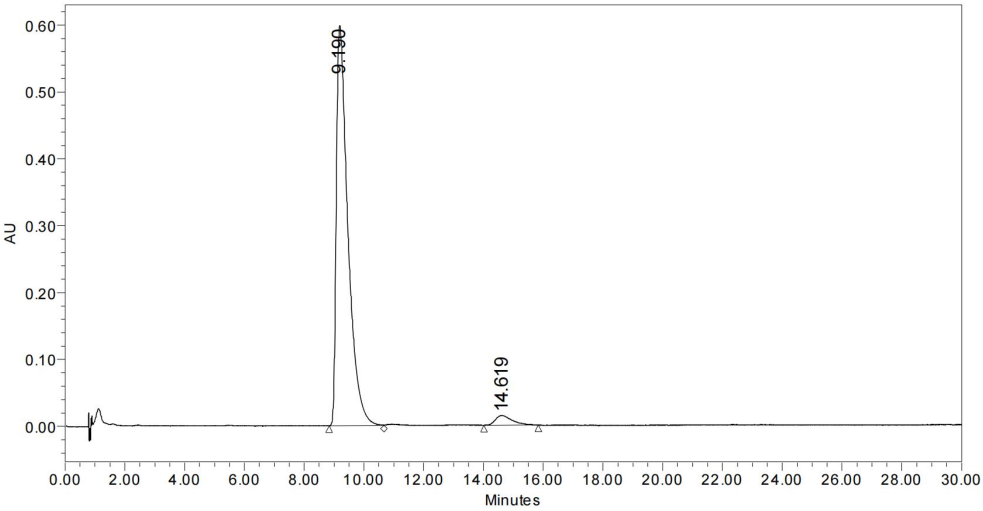


	RT	Area	% Area	Height
1	11.302	6857030	49.81	187467
2	16.941	6910519	50.19	132474

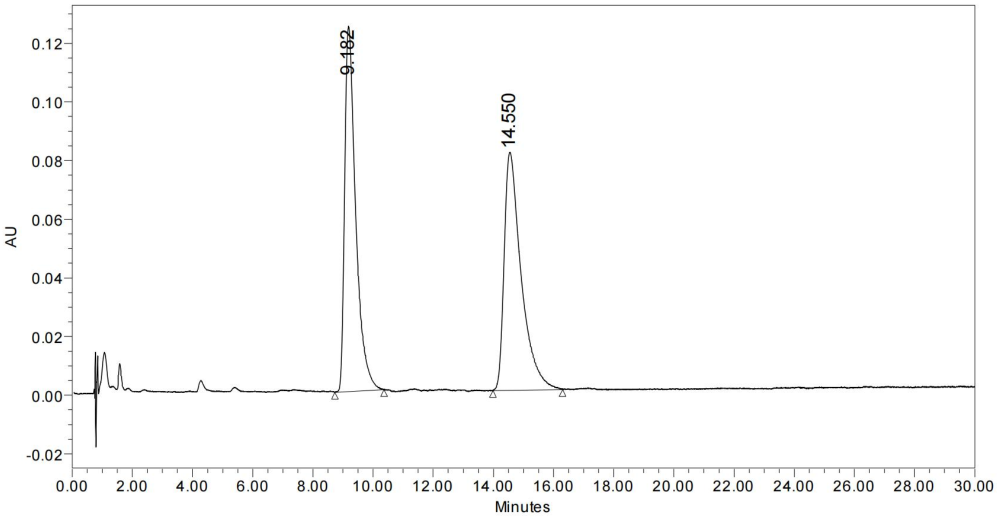


5ah

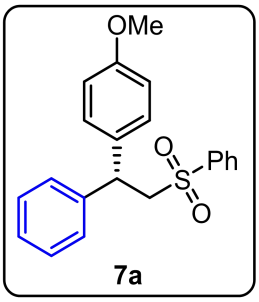
SFC (Trefoir CEL2, CO_2/MeOH = 95:5, 1 mL/min, 230.0 nm): t_R (major) = 9.190 min, t_R (minor) = 14.619 min, 96.5:3.5 er.



	RT	Area	% Area	Height
1	9.190	16120863	96.62	598016
2	14.619	563821	3.38	14658

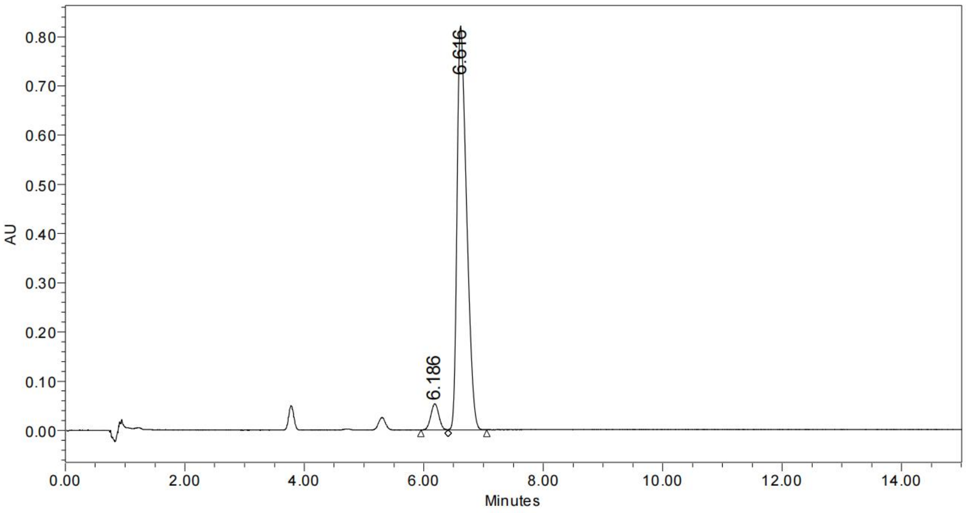


	RT	Area	% Area	Height
1	9.182	3168038	50.00	124563
2	14.550	3167762	50.00	81216

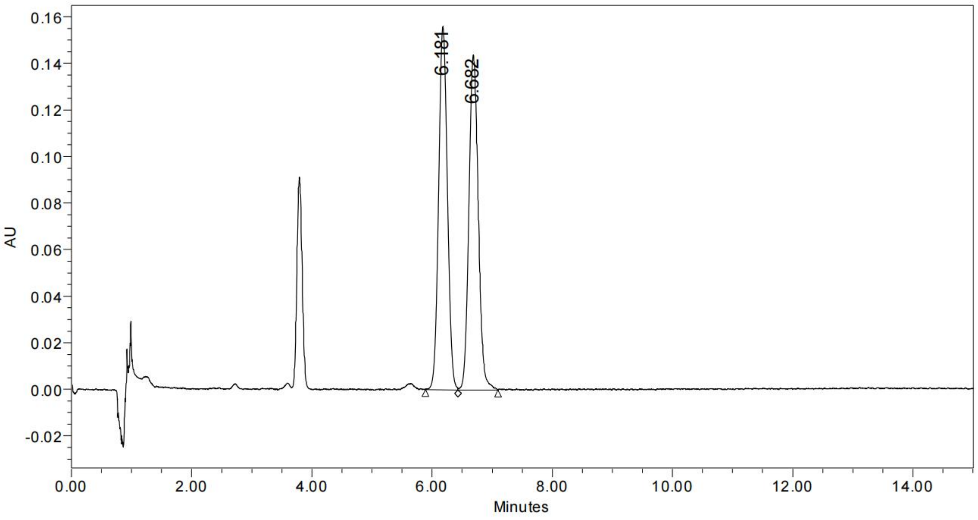


7a

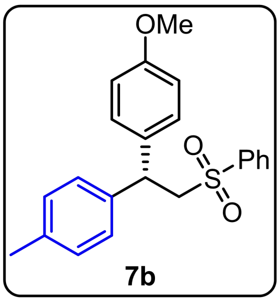
SFC (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 240.0 nm): t_R (minor) = 6.186 min, t_R (major) = 6.616 min, 95:5 er.



	RT	Area	% Area	Height
1	6.186	492495	5.14	52868
2	6.616	9084337	94.86	819779

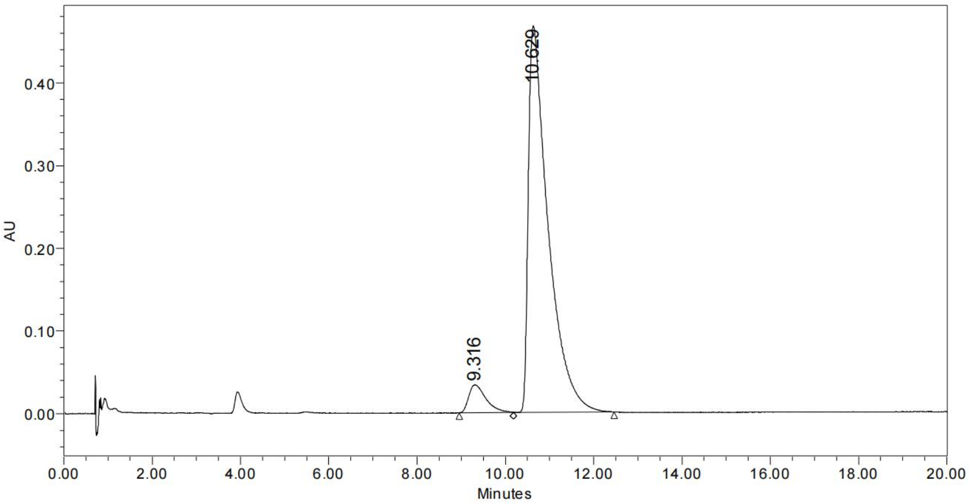


	RT	Area	% Area	Height
1	6.181	1566387	49.85	156027
2	6.682	1575767	50.15	143716

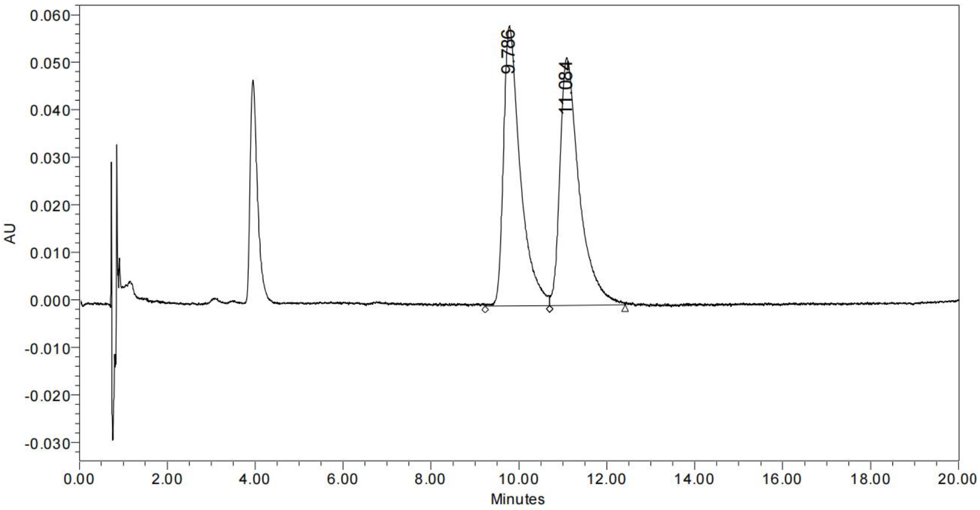


7b

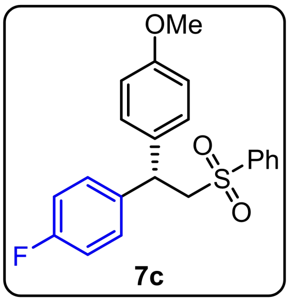
SFC (Trefoir CEL2, CO_2/MeOH = 85:15, 1 mL/min, 235.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 94:6 er.



	RT	Area	% Area	Height
1	9.316	925156	5.99	33710
2	10.629	14524722	94.01	467113

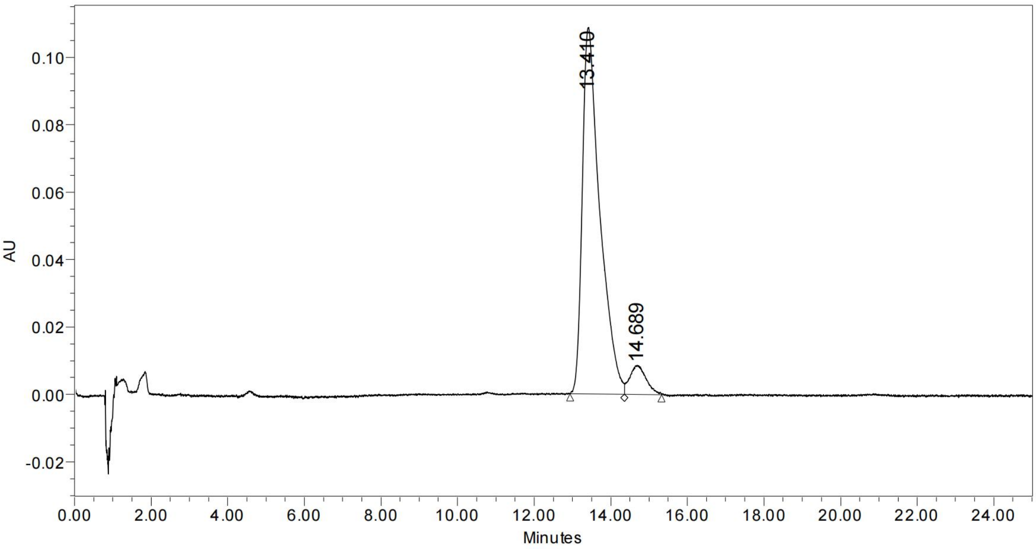


	RT	Area	% Area	Height
1	9.786	1568495	49.72	58926
2	11.084	1586294	50.28	52139

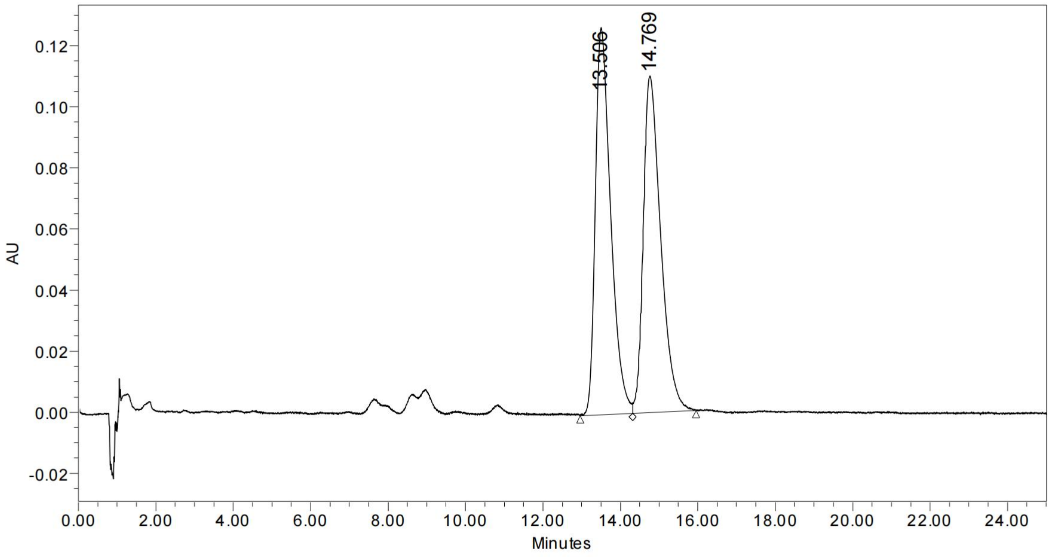


7c

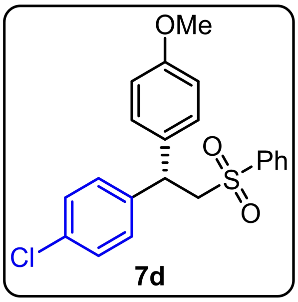
SFC (AD-3, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 13.410 min, t_R (minor) = 14.689 min, 93:7 er.



	RT	Area	% Area	Height
1	13.410	3440992	93.10	108609
2	14.689	254963	6.90	8593

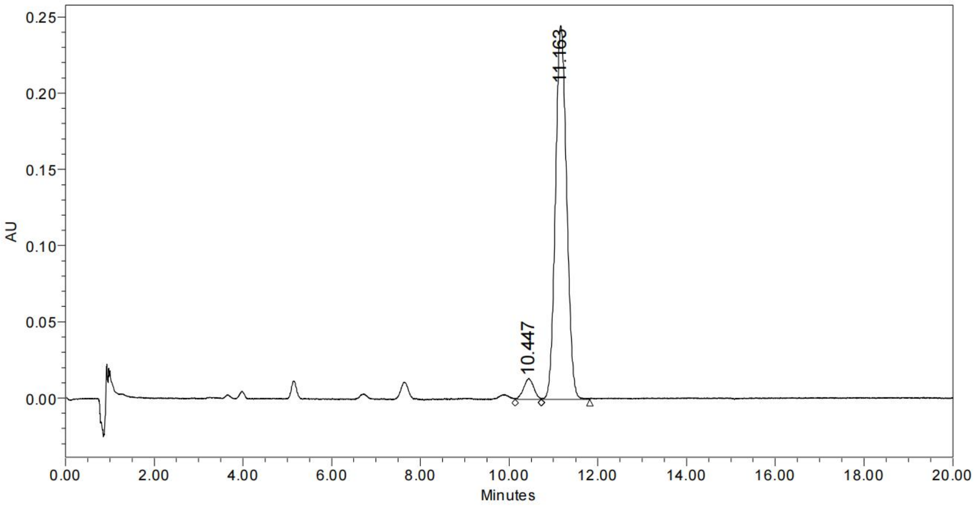


	RT	Area	% Area	Height
1	13.506	3465989	50.12	126704
2	14.769	3449787	49.88	110256

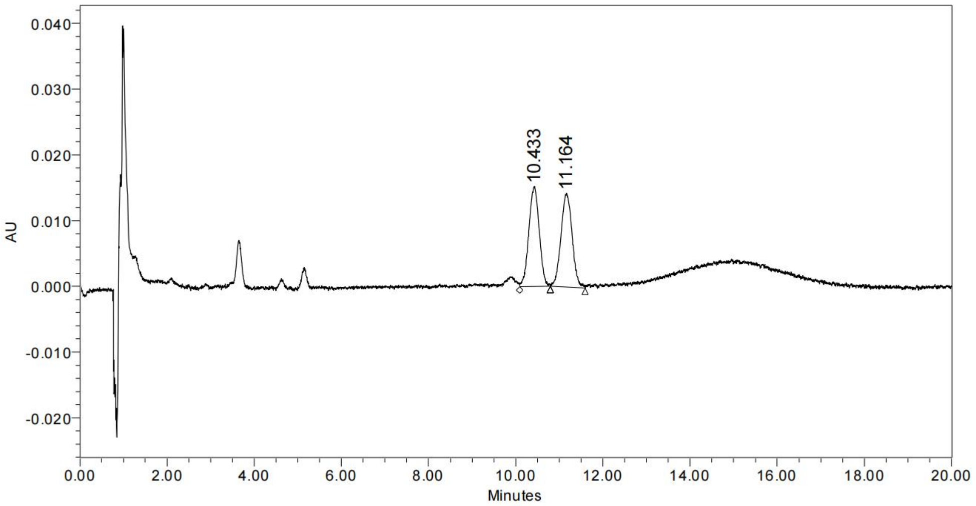


7d

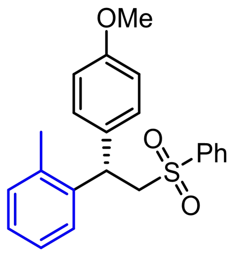
SFC (IG-3, CO_2/MeOH = 85:15, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 95:5 er.



	RT	Area	% Area	Height
1	10.447	216928	4.82	13556
2	11.163	4282414	95.18	245008

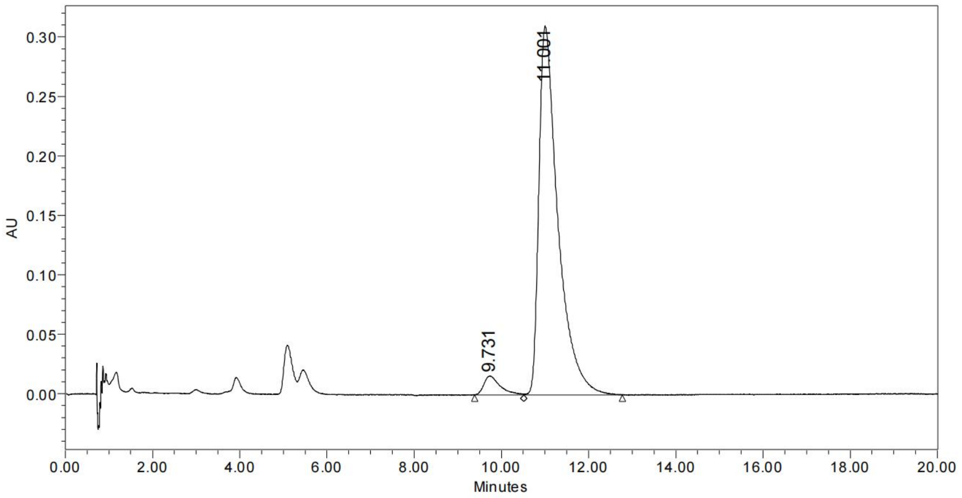


	RT	Area	% Area	Height
1	10.433	250407	49.92	15236
2	11.164	251239	50.08	14286

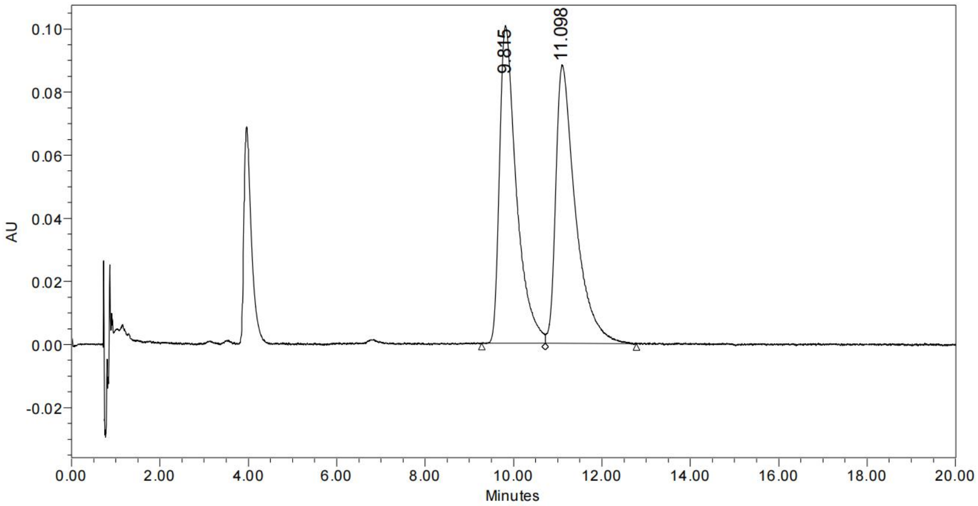


7e

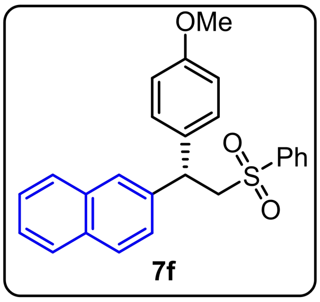
SFC (IG-3, CO_2/MeOH = 85:15, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 96:4 er.



	RT	Area	% Area	Height
1	9.731	417784	4.24	15984
2	11.001	9433226	95.76	310205

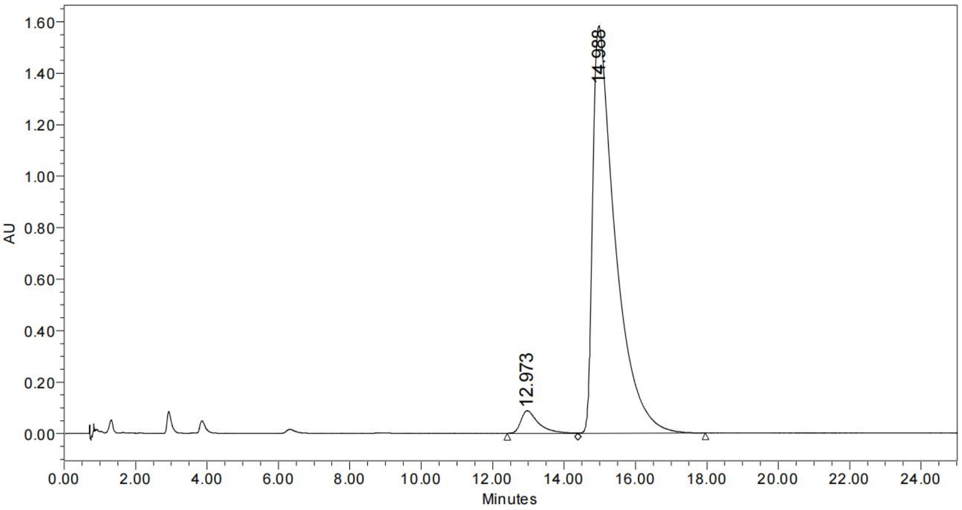


	RT	Area	% Area	Height
1	9.815	2663283	49.39	100564
2	11.098	2729377	50.61	88215

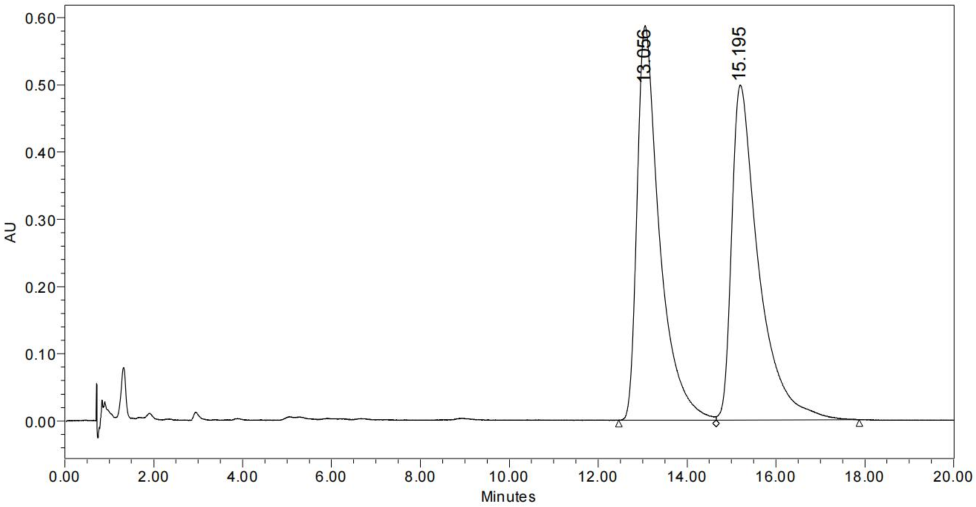


7f

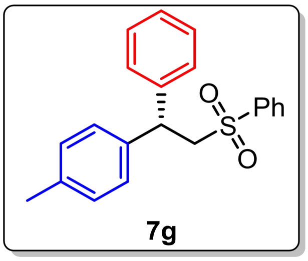
SFC (Trefoir CEL2, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 9.316 min, t_R (major) = 10.629 min, 96:4 er.



	RT	Area	% Area	Height
1	12.973	3012808	4.17	87789
2	14.988	69320427	95.83	1581902

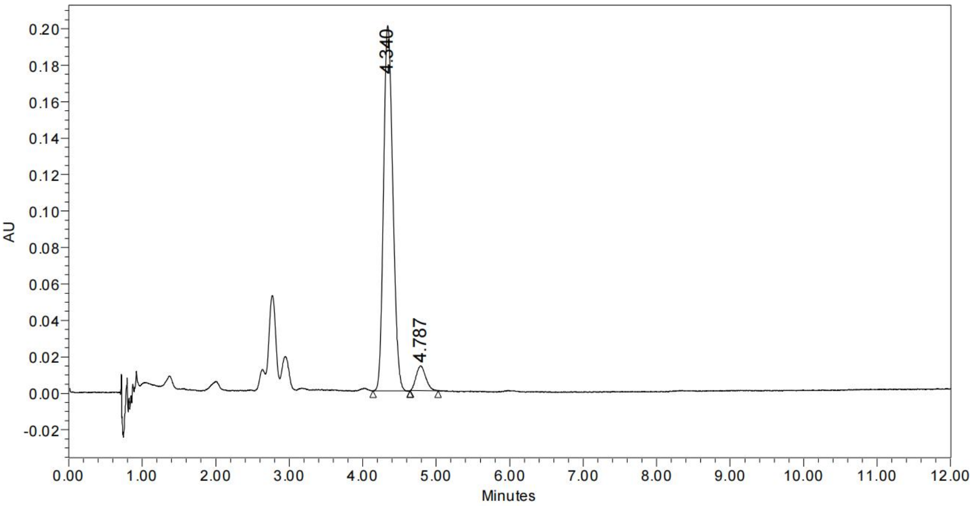


	RT	Area	% Area	Height
1	13.056	20609741	49.51	586786
2	15.195	21017892	50.49	498504

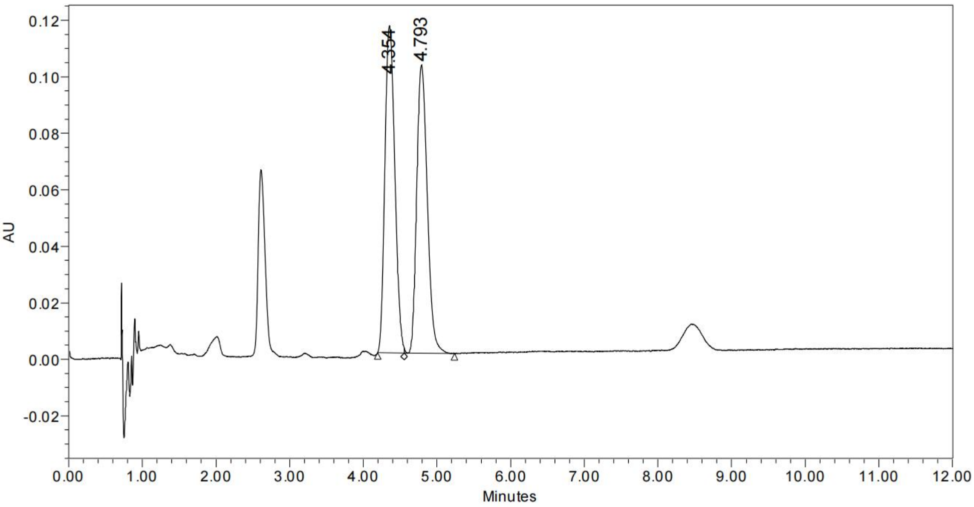


7g

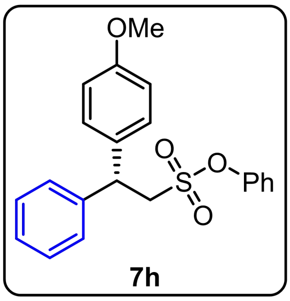
SFC (Trefoir CEL1, CO$_2$/MeOH = 90:10, 1 mL/min, 232.0 nm): t$_R$ (major) = 4.340 min, t$_R$ (minor) = 4.787 min, 93.5:6.5 er.



	RT	Area	% Area	Height
1	4.340	1744134	93.40	200237
2	4.787	123180	6.60	13509

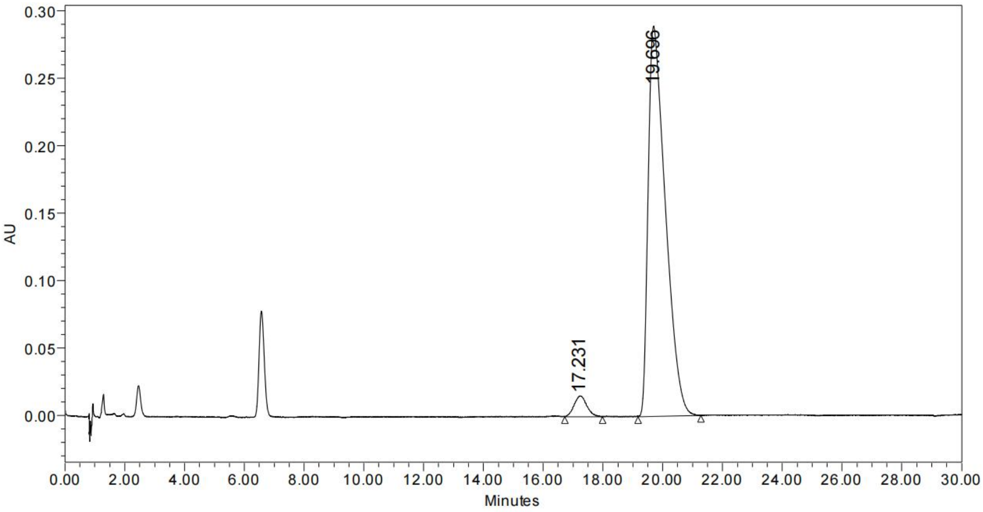


	RT	Area	% Area	Height
1	4.354	1075815	51.35	115764
2	4.793	1019384	48.65	101989

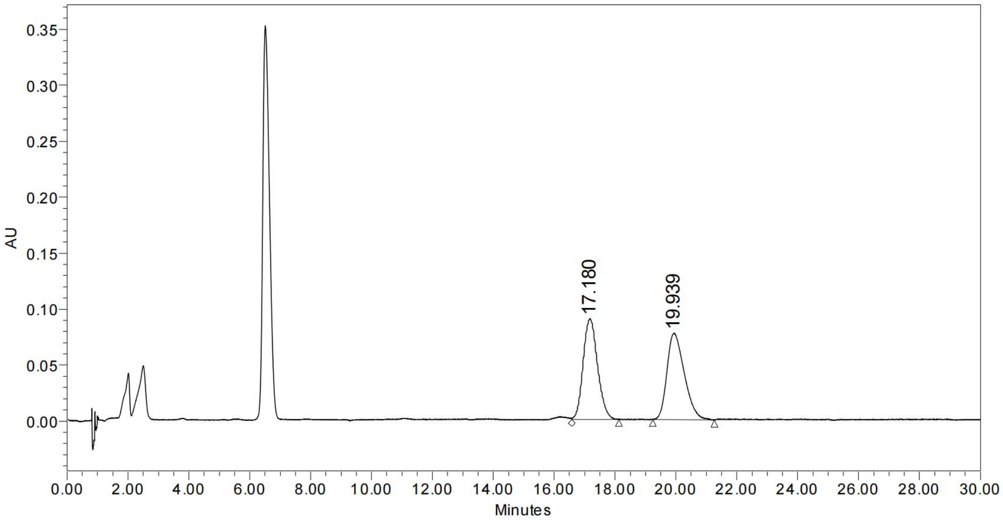


7h

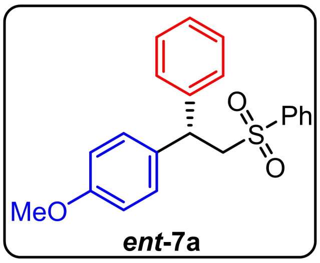
SFC (Trefoir CEL1, CO_2/MeOH = 97:3, 1 mL/min, 232.0 nm): t_R (minor) = 17.231 min, t_R (major) = 19.696 min, 96:4 er.



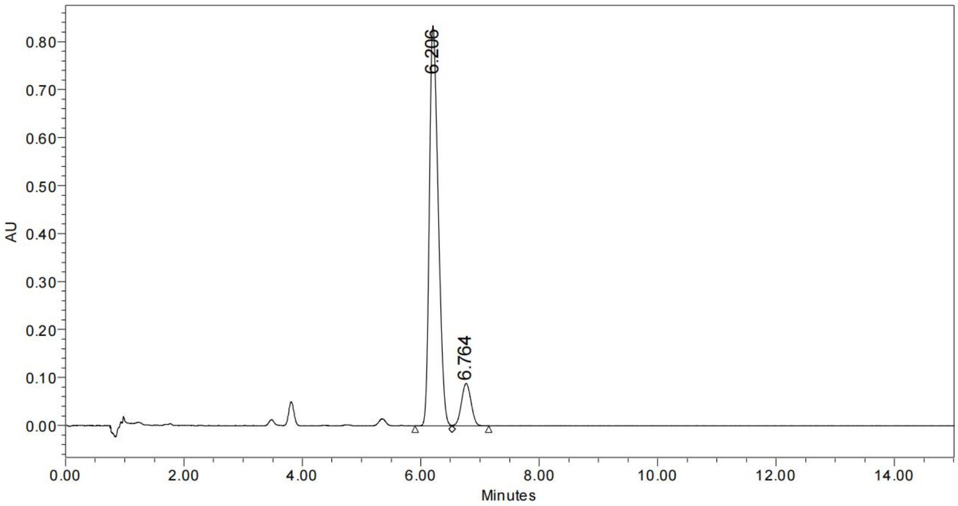
	RT	Area	% Area	Height
1	17.231	456551	3.80	15441
2	19.696	11560597	96.20	289117



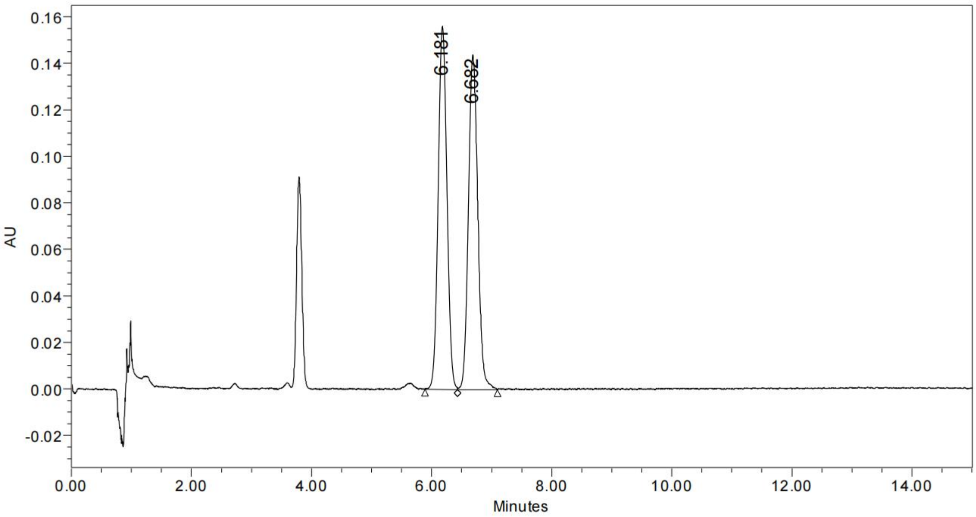
	RT	Area	% Area	Height
1	17.180	2974432	49.34	90127
2	19.939	3054615	50.66	77351



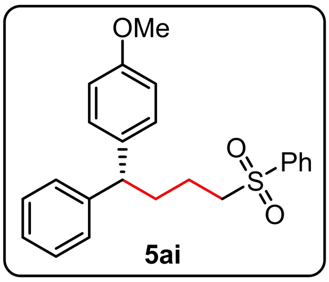
SFC (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 240.0 nm): t_R (major) = 6.206 min, t_R (minor) = 6.764 min, 90:10 er.



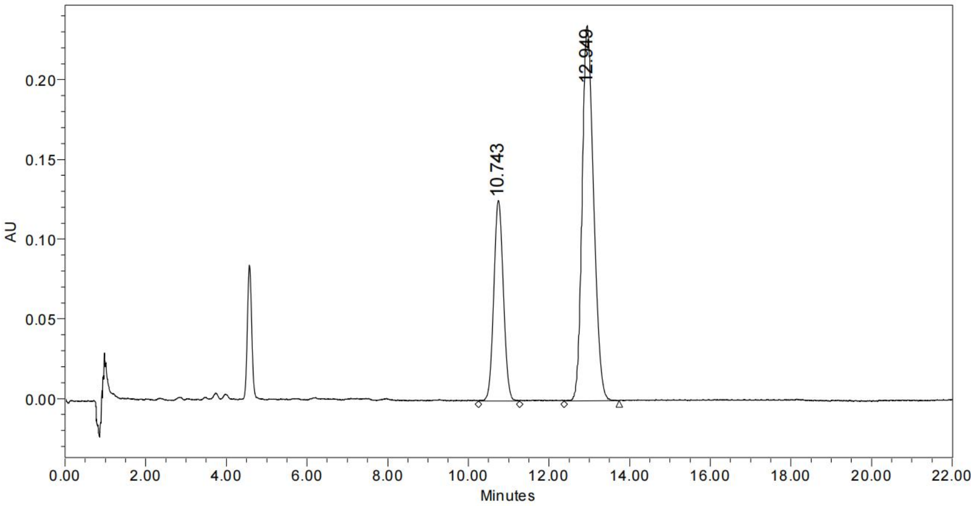
	RT	Area	% Area	Height
1	6.206	8643736	89.72	833287
2	6.764	990574	10.28	88224



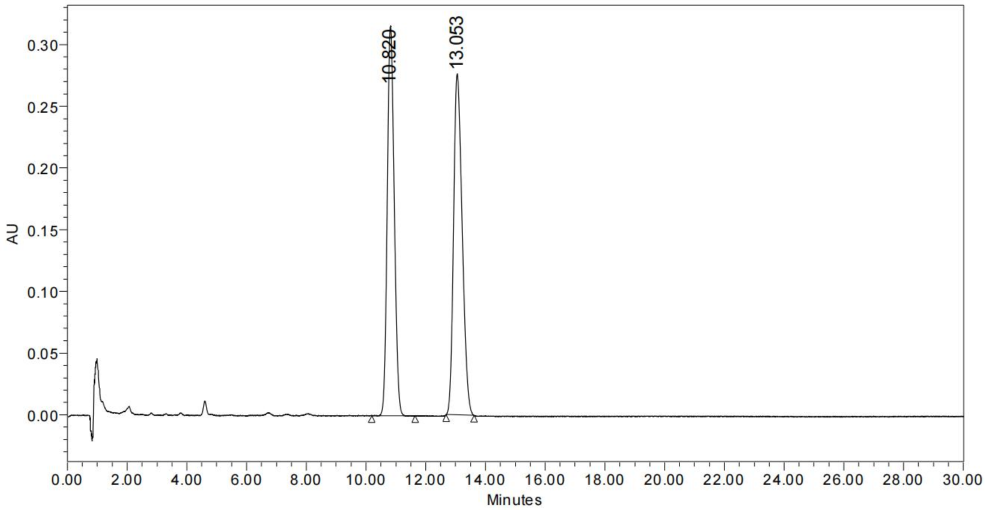
	RT	Area	% Area	Height
1	6.181	1566387	49.85	156027
2	6.682	1575767	50.15	143716



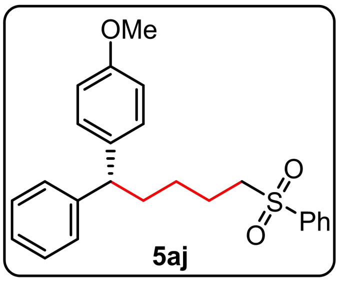
SFC (IG-3, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 10.743 min, t_R (major) = 12.949 min, 69.5:30.5 er.



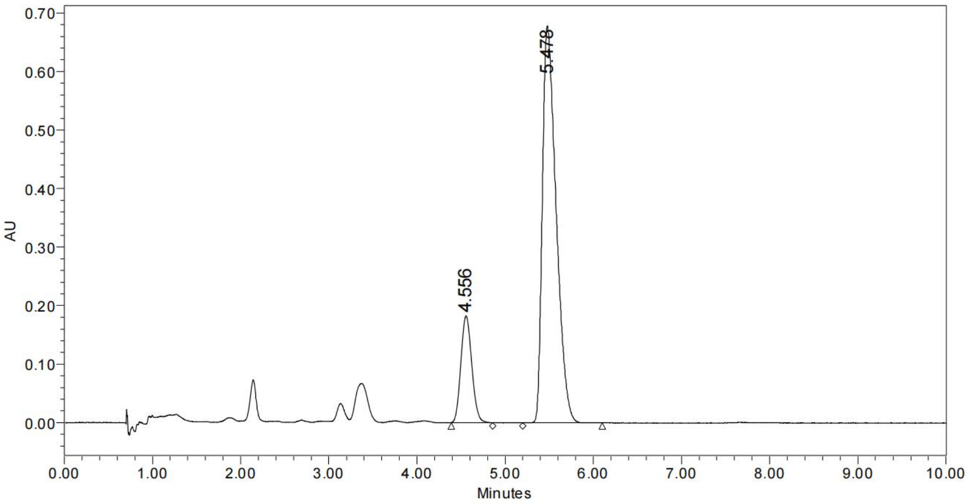
	RT	Area	% Area	Height
1	10.743	2067255	30.53	125752
2	12.949	4703138	69.47	235131



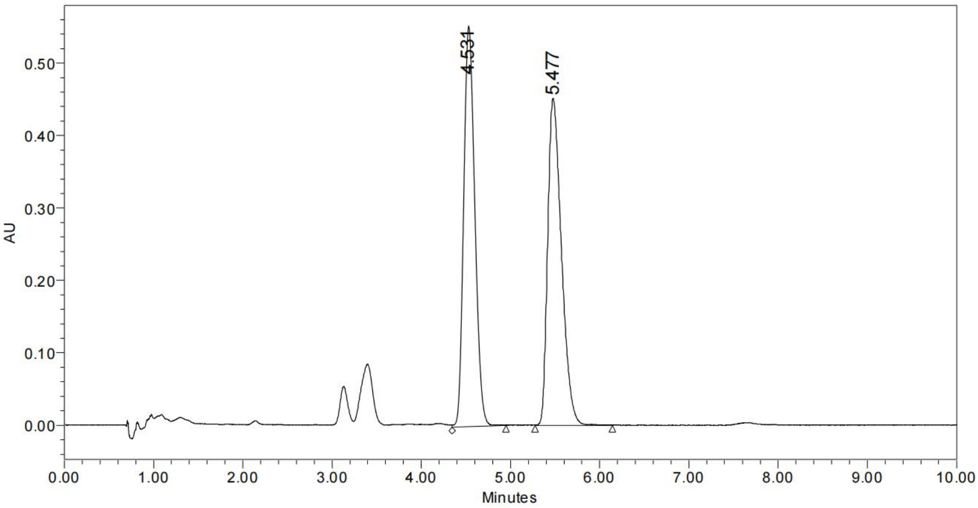
	RT	Area	% Area	Height
1	10.820	5106480	48.06	315689
2	13.053	5518532	51.94	276403



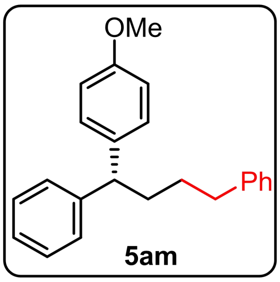
SFC (Trefoir CEL1, CO_2/MeOH = 80:20, 1 mL/min, 230.0 nm): t_R (minor) = 4.556 min, t_R (major) = 5.478 min, 82.5:17.5 er.



	RT	Area	% Area	Height
1	4.556	1558786	17.45	182122
2	5.478	7371611	82.55	677586

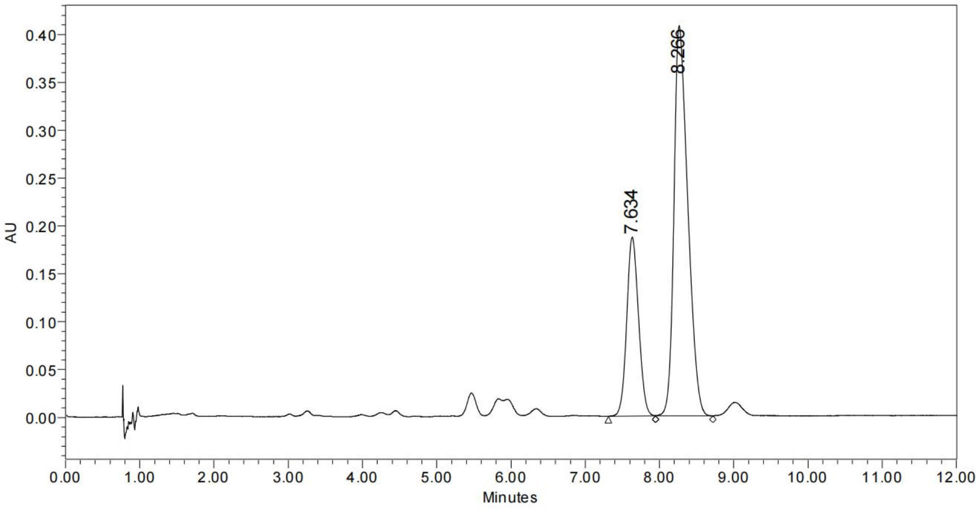


	RT	Area	% Area	Height
1	4.531	4783945	49.90	552899
2	5.477	4803701	50.10	451022

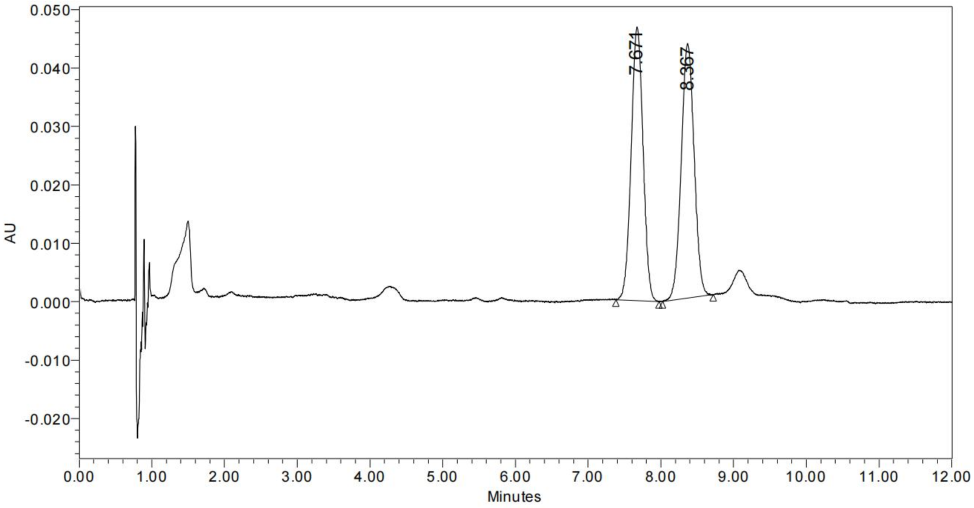


5am

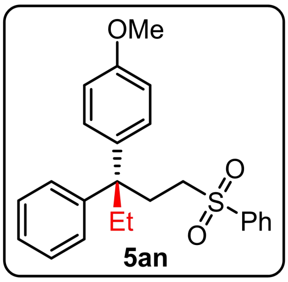
SFC (OD-3, CO_2/MeOH = 95:5, 1 mL/min, 235.0 nm): t_R (minor) = 7.634 min, t_R (major) = 8.266 min, 72:28 er.



	RT	Area	% Area	Height
1	7.634	2074446	28.20	186951
2	8.266	5282021	71.80	407341

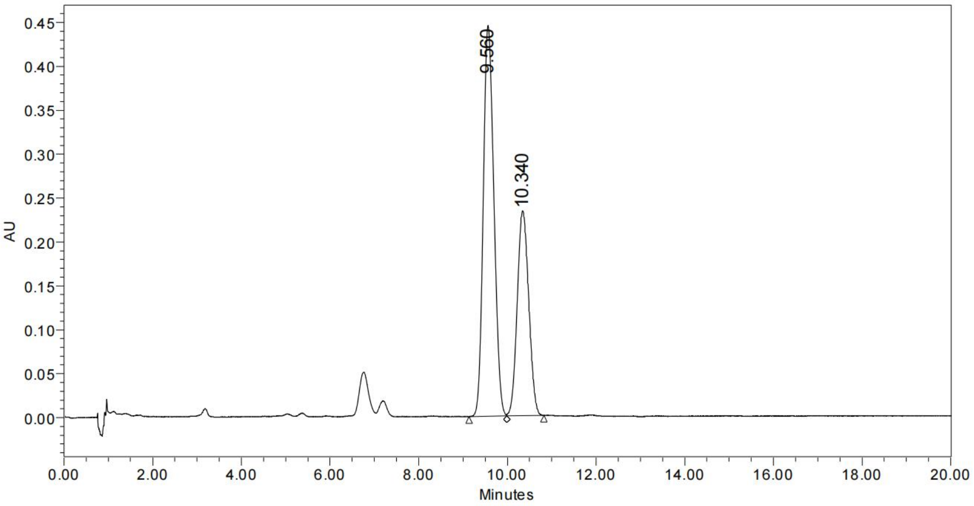


	RT	Area	% Area	Height
1	7.671	529578	49.74	46780
2	8.367	535185	50.26	43548

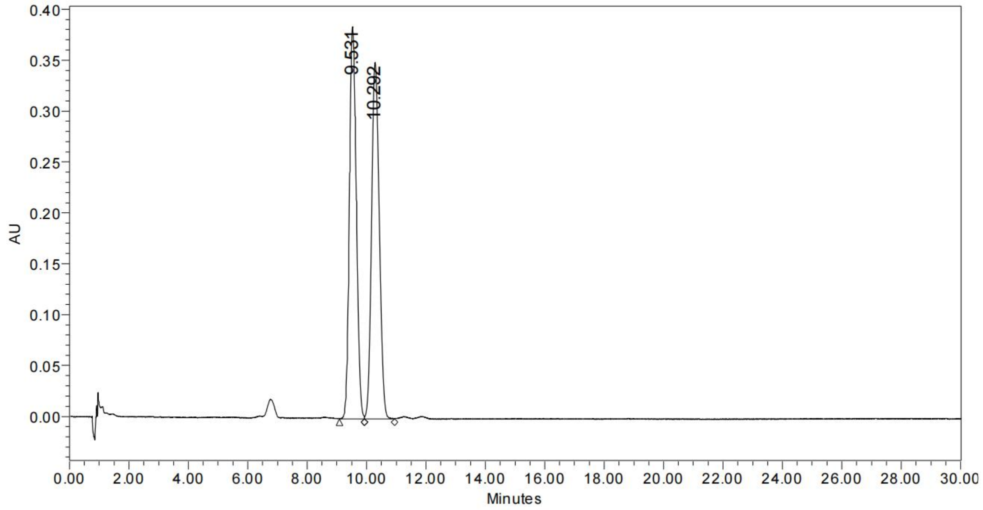


5an

SFC (IG-3, CO_2/MeOH = 90:10, 1 mL/min, 230.0 nm): t_R (major) = 9.560 min, t_R (minor) = 10.340 min, 63.5:36.5 er.



	RT	Area	% Area	Height
1	9.560	7373720	63.62	444632
2	10.340	4217083	36.38	233148



	RT	Area	% Area	Height
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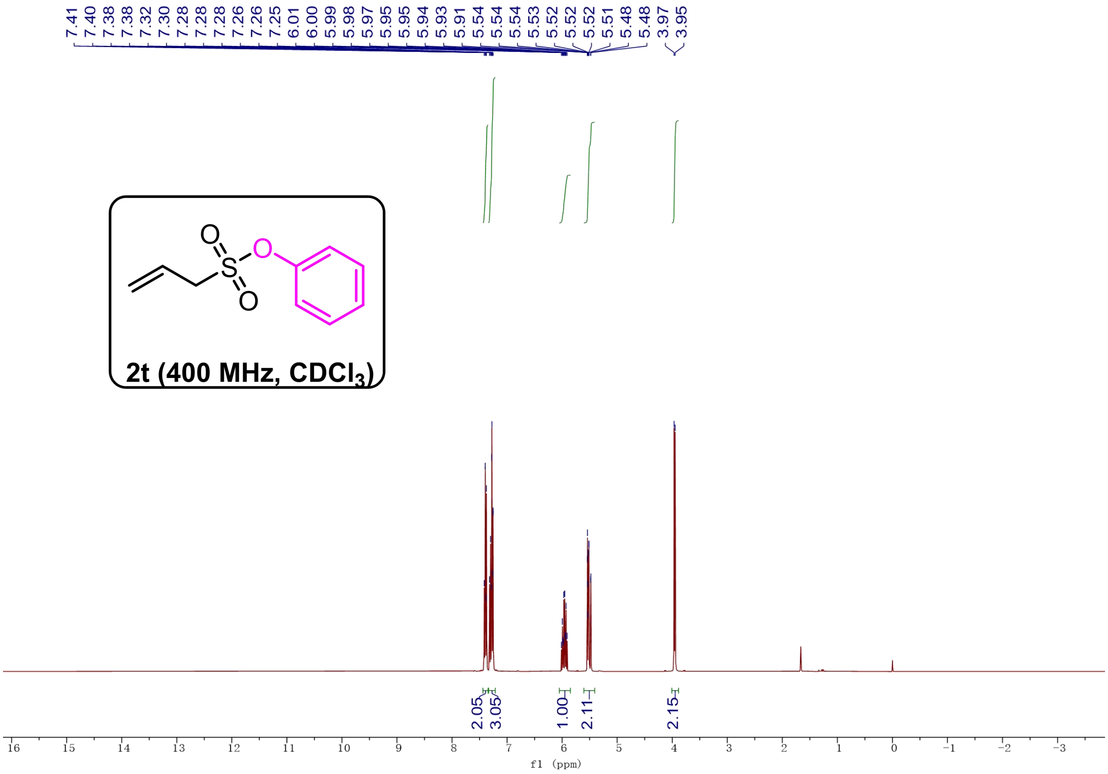
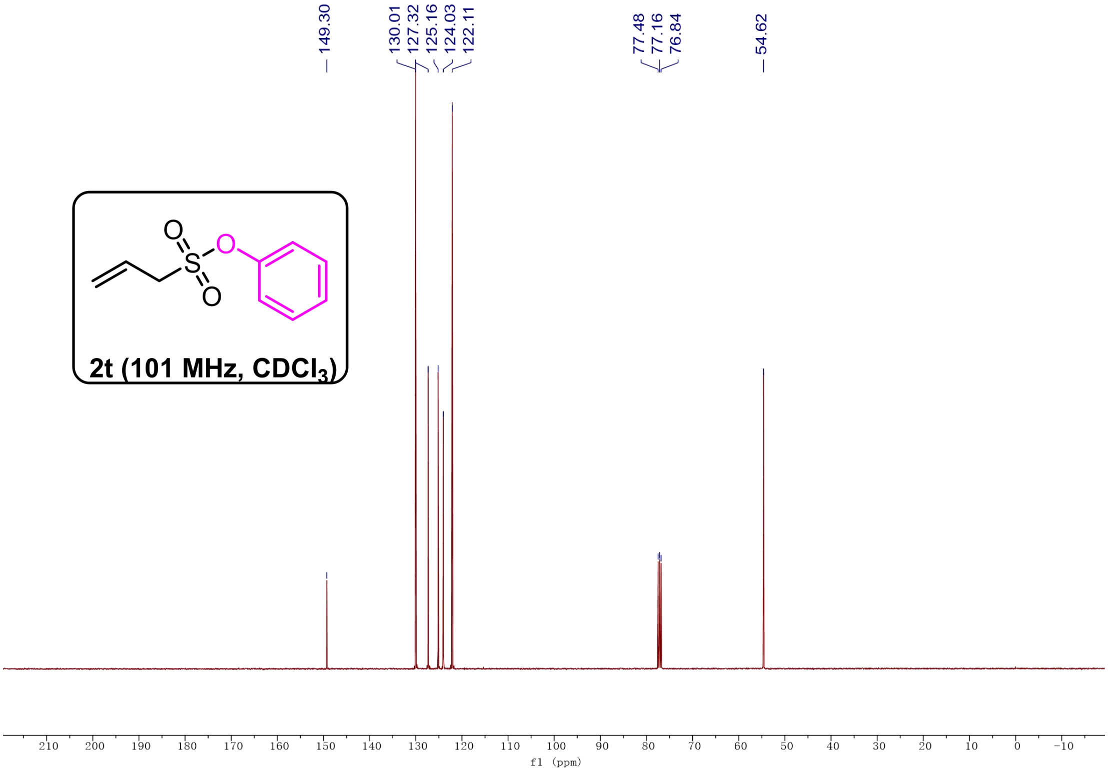
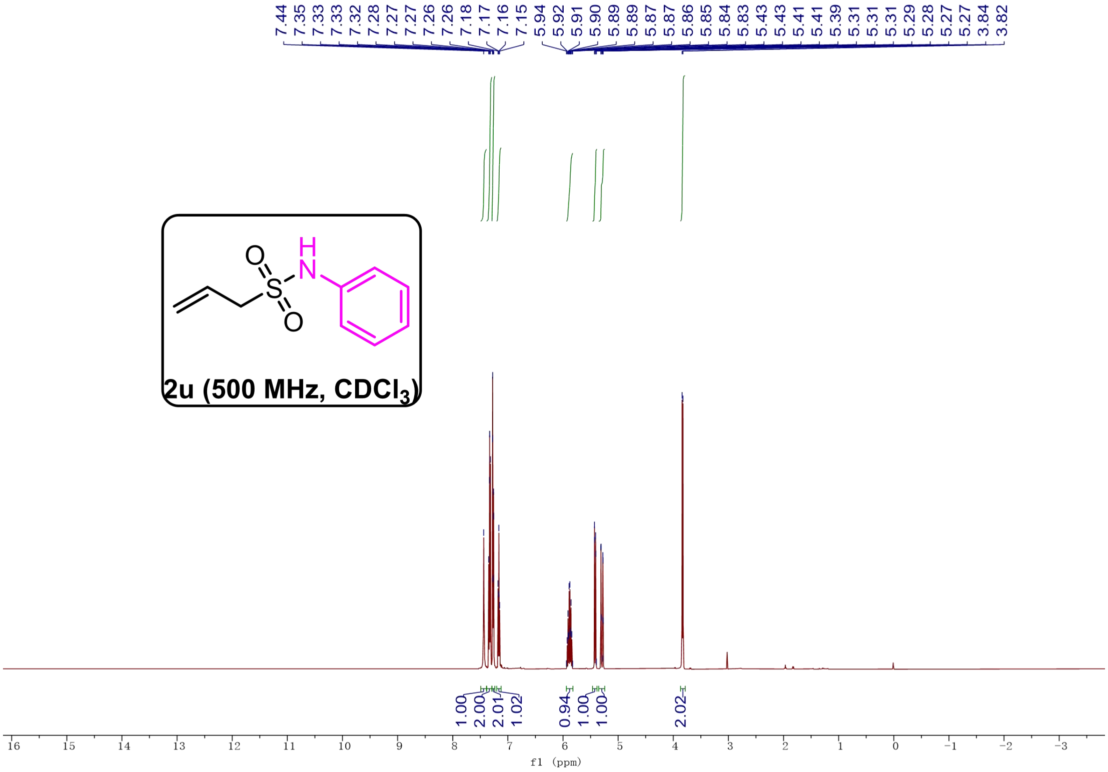
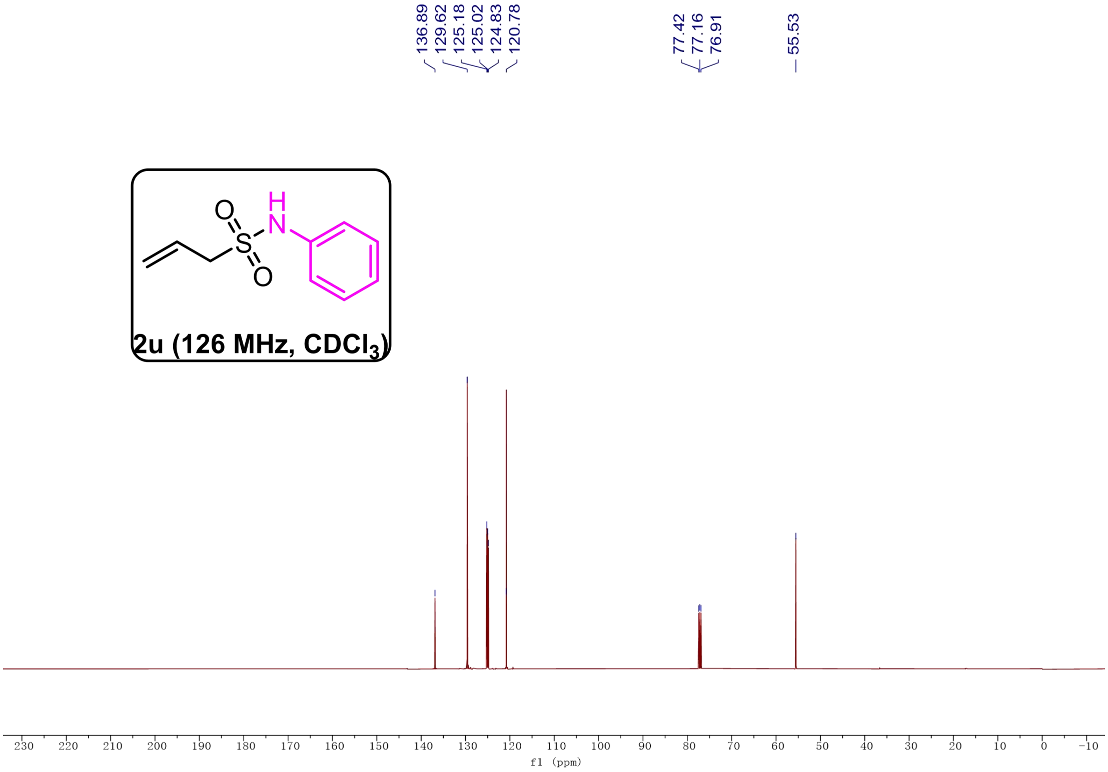
2	10.292	6302176	50.08	350040

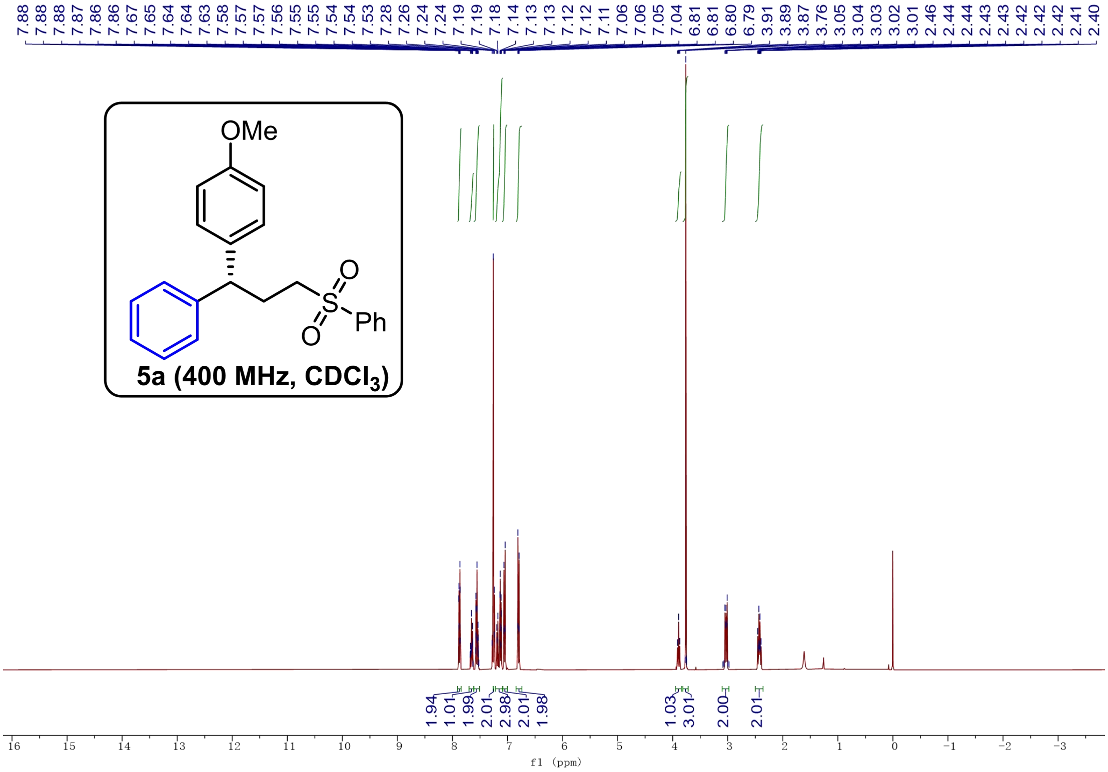
9. NMR Spectra

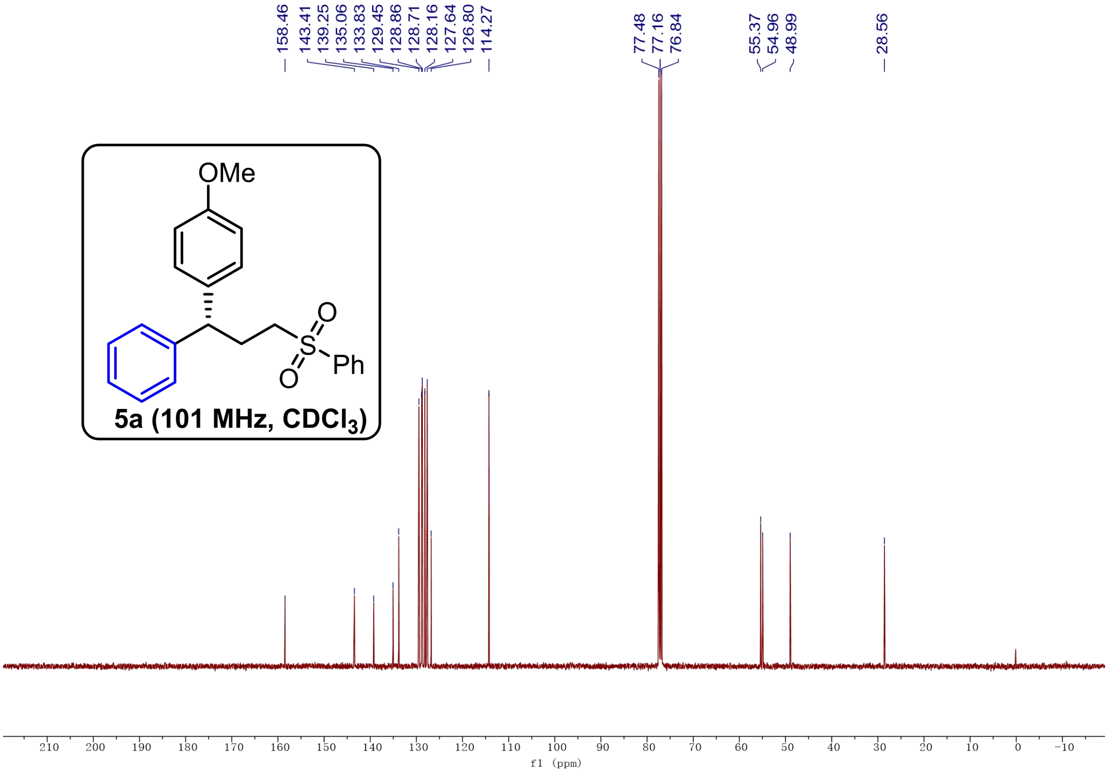


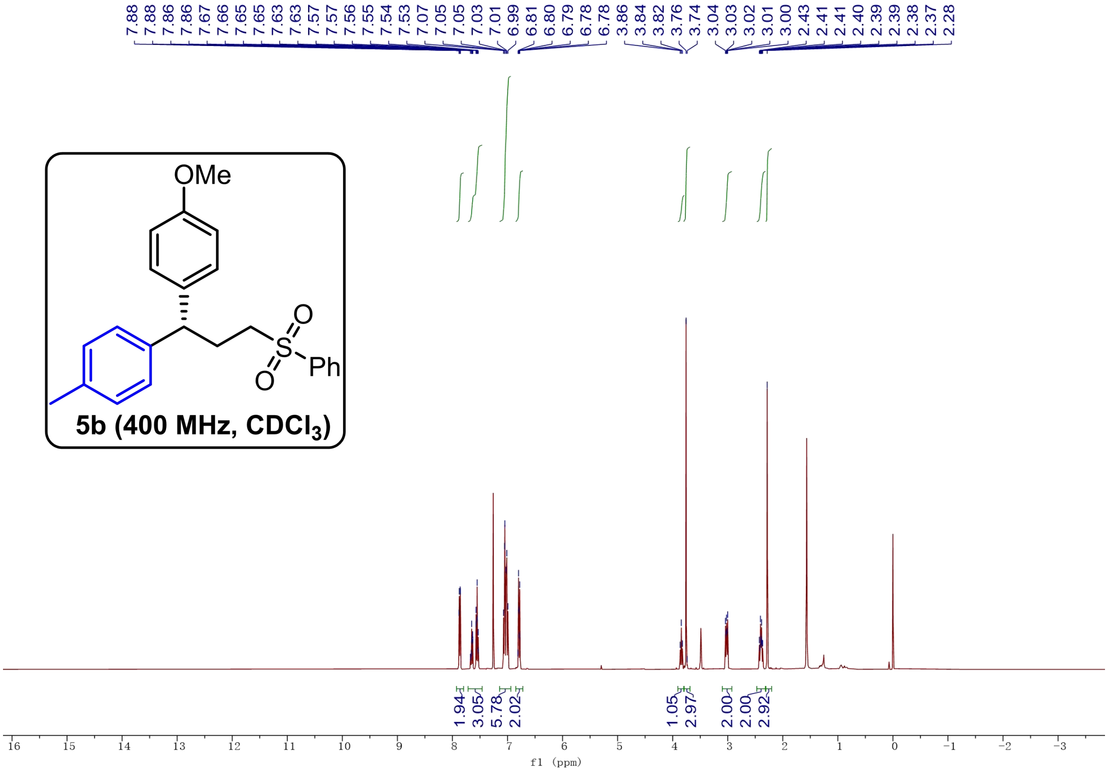


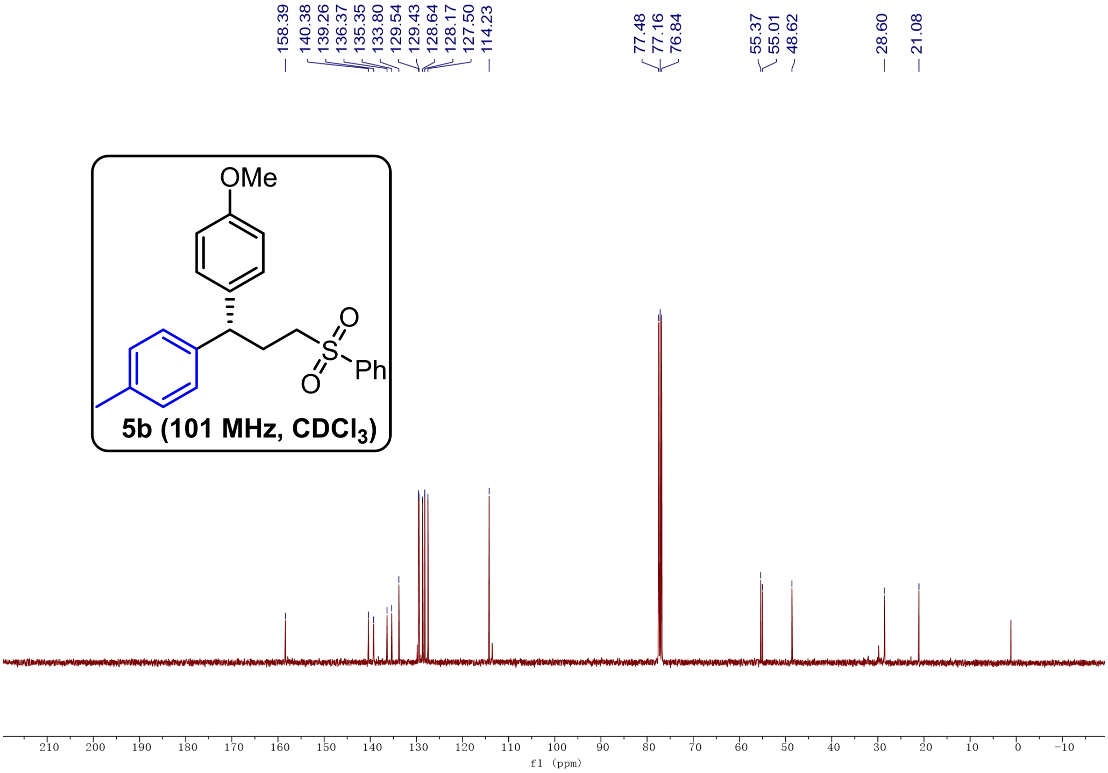

7.44
7.35
7.33
7.32
7.28
7.27
7.27
7.26
7.26
7.18
7.17
7.16
7.15
5.94
5.92
5.91
5.90
5.89
5.87
5.86
5.85
5.84
5.83
5.43
5.43
5.41
5.41
5.39
5.31
5.31
5.29
5.28
5.27
5.27
3.84
3.82
O
H
N
S
O
2u (500 MHz, $CDCl_3$)
1.00
2.00
2.01
1.02
0.94
1.00
1.00
2.02
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

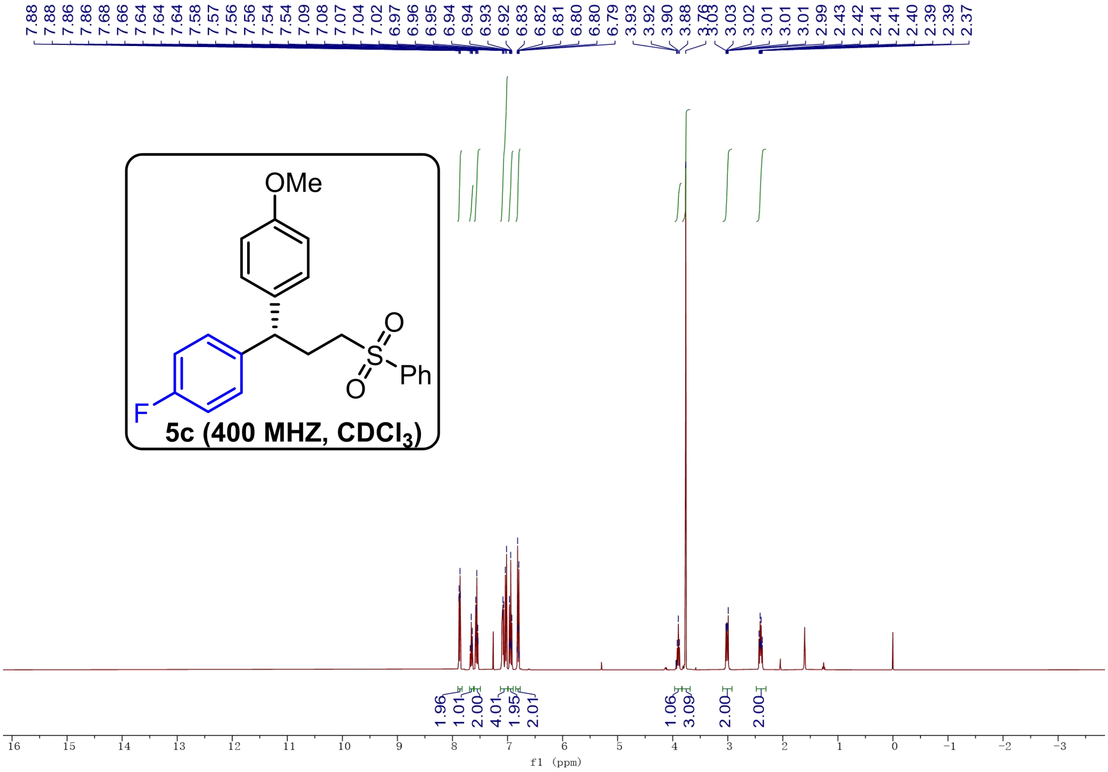

136.89
129.62
125.18
125.02
124.83
120.78
77.42
77.16
76.91
55.53
O
H
N
S
O
2u (126 MHz, $CDCl_3$)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

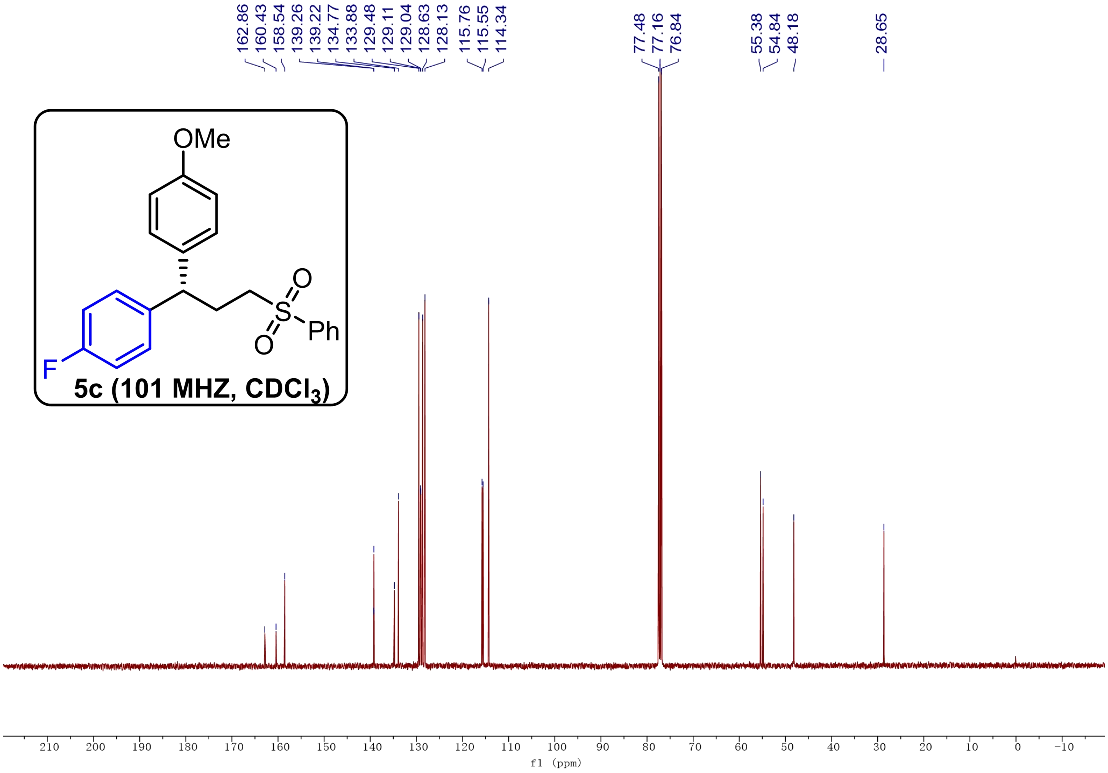

7.88
7.88
7.87
7.86
7.67
7.65
7.64
7.63
7.58
7.57
7.57
7.56
7.55
7.55
7.54
7.54
7.53
7.28
7.26
7.24
7.24
7.19
7.19
7.18
7.14
7.13
7.12
7.12
7.11
7.06
7.05
7.04
6.81
6.81
6.80
6.79
3.91
3.89
3.87
3.76
3.05
3.04
3.03
3.02
3.01
2.46
2.44
2.44
2.43
2.42
2.42
2.42
2.41
2.40
OMe
O
S
O
Ph
5a (400 MHz, CDCl3)
1.94
1.01
1.99
2.01
2.98
2.01
1.98
1.03
3.01
2.00
2.01
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

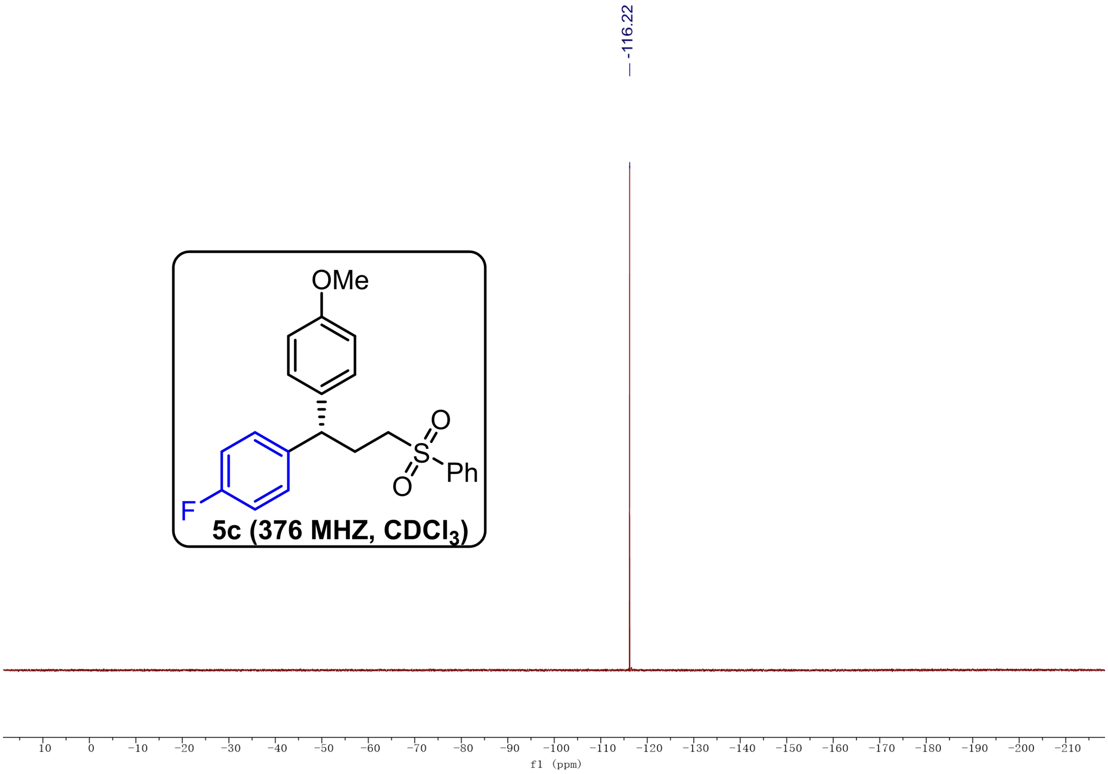

158.46
143.41
139.25
135.06
133.83
129.45
128.86
128.71
128.16
127.64
126.80
114.27
77.48
77.16
76.84
55.37
54.96
48.99
28.56
OMe
O
S
O
Ph
5a (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

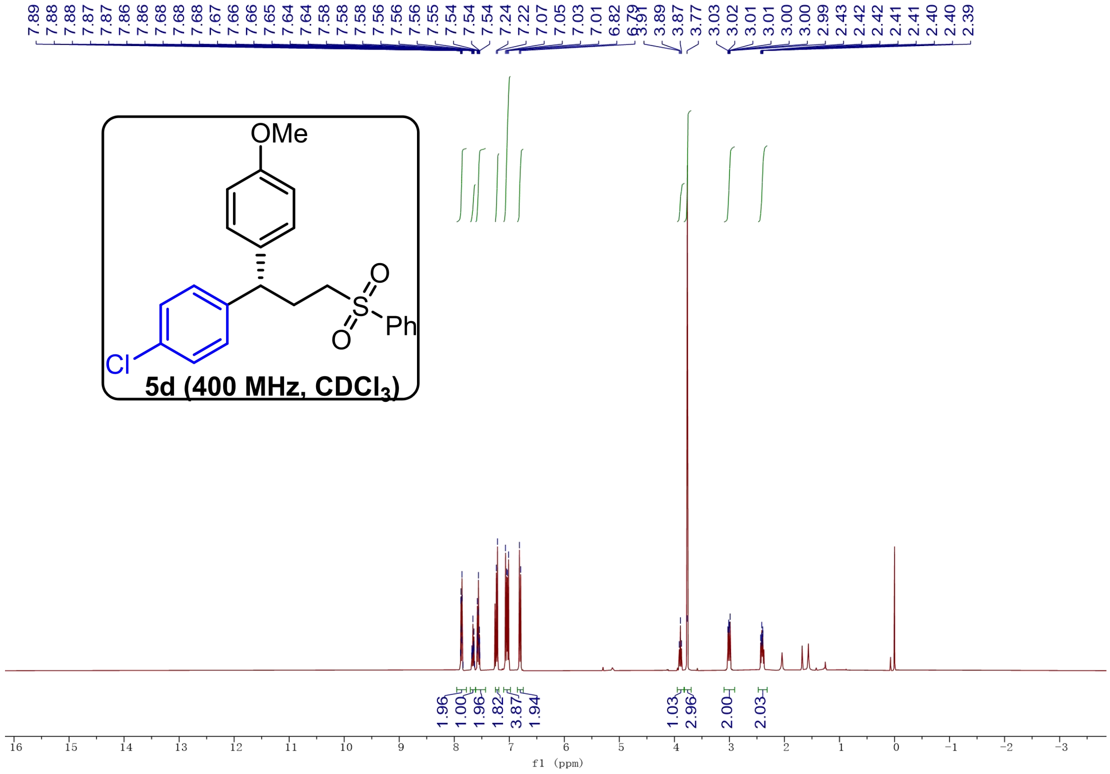

7.88
7.88
7.86
7.86
7.67
7.66
7.65
7.65
7.63
7.63
7.57
7.57
7.56
7.55
7.54
7.53
7.07
7.05
7.05
7.03
7.01
6.99
6.81
6.80
6.79
6.78
3.86
3.84
3.82
3.76
3.74
3.04
3.03
3.02
3.01
3.00
2.43
2.41
2.40
2.39
2.39
2.38
2.37
2.28
OMe
S
O
O
Ph
5b (400 MHz, CDCl$_3$)
1.94
3.05
5.78
2.02
1.05
2.97
2.00
2.00
2.92
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

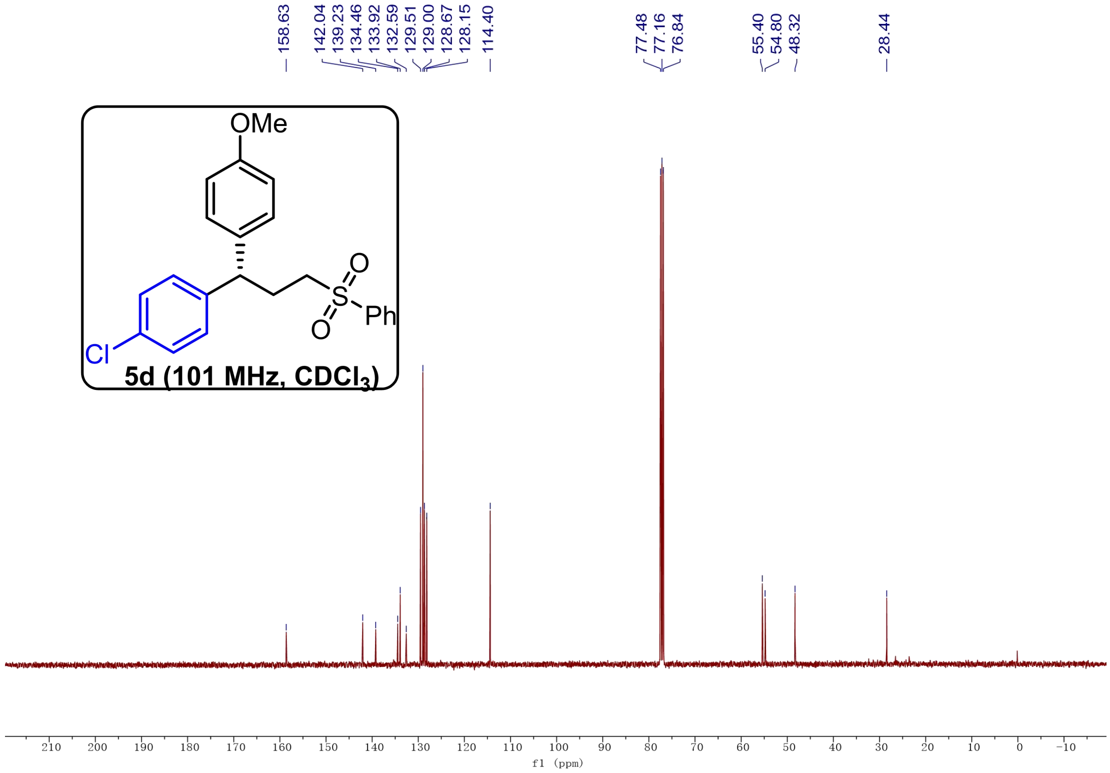

158.39
140.38
139.26
136.37
135.35
133.80
129.54
129.43
128.64
128.17
127.50
114.23
77.48
77.16
76.84
55.37
55.01
48.62
28.60
21.08
OMe
S
O
O
Ph
5b (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

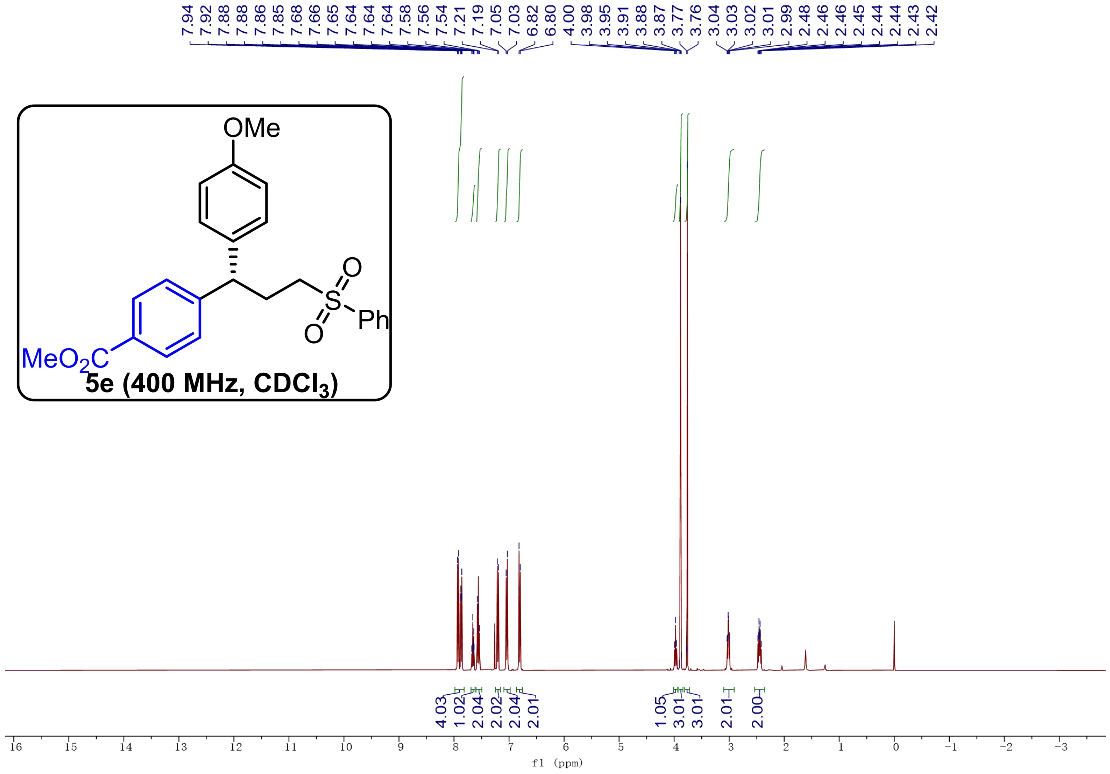

7.88 7.88 7.86 7.86 7.68 7.66 7.64 7.64 7.64 7.58 7.57 7.56 7.56 7.54 7.54 7.09 7.08 7.07 7.04 7.02 6.97 6.96 6.95 6.94 6.94 6.93 6.92 6.83 6.82 6.81 6.80 6.80 6.79 3.93 3.92 3.90 3.88 3.76 3.03 3.03 3.02 3.01 3.01 3.01 2.99 2.43 2.42 2.41 2.41 2.40 2.39 2.39 2.37
OMe
O
S
O
Ph
F
5c (400 MHZ, CDCl$_3$)
1.96
1.01
2.00
4.01
1.95
2.01
1.06
3.09
2.00
2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

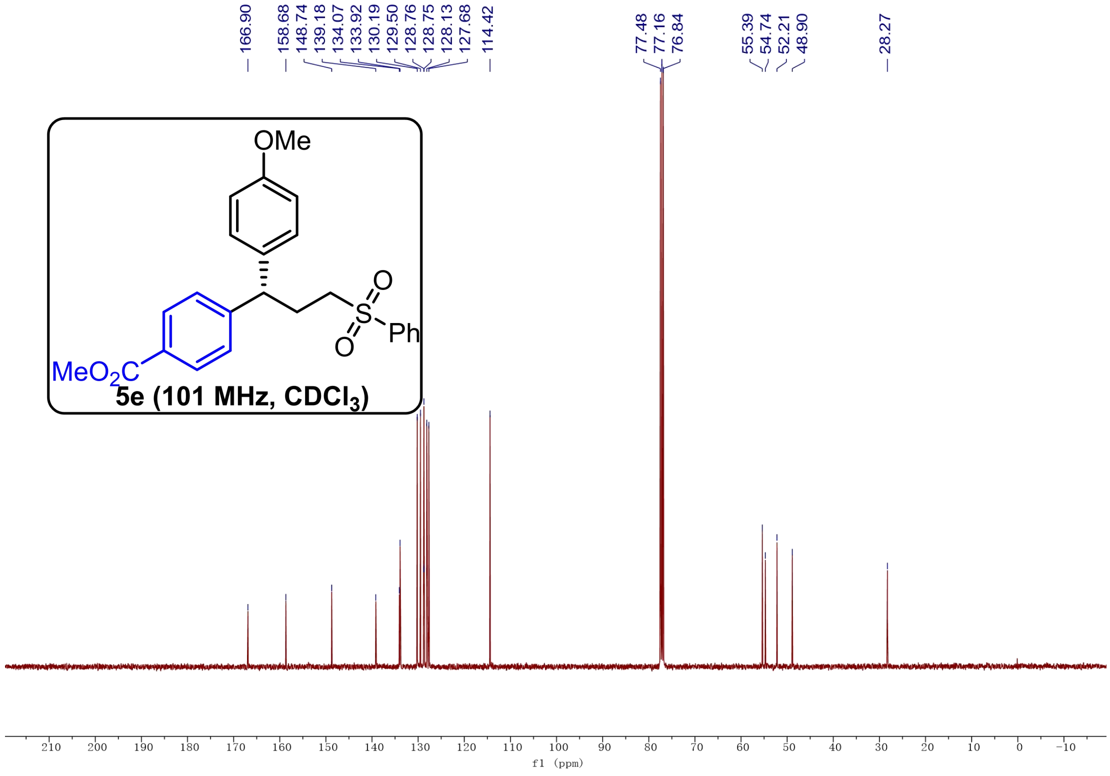

162.86 160.43 158.54 139.26 139.22 134.77 133.88 129.48 129.11 129.04 128.63 128.13 115.76 115.55 114.34
77.48 77.16 76.84
55.38 54.84 48.18
28.65
OMe
O
S
O
Ph
F
5c (101 MHZ, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

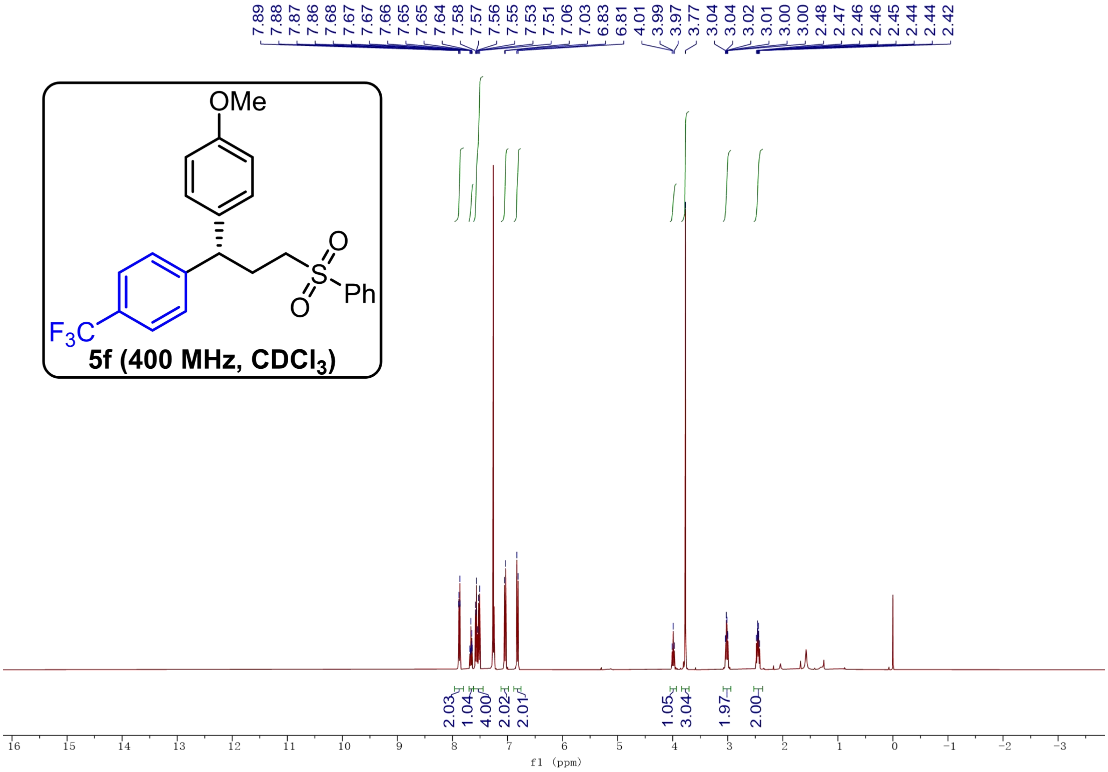

-116.22
OMe
O
S
Ph
O
F
5c (376 MHZ, CDCl$_3$)
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)

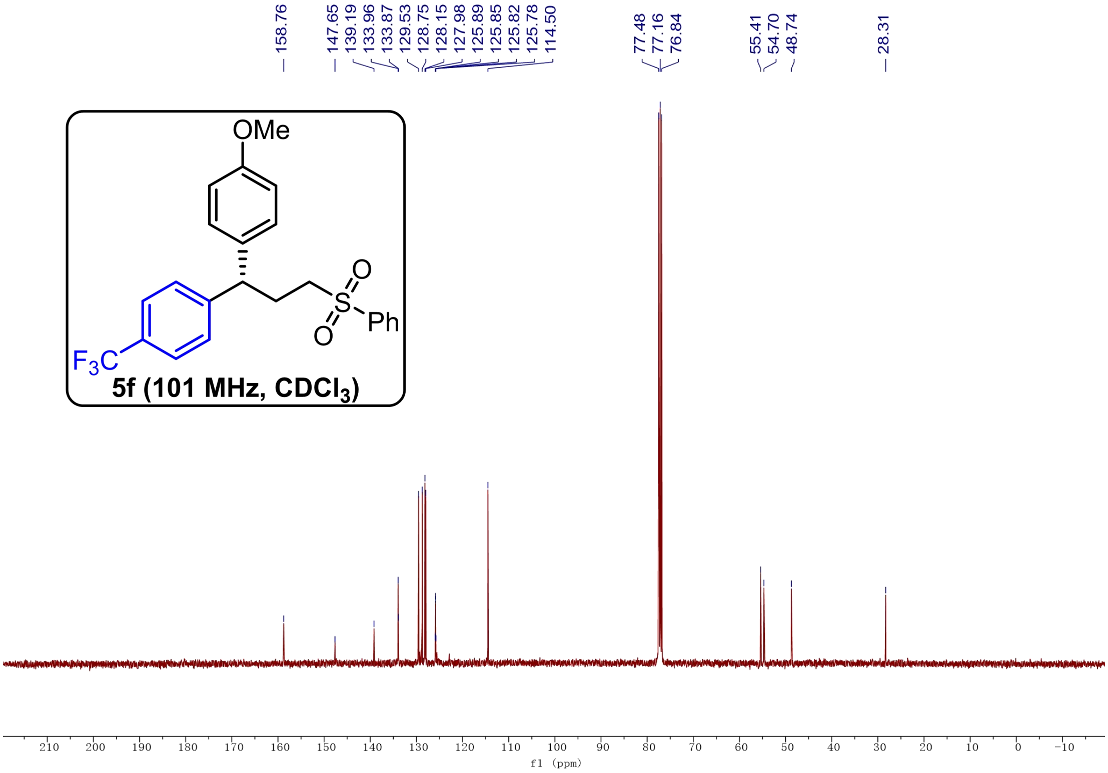

7.89
7.88
7.88
7.87
7.87
7.86
7.86
7.68
7.68
7.68
7.67
7.66
7.66
7.65
7.64
7.64
7.58
7.58
7.58
7.56
7.56
7.55
7.54
7.54
7.54
7.24
7.22
7.07
7.05
7.03
7.01
6.82
6.79
3.91
3.89
3.87
3.77
3.03
3.02
3.01
3.01
3.00
3.00
2.99
2.43
2.42
2.42
2.41
2.41
2.40
2.39
OMe
O
S
O
Ph
Cl
5d (400 MHz, CDCl3)
1.96
1.00
1.96
1.82
3.87
1.94
1.03
2.96
2.00
2.03
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

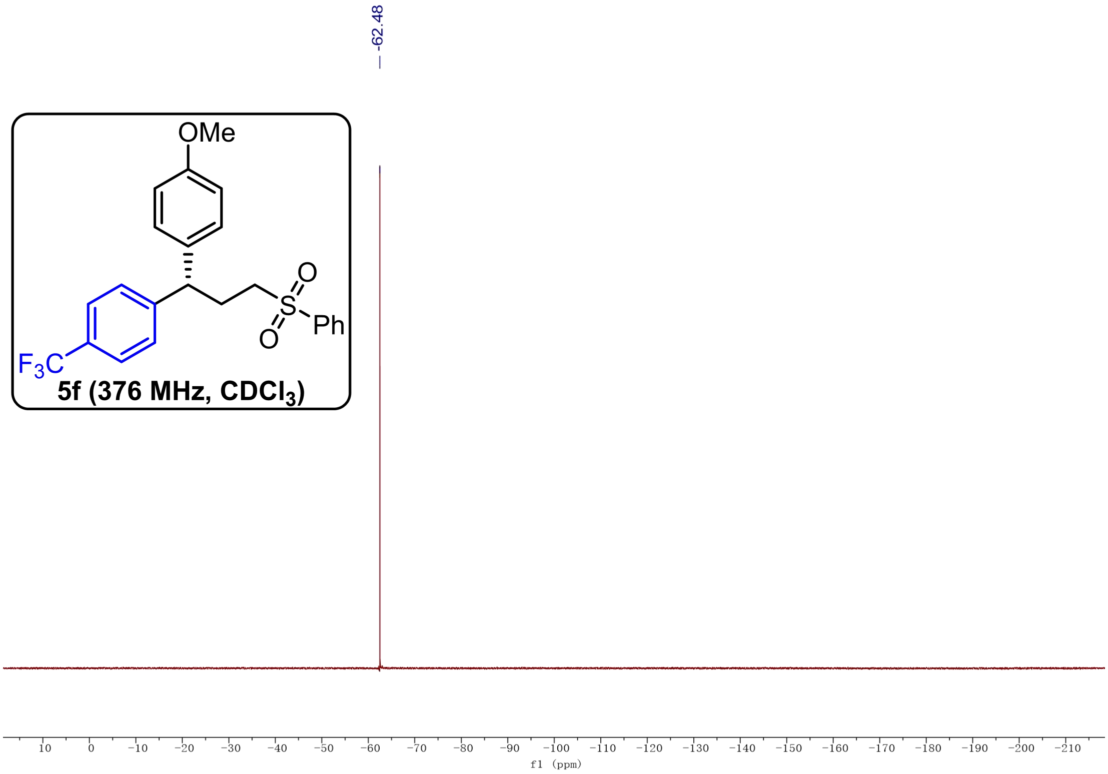

158.63
142.04
139.23
134.46
133.92
132.59
129.51
129.00
128.67
128.15
114.40
77.48
77.16
76.84
55.40
54.80
48.32
28.44
OMe
O
S
O
Ph
Cl
5d (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

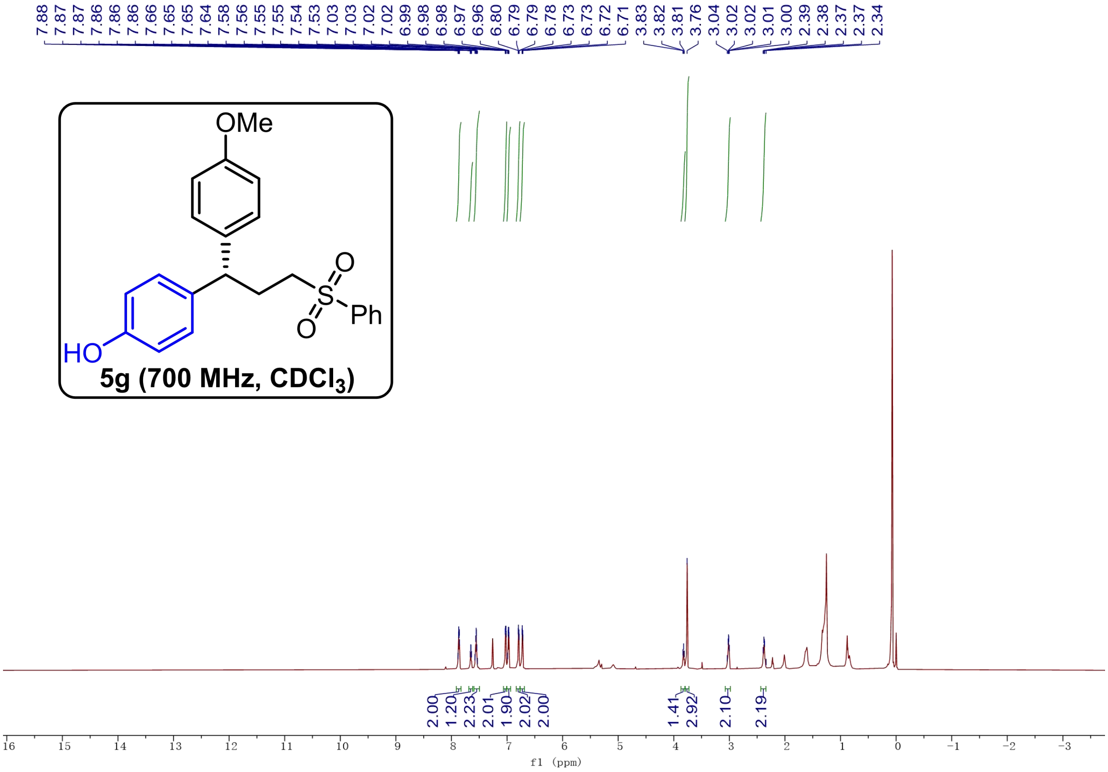

7.94
7.92
7.88
7.88
7.86
7.85
7.68
7.66
7.65
7.64
7.64
7.64
7.58
7.56
7.54
7.21
7.19
7.05
7.03
6.82
6.80
4.00
3.98
3.95
3.91
3.88
3.87
3.77
3.76
3.04
3.03
3.02
3.01
2.99
2.48
2.46
2.45
2.44
2.44
2.43
2.42
OMe
S
O
O
Ph
MeO_2C
5e (400 MHz, $CDCl_3$)
4.03
1.02
2.04
2.02
2.04
2.01
1.05
3.01
3.01
2.01
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

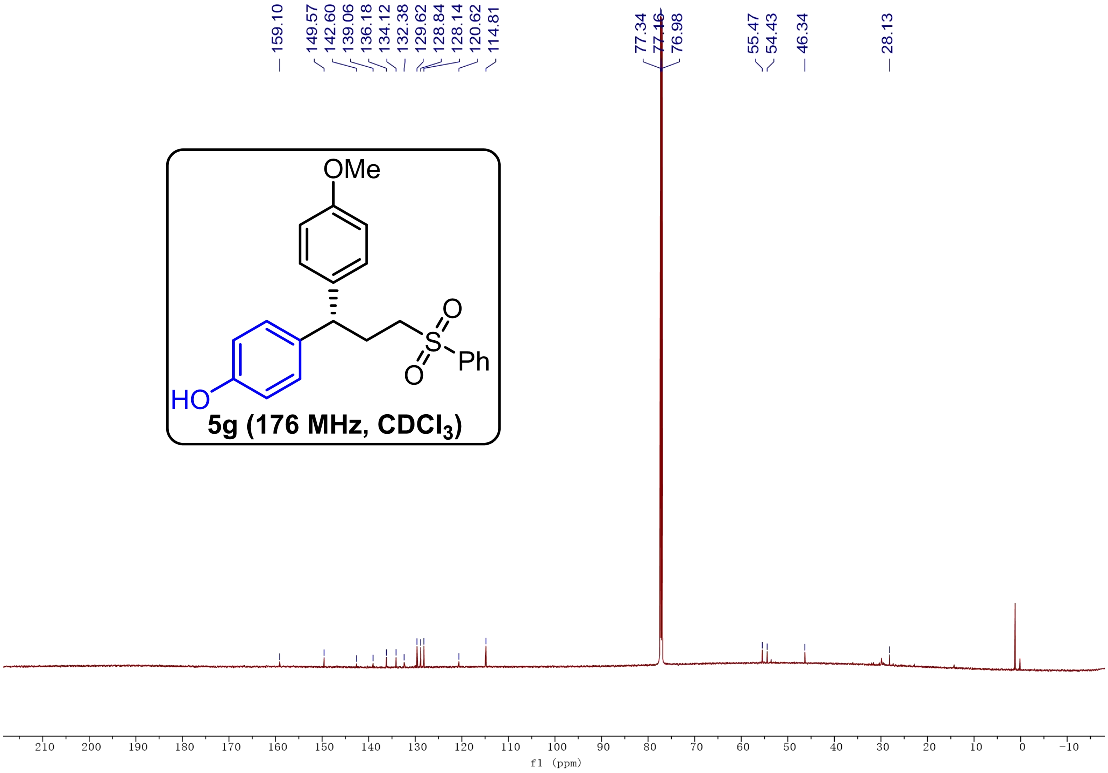

166.90
158.68
148.74
139.18
134.07
133.92
130.19
129.50
128.76
128.75
128.13
127.68
114.42
77.48
77.16
76.84
55.39
54.74
52.21
48.90
28.27
OMe
S
O
O
Ph
MeO_2C
5e (101 MHz, $CDCl_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

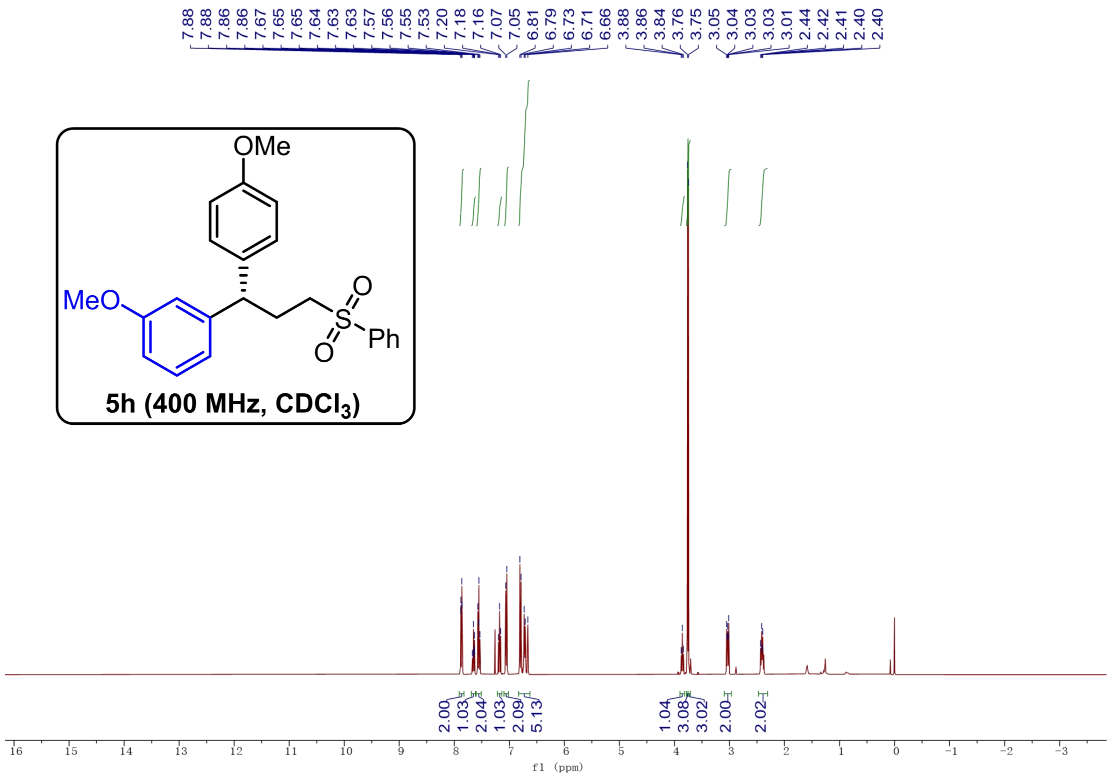

7.89
7.88
7.87
7.86
7.68
7.67
7.67
7.66
7.65
7.65
7.64
7.58
7.57
7.56
7.55
7.53
7.51
7.06
7.03
6.83
6.81
4.01
3.99
3.97
3.77
3.04
3.04
3.02
3.01
3.00
3.00
2.48
2.47
2.46
2.46
2.45
2.44
2.44
2.42
OMe
O
S
Ph
O
F_3C
5f (400 MHz, $CDCl_3$)
2.03
1.04
4.00
2.02
2.01
1.05
3.04
1.97
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

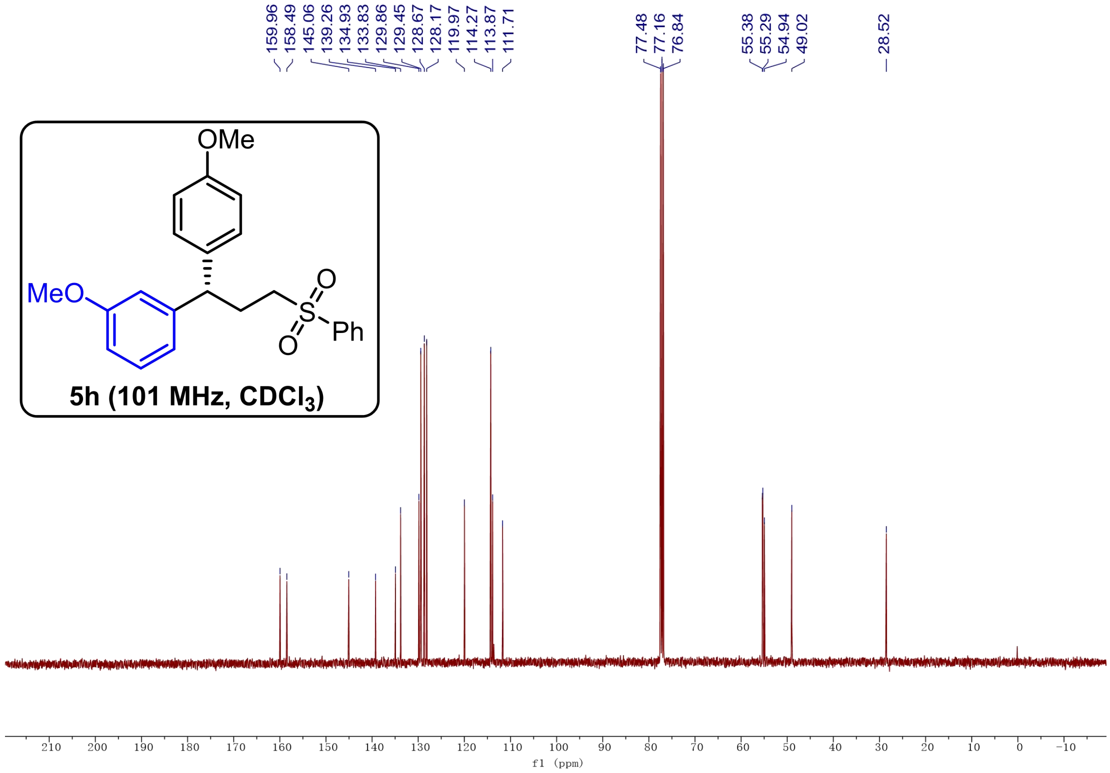

158.76
147.65
139.19
133.96
133.87
129.53
128.75
128.15
127.98
125.89
125.85
125.82
125.78
114.50
77.48
77.16
76.84
55.41
54.70
48.74
28.31
OMe
O
S
Ph
O
F_3C
5f (101 MHz, $CDCl_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

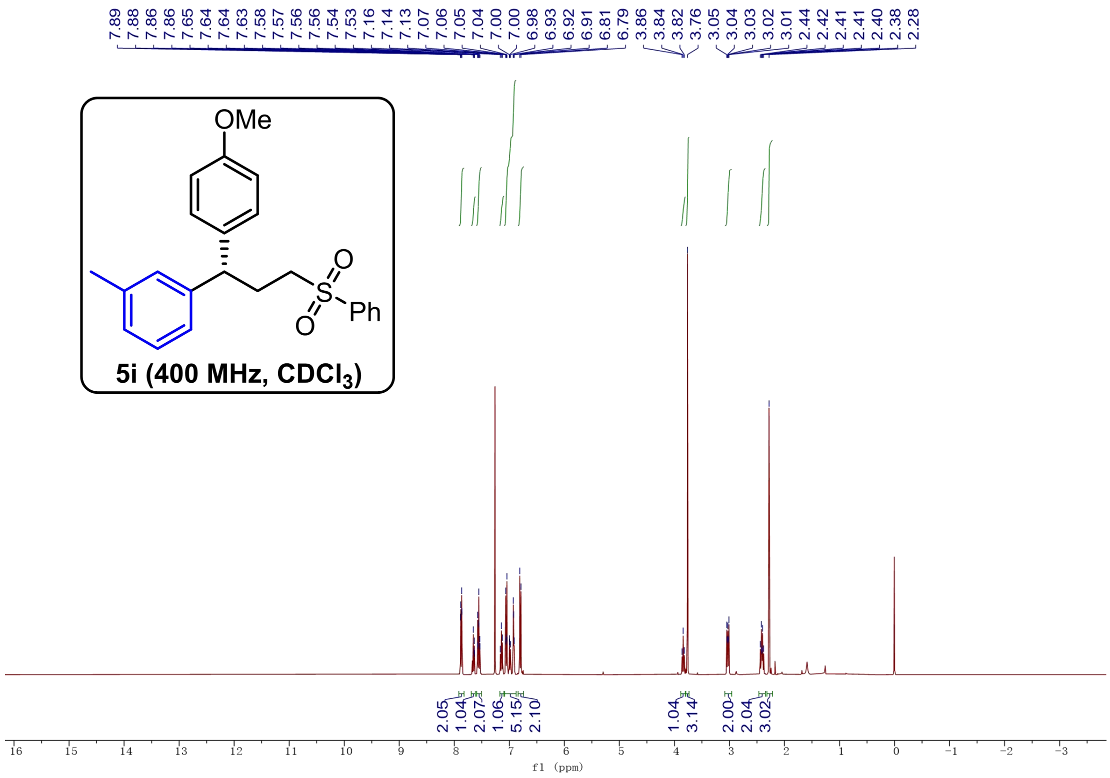

-62.48
OMe
O
S
O
Ph
F3C
5f (376 MHz, CDCl3)
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)

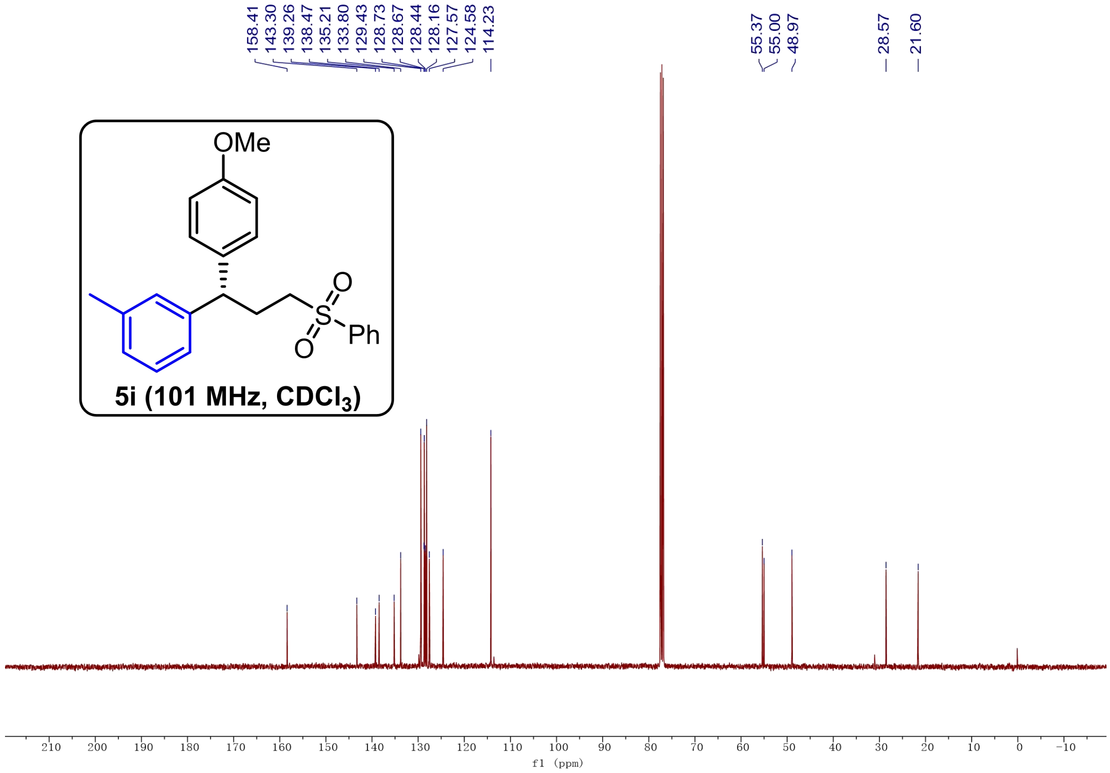

7.88
7.87
7.87
7.86
7.86
7.86
7.66
7.65
7.65
7.64
7.58
7.56
7.55
7.55
7.54
7.53
7.03
7.03
7.02
7.02
6.99
6.98
6.98
6.97
6.96
6.80
6.79
6.79
6.78
6.73
6.73
6.72
6.71
3.83
3.82
3.81
3.76
3.04
3.02
3.02
3.01
3.00
2.39
2.38
2.37
2.37
2.34
OMe
O
S
Ph
O
HO
5g (700 MHz, CDCl3)
2.00
1.20
2.23
2.01
1.90
2.02
2.00
1.41
2.92
2.10
2.19
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

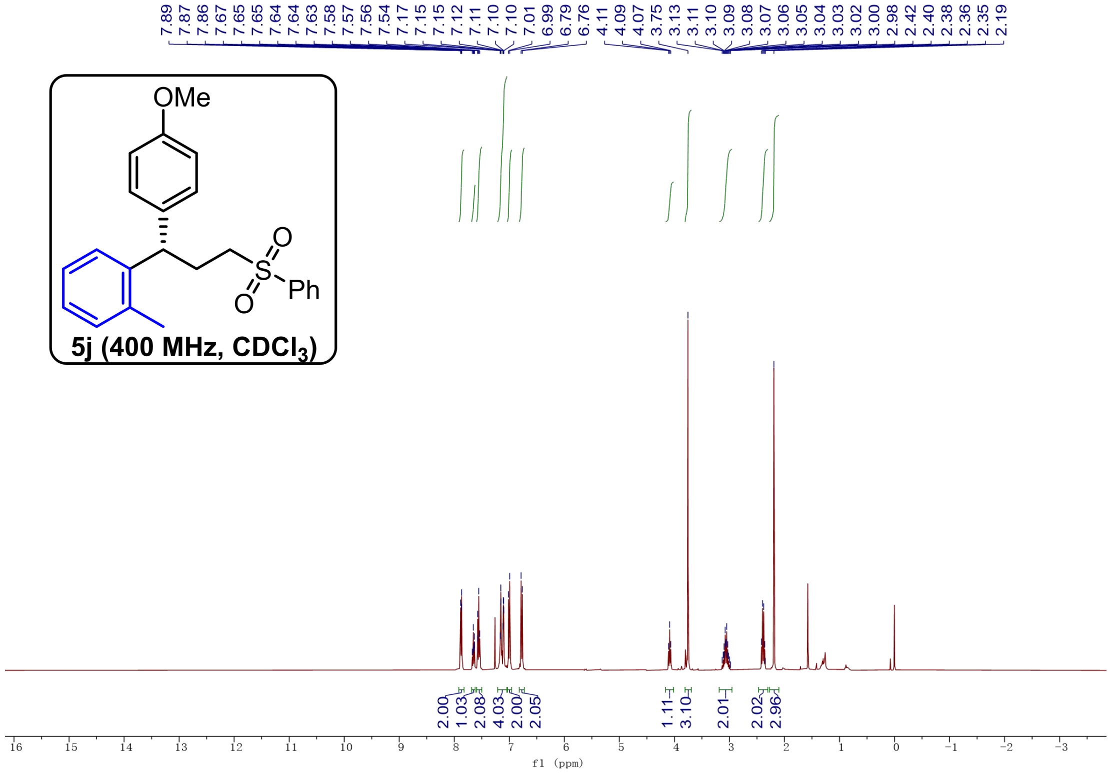

159.10
149.57
142.60
139.06
136.18
134.12
132.38
129.62
128.84
128.14
120.62
114.81
77.34
77.16
76.98
55.47
54.43
46.34
28.13
OMe
O
S
Ph
O
HO
5g (176 MHz, CDCl3)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

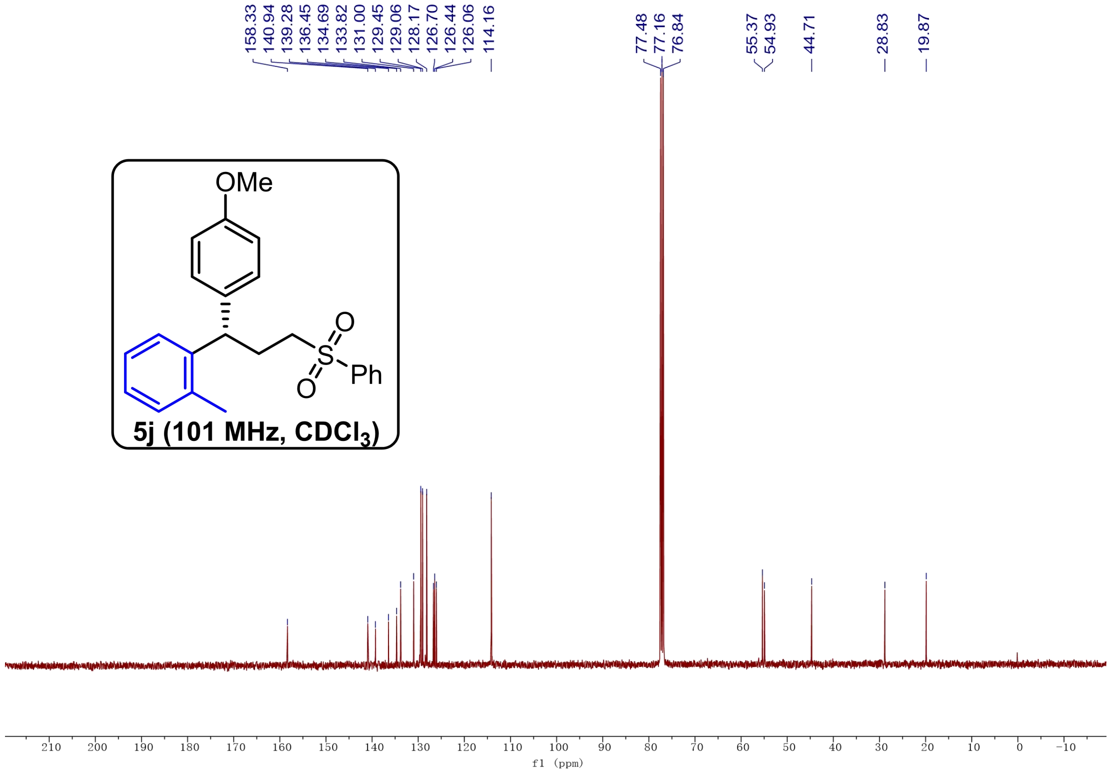

7.88
7.88
7.86
7.86
7.67
7.65
7.65
7.64
7.63
7.63
7.57
7.56
7.55
7.53
7.20
7.18
7.16
7.07
7.05
6.81
6.79
6.73
6.71
6.66
3.88
3.86
3.84
3.76
3.75
3.05
3.04
3.03
3.03
3.01
2.44
2.42
2.41
2.40
2.40
OMe
MeO
O
S
O
Ph
5h (400 MHz, CDCl3)
2.00
1.03
2.04
1.03
2.09
5.13
1.04
3.08
3.02
2.00
2.02
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

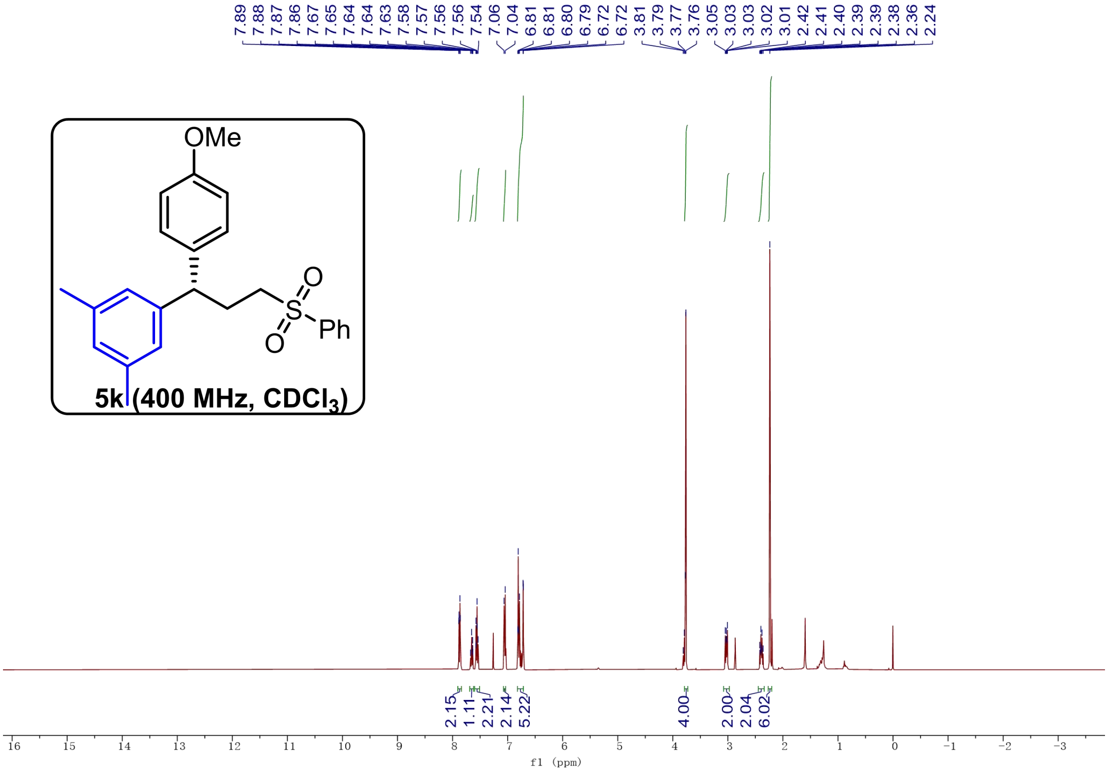

159.96
158.49
145.06
139.26
134.93
133.83
129.86
129.45
128.67
128.17
119.97
114.27
113.87
111.71
77.48
77.16
76.84
55.38
55.29
54.94
49.02
28.52
OMe
MeO
O
S
O
Ph
5h (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

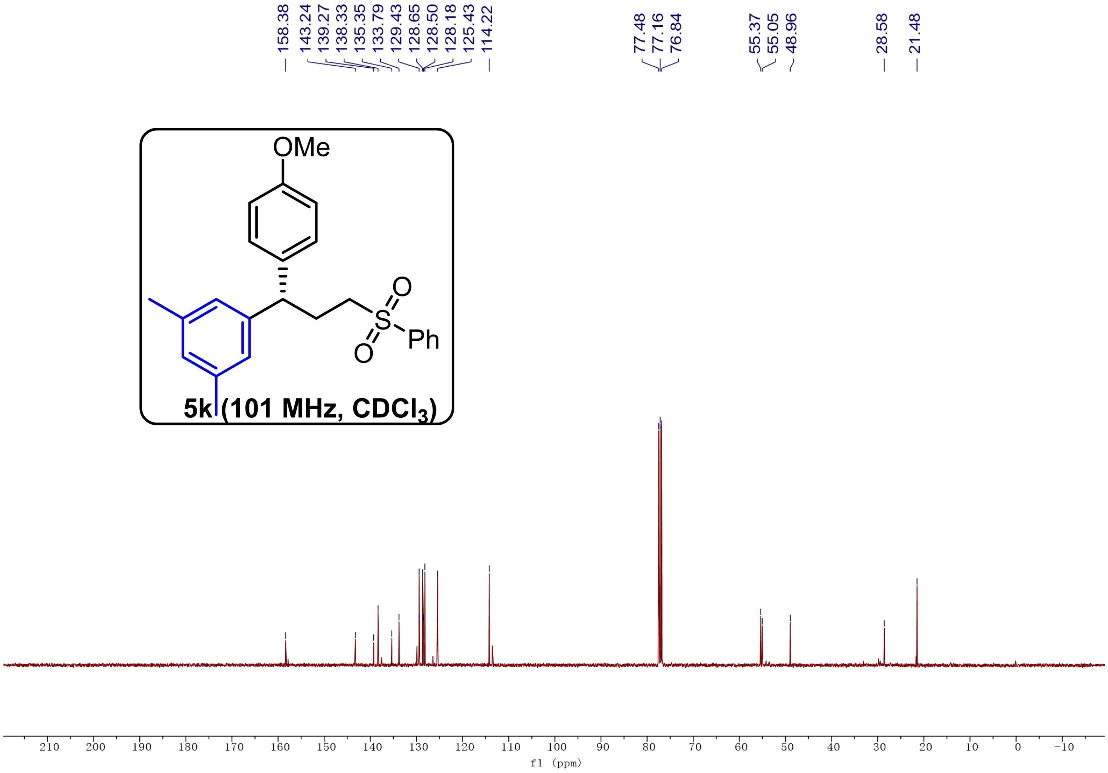

7.89
7.88
7.86
7.86
7.65
7.64
7.64
7.63
7.58
7.57
7.56
7.56
7.54
7.53
7.16
7.14
7.13
7.07
7.06
7.05
7.04
7.00
7.00
6.98
6.93
6.92
6.91
6.81
6.79
3.86
3.84
3.82
3.76
3.05
3.04
3.03
3.02
3.01
2.44
2.42
2.41
2.41
2.40
2.38
2.28
OMe
S
O
O
Ph
5i (400 MHz, CDCl$_3$)
2.05
1.04
2.07
1.06
5.15
2.10
1.04
3.14
2.00
2.04
3.02
f1 (ppm)

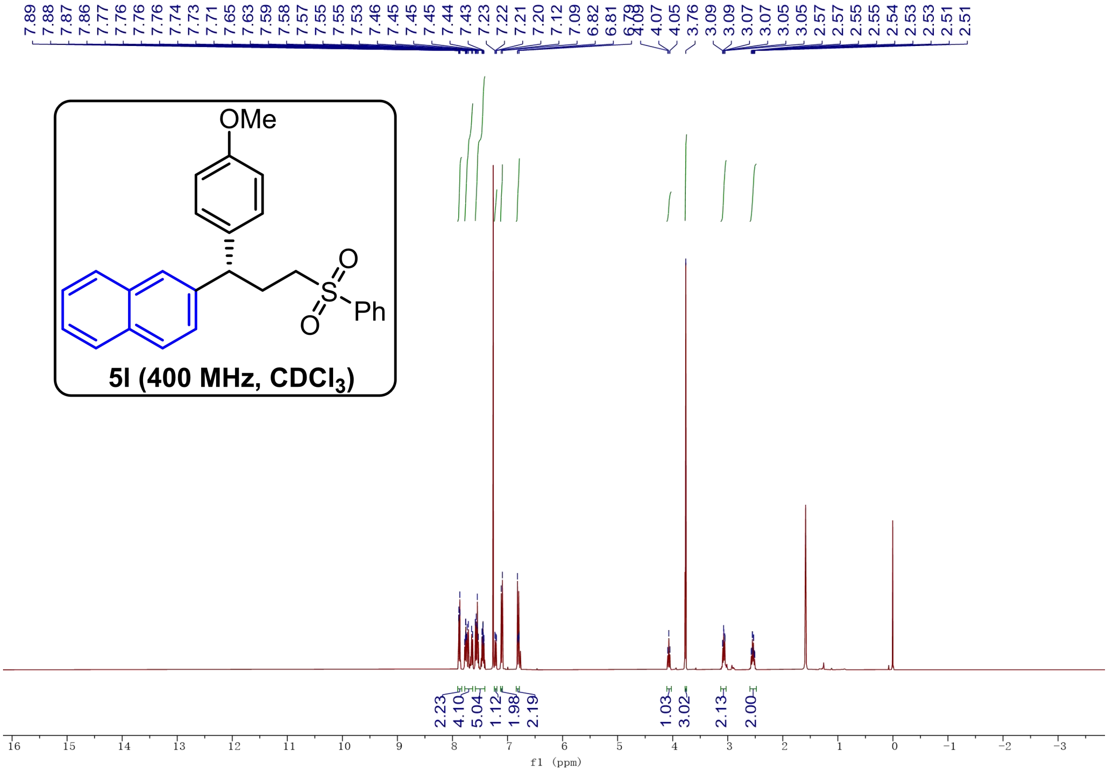

158.41
143.30
139.26
138.47
135.21
133.80
129.43
128.73
128.67
128.44
128.16
127.57
124.58
114.23
55.37
55.00
48.97
28.57
21.60
OMe
S
O
O
Ph
5i (101 MHz, CDCl$_3$)
f1 (ppm)

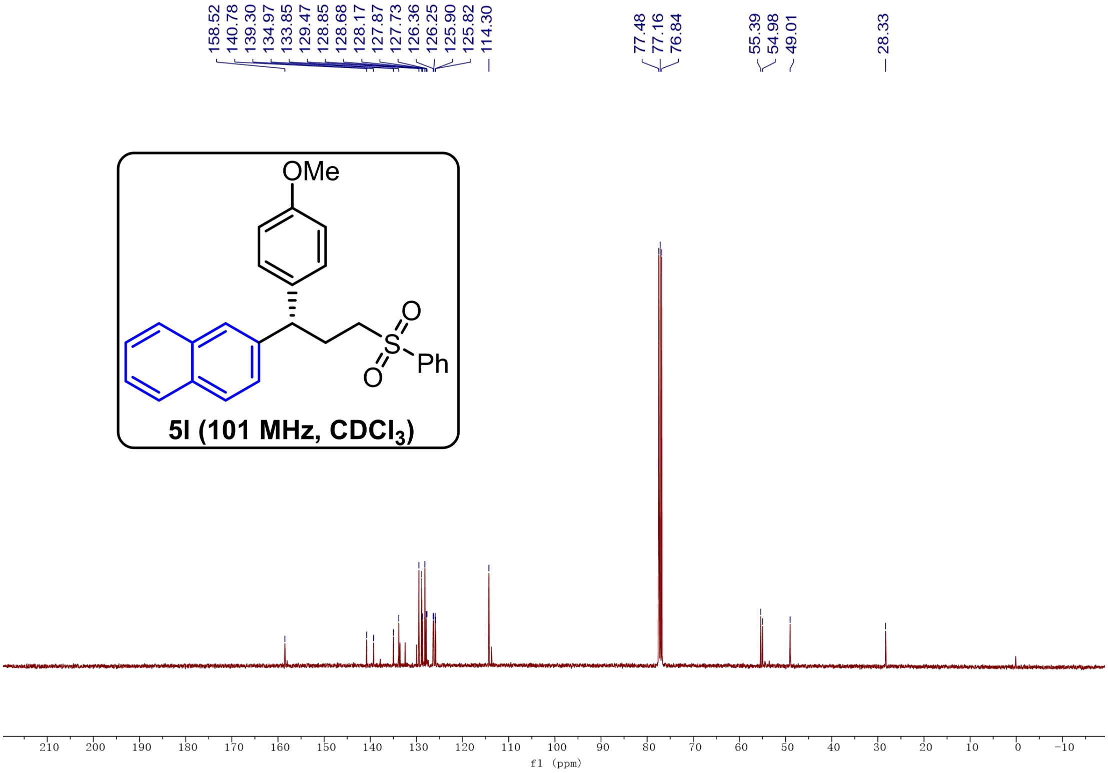

7.89
7.87
7.86
7.67
7.65
7.65
7.64
7.63
7.58
7.57
7.56
7.54
7.17
7.15
7.15
7.12
7.11
7.10
7.10
7.01
6.99
6.79
6.76
4.11
4.09
4.07
3.75
3.13
3.11
3.10
3.09
3.08
3.07
3.06
3.05
3.04
3.03
3.02
3.00
2.98
2.42
2.40
2.38
2.36
2.35
2.19
OMe
O
S
Ph
O
5j (400 MHz, CDCl3)
2.00
1.03
2.08
4.03
2.00
2.05
1.11
3.10
2.01
2.02
2.96
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

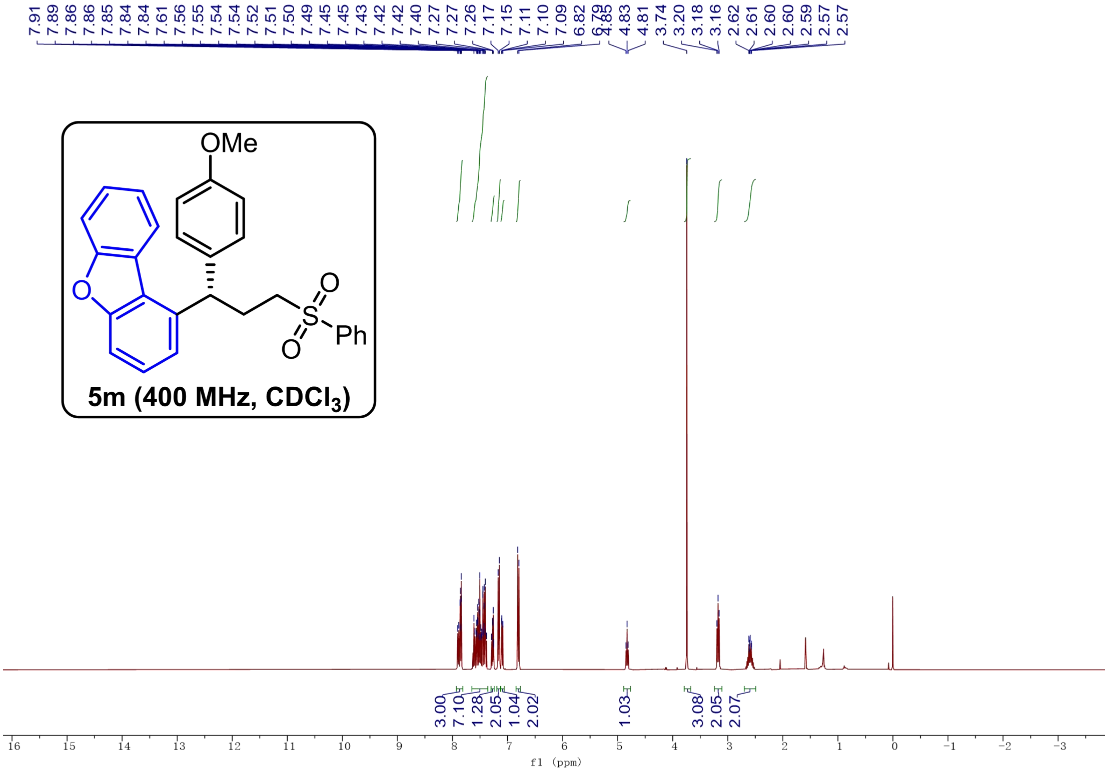

158.33
140.94
139.28
136.45
134.69
133.82
131.00
129.45
129.06
128.17
126.70
126.44
126.06
114.16
77.48
77.16
76.84
55.37
54.93
44.71
28.83
19.87
OMe
O
S
Ph
O
5j (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

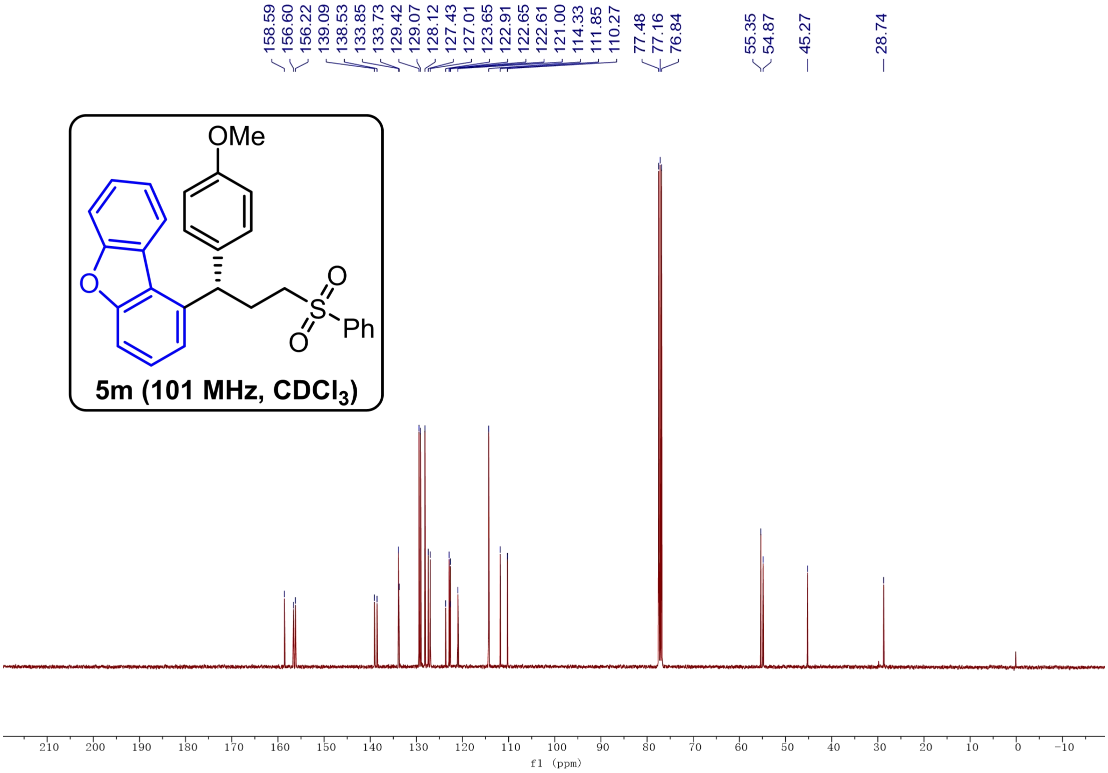

7.89
7.88
7.87
7.86
7.67
7.65
7.64
7.63
7.58
7.57
7.56
7.56
7.54
7.06
7.04
6.81
6.81
6.80
6.79
6.72
6.72
3.81
3.79
3.77
3.76
3.05
3.03
3.03
3.02
3.01
2.42
2.41
2.40
2.39
2.39
2.38
2.36
2.24
OMe
O
S
O
Ph
5k (400 MHz, CDCl$_3$)
2.15
1.11
2.21
2.14
5.22
4.00
2.00
2.04
6.02
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)

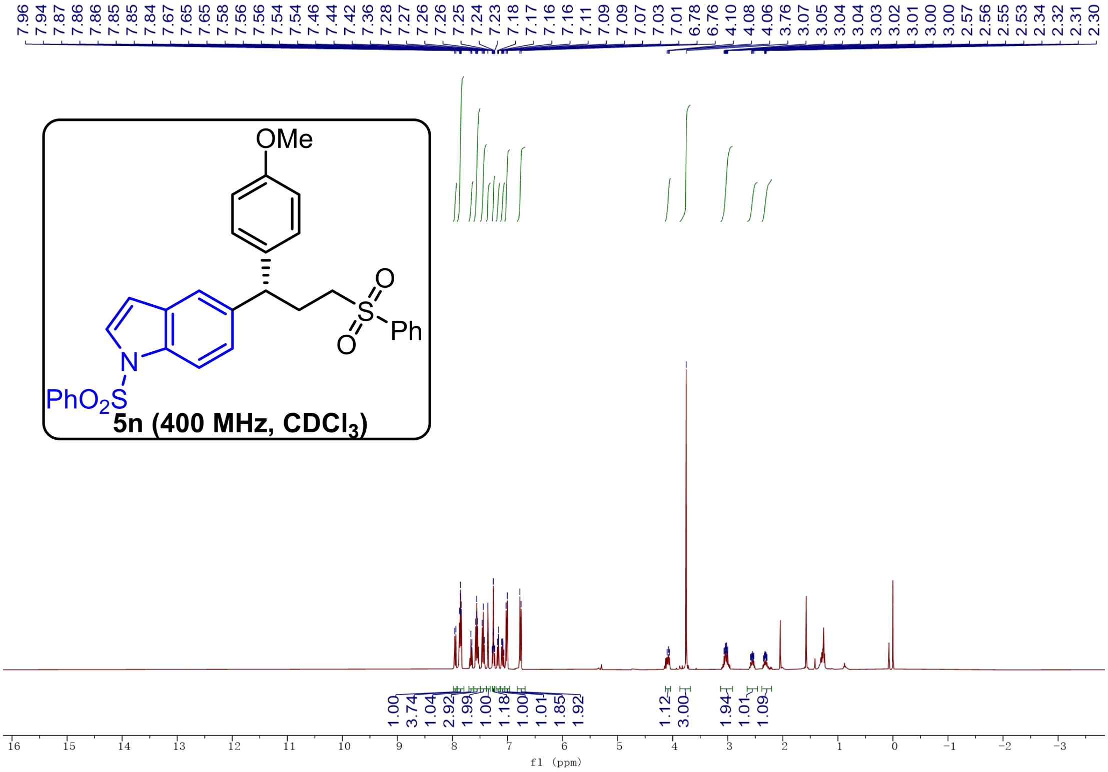

158.38
143.24
139.27
138.33
135.35
133.79
129.43
128.65
128.50
128.18
125.43
114.22
77.48
77.16
76.84
55.37
55.05
48.96
28.58
21.48
OMe
O
S
O
Ph
5k (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

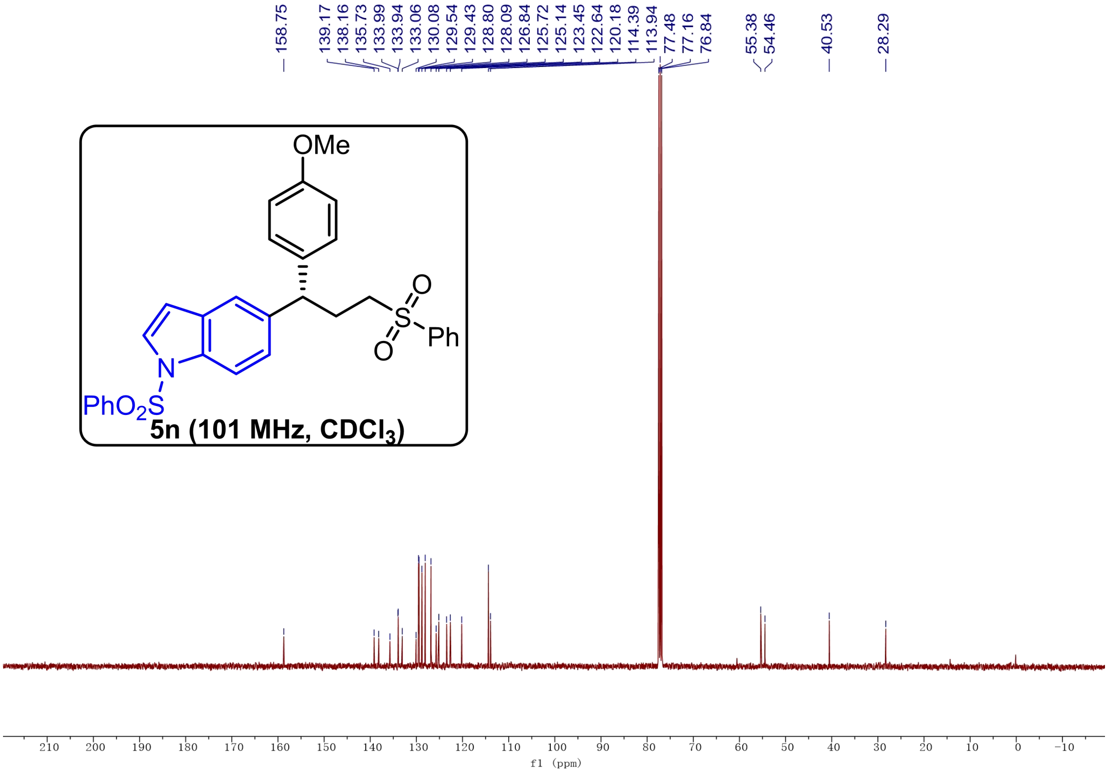

7.89
7.88
7.87
7.86
7.77
7.76
7.76
7.76
7.74
7.73
7.71
7.65
7.63
7.59
7.58
7.57
7.55
7.55
7.53
7.46
7.45
7.45
7.45
7.44
7.43
7.23
7.22
7.21
7.20
7.12
7.09
6.82
6.81
6.79
4.09
4.07
4.05
3.76
3.09
3.09
3.07
3.07
3.05
3.05
2.57
2.57
2.55
2.55
2.54
2.53
2.53
2.51
2.51
OMe
O
S
O
Ph
5l (400 MHz, CDCl$_3$)
2.23
4.10
5.04
1.12
1.98
2.19
1.03
3.02
2.13
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

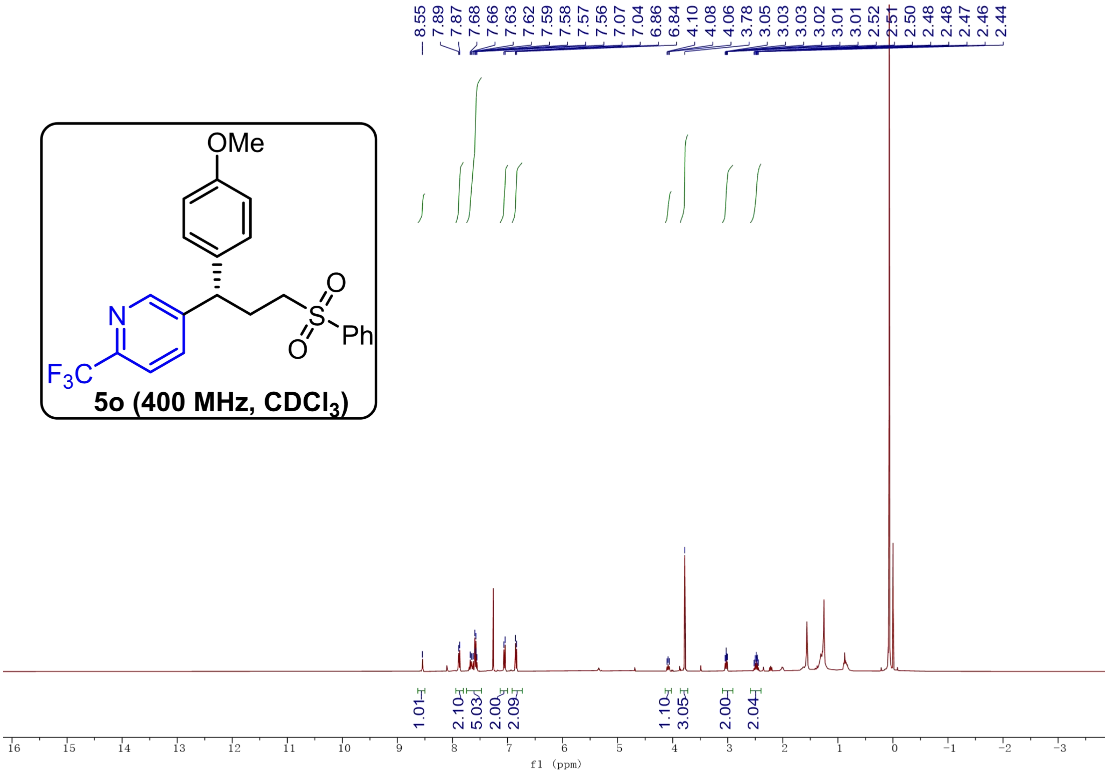

158.52
140.78
139.30
134.97
133.85
129.47
128.85
128.68
128.17
127.87
127.73
126.36
126.25
125.90
125.82
114.30
77.48
77.16
76.84
55.39
54.98
49.01
28.33
OMe
O
S
O
Ph
5l (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

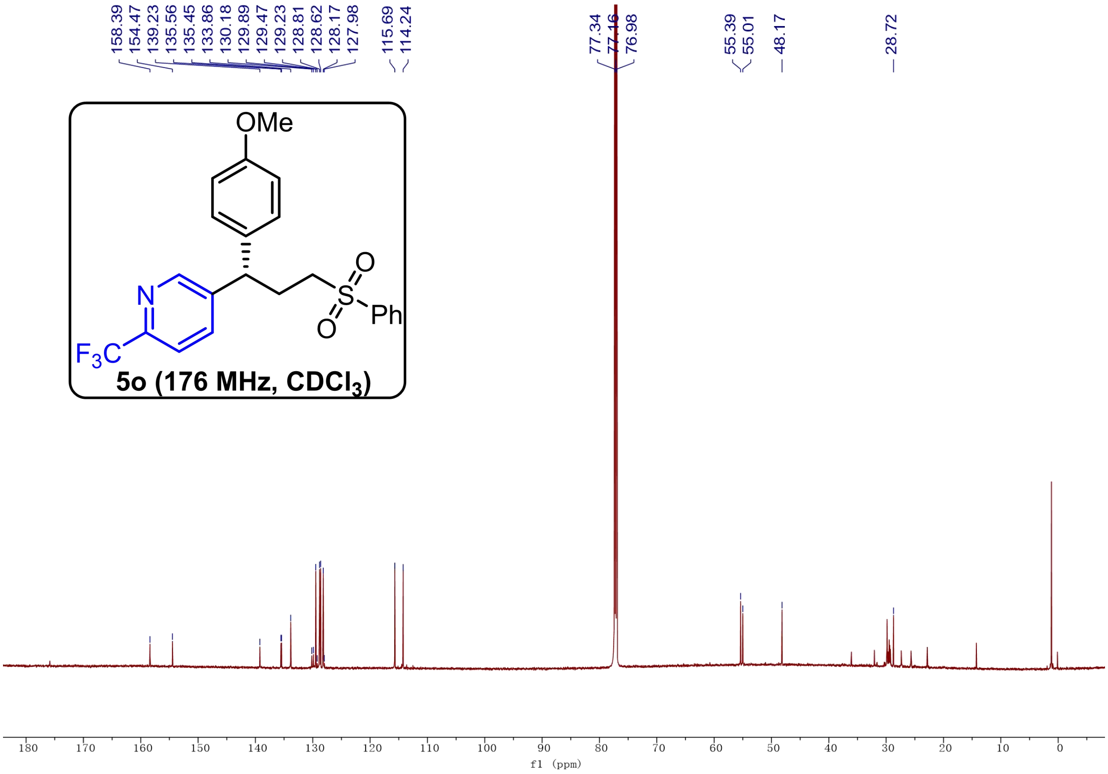

7.91 7.89 7.86 7.85 7.84 7.84 7.61 7.56 7.55 7.54 7.54 7.52 7.51 7.50 7.49 7.45 7.45 7.43 7.42 7.42 7.40 7.27 7.27 7.26 7.17 7.15 7.11 7.10 7.09 6.82 6.79 4.85 4.83 4.81 3.74 3.20 3.18 3.16 2.62 2.61 2.60 2.60 2.59 2.57 2.57
OMe
O
S
O
O
Ph
5m (400 MHz, CDCl$_3$)
3.00 7.10 1.28 2.05 1.04 2.02 1.03 3.08 2.05 2.07
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

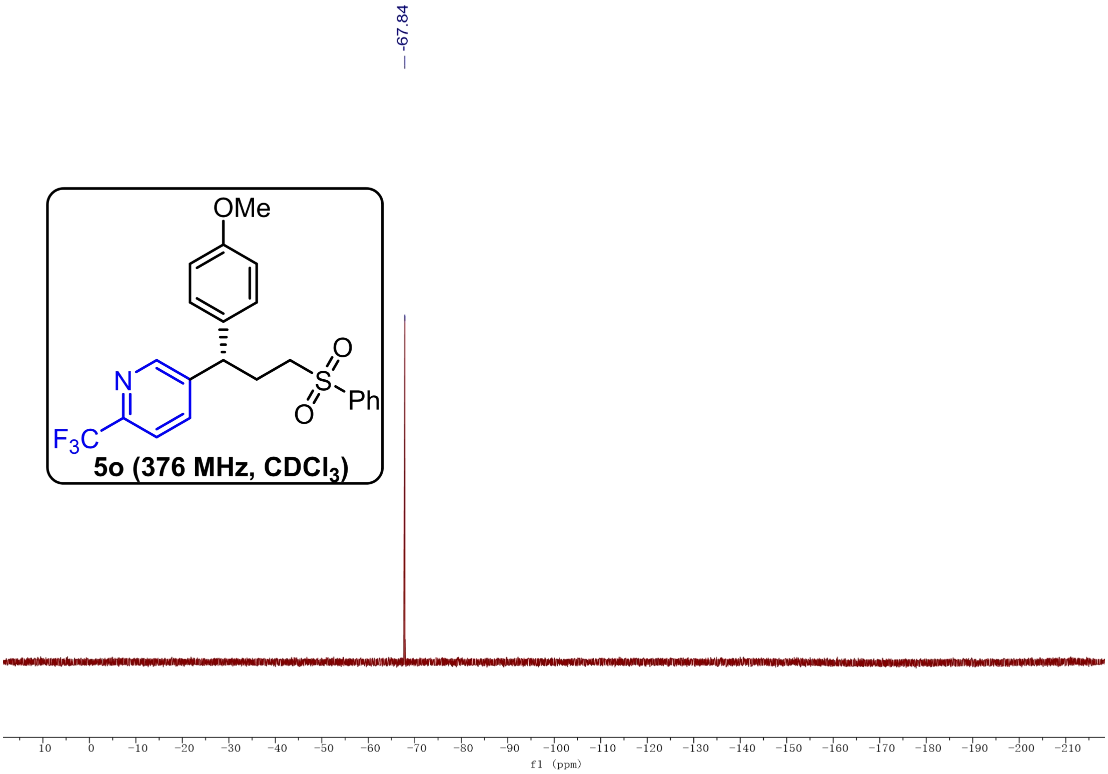

158.59 156.60 156.22 139.09 138.53 133.85 133.73 129.42 129.07 128.12 127.43 127.01 123.65 122.91 122.65 122.61 121.00 114.33 111.85 110.27 77.48 77.16 76.84 55.35 54.87 45.27 28.74
OMe
O
S
O
O
Ph
5m (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

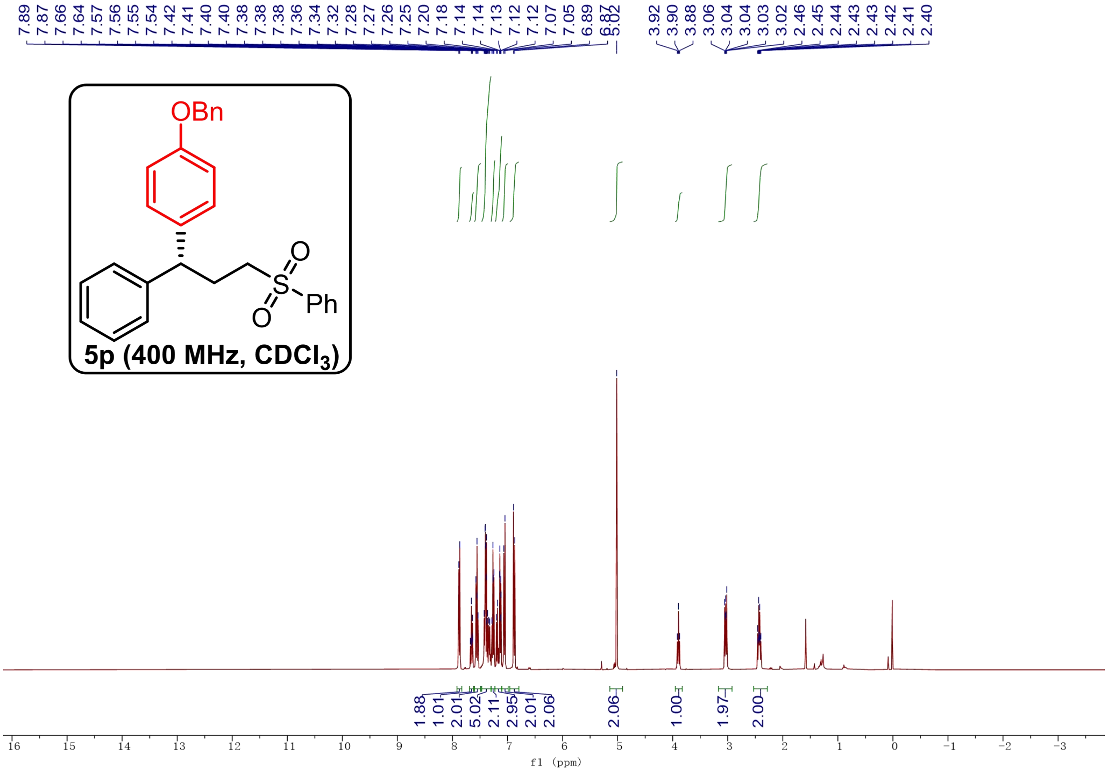

7.96
7.94
7.87
7.86
7.86
7.85
7.85
7.84
7.67
7.65
7.65
7.58
7.56
7.56
7.54
7.54
7.46
7.44
7.42
7.36
7.28
7.27
7.26
7.26
7.25
7.24
7.23
7.18
7.17
7.16
7.16
7.11
7.09
7.09
7.07
7.03
7.01
6.78
6.76
4.10
4.08
4.06
3.76
3.07
3.05
3.04
3.04
3.03
3.02
3.01
3.00
3.00
2.57
2.56
2.55
2.53
2.34
2.32
2.31
2.30
OMe
O
S
O
Ph
N
PhO$_2$S
5n (400 MHz, CDCl$_3$)
1.00
3.74
1.04
2.92
1.99
1.00
1.18
1.00
1.01
1.85
1.92
1.12
3.00
1.94
1.01
1.09
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

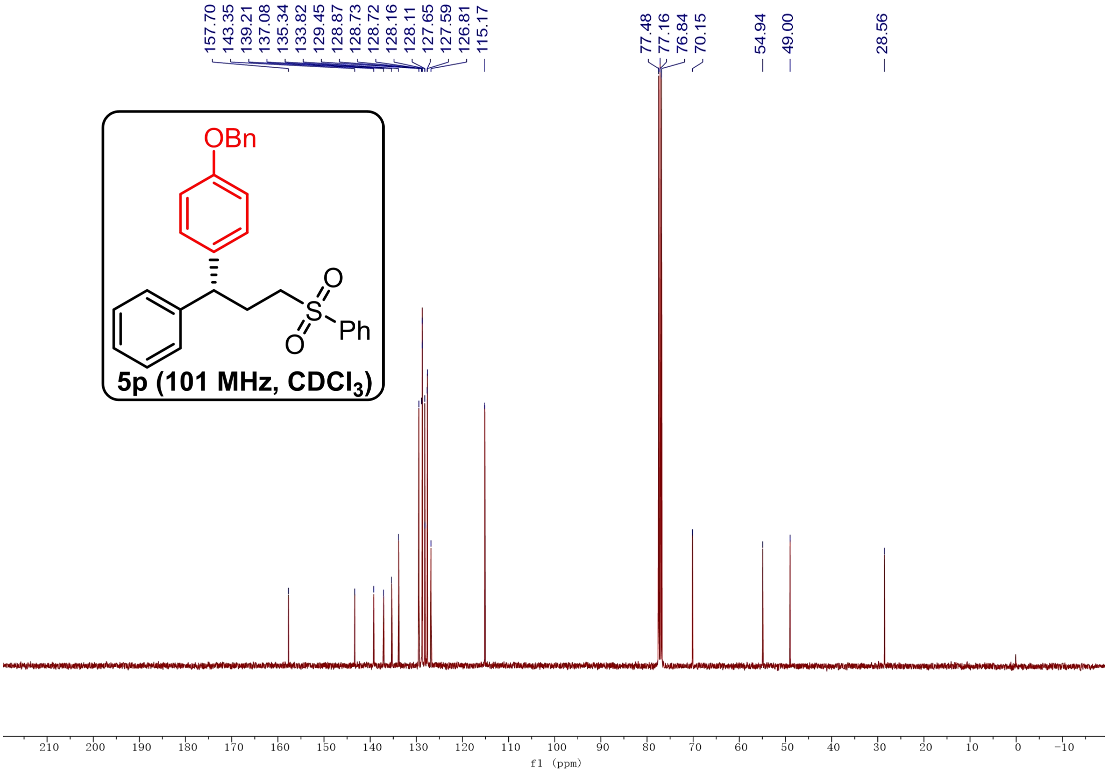

158.75
139.17
138.16
135.73
133.99
133.94
133.06
130.08
129.54
129.43
128.80
128.09
126.84
125.72
125.14
123.45
122.64
120.18
114.39
113.94
77.48
77.16
76.84
55.38
54.46
40.53
28.29
OMe
O
S
O
Ph
N
PhO$_2$S
5n (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

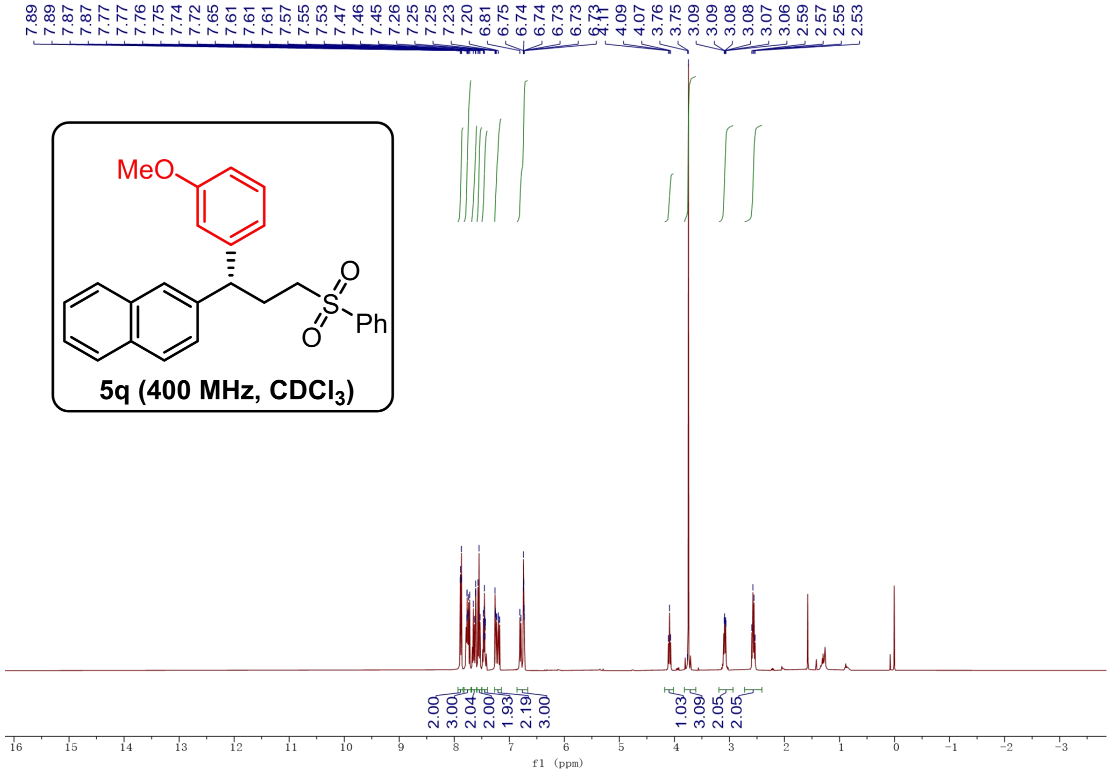

8.55
7.89
7.87
7.68
7.66
7.63
7.62
7.59
7.58
7.57
7.56
7.07
7.04
6.86
6.84
4.10
4.08
4.06
3.78
3.05
3.03
3.03
3.02
3.01
2.52
2.51
2.50
2.48
2.48
2.47
2.46
2.44
OMe
N
F3C
S
O
O
Ph
5o (400 MHz, CDCl3)
1.01
2.10
5.03
2.00
2.09
1.10
3.05
2.00
2.04
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

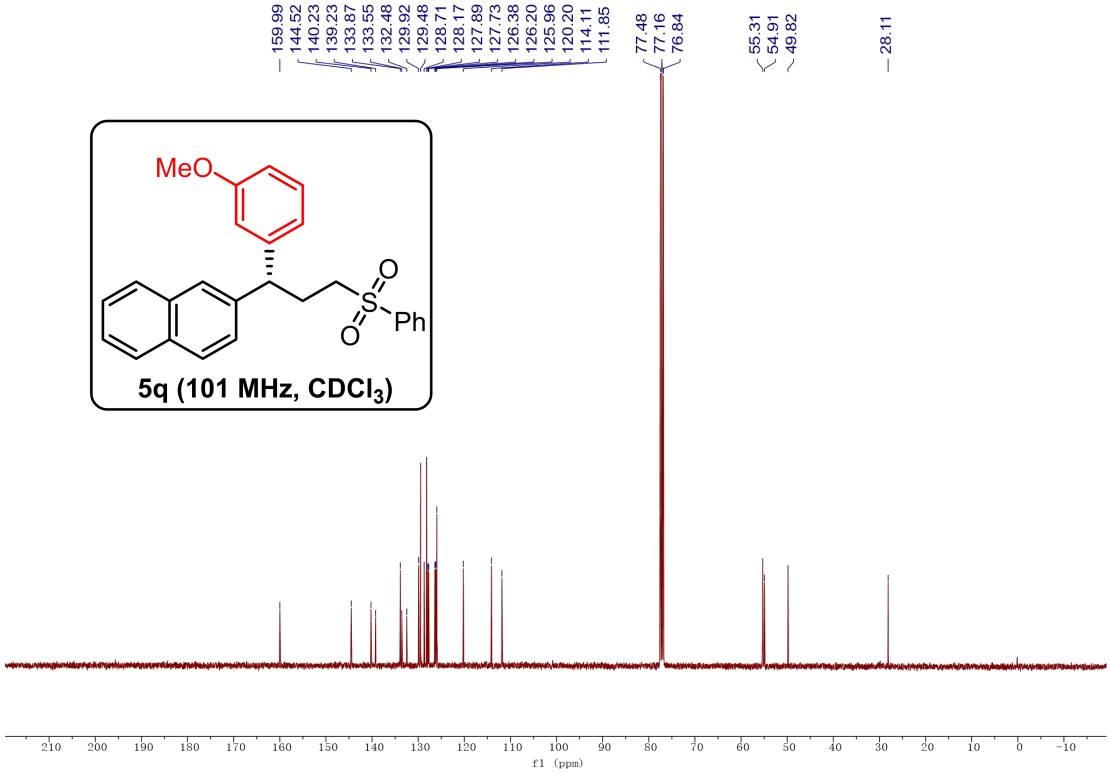

158.39
154.47
139.23
135.56
135.45
133.86
130.18
129.89
129.47
129.23
128.81
128.62
128.17
127.98
115.69
114.24
77.34
77.16
76.98
55.39
55.01
48.17
28.72
OMe
N
F3C
S
O
O
Ph
5o (176 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

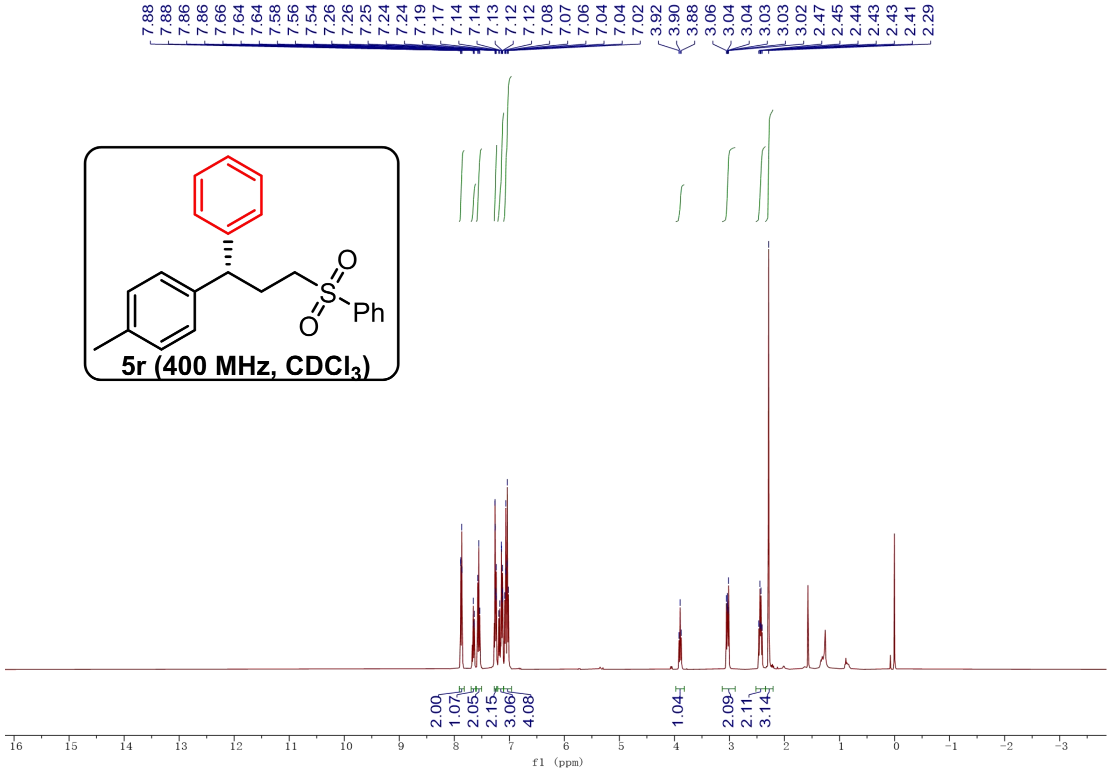

-67.84
OMe
N
F3C
S
O
O
Ph
5o (376 MHz, CDCl3)
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)


7.89
7.87
7.66
7.64
7.57
7.56
7.55
7.54
7.42
7.41
7.40
7.40
7.38
7.38
7.38
7.36
7.34
7.32
7.28
7.27
7.26
7.25
7.20
7.18
7.14
7.14
7.13
7.12
7.12
7.07
7.05
6.89
6.87
5.02
3.92
3.90
3.88
3.06
3.04
3.04
3.03
3.02
2.46
2.45
2.44
2.43
2.43
2.42
2.41
2.40
OBn
O
S
O
Ph
5p (400 MHz, CDCl$_3$)
1.88
1.01
2.01
5.02
2.11
2.95
2.01
2.06
2.06
1.00
1.97
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

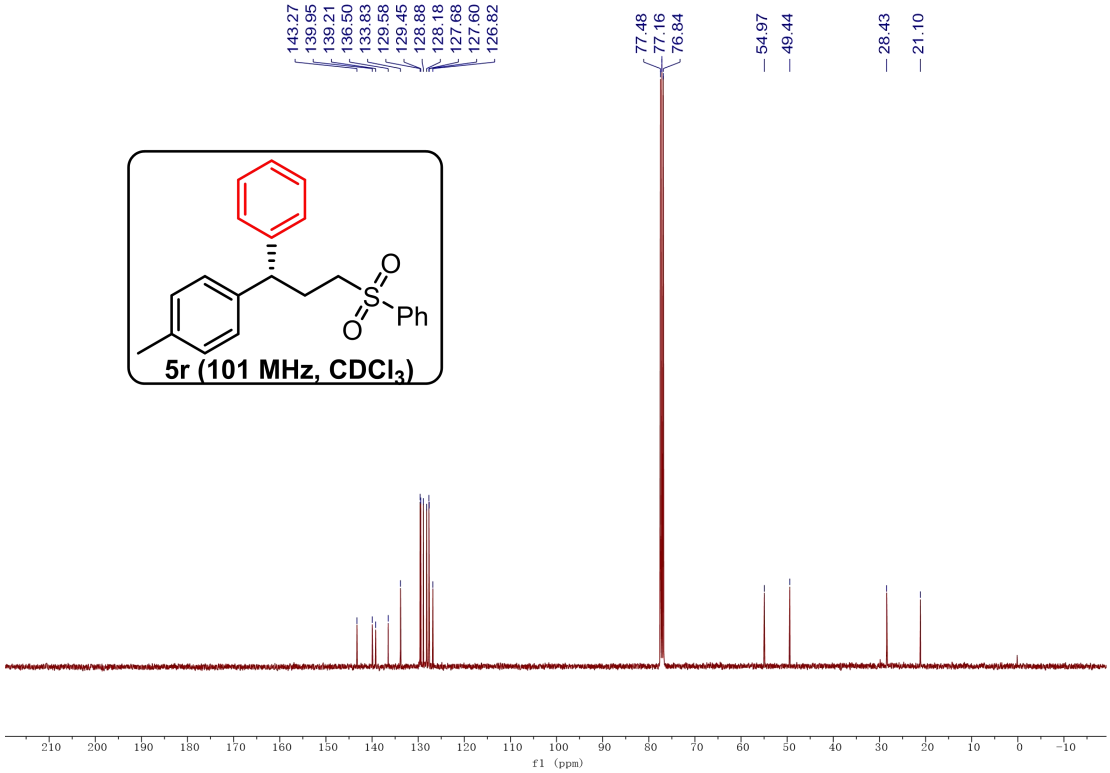

157.70
143.35
139.21
137.08
135.34
133.82
129.45
128.87
128.73
128.72
128.16
128.11
127.65
127.59
126.81
115.17
77.48
77.16
76.84
70.15
54.94
49.00
28.56
OBn
O
S
O
Ph
5p (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.89
7.89
7.87
7.87
7.77
7.77
7.76
7.75
7.74
7.72
7.65
7.61
7.61
7.61
7.57
7.55
7.53
7.47
7.46
7.45
7.26
7.25
7.25
7.23
7.20
6.81
6.75
6.74
6.74
6.73
6.73
6.73
4.11
4.09
4.07
3.76
3.75
3.09
3.09
3.08
3.08
3.07
3.06
2.59
2.57
2.55
2.53
MeO
O
S
O
Ph
5q (400 MHz, CDCl$_3$)
2.00
3.00
2.04
2.00
1.93
2.19
3.00
1.03
3.09
2.05
2.05
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

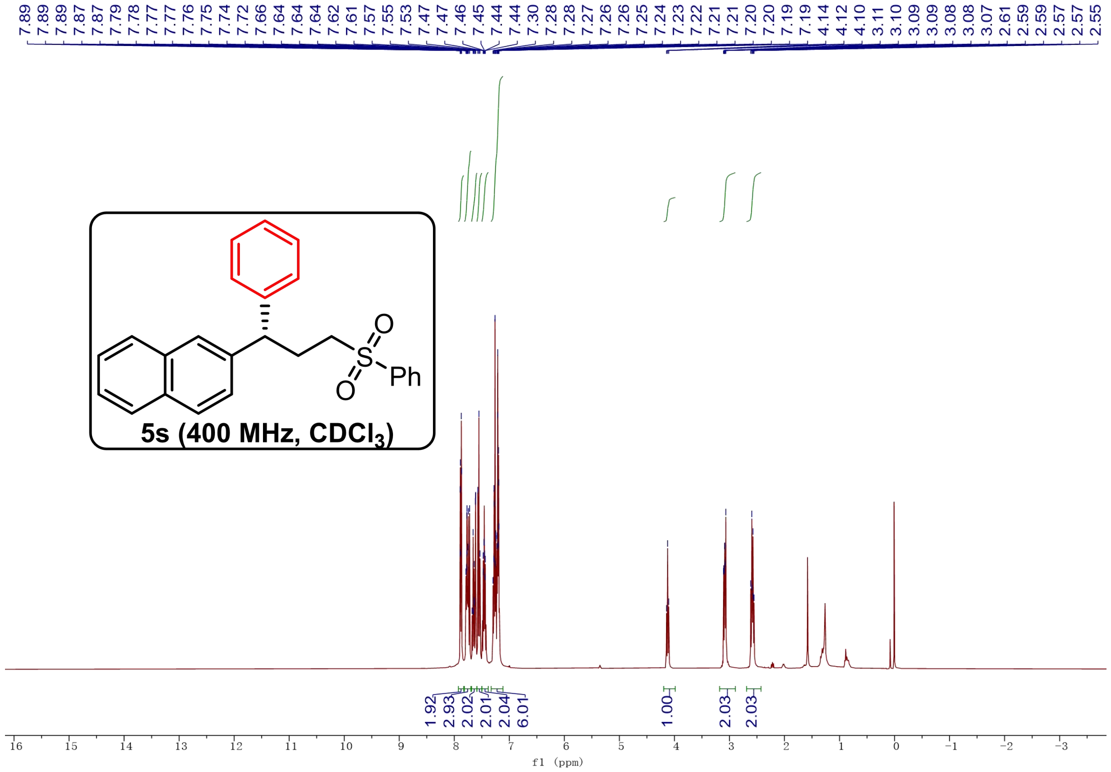

159.99
144.52
140.23
139.23
133.87
133.55
132.48
129.92
129.48
128.71
128.17
127.89
127.73
126.38
126.20
125.96
120.20
114.11
111.85
77.48
77.16
76.84
55.31
54.91
49.82
28.11
MeO
O
S
O
Ph
5q (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

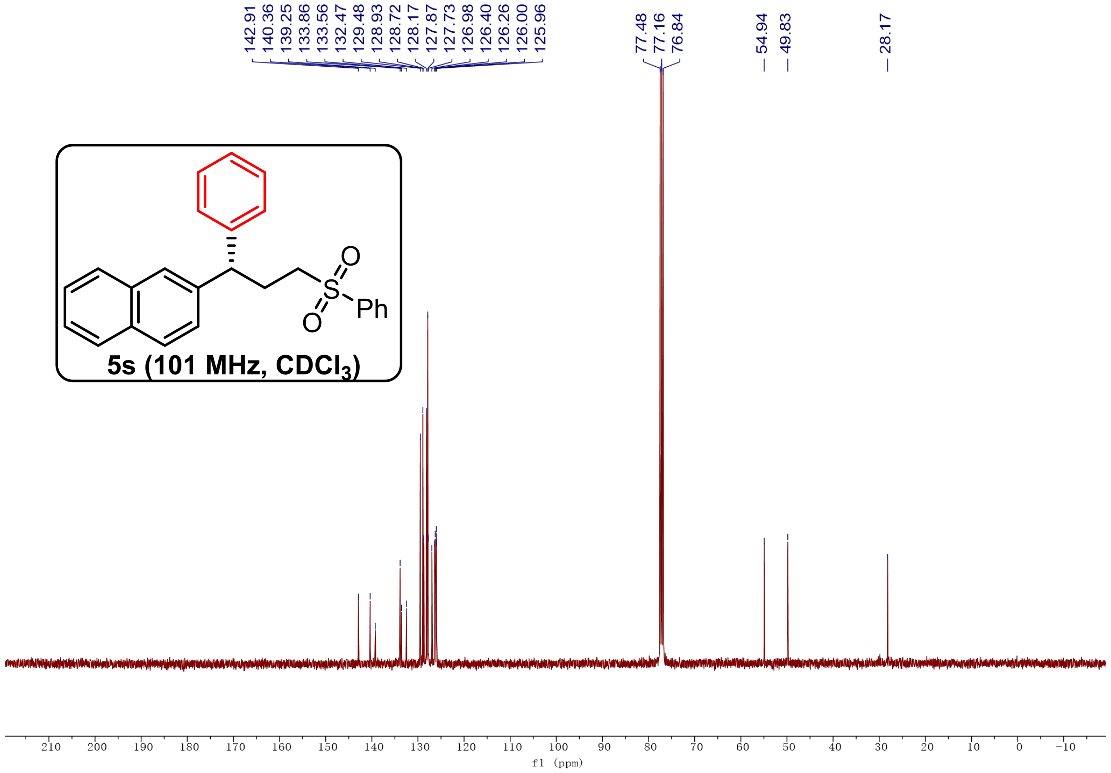


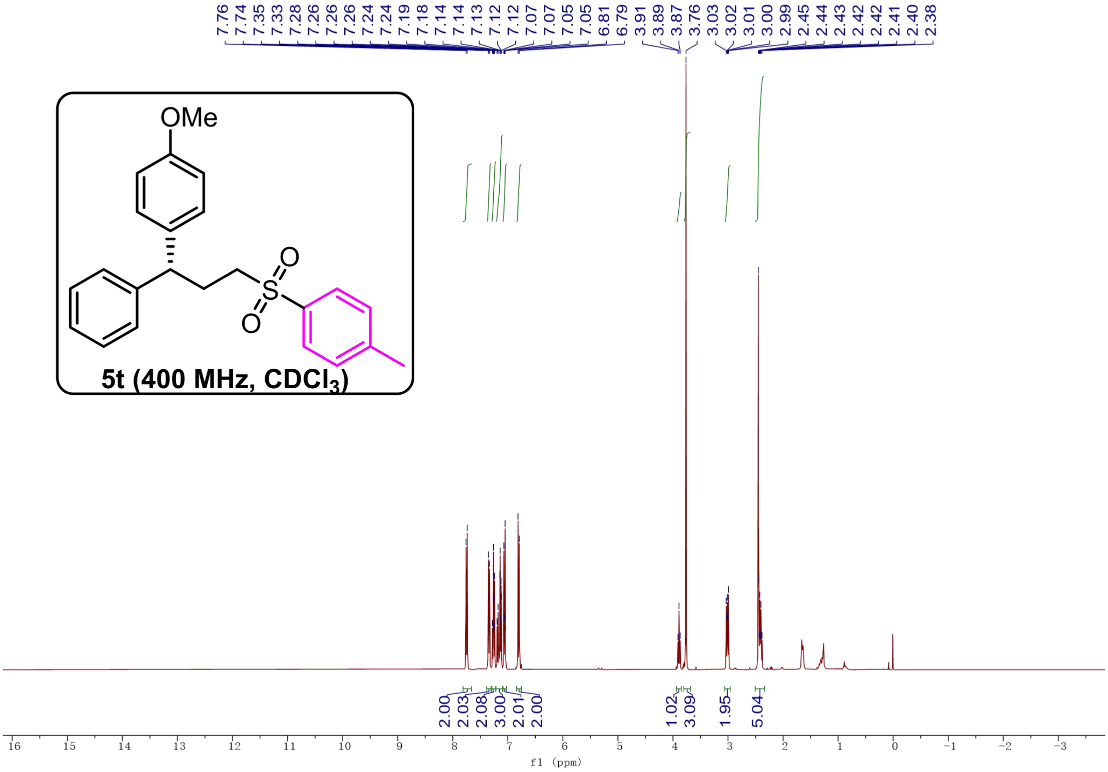
7.88
7.88
7.86
7.66
7.64
7.64
7.58
7.56
7.54
7.26
7.26
7.25
7.24
7.24
7.19
7.17
7.14
7.14
7.13
7.12
7.12
7.08
7.07
7.06
7.04
7.04
7.02
3.92
3.90
3.88
3.06
3.04
3.04
3.03
3.03
3.02
2.47
2.45
2.44
2.43
2.43
2.41
2.29
O
S
Ph
O
5r (400 MHz, CDCl3)
2.00
1.07
2.05
2.15
3.06
4.08
1.04
2.09
2.11
3.14
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)

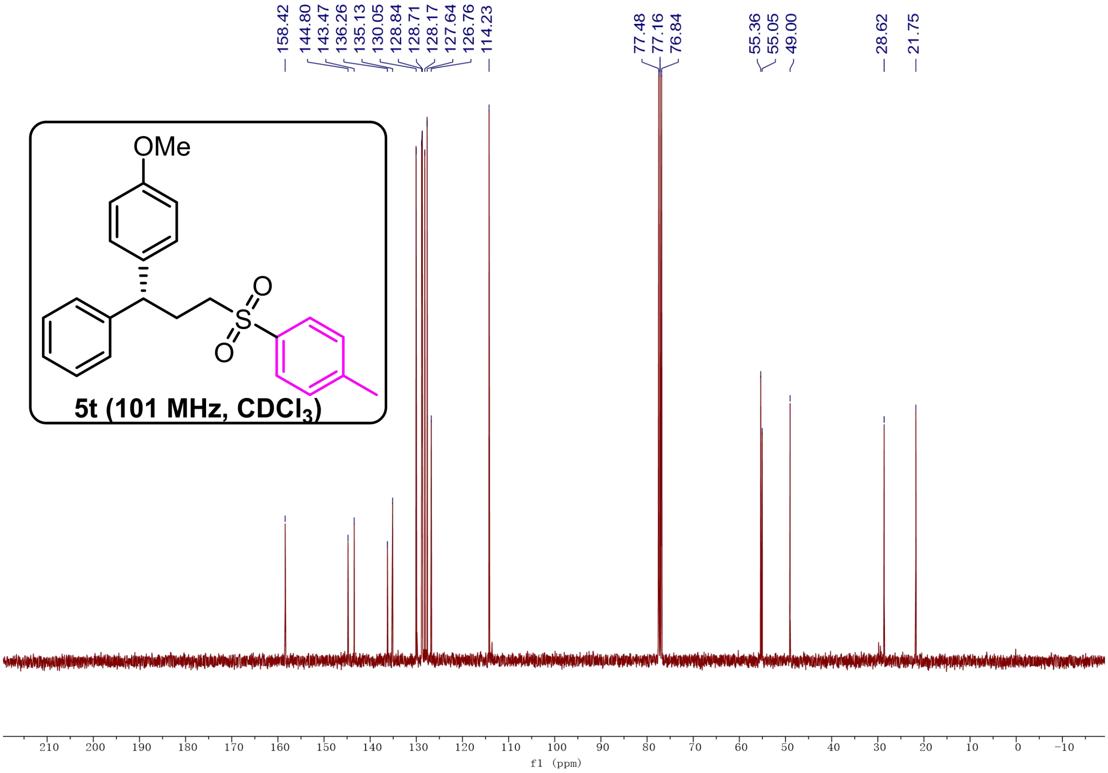


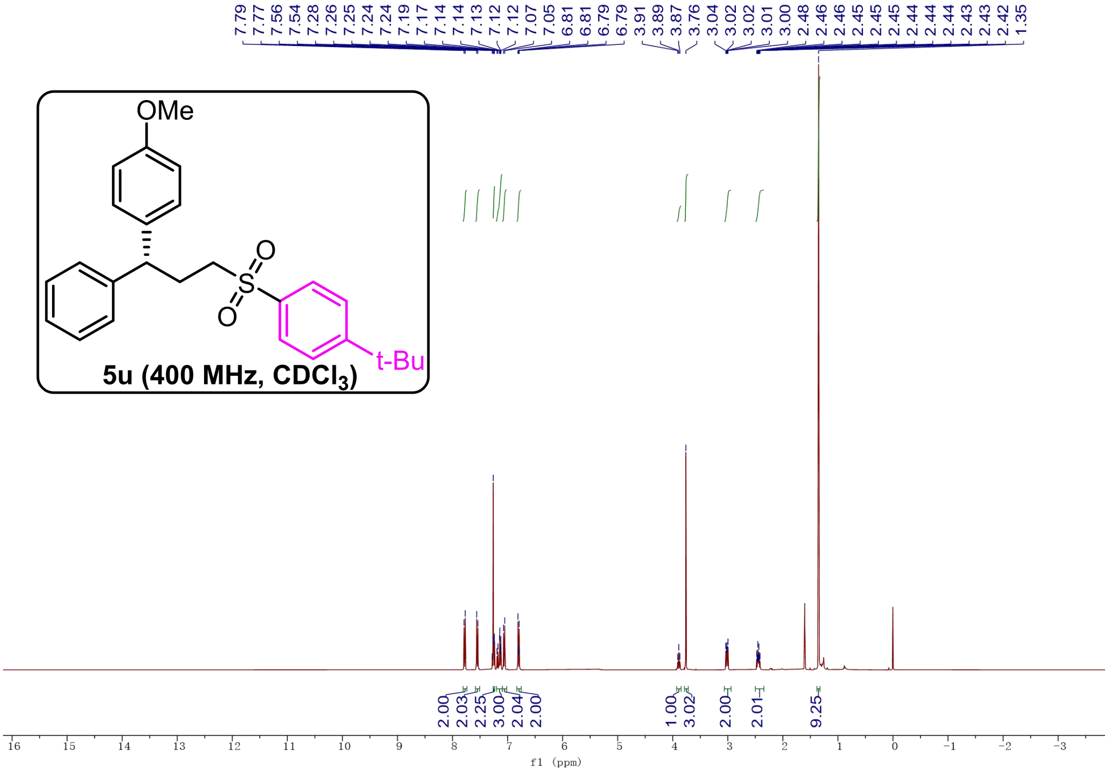
143.27
139.95
139.21
136.50
133.83
129.58
129.45
128.88
128.18
127.68
127.60
126.82
77.48
77.16
76.84
54.97
49.44
28.43
21.10
O
S
Ph
O
5r (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

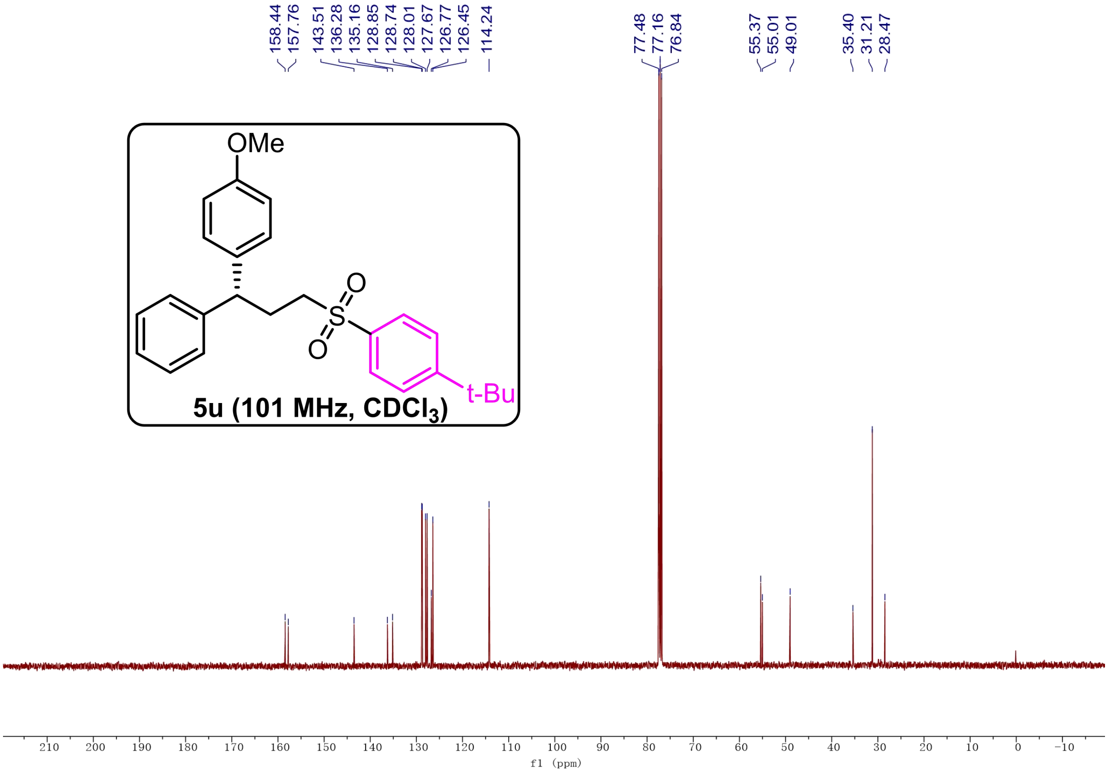

7.89 7.89 7.87 7.87 7.79 7.78 7.77 7.77 7.76 7.75 7.74 7.72 7.66 7.64 7.64 7.64 7.62 7.61 7.57 7.55 7.53 7.47 7.47 7.46 7.45 7.44 7.44 7.30 7.28 7.28 7.27 7.26 7.26 7.25 7.24 7.23 7.22 7.21 7.21 7.20 7.20 7.19 7.19 4.14 4.12 4.10 3.11 3.10 3.09 3.09 3.08 3.08 3.07 2.61 2.59 2.59 2.57 2.57 2.55
O
S
Ph
O
5s (400 MHz, CDCl$_3$)
1.92
2.93
2.02
2.01
2.04
6.01
1.00
2.03
2.03
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

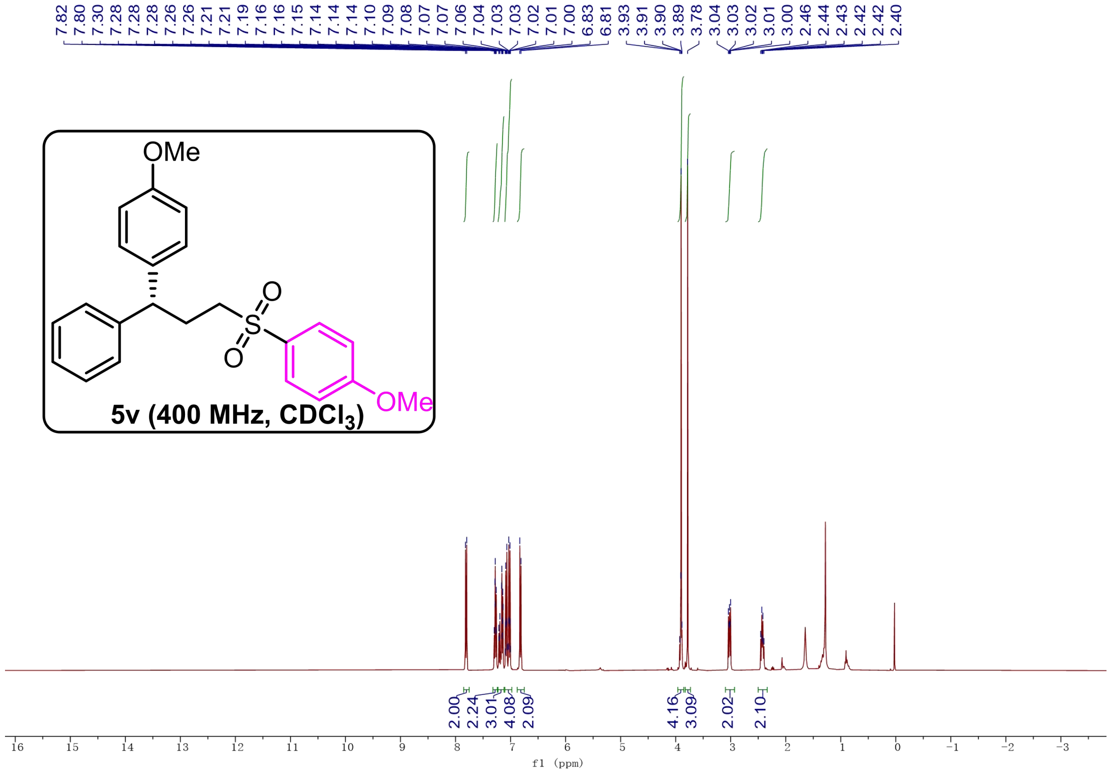

142.91 140.36 139.25 133.86 133.56 132.47 129.48 128.93 128.72 128.17 127.87 127.73 126.98 126.40 126.26 126.00 125.96
77.48 77.16 76.84
54.94
49.83
28.17
O
S
Ph
O
5s (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

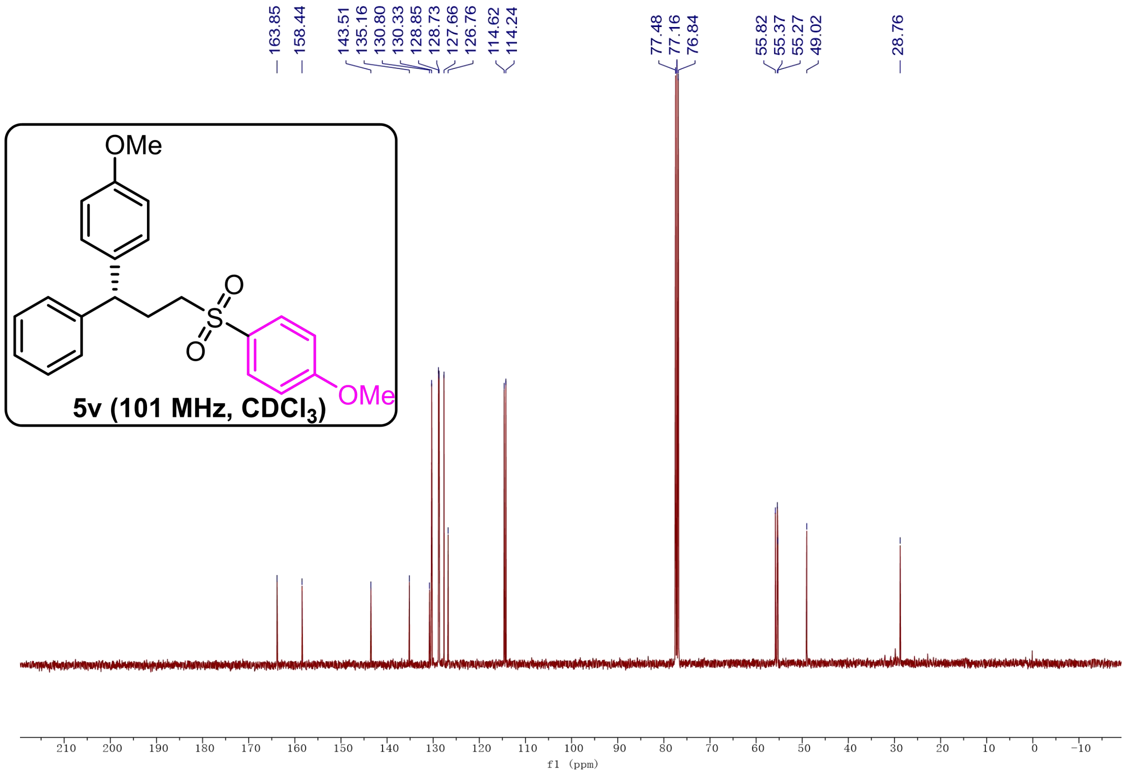

7.76
7.74
7.35
7.33
7.28
7.26
7.26
7.26
7.24
7.24
7.19
7.18
7.14
7.14
7.13
7.12
7.12
7.07
7.07
7.05
7.05
6.81
6.79
3.91
3.89
3.87
3.76
3.03
3.02
3.01
3.00
2.99
2.45
2.44
2.43
2.42
2.42
2.41
2.40
2.38
OMe
O
S
O
5t (400 MHz, CDCl$_3$)
2.00
2.03
2.08
3.00
2.01
2.00
1.02
3.09
1.95
5.04
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)

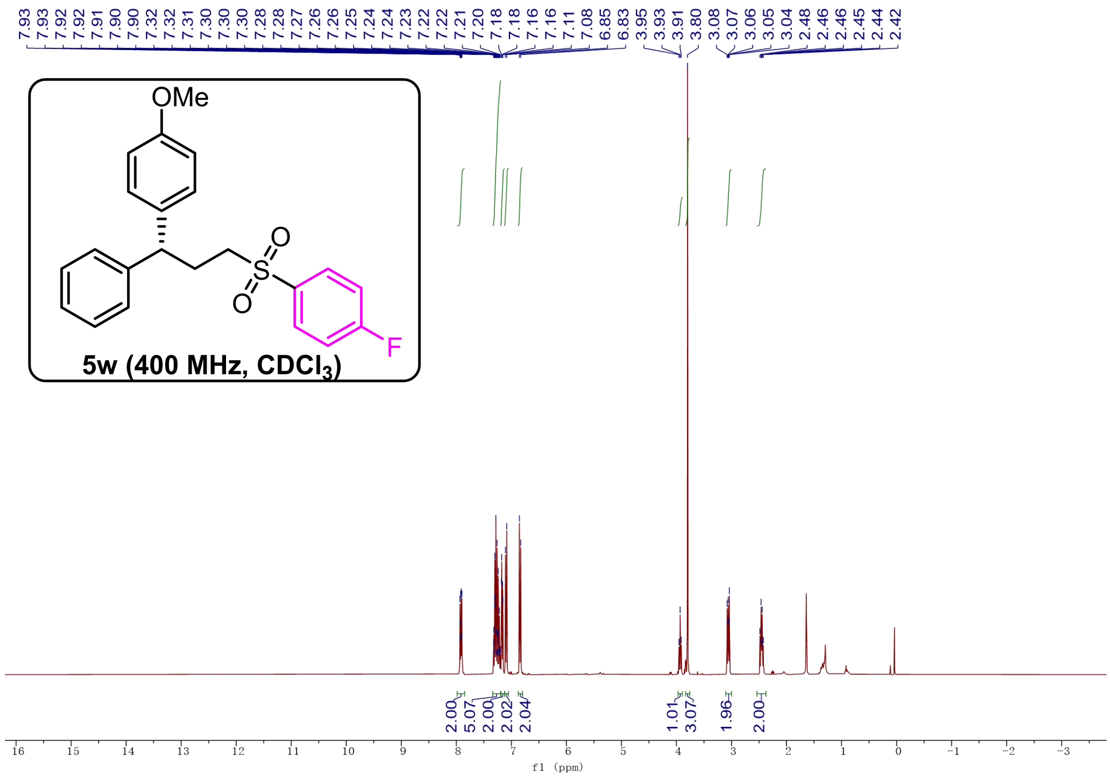

158.42
144.80
143.47
136.26
135.13
130.05
128.84
128.71
128.17
127.64
126.76
114.23
77.48
77.16
76.84
55.36
55.05
49.00
28.62
21.75
OMe
O
S
O
5t (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

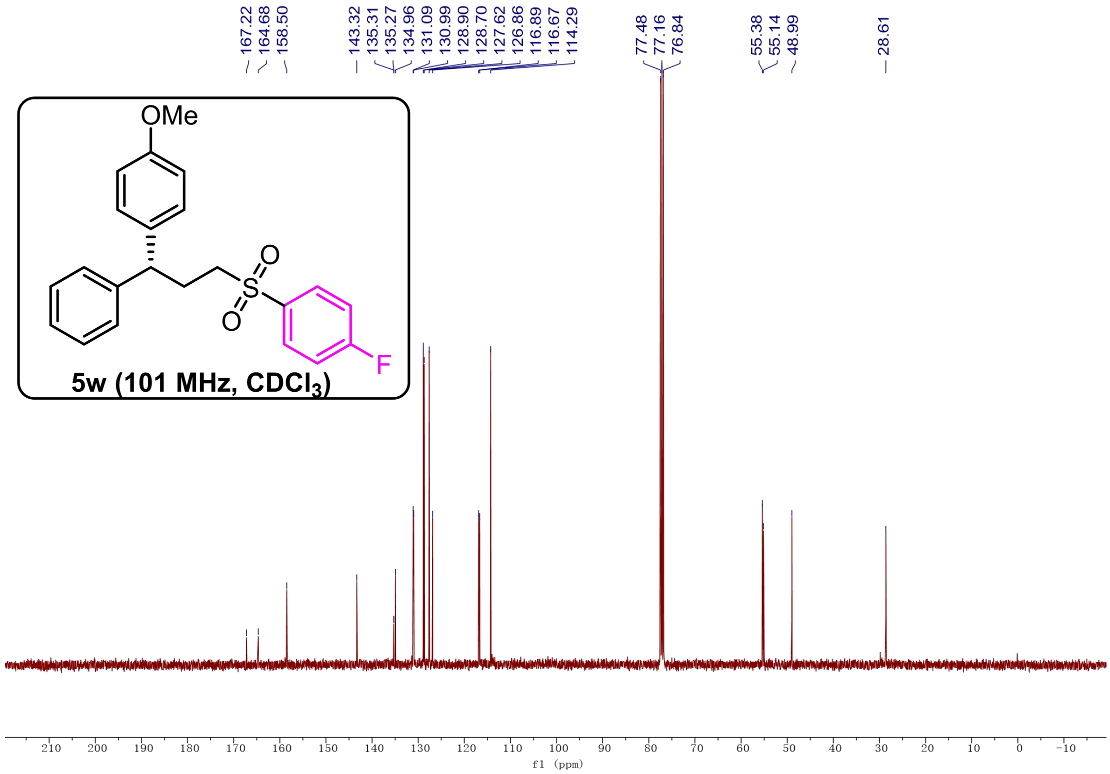

7.79
7.77
7.56
7.54
7.28
7.26
7.25
7.24
7.24
7.19
7.17
7.14
7.14
7.13
7.12
7.12
7.07
7.05
6.81
6.81
6.79
6.79
3.91
3.89
3.87
3.76
3.04
3.02
3.02
3.01
3.00
2.48
2.46
2.46
2.45
2.45
2.45
2.44
2.44
2.44
2.43
2.42
1.35
OMe
S
O
O
t-Bu
5u (400 MHz, CDCl$_3$)
2.00
2.03
2.25
3.00
2.04
2.00
1.00
3.02
2.00
2.01
9.25
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

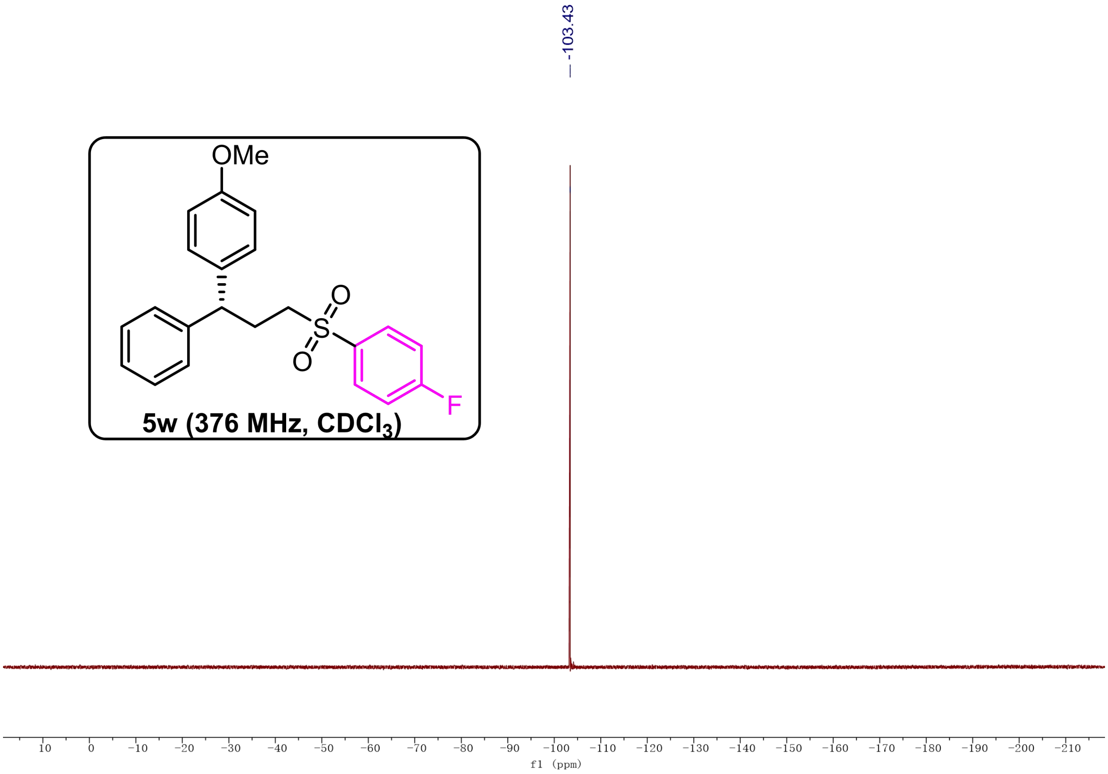

158.44
157.76
143.51
136.28
135.16
128.85
128.74
128.01
127.67
126.77
126.45
114.24
77.48
77.16
76.84
55.37
55.01
49.01
35.40
31.21
28.47
OMe
S
O
O
t-Bu
5u (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

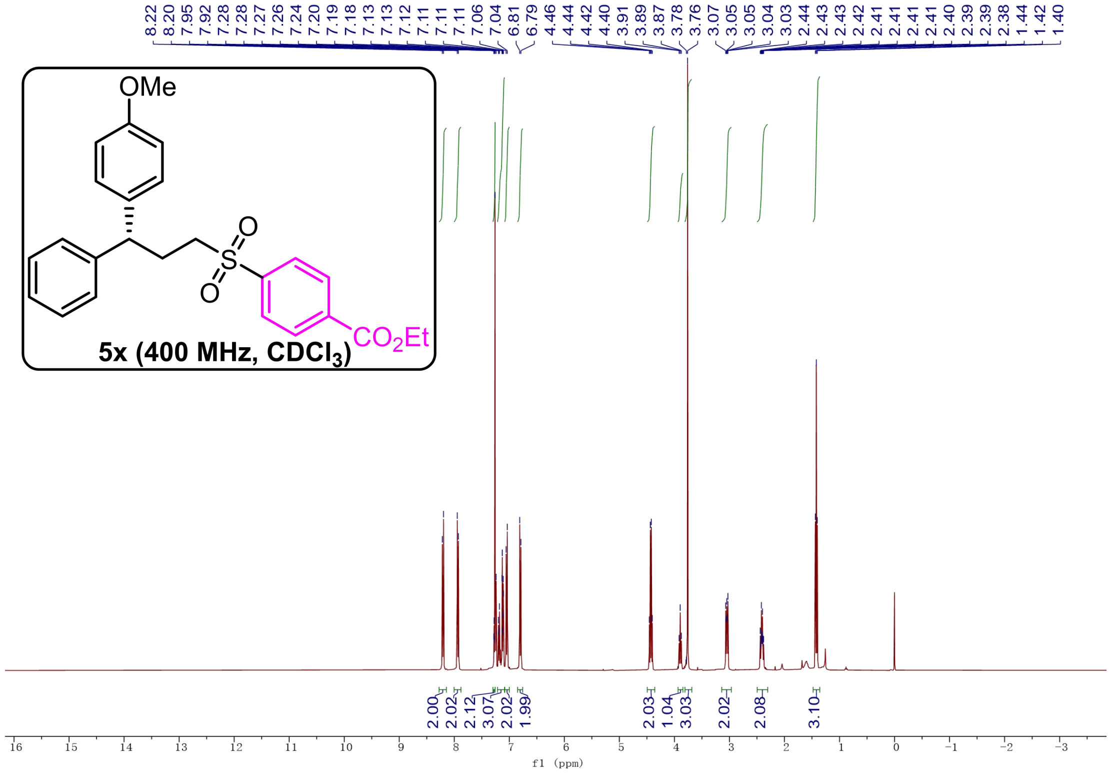

7.82
7.80
7.30
7.28
7.28
7.28
7.26
7.26
7.21
7.21
7.19
7.16
7.16
7.15
7.14
7.14
7.14
7.10
7.09
7.08
7.07
7.07
7.06
7.04
7.03
7.03
7.02
7.01
7.00
6.83
6.81
3.93
3.91
3.90
3.89
3.78
3.04
3.03
3.02
3.01
3.00
2.46
2.44
2.43
2.42
2.42
2.40
OMe
O
S
O
OMe
5v (400 MHz, CDCl$_3$)
2.00
2.24
3.01
4.08
2.09
4.16
3.09
2.02
2.10
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

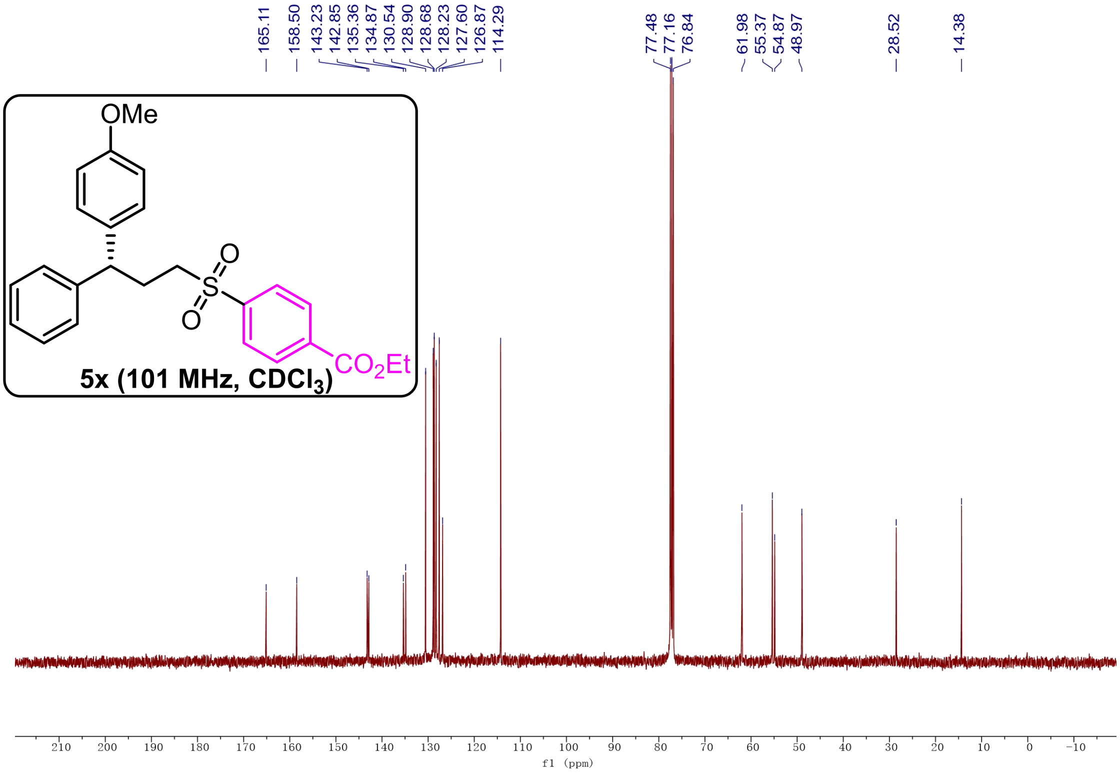

163.85
158.44
143.51
135.16
130.80
130.33
128.85
128.73
127.66
126.76
114.62
114.24
77.48
77.16
76.84
55.82
55.37
55.27
49.02
28.76
OMe
O
S
O
OMe
5v (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

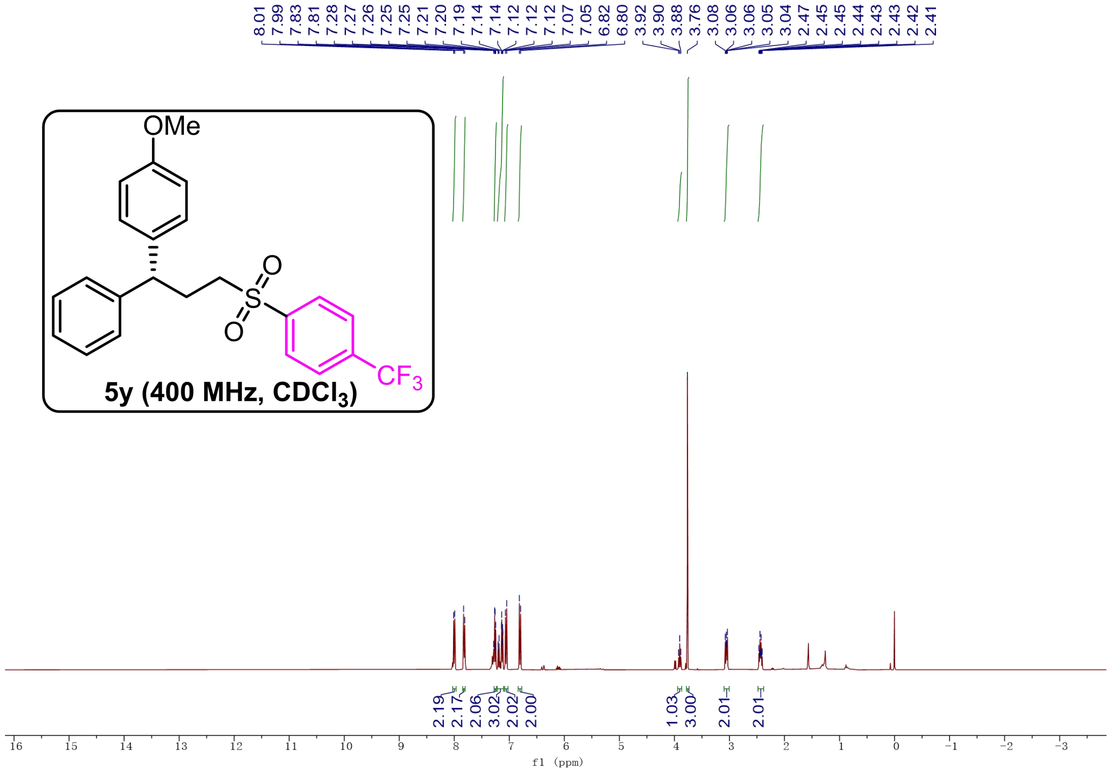

7.93 7.93 7.92 7.92 7.91 7.90 7.90 7.32 7.32 7.31 7.30 7.30 7.28 7.27 7.26 7.25 7.24 7.24 7.23 7.22 7.22 7.21 7.20 7.18 7.18 7.16 7.16 7.11 7.08 6.85 6.83 3.95 3.93 3.91 3.80 3.08 3.07 3.06 3.05 3.04 2.48 2.46 2.45 2.44 2.42
OMe
O
S
O
F
5w (400 MHz, CDCl$_3$)
2.00 5.07 2.00 2.02 2.04 1.01 3.07 1.96 2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

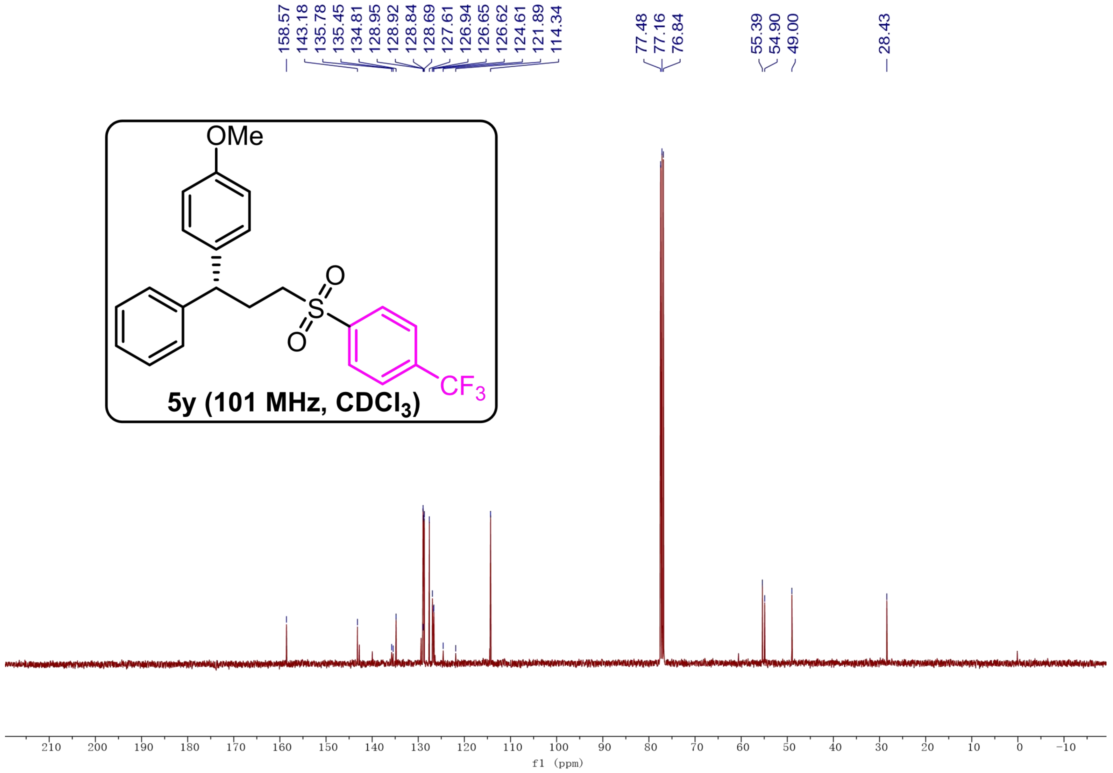

167.22 164.68 158.50 143.32 135.31 135.27 134.96 131.09 130.99 128.90 128.70 127.62 126.86 116.89 116.67 114.29 77.48 77.16 76.84 55.38 55.14 48.99 28.61
OMe
O
S
O
F
5w (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

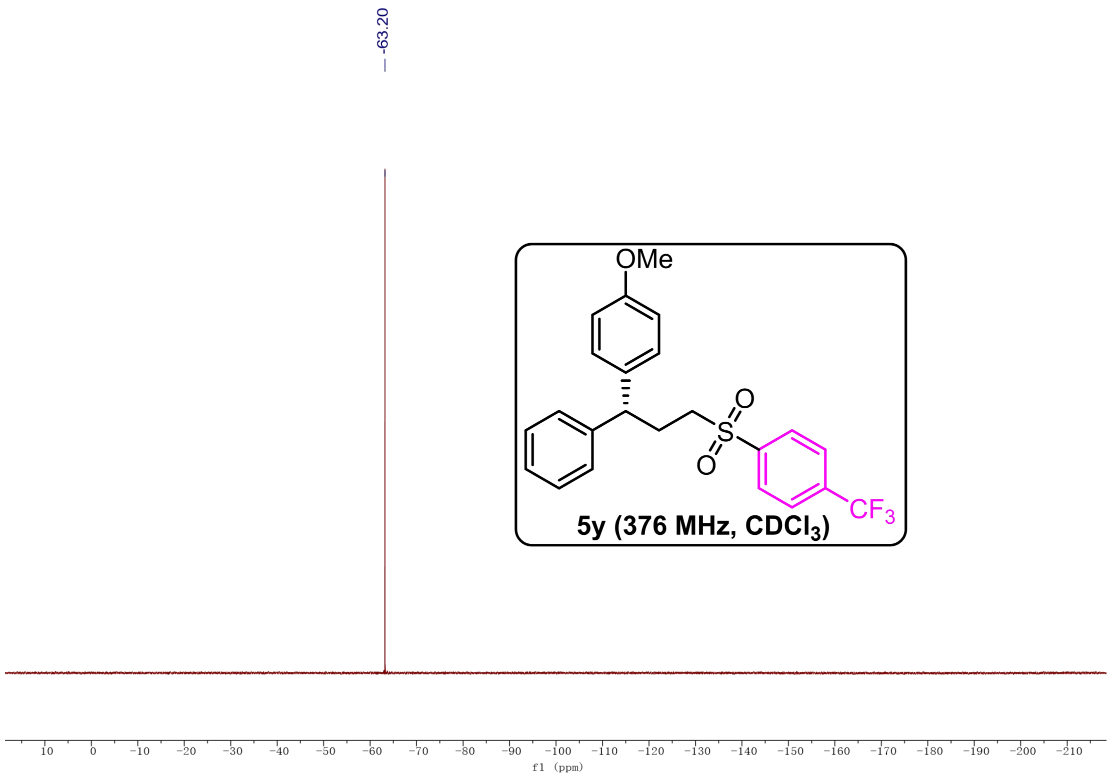

-103.43
OMe
O
S
O
F
5w (376 MHz, $CDCl_3$)
10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −100 −110 −120 −130 −140 −150 −160 −170 −180 −190 −200 −210
f1 (ppm)

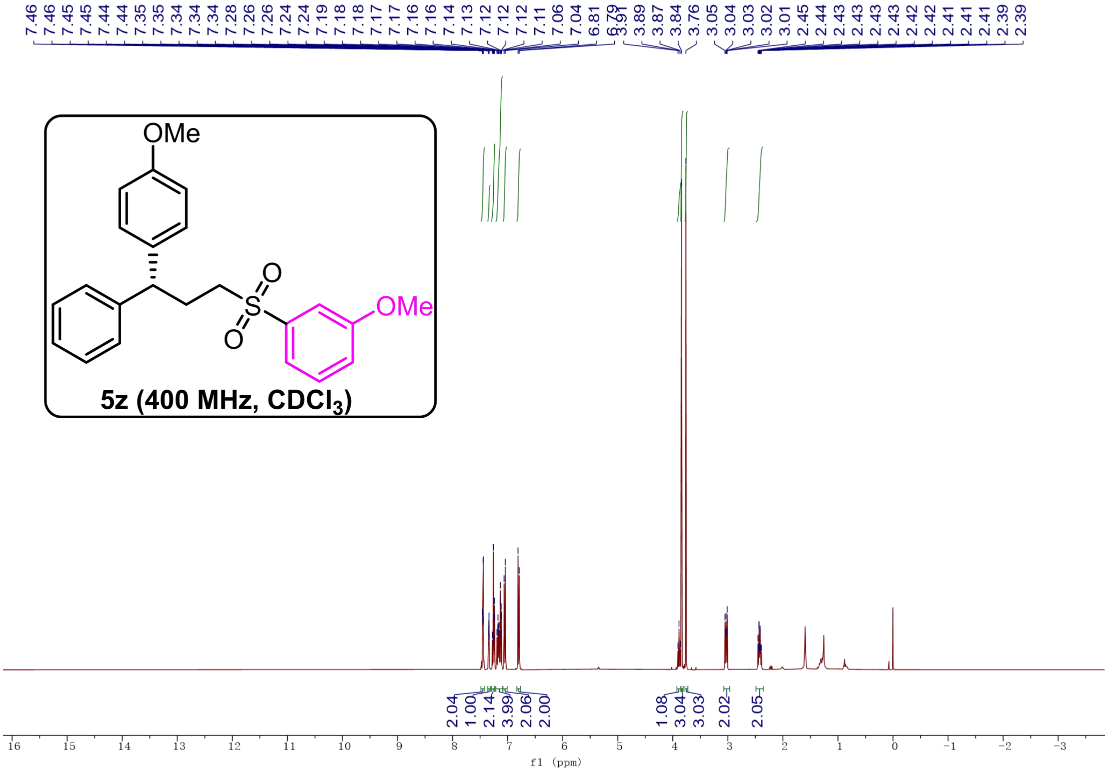

8.22
8.20
7.95
7.92
7.28
7.28
7.27
7.26
7.24
7.20
7.19
7.18
7.13
7.13
7.12
7.11
7.11
7.11
7.06
7.04
6.81
6.79
4.46
4.44
4.42
4.40
3.91
3.89
3.87
3.78
3.76
3.07
3.05
3.05
3.04
3.03
2.44
2.43
2.43
2.42
2.41
2.41
2.41
2.41
2.40
2.39
2.39
2.38
1.44
1.42
1.40
OMe
O
S
O
CO2Et
5x (400 MHz, CDCl3)
2.00
2.02
2.12
3.07
2.02
1.99
2.03
1.04
3.03
2.02
2.08
3.10
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

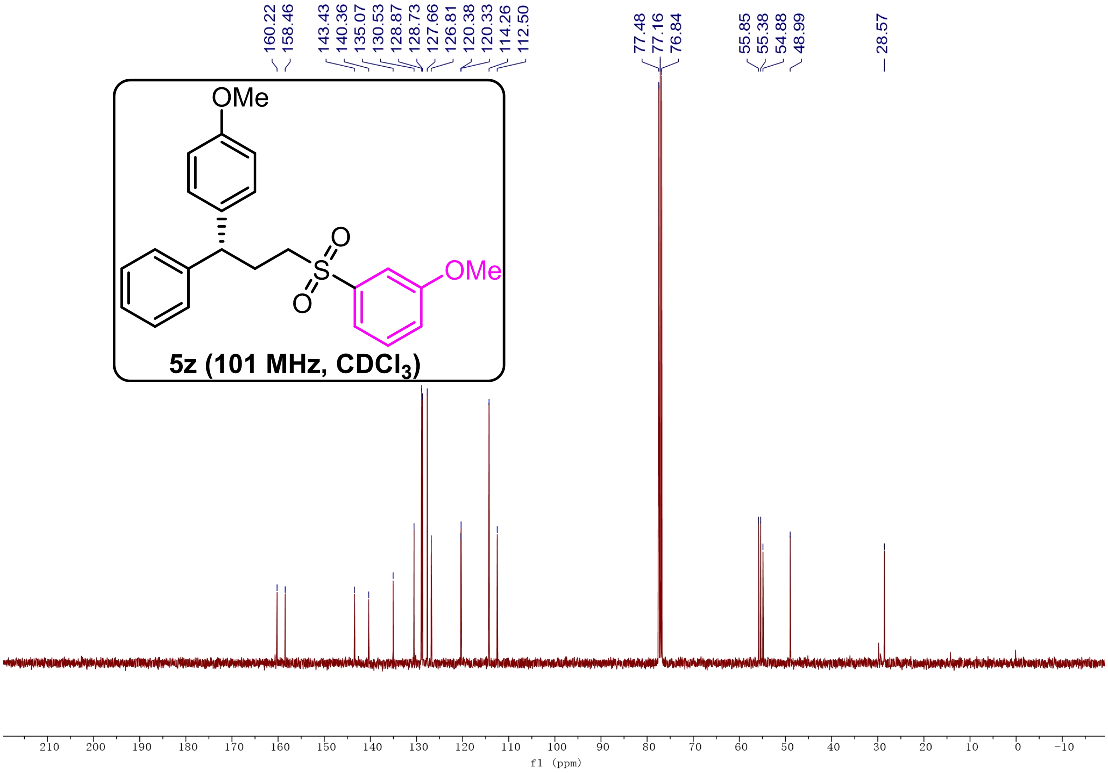

165.11
158.50
143.23
142.85
135.36
134.87
130.54
128.90
128.68
128.23
127.60
126.87
114.29
77.48
77.16
76.84
61.98
55.37
54.87
48.97
28.52
14.38
OMe
O
S
O
CO2Et
5x (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

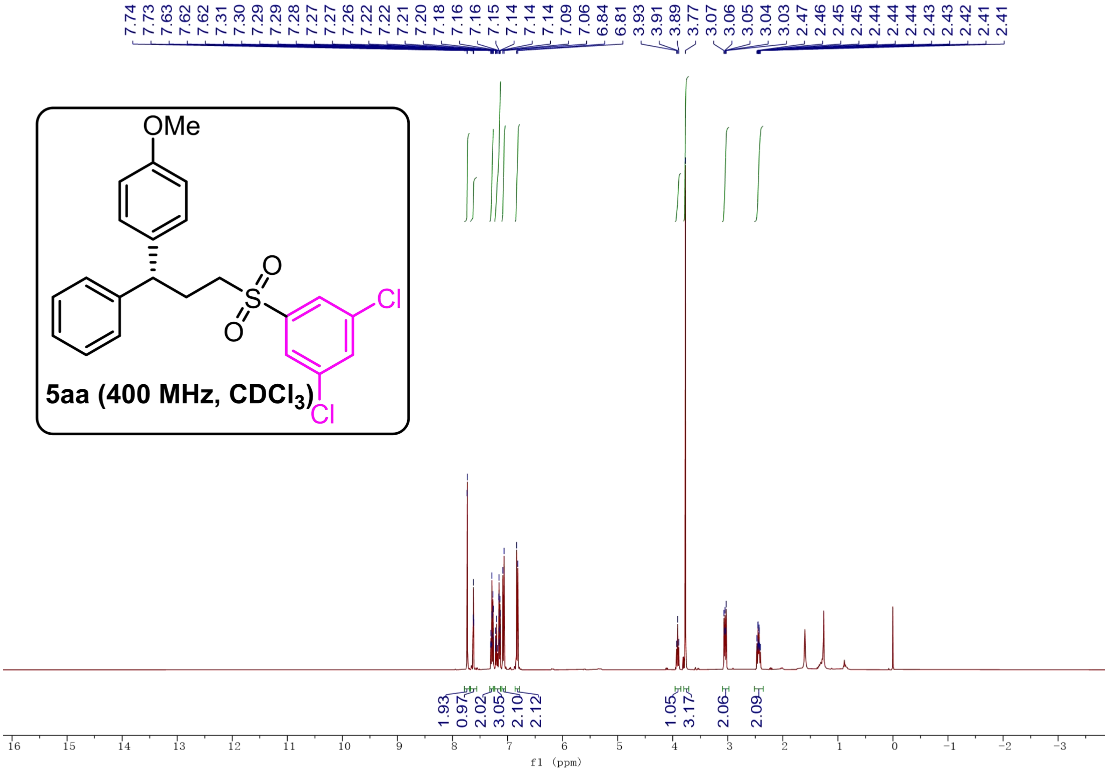

8.01
7.99
7.83
7.81
7.28
7.27
7.26
7.25
7.25
7.21
7.20
7.19
7.14
7.14
7.12
7.12
7.12
7.07
7.05
6.82
6.80
3.92
3.90
3.88
3.76
3.08
3.06
3.06
3.05
3.04
2.47
2.45
2.45
2.44
2.43
2.43
2.42
2.41
OMe
O
S
O
CF3
5y (400 MHz, CDCl3)
2.19
2.17
2.06
3.02
2.02
2.00
1.03
3.00
2.01
2.01
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)

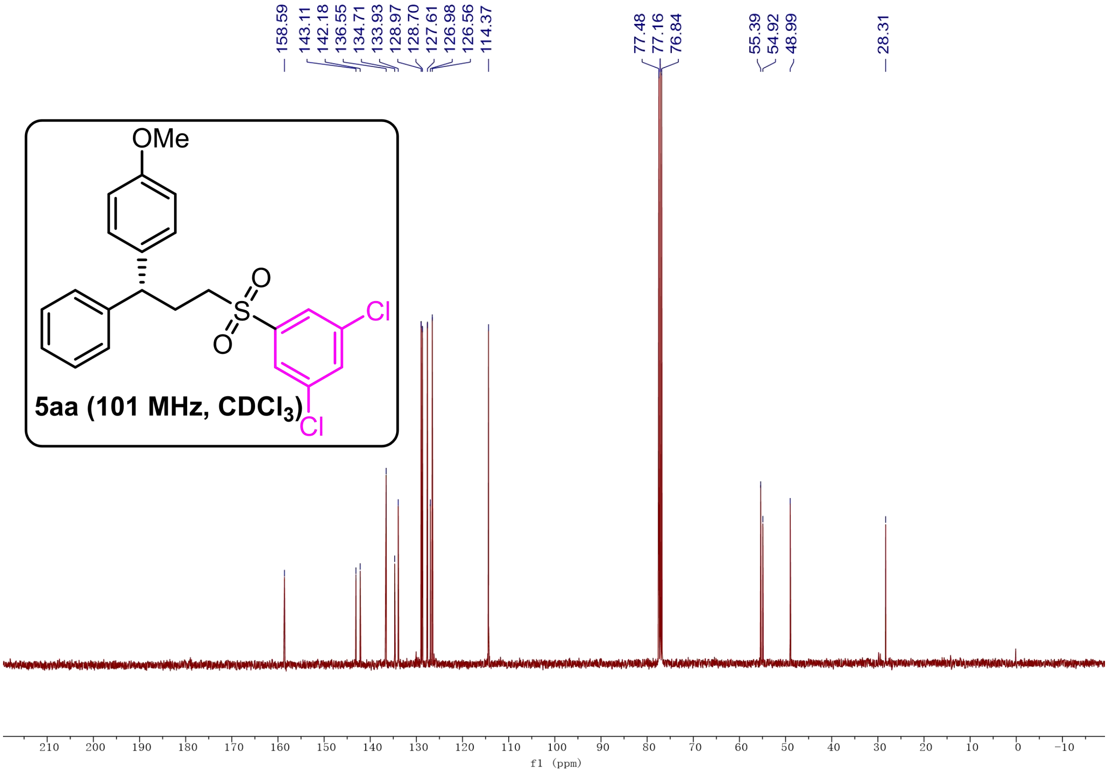

158.57
143.18
135.78
135.45
134.81
128.95
128.92
128.84
128.69
127.61
126.94
126.65
126.62
124.61
121.89
114.34
77.48
77.16
76.84
55.39
54.90
49.00
28.43
OMe
O
S
O
CF3
5y (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

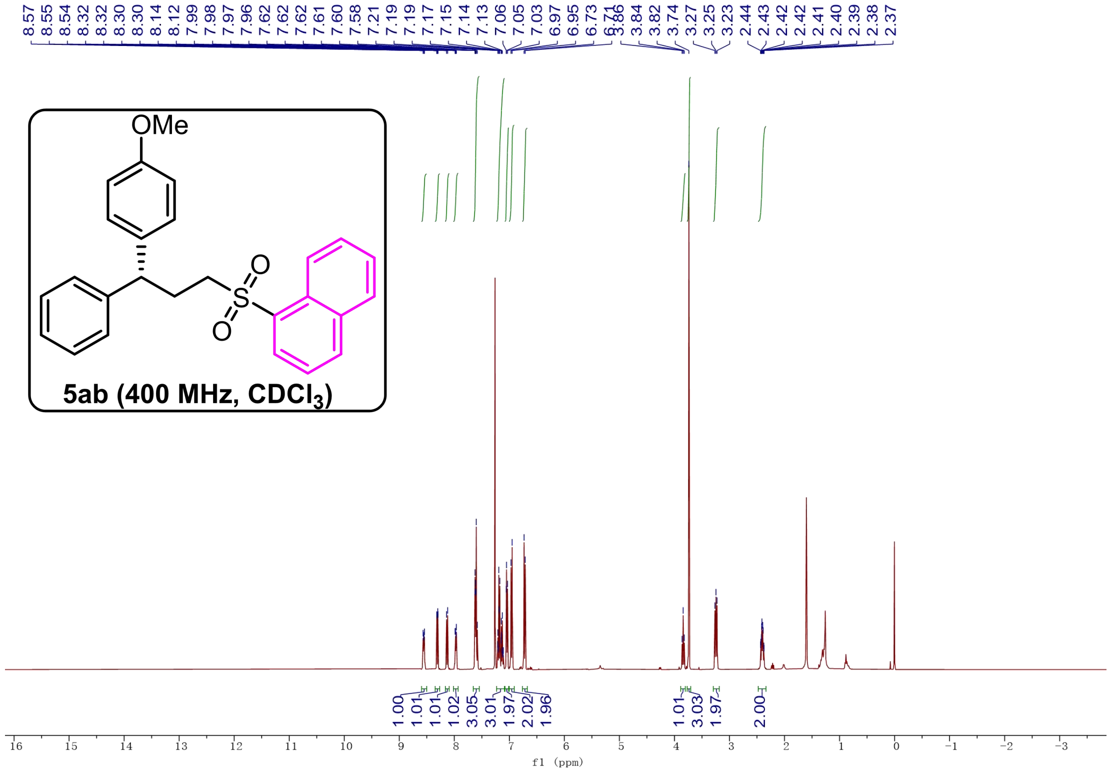

-63.20
OMe
O
S
O
CF3
5y (376 MHz, CDCl3)
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)

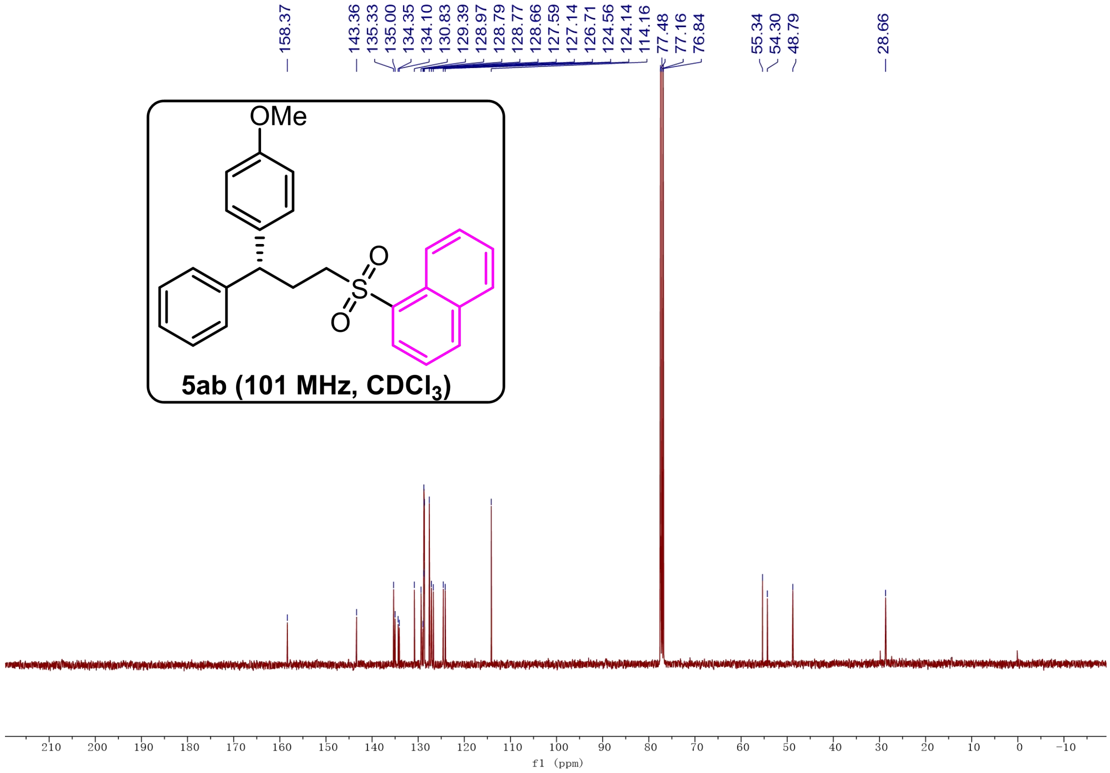

7.46
7.46
7.45
7.45
7.44
7.44
7.35
7.35
7.34
7.34
7.34
7.28
7.26
7.26
7.24
7.24
7.19
7.18
7.18
7.17
7.17
7.16
7.16
7.14
7.13
7.12
7.12
7.12
7.11
7.06
7.04
6.81
6.79
3.91
3.89
3.87
3.84
3.76
3.05
3.04
3.03
3.02
3.01
2.45
2.44
2.43
2.43
2.43
2.43
2.42
2.42
2.41
2.41
2.41
2.39
2.39
OMe
O
S
O
OMe
5z (400 MHz, CDCl3)
2.04
1.00
2.14
3.99
2.06
2.00
1.08
3.04
3.03
2.02
2.05
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

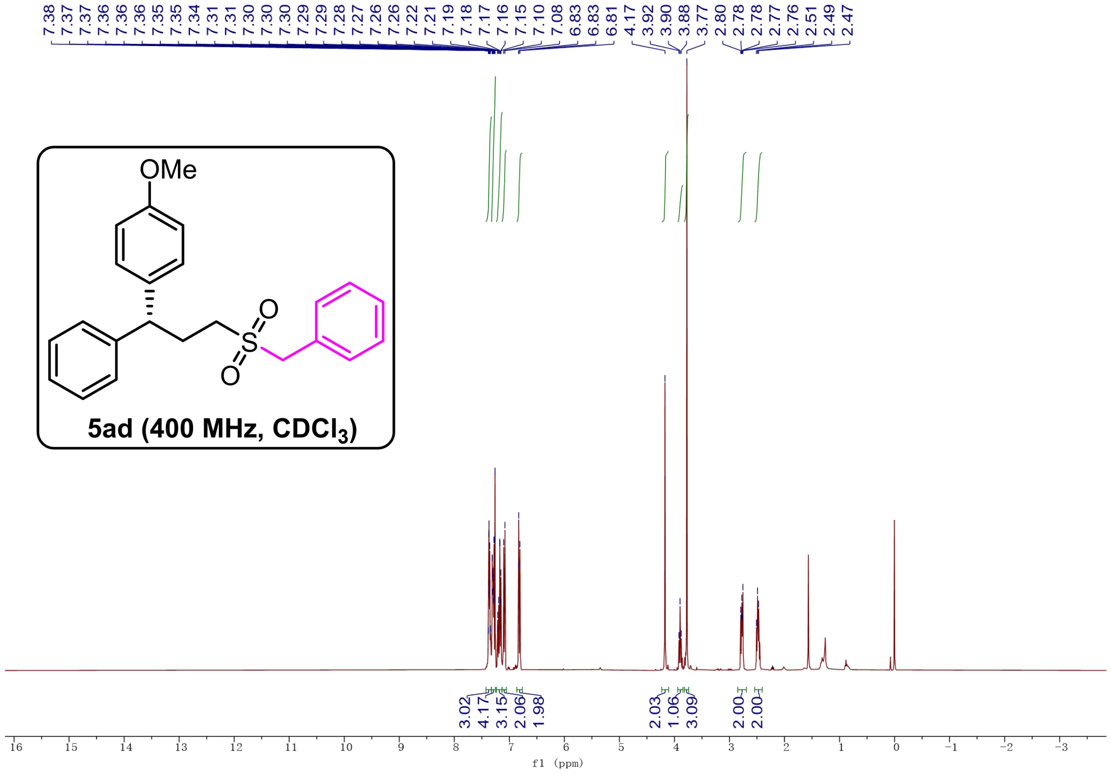

160.22
158.46
143.43
140.36
135.07
130.53
128.87
128.73
127.66
126.81
120.38
120.33
114.26
112.50
77.48
77.16
76.84
55.85
55.38
54.88
48.99
28.57
OMe
O
S
O
OMe
5z (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

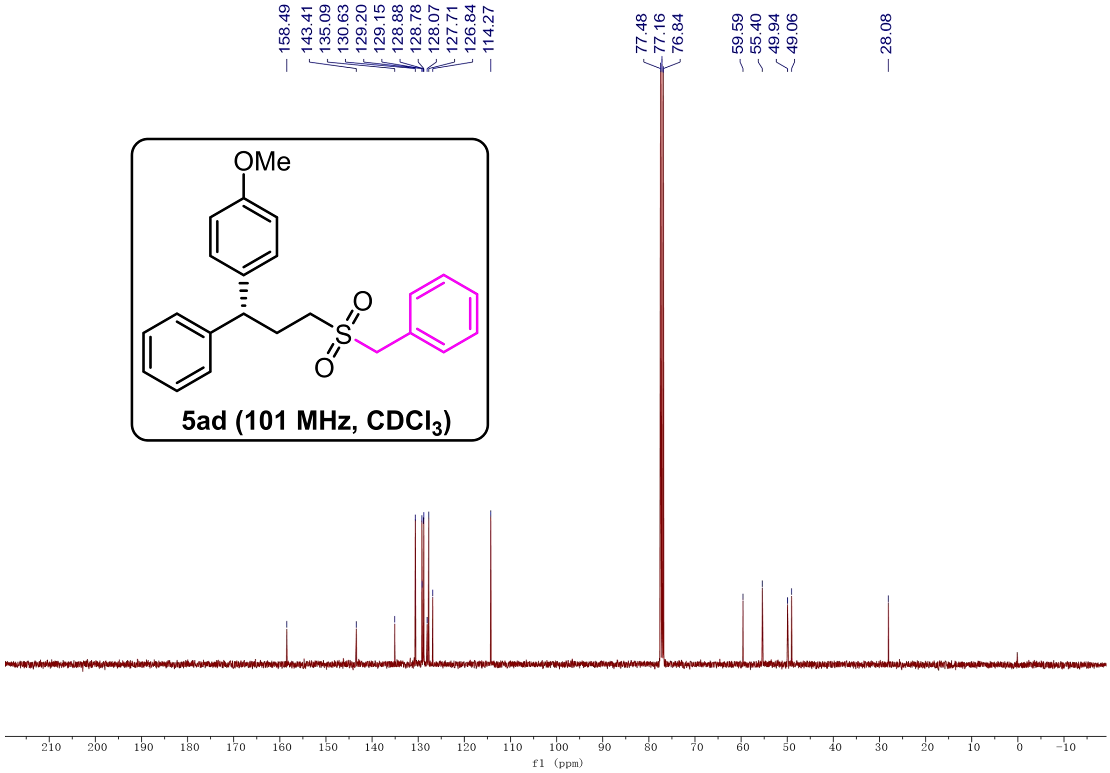

7.74 7.73 7.63 7.62 7.62 7.31 7.30 7.29 7.29 7.28 7.27 7.27 7.26 7.22 7.22 7.21 7.20 7.18 7.16 7.16 7.15 7.14 7.14 7.14 7.09 7.06 6.84 6.81 3.93 3.91 3.89 3.77 3.07 3.06 3.05 3.04 3.03 2.47 2.46 2.45 2.45 2.44 2.44 2.44 2.43 2.43 2.42 2.41 2.41
OMe
O
S
O
Cl
Cl
5aa (400 MHz, CDCl$_3$)
1.93 0.97 2.02 3.05 2.10 2.12 1.05 3.17 2.06 2.09
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

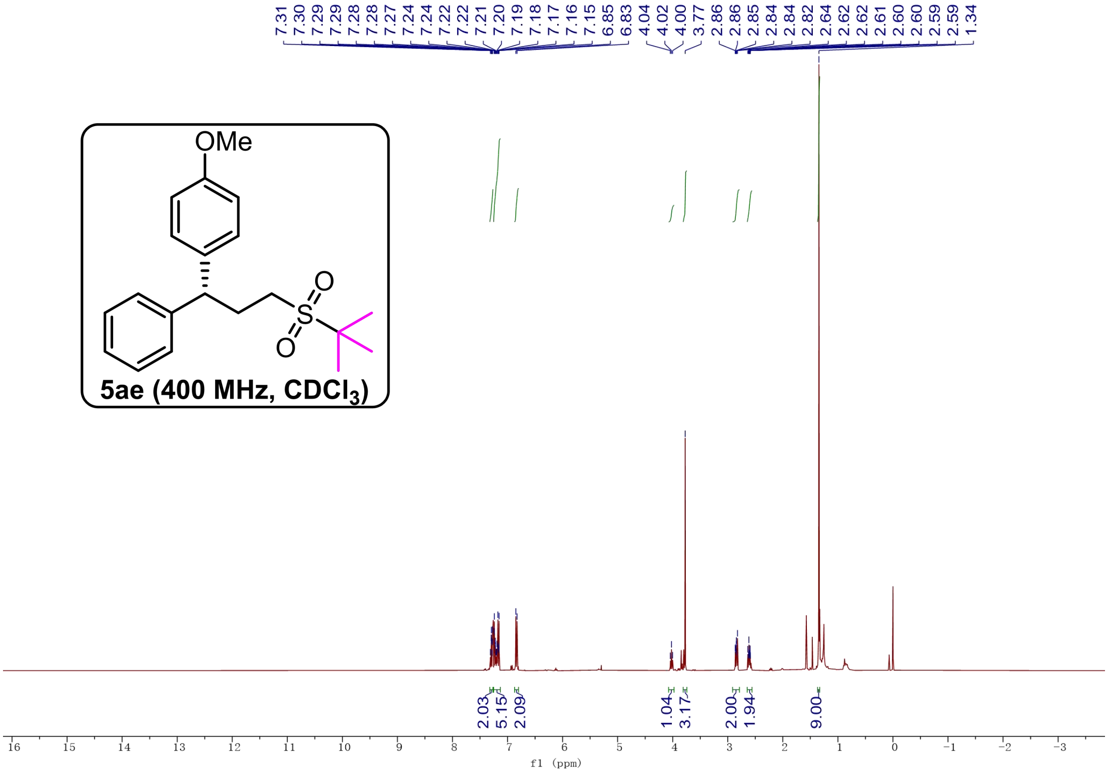

158.59 143.11 142.18 136.55 134.71 133.93 128.97 128.70 127.61 126.98 126.56 114.37 77.48 77.16 76.84 55.39 54.92 48.99 28.31
OMe
O
S
O
Cl
Cl
5aa (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

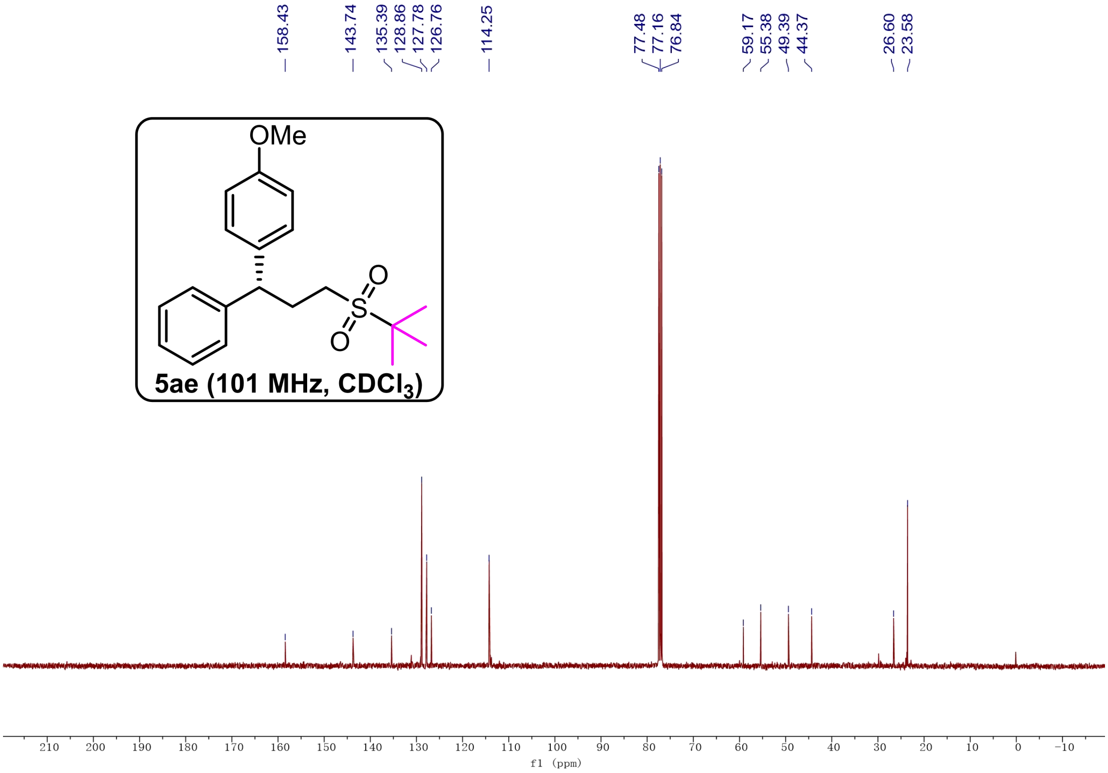

8.57
8.55
8.54
8.32
8.32
8.30
8.30
8.14
8.12
7.99
7.98
7.97
7.96
7.62
7.62
7.62
7.61
7.60
7.58
7.21
7.19
7.19
7.17
7.15
7.14
7.13
7.06
7.05
7.03
6.97
6.95
6.73
6.71
3.86
3.84
3.82
3.74
3.27
3.25
3.23
2.44
2.43
2.42
2.42
2.41
2.40
2.39
2.38
2.37
OMe
O
S
O
5ab (400 MHz, CDCl$_3$)
1.00
1.01
1.01
1.02
3.05
3.01
1.97
2.02
1.96
1.01
3.03
1.97
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)


158.37
143.36
135.33
135.00
134.35
134.10
130.83
129.39
128.97
128.79
128.77
128.66
127.59
127.14
126.71
124.56
124.14
114.16
77.48
77.16
76.84
55.34
54.30
48.79
28.66
OMe
O
S
O
5ab (101 MHz, CDCl$_3$)
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)


7.38
7.37
7.37
7.36
7.36
7.36
7.35
7.35
7.34
7.31
7.31
7.30
7.30
7.30
7.29
7.29
7.28
7.27
7.26
7.26
7.22
7.21
7.19
7.18
7.17
7.16
7.15
7.10
7.08
6.83
6.83
6.81
4.17
3.92
3.90
3.88
3.77
2.80
2.78
2.78
2.77
2.76
2.51
2.49
2.47
OMe
O
S
O
5ad (400 MHz, CDCl$_3$)
3.02
4.17
3.15
2.06
1.98
2.03
1.06
3.09
2.00
2.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)


158.49
143.41
135.09
130.63
129.20
129.15
128.88
128.78
128.07
127.71
126.84
114.27
77.48
77.16
76.84
59.59
55.40
49.94
49.06
28.08
OMe
O
S
O
5ad (101 MHz, CDCl$_3$)
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)


7.31
7.30
7.29
7.29
7.28
7.28
7.27
7.24
7.24
7.22
7.22
7.21
7.20
7.19
7.18
7.17
7.16
7.15
6.85
6.83
4.04
4.02
4.00
3.77
2.86
2.85
2.84
2.84
2.82
2.64
2.62
2.62
2.61
2.60
2.60
2.59
2.59
1.34
OMe
O
S
O
5ae (400 MHz, CDCl$_3$)
2.03
5.15
2.09
1.04
3.17
2.00
1.94
9.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)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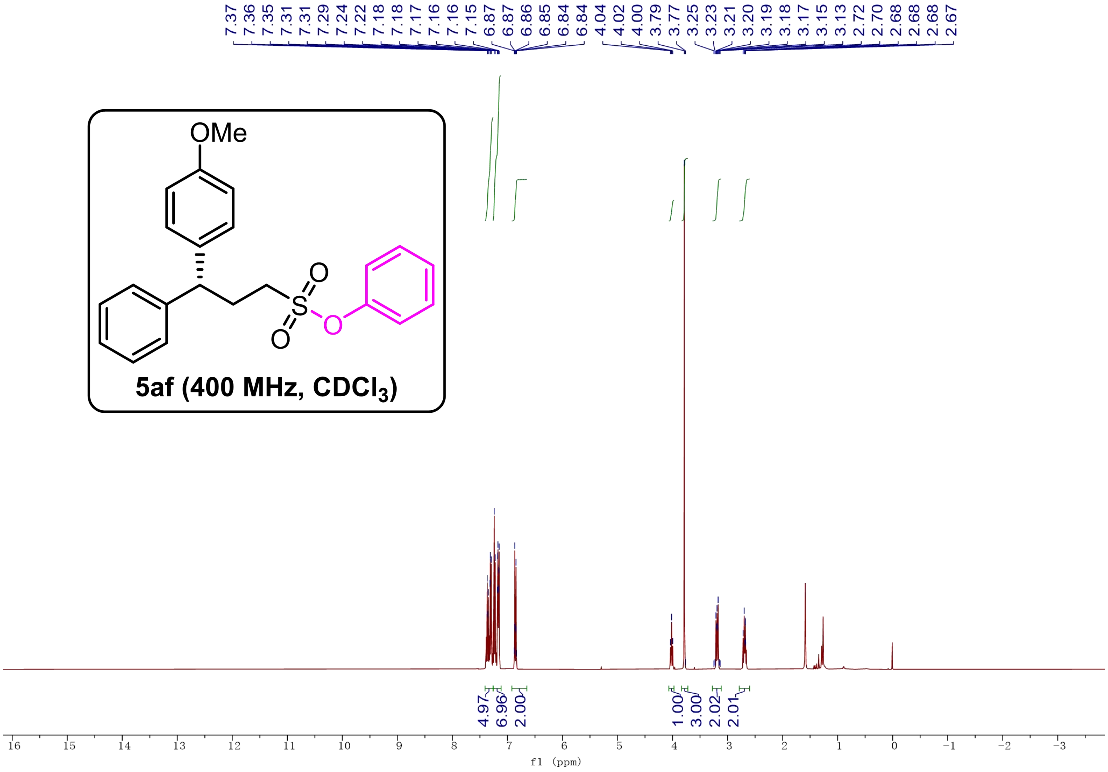
143.74
135.39
128.86
127.78
126.76
114.25
77.48
77.16
76.84
59.17
55.38
49.39
44.37
26.60
23.58
OMe
O
S
O
5ae (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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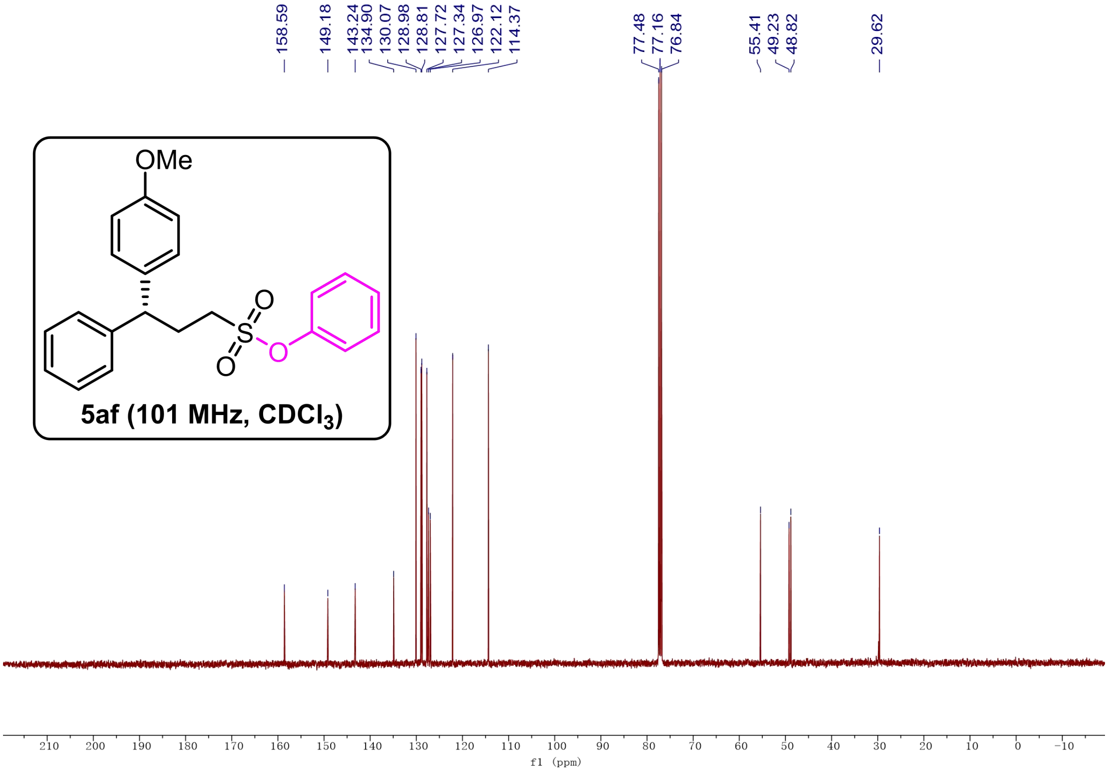
7.36
7.35
7.31
7.31
7.29
7.24
7.22
7.18
7.18
7.17
7.16
7.16
7.15
6.87
6.87
6.86
6.85
6.84
6.84
4.04
4.02
4.00
3.79
3.77
3.25
3.23
3.21
3.20
3.19
3.18
3.17
3.15
3.13
2.72
2.70
2.68
2.68
2.68
2.67
OMe
O
S
O
O
5af (400 MHz, CDCl3)
4.97
6.96
2.00
1.00
3.00
2.02
2.01
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)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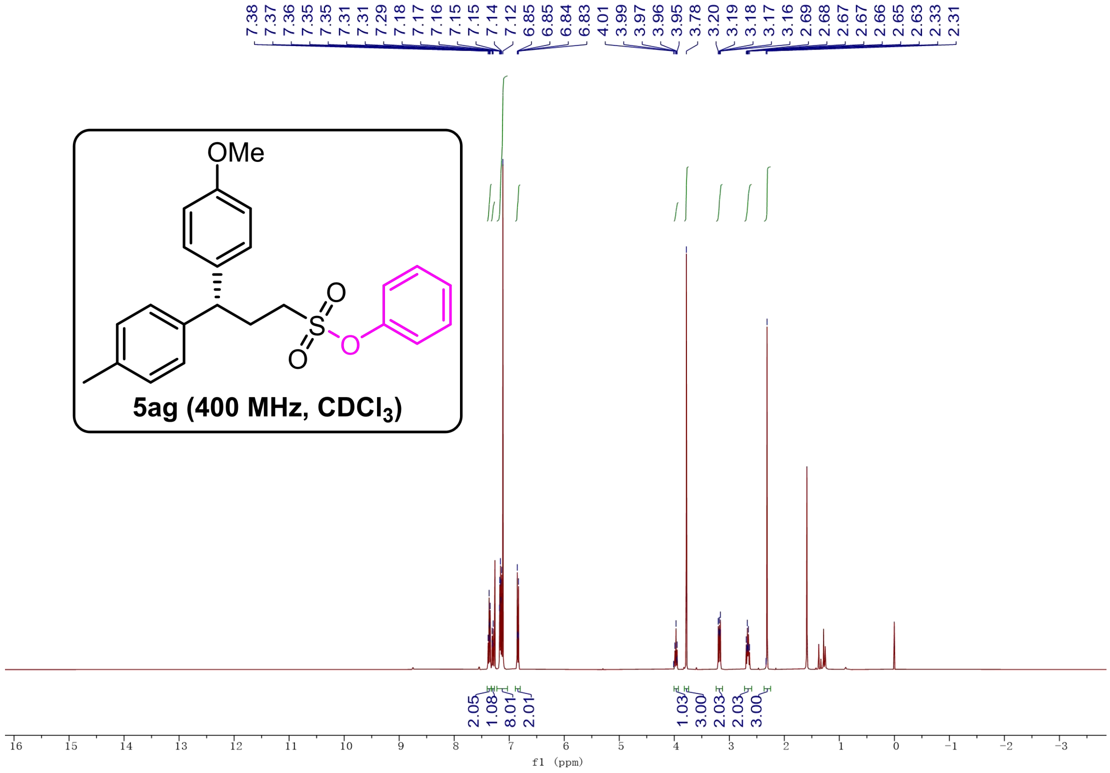
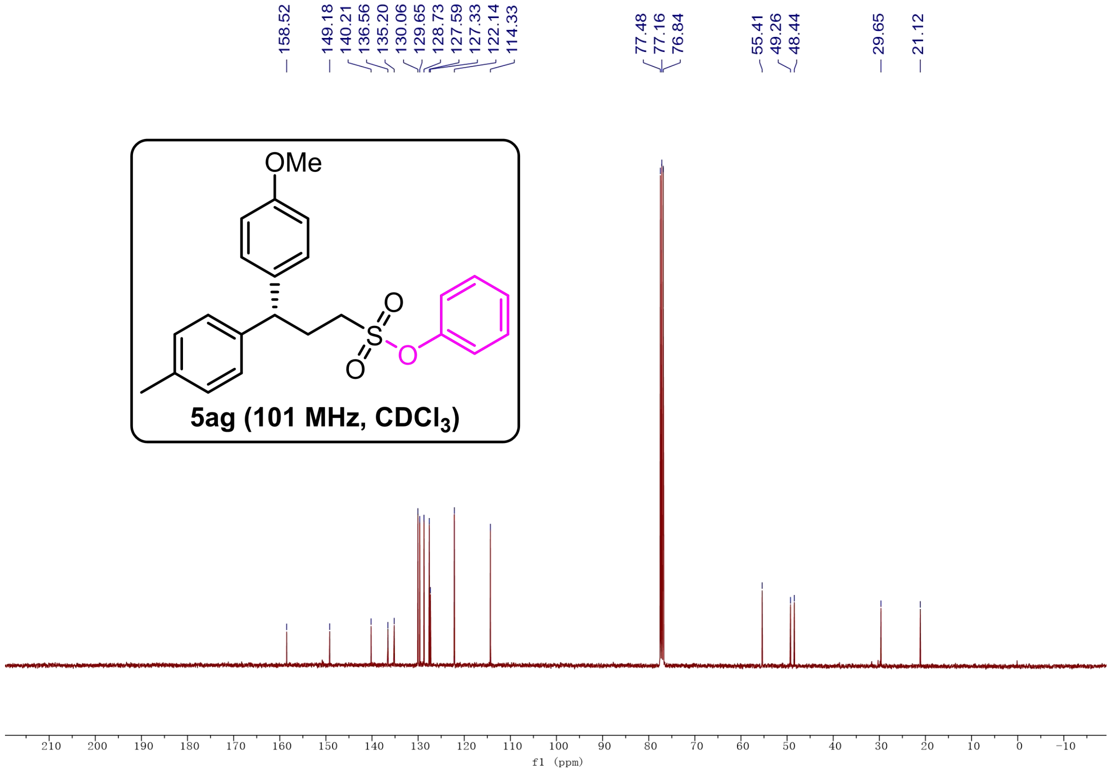
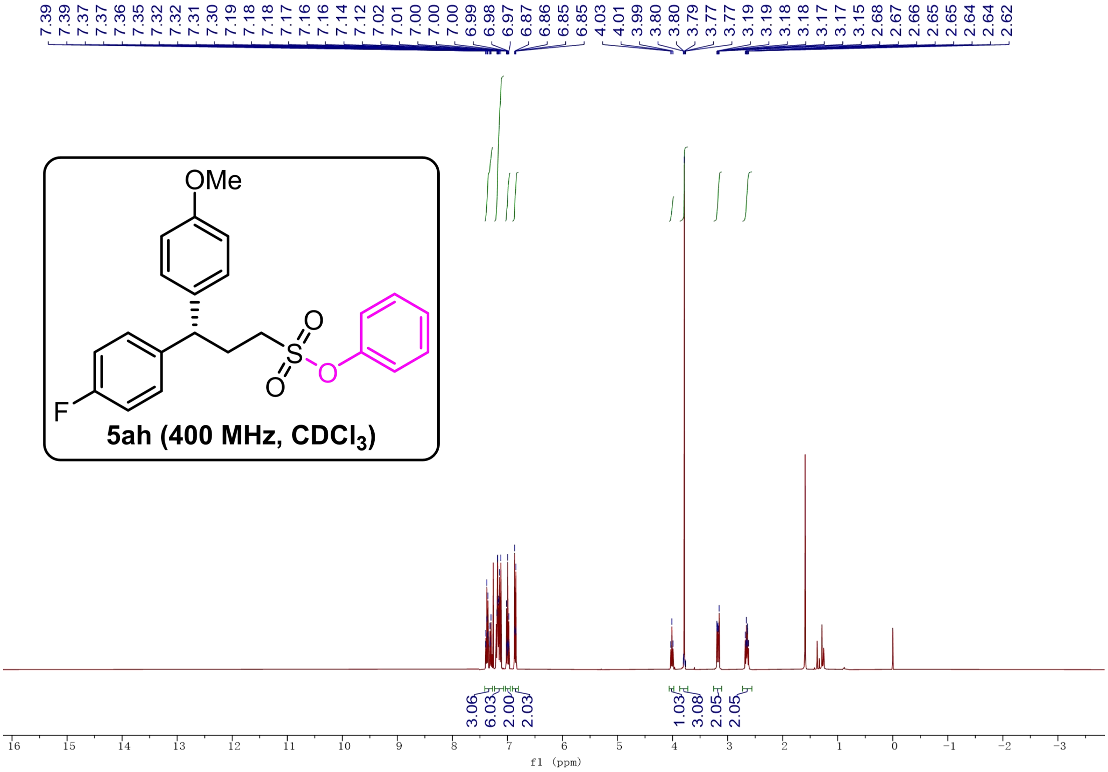
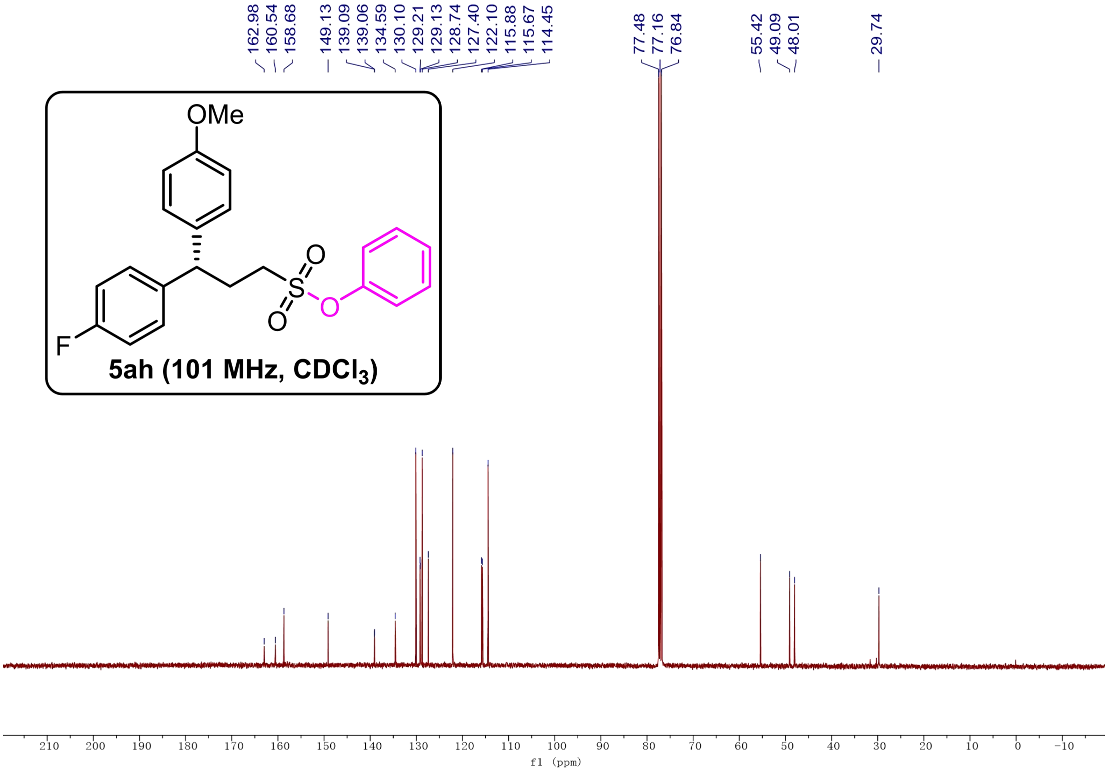
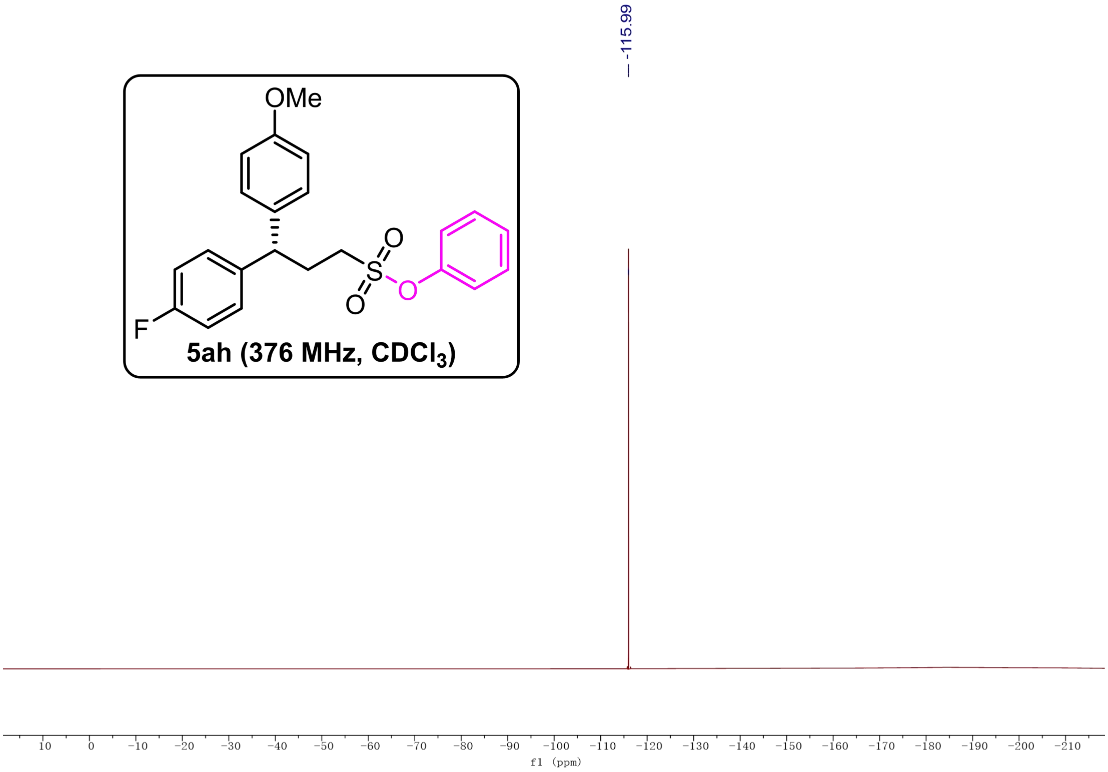
149.18
143.24
134.90
130.07
128.98
128.81
127.72
127.34
126.97
122.12
114.37
77.48
77.16
76.84
55.41
49.23
48.82
29.62
OMe
O
S
O
O
5af (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.38
7.37
7.36
7.35
7.35
7.31
7.31
7.29
7.18
7.17
7.16
7.15
7.15
7.14
7.12
6.85
6.85
6.84
6.83
4.01
3.99
3.97
3.96
3.95
3.78
3.20
3.19
3.18
3.17
3.16
2.69
2.68
2.67
2.67
2.66
2.65
2.63
2.33
2.31
OMe
O
O
S
O
5ag (400 MHz, CDCl$_3$)
2.05
1.08
8.01
2.01
1.03
3.00
2.03
2.03
3.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

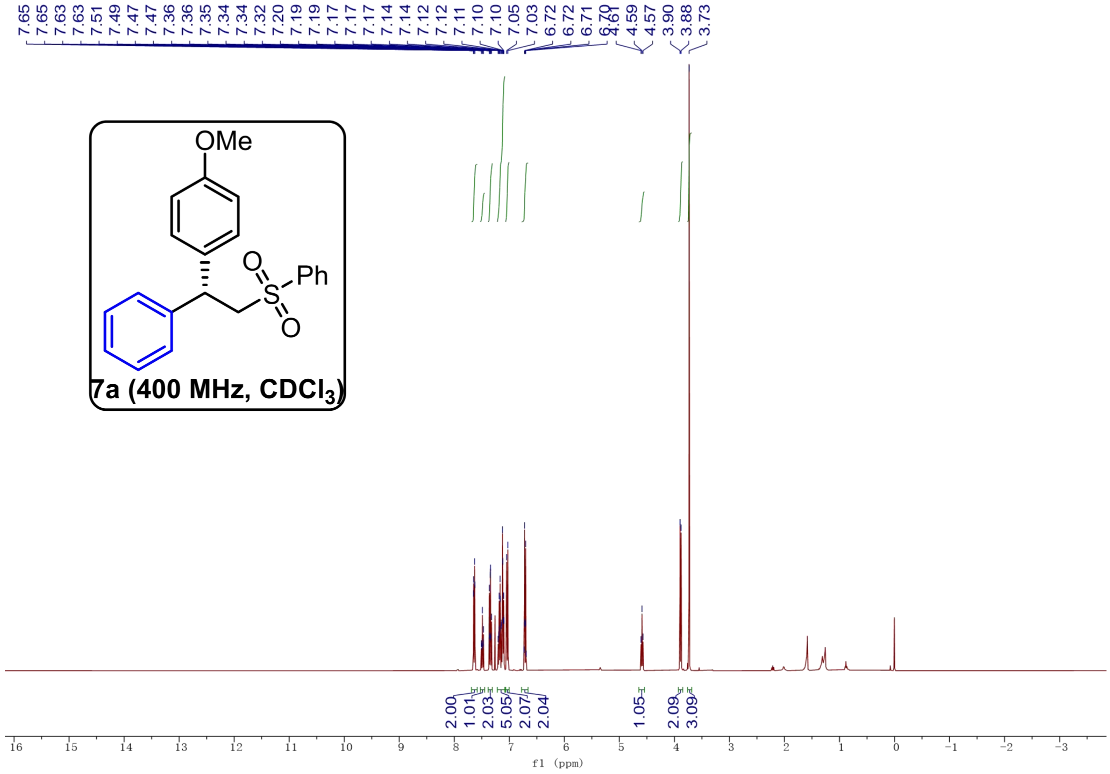

158.52
149.18
140.21
136.56
135.20
130.06
129.65
128.73
127.59
127.33
122.14
114.33
77.48
77.16
76.84
55.41
49.26
48.44
29.65
21.12
OMe
O
O
S
O
5ag (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

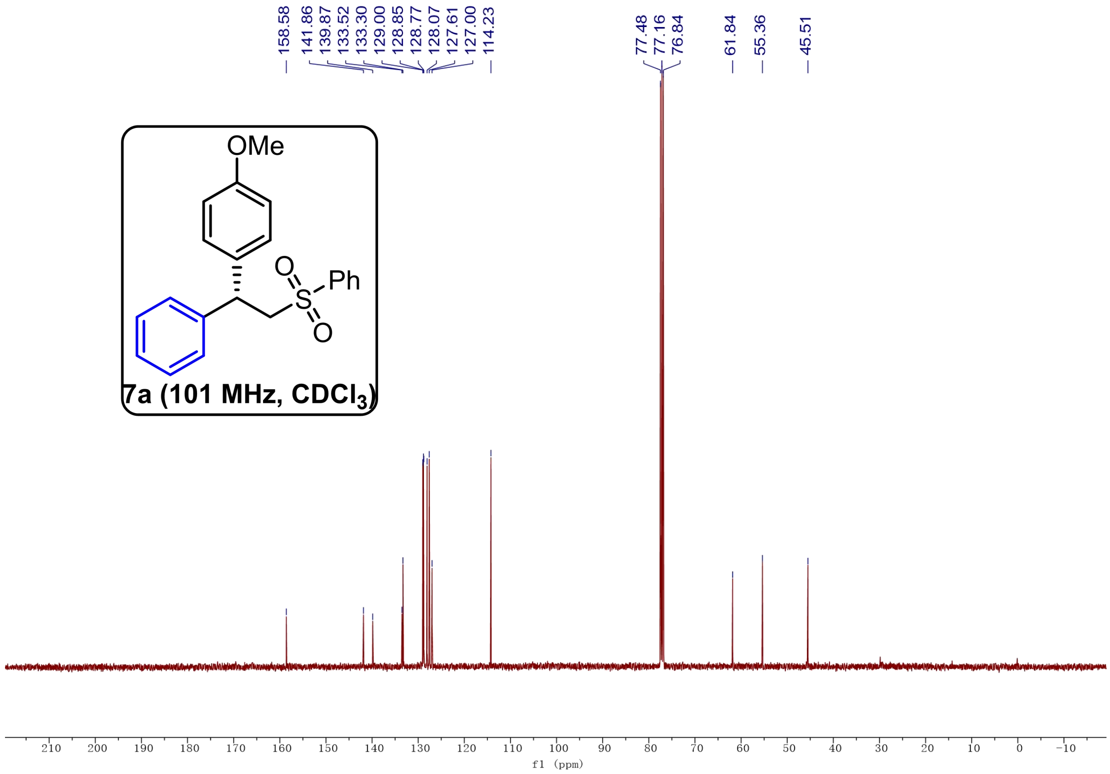

7.39
7.39
7.37
7.37
7.36
7.35
7.32
7.32
7.31
7.30
7.19
7.18
7.18
7.17
7.16
7.16
7.14
7.12
7.02
7.01
7.00
7.00
7.00
6.99
6.98
6.97
6.87
6.86
6.85
6.85
4.03
4.01
3.99
3.80
3.80
3.79
3.77
3.77
3.19
3.19
3.18
3.18
3.17
3.15
2.68
2.67
2.66
2.65
2.65
2.64
2.64
2.62
OMe
O
S
O
O
F
5ah (400 MHz, CDCl3)
3.06
6.03
2.00
2.03
1.03
3.08
2.05
2.05
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

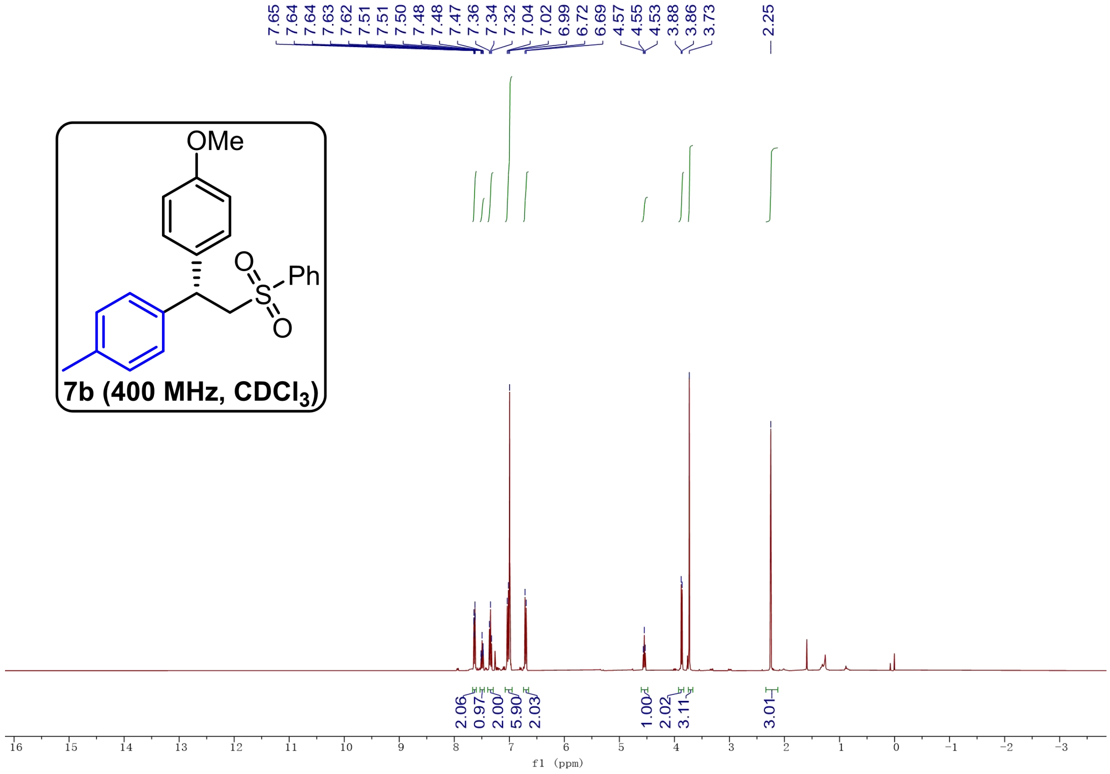

162.98
160.54
158.68
149.13
139.09
139.06
134.59
130.10
129.21
129.13
128.74
127.40
122.10
115.88
115.67
114.45
77.48
77.16
76.84
55.42
49.09
48.01
29.74
OMe
O
S
O
O
F
5ah (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

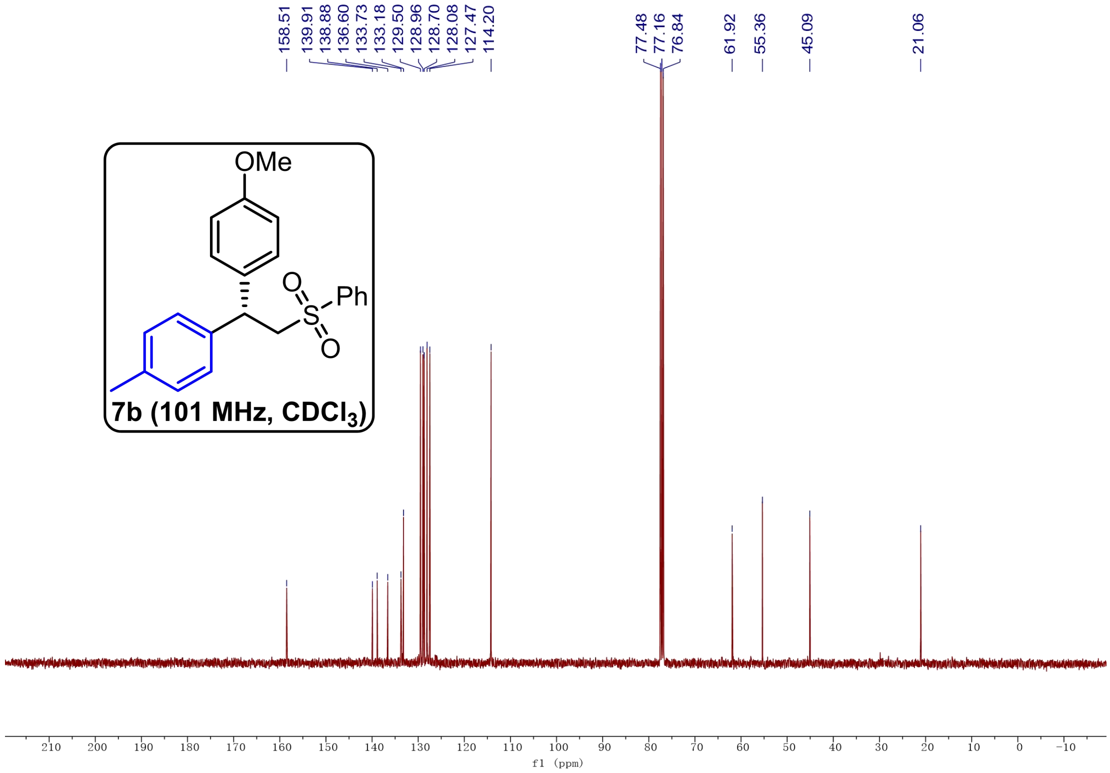


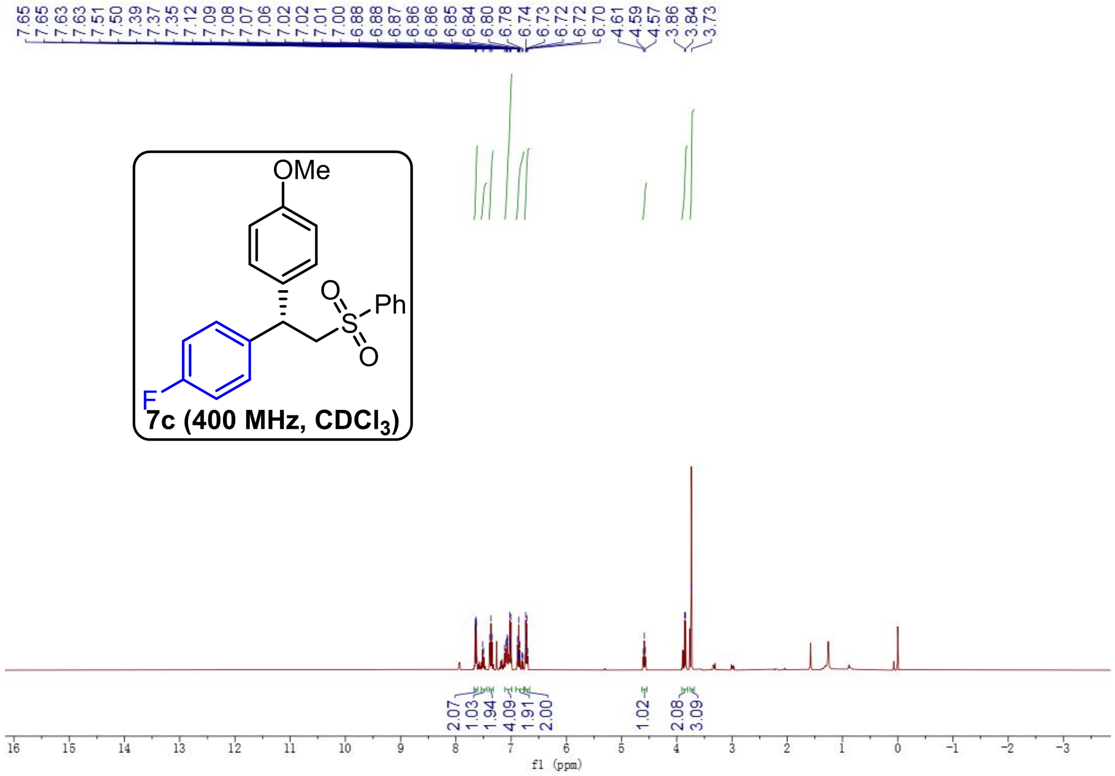
5ah (376 MHz, $CDCl_3$)

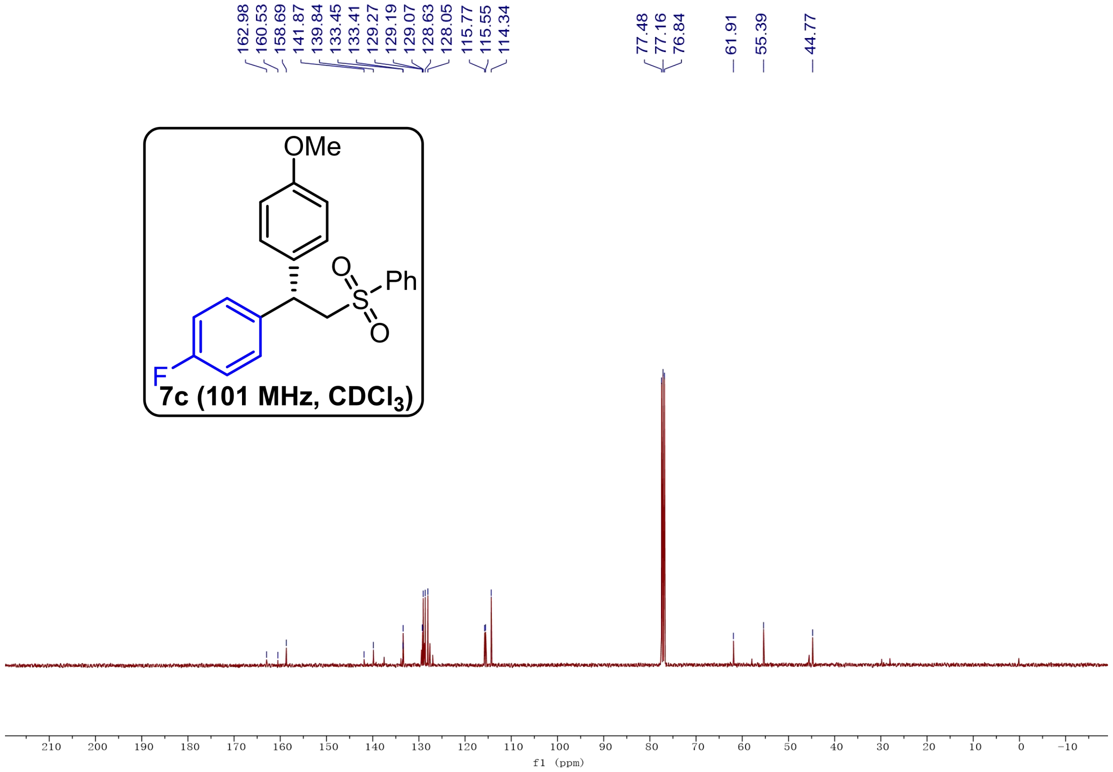

7.65
7.65
7.63
7.63
7.51
7.49
7.47
7.47
7.36
7.36
7.35
7.34
7.34
7.32
7.20
7.19
7.19
7.17
7.17
7.17
7.14
7.14
7.12
7.12
7.11
7.10
7.10
7.05
7.03
6.72
6.72
6.71
6.70
4.61
4.59
4.57
3.90
3.88
3.73
OMe
O
S
O
Ph
7a (400 MHz, CDCl$_3$)
2.00
1.01
2.03
5.05
2.07
2.04
1.05
2.09
3.09
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
f1 (ppm)

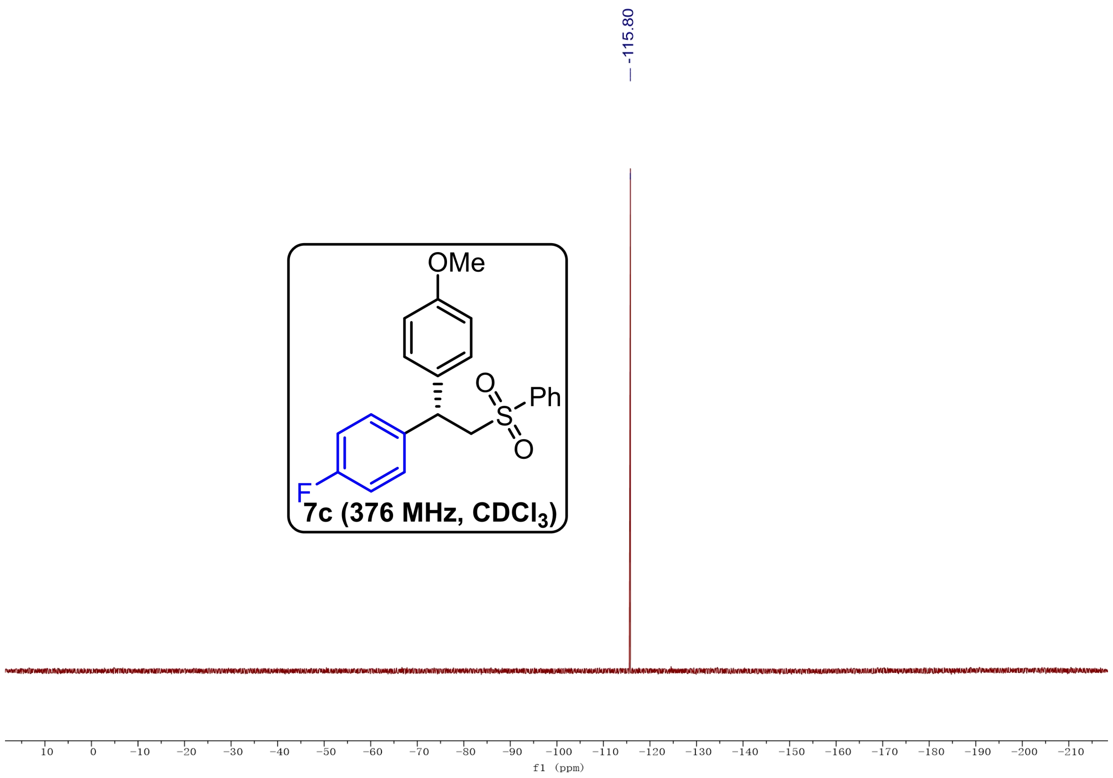

158.58
141.86
139.87
133.52
133.30
129.00
128.85
128.77
128.07
127.61
127.00
114.23
77.48
77.16
76.84
61.84
55.36
45.51
OMe
O
S
O
Ph
7a (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

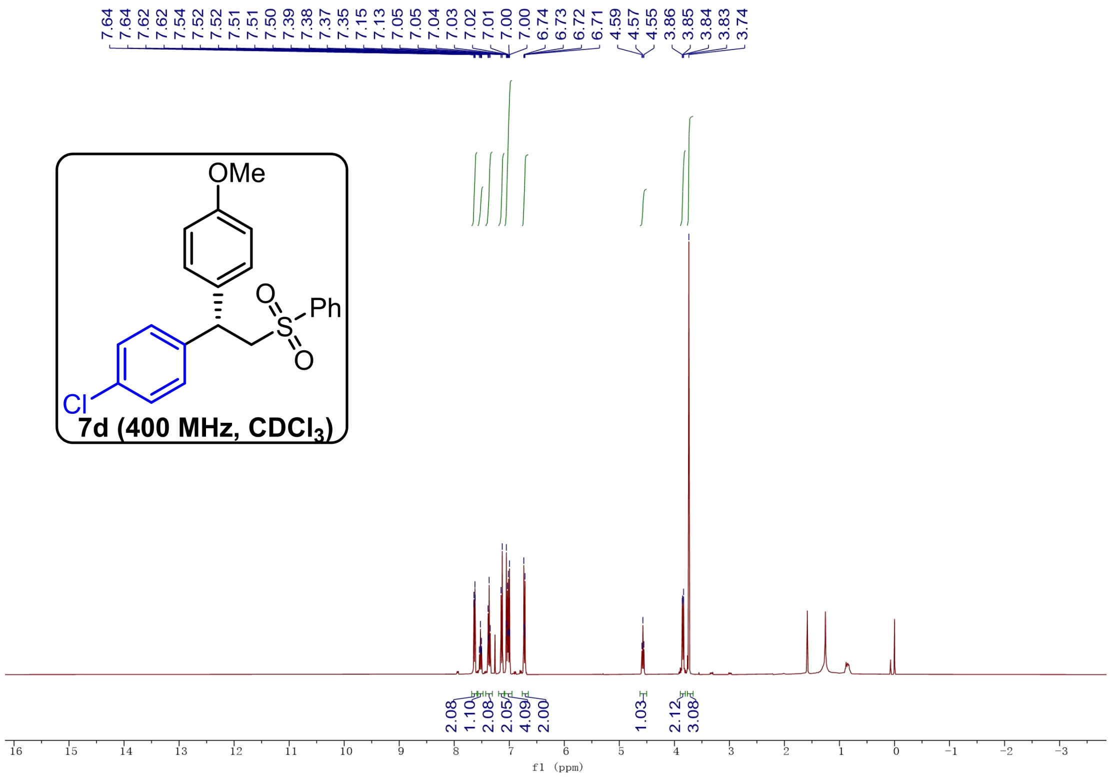

7.65
7.64
7.64
7.63
7.62
7.51
7.51
7.50
7.48
7.48
7.47
7.36
7.34
7.32
7.04
7.02
6.99
6.72
6.69
4.57
4.55
4.53
3.88
3.86
3.73
2.25
OMe
O
S
Ph
O
7b (400 MHz, CDCl$_3$)
2.06
0.97
2.00
5.90
2.03
1.00
2.02
3.11
3.01
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

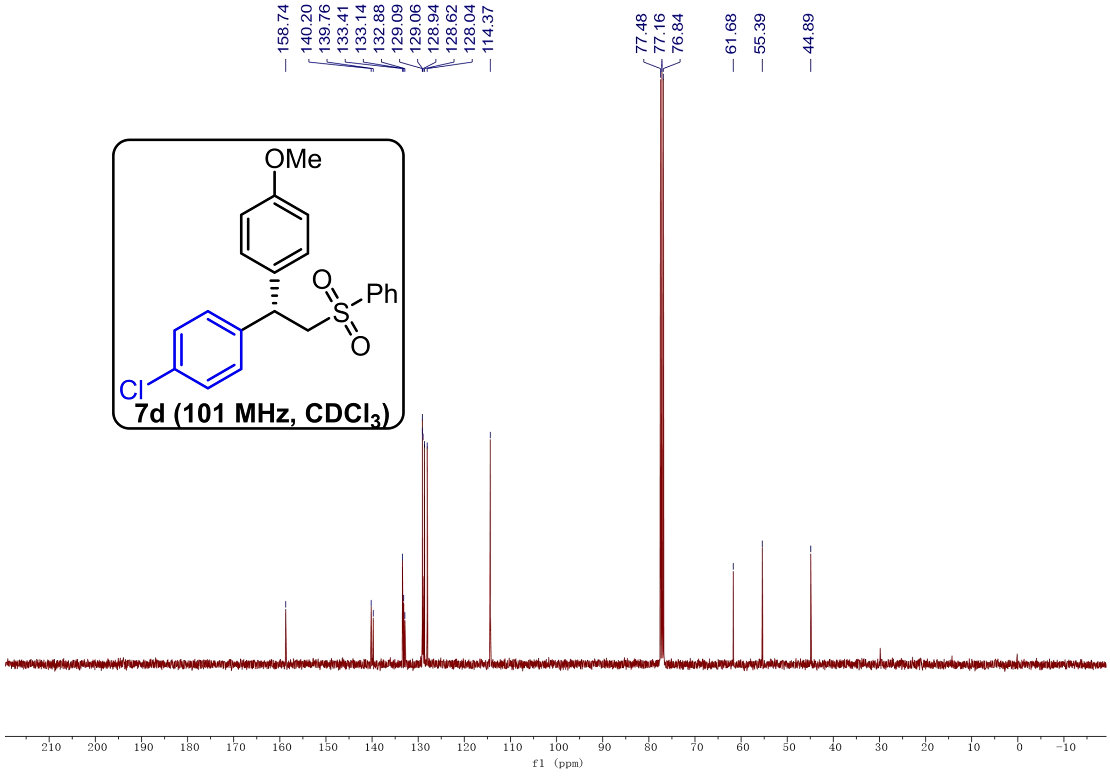

158.51
139.91
138.88
136.60
133.73
133.18
129.50
128.96
128.70
128.08
127.47
114.20
77.48
77.16
76.84
61.92
55.36
45.09
21.06
OMe
O
S
Ph
O
7b (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

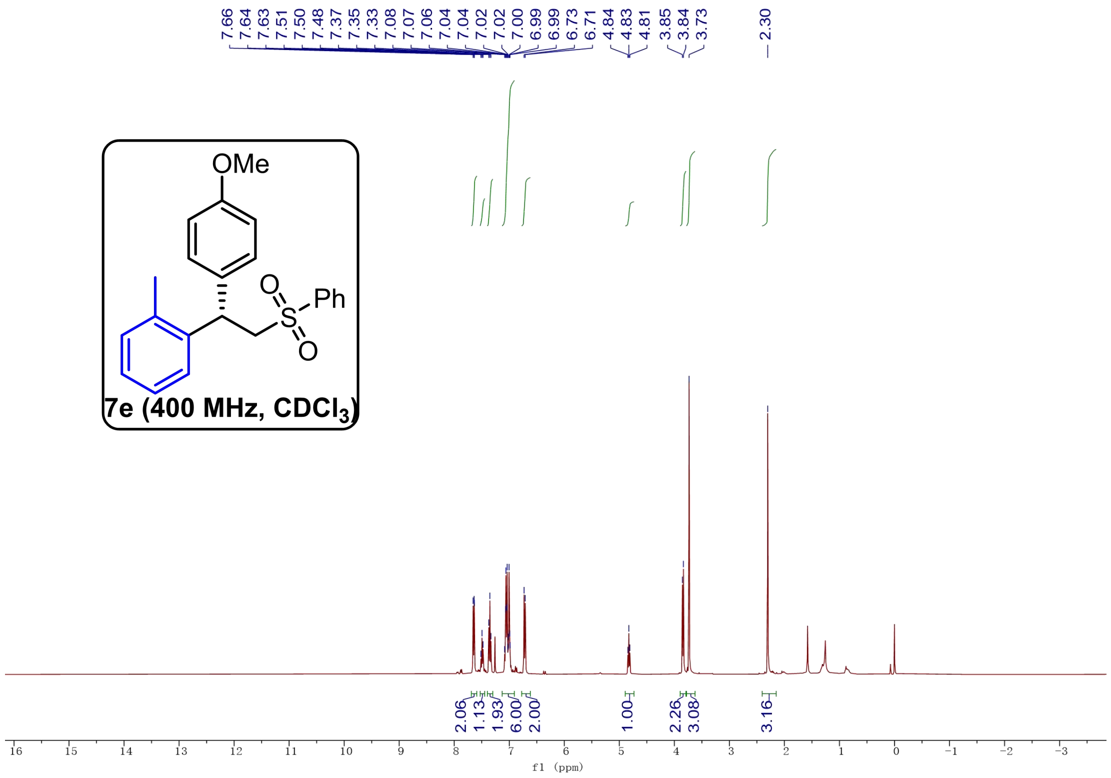

7.65
7.65
7.63
7.63
7.51
7.50
7.39
7.37
7.35
7.12
7.09
7.08
7.07
7.06
7.02
7.02
7.01
7.00
6.88
6.87
6.86
6.86
6.85
6.84
6.80
6.78
6.74
6.73
6.72
6.72
6.70
4.61
4.59
4.57
3.86
3.84
3.73
OMe
O
S
O
Ph
F
7c (400 MHz, CDCl$_3$)
2.07
1.03
1.94
4.09
1.91
2.00
1.02
2.08
3.09
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

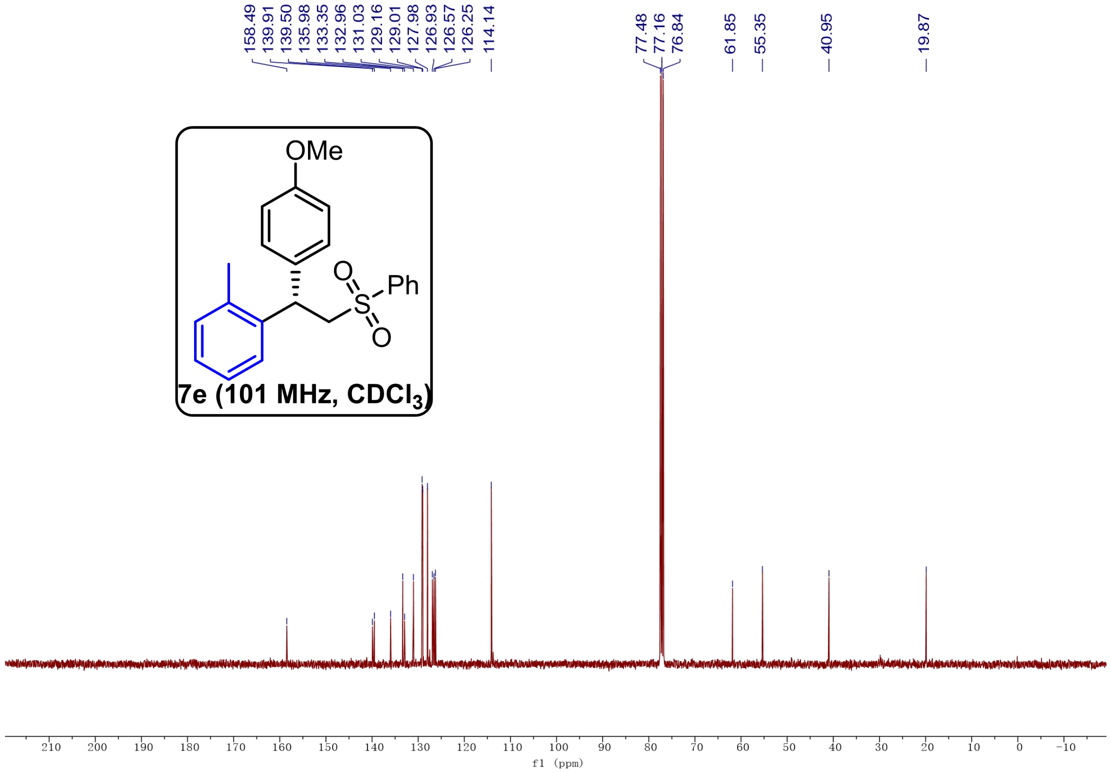

162.98
160.53
158.69
141.87
139.84
133.45
133.41
129.27
129.19
129.07
128.63
128.05
115.77
115.55
114.34
77.48
77.16
76.84
61.91
55.39
44.77
OMe
O
S
O
Ph
F
7c (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

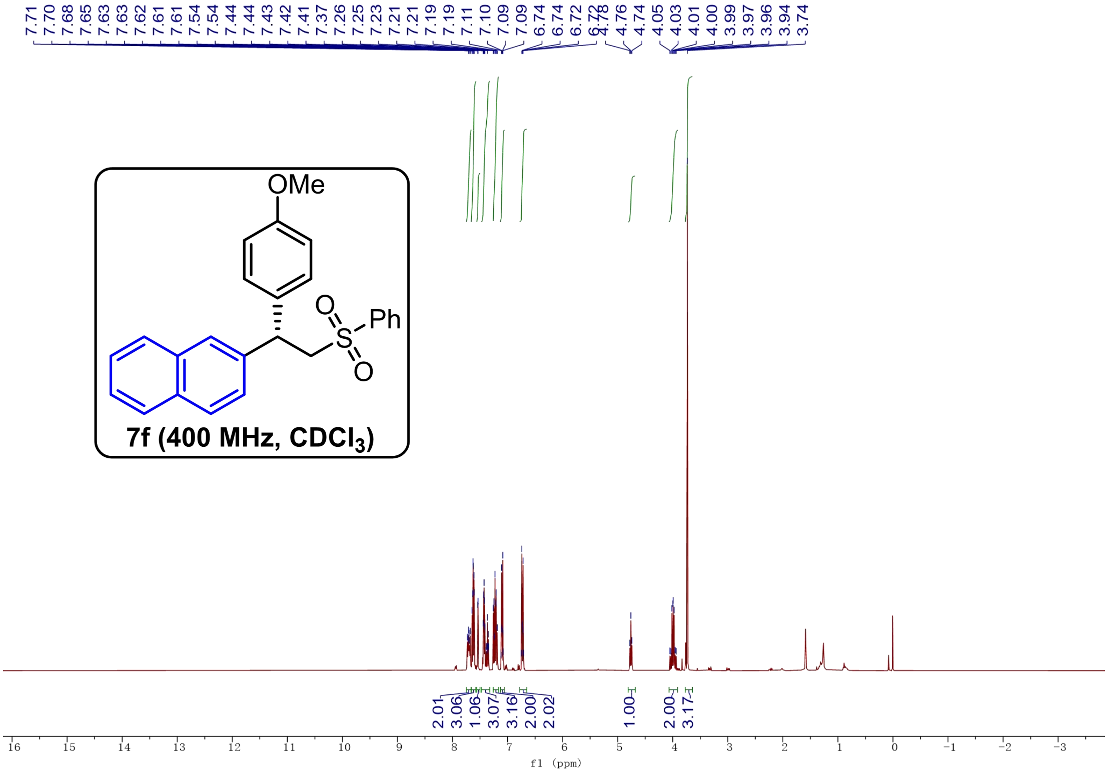

-115.80
OMe
O
S
Ph
O
F
7c (376 MHz, $CDCl_3$)
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)


7.64
7.64
7.62
7.62
7.54
7.52
7.52
7.51
7.51
7.50
7.39
7.38
7.37
7.35
7.15
7.13
7.05
7.05
7.04
7.03
7.02
7.01
7.00
7.00
6.74
6.73
6.72
6.71
4.59
4.57
4.55
3.86
3.85
3.84
3.83
3.74
OMe
O
S
Ph
O
Cl
7d (400 MHz, CDCl$_3$)
2.08
1.10
2.08
2.05
4.09
2.00
1.03
2.12
3.08
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

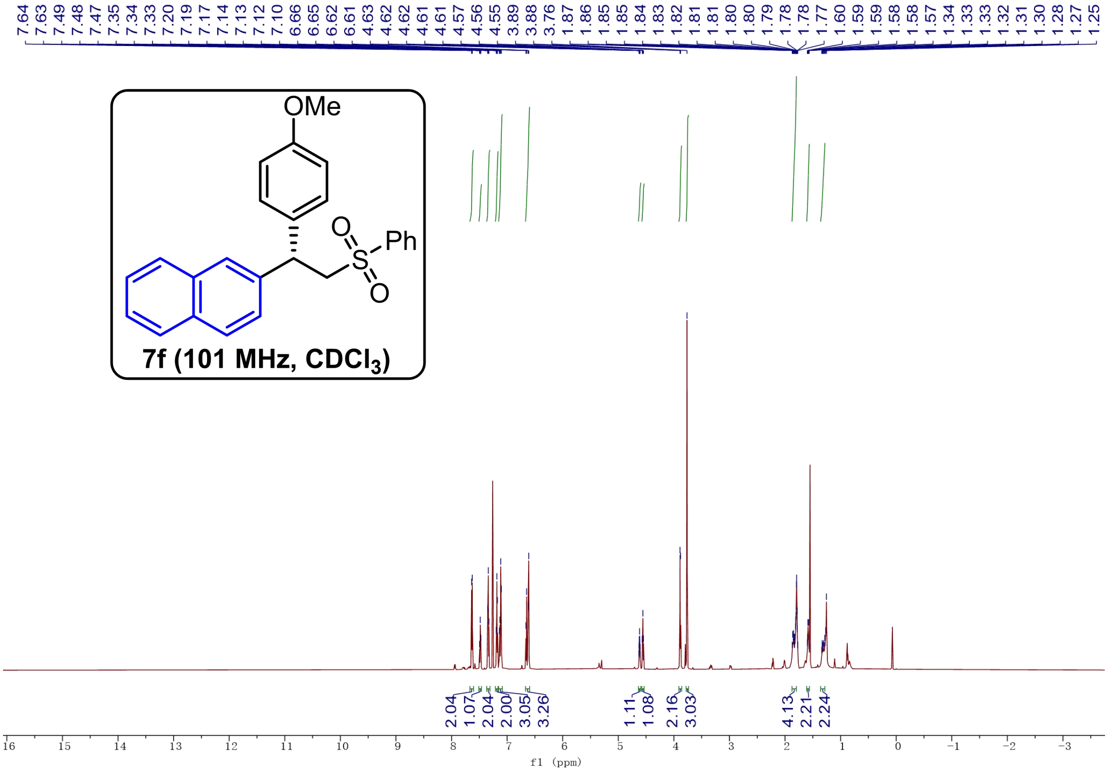

158.74
140.20
139.76
133.41
133.14
132.88
129.09
129.06
128.94
128.62
128.04
114.37
77.48
77.16
76.84
61.68
55.39
44.89
OMe
O
S
Ph
O
Cl
7d (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


7.66 7.64 7.63 7.51 7.50 7.48 7.37 7.35 7.33 7.08 7.07 7.06 7.04 7.02 7.02 7.00 6.99 6.99 6.73 6.71 4.84 4.83 4.81 3.85 3.84 3.73 2.30
OMe
O
S
O
Ph
7e (400 MHz, CDCl$_3$)
2.06 1.13 1.93 6.00 2.00 1.00 2.26 3.08 3.16
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

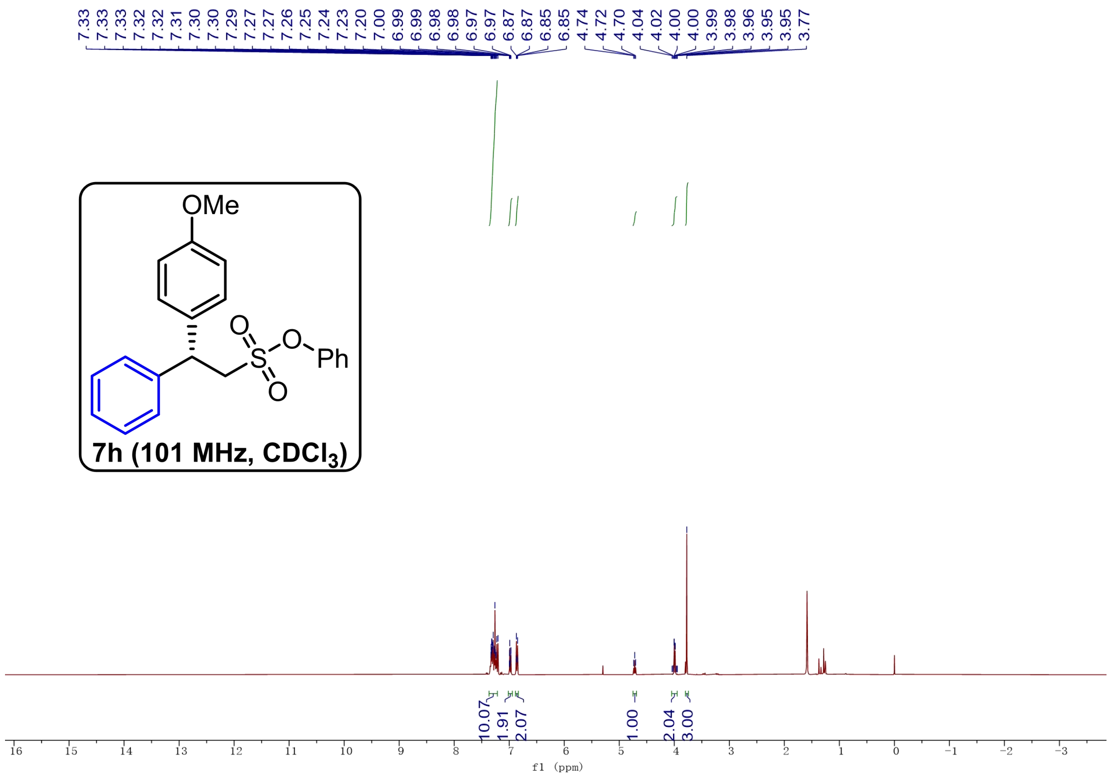

158.49 139.91 139.50 135.98 133.35 132.96 131.03 129.16 129.01 127.98 126.93 126.57 126.25 114.14 77.48 77.16 76.84 61.85 55.35 40.95 19.87
OMe
O
S
O
Ph
7e (101 MHz, CDCl$_3$)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

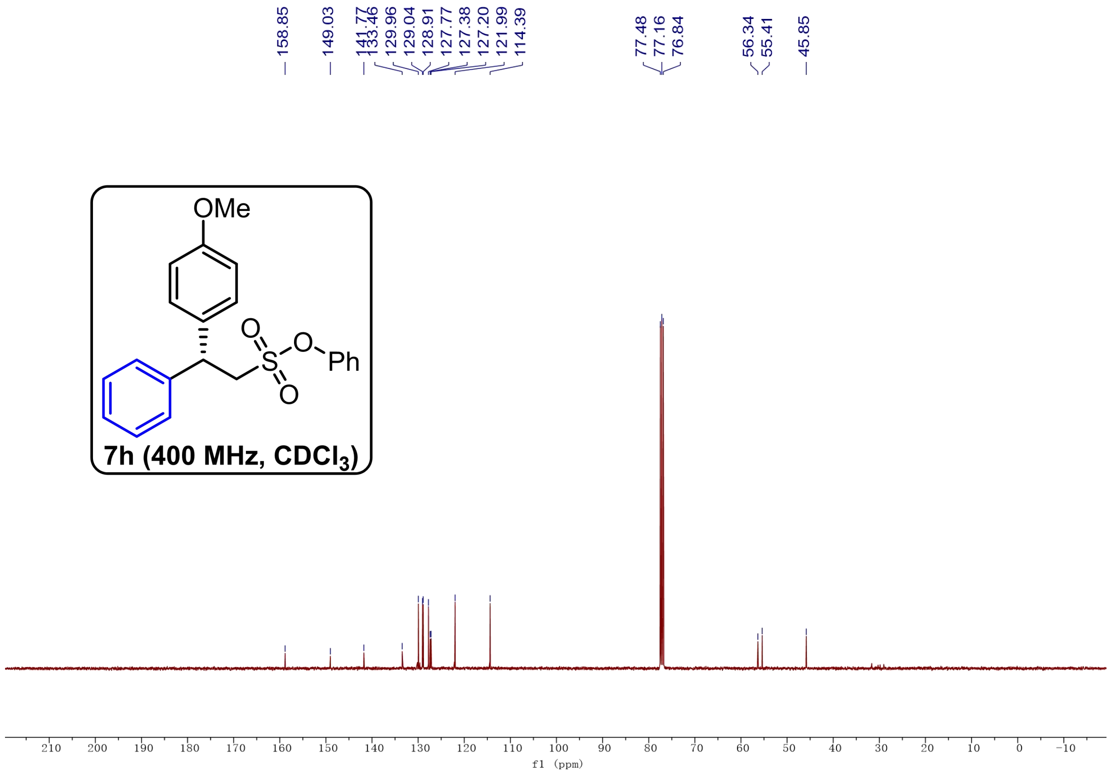


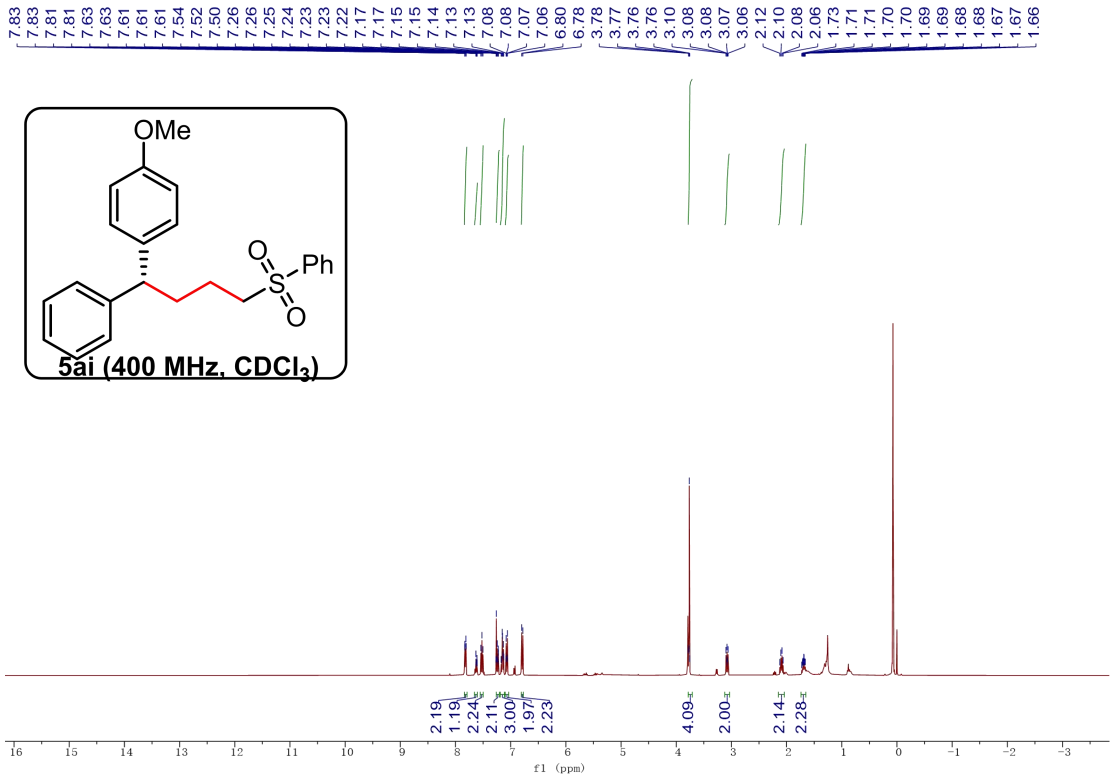
7f (400 MHz, $CDCl_3$)

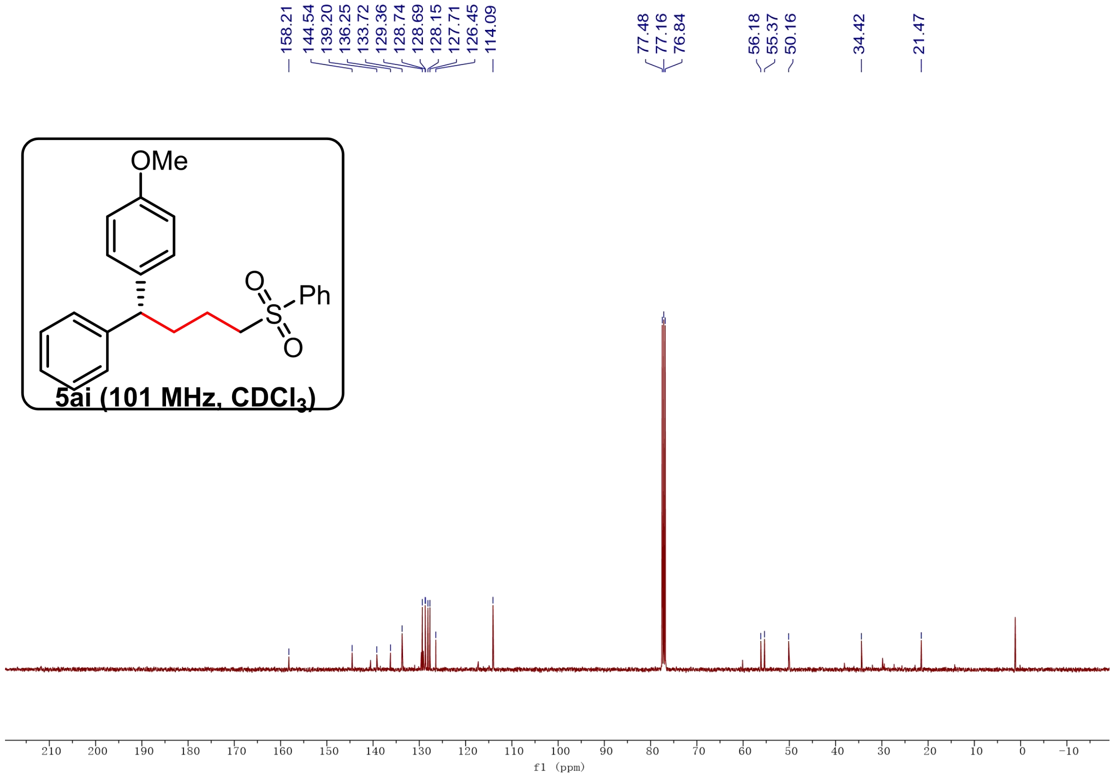


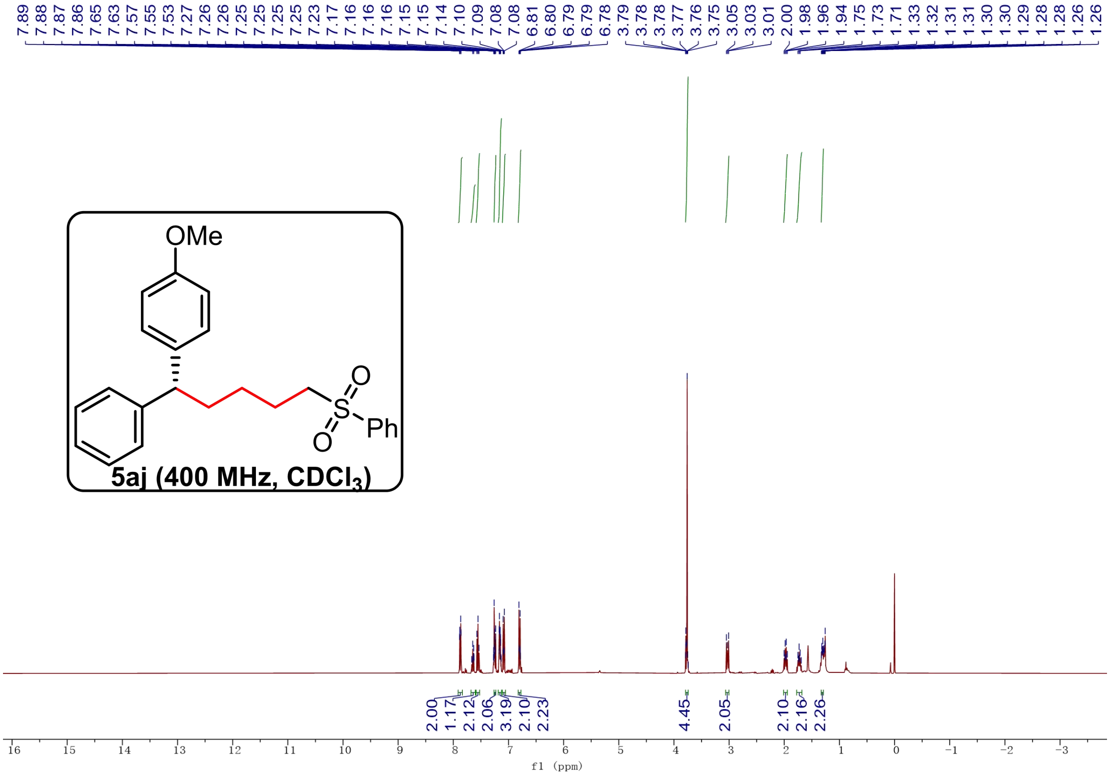
7f (101 MHz, $CDCl_3$)

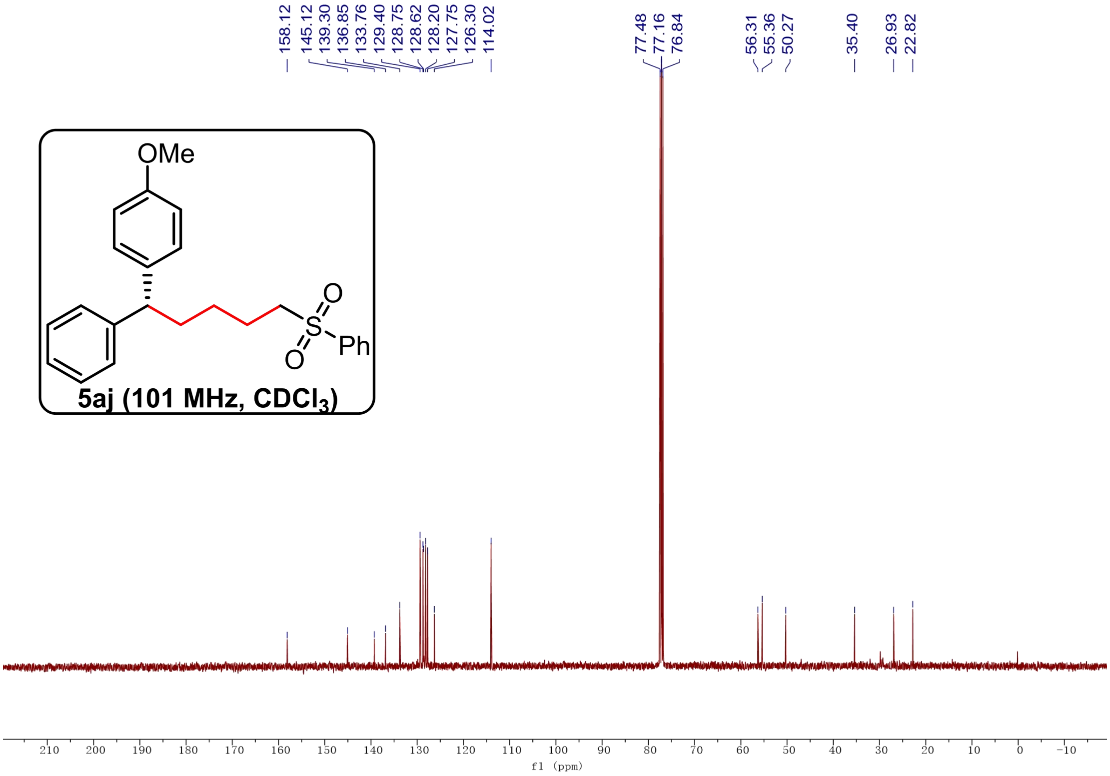

7.33
7.33
7.33
7.32
7.32
7.31
7.30
7.30
7.29
7.27
7.27
7.26
7.25
7.24
7.23
7.20
7.00
6.99
6.99
6.98
6.98
6.97
6.97
6.87
6.87
6.85
6.85
4.74
4.72
4.70
4.04
4.02
4.00
4.00
3.99
3.98
3.96
3.95
3.95
3.77
OMe
O
S
O
O
Ph
7h (101 MHz, CDCl3)
10.07
1.91
2.07
1.00
2.04
3.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

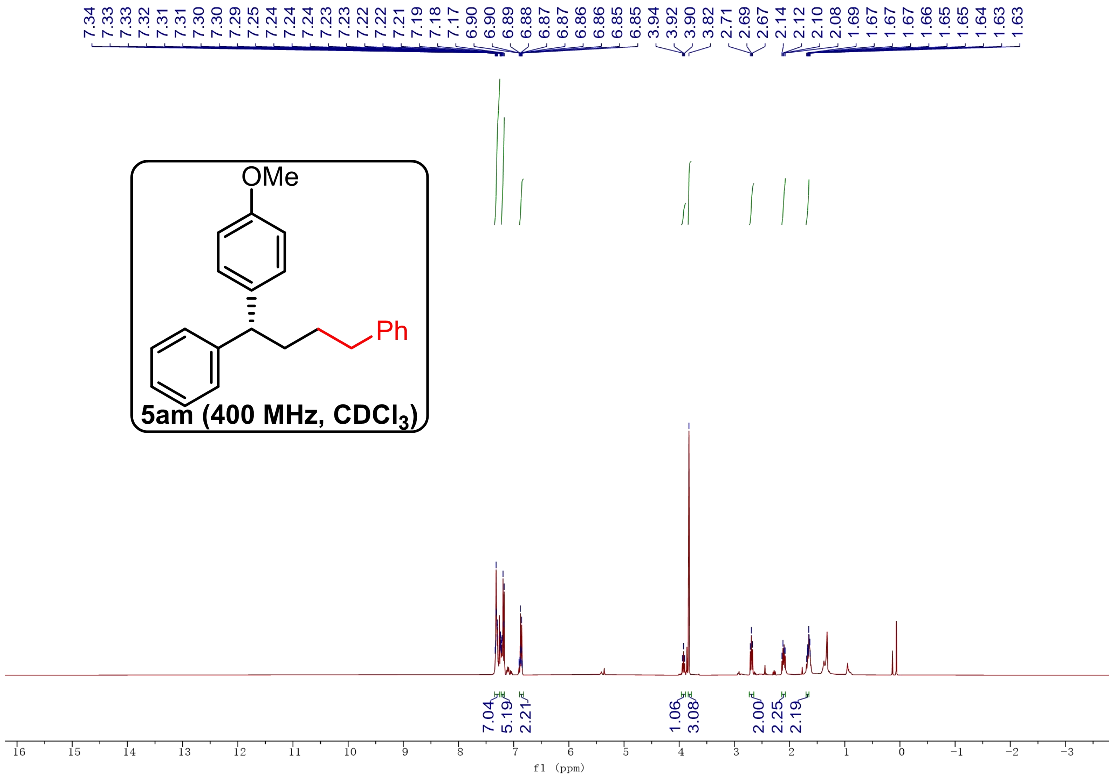

158.85
149.03
141.77
133.46
129.96
129.04
128.91
127.77
127.38
127.20
121.99
114.39
77.48
77.16
76.84
56.34
55.41
45.85
OMe
O
S
O
O
Ph
7h (400 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

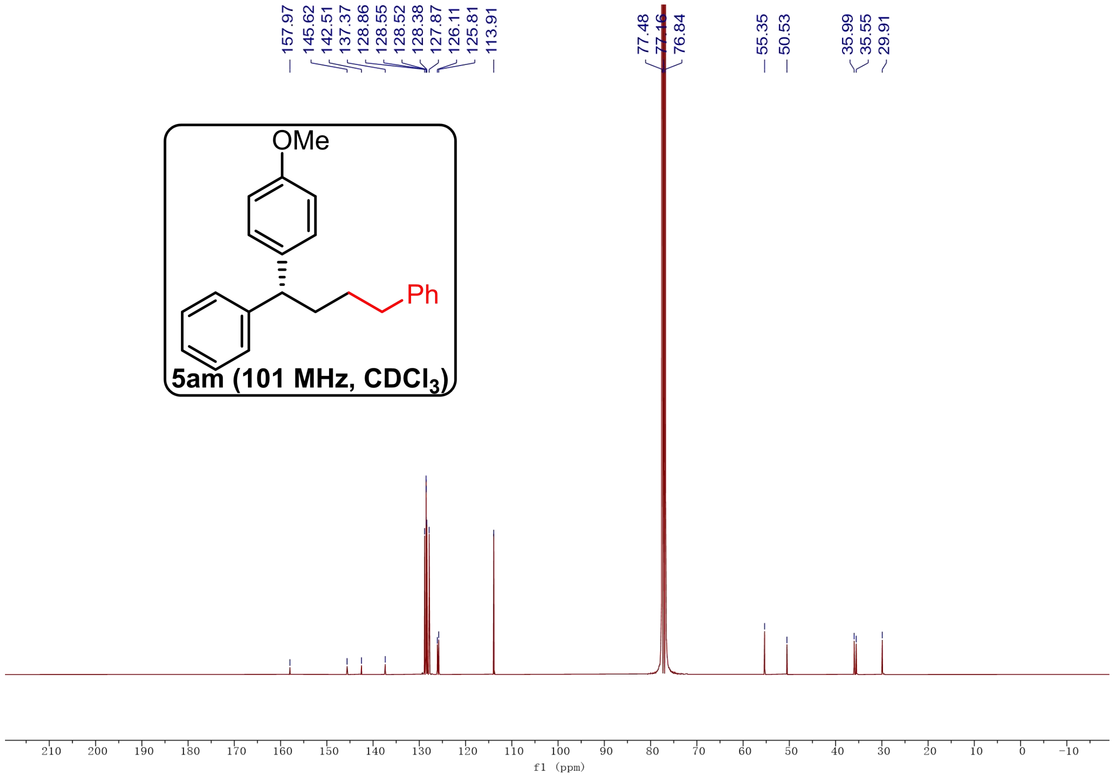

7.83
7.83
7.81
7.81
7.63
7.63
7.61
7.61
7.61
7.54
7.52
7.50
7.26
7.26
7.25
7.24
7.23
7.23
7.22
7.17
7.17
7.15
7.15
7.14
7.13
7.13
7.08
7.08
7.07
7.06
6.80
6.78
3.78
3.77
3.76
3.76
3.10
3.08
3.08
3.07
3.06
2.12
2.10
2.08
2.06
1.73
1.71
1.71
1.70
1.70
1.69
1.69
1.68
1.68
1.67
1.67
1.66
OMe
O
S
Ph
O
5ai (400 MHz, CDCl$_3$)
2.19
1.19
2.24
2.11
3.00
1.97
2.23
4.09
2.00
2.14
2.28
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

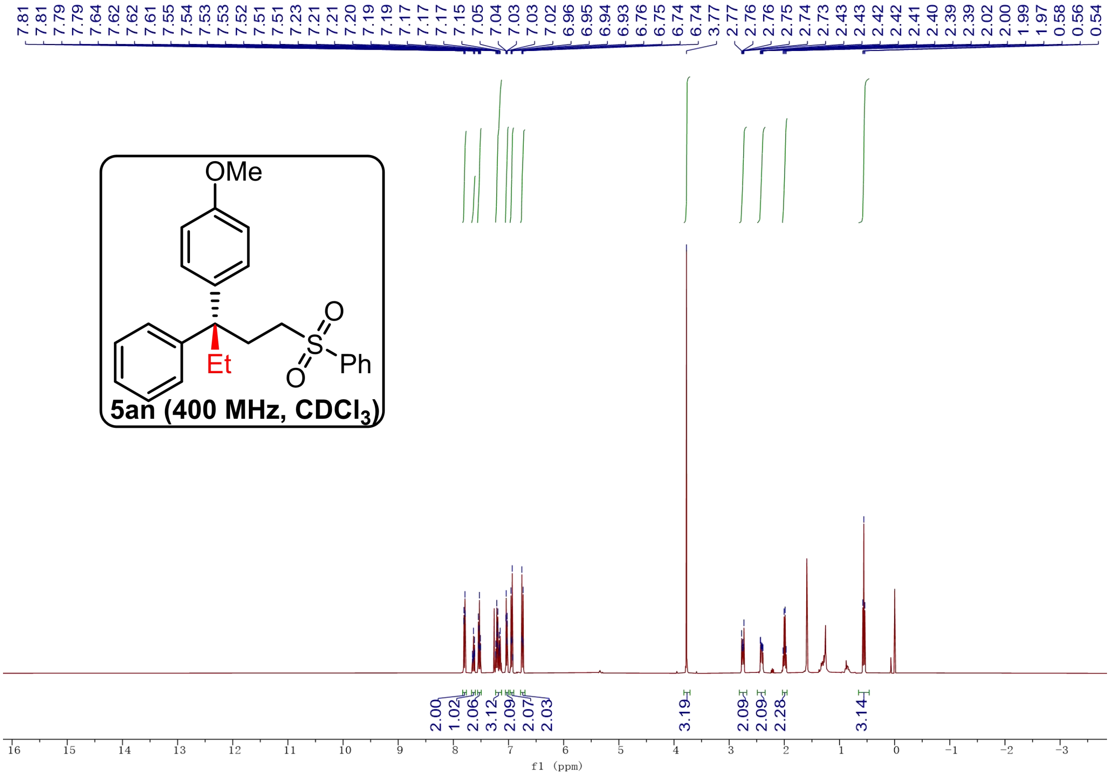

158.21
144.54
139.20
136.25
133.72
129.36
128.74
128.69
128.15
127.71
126.45
114.09
77.48
77.16
76.84
56.18
55.37
50.16
34.42
21.47
OMe
O
S
Ph
O
5ai (101 MHz, CDCl$_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

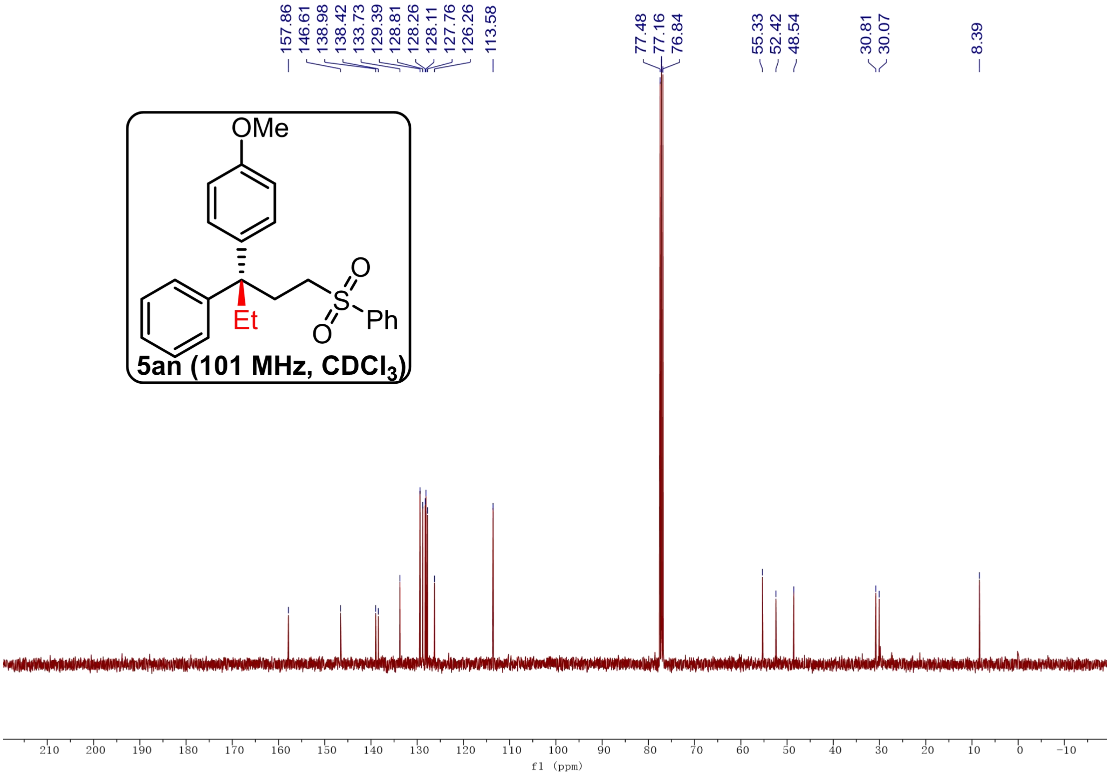

7.89
7.88
7.87
7.86
7.65
7.63
7.57
7.55
7.53
7.27
7.26
7.25
7.25
7.25
7.25
7.23
7.17
7.16
7.16
7.15
7.15
7.14
7.10
7.09
7.08
7.08
6.81
6.80
6.79
6.79
6.78
3.79
3.78
3.77
3.76
3.75
3.05
3.03
3.01
2.00
1.98
1.96
1.94
1.75
1.73
1.71
1.33
1.32
1.31
1.31
1.30
1.30
1.29
1.28
1.28
1.26
1.26
OMe
O
S
Ph
O
5aj (400 MHz, CDCl$_3$)
2.00
1.17
2.12
2.06
3.19
2.10
2.23
4.45
2.05
2.10
2.16
2.26
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)


158.12
145.12
139.30
136.85
133.76
129.40
128.75
128.62
128.20
127.75
126.30
114.02
77.48
77.16
76.84
56.31
55.36
50.27
35.40
26.93
22.82
OMe
O
S
Ph
O
5aj (101 MHz, CDCl$_3$)
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)


7.34
7.33
7.33
7.32
7.31
7.31
7.30
7.30
7.29
7.25
7.24
7.24
7.24
7.23
7.23
7.22
7.22
7.21
7.19
7.18
7.17
6.90
6.90
6.89
6.88
6.87
6.87
6.86
6.86
6.85
6.85
3.94
3.92
3.90
3.82
2.71
2.69
2.67
2.14
2.12
2.10
2.08
1.69
1.67
1.67
1.67
1.66
1.65
1.65
1.64
1.63
1.63
OMe
Ph
5am (400 MHz, $CDCl_3$)
7.04
5.19
2.21
1.06
3.08
2.00
2.25
2.19
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)


157.97
145.62
142.51
137.37
128.86
128.55
128.52
128.38
127.87
126.11
125.81
113.91
77.48
77.16
76.84
55.35
50.53
35.99
35.55
29.91
OMe
Ph
5am (101 MHz, $CDCl_3$)
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)


7.81
7.81
7.79
7.79
7.64
7.62
7.62
7.61
7.55
7.54
7.53
7.53
7.52
7.51
7.51
7.23
7.21
7.21
7.20
7.19
7.19
7.17
7.17
7.17
7.15
7.05
7.04
7.03
7.03
7.02
6.96
6.95
6.94
6.93
6.76
6.75
6.74
6.74
3.77
2.77
2.76
2.76
2.75
2.74
2.73
2.43
2.43
2.42
2.42
2.41
2.40
2.39
2.39
2.02
2.00
1.99
1.97
0.58
0.56
0.54
OMe
O
S
O
Ph
Et
5an (400 MHz, CDCl$_3$)
2.00
1.02
2.06
3.12
2.09
2.07
2.03
3.19
2.09
2.09
2.28
3.14
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)


157.86
146.61
138.98
138.42
133.73
129.39
128.81
128.26
128.11
127.76
126.26
113.58
77.48
77.16
76.84
55.33
52.42
48.54
30.81
30.07
8.39
OMe
O
S
O
Ph
Et
5an (101 MHz, CDCl$_3$)
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)