

β -Sulfonylation of α -Bromoaldehydes Enabled by N-Heterocyclic Carbene

Catalysis

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General Methods and Materials

All reactions were carried out under an atmosphere of nitrogen in dry glassware, and were monitored by analytical thin-layer chromatography (TLC), which was visualized by ultraviolet light (254 nm). All solvents were obtained from commercial sources and were purified according to standard procedures. Purification of the products was accomplished by flash chromatography using silica gel (200~300 mesh). Sodium sulfinates **2** and alcohols **3** are commercially available. 2-Bromoenal **1a** is commercially available and was used without further purification. Other 2-bromo-enals and (*E*)-**1** were prepared according to known procedures.¹ All NMR spectra were recorded on spectrometers, running at 300 MHz or 500 MHz for ¹H and 75 MHz for ¹³C respectively. Chemical shifts (δ) and coupling constants (J) are reported in ppm and Hz respectively. The solvent signals were used as references (residual CHCl₃ in CDCl₃: δ_{H} = 7.26 ppm, δ_{C} = 77.0 ppm; residual DMSO in DMSO-*d*₆: δ_{H} = 2.5 ppm, δ_{C} = 39.5 ppm). The following abbreviations are used to indicate the multiplicity in NMR spectra: s (singlet); d (doublet); t (triplet); q (quartet); m (multiplet). High resolution mass spectrometry (HRMS) was recorded on TOF perimer for ES⁺.

General experimental procedure for the synthesis of products **4**

To a 10 mL flask was charged with sodium sulfinate **2** (0.15 mmol), α -bromoenal **1** (0.225 mmol), carbene precursor **Q** (5.4 mg, 0.015 mmol) and Li₂CO₃ (16.4 mg, 0.225 mmol). Then PhMe (1 mL) and alcohol **3** (0.45mmol) were added and the resulting mixture was stirred at room temperature for 48 h. After completion of the reaction as monitored by TLC, the solvent was evaporated under reduced pressure and the residue was purified by chromatography on silica gel using hexane/EtOAc (10:1) as eluent to afford the products **4**.

Procedure for the scale-up synthesis of product **4aa**

To a 50 mL two-neck bound-bottom flask was charged with sodium benzenesulfinate **2a** (328 mg, 2 mmol), α -bromocinnamaldehyde **1a** (624 mg, 3 mmol), carbene precursor **Q** (73 mg, 0.2 mmol) and Li₂CO₃ (144 mg, 2 mmol). Then PhMe (13 mL) and cyclohexanol (600 mg, 6 mmol) were added and the resulting mixture was stirred at rt for 48 h. After completion of the reaction as monitored by TLC, the solvent was evaporated under reduced pressure and the residue was purified by chromatography on silica gel using hexane/EtOAc (10:1) as eluent to afford product **4a** (565mg, 76%).

Table S1. Initial screening of the reaction conditions for asymmetric synthesis^a

$\text{1a} + \text{2a} \xrightarrow[\text{DCM, rt, 24 h}]{\text{cat. (10 mol\%)/base, additive (10 mol\%)}} \text{4aa}$

Ar = Mes, **F**
C₆F₅, **G**
2,4,6-Cl₃C₆H₂, **H**

I

J

K

L

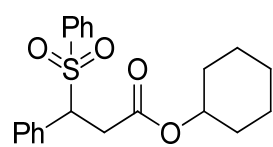
M

N

entry	catalyst	base	additive	yield (%) ^b	ee (%) ^c
1	F	NaOAc	none	trace	-
2	G	NaOAc	none	10	6
3	H	NaOAc	none	12	10
4	I	NaOAc	none	44	0
5	J	NaOAc	none	17	9
6	K	NaOAc	none	49	4
7	K	K ₂ CO ₃	none	49	0
8	K	DIPEA	none	trace	-
9	K	Et ₃ N	none	69	0
10	K	Li ₂ CO ₃	none	70	0
11	K	PhCOONa	none	78	0
12	K	PhCOONa	Mg(OTf) ₂	75	0
13	K	PhCOONa	Sc(OTf) ₃	82	0
14	K	PhCOONa	L	51	0
15	K	PhCOONa	M	53	0
16	K	PhCOONa	N	50	0

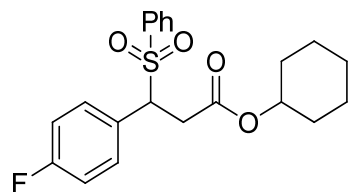
^a Unless otherwise noted, all reactions were performed in a 10 mL flask on a 0.15 mmol scale with 1.5 equiv. of **1a**, 1.0 equiv. of **2a**, 3.0 equiv. of **3a**, 10 mol% of a carbene precursor, 10 mol% of an additive, 1.5 equiv. of a base and 200 mg of 4 Å MS in anhydrous DCM (1 mL) at rt for 24 h under N₂. ^b Isolated yields based on **2a**. ^c ee values were determined by chiral HPLC analysis.

Cyclohexyl 3-phenyl-3-(phenylsulfonyl)propanoate (4aa). White solid, MP: 133-



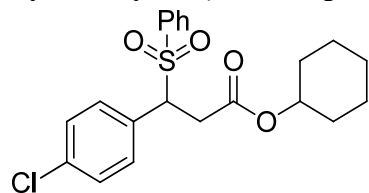
134°C; 56 mg, 99% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.61-7.54 (m, 3H), 7.42 (t, $J = 7.6$ Hz, 2H), 7.32-7.28 (m, 1H), 7.24 (t, $J = 7.3$ Hz, 2H), 7.13 (d, $J = 7.3$ Hz, 2H), 4.66 (dd, $J = 10.3$, 4.5 Hz, 2H), 3.44 (dd, $J = 16.1$, 4.5 Hz, 1H), 3.13 (dd, $J = 16.1$, 10.5 Hz, 1H), 1.70-1.63 (m, 4H), 1.52-1.44 (m, 1H), 1.30-1.11 (m, 5H). ^{13}C NMR (75 MHz, CDCl_3) δ 168.9, 136.5, 133.8, 131.7, 129.7, 129.2, 129.0, 128.7, 128.4, 73.7, 67.2, 33.7, 31.3, 31.2, 25.2, 23.49, 23.48. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{25}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 373.1474, found 373.1468.

Cyclohexyl 3-(4-fluorophenyl)-3-(phenylsulfonyl)propanoate (4ba). White solid,



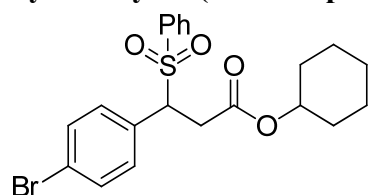
MP: 134-136°C; 50 mg, 86% yield. ^1H NMR (300 MHz, CDCl_3) δ 7.61-7.53 (m, 3H), 7.42 (t, $J = 7.5$ Hz, 2H), 7.12-7.08 (m, 2H), 6.92 (t, $J = 8.2$ Hz, 2H), 4.73-4.51 (m, 2H), 3.40 (dd, $J = 16.2$, 4.0 Hz, 1H), 3.05 (dd, $J = 16.0$, 10.8 Hz, 1H), 1.69-1.58 (m, 4H), 1.51-1.15 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 168.7, 163.1 (d, $J = 247.1$ Hz), 136.4, 133.9, 131.4 (d, $J = 8.5$ Hz), 129.1, 128.8, 127.6 (d, $J = 3.0$ Hz), 115.5 (d, $J = 21.6$ Hz), 73.8, 66.5, 33.8, 31.3, 31.2, 25.2, 23.5. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{24}\text{FO}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 391.1379, found 391.1380.

Cyclohexyl 3-(4-chlorophenyl)-3-(phenylsulfonyl)propanoate (4ca). White solid,



MP: 133-137°C; 50 mg, 82% yield. ^1H NMR (300 MHz, $\text{DMSO}-d_6$) δ 7.72 (d, $J = 7.5$ Hz, 1H), 7.66 (d, $J = 8.0$ Hz, 2H), 7.58 (t, $J = 7.5$ Hz, 2H), 7.35 (d, $J = 7.7$ Hz, 2H), 7.24 (d, $J = 8.4$ Hz, 2H), 4.97 (dd, $J = 9.0$, 6.0 Hz, 1H), 4.55-4.44 (m, 1H), 3.18-3.06 (m, 2H), 1.60-1.47 (m, 4H), 1.43-1.34 (m, 1H), 1.26-1.14 (m, 5H). ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$) δ 168.1, 136.2, 134.2, 133.6, 131.5, 130.7, 129.1, 128.7, 128.1, 72.6, 64.8, 33.3, 30.6, 30.6, 24.7, 22.7. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{24}\text{ClO}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 407.1084, found 407.1070.

Cyclohexyl 3-(4-bromophenyl)-3-(phenylsulfonyl)propanoate (4da). White solid,



MP: 145-147°C; 64 mg, 95% yield. ¹H NMR (300 MHz,

DMSO-*d*₆) δ 7.73 (t, *J* = 7.3 Hz, 1H), 7.67 (d, *J* = 7.7 Hz,

2H), 7.58 (t, *J* = 7.7 Hz, 2H), 7.49 (d, *J* = 7.7 Hz, 2H),

7.18 (d, *J* = 7.9 Hz, 2H), 4.96 (t, *J* = 7.9 Hz, 1H), 4.55-4.44 (m, 1H), 3.23-3.01 (m, 2H),

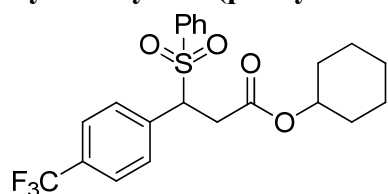
1.60-1.46 (m, 4H), 1.43-1.34 (m, 1H), 1.27-1.12 (m, 5H). ¹³C NMR (100 MHz, DMSO-

*d*₆) δ 168.1, 136.2, 134.2, 131.8, 131.11, 131.06, 129.1, 128.7, 122.2, 72.6, 64.9, 33.2,

30.63, 30.57, 24.7, 22.7. HRMS (ESI) calcd for C₂₁H₂₄BrO₄S (M+H)⁺: 451.0579, found

451.0565.

Cyclohexyl 3-(phenylsulfonyl)-3-(4-(trifluoromethyl)phenyl)propanoate (4ea).



White solid, MP: 132-133°C; 45 mg, 69% yield. ¹H

NMR (400 MHz, DMSO-*d*₆) δ 7.73 (t, *J* = 7.4 Hz, 1H),

7.70-7.64 (m, 4H), 7.57 (t, *J* = 7.8 Hz, 2H), 7.48 (d, *J*

= 8.1 Hz, 2H), 5.11 (dd, *J* = 9.0, 6.2 Hz, 1H), 4.53-4.39 (m, 1H), 3.23-3.14 (m, 2H),

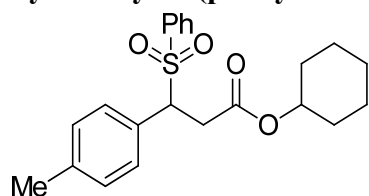
1.54-1.40 (m, 4H), 1.40-1.30 (m, 1H), 1.24-1.06 (m, 5H). ¹³C NMR (100 MHz, DMSO-

*d*₆) δ 168.2, 136.6, 136.2, 134.5, 130.8, 129.3, 129.2 (q, *J* = 31.6 Hz), 128.9, 125.1 (q,

J = 3.5 Hz), 124.1 (q, *J* = 270.7 Hz), 72.7, 65.0, 33.3, 30.66, 30.60, 24.7, 22.8. HRMS

(ESI) calcd for C₂₂H₂₄F₃O₄S (M+H)⁺: 441.1347, found 441.1342.

Cyclohexyl 3-(phenylsulfonyl)-3-(*p*-tolyl)propanoate (4fa). White solid, MP: 128-



129°C; 55 mg, 95% yield. ¹H NMR (400 MHz, CDCl₃)

δ 7.61-7.50 (m, 3H), 7.44-7.36 (m, 2H), 7.04-6.97 (m,

4H), 4.60 (dd, *J* = 10.4, 4.8 Hz, 2H), 3.38 (dd, *J* = 16.1,

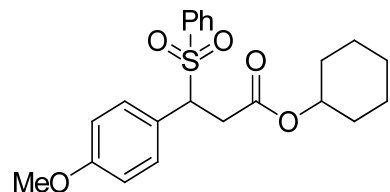
4.8 Hz, 1H), 3.06 (dd, *J* = 16.1, 10.4 Hz, 1H), 2.29 (s, 3H), 1.67-1.60 (m, 3H), 1.49-

1.42 (m, 1H), 1.33-1.11 (m, 6H). ¹³C NMR (75 MHz, CDCl₃) δ 168.9, 138.9, 136.6,

133.7, 129.5, 129.2, 129.1, 128.7, 128.5, 73.6, 66.9, 33.8, 31.3, 31.2, 25.2, 23.5, 21.2.

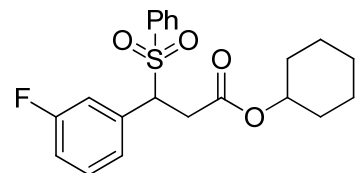
HRMS (ESI) calcd for C₂₂H₂₇O₄S (M+H)⁺: 387.1630, found 387.1625.

Cyclohexyl 3-(4-methoxyphenyl)-3-(phenylsulfonyl)propanoate (4ga). White solid, MP: 106-107°C; 56 mg, 92% yield. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.63-7.50 (m, 3H), 7.46-7.35 (m, 2H), 7.08-6.99 (m, 2H), 6.81-6.67 (m, 2H), 4.59 (dd, *J* = 10.5, 4.7



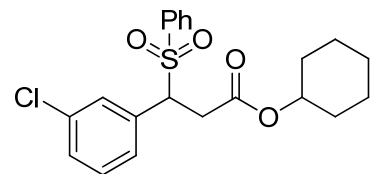
Hz, 2H), 3.77 (s, 3H), 3.38 (dd, *J* = 16.0, 4.7 Hz, 1H), 3.04 (dd, *J* = 16.0, 10.5 Hz, 1H), 1.69-1.58 (m, 4H), 1.50-1.42 (m, 1H), 1.30-1.20 (m, 5H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 168.96, 160.0, 136.6, 133.7, 130.8, 129.2, 128.7, 123.3, 113.8, 73.6, 66.6, 55.2, 33.8, 31.3, 31.2, 25.2, 23.5. HRMS (ESI) calcd for C₂₂H₂₇O₅S (M+H)⁺: 403.1579, found 403.1583.

Cyclohexyl 3-(3-fluorophenyl)-3-(phenylsulfonyl)propanoate (4ha). White solid,



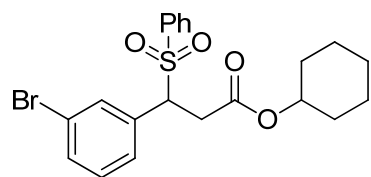
MP: 108-110°C; 53 mg, 91% yield. ¹H NMR (400 MHz, DMSO-*d*₆) δ 7.75-7.68 (m, 1H), 7.68-7.61 (m, 2H), 7.56 (t, *J* = 7.8 Hz, 2H), 7.31 (td, *J* = 8.0, 6.2 Hz, 1H), 7.15 (td, *J* = 8.4, 2.2 Hz, 1H), 7.09 (dt, *J* = 10.2, 1.9 Hz, 1H), 7.04 (d, *J* = 7.8 Hz, 1H), 5.05-4.92 (m, 1H), 4.52-4.47 (m, 1H), 3.20-3.08 (m, 2H), 1.62-1.43 (m, 4H), 1.42-1.35 (m, 1H), 1.27-1.11 (m, 5H). ¹³C NMR (100 MHz, DMSO-*d*₆) δ 168.2, 161.6 (d, *J* = 242.1 Hz), 136.2, 134.4 (d, *J* = 7.9 Hz), 134.3, 130.0 (d, *J* = 8.2 Hz), 129.1, 128.8, 125.9 (d, *J* = 2.7 Hz), 116.6 (d, *J* = 22.4 Hz), 115.6 (d, *J* = 20.7 Hz), 72.6, 65.0, 33.2, 30.7, 30.6, 24.7, 22.8. HRMS (ESI) calcd for C₂₂H₂₇O₄S (M+H)⁺: 387.1630, found 387.1618.

Cyclohexyl 3-(3-chlorophenyl)-3-(phenylsulfonyl)propanoate (4ia). White solid,



MP: 90-92°C; 60 mg, 99% yield. ¹H NMR (300 MHz, CDCl₃) δ 7.64-7.55 (m, 3H), 7.45 (t, *J* = 7.5 Hz, 2H), 7.27 (d, *J* = 6.7 Hz, 1H), 7.17 (t, *J* = 7.8 Hz, 1H), 7.09 (s, 1H), 7.03 (d, *J* = 7.5 Hz, 1H), 4.64-4.57 (m, 2H), 3.40 (dd, *J* = 16.3, 4.3 Hz, 1H), 3.06 (dd, *J* = 16.2, 10.5 Hz, 1H), 1.71-1.57 (m, 4H), 1.50-1.20 (m, 6H). ¹³C NMR (100 MHz, CDCl₃) δ 168.6, 136.3, 134.3, 134.1, 133.8, 129.7, 129.6, 129.18, 129.16, 128.9, 127.9, 73.9, 66.8, 33.6, 31.3, 31.2, 25.2, 23.5. HRMS (ESI) calcd for C₂₁H₂₄ClO₄S (M+H)⁺: 407.1084, found 407.1080.

Cyclohexyl 3-(3-bromophenyl)-3-(phenylsulfonyl)propanoate (4ja). White solid,



MP: 86-88°C; 57 mg, 84% yield. ¹H NMR (400 MHz,

DMSO-*d*₆) δ 7.72-7.65 (m, 1H), 7.64-7.58 (m, 2H),

7.55-7.51 (m, 2H), 7.48-7.40 (m, 1H), 7.36 (s, 1H), 7.20

(d, *J* = 5.0 Hz, 2H), 4.95 (dd, *J* = 8.8, 6.6 Hz, 1H), 4.53-4.37 (m, 1H), 3.10-3.07 (m,

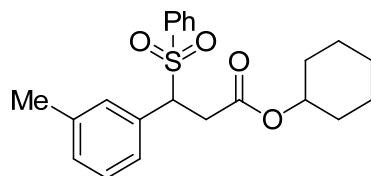
2H), 1.52-1.39 (m, 4H), 1.36-1.28 (s, 1H), 1.21-1.05 (m, 5H). ¹³C NMR (100 MHz,

DMSO-*d*₆) δ 168.1, 136.2, 134.3, 132.8, 131.6, 130.2, 129.2, 128.8, 128.6, 121.2, 72.6,

64.8, 33.2, 30.7, 30.6, 24.7, 22.75, 22.71. HRMS (ESI) calcd for C₂₁H₂₄BrO₄S (M+H)⁺:

451.0579, found 451.0564.

Cyclohexyl 3-(phenylsulfonyl)-3-(*m*-tolyl)propanoate (4ka). White solid, MP: 81-



83°C; 50 mg, 86% yield. ¹H NMR (300 MHz, DMSO-

*d*₆) δ 7.71 (t, *J* = 7.2 Hz, 1H), 7.65-7.59 (m, 2H), 7.59-

7.50 (m, 2H), 7.17-7.09 (m, 2H), 7.00-6.91 (m, 2H),

4.80 (dd, *J* = 9.6, 5.6 Hz, 1H), 4.54-4.44 (m, 1H), 3.22-2.99 (m, 2H), 2.20 (s, 3H), 1.58-

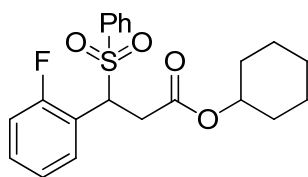
1.47 (m, 4H), 1.43-1.32 (m, 1H), 1.27-1.13 (m, 5H). ¹³C NMR (100 MHz, DMSO-*d*₆)

δ 168.3, 137.2, 136.4, 134.1, 131.4, 130.4, 129.4, 129.1, 128.8, 127.98, 126.8, 72.5,

65.7, 33.4, 30.7, 30.6, 24.73, 22.74, 20.80. HRMS (ESI) calcd for C₂₂H₂₇O₄S (M+H)⁺:

387.1630, found 387.1618.

Cyclohexyl 3-(2-fluorophenyl)-3-(phenylsulfonyl)propanoate (4la). White solid,



MP: 75-77°C; 43 mg, 74% yield. ¹H NMR (400 MHz,

DMSO-*d*₆) δ 7.69 (dt, *J* = 7.0, 3.4 Hz, 1H), 7.56-7.50 (m, 4H),

7.40-7.28 (m, 2H), 7.16 (t, *J* = 7.5 Hz, 1H), 7.06-6.91 (m, 1H),

5.00 (dd, *J* = 9.8, 5.2 Hz, 1H), 4.50-4.40 (m, 1H), 3.24 (dd, *J* = 16.4, 5.2 Hz, 1H), 3.14

(dd, *J* = 16.3, 10.0 Hz, 1H), 1.55-1.24 (m, 5H), 1.22-1.02 (m, 5H). ¹³C NMR (100 MHz,

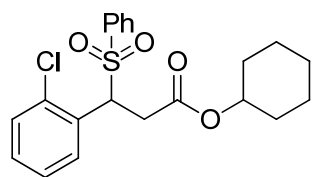
DMSO-*d*₆) δ 168.1, 160.6 (d, *J* = 244.1 Hz), 136.3, 134.5, 131.1 (d, *J* = 8.3 Hz), 129.9,

129.3, 128.7, 124.5 (d, *J* = 3.0 Hz), 119.1 (d, *J* = 13.2 Hz), 115.2 (d, *J* = 21.8 Hz), 72.7,

58.8, 32.7, 30.7, 30.6, 24.7, 22.80, 22.76. HRMS (ESI) calcd for C₂₁H₂₄FO₄S (M+H)⁺:

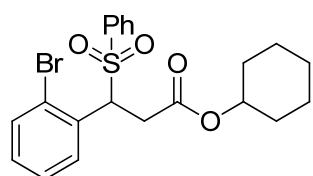
391.1379, found 391.1372.

Cyclohexyl 3-(2-chlorophenyl)-3-(phenylsulfonyl)propanoate (4ma). Colorless oil;



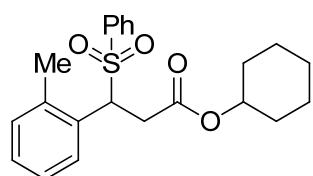
41 mg, 68% yield. ^1H NMR (400 MHz, Chloroform-*d*) δ 7.60-7.55 (m, 4H), 7.44-7.36 (m, 2H), 7.30 (td, $J = 7.5, 1.6$ Hz, 1H), 7.25-7.14 (m, 2H), 5.38 (dd, $J = 11.0, 4.4$ Hz, 1H), 4.61-4.56 (m, 1H), 3.48 (dd, $J = 16.3, 4.4$ Hz, 1H), 3.17 (dd, $J = 16.3, 11.0$ Hz, 1H), 1.67-1.56 (m, 4H), 1.50-1.41 (m, 1H), 1.25-1.56 (m, 5H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 168.5, 136.9, 136.1, 133.97, 130.1, 129.96, 129.7, 129.4, 129.2, 128.8, 127.1, 73.9, 61.8, 33.7, 31.3, 31.1, 25.1, 23.60, 23.57. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{24}\text{ClO}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 407.1084, found 407.1084.

Cyclohexyl 3-(2-bromophenyl)-3-(phenylsulfonyl)propanoate (4na). Colorless oil;



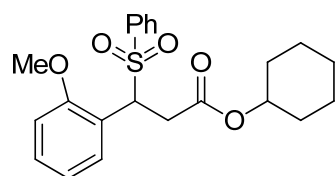
56 mg, 83% yield. ^1H NMR (400 MHz, Chloroform-*d*) δ 7.67-7.51 (m, 4H), 7.45-7.31 (m, 4H), 7.14 (td, $J = 7.9, 1.6$ Hz, 1H), 5.38 (dd, $J = 10.9, 4.4$ Hz, 1H), 4.65-4.51 (m, 1H), 3.46 (dd, $J = 16.3, 4.5$ Hz, 1H), 3.17 (dd, $J = 16.2, 11.0$ Hz, 1H), 1.70-1.54 (m, 4H), 1.50-1.43 (m, 1H), 1.27-1.13 (m, 5H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 168.4, 136.8, 134.0, 132.8, 131.6, 130.3, 129.8, 129.3, 128.8, 127.7, 127.3, 73.9, 64.4, 33.9, 31.3, 31.1, 25.1, 23.63, 23.60. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{24}\text{BrO}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 451.0579, found 451.0574.

Cyclohexyl 3-(phenylsulfonyl)-3-(*o*-tolyl)propanoate (4oa). Colorless oil; 53 mg, 92%



yield. ^1H NMR (400 MHz, Chloroform-*d*) δ 7.61-7.55 (m, 1H), 7.55-7.49 (m, 2H), 7.43-7.32 (m, 3H), 7.20-7.15 (m, 2H), 7.00-6.97 (m, 1H), 4.97 (dd, $J = 10.7, 4.4$ Hz, 1H), 4.60-4.54 (m, 1H), 3.44 (dd, $J = 16.3, 4.3$ Hz, 1H), 3.13 (dd, $J = 16.3, 10.7$ Hz, 1H), 1.97 (s, 3H), 1.68-1.54 (m, 4H), 1.49-1.41 (m, 1H), 1.27-1.14 (m, 5H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 169.06, 138.62, 137.09, 133.87, 130.33, 130.27, 129.26, 128.85, 128.75, 128.07, 126.25, 73.80, 62.02, 34.45, 31.35, 31.26, 25.20, 23.64, 19.27. HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{27}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 387.1630, found 387.1623.

Cyclohexyl 3-(2-methoxyphenyl)-3-(phenylsulfonyl)propanoate (4pa). Colorless



oil; 37 mg, 61% yield. ^1H NMR (400 MHz, Chloroform-*d*)

δ 7.55-7.48 (m, 3H), 7.41 (dd, J = 7.7, 1.6 Hz, 1H), 7.37-

7.30 (m, 2H), 7.21 (td, J = 8.3, 1.6 Hz, 1H), 7.00-6.90 (m,

1H), 6.54 (d, J = 7.9 Hz, 1H), 5.45-5.33 (m, 1H), 4.69-4.55 (m, 1H), 3.46 (dd, J = 16.2,

4.8 Hz, 1H), 3.30 (s, 3H), 3.16 (dd, J = 16.2, 10.8 Hz, 1H), 1.65-1.53 (m, 4H), 1.46-

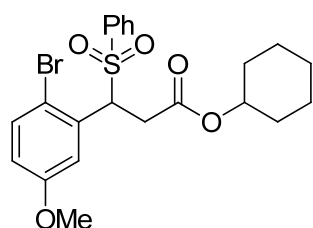
1.40 (m, 1H), 1.27-1.15 (m, 5H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 169.1, 157.4,

137.6, 133.3, 130.1, 129.2, 128.9, 128.1, 120.6, 120.3, 110.1, 77.2, 73.4, 58.4, 54.97,

32.8, 31.2, 31.1, 25.2, 23.4, 23.3. HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{27}\text{O}_5\text{S}$ ($\text{M}+\text{H}$) $^+$: 403.1579,

found 403.1571.

Cyclohexyl 3-(2-bromo-5-methoxyphenyl)-3-(phenylsulfonyl)propanoate (4qa).



White solid, MP: 98-99°C; 66 mg, 92% yield. ^1H NMR (400

MHz, DMSO-*d*₆) δ 7.76-7.72 (m, 1H), 7.60-7.54 (m, 4H),

7.40 (d, J = 8.8 Hz, 1H), 7.01 (d, J = 3.1 Hz, 1H), 6.89 (dd, J

= 8.9, 3.1 Hz, 1H), 5.19 (dd, J = 9.5, 5.3 Hz, 1H), 4.51-4.47

(m, 1H), 3.74 (s, 3H), 3.28 (dd, J = 16.2, 5.4 Hz, 1H), 3.17 (dd, J = 16.3, 9.6 Hz, 1H),

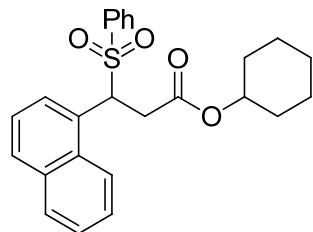
1.63-1.46 (m, 4H), 1.44-1.34 (m, 1H), 1.25-1.11 (m, 5H). ^{13}C NMR (100 MHz, DMSO-

*d*₆) δ 168.0, 158.5, 136.5, 134.5, 133.2, 132.1, 129.3, 128.8, 116.8, 116.4, 115.7, 72.8,

64.3, 55.5, 33.9, 30.7, 30.6, 24.7, 22.9. HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{25}\text{BrO}_5\text{S}$ ($\text{M}+\text{H}$) $^+$:

481.0684, found 481.0682.

Cyclohexyl 3-(naphthalen-1-yl)-3-(phenylsulfonyl)propanoate (4ra). Colorless oil;



48 mg, 75% yield. ^1H NMR (400 MHz, Chloroform-*d*) δ

7.88-7.68 (m, 3H), 7.58 (d, J = 7.2 Hz, 1H), 7.50-7.41 (m,

3H), 7.39-7.30 (m, 3H), 7.20 (t, J = 7.7 Hz, 2H), 5.68 (dd, J

= 10.2, 4.7 Hz, 1H), 4.60-4.40 (m, 1H), 3.62 (dd, J = 16.3,

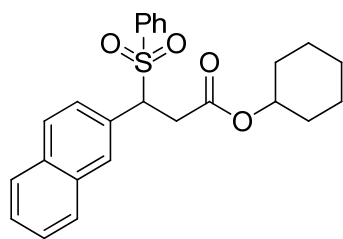
4.7 Hz, 1H), 3.28 (dd, J = 16.3, 10.2 Hz, 1H), 1.58-1.36 (m, 5H), 1.19-0.96 (m, 5H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 168.9, 136.5, 133.6, 133.4, 132.2, 129.7, 129.1,

128.6, 128.5, 128.1, 126.7, 126.5, 125.6, 124.9, 122.2, 73.7, 60.7, 34.8, 31.2, 30.95,

25.1, 23.4, 23.3. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{27}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 423.1630, found 423.1622.

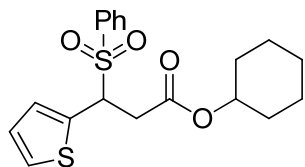
Cyclohexyl 3-(naphthalen-2-yl)-3-(phenylsulfonyl)propanoate (4sa). White solid,



MP: 120-124°C; 59 mg, 93% yield. ^1H NMR (300 MHz, CDCl_3) δ 7.81 (d, $J = 7.3$ Hz, 1H), 7.72 (t, $J = 7.2$ Hz, 2H), 7.62-7.53 (m, 4H), 7.52-7.44 (m, 2H), 7.37 (t, $J = 8.0$ Hz, 2H), 7.28-7.24 (m, 1H), 4.84 (dd, $J = 10.4, 4.7$ Hz, 1H), 4.67-4.56 (m, 1H), 3.53 (dd, $J = 16.3, 4.4$ Hz, 1H), 3.24

(dd, $J = 16.1, 10.3$ Hz, 1H), 1.71-1.58 (m, 4H), 1.51-1.40 (m, 1H), 1.30-1.17 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3) δ 168.9, 136.5, 133.8, 133.3, 132.8, 129.5, 129.2, 129.1, 128.8, 128.2, 128.1, 127.6, 126.7, 126.3, 73.7, 67.4, 33.9, 31.3, 31.2, 25.2, 23.5. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{27}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 423.1630, found 423.1627. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{27}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 423.1630, found 423.1627.

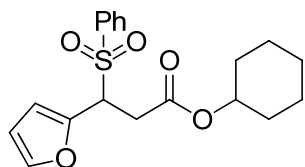
Cyclohexyl 3-(phenylsulfonyl)-3-(thiophen-2-yl)propanoate (4ta). White solid, MP:



112-114°C; 45 mg, 80% yield. ^1H NMR (400 MHz, Chloroform- d) δ 7.62-7.58 (m, 3H), 7.44 (t, $J = 7.8$ Hz, 2H), 7.24 (d, $J = 4.9$ Hz, 1H), 6.94-6.79 (m, 2H), 4.92 (dd, $J = 10.5,$

4.4 Hz, 1H), 4.73-4.58 (m, 1H), 3.44 (dd, $J = 16.1, 4.5$ Hz, 1H), 3.03 (dd, $J = 16.1, 10.5$ Hz, 1H), 1.71-1.61 (m, 4H), 1.52-1.42 (m, 1H), 1.34-1.18 (m, 5H). ^{13}C NMR (100 MHz, Chloroform- d) δ 168.5, 136.1, 133.9, 133.5, 129.2, 129.0, 128.8, 127.1, 126.8, 73.8, 62.9, 35.1, 31.3, 31.2, 25.2, 23.5. HRMS (ESI) calcd for $\text{C}_{19}\text{H}_{23}\text{O}_4\text{S}_2$ ($\text{M}+\text{H}$) $^+$: 389.1038, found 379.1036.

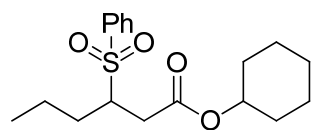
Cyclohexyl 3-(furan-2-yl)-3-(phenylsulfonyl)propanoate (4ua). White solid, MP:



94-97°C; 26 mg, 48% yield (0.03 M). ^1H NMR (300 MHz, Chloroform- d) δ 7.69-7.55 (m, 3H), 7.50-7.44 (m, 2H), 7.26 (s, 1H), 6.34-6.20 (m, 2H), 4.82 (dd, $J = 10.7, 4.6$ Hz, 1H),

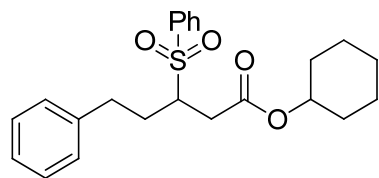
4.72-4.64 (m, 1H), 3.32 (dd, $J = 16.3, 4.6$ Hz, 1H), 3.03 (dd, $J = 16.3, 10.7$ Hz, 1H), 1.75-1.60 (m, 4H), 1.50-1.42 (m, 1H), 1.36-1.19 (m, 5H). ^{13}C NMR (101 MHz, Chloroform- d) δ 168.5, 145.4, 143.3, 136.6, 133.99, 129.1, 128.9, 111.4, 110.99, 73.8, 61.5, 32.4, 31.3, 31.2, 25.2, 23.5, 23.4. HRMS (ESI) calcd for $\text{C}_{19}\text{H}_{23}\text{O}_5\text{S}$ ($\text{M}+\text{H}$) $^+$: 363.1266, found 363.1266.

Cyclohexyl 3-(phenylsulfonyl)hexanoate (4va). Colorless oil; 33 mg, 66% yield. ¹H



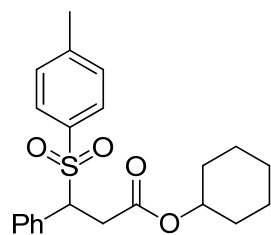
NMR (400 MHz, Chloroform-*d*) δ 7.90-7.87 (m, 2H), 7.70-7.61 (m, 1H), 7.58-7.54 (m, 2H), 4.70-4.64 (m, 1H), 3.63-3.56 (m, 1H), 2.86 (dd, J = 16.7, 5.4 Hz, 1H), 2.44 (dd, J = 16.7, 7.3 Hz, 1H), 1.94-1.83 (m, 1H), 1.82-1.73 (m, 2H), 1.72-1.64 (m, 2H), 1.56-1.46 (m, 2H), 1.42-1.24 (m, 7H), 0.86 (t, J = 7.3 Hz, 3H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 169.7, 137.3, 133.8, 129.1, 128.9, 73.7, 60.7, 33.7, 31.38, 31.35, 30.6, 25.2, 23.6, 19.8, 13.8. HRMS (ESI) calcd for C₁₈H₂₇O₄S (M+H)⁺: 339.1630, found 423.1627.

Cyclohexyl 5-phenyl-3-(phenylsulfonyl)pentanoate (4wa). Colorless oil; 41 mg, 69%



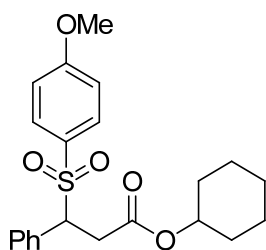
yield. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.92-7.83 (m, 2H), 7.70-7.61 (m, 1H), 7.55 (t, J = 7.7 Hz, 2H), 7.28-7.21 (m, 2H), 7.21-7.13 (m, 1H), 7.12-7.03 (m, 2H), 4.73-4.68 (m, 1H), 3.68-3.62 (m, 1H), 2.93 (dd, J = 16.6, 5.6 Hz, 1H), 2.80-2.72 (m, 1H), 2.69-2.61 (m, 1H), 2.53 (dd, J = 16.6, 7.4 Hz, 1H), 2.29-2.16 (m, 1H), 1.90-1.75 (m, 3H), 1.73-1.65 (m, 2H), 1.56-1.50 (m, 1H), 1.42-1.23 (m, 5H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 169.5, 140.1, 137.1, 133.8, 129.2, 128.9, 128.5, 128.2, 126.2, 73.78, 60.3, 33.8, 32.6, 31.4, 31.3, 30.34, 25.2, 23.6. HRMS (ESI) calcd for C₂₃H₂₉O₄S (M+H)⁺: 401.1787, found 401.1783.

Cyclohexyl 3-phenyl-3-tosylpropanoate (4ab). White solid, MP: 101-103°C; 46 mg,



79% yield. ¹H NMR (300 MHz, CDCl₃) δ 7.40 (d, J = 7.5 Hz, 2H), 7.32-7.24 (m, 2H), 7.22-7.17 (m, 3H), 7.12 (d, J = 7.4 Hz, 2H), 4.64-4.59 (m, 2H), 3.40 (dd, J = 16.4, 4.2 Hz, 1H), 3.08 (dd, J = 16.0, 10.5 Hz, 1H), 2.39 (s, 3H), 1.65-1.55 (m, 4H), 1.50-1.41 (m, 1H), 1.29-1.18 (m, 5H). ¹³C NMR (75 MHz, CDCl₃) δ 168.9, 144.8, 133.6, 131.8, 129.7, 129.4, 129.2, 128.9, 128.4, 73.6, 67.2, 33.8, 31.3, 31.2, 25.2, 23.5, 21.6. HRMS (ESI) calcd for C₂₂H₂₇O₄S (M+H)⁺: 387.1630, found 387.1626.

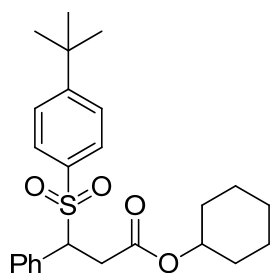
Cyclohexyl 3-((4-methoxyphenyl)sulfonyl)-3-phenylpropanoate (4ac). White solid,



MP: 78-81°C; 20 mg, 33% yield. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.46-7.37 (m, 2H), 7.29-7.26 (m, 1H), 7.25-7.19 (m, 2H), 7.16-7.06 (m, 2H), 6.87-6.77 (m, 2H), 4.60 (dd, *J* = 10.4, 4.8 Hz, 2H), 3.83 (s, 3H), 3.40 (dd, *J* = 16.1, 4.8 Hz, 1H), 3.07 (dd, *J* = 16.1, 10.4 Hz, 1H), 1.67-1.52 (m, 4H), 1.49-

1.39 (m, 1H), 1.27-1.17 (m, 5H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 168.96, 163.8, 131.93 131.3, 129.7, 128.9, 128.3, 127.9, 113.9, 73.6, 67.4, 55.6, 33.9, 31.3, 31.2, 25.2, 23.48, 23.45. HRMS (ESI) calcd for C₂₂H₂₇O₅S (M+H)⁺: 403.1579, found 403.1576.

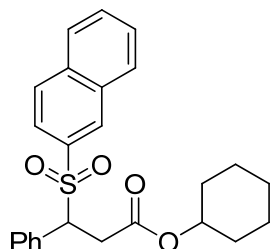
Cyclohexyl 3-((4-(*tert*-butyl)phenyl)sulfonyl)-3-phenylpropanoate (4ad). White



solid, MP: 73-76°C; 55 mg, 85% yield. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.6 Hz, 2H), 7.39 (d, *J* = 8.7 Hz, 2H), 7.30-7.25 (m, 1H), 7.21 (t, *J* = 7.3 Hz, 2H), 7.15-7.08 (m, 2H), 4.64-4.55 (m, 2H), 3.38 (dd, *J* = 16.2, 4.8 Hz, 1H), 3.09 (dd, *J* = 16.1, 10.4 Hz, 1H), 1.64-1.54 (m, 4H), 1.48-1.42 (m,

1H), 1.30 (s, 9H), 1.26-1.18 (m, 5H). ¹³C NMR (101 MHz, Chloroform-*d*) δ 168.9, 157.7, 133.4, 131.7, 129.7, 128.99, 128.86, 128.3, 125.7, 73.5, 67.2, 35.2, 33.9, 31.2, 31.1, 30.96, 25.1, 23.5, 23.4. HRMS (ESI) calcd for C₂₅H₃₃O₄S (M+H)⁺: 429.2100, found 429.2100.

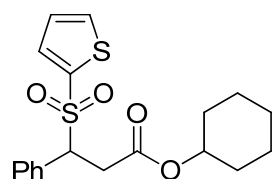
Cyclohexyl 3-(naphthalen-2-ylsulfonyl)-3-phenylpropanoate (4ah). White solid,



MP: 132-134°C; 34 mg, 54% yield. ¹H NMR (300 MHz, DMSO-*d*₆) δ 8.35 (s, 1H), 8.19-7.98 (m, 3H), 7.79-7.53 (m, 3H), 7.37-7.11 (m, 5H), 4.97 (dd, *J* = 9.5, 5.6 Hz, 1H), 4.46-4.35 (s, 1H), 3.27-3.09 (m, 2H), 1.54-1.31 (m, 5H), 1.22-1.08 (m, 5H).

¹³C NMR (100 MHz, DMSO-*d*₆) δ 168.3, 134.8, 133.7, 131.53, 131.46, 130.7, 129.83, 129.5, 129.0, 128.8, 128.1, 127.8, 127.7, 123.4, 72.6, 65.7, 33.6, 30.7, 30.6, 24.7, 22.78. HRMS (ESI) calcd for C₂₅H₂₇O₄S (M+H)⁺: 423.1630, found 423.1623.

Cyclohexyl 3-phenyl-3-(thiophen-2-ylsulfonyl)propanoate (4ai). White solid, MP:



138-139°C; 23 mg, 41% yield. ^1H NMR (300 MHz, $\text{DMSO}-d_6$)

δ 8.08 (dd, $J = 4.9, 1.4$ Hz, 1H), 7.55 (dd, $J = 3.8, 1.4$ Hz, 1H),

7.37- 7.26 (m, 3H), 7.26-7.18 (m, 3H), 4.91 (dd, $J = 9.8, 5.4$ Hz,

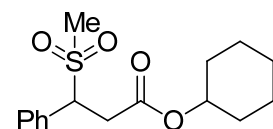
1H), 4.56-4.47 (m, 1H), 3.27 (dd, $J = 16.0, 5.4$ Hz, 1H), 3.14 (dd, $J = 16.0, 9.8$ Hz, 1H),

1.60-1.48 (m, 4H), 1.44-1.36 (m, 1H), 1.26-1.14 (m, 5H). ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$) δ 168.2, 136.59, 136.54, 135.8, 131.7, 129.6, 128.9, 128.27, 128.22, 72.6, 67.2, 33.6,

30.7, 30.6, 24.7, 22.8. HRMS (ESI) calcd for $\text{C}_{19}\text{H}_{23}\text{O}_4\text{S}_2$ ($\text{M}+\text{H}$) $^+$: 379.1038, found

379.1032.

Cyclohexyl 3-(methylsulfonyl)-3-phenylpropanoate (4aj). White solid, MP: 109-



111°C; 32 mg, 69% yield. ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ

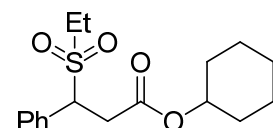
7.54-7.44 (m, 2H), 7.43-7.37 (m, 3H), 4.83 (dd, $J = 10.7, 4.7$ Hz,

1H), 4.58-4.50 (m, 1H), 3.34-3.26 (m, 1H), 3.08 (dd, $J = 15.9, 10.8$ Hz, 1H), 2.86 (s,

3H), 1.61-1.50 (m, 4H), 1.44-1.36 (m, 1H), 1.26-1.14 (m, 5H). ^{13}C NMR (101 MHz, $\text{DMSO}-d_6$) δ 168.6, 132.4, 129.7, 128.8, 128.4, 72.4, 64.2, 37.9, 33.0, 30.7, 30.6, 24.7,

22.8. HRMS (ESI) calcd for $\text{C}_{16}\text{H}_{23}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 311.1317, found 311.1315.

Cyclohexyl 3-(ethylsulfonyl)-3-phenylpropanoate (4ak). White solid, MP: 68-71°C;



36 mg, 75% yield. ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ 7.53-7.45

(m, 2H), 7.43-7.37 (m, 3H), 4.81 (dd, $J = 10.5, 4.8$ Hz, 1H),

4.60-4.48 (m, 1H), 3.28 (d, $J = 4.8$ Hz, 1H), 3.09-2.99 (m, 2H), 2.95-2.85 (m, 1H), 1.61-

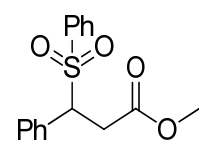
1.50 (m, 4H), 1.45-1.37 (m, 1H), 1.27-1.17 (m, 5H), 1.10 (t, $J = 7.4$ Hz, 3H). ^{13}C NMR

(101 MHz, $\text{DMSO}-d_6$) δ 168.6, 132.4, 129.6, 128.8, 128.5, 72.5, 62.8, 44.0, 33.0, 30.74,

30.66, 24.7, 22.8, 5.4. HRMS (ESI) calcd for $\text{C}_{17}\text{H}_{25}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 325.1474, found

325.1469.

Methyl 3-phenyl-3-(phenylsulfonyl)propanoate (4al). White solid, MP: 137-139°C;



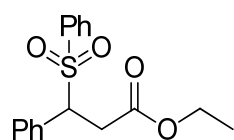
40 mg, 87% yield. ^1H NMR (400 MHz, Chloroform- d) δ 7.61-7.51 (m,

3H), 7.41-7.37 (m, 2H), 7.32 – 7.31-7.27 (m, 1H), 7.25-7.19 (m, 2H),

7.16-7.09 (m, 2H), 4.66 (dd, $J = 9.7, 4.9$ Hz, 1H), 3.58 (s, 3H), 3.46

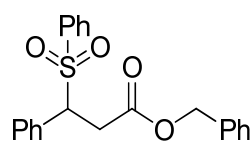
(dd, $J = 16.5, 4.9$ Hz, 1H), 3.12 (dd, $J = 16.5, 9.8$ Hz, 1H). ^{13}C NMR (100 MHz, Chloroform- d) δ 170.1, 136.4, 133.8, 131.6, 129.6, 129.1, 129.1, 128.7, 128.5, 67.0, 52.3, 33.2. HRMS (ESI) calcd for $\text{C}_{16}\text{H}_{17}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 305.0848, found 305.0833.

Ethyl 3-phenyl-3-(phenylsulfonyl)propanoate (4am). White solid, MP: 97-100°C; 39



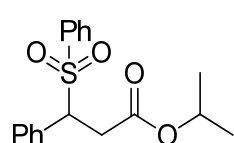
mg, 81% yield. ^1H NMR (400 MHz, DMSO- d_6) δ 7.73-7.68 (m, 1H), 7.65-7.58 (m, 2H), 7.58-7.49 (m, 2H), 7.36-7.23 (m, 3H), 7.21-7.18 (m, 2H), 4.88 (dd, $J = 9.5, 5.5$ Hz, 1H), 3.95-3.86 (m, 2H), 3.21 (dd, $J = 16.2, 5.5$ Hz, 1H), 3.12 (dd, $J = 16.3, 9.4$ Hz, 1H), 1.01 (t, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, DMSO- d_6) δ 168.9, 136.4, 134.1, 131.6, 129.7, 129.1, 128.8, 128.7, 128.1, 65.6, 60.5, 33.1, 13.7. HRMS (ESI) calcd for $\text{C}_{17}\text{H}_{19}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 319.1004, found 319.1001.

Benzyl 3-phenyl-3-(phenylsulfonyl)propanoate (4an). White solid, MP: 123-125°C;



30 mg, 53% yield. ^1H NMR (300 MHz, CDCl_3) δ 7.61-7.53 (m, 3H), 7.41 (t, $J = 7.7$ Hz, 2H), 7.35-7.09 (m, 10H), 5.10-4.94 (m, 2H), 4.69 (dd, $J = 9.9, 4.4$ Hz, 1H), 3.50 (dd, $J = 16.1, 4.4$ Hz, 1H), 3.21 (dd, $J = 16.3, 10.2$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ 169.4, 136.5, 135.2, 133.8, 131.6, 129.7, 129.2, 129.1, 128.7, 128.5, 128.5, 128.3, 128.1, 67.1, 67.0, 33.5. HRMS (ESI) calcd for $\text{C}_{22}\text{H}_{21}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 381.1161, found 381.1162.

Isopropyl 3-phenyl-3-(phenylsulfonyl)propanoate (4ao). White solid, MP: 129-



131°C; 43 mg, 86% yield. ^1H NMR (300 MHz, CDCl_3) δ 7.65-7.52 (m, 3H), 7.42 (t, $J = 7.7$ Hz, 2H), 7.33-7.21 (m, 3H), 7.13 (d, $J = 8.2$ Hz, 2H), 4.94-4.81 (m, 1H), 4.66 (dd, $J = 10.4, 4.8$ Hz, 1H), 3.43 (dd, $J = 16.2, 4.9$ Hz, 1H), 3.10 (dd, $J = 16.3, 10.6$ Hz, 1H), 1.08 (t, $J = 5.8$ Hz, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 168.9, 136.6, 133.7, 131.7, 129.7, 129.2, 128.96, 128.7, 128.4, 68.8, 67.2, 33.7, 21.5, 21.5. HRMS (ESI) calcd for $\text{C}_{18}\text{H}_{21}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 333.1161, found 333.1159.

Phenyl 3-phenyl-3-(phenylsulfonyl)propanoate (4ap). White solid, MP: 138-141°C;

38 mg, 69% yield. ^1H NMR (300 MHz, Chloroform-*d*) δ 7.63-7.57 (m, 3H), 7.46-7.41 (m, 2H), 7.36-7.27 (m, 5H), 7.24-7.15 (m, 3H), 6.91- 6.81 (m, 2H), 4.78 (dd, $J = 9.8, 5.4$ Hz, 1H), 3.73 (dd, $J = 16.3, 5.4$ Hz, 1H), 3.39 (dd, $J = 16.3, 9.8$ Hz, 1H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 168.3, 150.2, 136.3, 133.9, 131.5, 129.7, 129.4, 129.21, 129.19, 128.8, 128.6, 126.0, 121.2, 67.2, 33.7. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{19}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^+$: 367.1004, found 367.1006.

6-Bromonaphthalen-2-yl 3-phenyl-3-(phenylsulfonyl)propanoate (4aq). White

solid, MP: 183-184°C; 32 mg, 43% yield. ^1H NMR (400 MHz, Chloroform-*d*) δ 7.98 (s, 1H), 7.84-7.52 (m, 7H), 7.49-7.41 (m, 2H), 7.39-7.29 (m, 4H), 7.22 (d, $J = 7.4$ Hz, 1H), 7.04 (d, $J = 8.8$ Hz, 1H), 4.83 (dd, $J = 9.5, 5.7$ Hz, 1H), 3.79 (dd, $J = 16.4, 5.9$ Hz, 1H), 3.44 (dd, $J = 16.4, 9.3$ Hz, 1H). ^{13}C NMR (75 MHz, Chloroform-*d*) δ 168.3, 148.2, 136.2, 133.95, 132.4, 131.9, 131.5, 129.95, 129.71, 129.65, 129.26, 129.19, 128.8, 128.6, 128.5, 121.8, 119.7, 118.4, 67.1, 33.7. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{19}\text{BrNaO}_4\text{S}$ ($\text{M}+\text{Na}$) $^+$: 517.0085, found 517.0084.

S-Cyclohexyl 3-phenyl-3-(phenylsulfonyl)propanethioate (6). White solid, MP:

138-139°C; 48 mg, 83% yield. ^1H NMR (300 MHz, Chloroform-*d*) δ 7.59-7.48 (m, 3H), 7.40-7.35 (m, 2H), 7.27-7.17 (m, 3H), 7.12-7.08 (m, 2H), 4.69 (dd, $J = 10.3, 4.3$ Hz, 1H), 3.61 (dd, $J = 16.1, 4.3$ Hz, 1H), 3.37 (dd, $J = 16.1, 10.3$ Hz, 2H), 1.84-1.77 (m, 1H), 1.68-1.46 (m, 4H), 1.41-1.10 (m, 5H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 194.6, 136.6, 133.7, 131.2, 129.7, 129.0, 128.9, 128.7, 128.4, 66.97, 42.8, 41.7, 32.7, 32.5, 25.7, 25.3. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{25}\text{O}_3\text{S}_2$ ($\text{M}+\text{H}$) $^+$: 389.1245, found 389.1241.

N,3-diphenyl-3-(phenylsulfonyl)propanamide (7). White solid, MP: 183-184°C; 44

mg, 80% yield (0.03 M). ^1H NMR (400 MHz, Chloroform-*d*) δ 8.08 (brs, 1H), 7.64-7.50 (m, 3H), 7.41-7.34 (m, 4H), 7.30-7.16 (m, 7H), 7.03 (t, $J = 7.3$ Hz, 1H), 4.89 (dd, $J = 9.2, 4.8$ Hz, 1H), 3.68 (dd, J

= 15.6, 4.8 Hz, 1H), 3.30 (dd, J = 15.6, 9.3 Hz, 1H). ^{13}C NMR (100 MHz, Chloroform- d) δ 166.6, 137.5, 136.7, 133.9, 132.0, 129.7, 129.1, 128.97, 128.9, 128.8, 128.6, 124.4, 119.9, 67.3, 35.8. HRMS (ESI) calcd for $\text{C}_{21}\text{H}_{20}\text{NO}_3\text{S}$ ($\text{M}+\text{H}$) $^+$: 366.1164, found 366.1160.

Reduction of compound **4aa** with LiAlH_4

To a solution of **4aa** (37.2 mg, 0.1 mmol) in dry THF (2 mL) was added LiAlH_4 (53 mg, 0.3 mmol) at 0 °C. After being stirred for 3 h at room temperature, the mixture was quenched with H_2O (0.1 mL), and extracted with CH_2Cl_2 . The combined organic layer was washed with saturated NaCl, dried over anhydrous sodium sulfate, filtered, and concentrated in vacuo. The crude product was purified by flash chromatography on silica gel to afford the product **9** (20 mg, 72% yield).

3-Phenyl-3-(phenylsulfonyl)propan-1-ol (9). White solid, MP: 119-120°C. ^1H NMR (400 MHz, Chloroform- d) δ 7.58-7.53 (m, 3H), 7.43-7.34 (m, 2H), 7.33-7.20 (m, 3H), 7.15-7.12 (m, 2H), 4.45-4.31 (m, 1H), 3.85-3.80 (m, 1H), 3.50-3.43 (m, 1H), 2.79-2.64 (m, 1H), 2.40-2.32 (m, 1H). ^{13}C NMR (100 MHz, Chloroform- d) δ 137.2, 133.5, 132.0, 129.9, 128.9, 128.8, 128.6, 128.5, 68.0, 59.3, 30.7. HRMS (ESI) calcd for $\text{C}_{15}\text{H}_{17}\text{O}_3\text{S}$ ($\text{M}+\text{H}$) $^+$: 277.0898, found 277.0894.

Hydrolysis of **4aa** with HCl

To an 50 mL flask was add hydrochloric acid (5 mL, 12 mol/L), then **4aa** (74.4 mg, 0.2 mmol) was added and the resulting mixture was refluxed at 120°C for 12 h. After completion of the reaction as monitored by TLC, H_2O (20 mL) was added to the mixture and extracted with CH_2Cl_2 . The combined organic layer was washed with saturated NaCl, dried over anhydrous sodium sulfate, filtered, and concentrated in vacuo. The crude product was purified by flash chromatography on silica gel to afford the product **10** (35 mg, 61% yield).

3-Phenyl-3-(phenylsulfonyl)propanoic acid (10). White solid, MP: 167-169°C. ^1H NMR (400 MHz, Chloroform- d) δ 7.61-7.46 (m, 3H), 7.40 (t, J = 7.8 Hz, 2H), 7.32 (t, J = 7.3 Hz, 1H), 7.25 (t, J = 7.4 Hz, 2H), 7.11 (d, J = 7.3 Hz, 2H), 4.61 (dd, J = 9.7, 4.8

Hz, 1H), 3.50 (dd, $J = 17.0, 4.8$ Hz, 1H), 3.14 (dd, $J = 17.0, 9.7$ Hz, 1H). ^{13}C NMR (100 MHz, Chloroform- d) δ 175.0, 136.3, 133.9, 131.4, 129.6, 129.2, 129.1, 128.8, 128.5, 66.7, 33.1. HRMS (ESI) calcd for $\text{C}_{15}\text{H}_{15}\text{O}_4\text{S}$ ($\text{M}+\text{H}$) $^{+}$: 291.0691, found 291.0681.

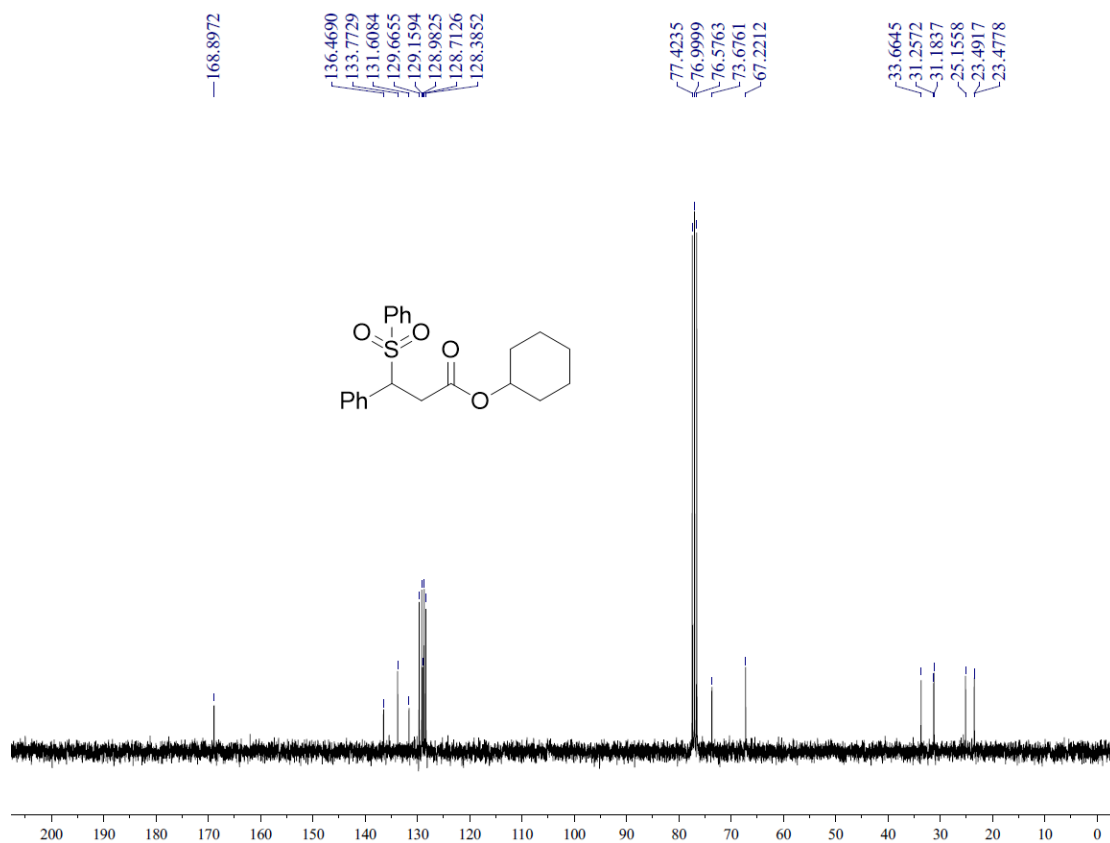
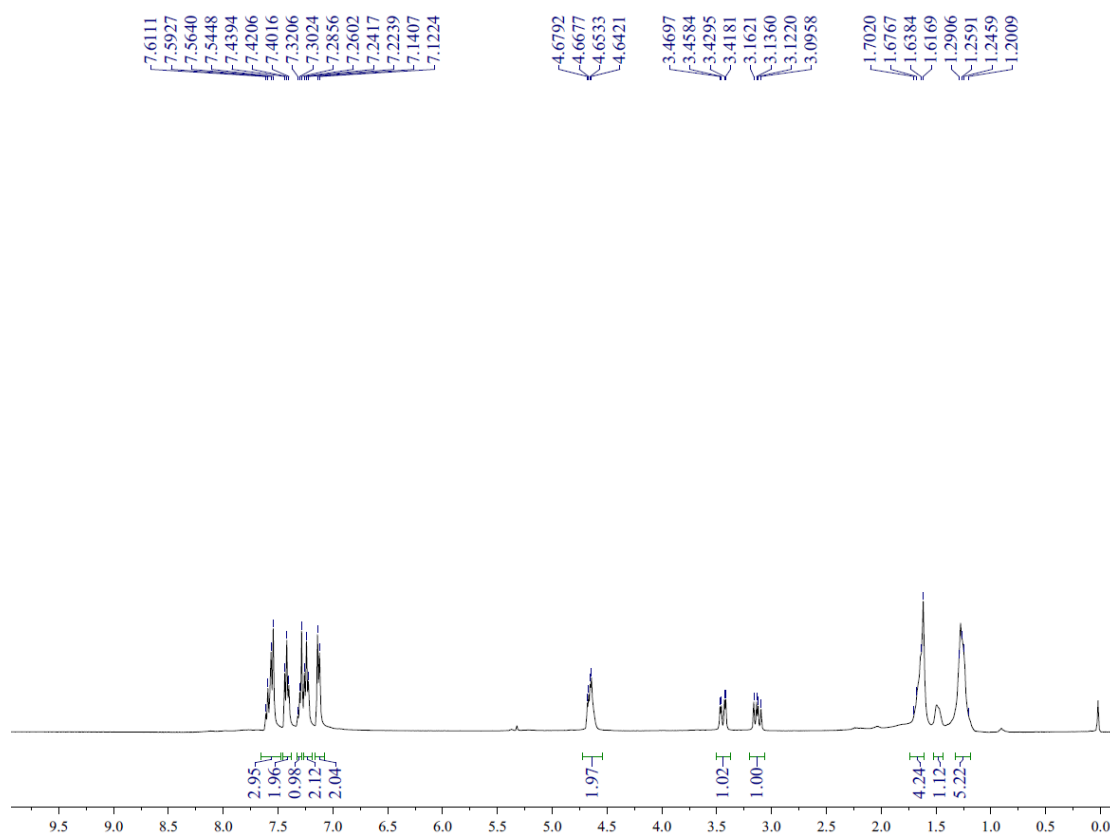
Condensation of acid **10** with *n*-butylamine

To a solution of acid **10** (34.8 mg, 0.12 mmol) and DCC (41.3 mg, 0.2 mmol) in CH_2Cl_2 (2 mL) was added *n*-butylamine (7.3 mg, 0.1 mmol) dropwise and the resulting mixture was stirred at room temperature for 15 min. Then the reaction mixture was directly purified by chromatography on silica gel to afford the product **11** (28 mg, 81% yield).

***N*-Butyl-3-phenyl-3-(phenylsulfonyl)propanamide (11).** White solid, MP: 113-115°C. ^1H NMR (400 MHz, Chloroform- d) δ 7.59-5.55 (m, 3H), 7.40 (t, $J = 7.9$ Hz, 2H), 7.30-7.28 (m, 1H), 7.25-7.16 (m, 4H), 6.03 (t, $J = 4.4$ Hz, 1H), 4.79 (dd, $J = 9.9, 4.7$ Hz, 1H), 3.39 (dd, $J = 14.9, 4.7$ Hz, 1H), 3.16-2.98 (m, 3H), 1.32-1.22 (m, 2H), 1.16-1.07 (m, 2H), 0.77 (t, $J = 7.3$ Hz, 3H). ^{13}C NMR (100 MHz, Chloroform- d) δ 168.1, 136.9, 133.7, 131.9, 129.7, 128.9, 128.8, 128.7, 128.4, 67.5, 39.3, 34.8, 31.2, 19.7, 13.5. HRMS (ESI) calcd for $\text{C}_{19}\text{H}_{24}\text{NO}_3\text{S}$ ($\text{M}+\text{H}$) $^{+}$: 346.1477, found 346.1477.

1. (a) Mal, K.; Sharma, A.; Maulik, P. R.; Das, I., *Chem.– A Eur. J.* **2014**, *20*, 662. (b) Schmidt, D.; Malakar, C. C.; Beifuss, U., *Org. Lett.* **2014**, *16*, 4862.

4aa



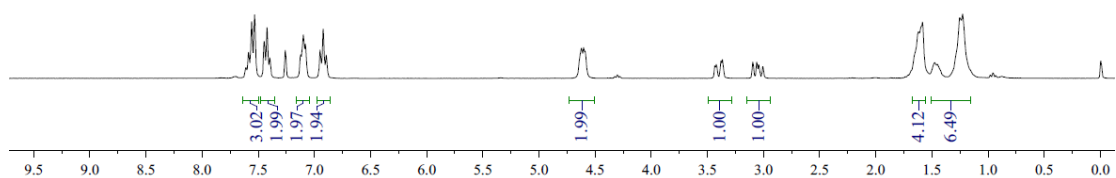
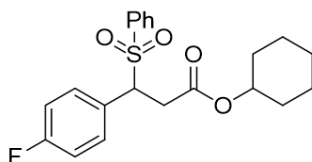
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7.0809
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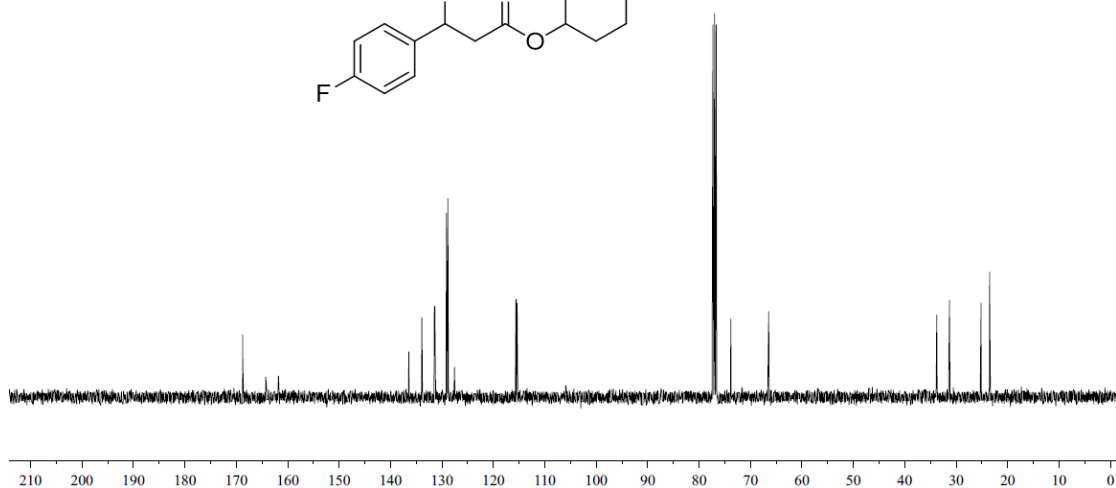
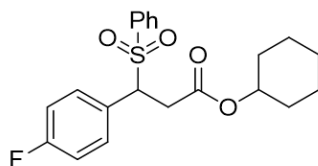


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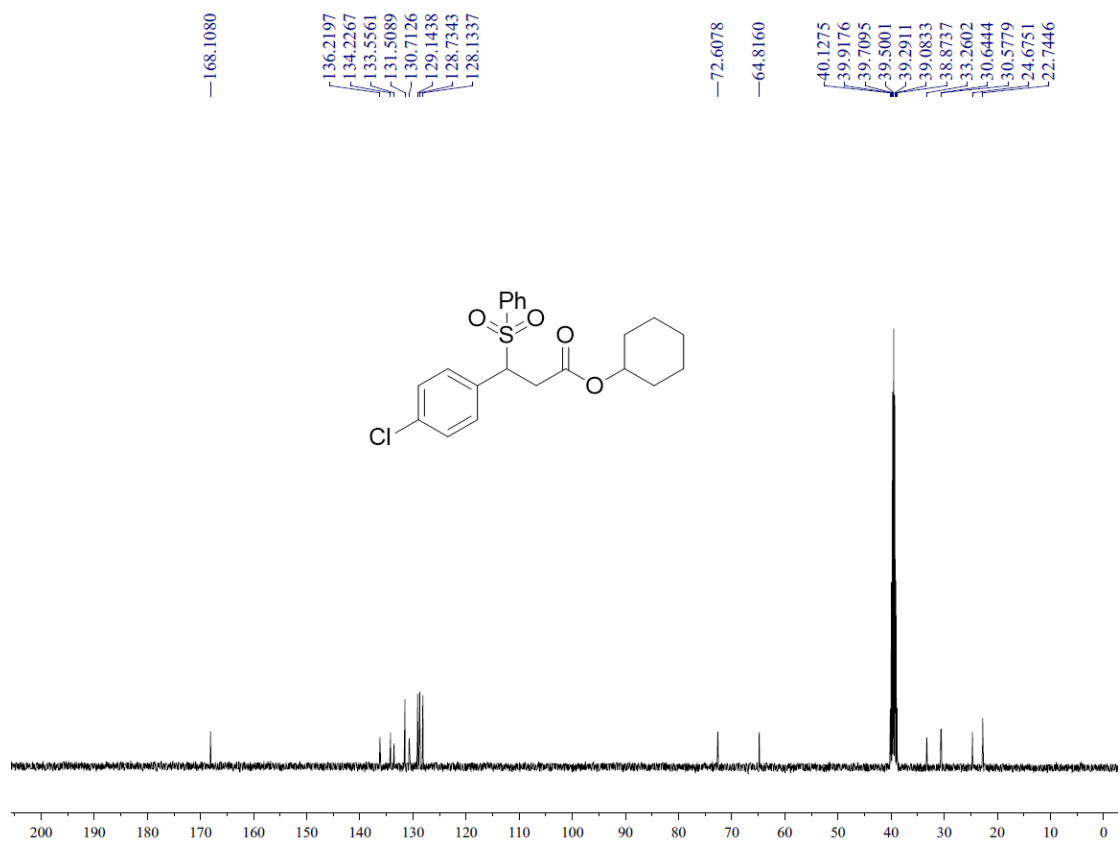
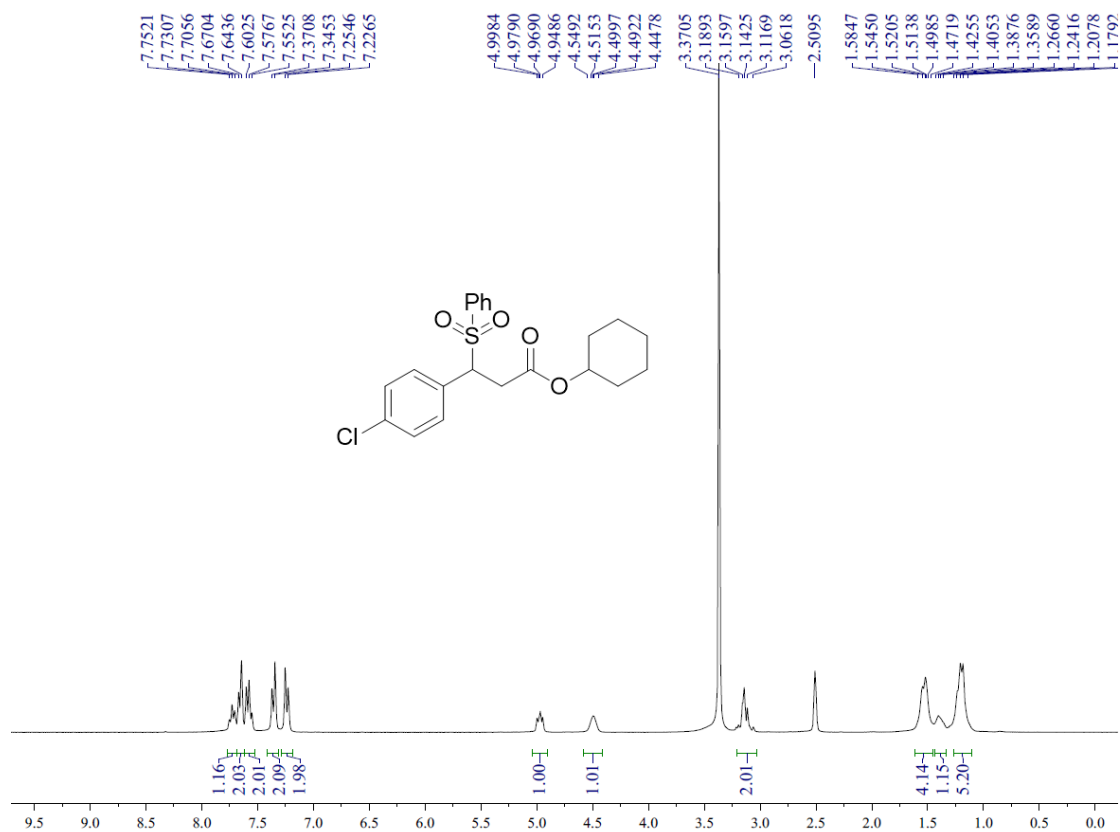
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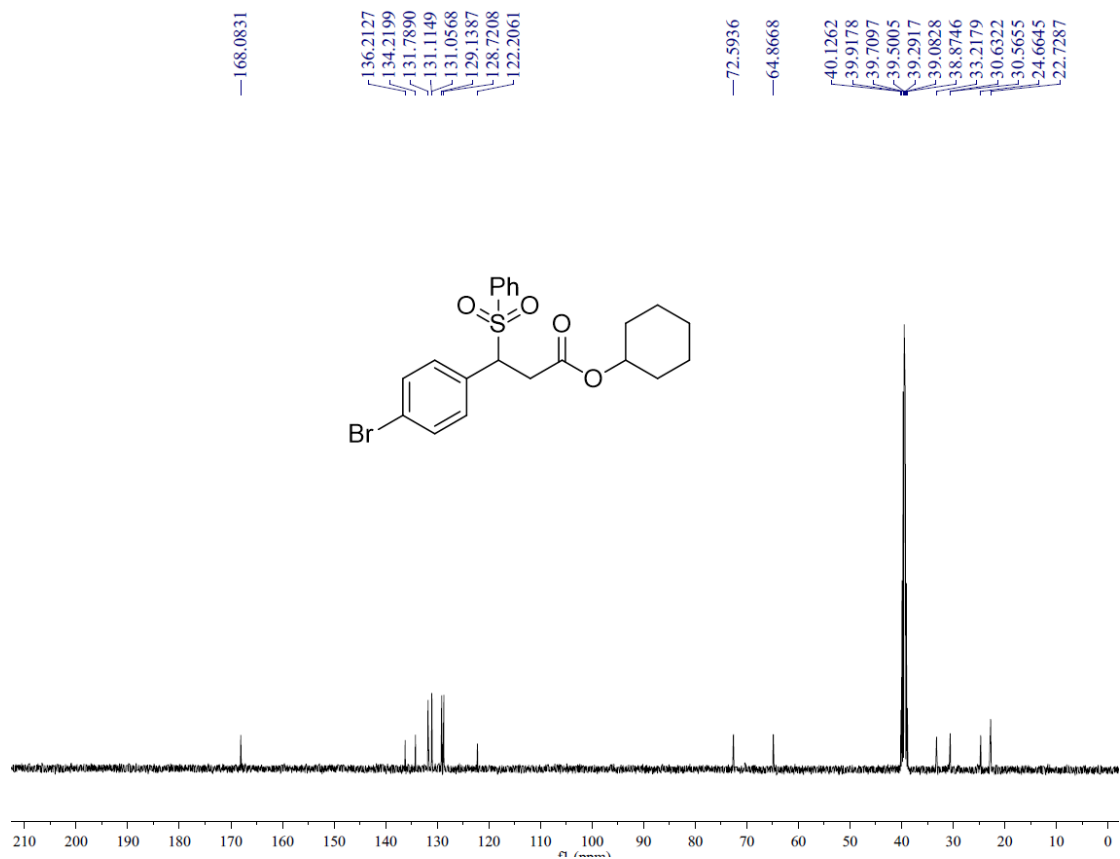
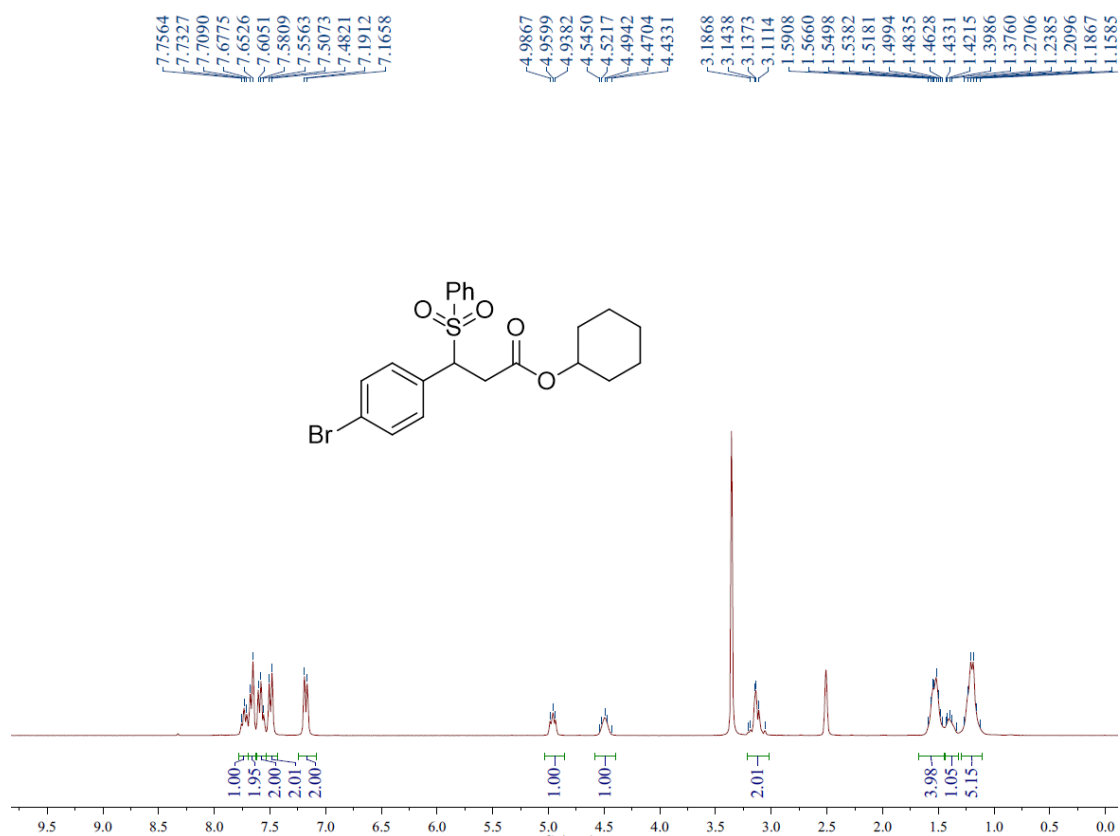
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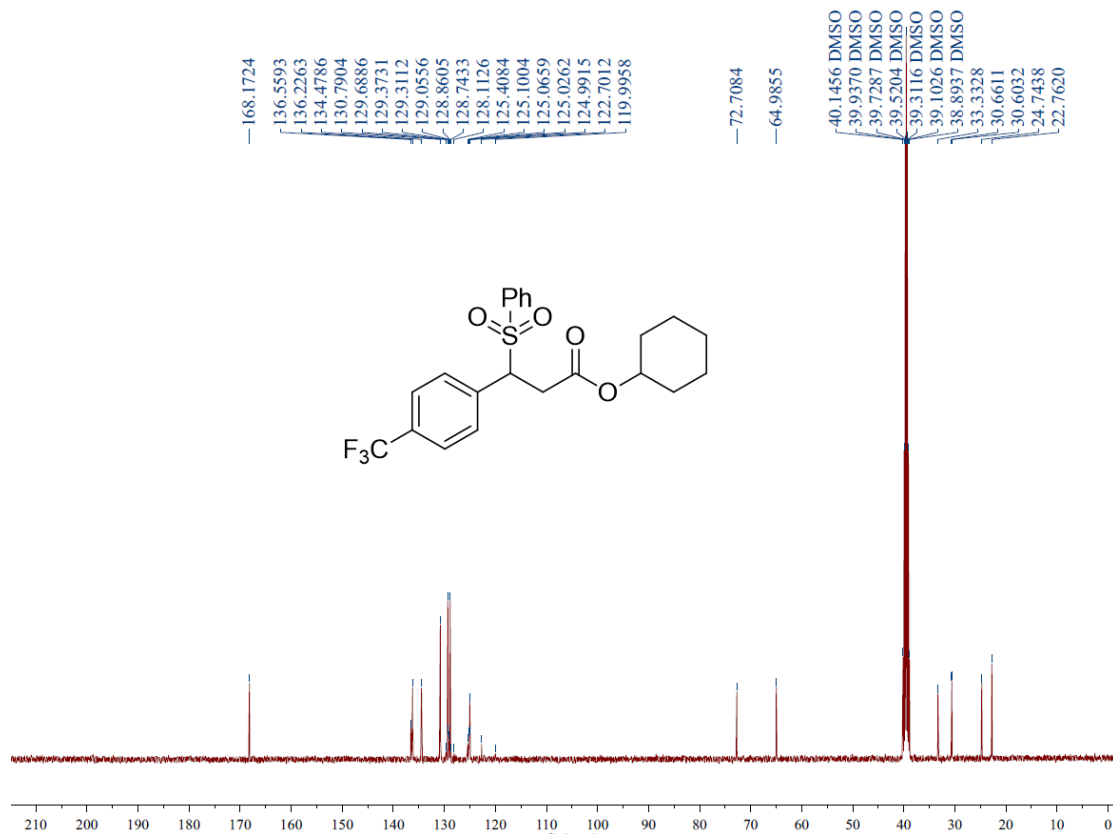
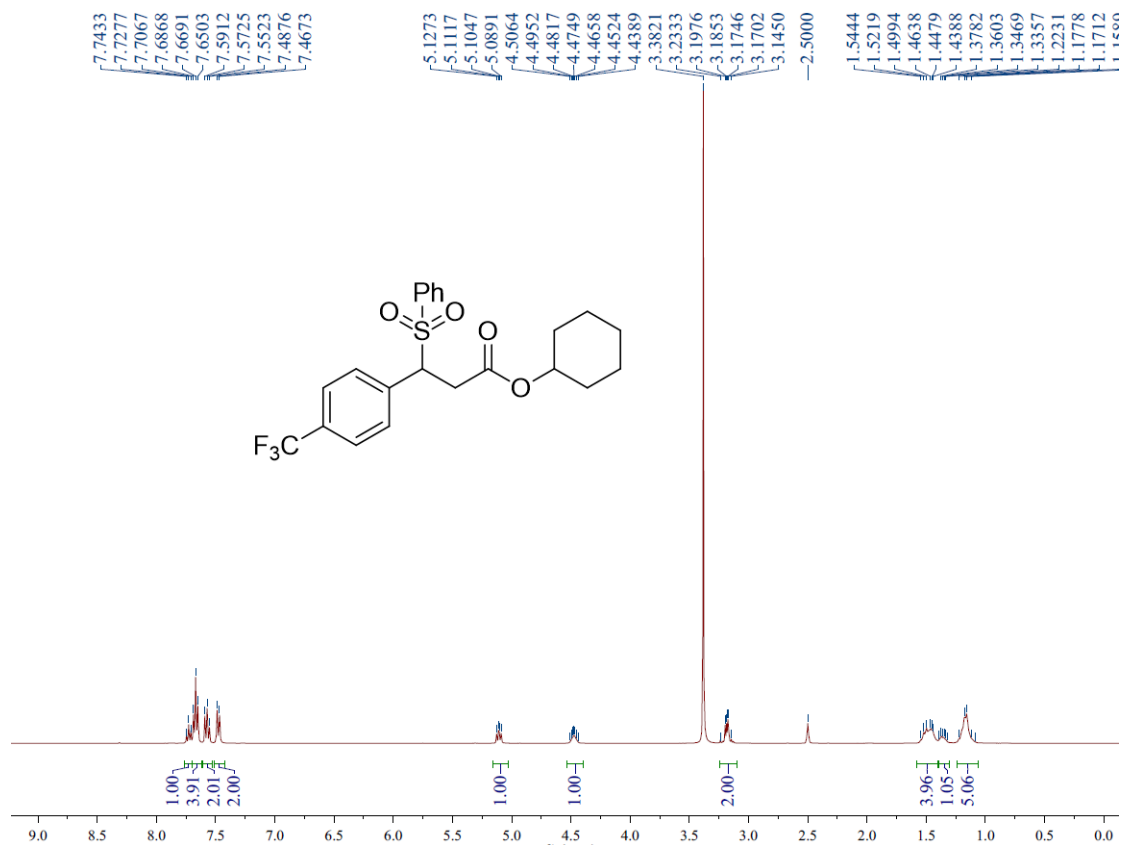
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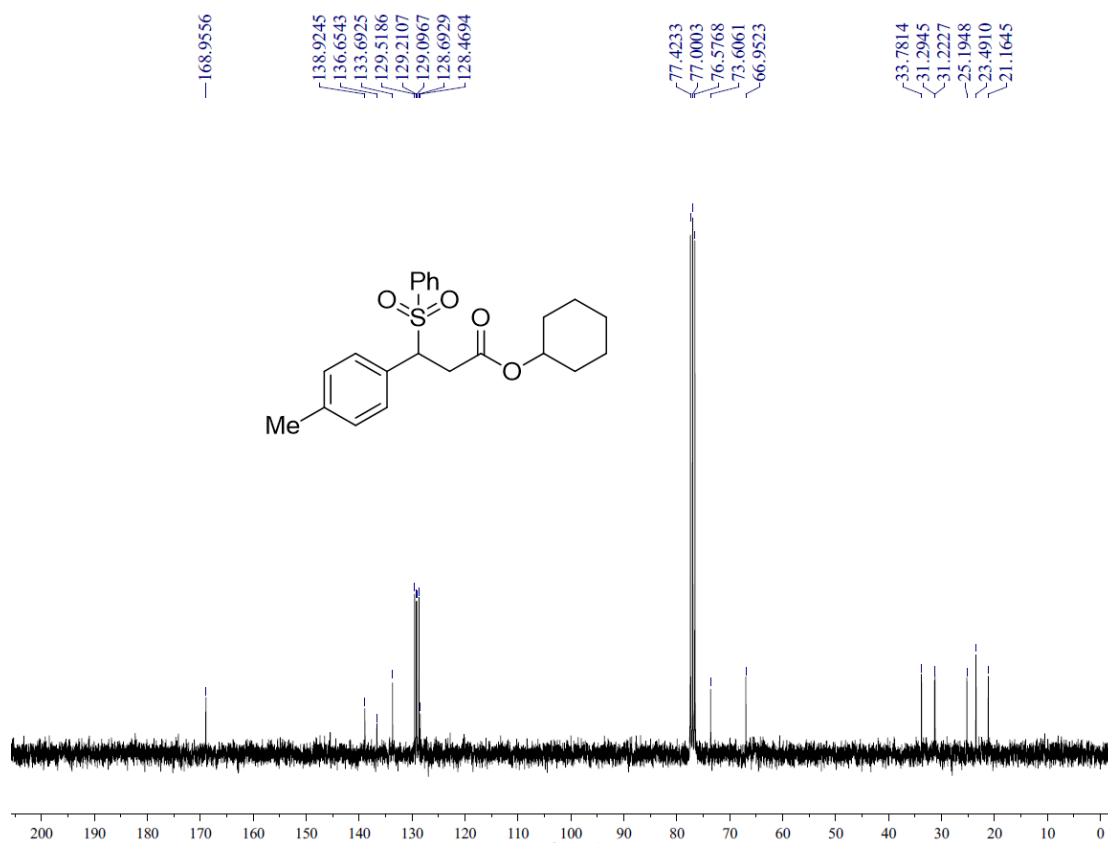
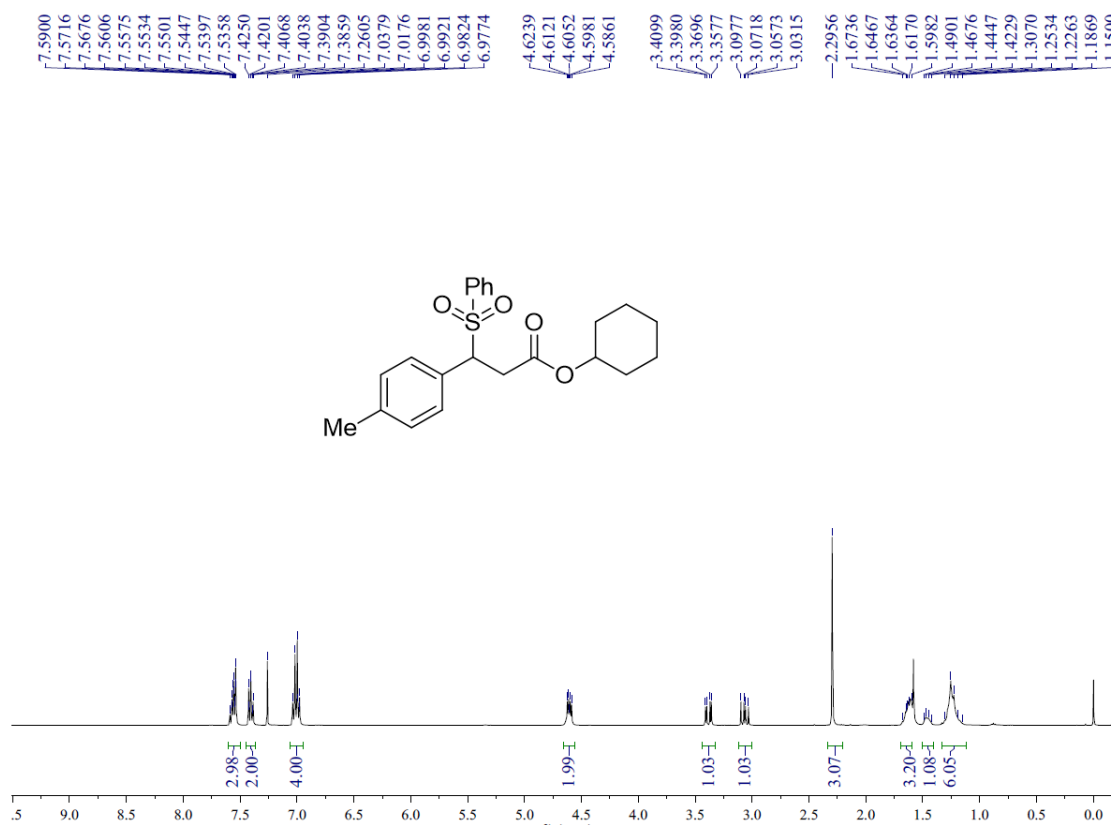
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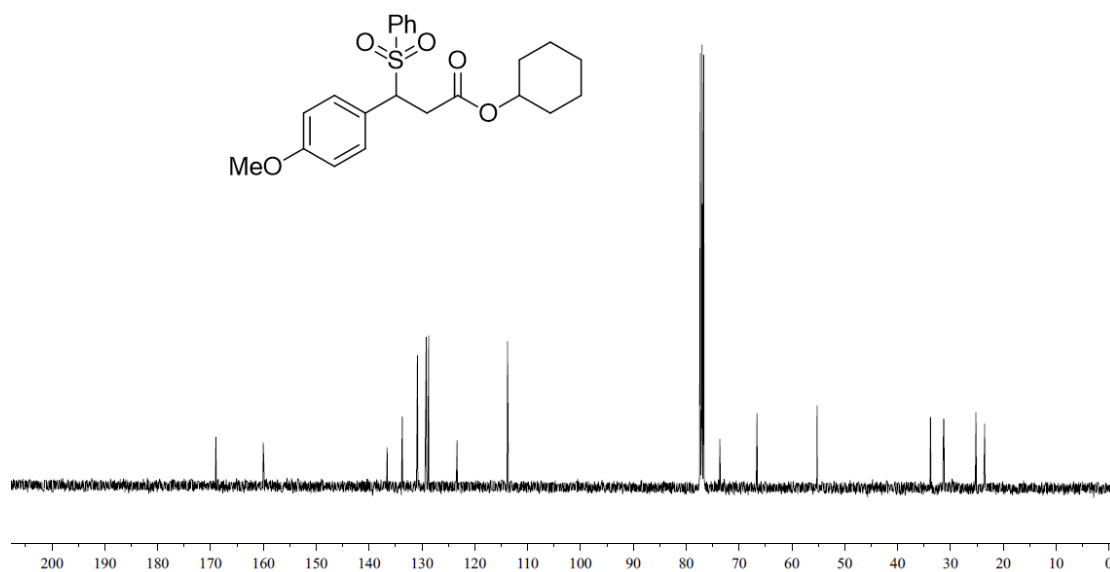
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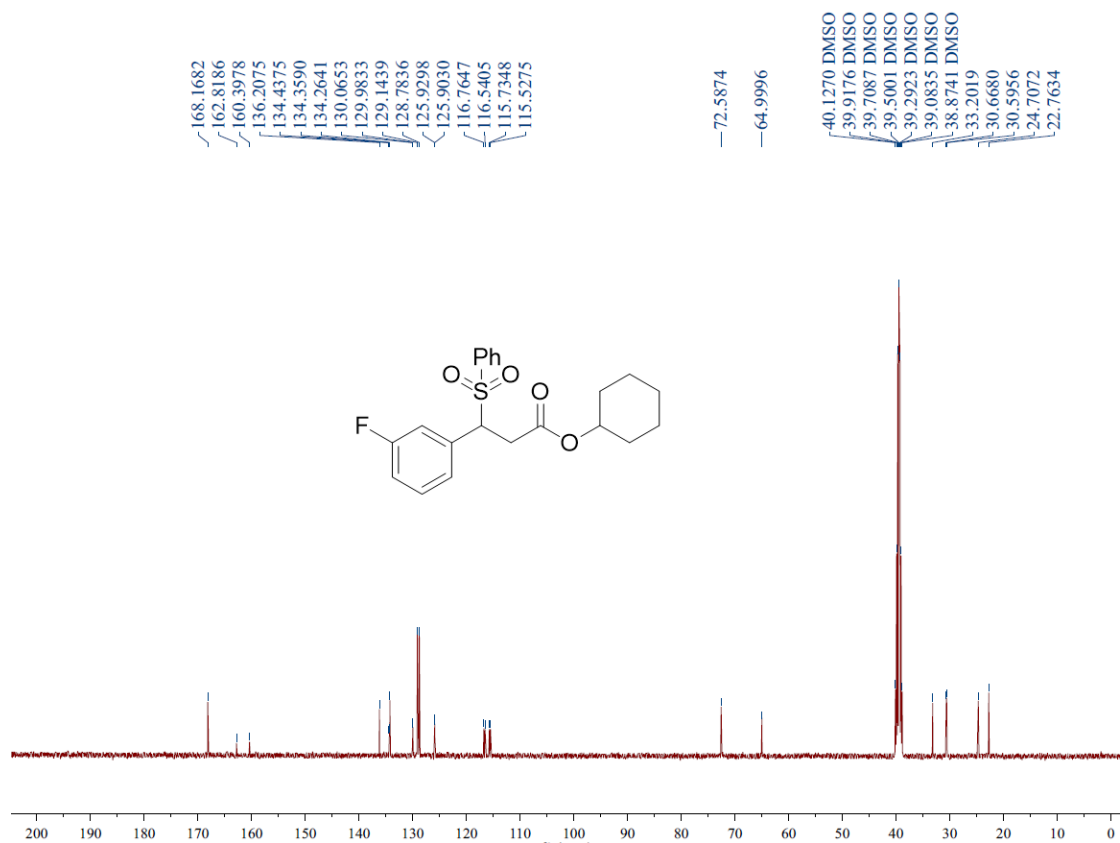
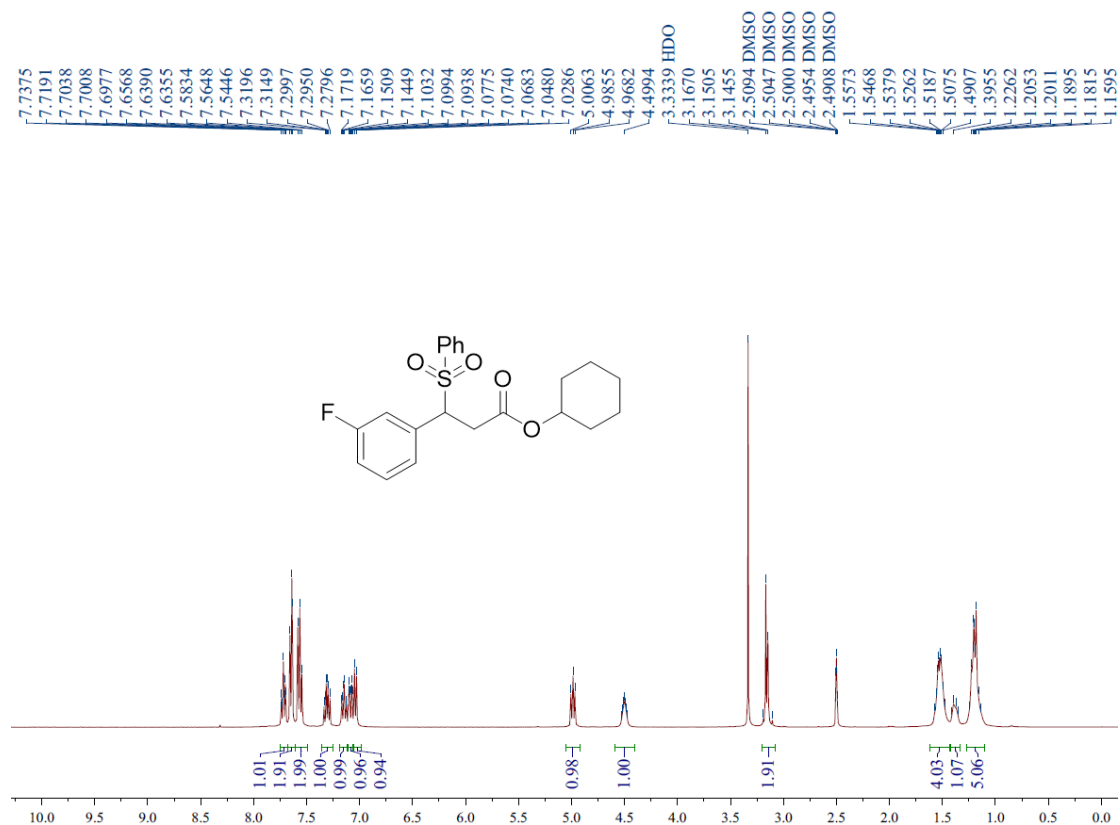
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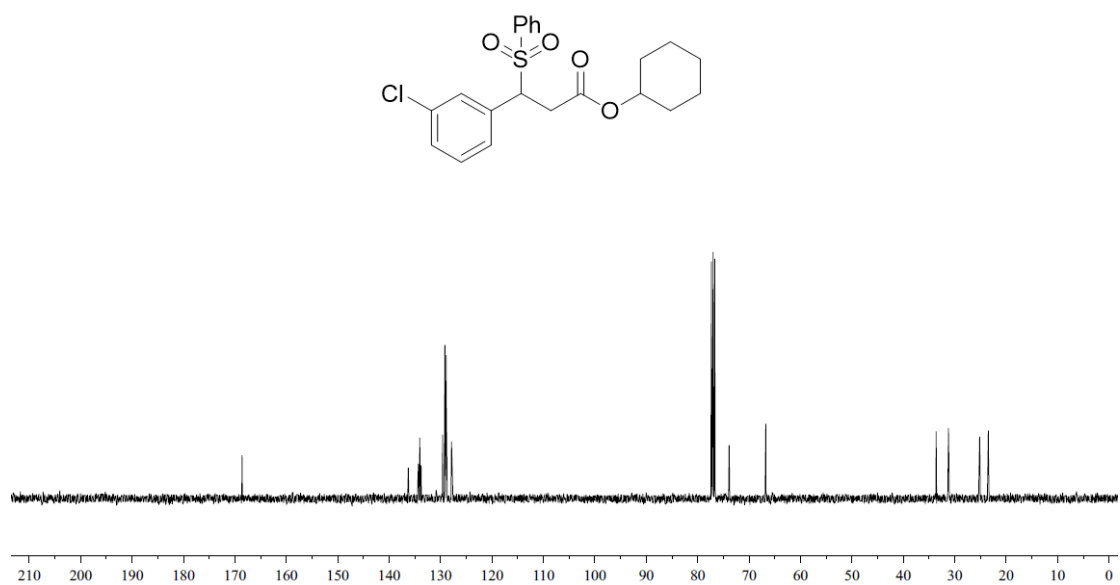
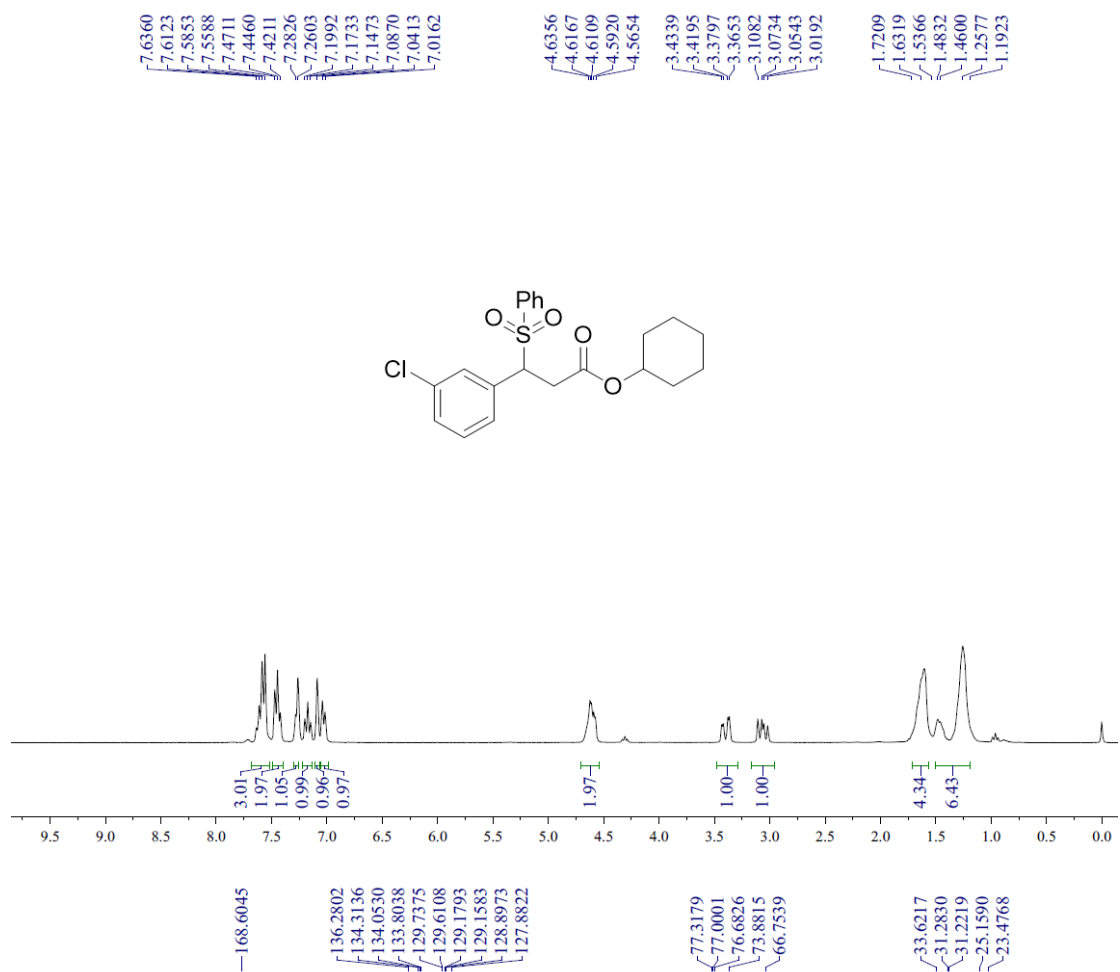
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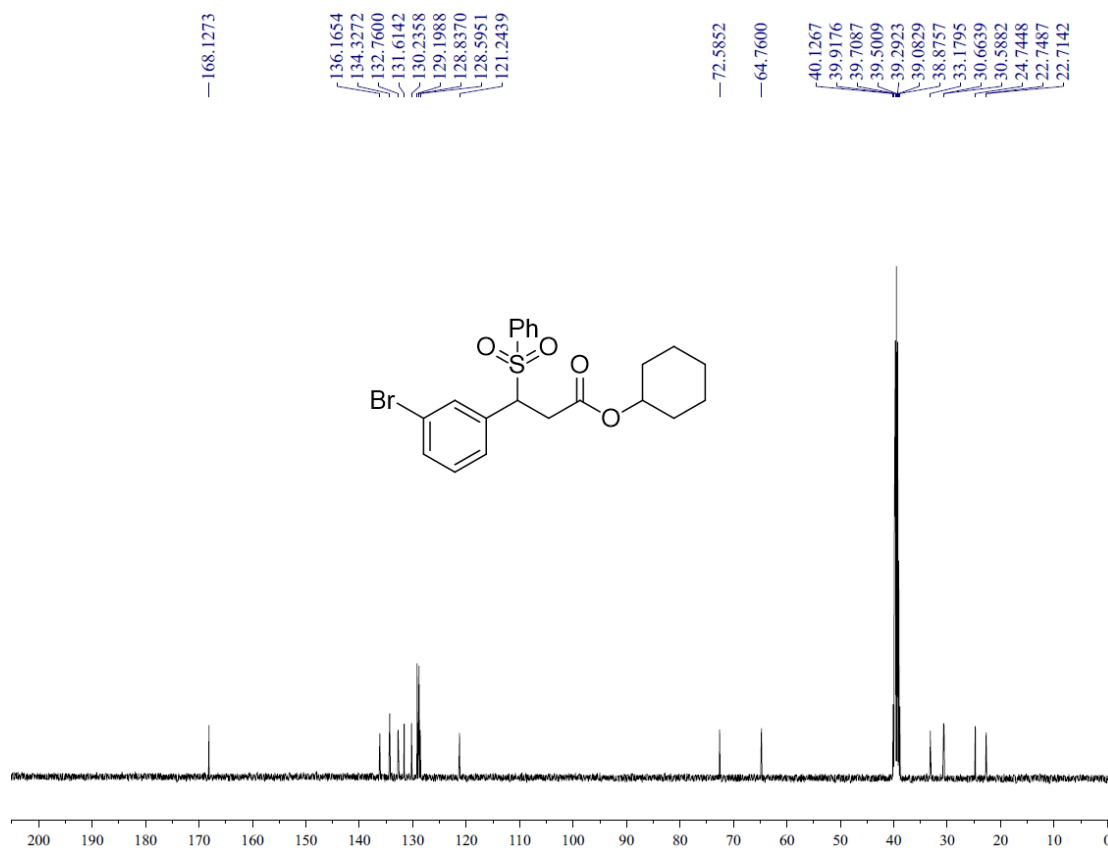
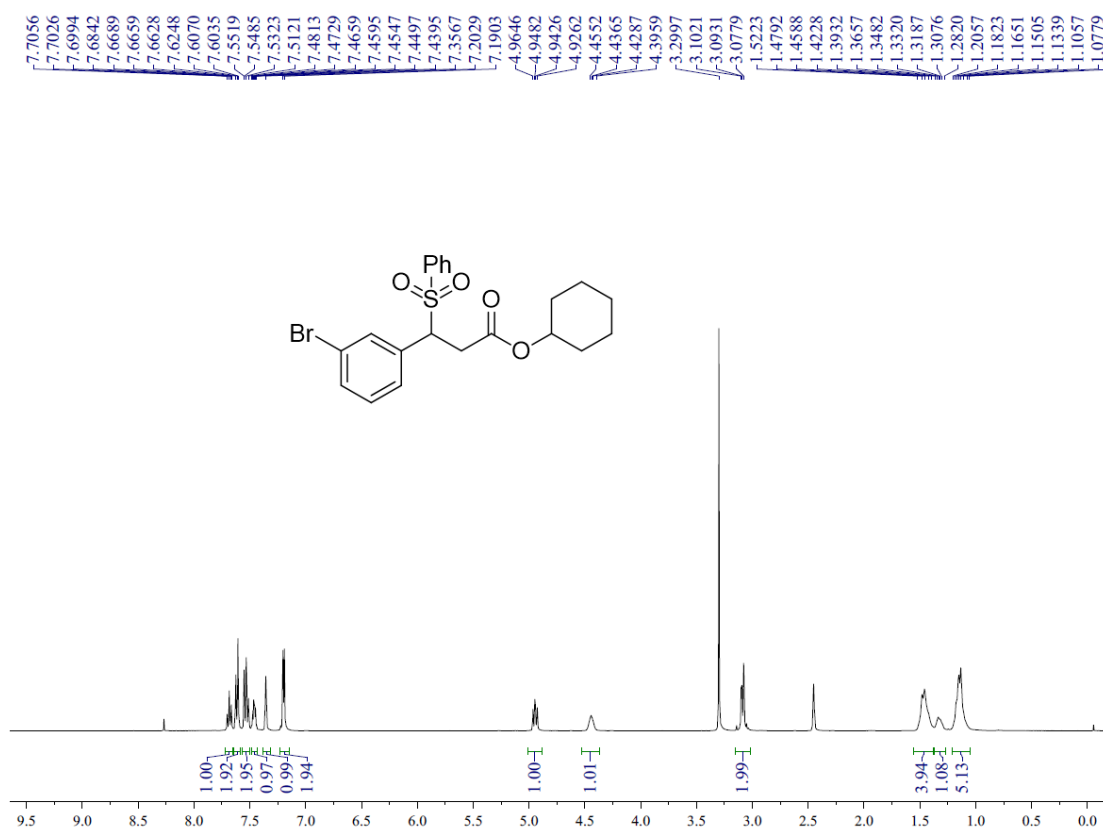
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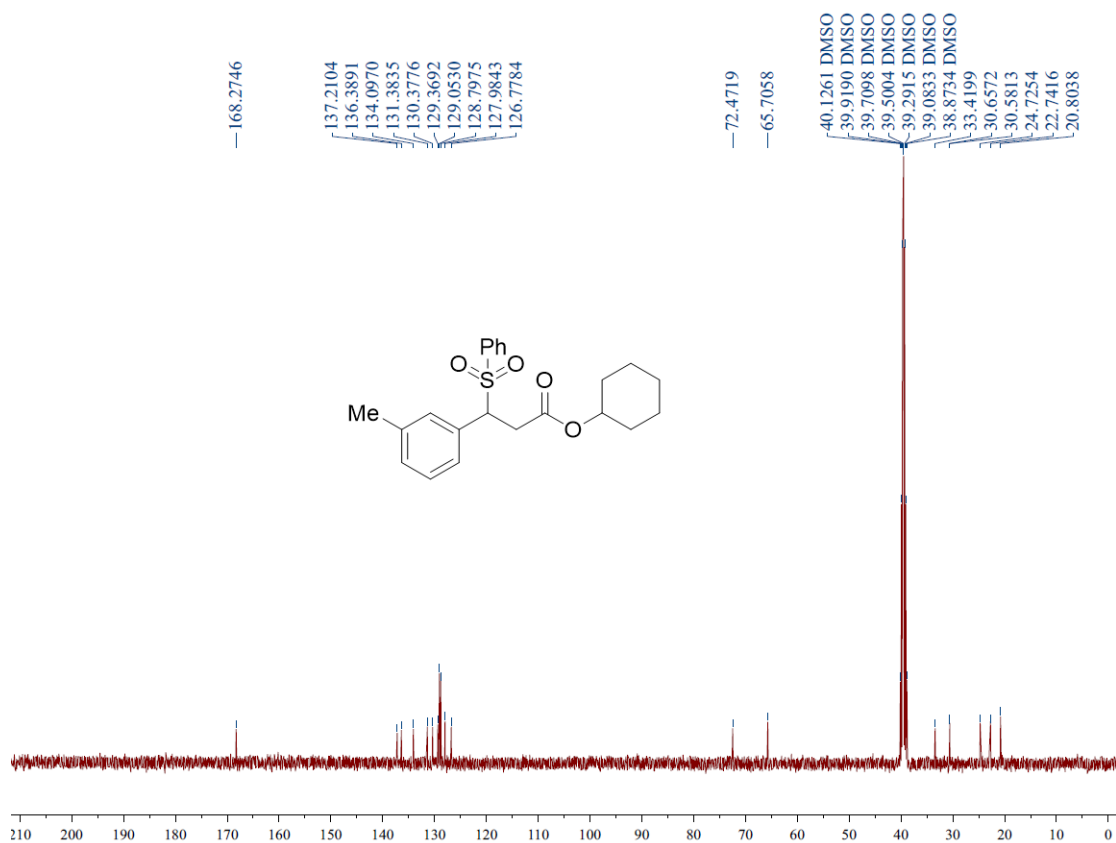
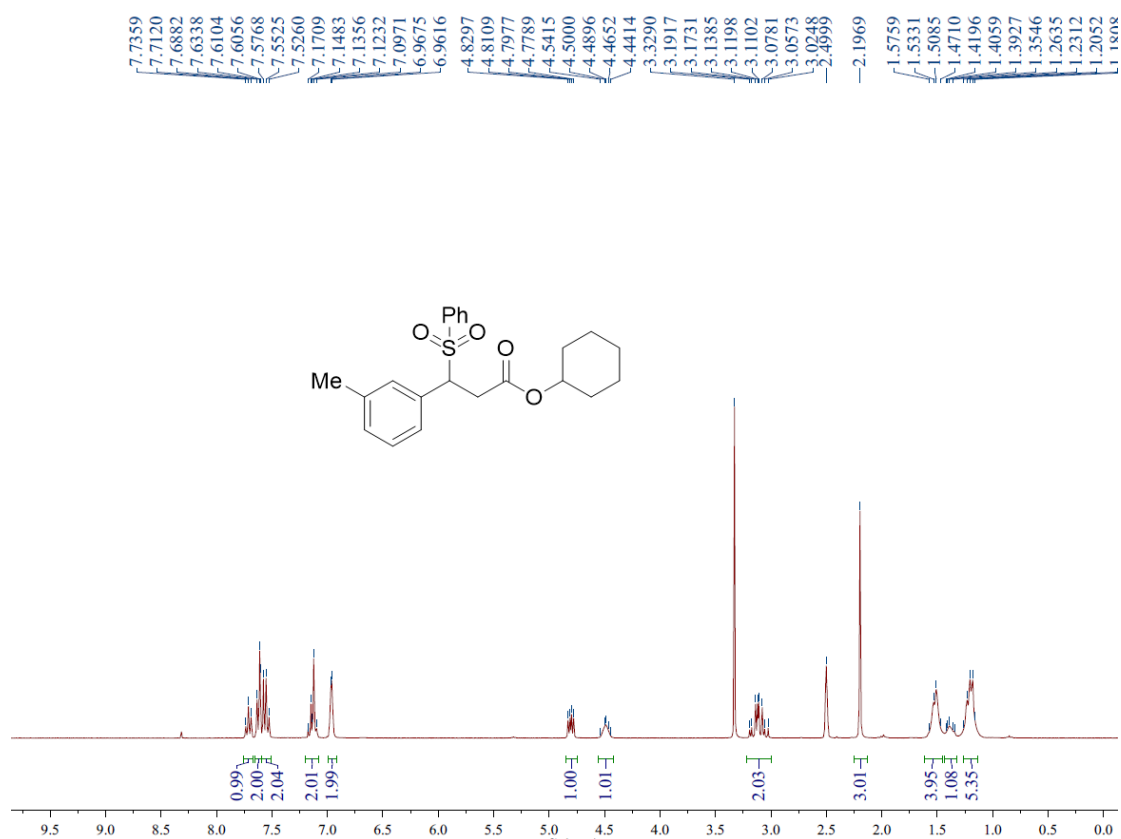
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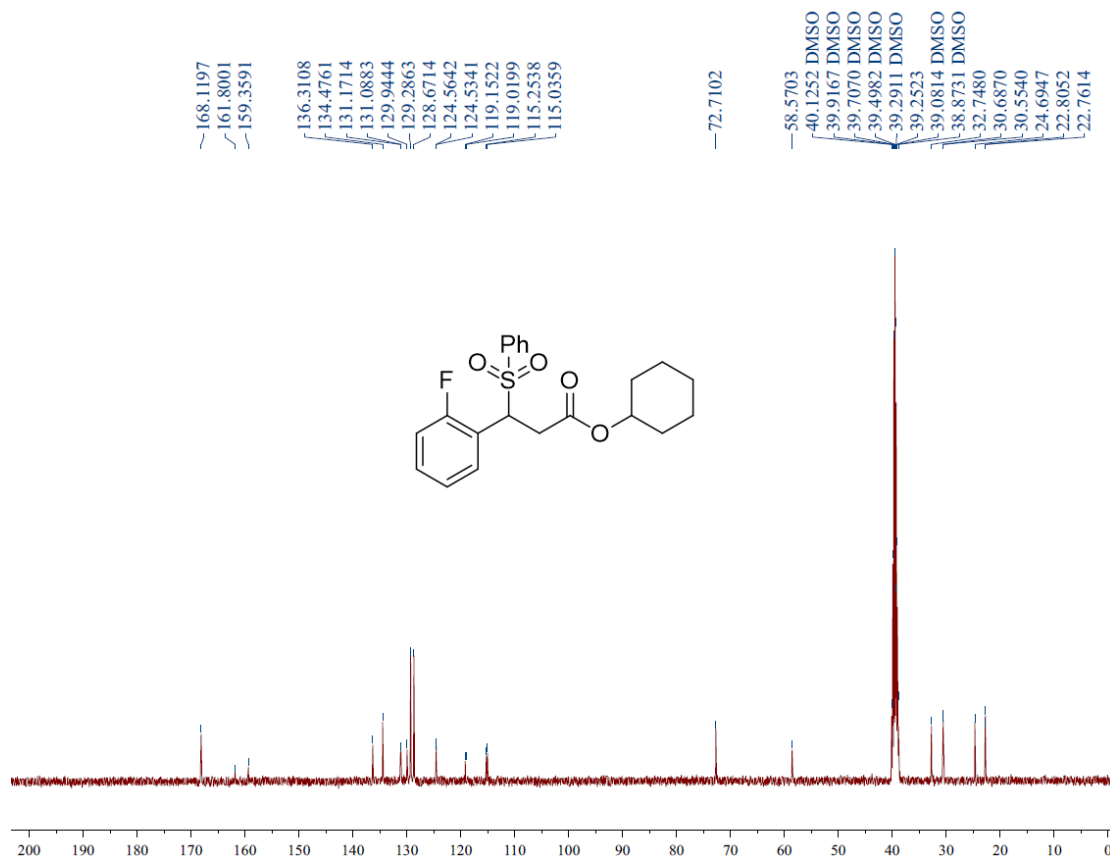
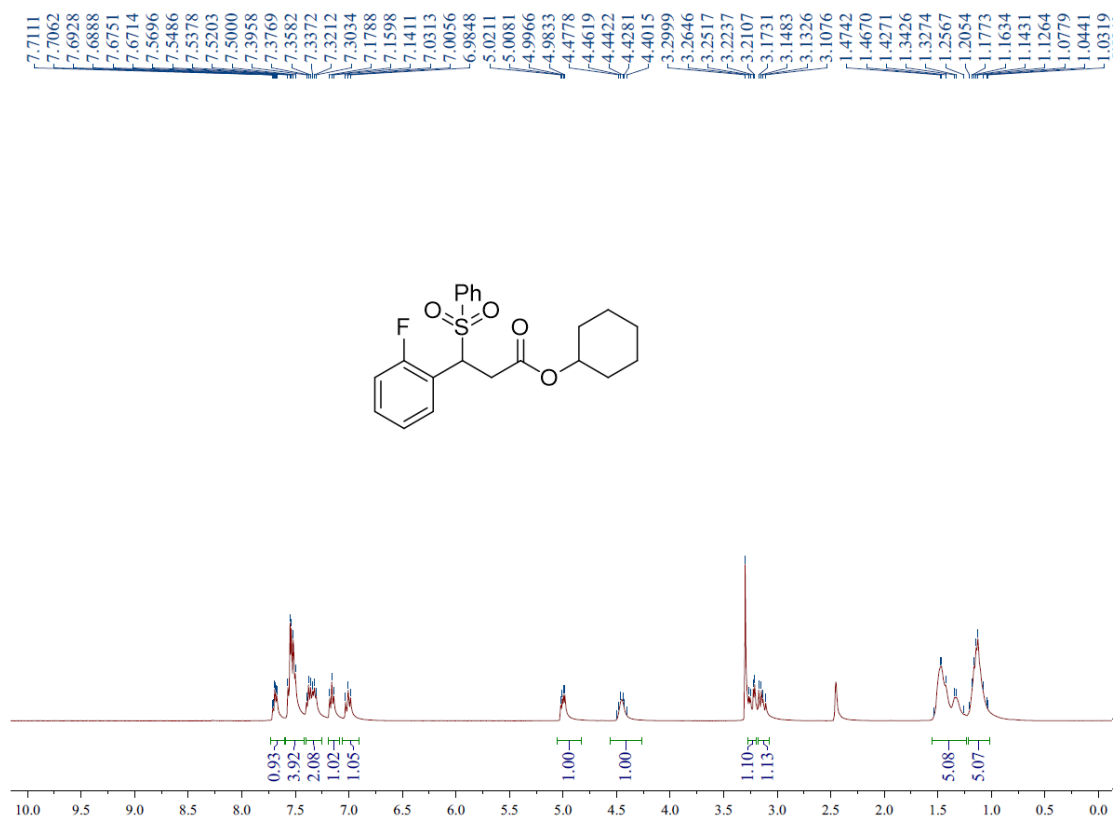
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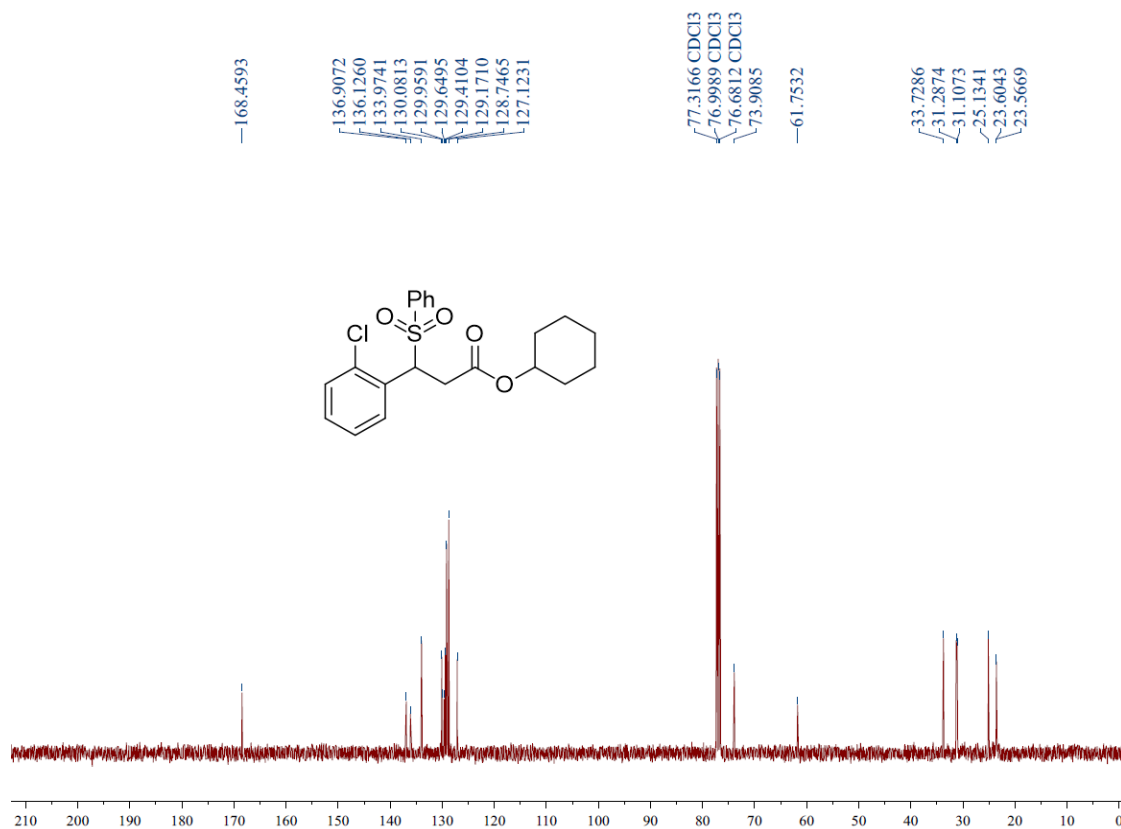
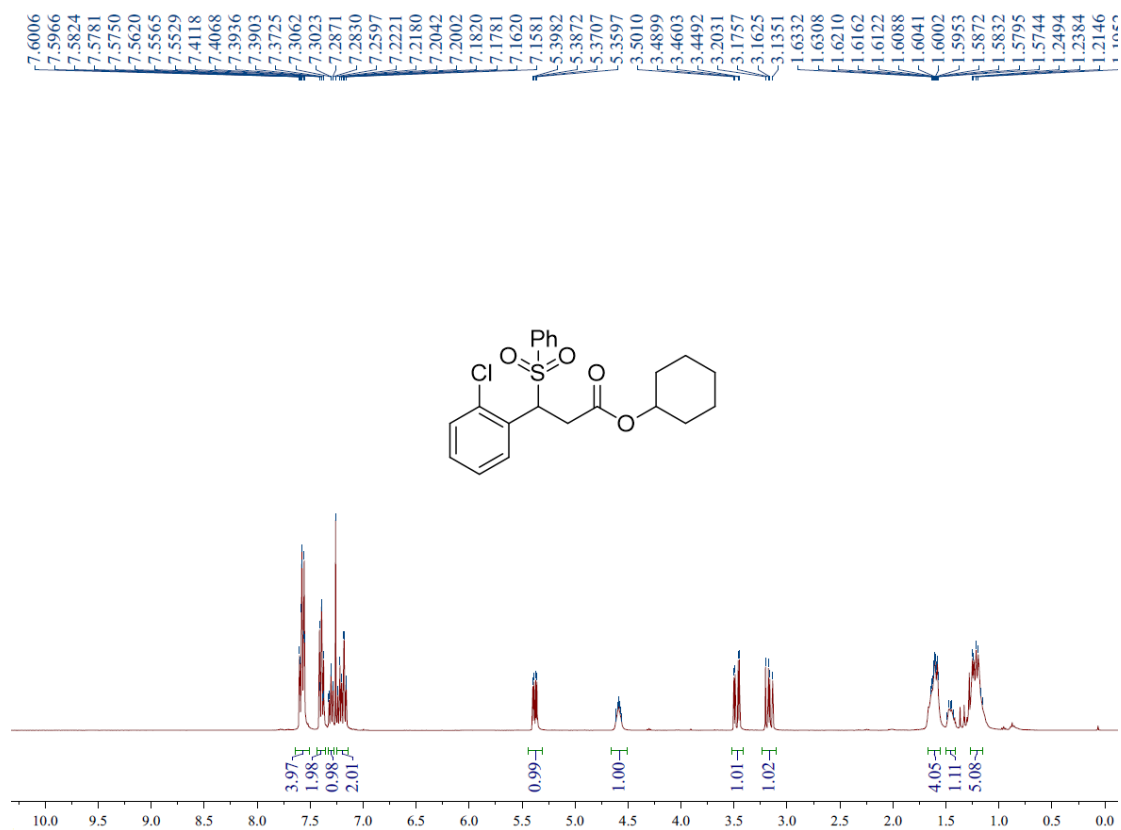
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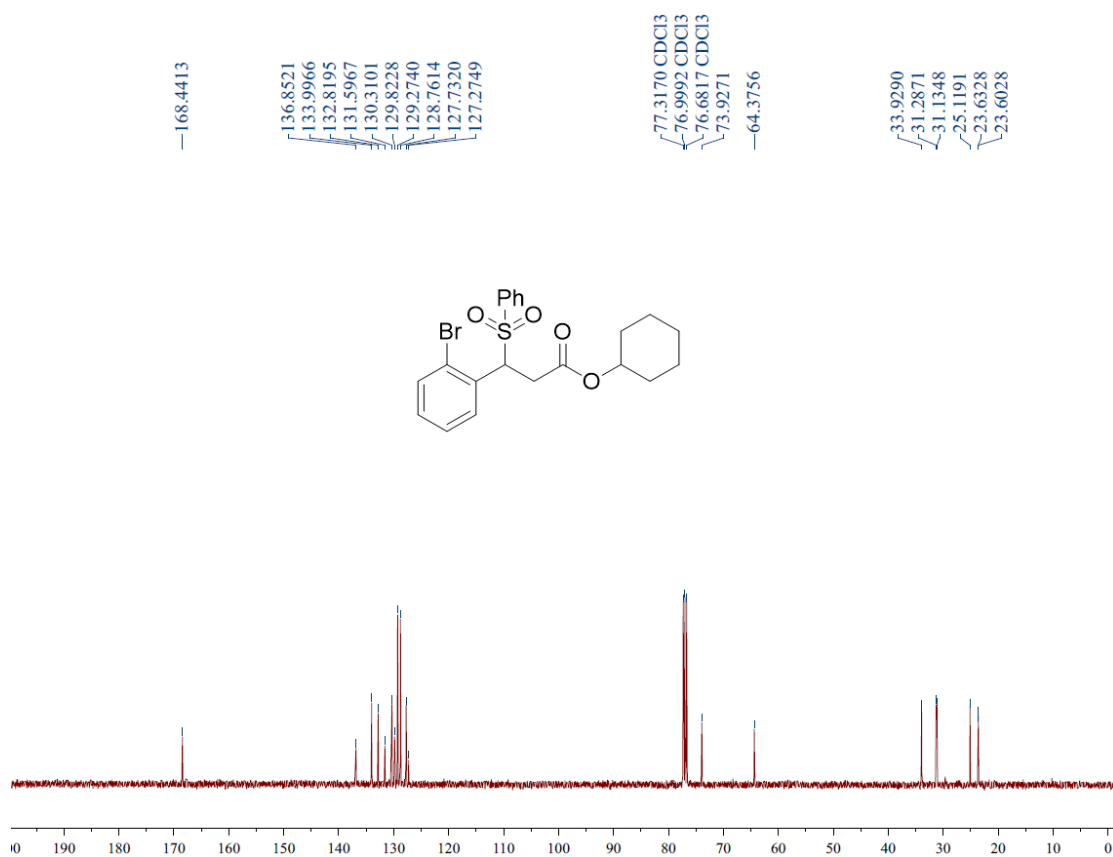
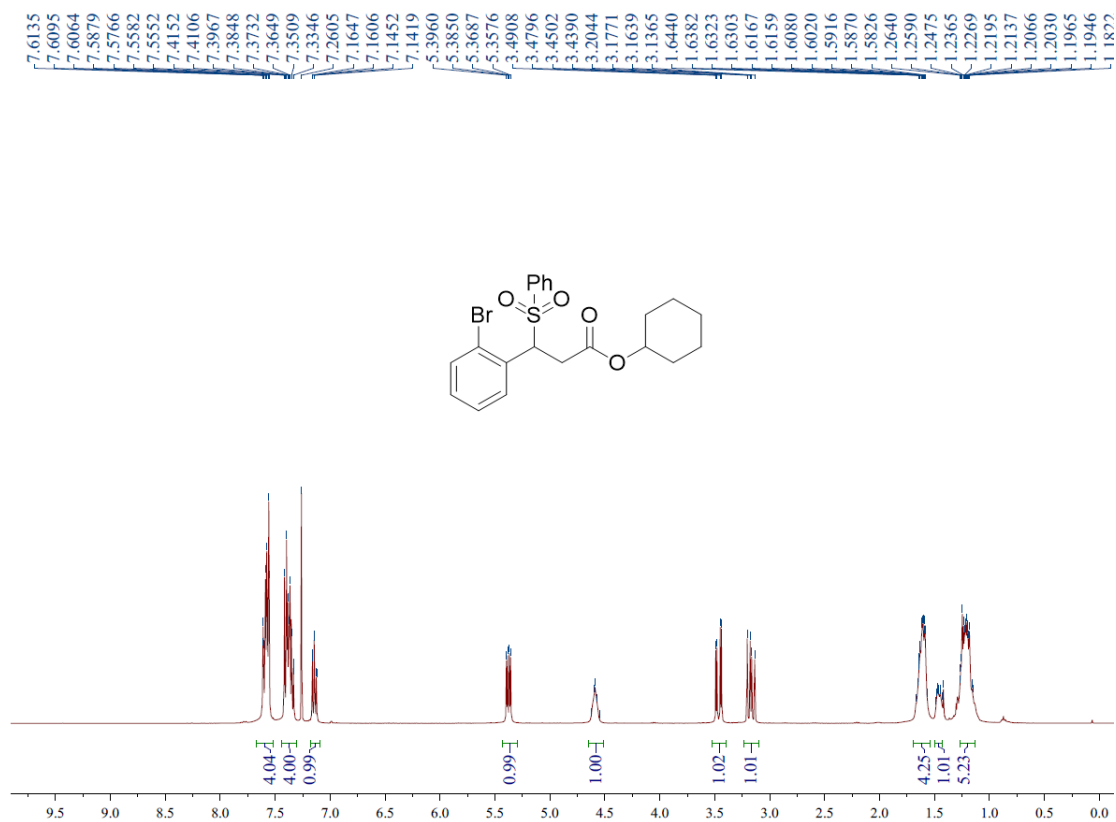
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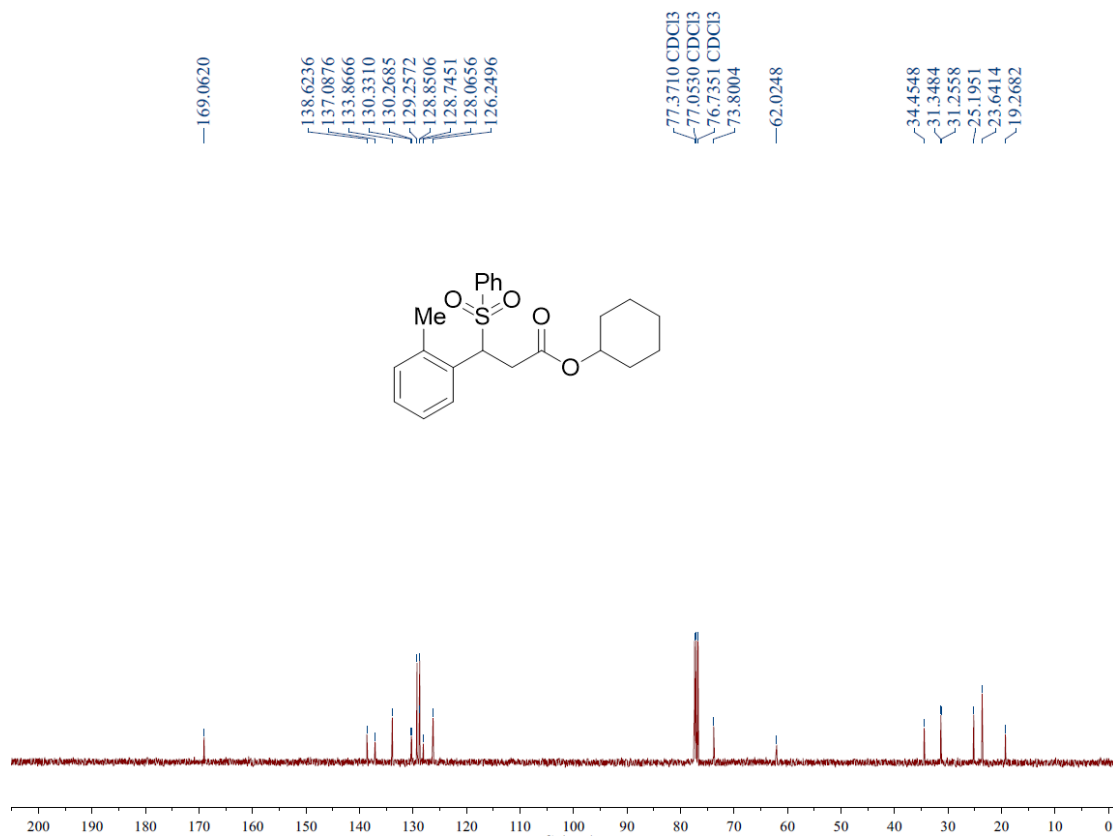
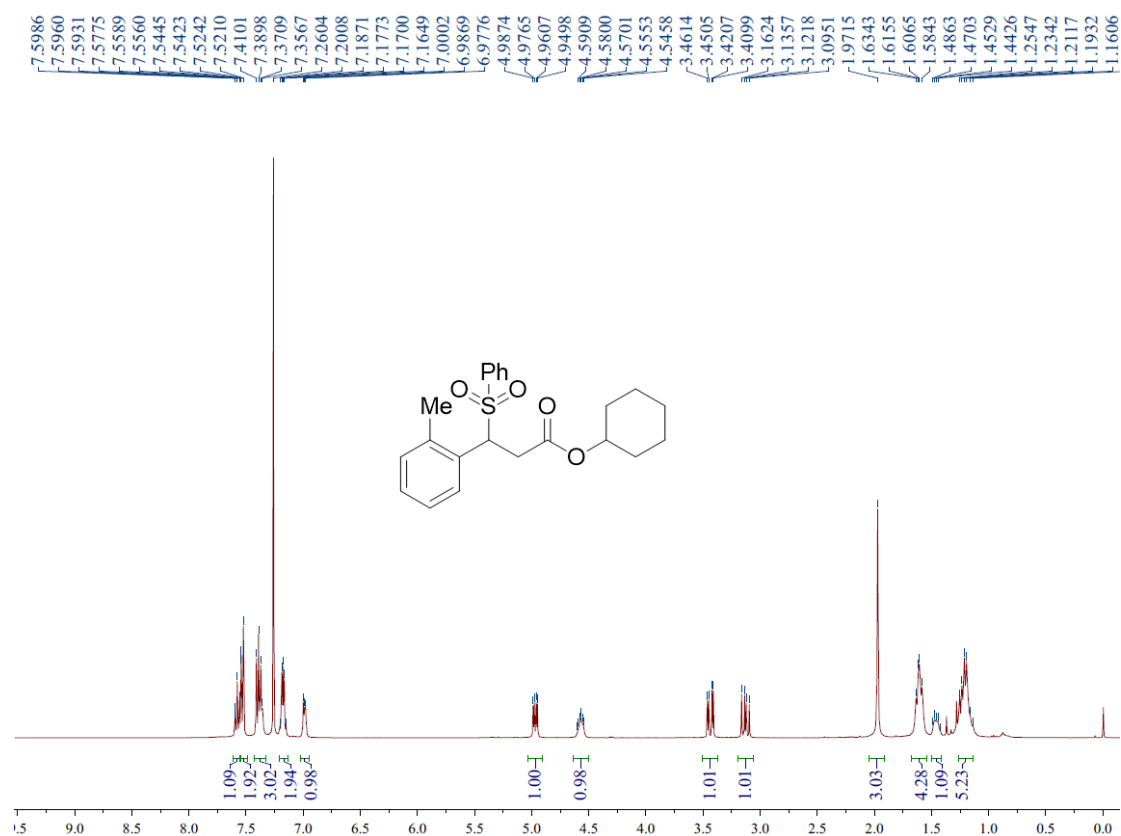
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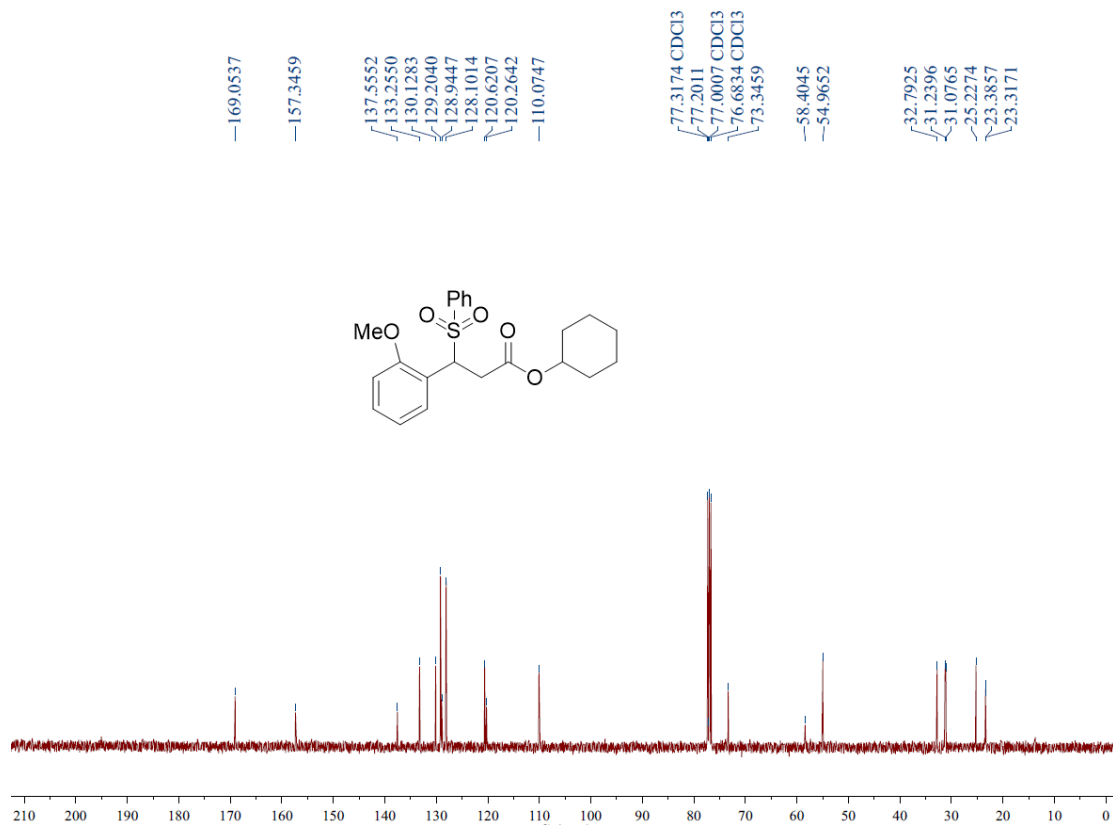
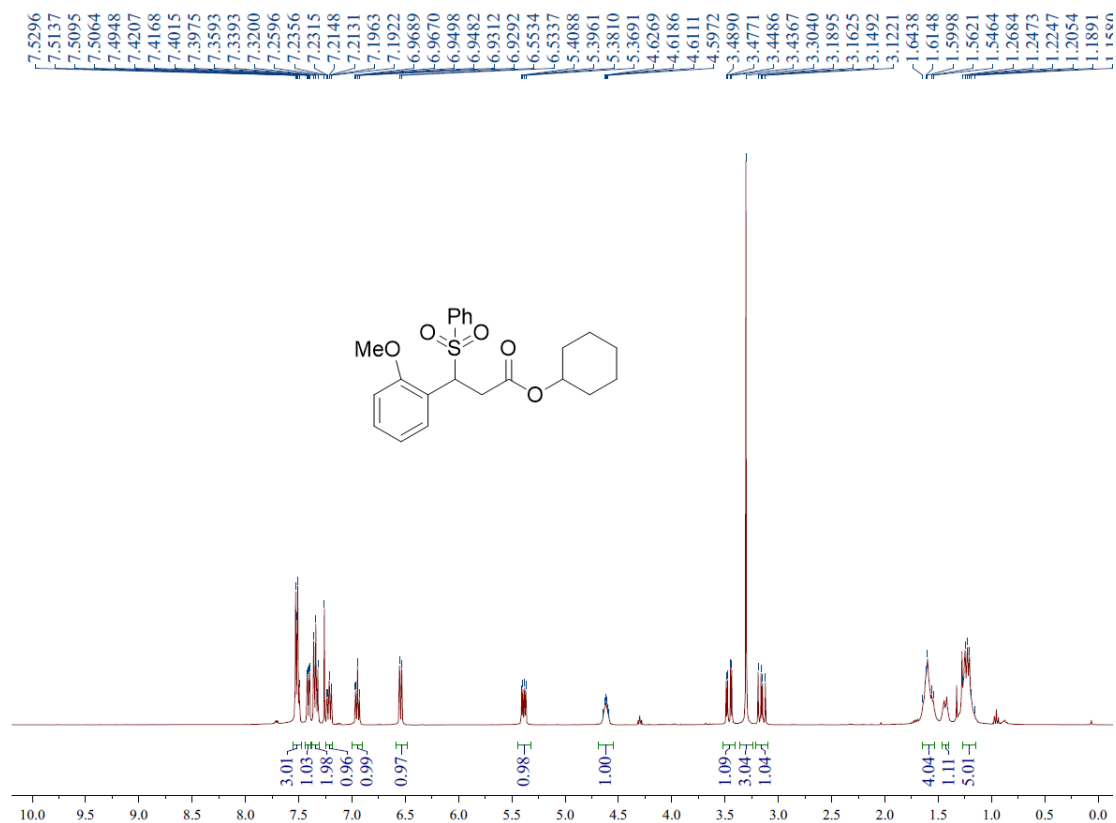
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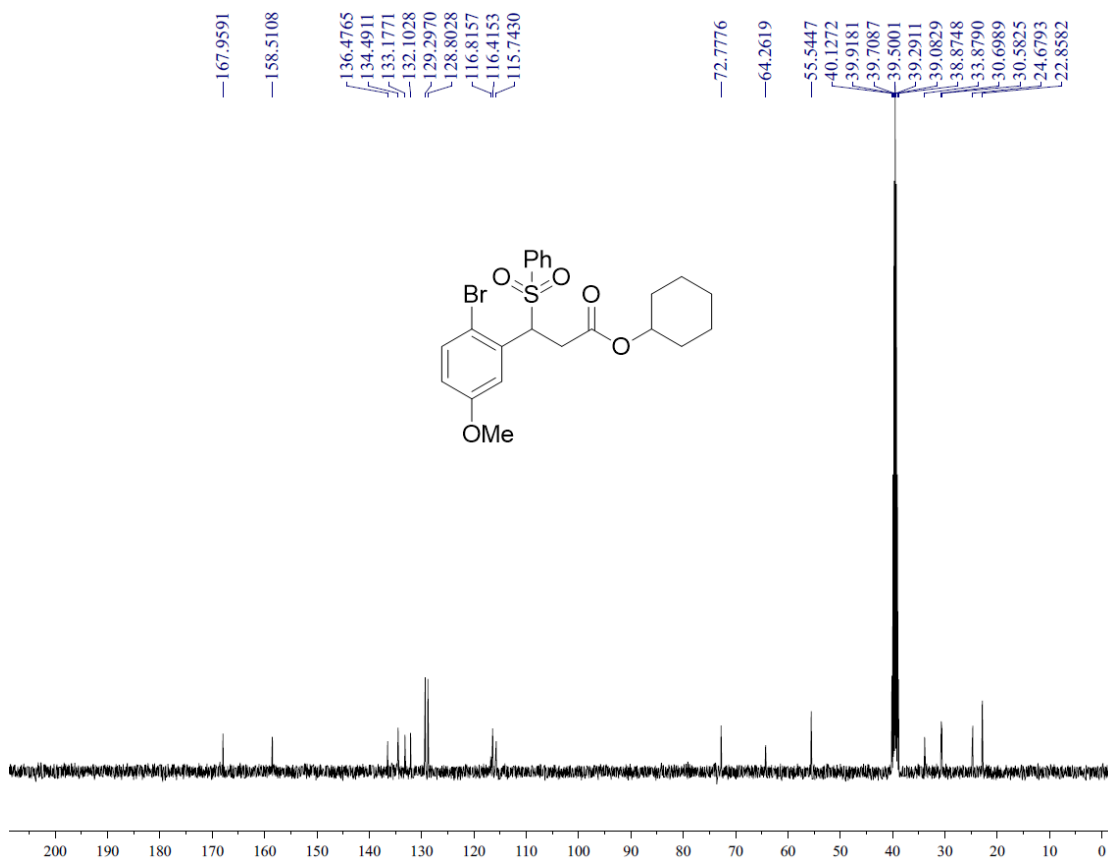
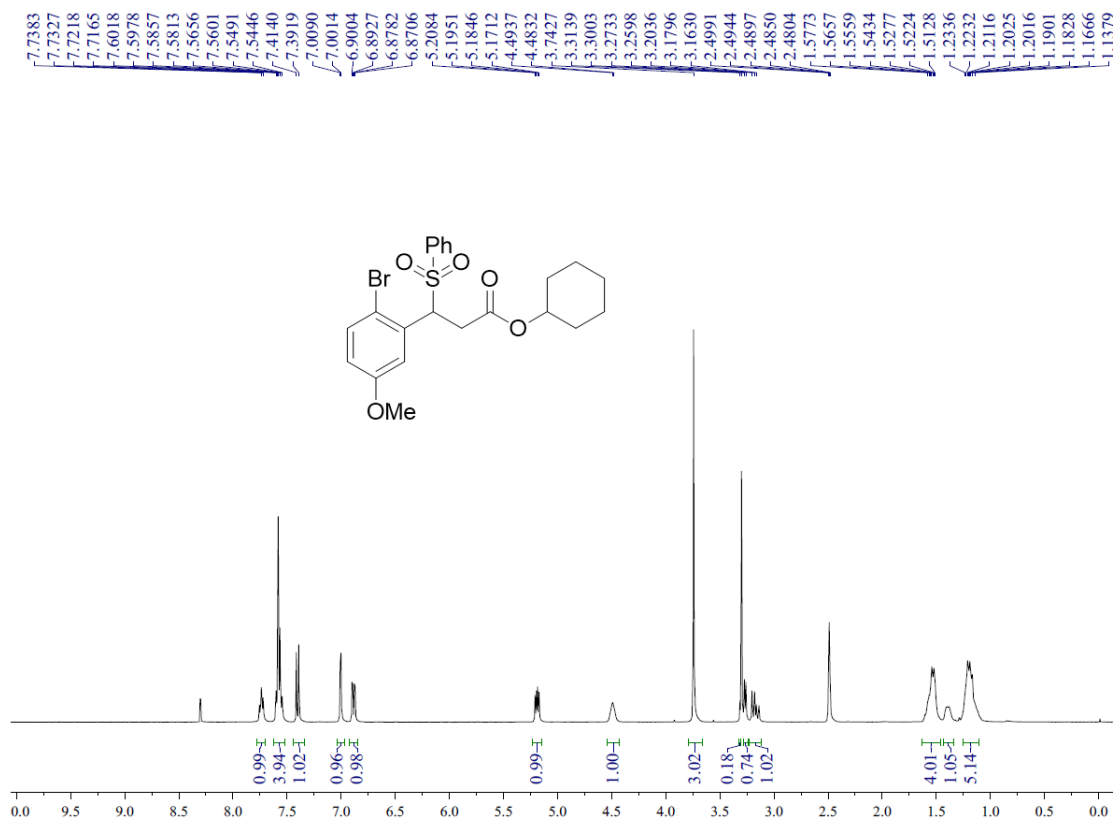
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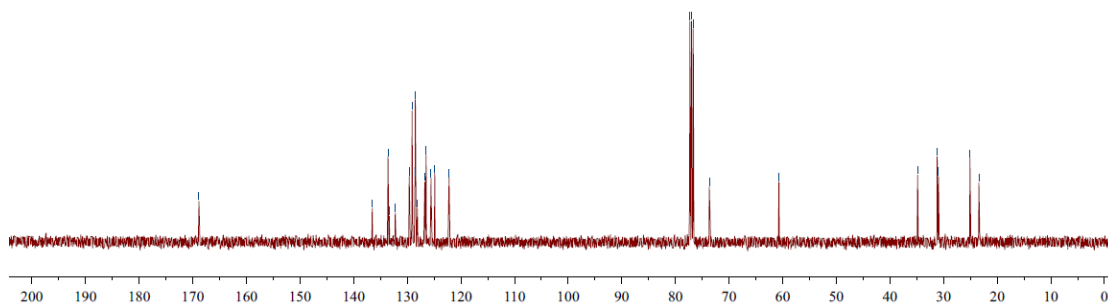
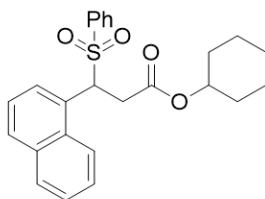
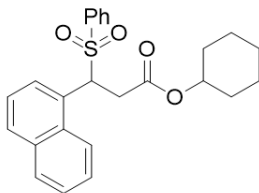
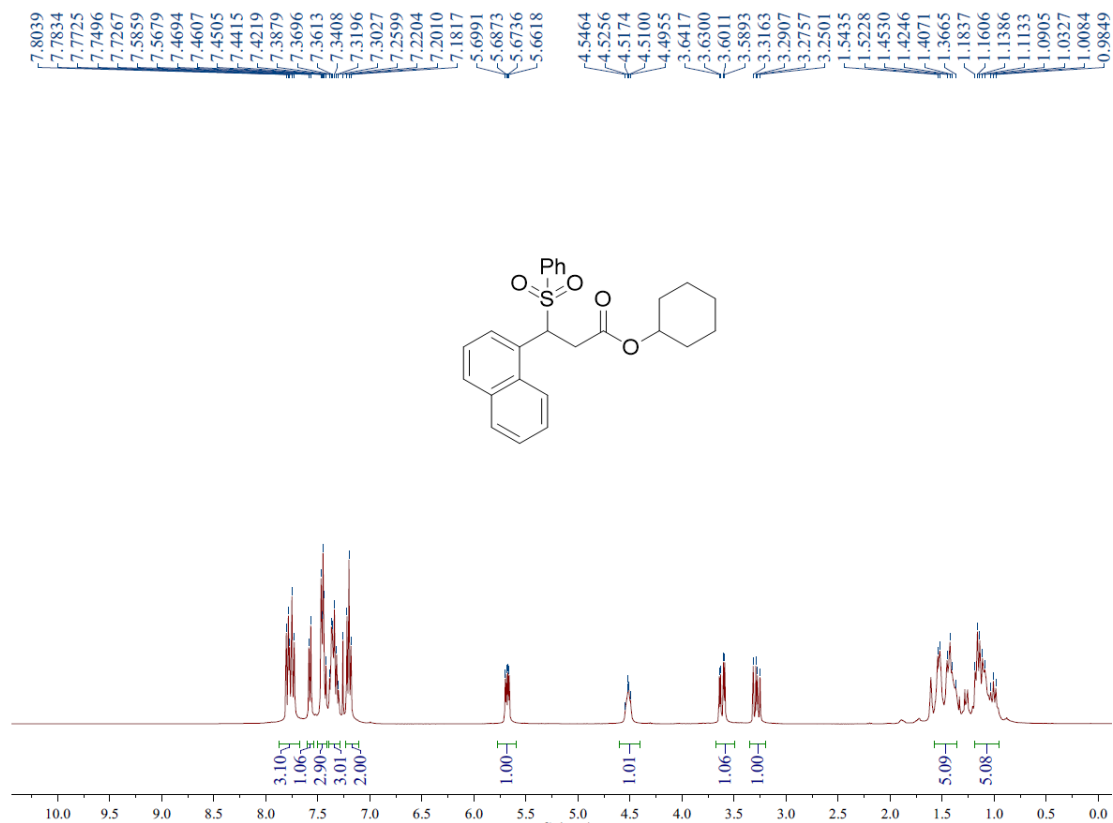
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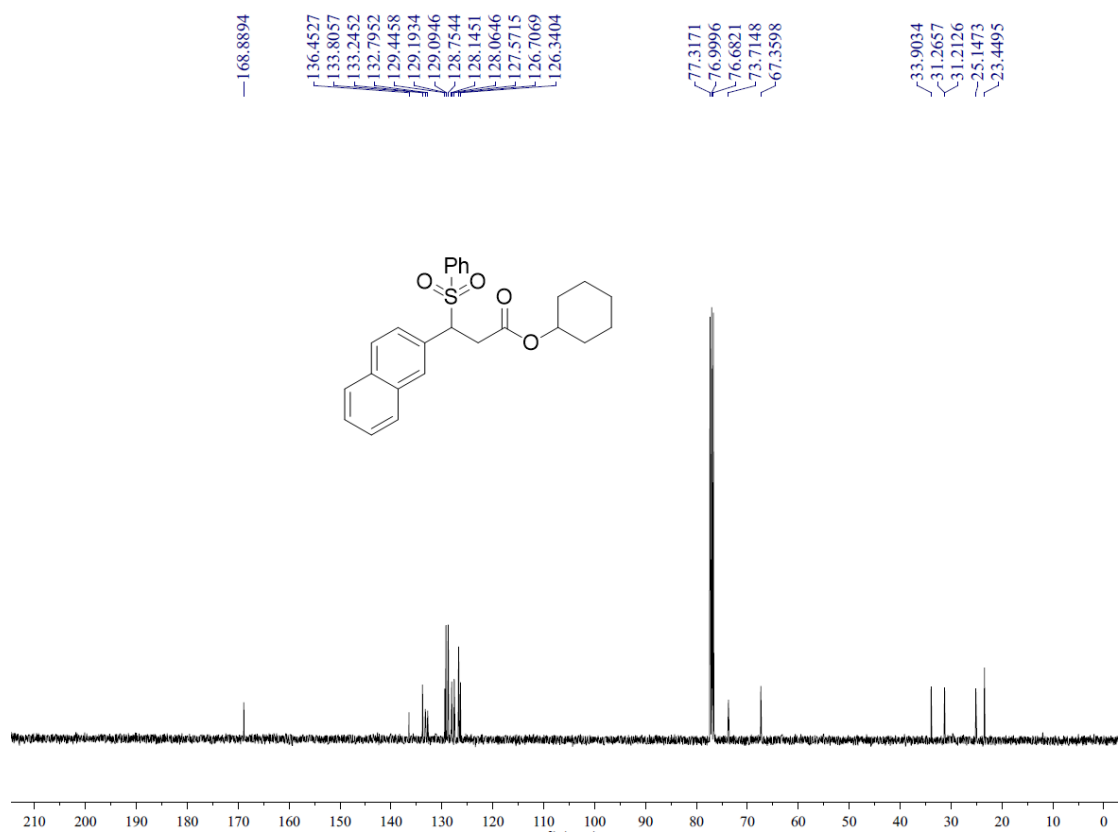
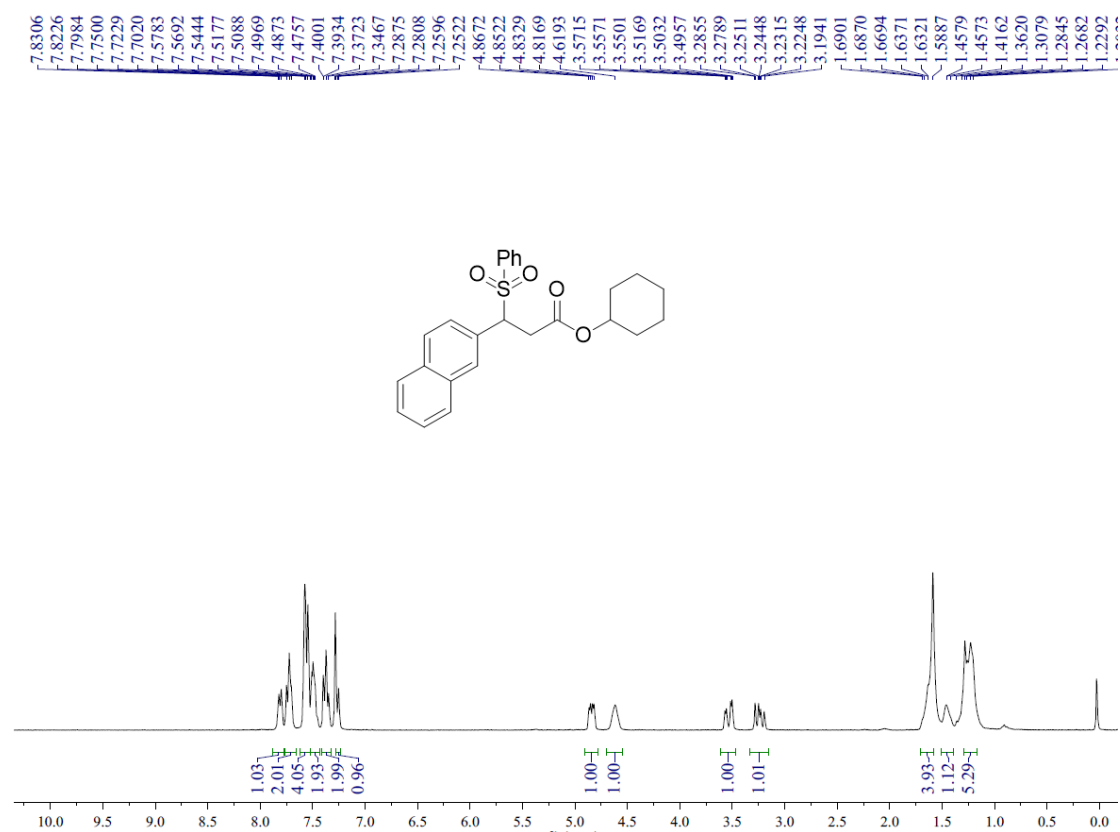
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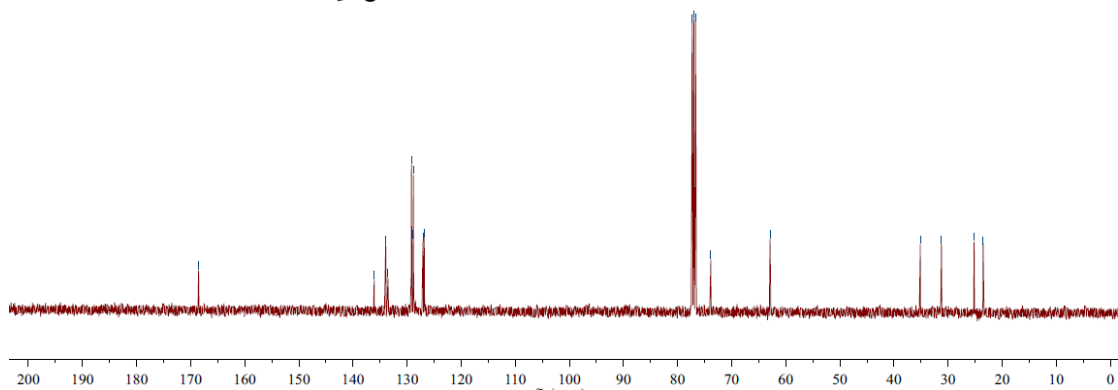
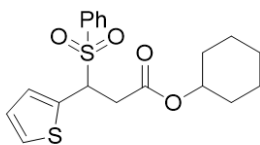
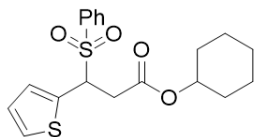
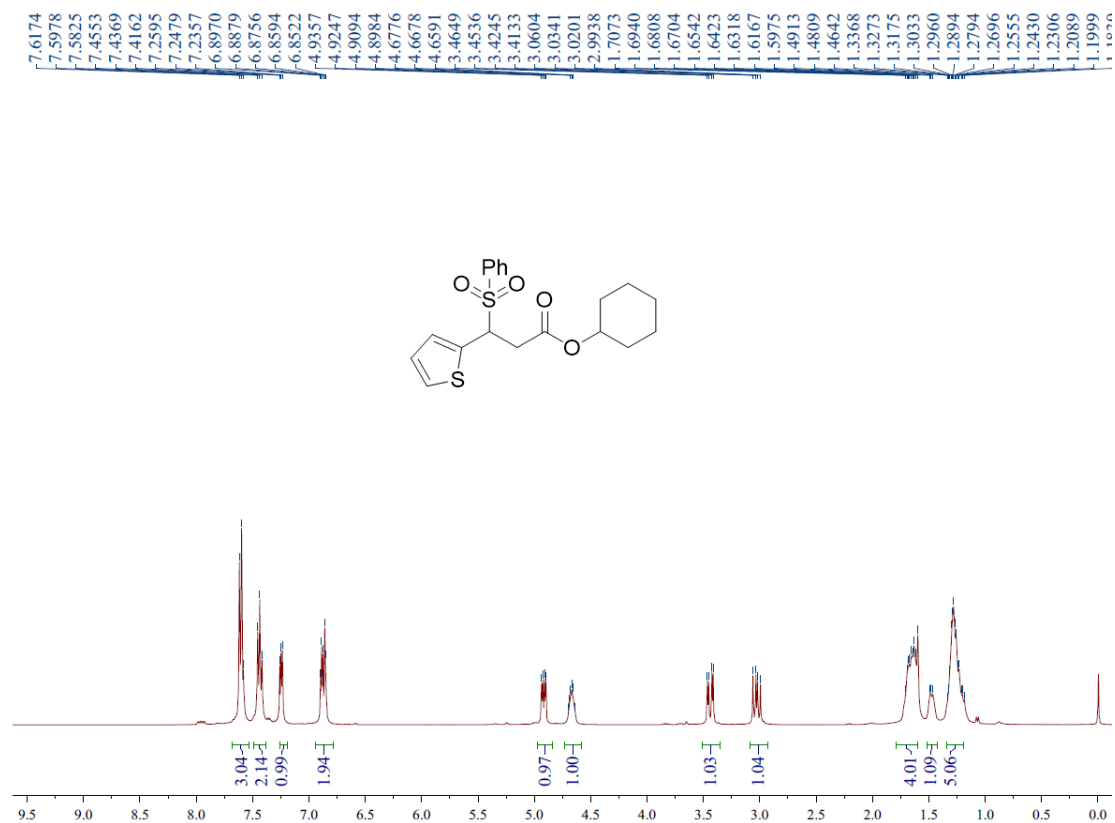
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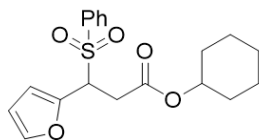
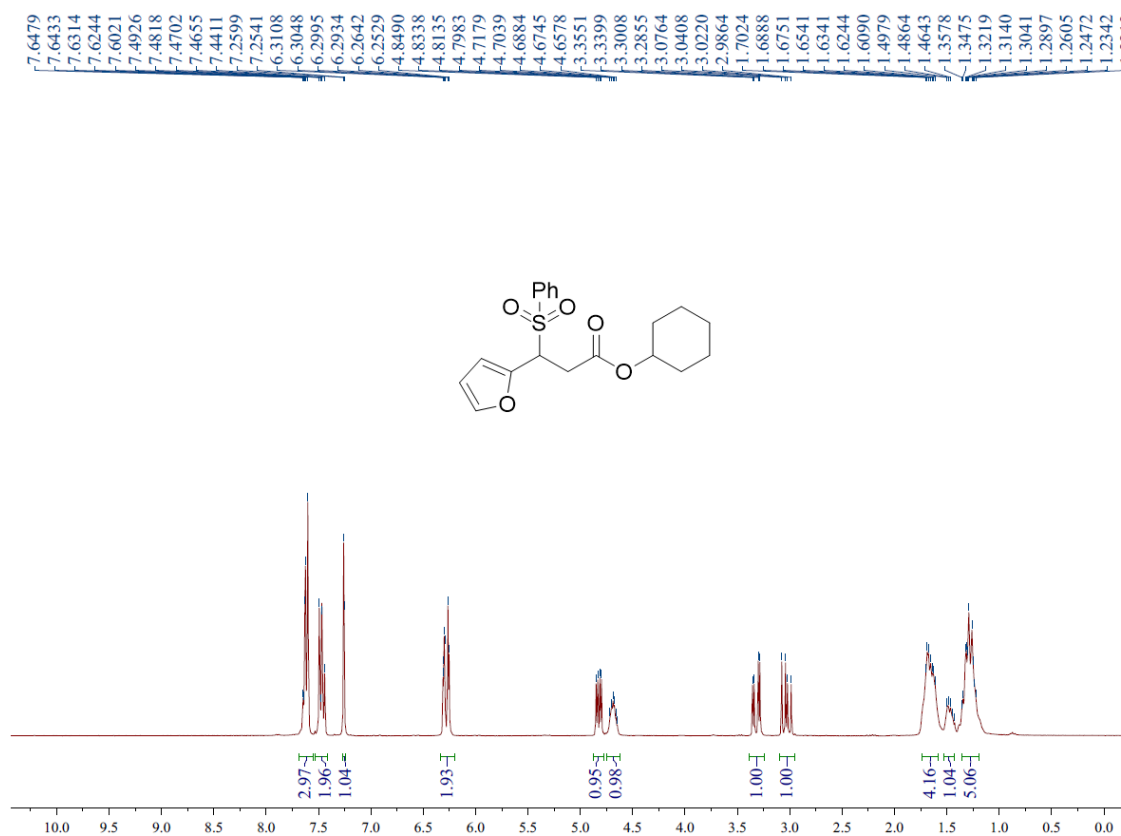
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4ta



4ua



—168.5347

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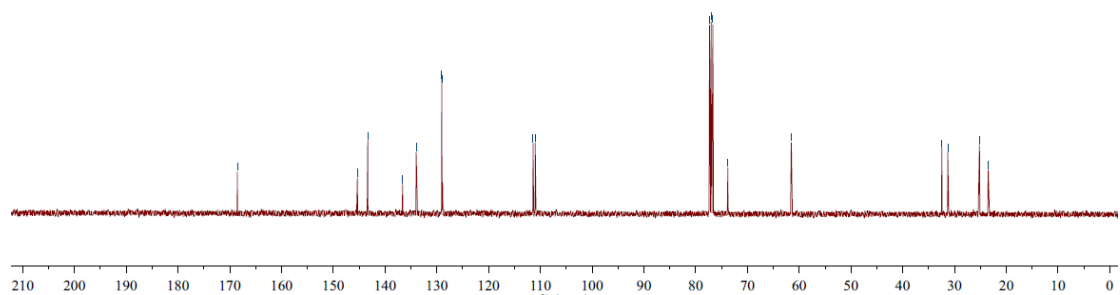
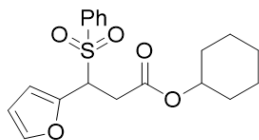
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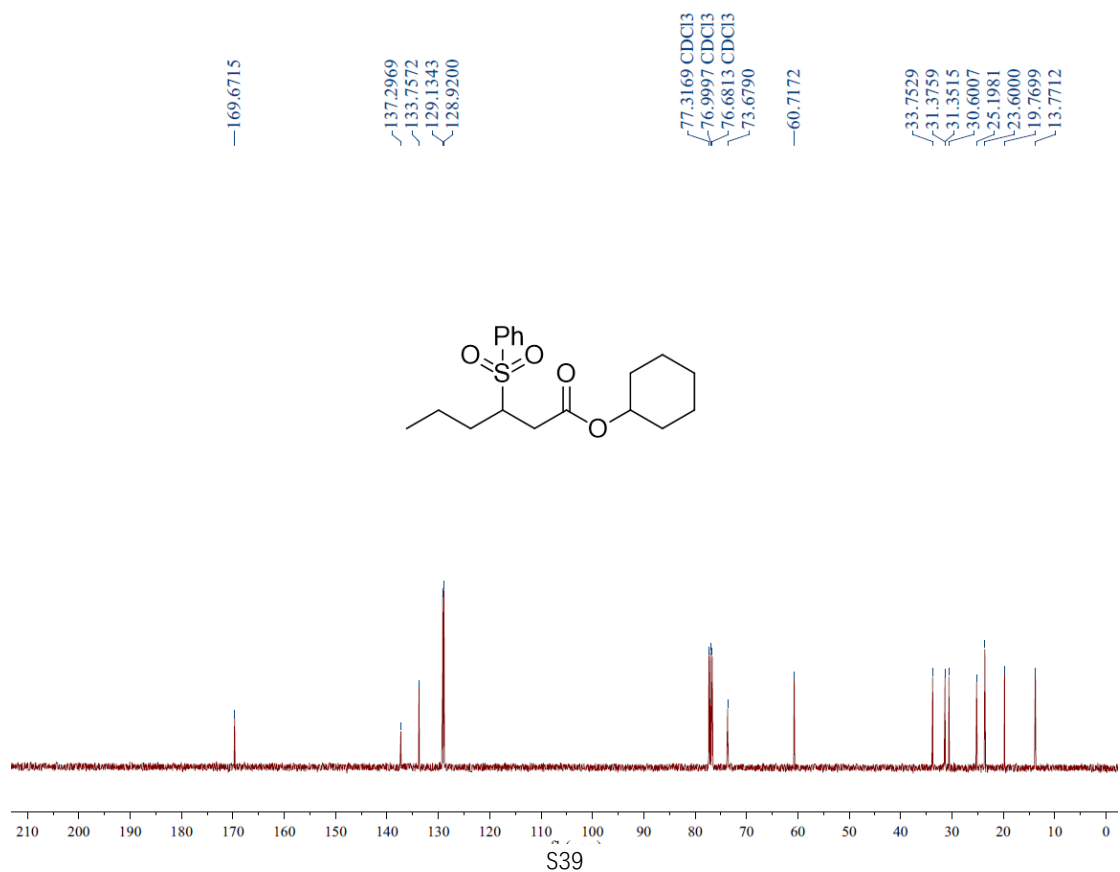
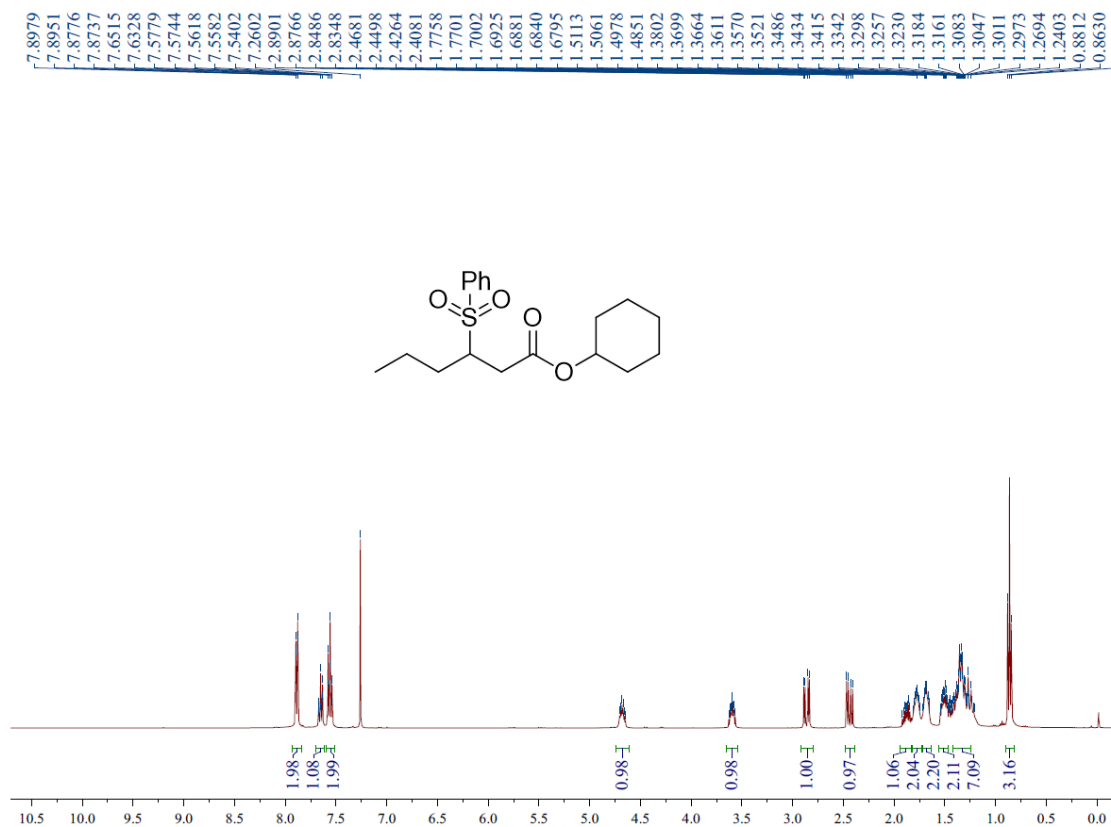
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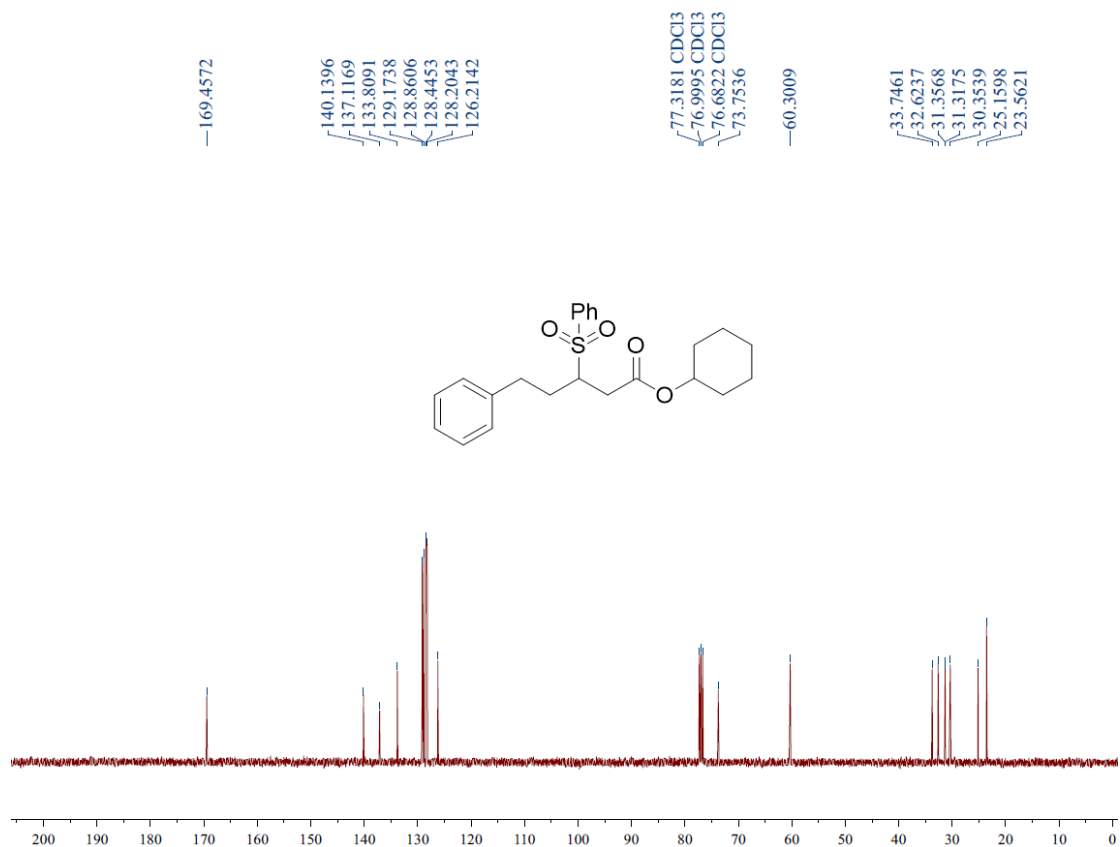
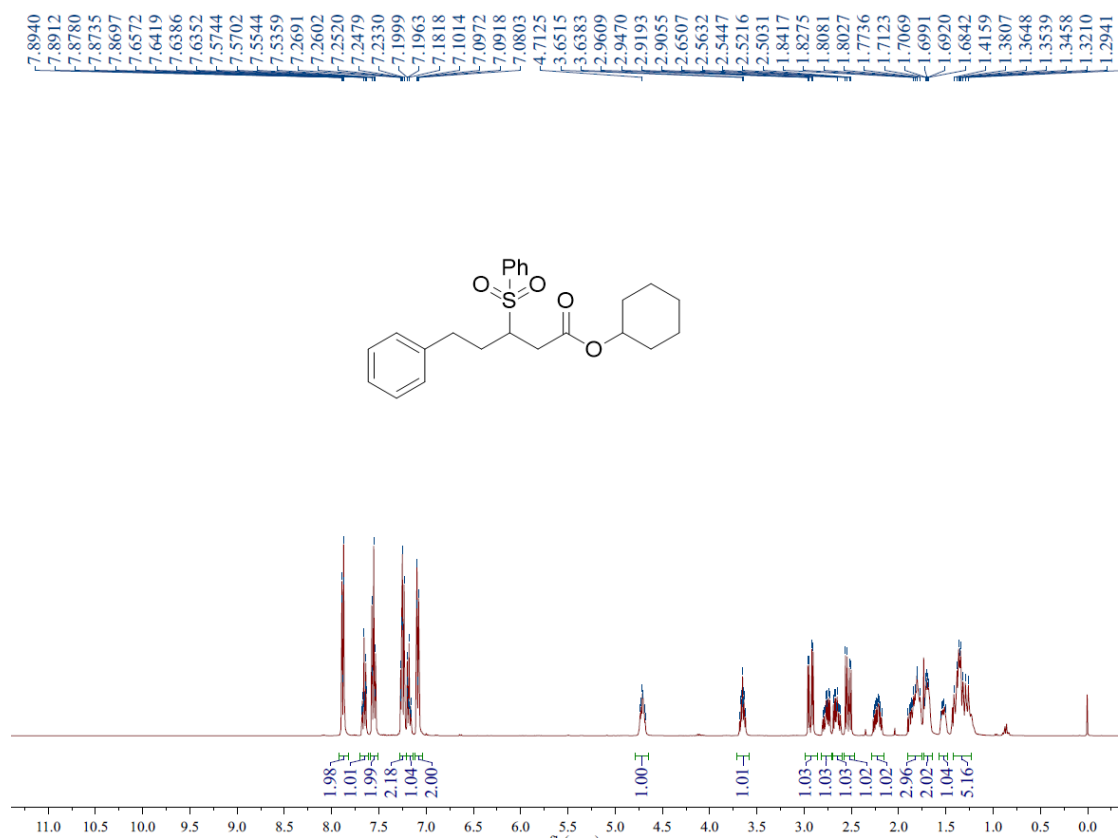
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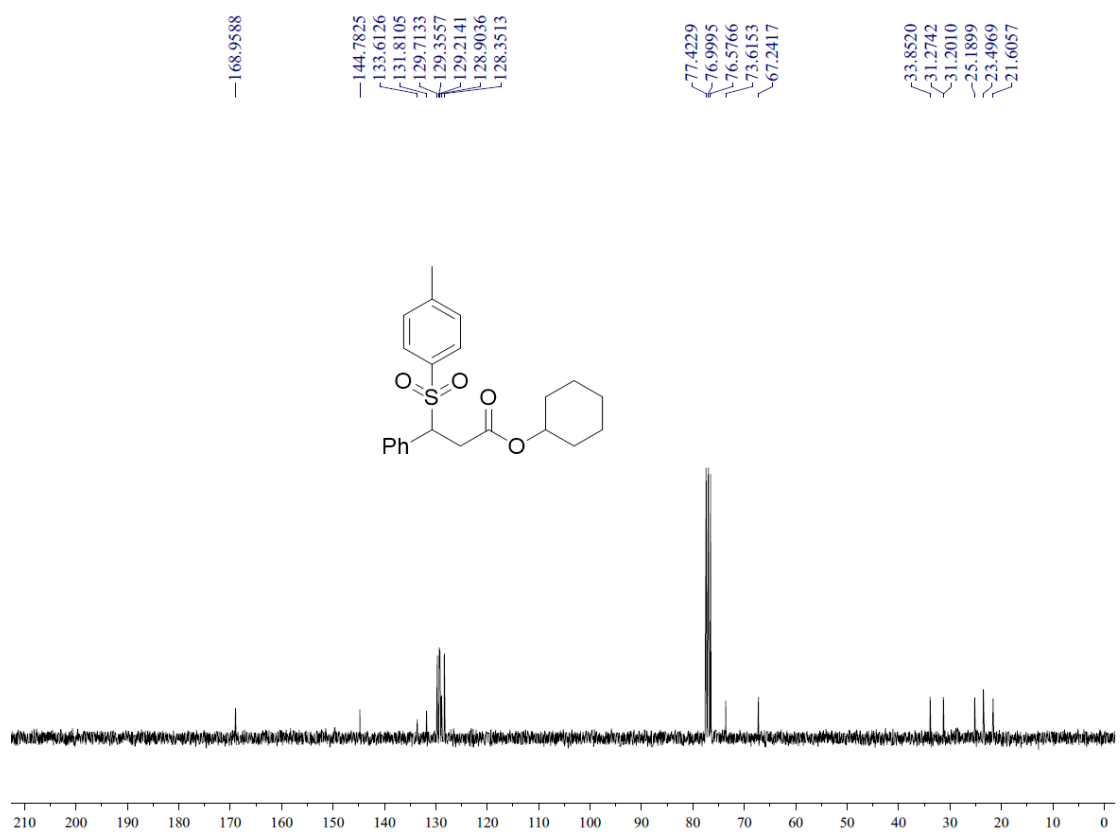
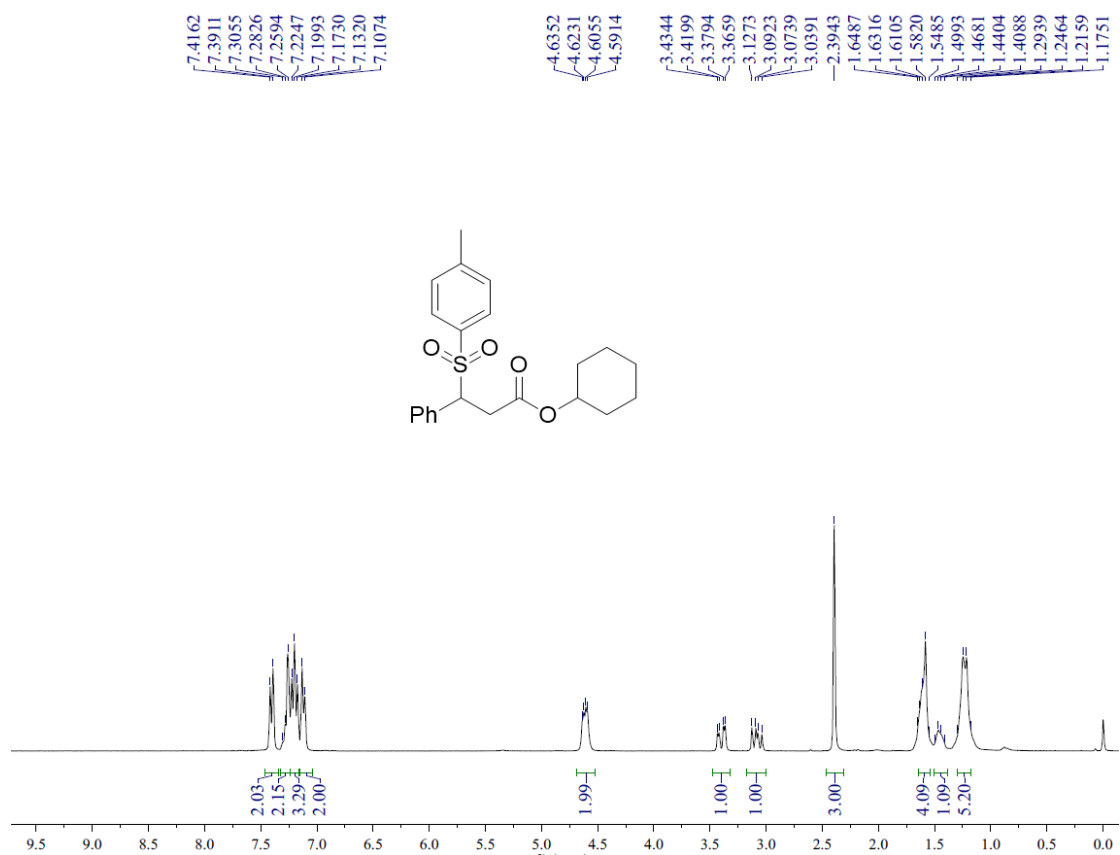
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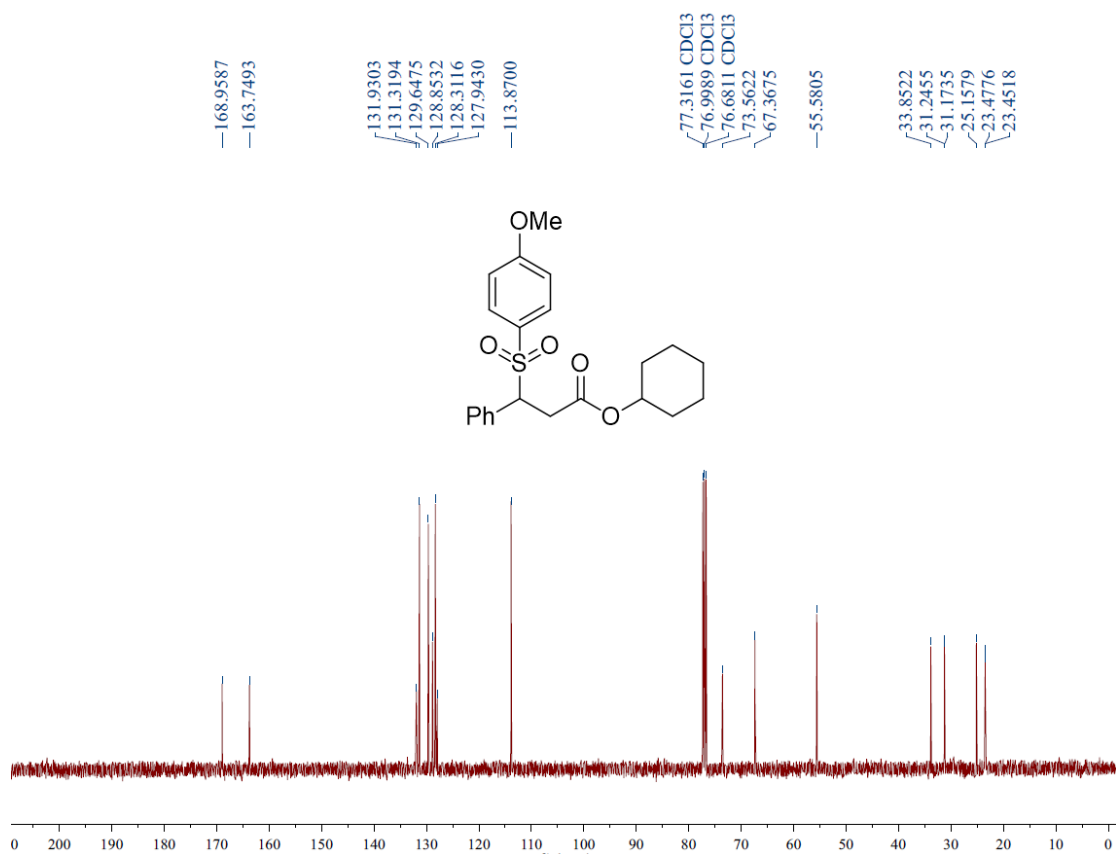
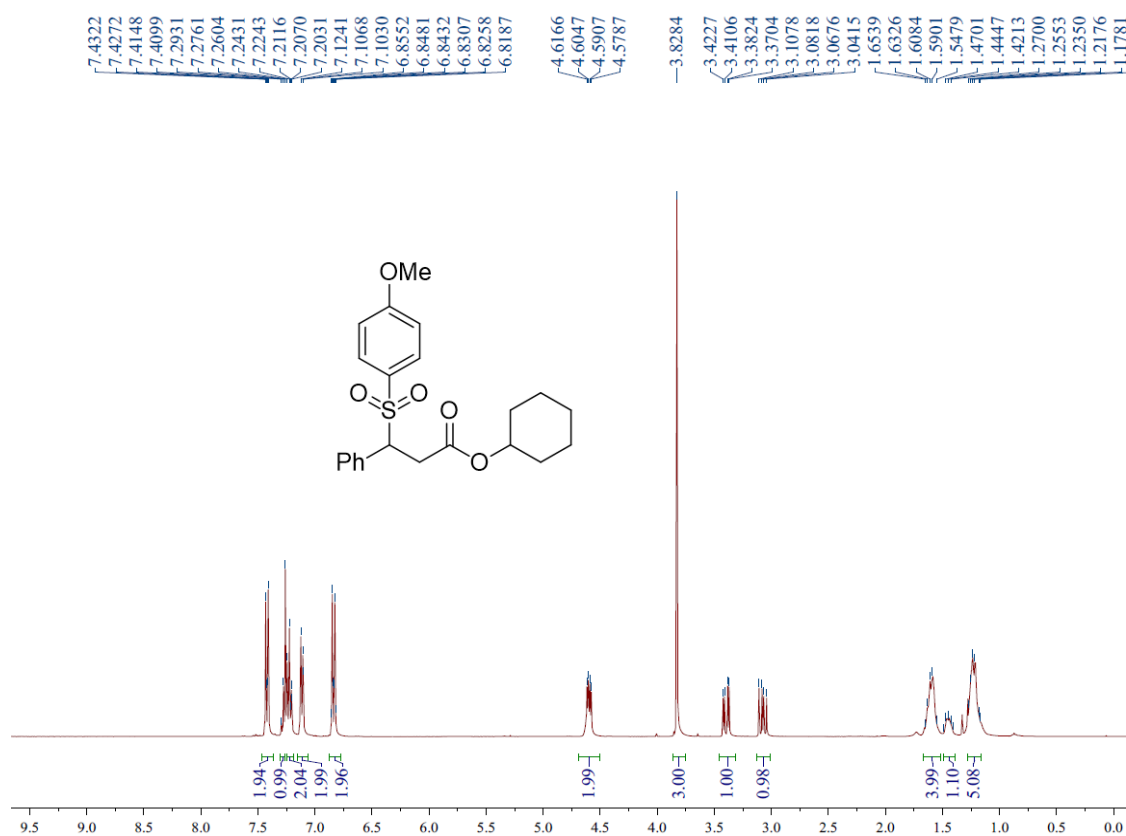
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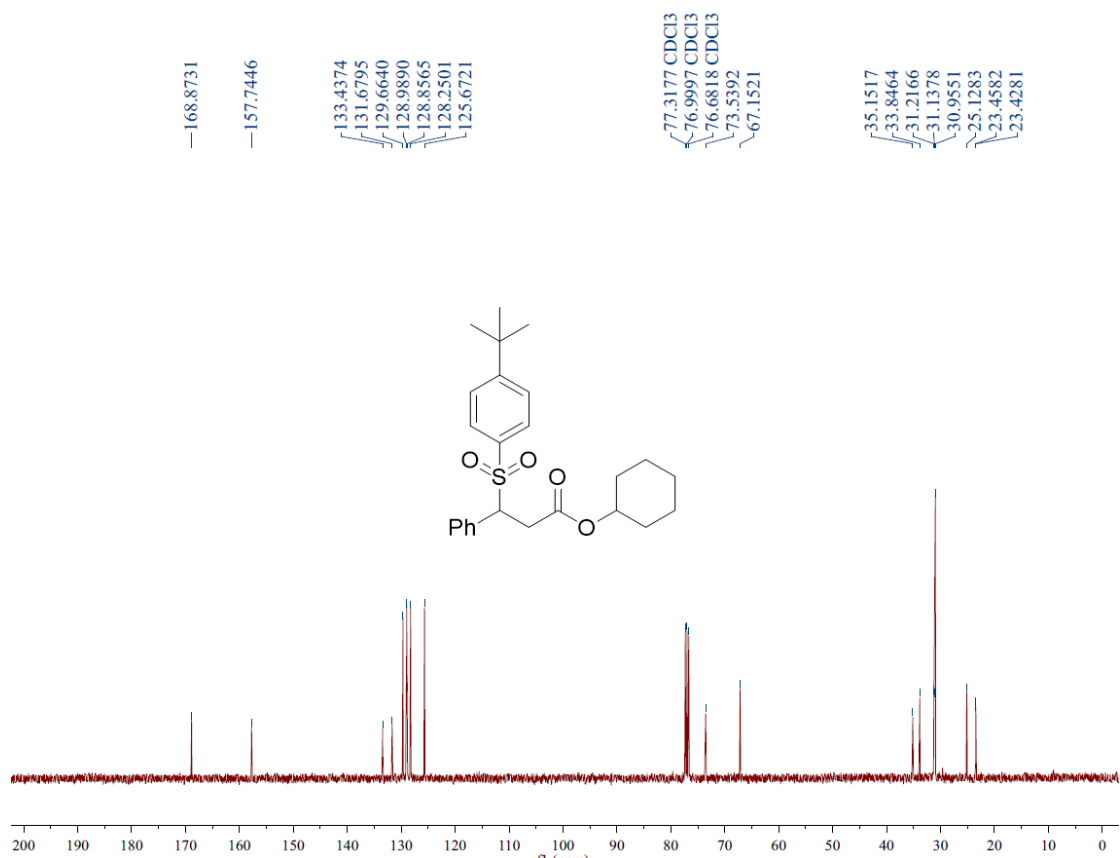
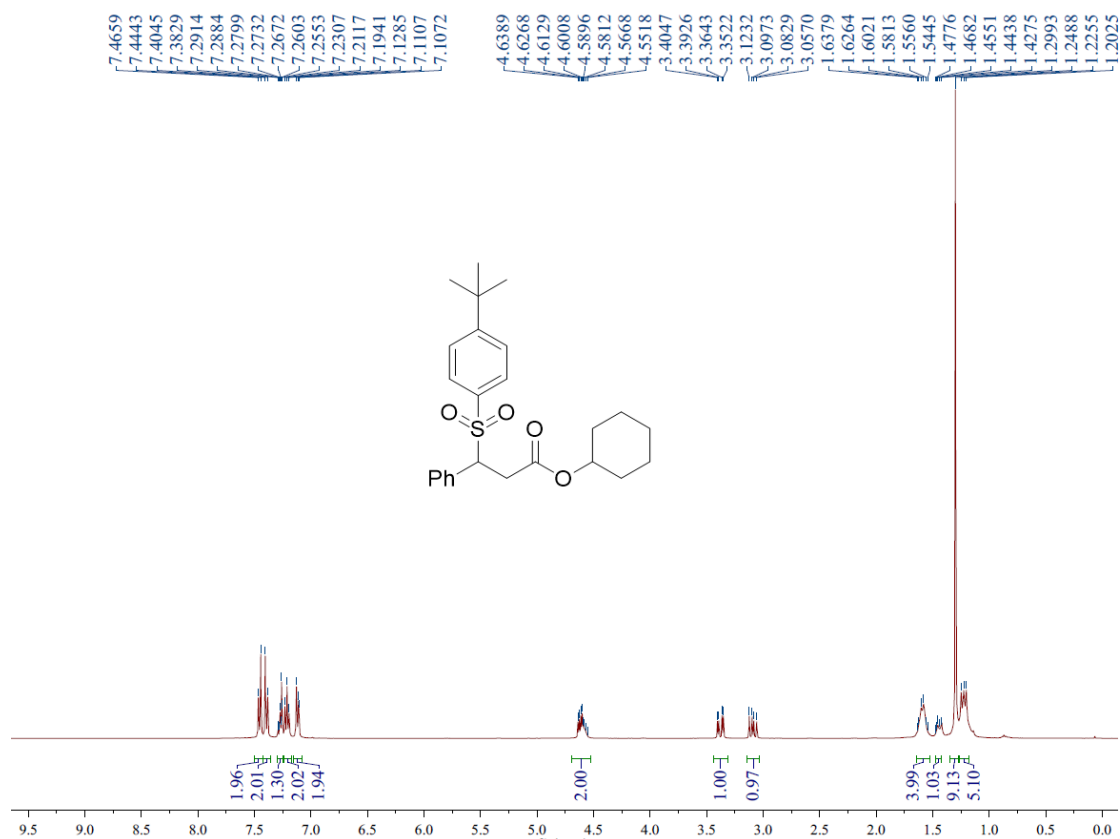
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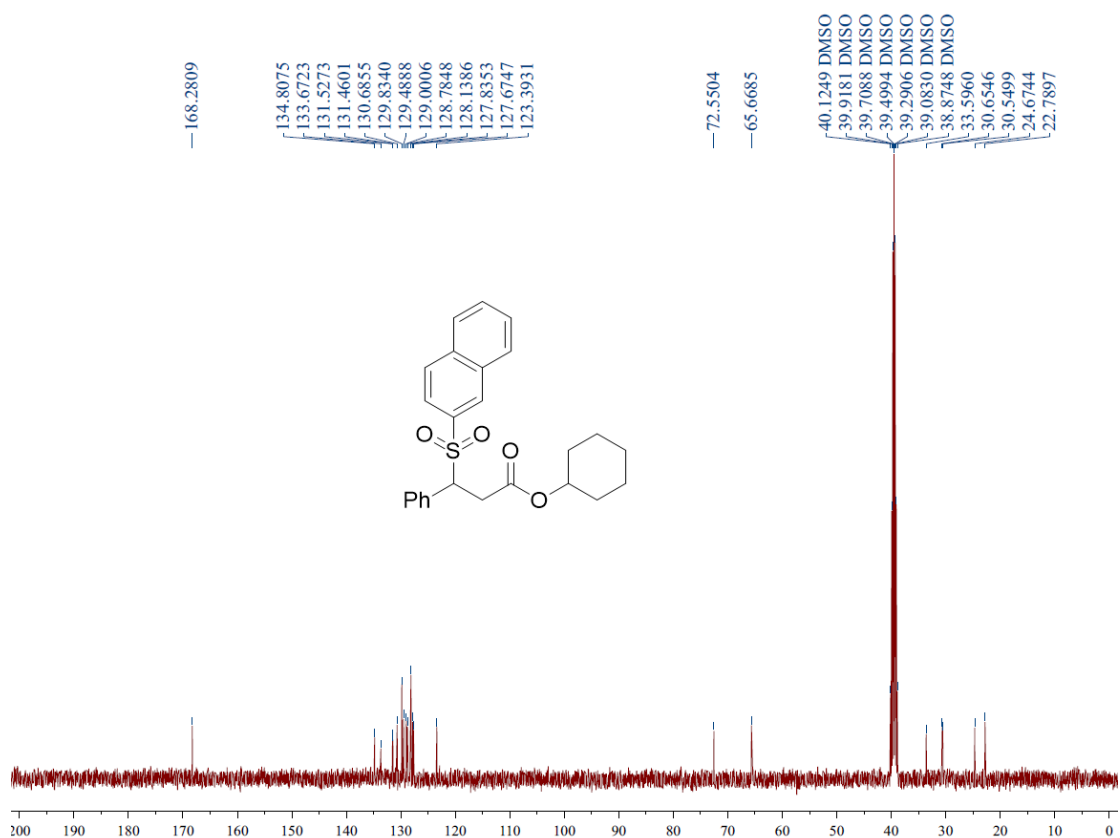
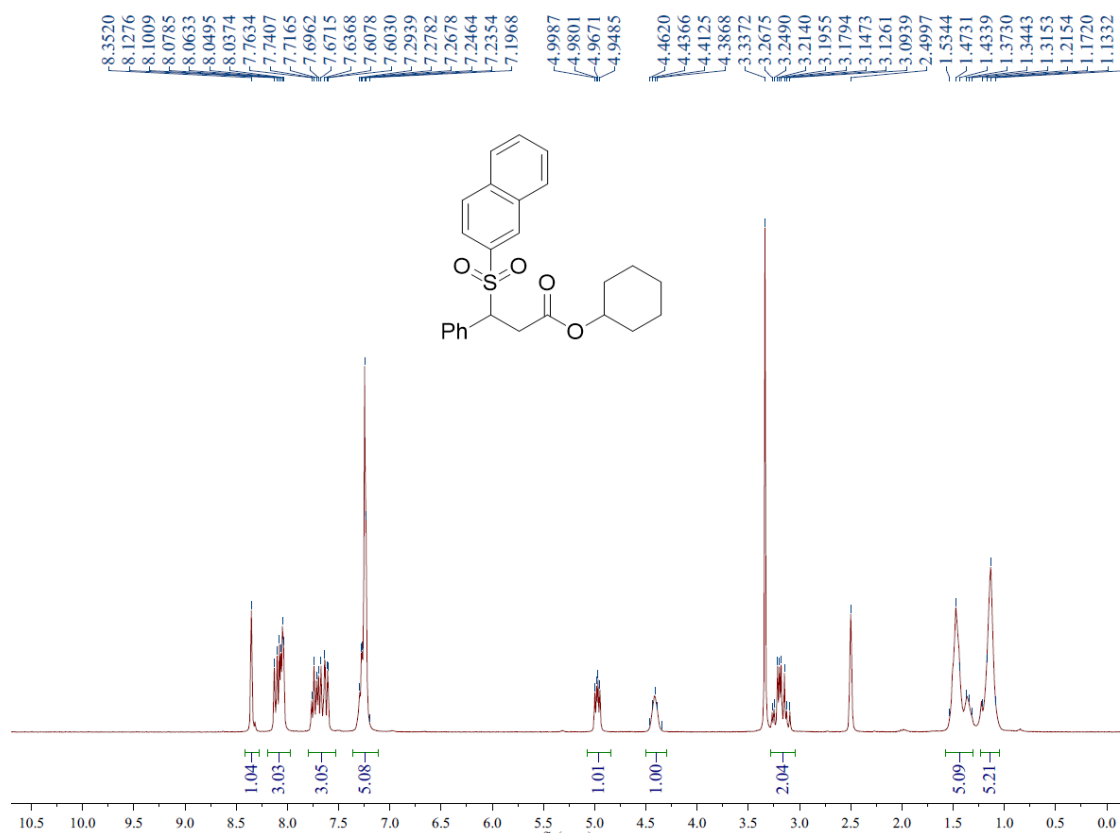
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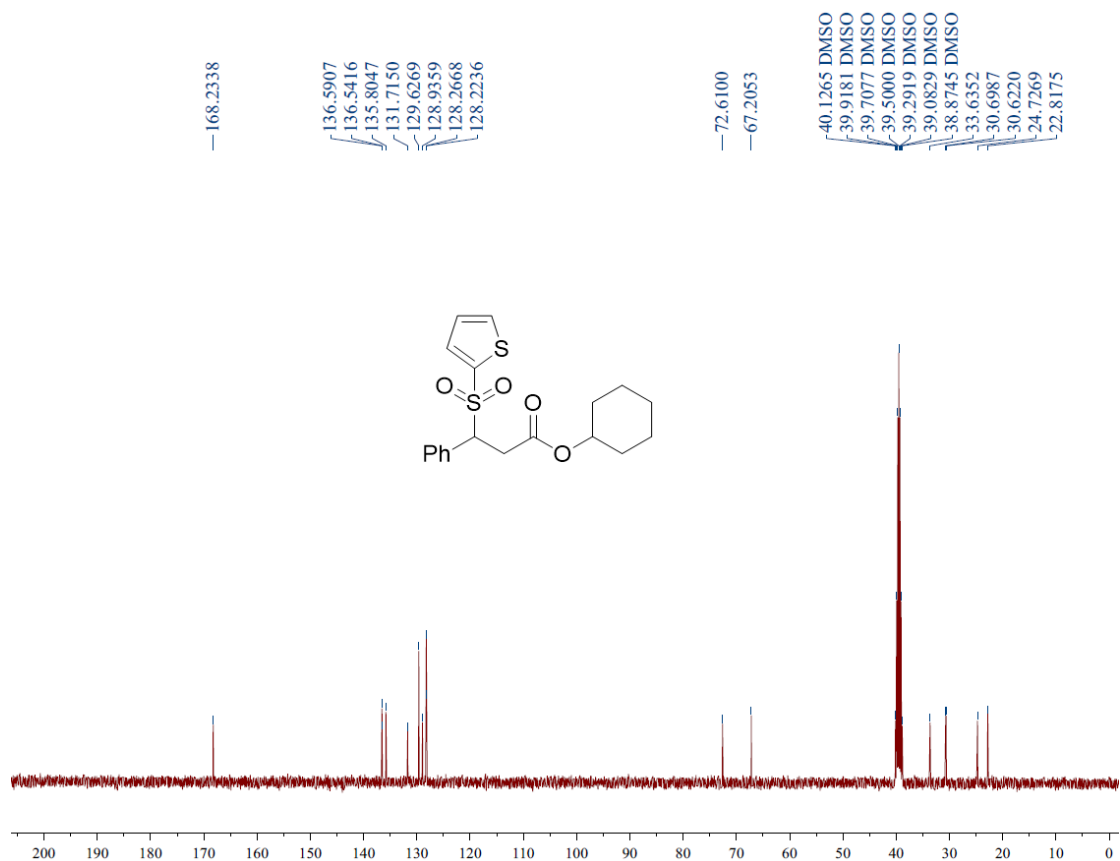
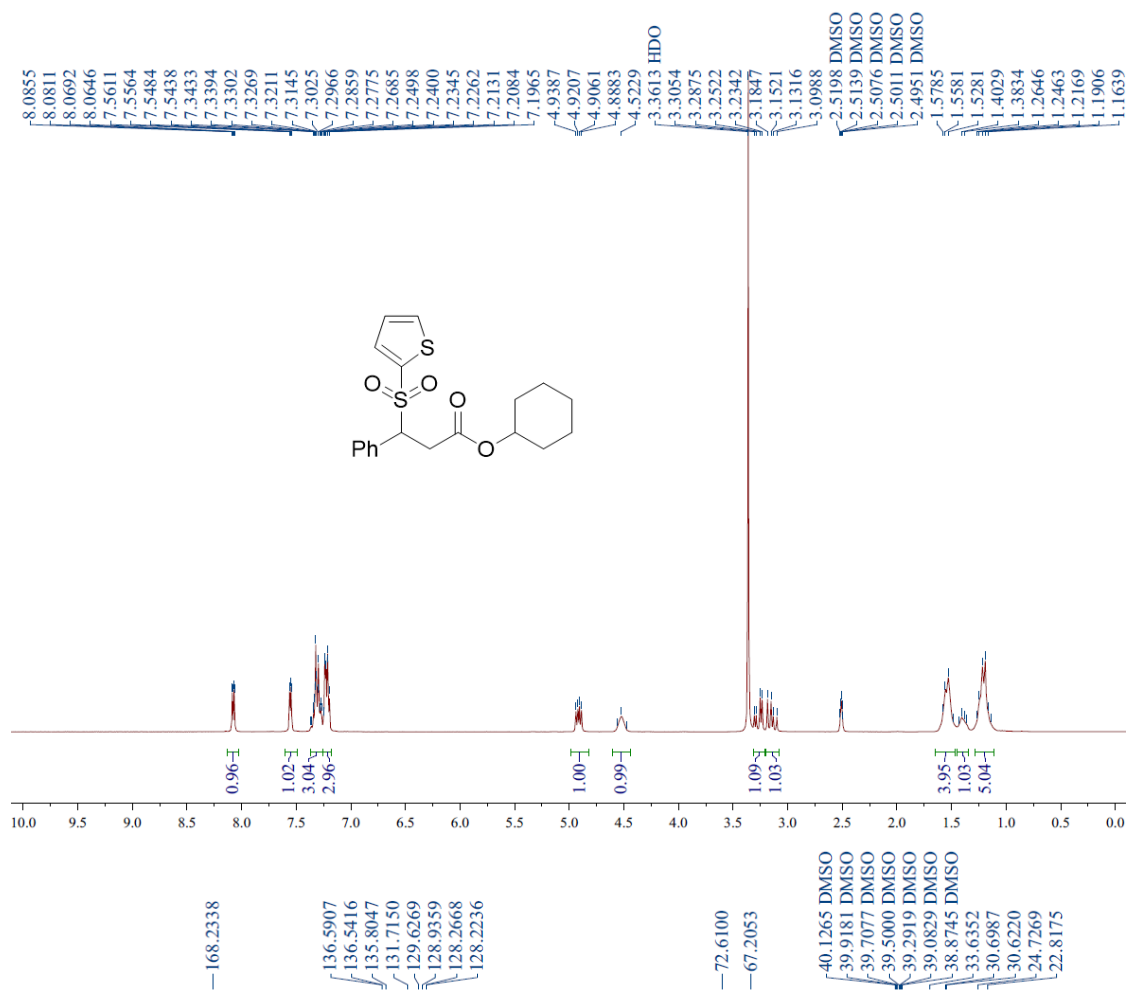
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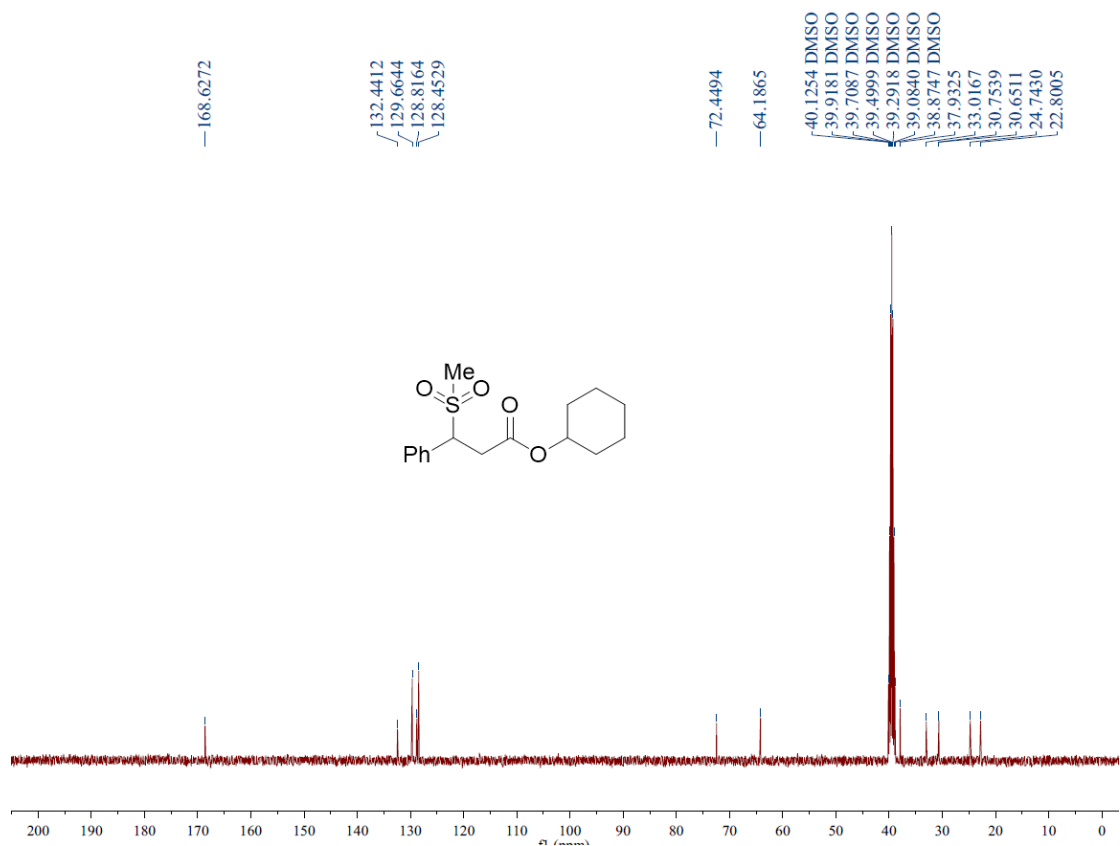
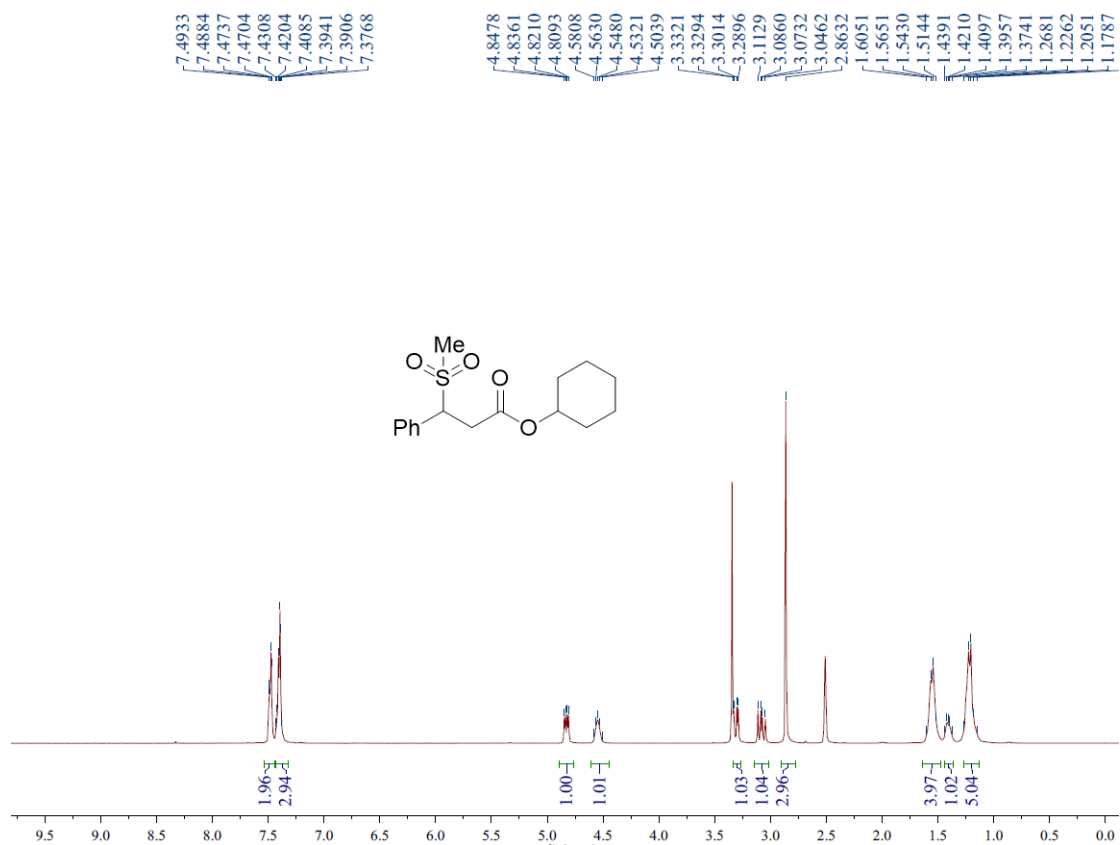
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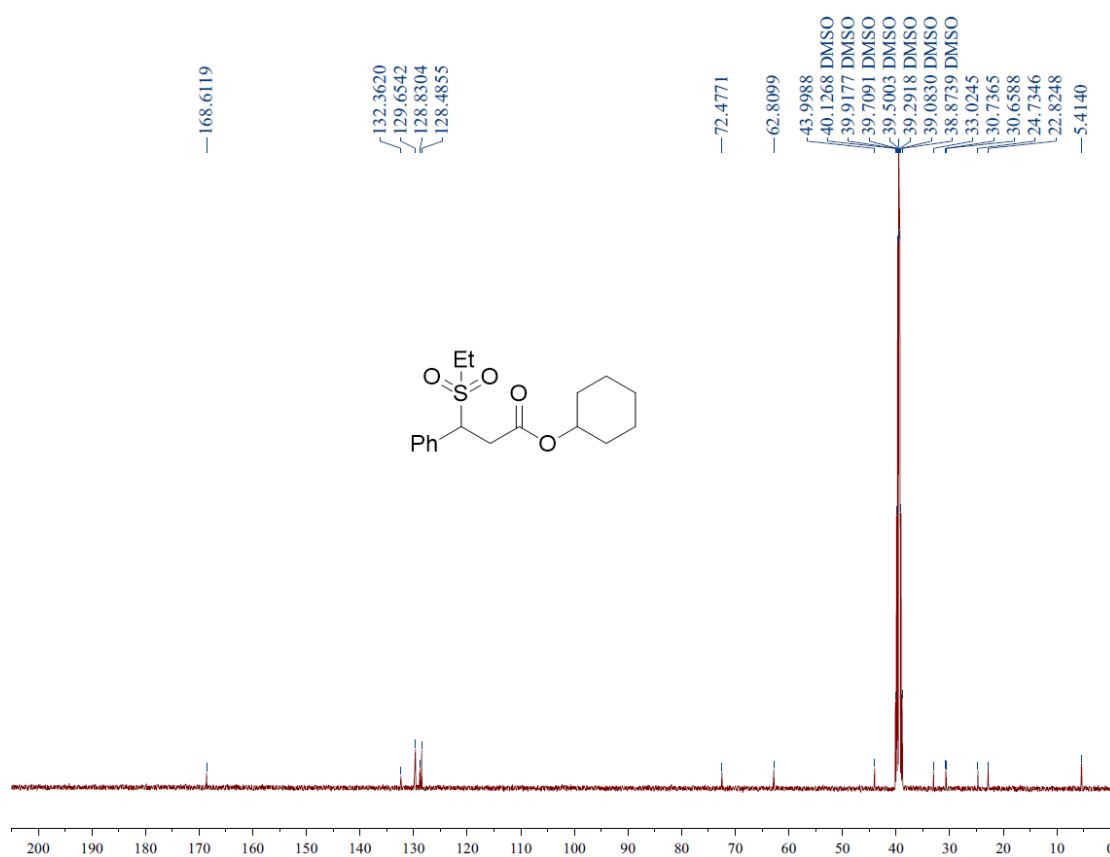
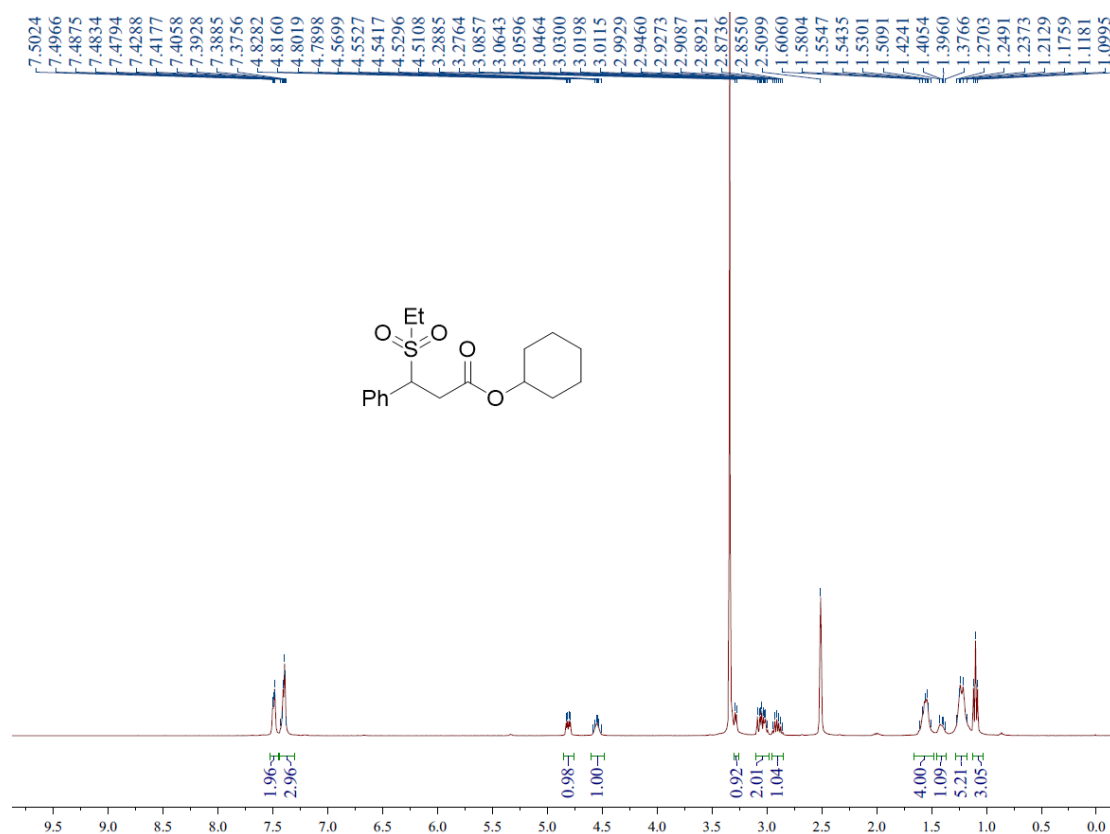
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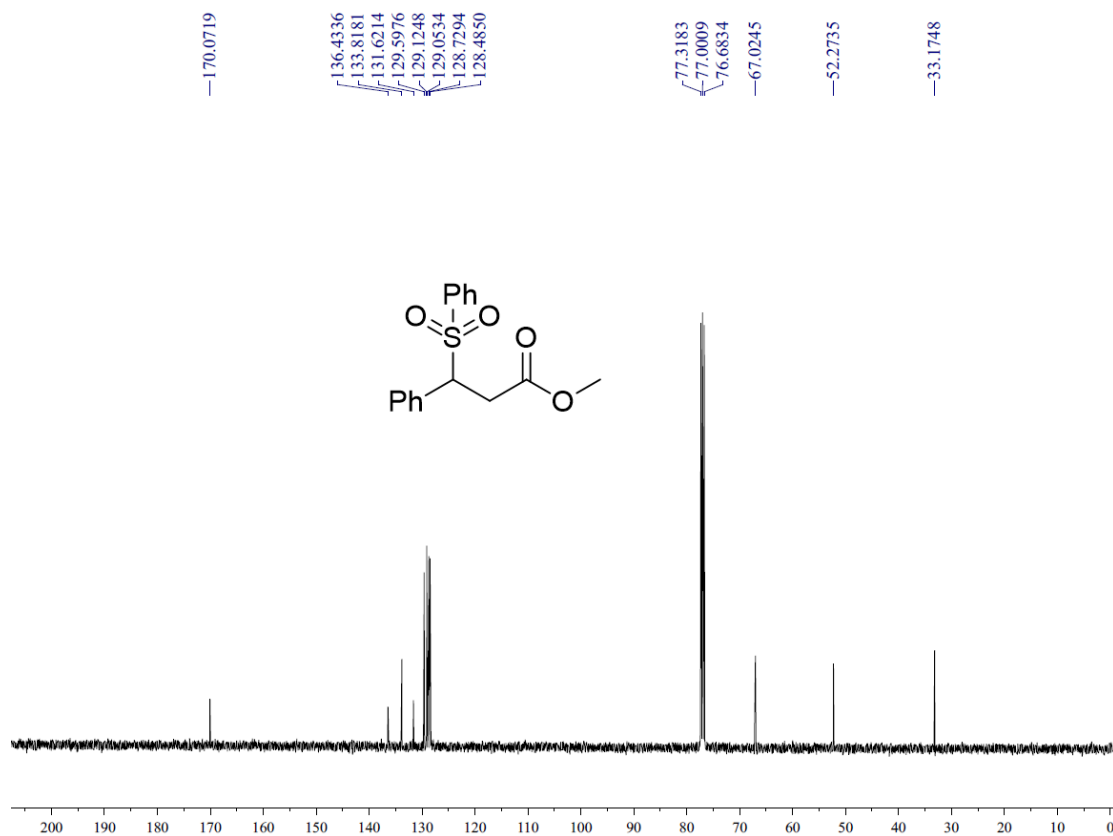
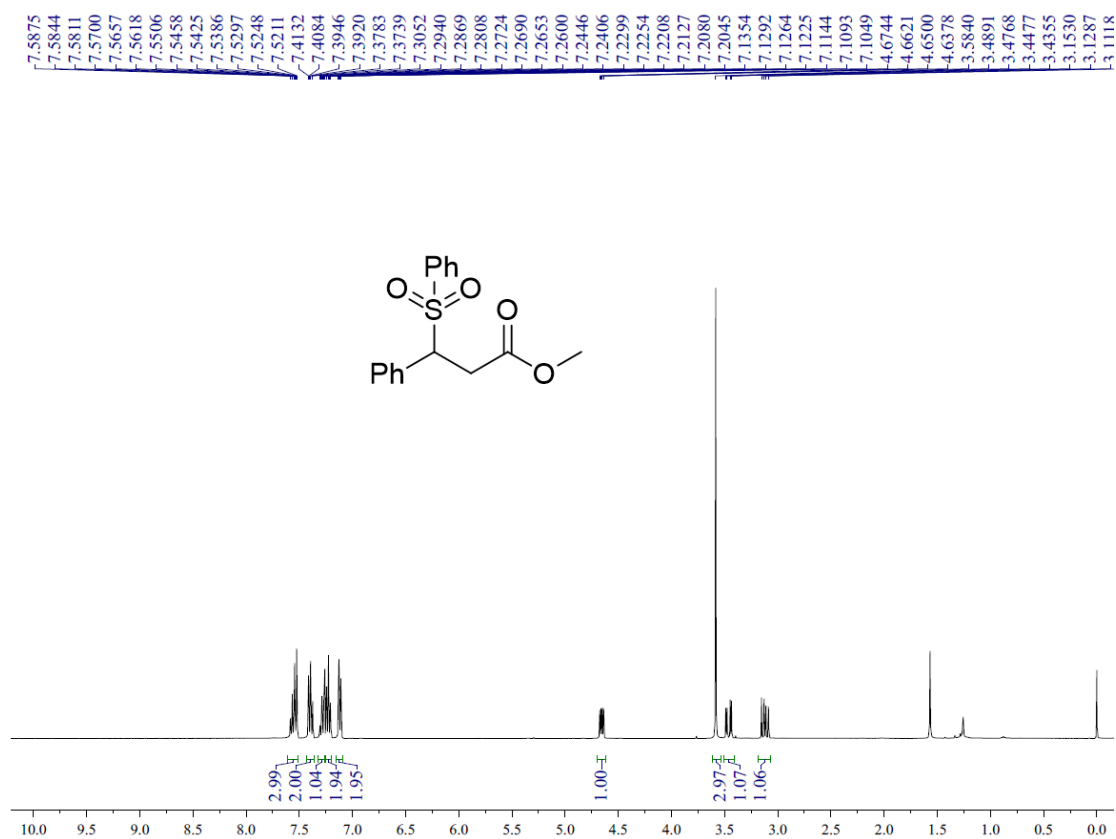
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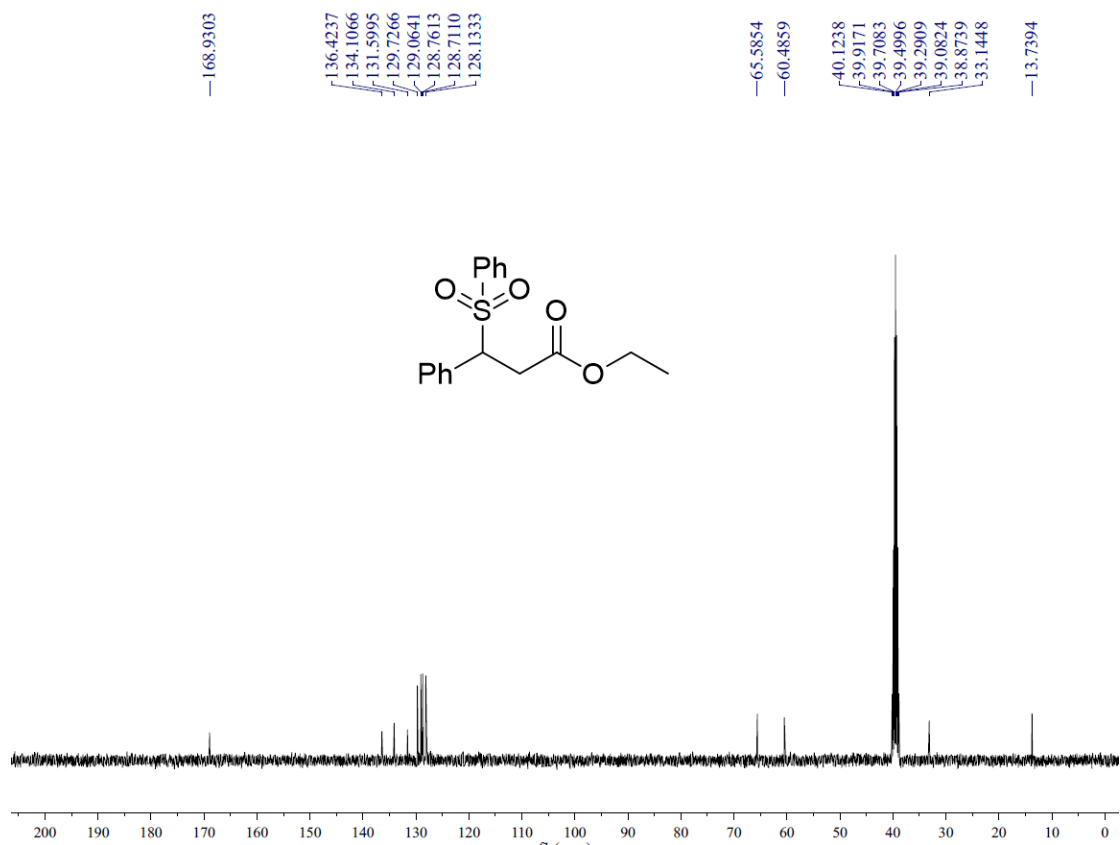
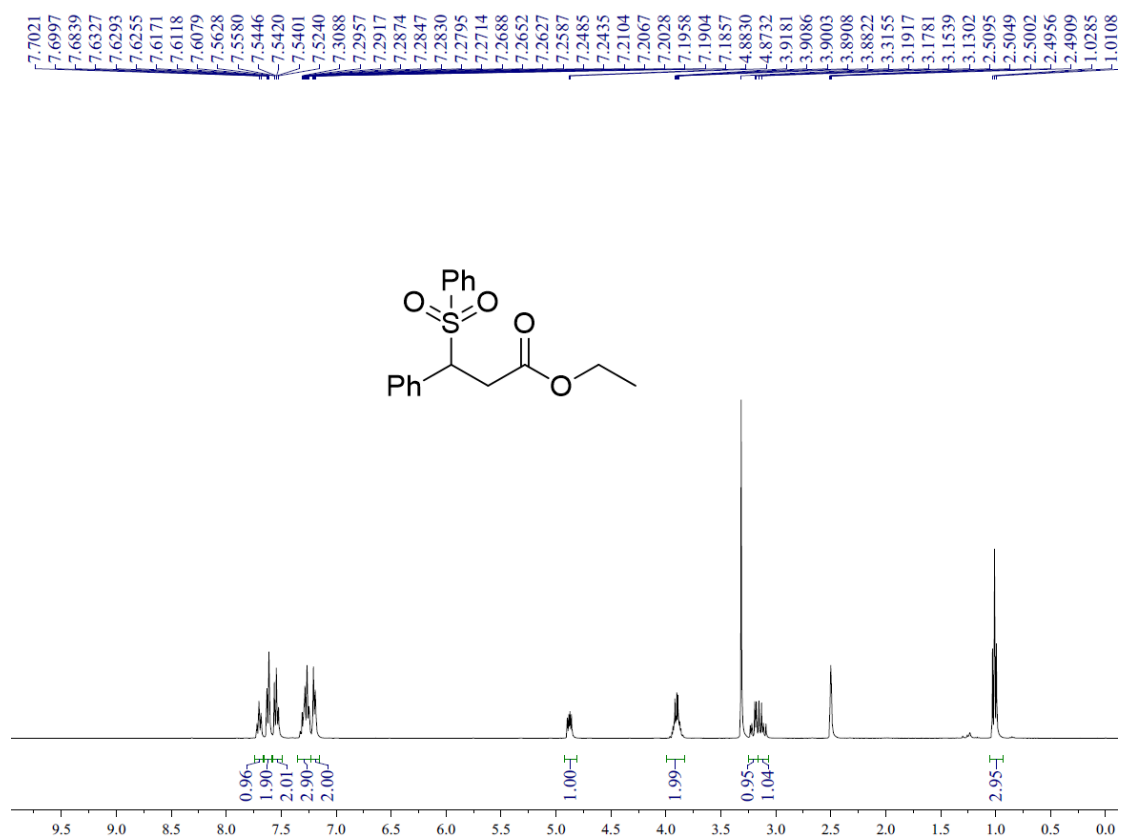
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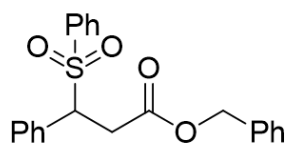
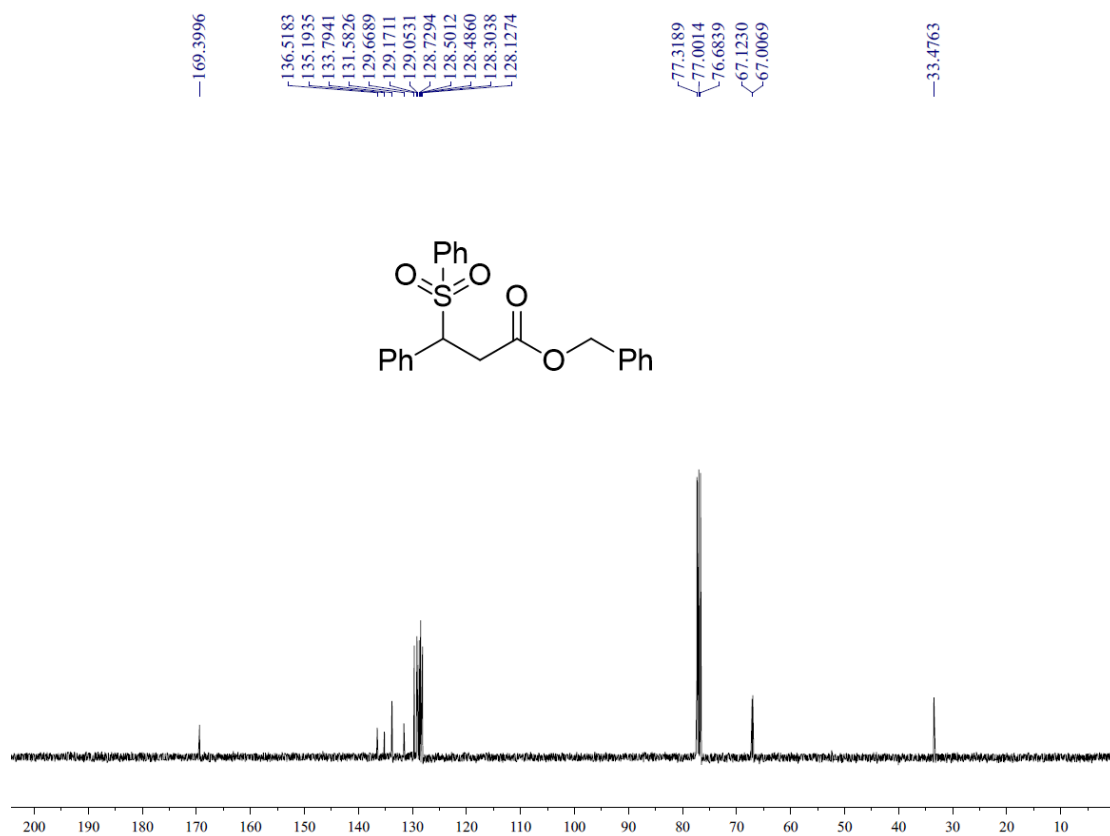
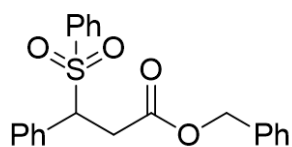
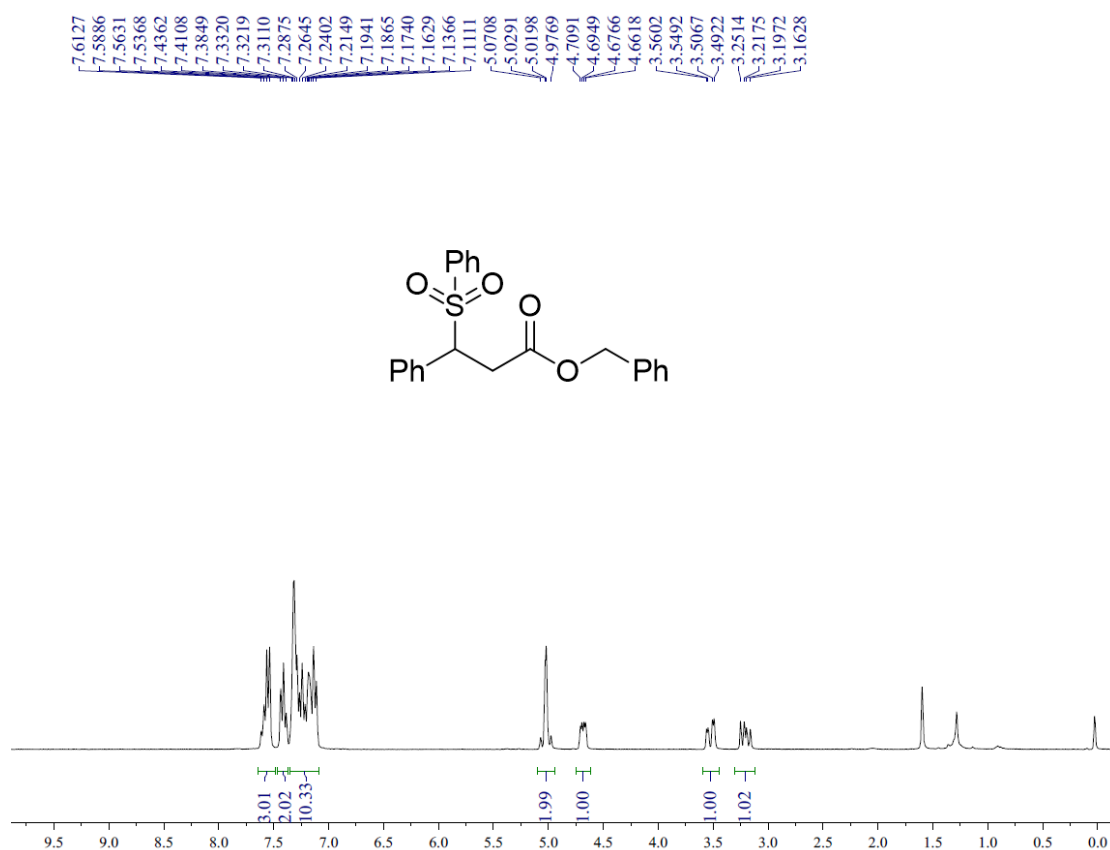
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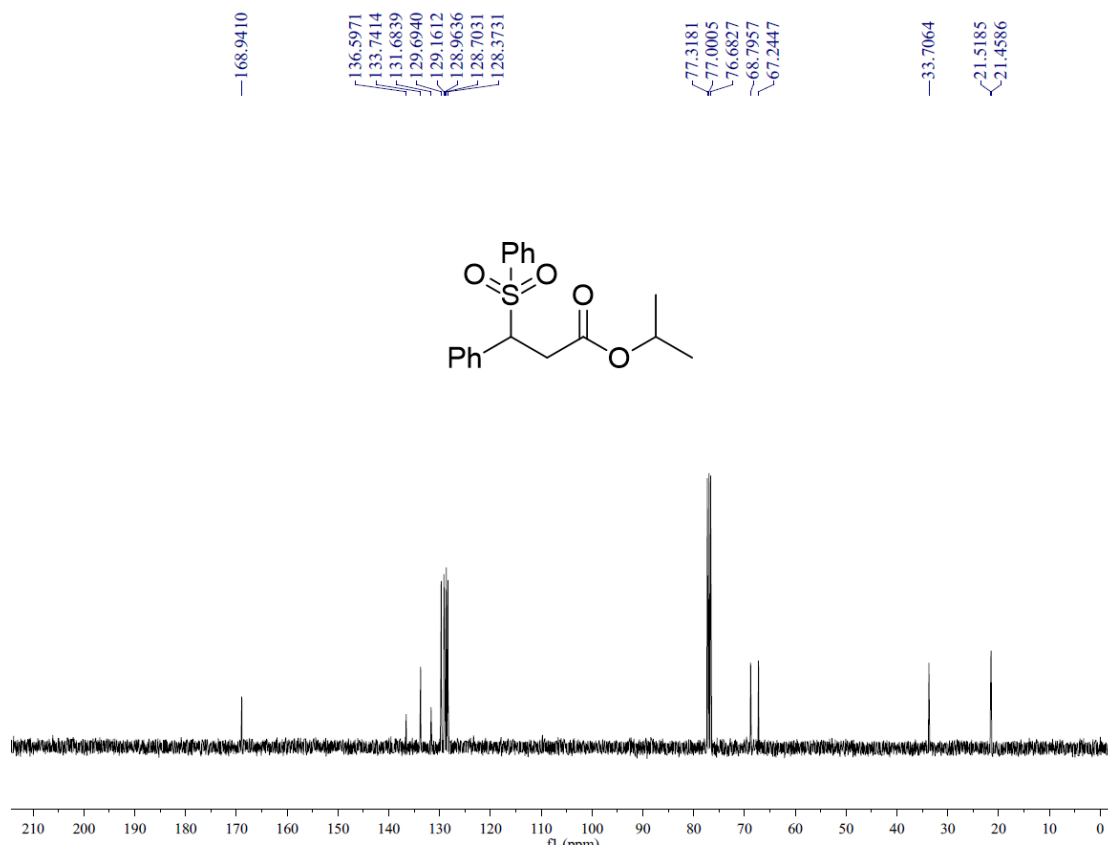
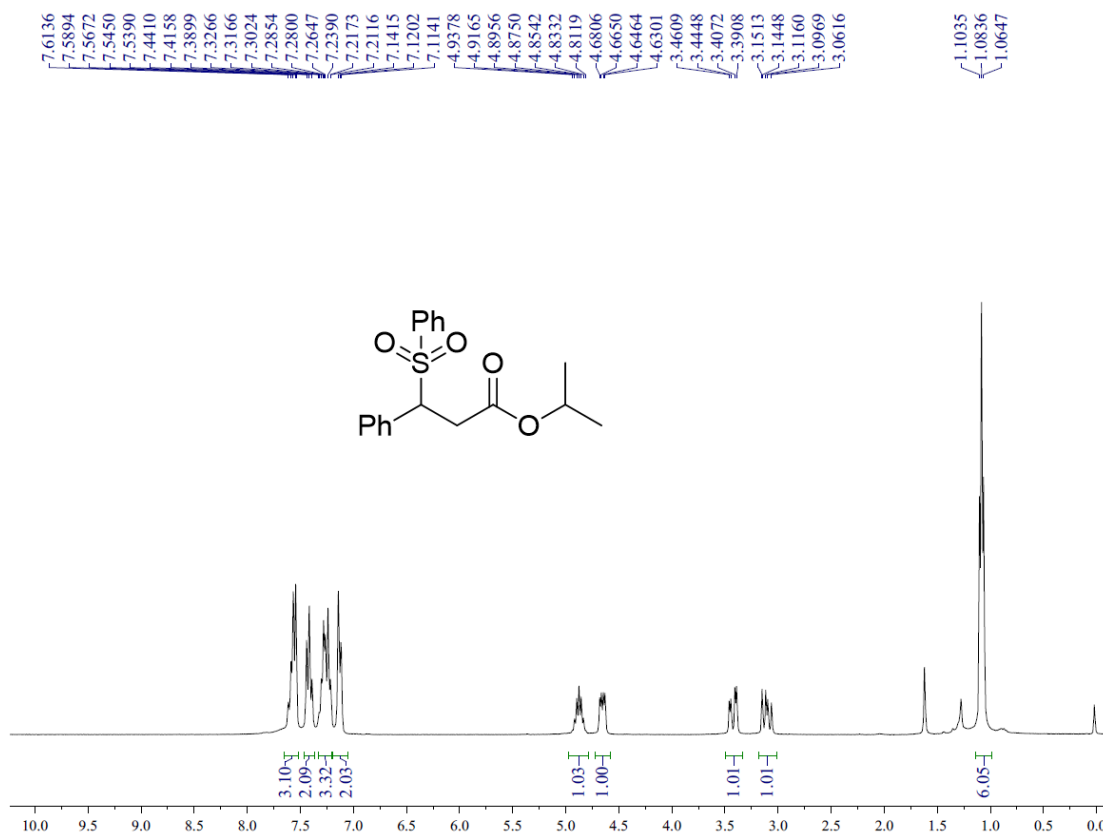
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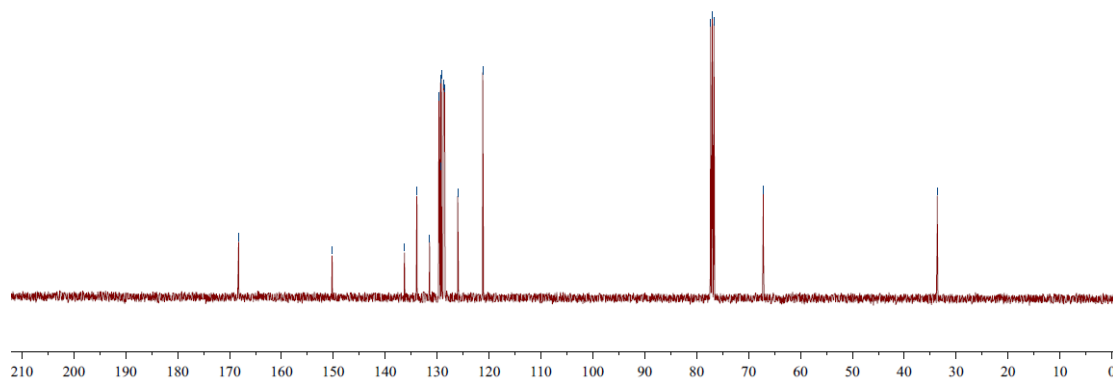
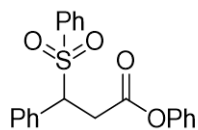
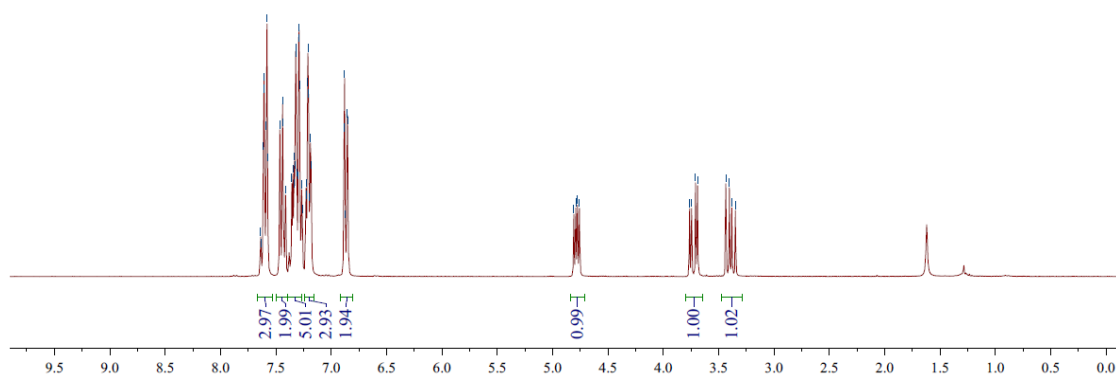
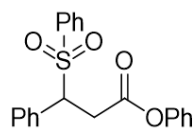
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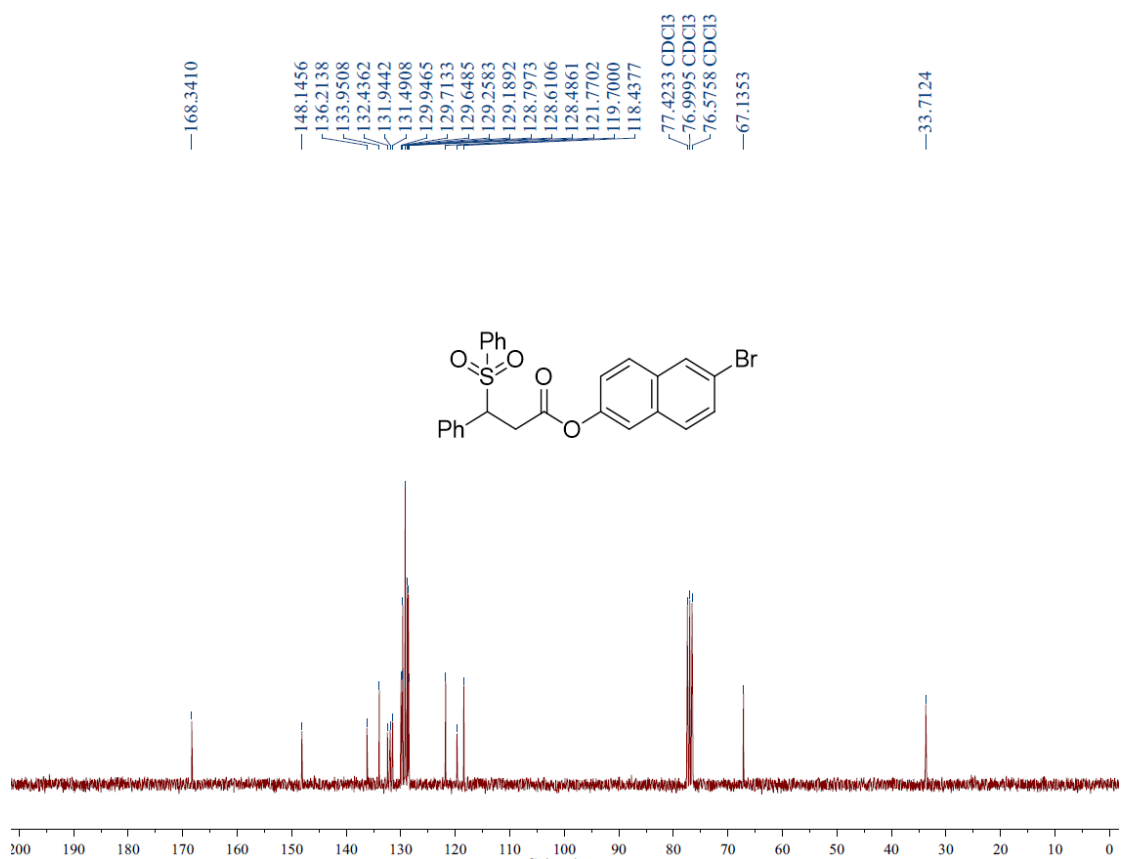
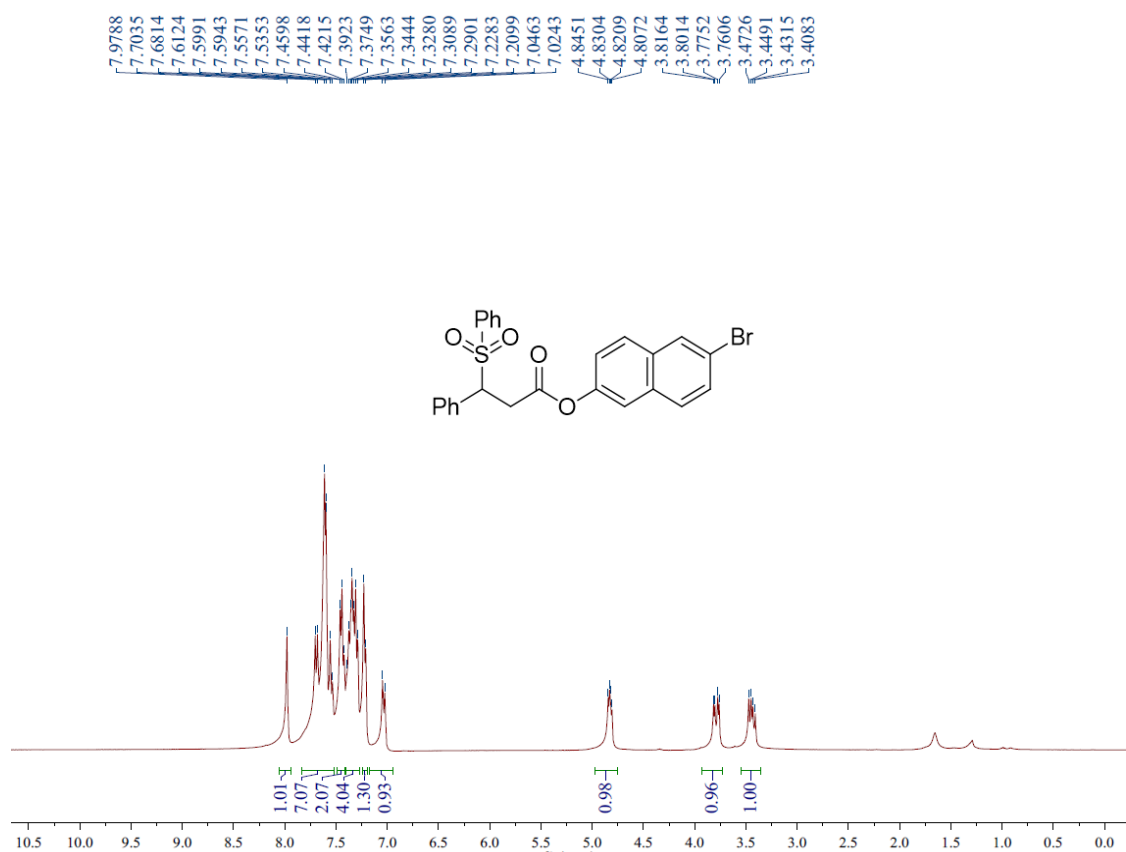
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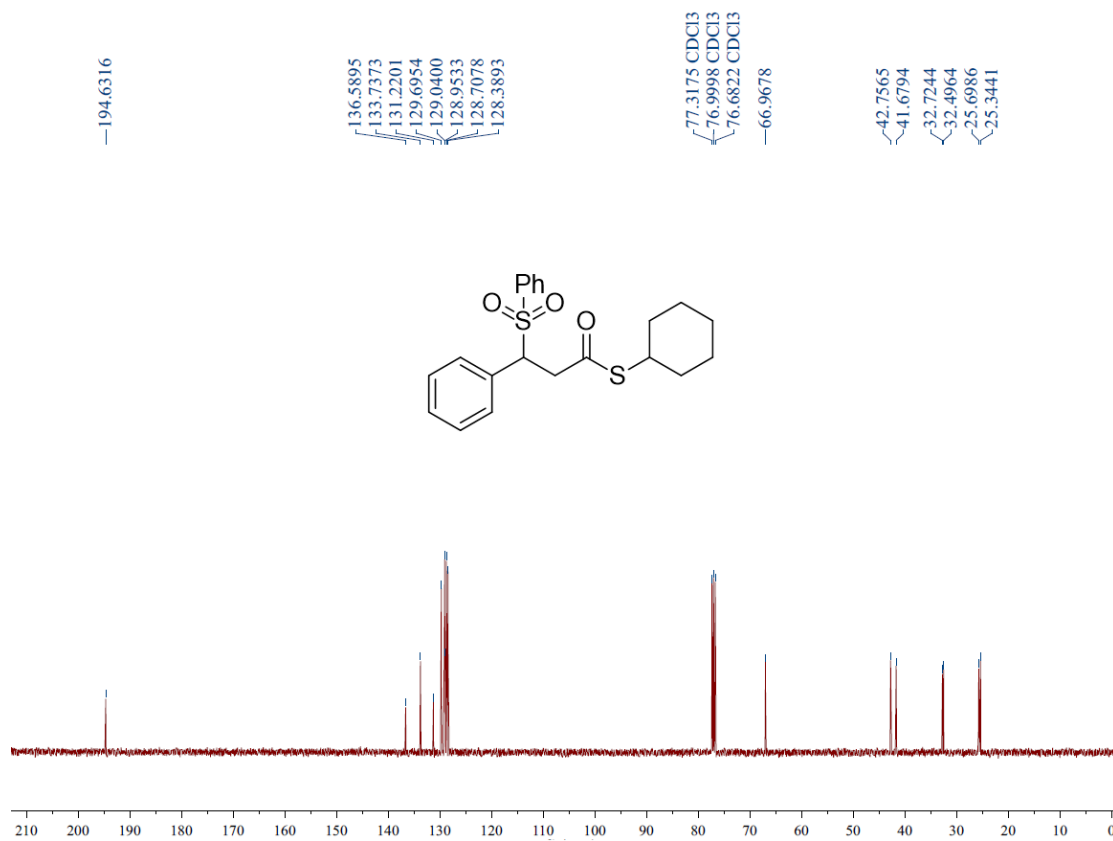
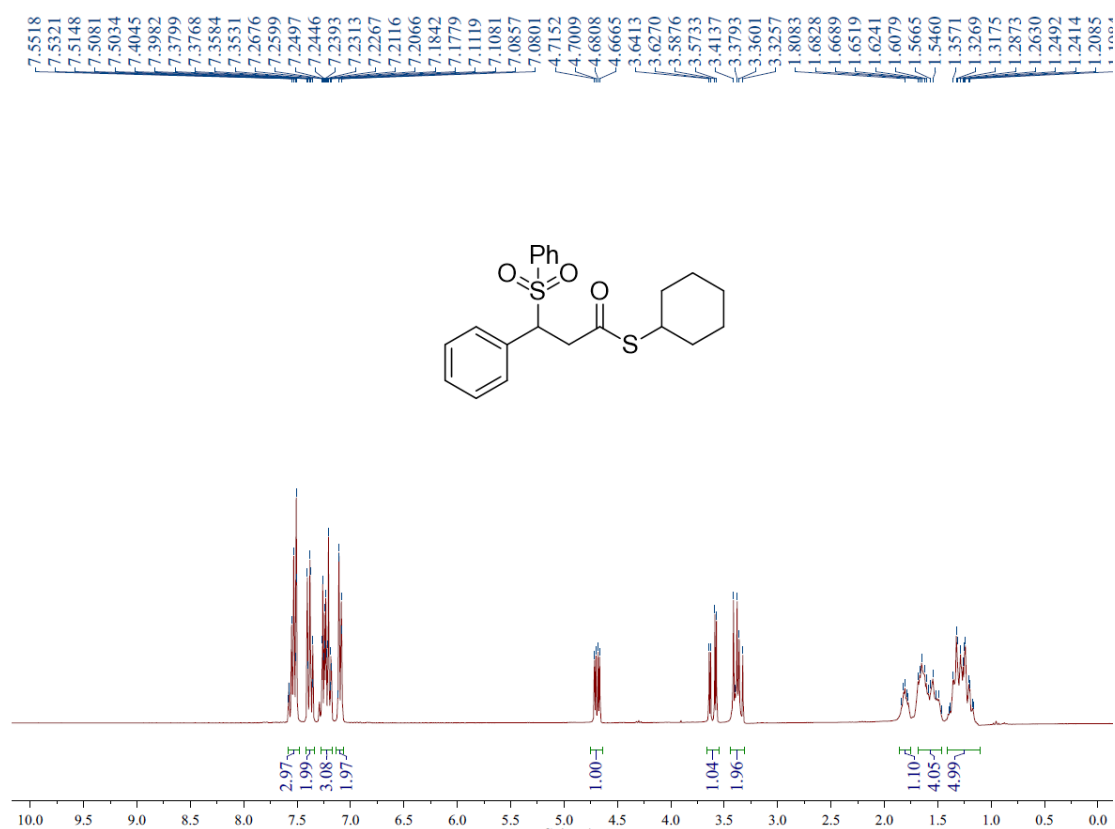
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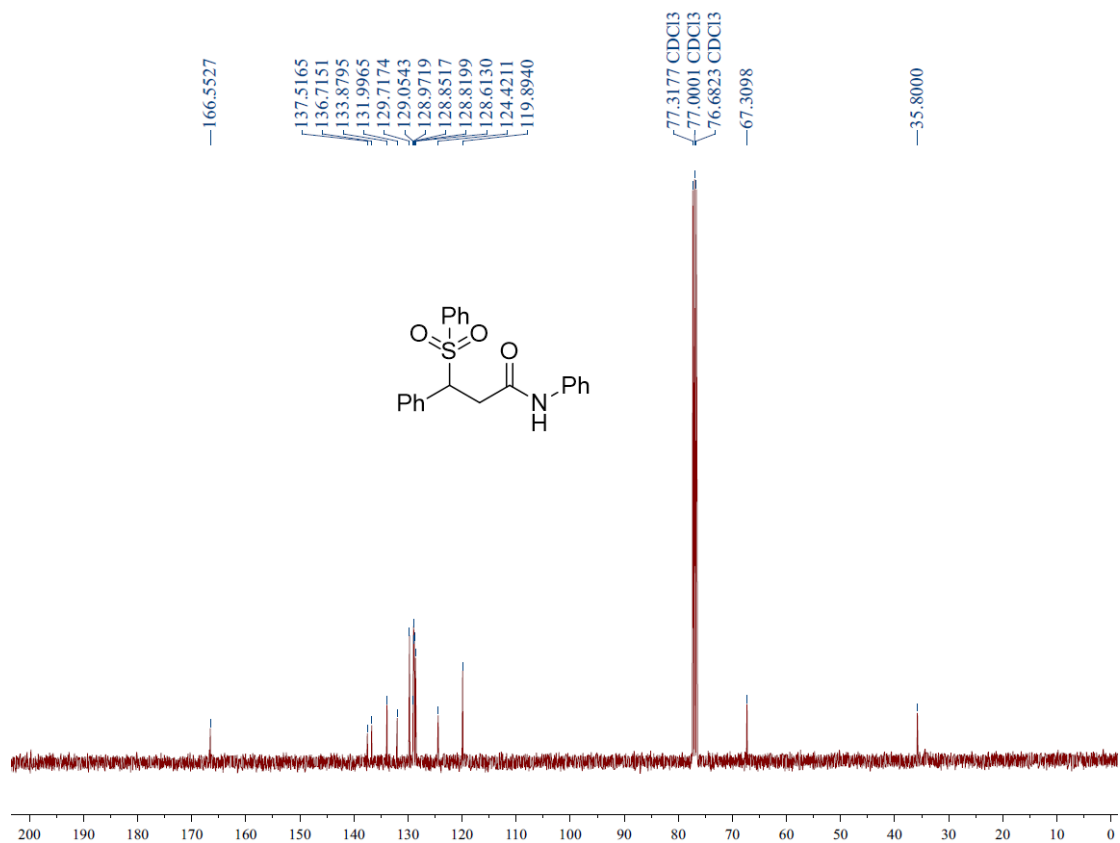
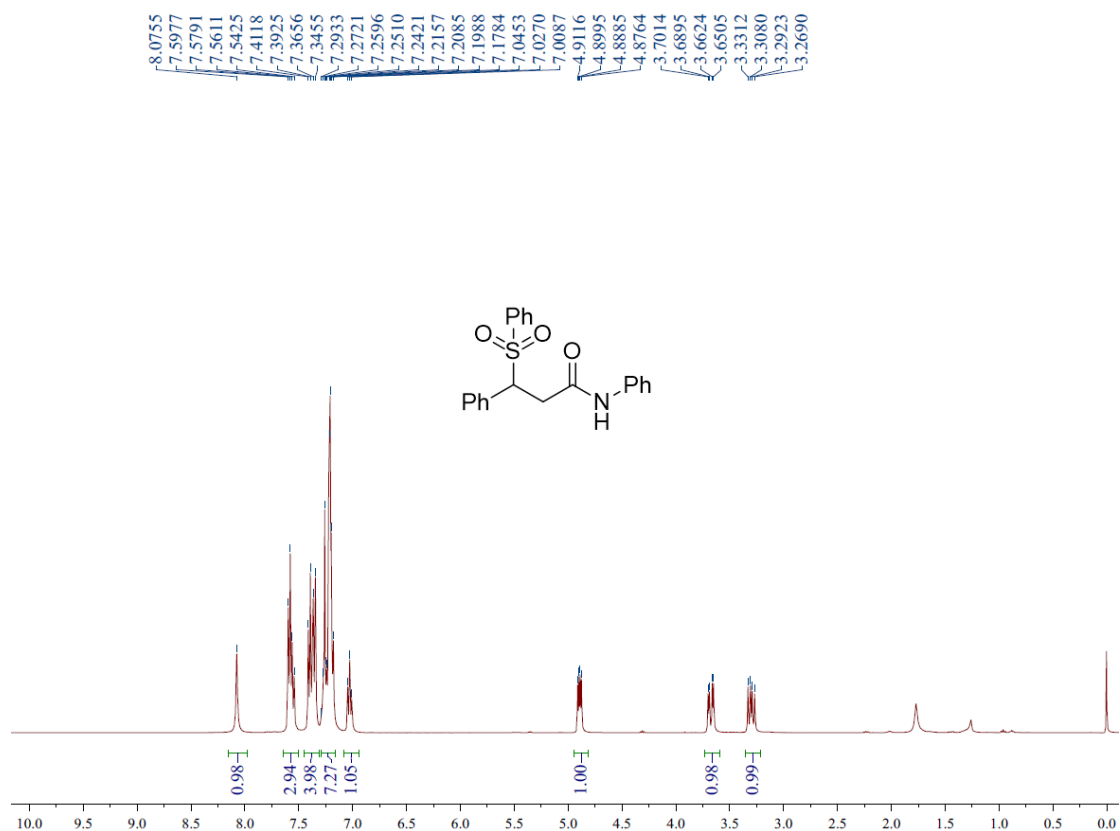
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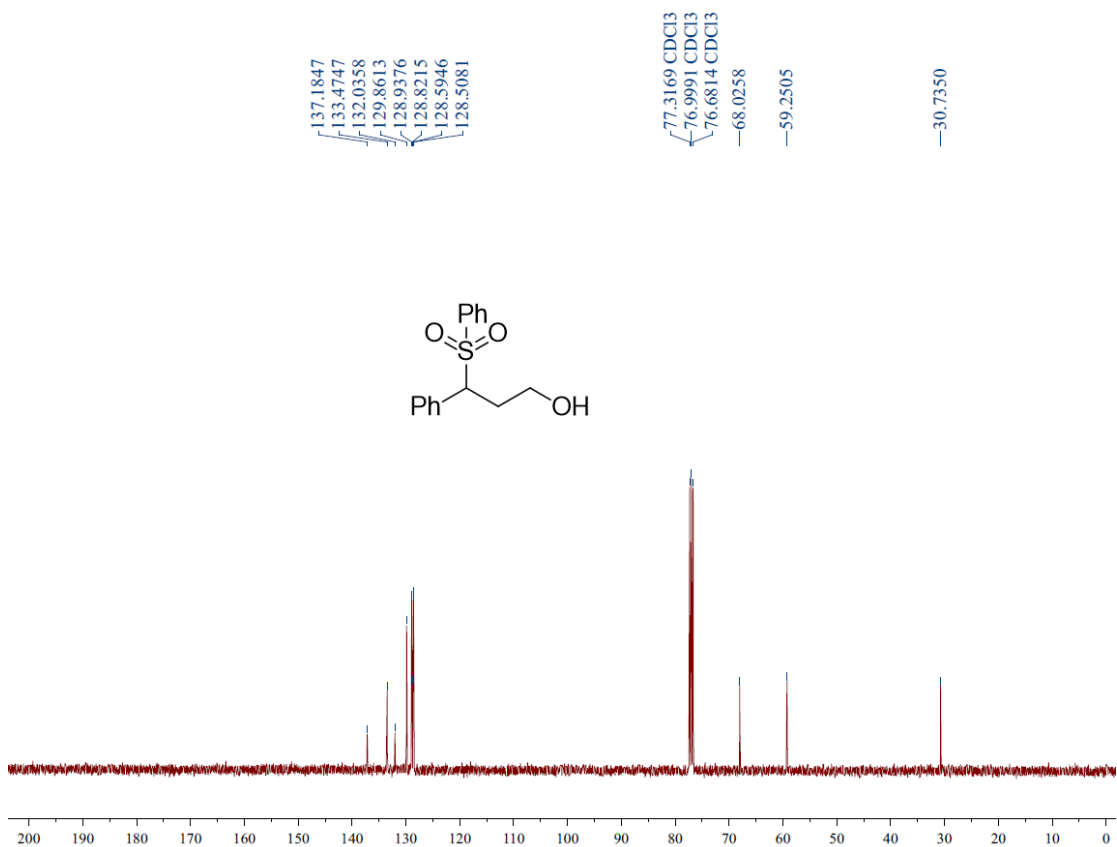
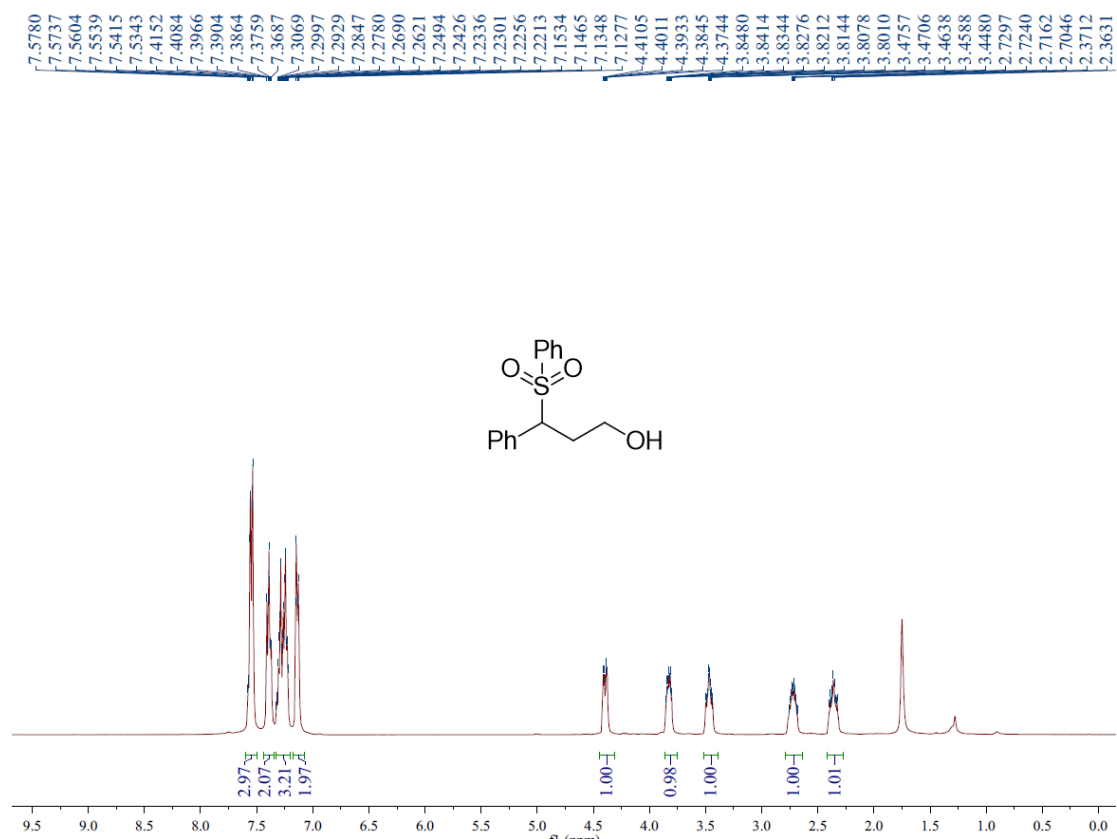


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