

Supporting Information

Copper-Catalyzed Selective 1,2-Disulfidation of 1,3-Dienes

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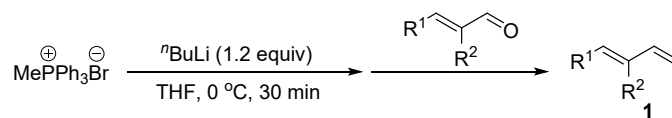
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1. General information

Reactions via general procedure were carried out under an air atmosphere unless otherwise noted. Column chromatography was performed using silica gel (200-300 mesh). ^1H NMR, ^{13}C NMR and ^{31}P NMR spectra were recorded on Bruker-AV (400, 100, 162 MHz, respectively) instrument using CDCl_3 or Dimethyl Sulfoxide- d_6 as solvent, Chemical shifts are given in ppm and coupling constants in 400Hz. Chemical shift values are reported in δ (ppm) relative to CDCl_3 (^1H NMR, $\delta = 7.26$; ^{13}C NMR, $\delta = 77.00$), respectively. In order to indicate the signal multiplicity, the following abbreviations were used: s (singlet), d (doublet), t (triplet), q (quartet) and m (multiplet) as well as combinations of them. Mass spectra were measured on Agilent 5975 GC-MS instrument (EI). High-resolution mass spectra (ESI) were obtained with the Thermo Scientific LTQ Orbitrap XL mass spectrometer. Melting points were measured with a YUHUA X-5 melting point instrument and were uncorrected.

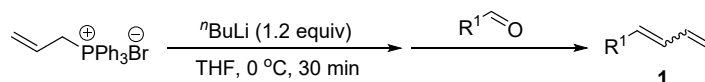
2. General Procedure for the Synthesis of 1,3-dienes (1)¹⁻⁵

Method A :



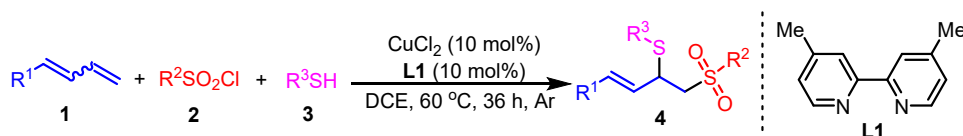
ⁿBuLi (6 mmol, 2.5 M in hexane) was added dropwise to a stirred suspension of MePPh₃Br (6 mmol, 1.2 equiv.) in anhydrous THF (30 mL) at 0 °C under a nitrogen atmosphere. The mixture was stirred for 30 min. Then cinnamaldehydes (5 mmol, 1.0 equiv.) was added, and the reaction was kept stirring for 4-8 h with TLC detection. After the complete consumption of cinnamaldehyde, the mixture was poured into saturated aq. NH₄Cl and extracted with EtOAc (30 mL × 3). The combined organic extracts were dried over anhydrous Na₂SO₄, and then concentrated. The product was purified by column chromatography on silica gel to afford desired 1,3-dienes.

Method B:



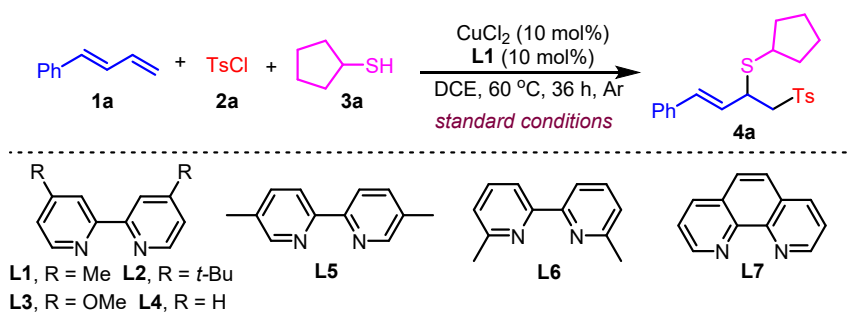
nBuLi (6 mmol, 2.5 M in hexane) was added dropwise to a stirred suspension of allylPPh₃Br (6 mmol, 1.2 equiv.) in anhydrous THF (30 mL) at 0 °C under a nitrogen atmosphere. The mixture was stirred for 30 min. Then the aldehyde (5 mmol, 1.0 equiv.) was added, and the reaction was kept stirring for 4-8 h with TLC detection. After the complete consumption of cinnamaldehyde, the mixture was poured into saturated aq. NH₄Cl and extracted with EtOAc (30 mL × 3). The combined organic extracts were dried over anhydrous Na₂SO₄, and then concentrated. The product was purified by column chromatography on silica gel to afford desired 1,3-dienes.

3. General procedures for the synthesis of 4.



Standard conditions: A 10 mL reaction vessel was charged with 1,3-butadienes **1** (0.2 mmol), sulfonyl chlorides **2** (1.5 equiv, 0.3 mmol), mercaptans or thiophenols **3** (1.5 equiv, 0.3 mmol), CuCl₂ (10 mol %), **L1** (10 mol %) and DCM (2 mL) at 60 °C for 36 h under an argon atmosphere. Until complete consumption of the starting material was observed by TLC and/or GC-MS analysis. The extracts were combined, dried over sodium sulfate, filtered and the volatiles were removed under reduced pressure. The reaction yield was quantified by separation, and then column chromatography was performed using silica gel (200-300 mesh) or thin layer chromatography was performed using silica gel (GF254) to give product **4** (petroleum ether/ethyl acetate, 15 : 1 to 9 : 1). **Gram-scale experiment:** A 100 mL reaction vessel was charged with 1-phenylbutadiene **1a** (0.65 g, 5 mmol), 4-methylbenzenesulfonyl chloride **2a** (1.5 equiv, 7.5 mmol, 1.42 g), cyclopentanethiol **3a** (1.5 equiv, 7.5 mmol, 0.76 g), CuCl₂ (10 mol %, 67.2 mg), **L1** (10 mol %, 93.1 mg) and DCM (50 mL) at 60 °C for 60 h under an argon atmosphere gave the target product **4a** in 50% (0.97 g) yield.

4. Optimization of the reaction conditions for the synthesis of 4a^a



Entry	Catalyst	Ligand	Solvent	T/°C	Yield (%) ^b
1	CuCl	L1	DCM	60 °C	62
2	CuO	L1	DCM	60 °C	32

3	CuCN	L1	DCM	60 °C	trace
4	CuBr	L1	DCM	60 °C	17
5	Cu(CH ₃ CN) ₄ PF ₆	L1	DCM	60 °C	27
	6				
6	CuCl₂	L1	DCM	60 °C	68
7	Cu(OTf) ₂	L1	DCM	60 °C	35
8	Cu(OAc) ₂ ·H ₂ O	L1	DCM	60 °C	40
9	Cu ₂ O	L1	DCM	60 °C	18
10	CuCl ₂	L2	DCM	60 °C	59
11	CuCl ₂	L3	DCM	60 °C	trace
12	CuCl ₂	L4	DCM	60 °C	trace
13	CuCl ₂	L5	DCM	60 °C	27
14	CuCl ₂	L6	DCM	60 °C	48
15	CuCl ₂	L7	DCM	60 °C	10
16	CuCl ₂	L1	DCE	60 °C	60
17	CuCl ₂	L1	CHCl ₃	60 °C	52
18	CuCl ₂	L1	THF	60 °C	trace
19	CuCl ₂	L1	toluene	60 °C	ND
20	CuCl ₂	L1	DMF	60 °C	ND
21	CuCl ₂	L1	NMP	60 °C	21
22	CuCl ₂	L1	1,4-dioxane	60 °C	trace
23	CuCl ₂	L1	EA	60 °C	ND
24	CuCl ₂	L1	acetone	60 °C	12
25	CuCl ₂	L1	CH ₃ CN	60 °C	ND
26 ^c	CuCl ₂	L1	DCM	60 °C	38
27 ^d	CuCl ₂	L1	DCM	60 °C	trace
28	CuCl ₂	L1	DCM	40 °C	35
29	CuCl ₂	L1	DCM	80 °C	52
30	---	L1	DCM	60 °C	ND
31	CuCl ₂	---	DCM	60 °C	ND
32 ^e	CuCl ₂	L1	DCM	60 °C	47
33 ^f	CuCl ₂	L1	DCM	60 °C	18

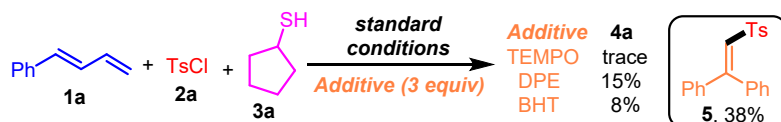
^a Reaction conditions: **1a** (0.2 mmol), **2a** (1.5 equiv), **3a** (1.5 equiv), CuCl₂ (10 mol%), **L1** (10 mol %), DCM (2 mL) at 60 °C (oil bath) for 48 h under an argon atmosphere. ^b Isolated yield, ND (not detected) and trace were determined by TLC analysis. ^c 2.0 equiv K₂CO₃. ^d 2.0 equiv Et₃N. ^e 24 h. ^f at air.

5. Mechanistic Investigations

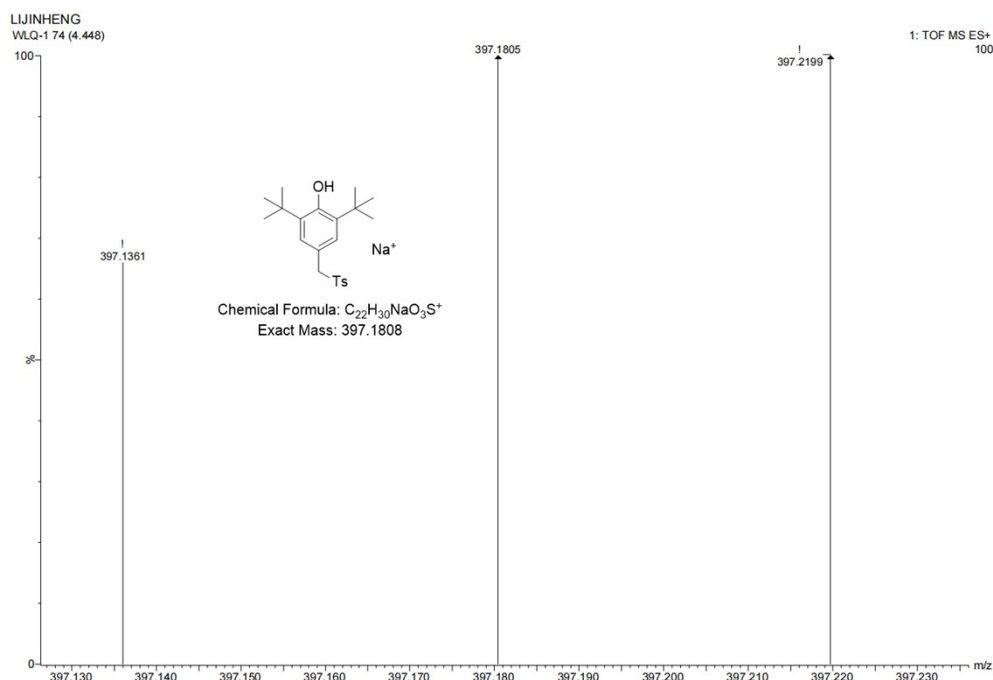
5.1 Free radical capture experiments

The following reaction was carried out under standard condition: A 10 mL

reaction vessel was charged with 1-phenylbutadiene **1a** (0.2 mmol), 4-methylbenzenesulfonyl chloride **2a** (1.5 equiv, 0.3 mmol), cyclopentanethiol **3a** (1.5 equiv, 0.3 mmol), CuCl₂ (10 mol %), **L1** (10 mol %), 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) (3.0 equiv) or 1,1-Diphenylethylene (3.0 equiv) or 2,6-di-*tert*-butyl-4-methylphenol (BHT) and DCE (2 mL) at 60 °C for 24 h under an argon atmosphere. After completion, the consequence was detected by TLC and/or GC-MS analysis.

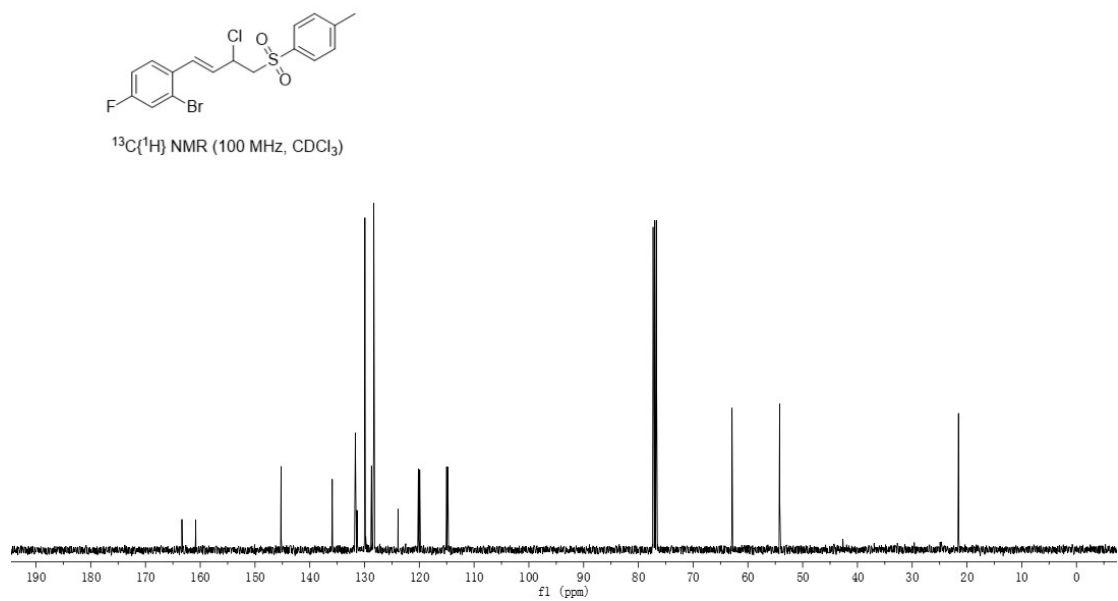
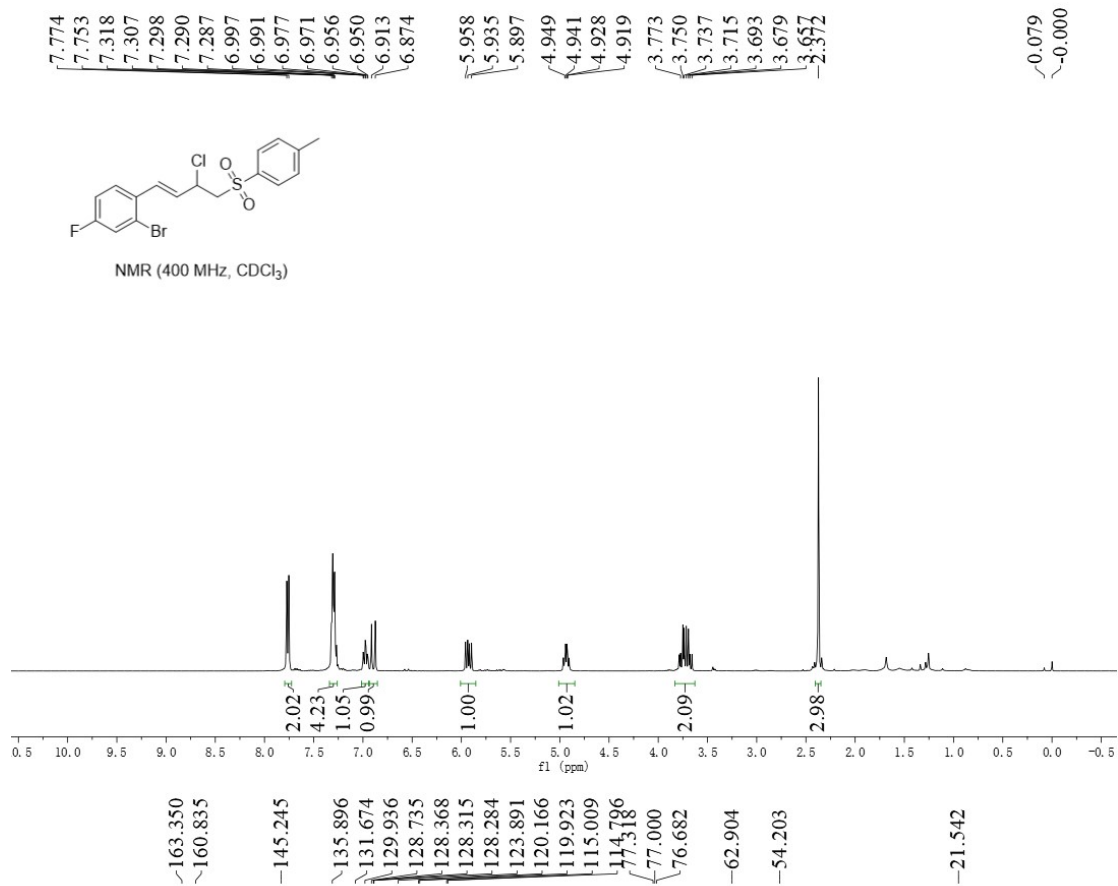
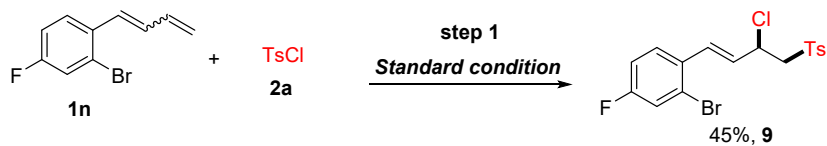


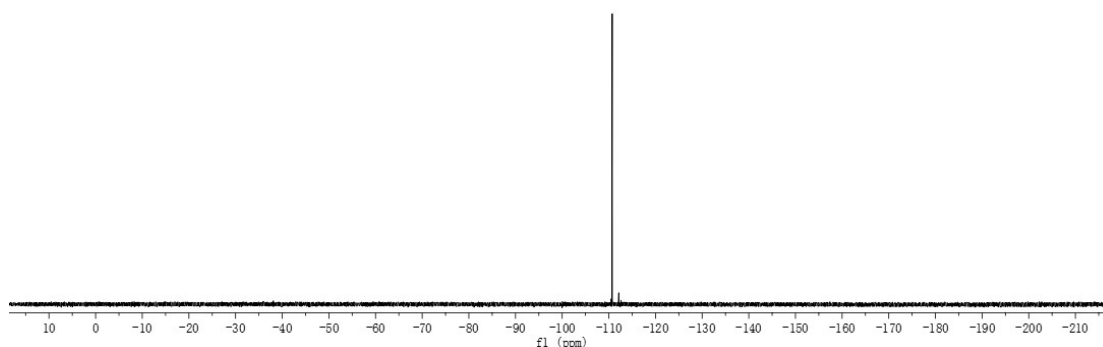
HRMS detection of BHT-trapped sulfonyl radical:



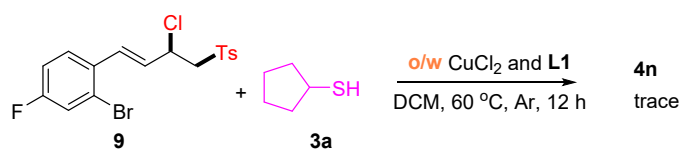
5.2 Step-by-step reaction

Setp 1: a 10 mL reaction vessel was charged with 2-bromo-1-(buta-1,3-dien-1-yl)-4-fluorobenzene **1n** (0.2 mmol), 4-methylbenzenesulfonyl chloride **2a** (1.5 equiv, 0.3 mmol), CuCl₂ (10 mol %, 0.002 mmol), **L1** (10 mol %, 0.002 mmol) and DCM (2 mL) at 60 °C for 24 h under an argon atmosphere. After completion, column chromatography was performed using silica gel (200-300 mesh) to give intermediate product **9** in 45% yield (petroleum ether/ethyl acetate, 12 :1) and NMR was performed.





Setp 2: Subsequently, the above obtained intermediate product **9** (0.2 mmol), cyclopentyl mercaptan **3a** (1.5 equiv, 0.3 mmol) in DCM (2 mL) at 60 °C with stirring for a further 12 h, only trace amounts of product **4n** is produced. Then, CuCl₂ (10 mol%) and **L1** (10 mol%) were added to react with argon atmosphere at 60 °C for 12 h. Likewise, only trace amounts of product **4n** is produced.

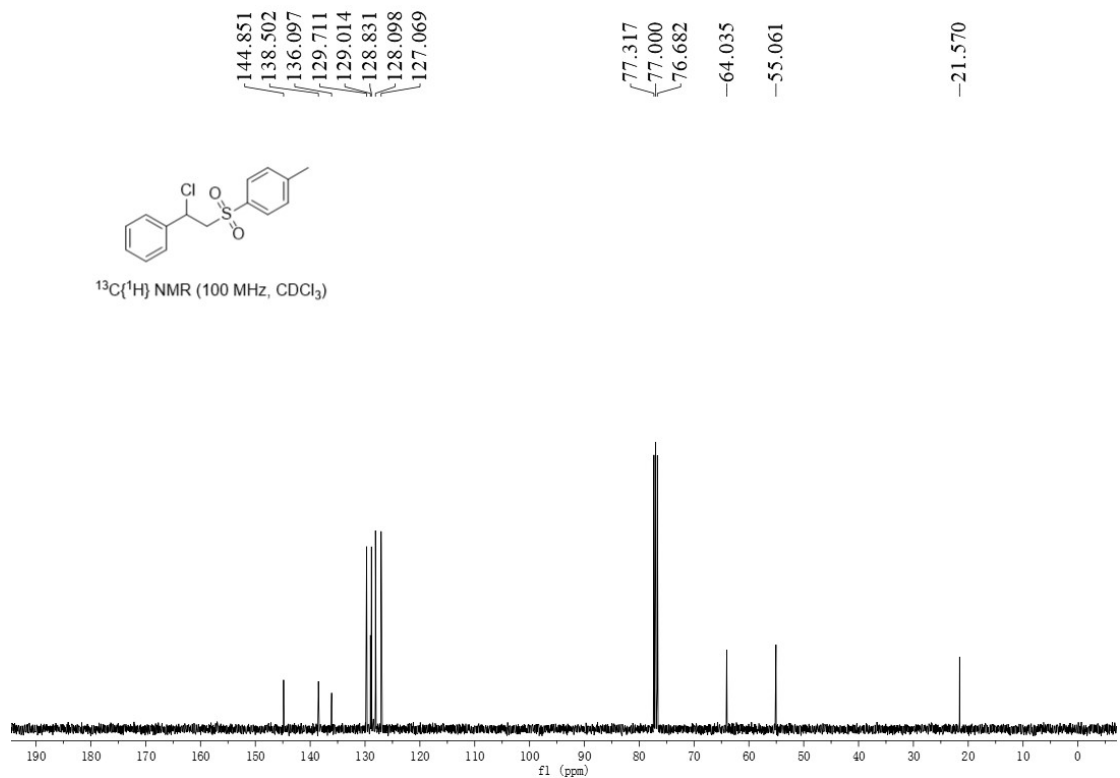
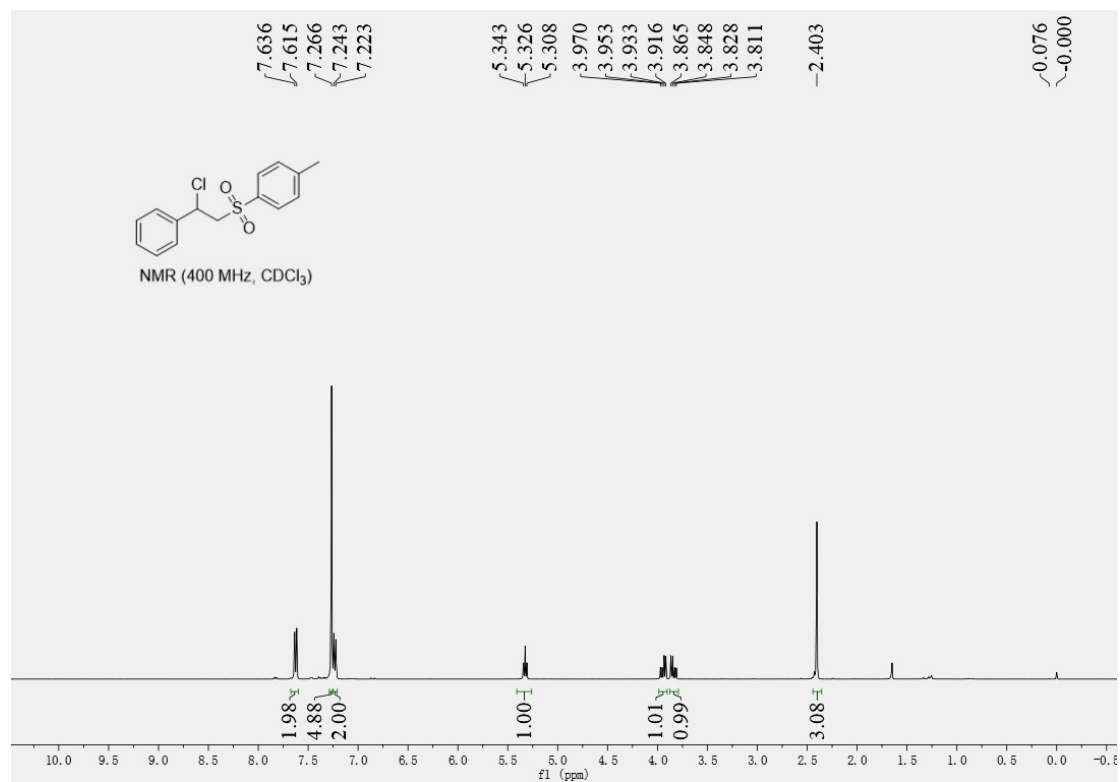
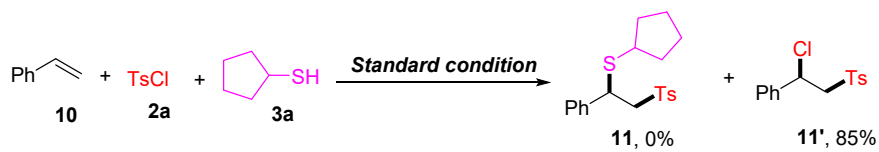


5.3 Other olefinic substrates

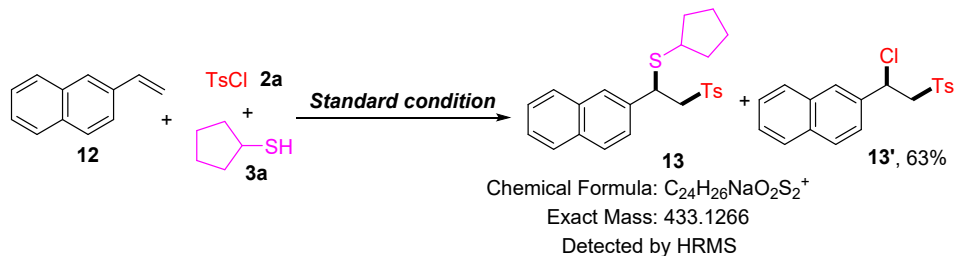
The following reaction was carried out under standard condition: A 10 mL reaction vessel was charged with alkenes (0.2 mmol), 4-methylbenzenesulfonyl chloride **2a** (1.5 equiv, 0.3 mmol), cyclopentanethiol **3a** (1.5 equiv, 0.3 mmol), CuCl₂ (10 mol %), **L1** (10 mol %), and DCM (2 mL) at 60 °C for 36 h under an argon atmosphere. After completion, the consequence was detected by TLC and/or GC-MS analysis. Then, separated by column chromatography was performed using silica gel (200-300 mesh).

Reaction with styrene **10** : column chromatography was performed using silica gel (200-300 mesh) to give 1,2-sulfone chlorinated products **11'** in 88% yield

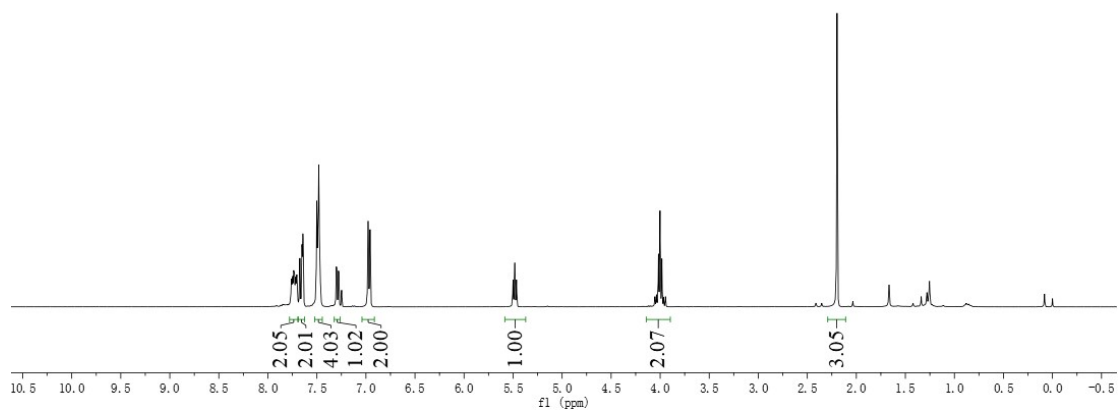
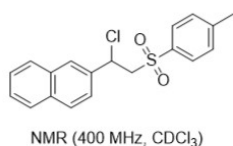
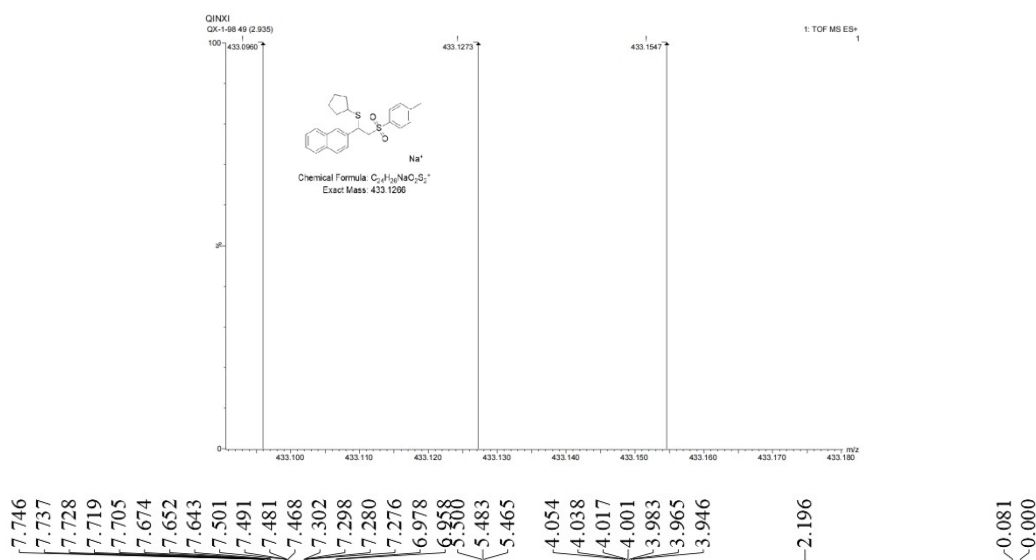
(petroleum ether/ethyl acetate, 15 :1) and NMR was performed.

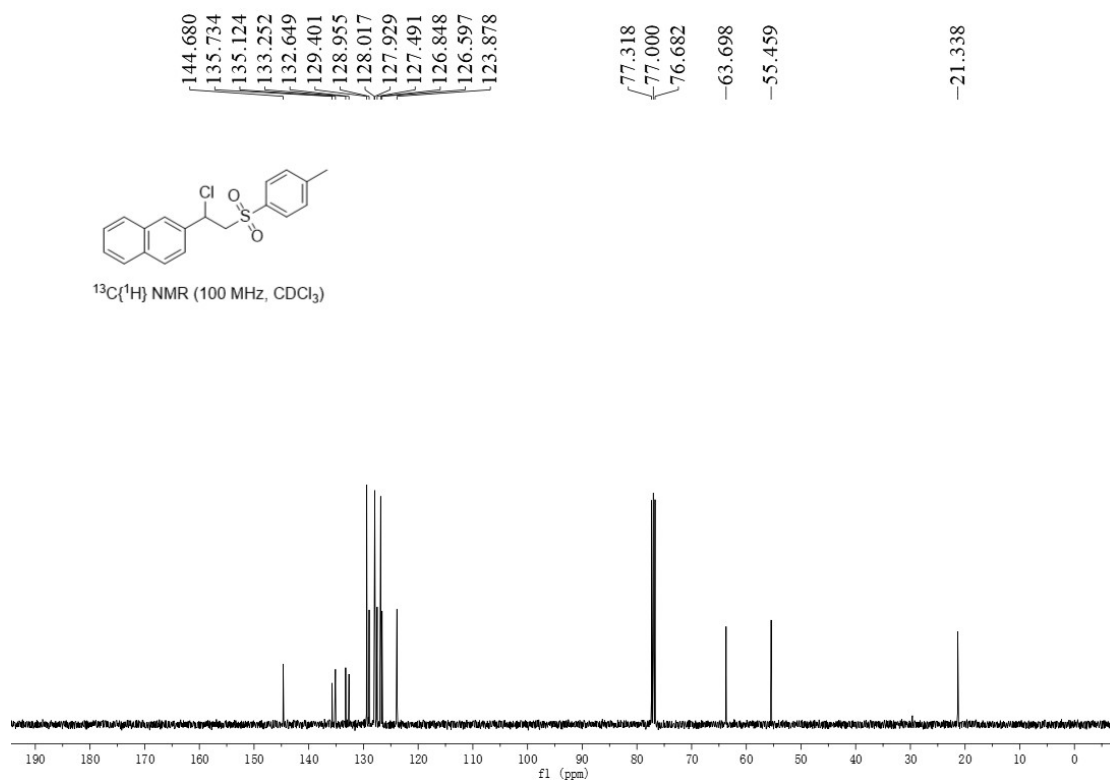


Reaction with 2-vinylnaphthalene **12** : column chromatography was performed using silica gel (200-300 mesh) to give 1,2-sulfone chlorinated products **13'** 63% yield, separately (petroleum ether/ethyl acetate, 12 :1) and NMR was performed.

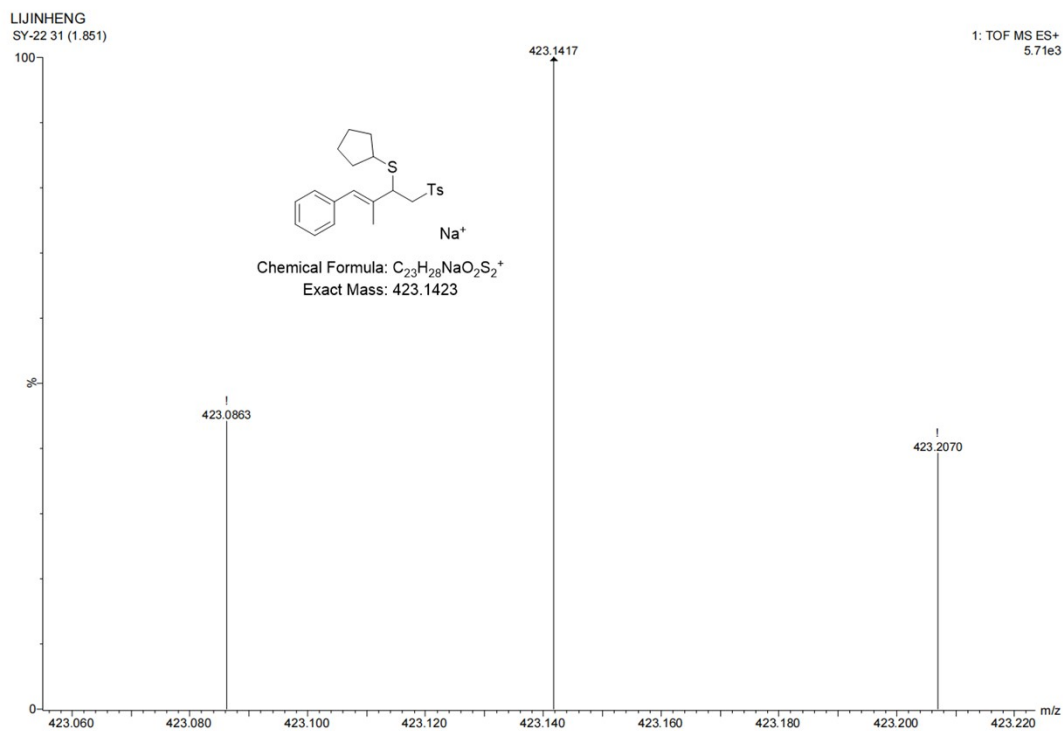
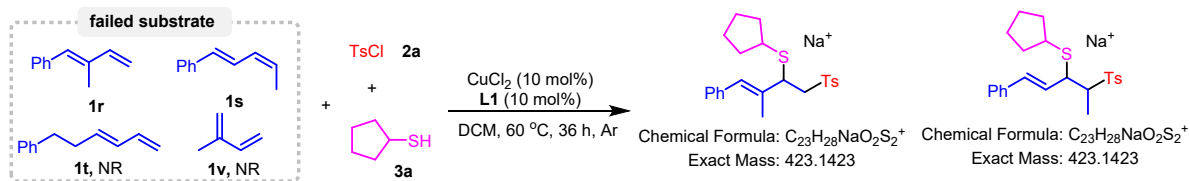


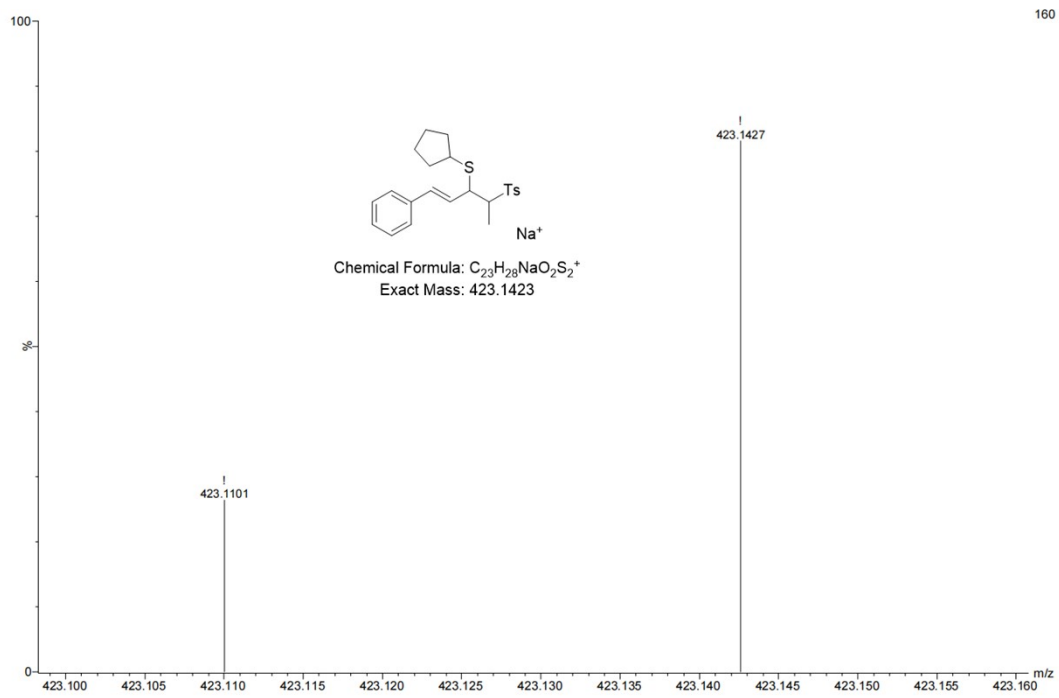
HRMS of product 13:



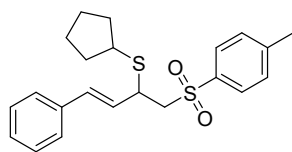


5.4 Failed substrates

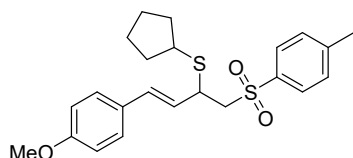




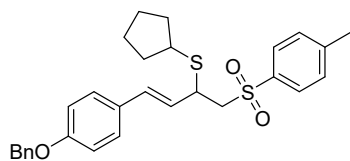
6. Characterization data of products



(*E*)-cyclopentyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4a**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 52.5 mg, 68% yield, Yellow solid (mp 55-57 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.71 (d, *J* = 8.1 Hz, 2H), 7.30 – 7.21 (m, 3H), 7.17 (dd, *J* = 7.1, 5.0 Hz, 4H), 6.28 (d, *J* = 15.7 Hz, 1H), 5.64 (dd, *J* = 15.7, 9.6 Hz, 1H), 3.90 (td, *J* = 8.9, 5.8 Hz, 1H), 3.52 – 3.35 (m, 2H), 3.03-2.96 (m, 1H), 2.27 (s, 3H), 1.98-1.86 (m, 2H), 1.76 – 1.67 (m, 2H), 1.60 – 1.48 (m, 3H), 1.45-1.38 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.7, 136.4, 135.9, 131.8, 129.7, 128.4, 128.3, 127.7, 127.2, 126.4, 60.2, 42.6, 42.2, 34.1, 32.9, 24.9, 24.7, 21.4; HRMS (ESI-TOF) *m/z*: C₂₂H₂₆NaO₂S₂⁺ (M + Na)⁺ calcd for 409.1266, found 409.1275.

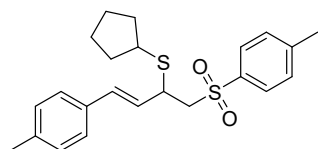


(*E*)-cyclopentyl(4-(4-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (**4b**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 35.8 mg, 43% yield, Yellow solid (mp 81-83 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.70 (d, *J* = 8.2 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.10 (d, *J* = 8.6 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 6.24 (d, *J* = 15.6 Hz, 1H), 5.48 (dd, *J* = 15.6, 9.5 Hz, 1H), 3.89 (td, *J* = 9.2, 5.3 Hz, 1H), 3.81 (s, 3H), 3.51 – 3.37 (m, 2H), 3.03-2.96 (m, 1H), 2.31 (s, 3H), 2.00 – 1.84 (m, 2H), 1.76 – 1.65 (m, 2H), 1.59 – 1.48 (m, 3H), 1.45-1.37 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 159.3, 144.6, 136.6, 131.4, 129.7, 128.8, 128.4, 127.7, 125.0, 113.8, 60.3, 55.3, 42.7, 42.4, 34.2, 33.0, 25.0, 24.7, 21.5; HRMS (ESI-TOF) *m/z*: C₂₃H₂₈NaO₃S₂⁺ (M + Na)⁺ calcd for 439.1372, found 439.1385.

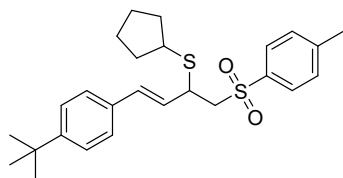


(*E*)-(4-(4-(benzyloxy)phenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4c**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 44.3 mg, 45% yield:

Yellow solid (mp 93-95 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.70 (d, $J = 7.8$ Hz, 2H), 7.46 – 7.37 (m, 4H), 7.33 (d, $J = 7.1$ Hz, 1H), 7.17 (d, $J = 7.9$ Hz, 2H), 7.09 (d, $J = 8.2$ Hz, 2H), 6.88 (d, $J = 8.3$ Hz, 2H), 6.23 (d, $J = 15.6$ Hz, 1H), 5.48 (dd, $J = 15.6, 9.6$ Hz, 1H), 5.07 (s, 2H), 3.94 – 3.82 (m, 1H), 3.51 – 3.35 (m, 2H), 3.02-2.95 (m, 1H), 2.27 (s, 3H), 2.02 – 1.82 (m, 2H), 1.77 – 1.64 (m, 2H), 1.58 – 1.47 (m, 3H), 1.45 – 1.37 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 158.5, 144.6, 136.8, 136.6, 131.4, 129.7, 129.0, 128.6, 128.4, 128.0, 127.7, 127.4, 125.2, 114.8, 70.0, 60.3, 42.6, 42.4, 34.2, 33.0, 24.9, 24.7, 21.5; HRMS (ESI-TOF) m/z : $\text{C}_{29}\text{H}_{32}\text{NaO}_3\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 515.1685, found 515.1693.

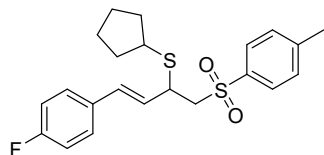


(*E*)-cyclopentyl(4-(*p*-tolyl)-1-tosylbut-3-en-2-yl)sulfane (**4d**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 46.4 mg, 58% yield, Yellow oil (mp 75-77 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.70 (d, $J = 8.2$ Hz, 2H), 7.18 (d, $J = 8.0$ Hz, 2H), 7.11 – 7.02 (m, 4H), 6.25 (d, $J = 15.6$ Hz, 1H), 5.58 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.89 (td, $J = 9.0, 5.5$ Hz, 1H), 3.51 – 3.32 (m, 2H), 3.02-2.95 (m, 1H), 2.33 (s, 3H), 2.29 (s, 3H), 1.97-1.85 (m, 2H), 1.76 – 1.65 (m, 2H), 1.59 – 1.46 (m, 3H), 1.43-1.37 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.6, 137.6, 136.5, 133.2, 131.8, 129.7, 129.1, 128.3, 126.3, 126.2, 60.3, 42.6, 42.3, 34.2, 33.0, 24.9, 24.7, 21.4, 21.2; HRMS (ESI-TOF) m/z : $\text{C}_{23}\text{H}_{28}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 423.1423, found 423.1433.

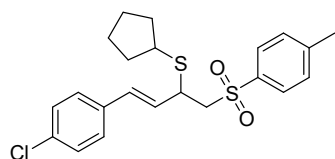


(*E*)-(4-(4-(*tert*-butyl)phenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4e**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 63.7 mg, 72% yield: Yellow solid (mp 51-53 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.70 (d, $J = 8.2$ Hz, 2H), 7.30 (d, $J = 8.3$ Hz, 2H), 7.16 (d, $J = 8.0$ Hz, 2H), 7.11 (d, $J = 8.3$ Hz, 2H), 6.24 (d, $J = 15.6$ Hz, 1H), 5.57 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.88 (td, $J = 8.9, 5.7$ Hz, 1H), 3.47-

3.42 (m, 2H), 3.01-2.95 (m, 1H), 2.25 (s, 3H), 2.00 – 1.82 (m, 2H), 1.75 – 1.65 (m, 2H), 1.59 – 1.46 (m, 3H), 1.45 – 1.37 (m, 1H), 1.31 (s, 9H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 150.9, 144.6, 136.4, 133.2, 131.6, 129.7, 128.3, 126.4, 126.1, 125.3, 60.2, 42.6, 42.3, 34.5, 34.2, 32.9, 31.2, 24.9, 24.7, 21.4; HRMS (ESI-TOF) m/z : $\text{C}_{26}\text{H}_{34}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 465.1892, found 465.1901.

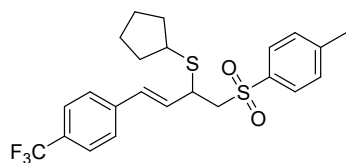


(*E*)-cyclopentyl(4-(4-fluorophenyl)-1-tosylbut-3-en-2-yl)sulfane (**4f**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 60.6 mg, 75% yield, Yellow solid (mp 94-96 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.71 (d, J = 8.2 Hz, 2H), 7.20 (d, J = 8.0 Hz, 2H), 7.15 (dd, J = 8.6, 5.5 Hz, 2H), 6.96 (t, J = 8.6 Hz, 2H), 6.27 (d, J = 15.7 Hz, 1H), 5.59 (dd, J = 15.7, 9.5 Hz, 1H), 3.90 (td, J = 9.1, 5.4 Hz, 1H), 3.52 – 3.35 (m, 2H), 3.02-2.95 (m, 1H), 2.30 (s, 3H), 2.01 – 1.84 (m, 2H), 1.72 – 1.62 (m, 2H), 1.60 – 1.48 (m, 3H), 1.47 – 1.37 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 162.3 (d, J = 245.9 Hz, 1C), 144.7, 136.5, 132.1 (d, J = 3.3 Hz, 1C), 130.5, 129.7, 128.2, 127.9 (d, J = 8 Hz, 1C), 127.1, 115.3 (d, J = 21.4 Hz, 1C), 60.1, 42.7, 42.1, 34.1, 33.0, 24.9, 24.7, 21.4; ^{19}F NMR (376 MHz, CDCl_3) δ -113.8 (s, 1F); HRMS (ESI-TOF) m/z : $\text{C}_{22}\text{H}_{25}\text{FNaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 427.1172, found 427.1185.

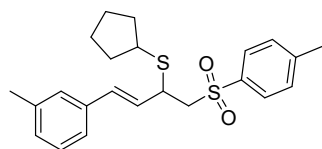


(*E*)-(4-(4-chlorophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4g**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 59.7 mg, 71% yield, Yellow solid (mp 79-81 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.71 (d, J = 8.1 Hz, 2H), 7.28 – 7.17 (m, 4H), 7.11 (d, J = 8.4 Hz, 2H), 6.26 (d, J = 15.7 Hz, 1H), 5.66 (dd, J = 15.6, 9.5 Hz, 1H), 3.90 (td, J = 9.3, 4.9 Hz, 1H), 3.53 – 3.34 (m, 2H), 3.05 – 2.92 (m, 1H), 2.31 (s, 3H), 2.02 – 1.84 (m, 2H), 1.74-1.65 (m, 2H), 1.59 – 1.48 (m, 3H), 1.47 – 1.38 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.8, 136.5, 134.5, 133.4, 130.5, 129.7, 128.6, 128.3, 128.1, 127.6, 60.1, 42.8, 42.1, 34.2, 33.0, 24.9, 24.7, 21.5;

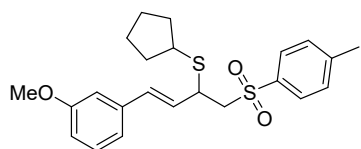
HRMS (ESI-TOF) m/z : $C_{22}H_{25}ClNaO_2S_2^+$ ($M + Na$) $^+$ calcd for 443.0877, found 443.0883.



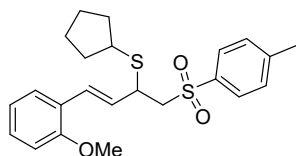
(*E*)-3-(3-(cyclopentylthio)-4-tosylbut-1-en-1-yl)thiophene (**4h**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 55.4 mg, 61% yield, Yellow solid (mp 105-107 °C), 1H NMR (400 MHz, $CDCl_3$) δ : 7.71 (d, $J = 8.1$ Hz, 2H), 7.53 (d, $J = 8.1$ Hz, 2H), 7.33 – 7.25 (m, 2H), 7.20 (d, $J = 8.0$ Hz, 2H), 6.34 (d, $J = 15.7$ Hz, 1H), 5.81 (dd, $J = 15.7, 9.5$ Hz, 1H), 4.01 – 3.85 (m, 1H), 3.54 – 3.35 (m, 2H), 3.06 – 2.92 (m, 1H), 2.29 (s, 3H), 2.03 – 1.84 (m, 2H), 1.79 – 1.65 (m, 2H), 1.60 – 1.48 (m, 3H), 1.48 – 1.39 (m, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ : 144.9, 139.5, 136.5, 130.2 (q, $J = 12.1$ Hz, 1C), 129.8, 129.5 (q, $J = 32.2$ Hz, 1C), 129.1, 128.3, 126.6, 125.4 (q, $J = 3.8$ Hz, 1C), 124.0 (q, $J = 273.3$ Hz, 1C), 60.0, 42.8, 42.0, 34.2, 33.1, 24.9, 24.7, 21.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.6 (s, 3F); HRMS (ESI-TOF) m/z : $C_{23}H_{25}F_3NaO_2S_2^+$ ($M + Na$) $^+$ calcd for 477.1140, found 477.1151.



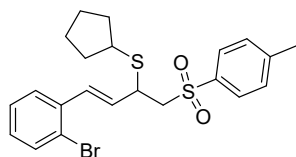
(*E*)-cyclopentyl(4-(*m*-tolyl)-1-tosylbut-3-en-2-yl)sulfane (**4i**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 44.0 mg, 55% yield, Yellow oil, 1H NMR (400 MHz, $CDCl_3$) δ : 7.71 (d, $J = 8.2$ Hz, 2H), 7.17 (dd, $J = 15.0, 7.7$ Hz, 3H), 7.04 (d, $J = 7.5$ Hz, 1H), 6.97 (d, $J = 11.4$ Hz, 2H), 6.25 (d, $J = 15.7$ Hz, 1H), 5.62 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.89 (td, $J = 9.1, 5.4$ Hz, 1H), 3.50 – 3.36 (m, 2H), 3.05 – 2.92 (m, 1H), 2.32 (s, 3H), 2.30 (s, 3H), 1.98-1.85 (m, 2H), 1.74-1.65 (m, 2H), 1.59 – 1.46 (m, 3H), 1.46 – 1.37 (m, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ : 144.7, 137.9, 136.5, 135.9, 132.0, 129.7, 128.6, 128.4, 128.3, 127.1, 127.0, 123.7, 60.2, 42.6, 42.3, 34.2, 32.9, 25.0, 24.7, 21.5, 21.3; HRMS (ESI-TOF) m/z : $C_{23}H_{28}NaO_2S_2^+$ ($M + Na$) $^+$ calcd for 423.1423, found 423.1429.



(*E*)-cyclopentyl(4-(3-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (**4j**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 49.9 mg, 60% yield, Yellow solid (mp 91-93 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.70 (d, *J* = 8.2 Hz, 2H), 7.21-7.17 (m, 3H), 6.82 – 6.74 (m, 2H), 6.69 (s, 1H), 6.25 (d, *J* = 15.6 Hz, 1H), 5.63 (dd, *J* = 15.6, 9.6 Hz, 1H), 3.90 (td, *J* = 9.1, 5.4 Hz, 1H), 3.80 (s, 3H), 3.51 – 3.38 (m, 2H), 3.02-2.96 (m, 1H), 2.29 (s, 3H), 2.01 – 1.84 (m, 2H), 1.76 – 1.66 (m, 2H), 1.61 – 1.48 (m, 3H), 1.47 – 1.38 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.7, 137.9, 136.5, 135.9, 132.0, 129.7, 128.6, 128.4, 128.3, 127.1, 127.0, 123.7, 60.2, 42.6, 42.3, 34.2, 32.9, 25.0, 24.7, 21.5, 21.3; HRMS (ESI-TOF) *m/z*: C₂₃H₂₈NaO₃S₂⁺ (M + Na)⁺ calcd for 439.1372, found 439.1378.

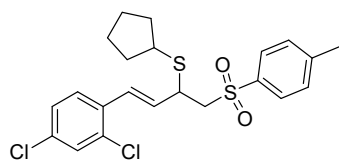


(*E*)-cyclopentyl(4-(2-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (**4k**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 37.5 mg, 45% yield, Yellow solid (mp 73-75 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.72 (d, *J* = 8.0 Hz, 2H), 7.19 (t, *J* = 9.6 Hz, 3H), 7.11 (d, *J* = 7.2 Hz, 1H), 6.85 (t, *J* = 7.1 Hz, 2H), 6.61 (d, *J* = 15.8 Hz, 1H), 5.63 (dd, *J* = 15.8, 9.6 Hz, 1H), 3.89 (dd, *J* = 15.9, 7.6 Hz, 1H), 3.83 (s, 3H), 3.45 (d, *J* = 7.0 Hz, 2H), 3.03 – 2.97 (m, 1H), 2.29 (s, 3H), 2.00 – 1.96 (m, 1H), 1.93 – 1.84 (m, 1H), 1.73-1.67 (m, 2H), 1.59 – 1.48 (m, 3H), 1.46 – 1.38 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 156.6, 144.6, 136.5, 129.6, 128.8, 128.5, 127.5, 126.8, 126.8, 125.1, 120.4, 110.7, 60.3, 55.4, 42.8, 42.6, 34.2, 32.9, 25.0, 24.7, 21.5; HRMS (ESI-TOF) *m/z*: C₂₃H₂₈NaO₃S₂⁺ (M + Na)⁺ calcd for 439.1372, found 439.1381.

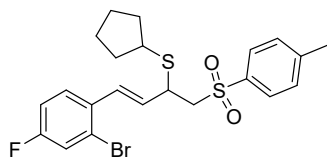


(*E*)-(4-(2-bromophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4l**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 39.0 mg, 42% yield, Yellow

solid (mp 61-63 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.75 (d, *J* = 8.0 Hz, 2H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.25 (d, *J* = 7.9 Hz, 3H), 7.20 (d, *J* = 4.2 Hz, 2H), 7.14 – 7.05 (m, 1H), 6.61 (d, *J* = 15.5 Hz, 1H), 5.63 (dd, *J* = 15.5, 9.6 Hz, 1H), 3.89 (td, *J* = 9.2, 5.2 Hz, 1H), 3.51 – 3.36 (m, 2H), 3.10 – 2.94 (m, 1H), 2.31 (s, 3H), 2.05-2.01 (m, 1H), 1.97 – 1.85 (m, 1H), 1.79 – 1.65 (m, 2H), 1.57-1.51 (m, 3H), 1.44 – 1.38 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.9, 136.4, 136.1, 132.8, 130.4, 130.1, 129.8, 129.0, 128.4, 127.4, 127.2, 123.4, 60.0, 42.7, 42.1, 34.2, 32.8, 25.0, 24.8, 21.5; HRMS (ESI-TOF) *m/z*: C₂₂H₂₅BrNaO₂S₂⁺ (M + Na)⁺ calcd for 487.0372, found 487.0383.

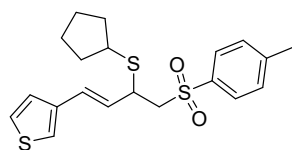


(*E*)-cyclopentyl(4-(2,4-dichlorophenyl)-1-tosylbut-3-en-2-yl)sulfane (**4m**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 33.6 mg, 37% yield, Yellow solid (mp 51-53 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.74 (d, *J* = 8.0 Hz, 2H), 7.36 (s, 1H), 7.26 (d, *J* = 7.6 Hz, 2H), 7.16 (q, *J* = 8.5 Hz, 2H), 6.59 (d, *J* = 15.6 Hz, 1H), 5.70 (dd, *J* = 15.6, 9.6 Hz, 1H), 3.95 – 3.83 (m, 1H), 3.50 – 3.35 (m, 2H), 3.05 – 2.93 (m, 1H), 2.34 (s, 3H), 2.03 – 1.95 (m, 1H), 1.95 – 1.85 (m, 1H), 1.76 – 1.65 (m, 2H), 1.60 – 1.49 (m, 3H), 1.45-1.39 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.9, 136.4, 133.8, 133.4, 133.0, 130.7, 129.8, 129.3, 128.3, 127.7, 127.1, 126.7, 60.0, 42.8, 42.1, 34.2, 32.9, 24.9, 24.7, 21.5; HRMS (ESI-TOF) *m/z*: C₂₂H₂₄Cl₂NaO₂S₂⁺ (M + Na)⁺ calcd for 477.0487, found 477.0492.

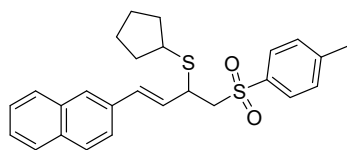


(*E*)-(4-(2-bromo-4-fluorophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4n**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 31.8 mg, 33% yield, Yellow solid (mp 59-61 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.75 (d, *J* = 7.4 Hz, 2H), 7.28 (t, *J* = 7.7 Hz, 3H), 7.23 – 7.17 (m, 1H), 6.94 (t, *J* = 8.2 Hz, 1H), 6.56 (d, *J* = 15.5 Hz, 1H), 5.61 (dd, *J* = 15.5, 9.6 Hz, 1H), 3.89 (td, *J* = 9.2, 5.3 Hz, 1H), 3.54 –

3.34 (m, 2H), 3.11 – 2.90 (m, 1H), 2.34 (s, 3H), 2.06 – 1.97 (m, 1H), 1.97 – 1.86 (m, 1H), 1.77 – 1.66 (m, 2H), 1.62 – 1.49 (m, 3H), 1.46 – 1.37 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 161.7 (d, $J = 250.3$ Hz, 1C), 144.8, 136.4, 132.5 (d, $J = 3.6$ Hz, 1C), 130.1 (d, $J = 2.5$ Hz, 1C), 129.8, 129.2, 128.3, 128.1 (d, $J = 7.8$ Hz, 1C), 123.2 (d, $J = 9.3$ Hz, 1C), 119.7 (d, $J = 24.2$ Hz, 1C), 114.7 (d, $J = 21.2$ Hz, 1C), 59.9, 42.7, 42.0, 34.2, 32.8, 24.9, 24.7, 21.5; ^{19}F NMR (376 MHz, CDCl_3) δ -112.2 (s, 1F); HRMS (ESI-TOF) m/z : $\text{C}_{22}\text{H}_{24}\text{BrFNaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 505.0277, found 505.0283.

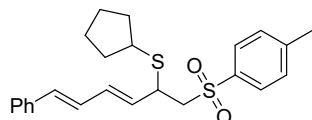


(*E*)-3-(3-(cyclopentylthio)-4-tosylbut-1-en-1-yl)thiophene (**4o**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 40.0 mg, 51% yield, Yellow solid (mp 66-68 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.70 (d, $J = 8.0$ Hz, 2H), 7.21 (t, $J = 7.7$ Hz, 3H), 7.05 (s, 1H), 6.94 (d, $J = 5.0$ Hz, 1H), 6.32 (d, $J = 15.6$ Hz, 1H), 5.49 (dd, $J = 15.6, 9.5$ Hz, 1H), 3.86 (td, $J = 9.3, 5.0$ Hz, 1H), 3.51 – 3.33 (m, 2H), 3.03-2.96 (m, 1H), 2.31 (s, 3H), 1.98-1.86 (m, 2H), 1.70-1.67 (m, 2H), 1.59 – 1.48 (m, 3H), 1.46 – 1.39 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 138.7, 136.6, 129.7, 128.3, 127.2, 126.1, 125.8, 124.9, 122.5, 60.3, 42.7, 42.2, 34.2, 33.0, 24.9, 24.7, 21.5; HRMS (ESI-TOF) m/z : $\text{C}_{20}\text{H}_{24}\text{NaO}_2\text{S}_3^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 415.0831, found 415.0839.

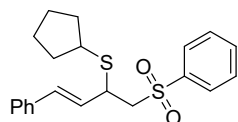


(*E*)-cyclopentyl(4-(naphthalen-2-yl)-1-tosylbut-3-en-2-yl)sulfane (**4p**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 43.6 mg, 50% yield, Yellow solid (mp 75-77 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.77 (s, 2H), 7.71 (d, $J = 8.2$ Hz, 3H), 7.57 (s, 1H), 7.49 – 7.41 (m, 2H), 7.30 (d, $J = 8.5$ Hz, 1H), 7.13 (d, $J = 7.9$ Hz, 2H), 6.45 (d, $J = 15.6$ Hz, 1H), 5.75 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.97 (dd, $J = 15.3, 8.1$ Hz, 1H), 3.49 (d, $J = 6.8$ Hz, 2H), 3.06-2.99 (m, 1H), 2.17 (s, 3H), 2.00-1.97 (m, 1H),

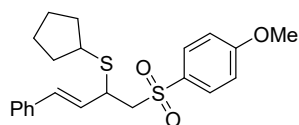
1.92-1.88 (m, 1H), 1.76 – 1.65 (m, 2H), 1.61 – 1.47 (m, 3H), 1.45-1.41 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 136.5, 133.4, 133.4, 133.0, 131.9, 129.7, 128.3, 128.0, 127.9, 127.6 (2C), 126.4, 126.3, 126.0, 123.4, 60.2, 42.7, 42.4, 34.2, 33.0, 24.9, 24.7, 21.4; HRMS (ESI-TOF) m/z : $\text{C}_{26}\text{H}_{28}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 459.1423, found 459.1429.



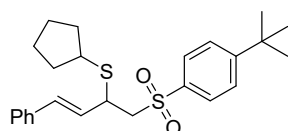
Cyclopentyl((3E,5E)-6-phenyl-1-tosylhexa-3,5-dien-2-yl)sulfane (**4q**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 34.6 mg, 42% yield, Yellow solid (mp 49-51 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.71 (d, $J = 8.1$ Hz, 2H), 7.35 – 7.28 (m, 6H), 7.28 – 7.21 (m, 1H), 6.17 – 5.96 (m, 2H), 5.87 (dd, $J = 14.3, 8.8$ Hz, 1H), 5.63 – 5.49 (m, 1H), 4.46 (d, $J = 8.8$ Hz, 1H), 3.79 (d, $J = 7.7$ Hz, 2H), 2.97 – 2.75 (m, 1H), 2.43 (s, 3H), 2.00 – 1.85 (m, 2H), 1.73-1.69 (m, 2H), 1.59 – 1.47 (m, 4H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 140.4, 138.4, 136.2, 135.5, 129.7, 129.1, 128.6, 128.4, 127.7, 127.3, 118.2, 60.3, 51.9, 43.3, 33.8, 33.4, 24.9, 24.8, 21.6; HRMS (ESI-TOF) m/z : $\text{C}_{24}\text{H}_{28}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 435.1423, found 435.1431.



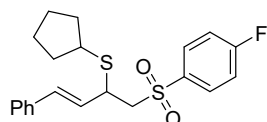
(*E*)-cyclopentyl(4-phenyl-1-(phenylsulfonyl)but-3-en-2-yl)sulfane (**4r**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 46.1 mg, 62% yield, Yellow solid (mp 57-59 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.85 (d, $J = 7.7$ Hz, 2H), 7.52 (t, $J = 7.4$ Hz, 1H), 7.42 (t, $J = 7.7$ Hz, 2H), 7.31 – 7.23 (m, 3H), 7.20 (d, $J = 7.2$ Hz, 2H), 6.35 (d, $J = 15.6$ Hz, 1H), 5.70 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.93 (td, $J = 9.0, 5.7$ Hz, 1H), 3.55 – 3.39 (m, 2H), 3.04-2.97 (m, 1H), 2.01 – 1.85 (m, 2H), 1.75 – 1.65 (m, 2H), 1.59 – 1.48 (m, 3H), 1.45 – 1.38 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 139.6, 135.9, 133.6, 132.0, 129.1, 128.4, 128.3, 127.9, 127.2, 126.5, 60.2, 42.7, 42.2, 34.2, 33.0, 24.9, 24.7; HRMS (ESI-TOF) m/z : $\text{C}_{21}\text{H}_{24}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 395.1110, found 395.1115.



(*E*)-cyclopentyl(1-((4-methoxyphenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4s**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 44.2 mg, 55% yield, Yellow solid (mp 72-74 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.80 – 7.70 (m, 2H), 7.31 – 7.22 (m, 3H), 7.21 – 7.16 (m, 2H), 6.87 – 6.76 (m, 2H), 6.29 (d, *J* = 15.7 Hz, 1H), 5.63 (dd, *J* = 15.7, 9.6 Hz, 1H), 3.90 (td, *J* = 9.5, 4.6 Hz, 1H), 3.70 (s, 3H), 3.53 – 3.37 (m, 2H), 3.03-2.96 (m, 1H), 2.02 – 1.86 (m, 2H), 1.74 – 1.65 (m, 2H), 1.61 – 1.49 (m, 3H), 1.47 – 1.38 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 163.5, 136.0, 131.8, 130.8, 130.6, 128.4, 127.8, 127.3, 126.4, 114.2, 60.3, 55.5, 42.6, 42.3, 34.2, 32.9, 24.9, 24.7; HRMS (ESI-TOF) *m/z*: C₂₂H₂₆NaO₃S₂⁺ (M + Na)⁺ calcd for 425.1216, found 425.1219.

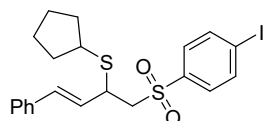


(*E*)-1-((4-(*tert*-butyl)phenyl)sulfonyl)-4-phenylbut-3-en-2-yl(cyclopentyl)sulfane (**4t**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 66.8 mg, 78% yield, Yellow solid (mp 64-66 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.74 (d, *J* = 8.5 Hz, 2H), 7.39 (d, *J* = 8.5 Hz, 2H), 7.32 – 7.19 (m, 3H), 7.19 – 7.13 (m, 2H), 6.34 (d, *J* = 15.7 Hz, 1H), 5.61 (dd, *J* = 15.6, 9.6 Hz, 1H), 3.96 (td, *J* = 9.0, 5.6 Hz, 1H), 3.55 – 3.38 (m, 2H), 3.03-2.96 (m, 1H), 2.03 – 1.84 (m, 2H), 1.77 – 1.66 (m, 2H), 1.60 – 1.47 (m, 3H), 1.45 – 1.37 (m, 1H), 1.22 (s, 9H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 157.5, 136.4, 136.0, 132.0, 128.5, 128.2, 127.8, 127.2, 126.4, 126.0, 60.1, 42.6, 42.3, 35.1, 34.1, 33.0, 30.8, 24.9, 24.7; HRMS (ESI-TOF) *m/z*: C₂₅H₃₂NaO₂S₂⁺ (M + Na)⁺ calcd for 451.1736, found 451.1741.

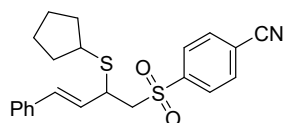


(*E*)-cyclopentyl(1-((4-fluorophenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4u**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 54.6 mg, 70% yield, Yellow solid (mp 75-77 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.85 (dd, *J* = 7.7, 5.5 Hz,

2H), 7.32 – 7.24 (m, 3H), 7.20 (d, $J = 7.5$ Hz, 2H), 7.06 (t, $J = 8.3$ Hz, 2H), 6.35 (d, $J = 15.7$ Hz, 1H), 5.68 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.93 (td, $J = 9.3, 4.9$ Hz, 1H), 3.55 – 3.39 (m, 2H), 3.04-2.97 (m, 1H), 2.03 – 1.85 (m, 2H), 1.78 – 1.65 (m, 2H), 1.60 – 1.48 (m, 3H), 1.46 – 1.37 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 165.7 (d, $J = 255.0$ Hz, 1C), 135.8, 135.6 (d, $J = 3.1$ Hz, 1C), 132.1, 131.3 (d, $J = 9.6$ Hz, 1C), 128.5, 128.0, 127.2, 126.4, 116.4 (d, $J = 22.5$ Hz, 1C), 60.4, 42.7, 42.4, 34.2, 33.0, 24.9, 24.7; ^{19}F NMR (376 MHz, CDCl_3) δ -103.3 (s, 1F); HRMS (ESI-TOF) m/z : $\text{C}_{21}\text{H}_{23}\text{FNaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 413.1016, found 413.1022.

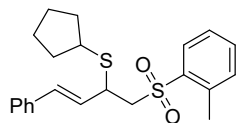


(*E*)-cyclopentyl(1-((4-iodophenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4v**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 65.7 mg, 66% yield, Yellow solid (mp 81-83 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.74 (d, $J = 8.3$ Hz, 2H), 7.52 (d, $J = 8.4$ Hz, 2H), 7.32 (t, $J = 7.4$ Hz, 2H), 7.28 – 7.22 (m, 1H), 7.16 (d, $J = 7.4$ Hz, 2H), 6.32 (d, $J = 15.7$ Hz, 1H), 5.60 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.92 (td, $J = 9.4, 4.9$ Hz, 1H), 3.55 – 3.37 (m, 2H), 3.10 – 2.89 (m, 1H), 2.02 – 1.83 (m, 2H), 1.77 – 1.65 (m, 2H), 1.59 – 1.48 (m, 3H), 1.47 – 1.38 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 139.2, 138.4, 135.7, 132.2, 129.7, 128.6, 128.1, 127.0, 126.4, 101.7, 60.1, 42.8, 42.2, 34.2, 33.0, 24.9, 24.7; HRMS (ESI-TOF) m/z : $\text{C}_{21}\text{H}_{23}\text{INaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 521.0076, found 521.0081.

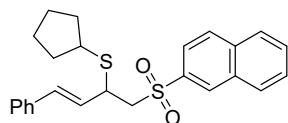


(*E*)-4-((2-(cyclopentylthio)-4-phenylbut-3-en-1-yl)sulfonyl)benzonitrile (**4w**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 42.1 mg, 53% yield, Yellow solid (mp 105-107 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.93 (d, $J = 8.4$ Hz, 2H), 7.64 (d, $J = 8.4$ Hz, 2H), 7.36 – 7.25 (m, 3H), 7.20 – 7.09 (m, 2H), 6.33 (d, $J = 15.7$ Hz, 1H), 5.55 (dd, $J = 15.7, 9.7$ Hz, 1H), 3.94 (td, $J = 9.7, 4.7$ Hz, 1H), 3.62 – 3.41 (m, 2H), 3.10 – 2.92 (m, 1H), 2.04 – 1.85 (m, 2H), 1.76 – 1.64 (m, 2H), 1.60 – 1.48 (m, 3H), 1.45 – 1.35 (m, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 143.8, 135.4, 132.7, 132.5, 129.1, 128.7, 128.5, 126.8, 126.3, 117.2, 116.9, 60.0, 42.8, 42.2, 34.2,

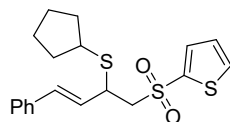
32.9, 24.9, 24.7; HRMS (ESI-TOF) m/z : $C_{22}H_{23}NNaO_2S_2^+$ ($M + Na$) $^+$ calcd for 420.1062, found 420.1067.



(*E*)-cyclopentyl(4-phenyl-1-(*o*-tolylsulfonyl)but-3-en-2-yl)sulfane (**4x**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 44.8 mg, 58% yield, Yellow oil, 1H NMR (400 MHz, $CDCl_3$) δ : 7.90 (dd, $J = 7.9, 1.0$ Hz, 1H), 7.37 (td, $J = 7.5, 1.2$ Hz, 1H), 7.29-7.24 (m, 4H), 7.21 – 7.13 (m, 3H), 6.28 (d, $J = 15.6$ Hz, 1H), 5.71 (dd, $J = 15.6, 9.5$ Hz, 1H), 3.92 (dt, $J = 9.2, 7.1$ Hz, 1H), 3.60 – 3.44 (m, 2H), 3.09 – 2.93 (m, 1H), 2.69 (s, 3H), 2.00 – 1.84 (m, 2H), 1.73-1.66 (m, 2H), 1.57-1.48 (m, 3H), 1.46-1.39 (m, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ : 137.7, 137.6, 136.0, 133.6, 132.5, 132.0, 130.6, 128.4, 127.8, 127.1, 126.5 (2C), 59.3, 42.8, 42.2, 34.2, 33.0, 25.0, 24.7, 20.4; HRMS (ESI-TOF) m/z : $C_{22}H_{26}NaO_2S_2^+$ ($M + Na$) $^+$ calcd for 409.1266, found 409.1274.

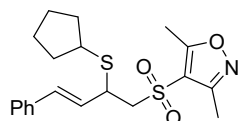


(*E*)-cyclopentyl(1-(naphthalen-2-ylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4y**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 46.4 mg, 55% yield, Yellow solid (mp 77-79 °C), 1H NMR (400 MHz, $CDCl_3$) δ : 8.39 (s, 1H), 7.88 (d, $J = 8.6$ Hz, 1H), 7.84 – 7.78 (m, 2H), 7.74 (d, $J = 8.2$ Hz, 1H), 7.60 (t, $J = 7.6$ Hz, 1H), 7.51 (t, $J = 7.5$ Hz, 1H), 7.18 – 7.09 (m, 3H), 7.01 (dd, $J = 7.1, 2.0$ Hz, 2H), 6.31 (d, $J = 15.7$ Hz, 1H), 5.63 (dd, $J = 15.6, 9.6$ Hz, 1H), 3.96 (td, $J = 9.2, 5.3$ Hz, 1H), 3.63 – 3.45 (m, 2H), 3.02-2.95 (m, 1H), 2.00 – 1.83 (m, 2H), 1.75 – 1.63 (m, 2H), 1.58-1.46 (m, 3H), 1.44 – 1.37 (m, 1H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ : 136.3, 135.7, 135.2, 132.0, 132.0, 130.6, 129.4, 129.3, 129.2, 128.3, 127.8, 127.7, 127.5, 127.1, 126.3, 122.7, 60.1, 42.7, 42.4, 34.2, 33.0, 24.9, 24.7; HRMS (ESI-TOF) m/z : $C_{25}H_{26}NaO_2S_2^+$ ($M + Na$) $^+$ calcd for 445.1266, found 445.1267.

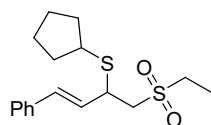


(*E*)-2-((2-(cyclopentylthio)-4-phenylbut-3-en-1-yl)sulfonyl)thiophene (**4z**), by silica

gel column chromatography (hexane/ethyl acetate = 15:1), 40.1 mg, 53% yield, Yellow solid (mp 61-63 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.64-7.60 (m, 2H), 7.34 – 7.22 (m, 5H), 7.01 (dd, *J* = 4.8, 3.9 Hz, 1H), 6.40 (d, *J* = 15.7 Hz, 1H), 5.83 (dd, *J* = 15.6, 9.5 Hz, 1H), 3.97 (td, *J* = 8.6, 5.9 Hz, 1H), 3.66 – 3.47 (m, 2H), 3.03 (p, *J* = 7.1 Hz, 1H), 2.04 – 1.86 (m, 2H), 1.78 – 1.66 (m, 2H), 1.60 – 1.49 (m, 3H), 1.48-1.39 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 140.6, 136.0, 134.7, 134.2, 132.0, 128.5, 127.9, 127.8, 127.0, 126.5, 61.7, 42.7, 42.3, 34.2, 33.0, 25.0, 24.7; HRMS (ESI-TOF) *m/z*: C₁₉H₂₂NaO₂S₃⁺ (M + Na)⁺ calcd for 401.0674, found 401.0679.

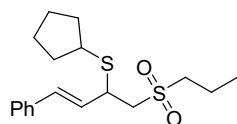


(*E*)-4-((2-(cyclopentylthio)-4-phenylbut-3-en-1-yl)sulfonyl)-3,5-dimethylisoxazole (**4za**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 48.5 mg, 62% yield, Yellow solid (mp 60-62 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.35 – 7.30 (m, 2H), 7.27 (d, *J* = 7.6 Hz, 3H), 6.42 (d, *J* = 15.6 Hz, 1H), 5.84 (dd, *J* = 15.6, 9.6 Hz, 1H), 3.95 (dd, *J* = 14.7, 8.8 Hz, 1H), 3.51 – 3.36 (m, 2H), 3.06-2.99 (m, 1H), 2.54 (s, 3H), 2.44 (s, 3H), 2.04 – 1.87 (m, 2H), 1.77 – 1.66 (m, 2H), 1.61 – 1.49 (m, 3H), 1.45-1.40 (m, 1H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 174.9, 157.5, 135.5, 132.1, 128.7, 128.2, 126.7, 126.4, 115.9, 60.8, 42.7, 42.2, 34.3, 32.9, 25.0, 24.7, 12.8, 10.9; HRMS (ESI-TOF) *m/z*: C₂₀H₂₅NNaO₃S₂⁺ (M + Na)⁺ calcd for 414.1168, found 414.1175.

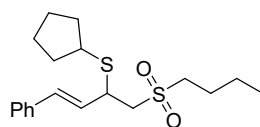


(*E*)-cyclopentyl(1-(ethylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4zb**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 46.0 mg, 71% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.40 (d, *J* = 7.3 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 2H), 7.27 (dd, *J* = 8.7, 5.4 Hz, 1H), 6.56 (d, *J* = 15.7 Hz, 1H), 6.05 (dd, *J* = 15.7, 9.6 Hz, 1H), 4.03 (dd, *J* = 16.3, 7.1 Hz, 1H), 3.37 – 3.19 (m, 2H), 3.12-3.04 (m, 3H), 2.08 – 1.91 (m, 2H), 1.80 – 1.68 (m, 2H), 1.66 – 1.45 (m, 4H), 1.37 (t, *J* = 7.5 Hz, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 135.8, 132.2, 128.7, 128.1, 127.6, 126.5, 56.2, 49.1, 43.0, 42.2, 34.2, 33.0, 24.9, 24.7, 6.5; HRMS (ESI-TOF) *m/z*: C₁₇H₂₄NaO₂S₂⁺

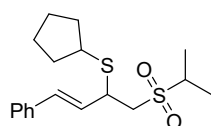
(M + Na)⁺ calcd for 347.1110, found 347.1117.



(*E*)-cyclopentyl(4-phenyl-1-(propylsulfonyl)but-3-en-2-yl)sulfane (**4zc**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 42.6 mg, 63% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.39 (d, *J* = 7.2 Hz, 2H), 7.33 (t, *J* = 7.5 Hz, 2H), 7.27 (t, *J* = 6.9 Hz, 1H), 6.56 (d, *J* = 15.7 Hz, 1H), 6.05 (dd, *J* = 15.7, 9.6 Hz, 1H), 4.09 – 3.96 (m, 1H), 3.37 – 3.22 (m, 2H), 3.07 (dd, *J* = 13.9, 6.9 Hz, 1H), 3.02 (dd, *J* = 10.0, 5.8 Hz, 2H), 2.13 – 1.91 (m, 2H), 1.91 – 1.79 (m, 2H), 1.79 – 1.67 (m, 2H), 1.67 – 1.44 (m, 4H), 1.01 (t, *J* = 7.3 Hz, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 135.8, 132.2, 128.7, 128.1, 127.7, 126.5, 57.0, 56.4, 43.0, 42.1, 34.3, 33.0, 24.9, 24.7, 15.8, 13.1; HRMS (ESI-TOF) *m/z*: C₁₈H₂₆NaO₂S₂⁺ (M + Na)⁺ calcd for 361.1266, found 361.1269.

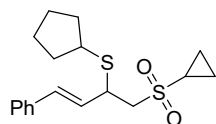


(*E*)-(1-(butylsulfonyl)-4-phenylbut-3-en-2-yl)(cyclopentyl)sulfane (**4zd**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 36.6 mg, 52% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.39 (d, *J* = 7.2 Hz, 2H), 7.33 (t, *J* = 7.4 Hz, 2H), 7.27 (dd, *J* = 7.9, 6.4 Hz, 1H), 6.56 (d, *J* = 15.7 Hz, 1H), 6.05 (dd, *J* = 15.7, 9.6 Hz, 1H), 4.09 – 3.93 (m, 1H), 3.35 – 3.22 (m, 2H), 3.15 – 2.96 (m, 3H), 2.09 – 1.91 (m, 2H), 1.84 – 1.69 (m, 4H), 1.66 – 1.54 (m, 3H), 1.53 – 1.46 (m, 1H), 1.43 – 1.36 (m, 2H), 0.88 (t, *J* = 7.3 Hz, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 135.8, 132.2, 128.7, 128.1, 127.7, 126.5, 57.0, 54.5, 43.0, 42.1, 34.3, 33.0, 25.0, 24.7, 23.9, 21.6, 13.4; HRMS (ESI-TOF) *m/z*: C₁₉H₂₈NaO₂S₂⁺ (M + Na)⁺ calcd for 375.1423, found 375.1429.

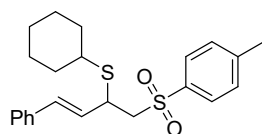


(*E*)-cyclopentyl(1-(isopropylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4ze**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 44.0 mg, 65% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.40 (d, *J* = 7.3 Hz, 2H), 7.33 (t, *J* = 7.4

Hz, 2H), 7.26 (t, $J = 7.2$ Hz, 1H), 6.56 (d, $J = 15.7$ Hz, 1H), 6.08 (dd, $J = 15.6, 9.6$ Hz, 1H), 4.05 (td, $J = 8.9, 5.5$ Hz, 1H), 3.36 – 3.16 (m, 3H), 3.14 – 3.02 (m, 1H), 2.08 – 1.91 (m, 2H), 1.81 – 1.68 (m, 2H), 1.66 – 1.45 (m, 4H), 1.37 (d, $J = 6.8$ Hz, 6H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 135.9, 132.0, 128.6, 128.0, 127.7, 126.5, 54.1, 53.7, 43.0, 41.7, 34.3, 33.0, 25.0, 24.7, 15.2, 15.0; HRMS (ESI-TOF) m/z : $\text{C}_{18}\text{H}_{26}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 361.1266, found 361.1275.

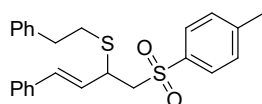


(*E*)-cyclopentyl(1-(cyclopropylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4zf**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 40.3 mg, 60% yield, Yellow oil, ^1H NMR (400 MHz, CDCl_3) δ : 7.40 (d, $J = 7.6$ Hz, 2H), 7.33 (t, $J = 7.4$ Hz, 2H), 7.26 (t, $J = 7.1$ Hz, 1H), 6.56 (d, $J = 15.7$ Hz, 1H), 6.10 (dd, $J = 15.7, 9.6$ Hz, 1H), 4.07 (dd, $J = 16.4, 7.1$ Hz, 1H), 3.37 (d, $J = 7.0$ Hz, 2H), 3.12-3.05 (m, 1H), 2.52 – 2.42 (m, 1H), 2.07-1.93 (m, 2H), 1.80 – 1.70 (m, 2H), 1.65 – 1.46 (m, 4H), 1.27 – 1.19 (m, 2H), 1.02 – 0.96 (m, 2H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 135.9, 131.9, 128.7, 128.0, 127.9, 126.5, 58.4, 42.9, 42.2, 34.3, 33.0, 31.2, 25.0, 24.7, 5.4, 5.2; HRMS (ESI-TOF) m/z : $\text{C}_{18}\text{H}_{24}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 359.1110, found 359.1117.

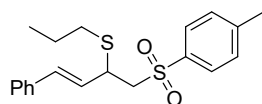


(*E*)-octyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zg**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 48.8 mg, 61% yield, Yellow solid (mp 55-57 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.70 (d, $J = 8.1$ Hz, 2H), 7.30 – 7.21 (m, 3H), 7.16 (t, $J = 7.8$ Hz, 4H), 6.28 (d, $J = 15.7$ Hz, 1H), 5.62 (dd, $J = 15.7, 9.5$ Hz, 1H), 3.97 (dd, $J = 16.2, 7.3$ Hz, 1H), 3.51 – 3.37 (m, 2H), 2.59 (td, $J = 10.2, 3.6$ Hz, 1H), 2.27 (s, 3H), 1.95 (d, $J = 13.1$ Hz, 1H), 1.81 – 1.71 (m, 2H), 1.67-1.66 (m, 1H), 1.56-1.53 (m, 1H), 1.34 – 1.20 (m, 5H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 136.5, 136.0, 131.8, 129.7, 128.4, 128.3, 127.8, 127.4, 126.4, 60.4, 42.7, 40.5, 33.6, 33.0, 25.9, 25.6 (2C), 21.4; HRMS (ESI-TOF) m/z : $\text{C}_{23}\text{H}_{28}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd

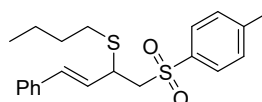
for 423.1423, found 423.1425.



(*E*)-phenethyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zh**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 40.5 mg, 48% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.69 (d, *J* = 8.0 Hz, 2H), 7.31 – 7.22 (m, 5H), 7.18 (dd, *J* = 15.6, 7.9 Hz, 5H), 7.11 (d, *J* = 7.4 Hz, 2H), 6.23 (d, *J* = 15.7 Hz, 1H), 5.60 (dd, *J* = 15.7, 9.6 Hz, 1H), 3.84 (dd, *J* = 14.8, 8.6 Hz, 1H), 3.51 – 3.35 (m, 2H), 2.82 (dd, *J* = 13.9, 6.4 Hz, 2H), 2.77 – 2.61 (m, 2H), 2.28 (s, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.8, 139.9, 136.3, 135.6, 132.4, 129.7, 128.5 (3C), 128.4, 128.3, 127.9, 126.6, 126.4, 60.0, 42.1, 35.9, 32.2, 21.5; HRMS (ESI-TOF) *m/z*: C₂₅H₂₆NaO₂S₂⁺ (M + Na)⁺ calcd for 445.1266, found 445.1270.

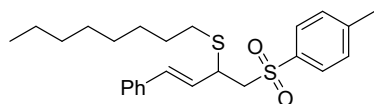


(*E*)-(4-phenyl-1-tosylbut-3-en-2-yl)(propyl)sulfane (**4zi**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 51.9 mg, 72% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.71 (d, *J* = 8.0 Hz, 2H), 7.31 – 7.21 (m, 3H), 7.18 (t, *J* = 7.6 Hz, 4H), 6.26 (d, *J* = 15.7 Hz, 1H), 5.60 (dd, *J* = 15.6, 9.5 Hz, 1H), 3.84 (td, *J* = 9.0, 5.4 Hz, 1H), 3.53 – 3.37 (m, 2H), 2.52 – 2.42 (m, 1H), 2.42 – 2.32 (m, 1H), 2.28 (s, 3H), 1.62 – 1.48 (m, 2H), 0.93 (t, *J* = 7.3 Hz, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.8, 136.4, 135.9, 132.2, 129.7, 128.4, 128.3, 127.8, 126.9, 126.4, 60.2, 41.9, 32.7, 22.5, 21.5, 13.4; HRMS (ESI-TOF) *m/z*: C₂₀H₂₄NaO₂S₂⁺ (M + Na)⁺ calcd for 383.1110, found 383.1123.

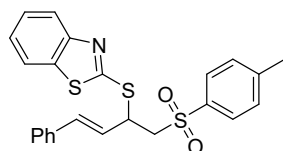


(*E*)-butyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zj**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 50.9 mg, 68% yield, Yellow oil, ¹H NMR (400 MHz, CDCl₃) δ: 7.71 (d, *J* = 8.0 Hz, 2H), 7.30 – 7.22 (m, 3H), 7.18 (t, *J* = 8.3 Hz, 4H), 6.27 (d, *J* = 15.7 Hz, 1H), 5.61 (dd, *J* = 15.6, 9.5 Hz, 1H), 3.84 (dd, *J* = 14.5, 8.9 Hz, 1H), 3.55 – 3.37 (m, 2H), 2.52-2.36 (m, 2H), 2.29 (s, 3H), 1.56 – 1.46

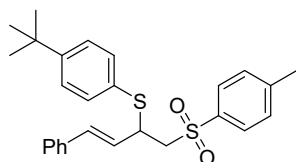
(m, 2H), 1.37 – 1.30 (m, 2H), 0.87 (t, $J = 7.3$ Hz, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.8, 136.5, 135.9, 132.2, 129.7, 128.4, 128.4, 127.8, 126.9, 126.4, 60.2, 41.9, 31.2, 30.4, 21.9, 21.5, 13.6; HRMS (ESI-TOF) m/z : $\text{C}_{21}\text{H}_{26}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 397.1266, found 397.1268.



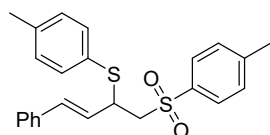
(*E*)-octyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zk**), by silica gel column chromatography (hexane/ethyl acetate = 20:1), 60.2 mg, 70% yield, Yellow oil, ^1H NMR (400 MHz, CDCl_3) δ : 7.71 (d, $J = 8.2$ Hz, 2H), 7.24 (dd, $J = 14.4, 7.1$ Hz, 3H), 7.17 (t, $J = 7.6$ Hz, 4H), 6.26 (d, $J = 15.7$ Hz, 1H), 5.60 (dd, $J = 15.7, 9.5$ Hz, 1H), 3.94 – 3.77 (m, 1H), 3.52 – 3.38 (m, 2H), 2.51 – 2.35 (m, 2H), 2.28 (s, 3H), 1.57 – 1.44 (m, 2H), 1.33 – 1.20 (m, 10H), 0.86 (t, $J = 6.8$ Hz, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 136.4, 135.9, 132.1, 129.7, 128.4, 128.3, 127.8, 126.8, 126.4, 60.1, 41.9, 31.7, 30.7, 29.1 (3C), 28.8, 22.6, 21.4, 14.0; HRMS (ESI-TOF) m/z : $\text{C}_{25}\text{H}_{34}\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 453.1892, found 453.1898.



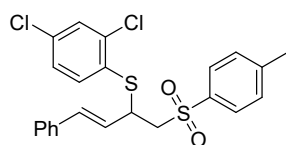
(*E*)-2-((4-phenyl-1-tosylbut-3-en-2-yl)thio)benzo[d]thiazole (**4zl**), by silica gel column chromatography (hexane/ethyl acetate = 9:1), 70.4 mg, 78% yield, Yellow solid (mp 133-135 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.85 (d, $J = 8.1$ Hz, 1H), 7.75 (dd, $J = 15.8, 8.0$ Hz, 3H), 7.44 (t, $J = 7.7$ Hz, 1H), 7.32 (d, $J = 7.8$ Hz, 1H), 7.29 – 7.18 (m, 7H), 6.64 (d, $J = 15.7$ Hz, 1H), 6.09 (dd, $J = 15.7, 9.0$ Hz, 1H), 4.94 (td, $J = 10.0, 3.5$ Hz, 1H), 4.09 (dd, $J = 14.3, 3.5$ Hz, 1H), 3.83 (dd, $J = 14.3, 10.5$ Hz, 1H), 2.33 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 163.0, 152.9, 144.9, 136.3, 135.6, 135.4, 135.0, 129.8, 128.4 (2C), 128.2, 126.7, 126.1, 124.7, 124.1, 121.9, 121.0, 60.0, 45.1, 21.5; HRMS (ESI-TOF) m/z : $\text{C}_{24}\text{H}_{21}\text{NNaO}_2\text{S}_3^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 474.0627, found 474.0629.



(*E*)-4-(4-(tert-butyl)phenyl)(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zm**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 27.9 mg, 31% yield, Yellow solid (mp 115-117 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.67 (d, *J* = 8.0 Hz, 2H), 7.29 (s, 4H), 7.27 – 7.22 (m, 3H), 7.18 (d, *J* = 7.9 Hz, 2H), 7.04 (d, *J* = 7.2 Hz, 2H), 6.12 (d, *J* = 15.7 Hz, 1H), 5.65 (dd, *J* = 15.7, 9.2 Hz, 1H), 4.13 (td, *J* = 9.7, 3.9 Hz, 1H), 3.59 – 3.40 (m, 2H), 2.29 (s, 3H), 1.30 (s, 9H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 152.0, 144.8, 136.3, 136.0, 134.3, 133.3, 129.7, 128.4, 128.3, 128.1, 127.8, 126.4, 126.2, 125.7, 60.1, 45.9, 34.6, 31.2, 21.5; HRMS (ESI-TOF) *m/z*: C₂₇H₃₀NaO₂S₂⁺ (M + Na)⁺ calcd for 473.1579, found 473.1588.

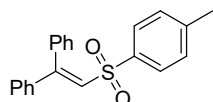


(*E*)-4-phenyl-1-tosylbut-3-en-2-yl(*p*-tolyl)sulfane (**4zn**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 20.4 mg, 25% yield, Yellow solid (mp 99-101 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.66 (d, *J* = 7.8 Hz, 2H), 7.30 – 7.20 (m, 6H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.08 (t, *J* = 8.7 Hz, 4H), 6.14 (d, *J* = 15.7 Hz, 1H), 5.65 (dd, *J* = 15.7, 9.2 Hz, 1H), 4.10 (td, *J* = 9.8, 3.7 Hz, 1H), 3.58 – 3.38 (m, 2H), 2.33 (s, 3H), 2.28 (s, 3H); ¹³C{¹H} NMR (100 MHz, CDCl₃) δ: 144.8, 138.9, 136.2, 136.0, 135.8, 134.7, 133.2, 129.9, 129.7, 128.4, 128.3, 128.0, 127.8, 126.4, 125.9, 60.1, 46.0, 21.5, 21.2; HRMS (ESI-TOF) *m/z*: C₂₄H₂₄NaO₂S₂⁺ (M + Na)⁺ calcd for 431.1110, found 431.1115.

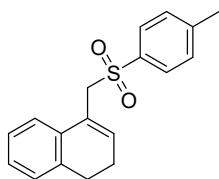


(*E*)-2,4-dichlorophenyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4zo**), by silica gel column chromatography (hexane/ethyl acetate = 12:1), 18.5 mg, 20% yield, Yellow solid (mp 85-87 °C), ¹H NMR (400 MHz, CDCl₃) δ: 7.68 (d, *J* = 7.9 Hz, 2H), 7.40 (s, 1H), 7.35 (d, *J* = 8.4 Hz, 2H), 7.26 – 7.17 (m, 5H), 7.06 (d, *J* = 7.0 Hz, 2H), 6.17 (d, *J*

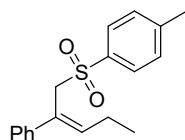
= 15.7 Hz, 1H), 5.69 (dd, $J = 15.7, 9.2$ Hz, 1H), 4.31 (td, $J = 9.8, 3.2$ Hz, 1H), 3.59 – 3.36 (m, 2H), 2.29 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 145.1, 138.8, 136.3, 136.1, 135.7, 135.2, 133.9, 130.1, 130.0, 129.9, 128.5, 128.4, 128.1, 127.7, 126.5, 125.1, 59.8, 45.2, 21.6; HRMS (ESI-TOF) m/z : $\text{C}_{23}\text{H}_{20}\text{Cl}_2\text{NaO}_2\text{S}_2^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 485.0174, found 485.0178.



(2-tosylethene-1,1-diyl)dibenzene (**5**), by silica gel column chromatography (hexane/ethyl acetate = 20:1), 25.4 mg, 38% yield, Yellow solid (mp 103-105 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.47 (d, $J = 8.1$ Hz, 2H), 7.40 – 7.33 (m, 2H), 7.29 (t, $J = 7.1$ Hz, 4H), 7.20 (d, $J = 7.4$ Hz, 2H), 7.14 (d, $J = 8.0$ Hz, 2H), 7.09 (d, $J = 7.2$ Hz, 2H), 7.00 (s, 1H), 2.37 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 154.6, 143.7, 139.1, 138.4, 135.5, 130.2, 129.7, 129.2, 128.8 (2C), 128.5, 128.1, 127.7, 127.6, 21.5; HRMS (ESI-TOF) m/z : $\text{C}_{21}\text{H}_{18}\text{NaO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 357.0920, found 357.0931.

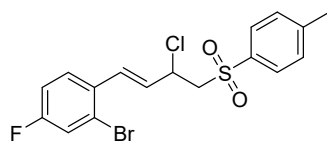


4-(tosylmethyl)-1,2-dihydronaphthalene (**7**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 13.7 mg, 23% yield, Yellow solid (mp 93-95 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.61 (d, $J = 8.2$ Hz, 2H), 7.18 (t, $J = 5.2$ Hz, 6H), 6.04 (t, $J = 7.3$ Hz, 1H), 4.35 (s, 2H), 3.57 (t, $J = 6.6$ Hz, 2H), 2.66-2.61 (m, 2H), 2.37 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 140.5, 135.9, 133.6, 130.7, 129.5, 128.4 (2C), 128.3, 127.4, 126.5 (2C), 58.0, 43.6, 32.5, 21.5; HRMS (ESI-TOF) m/z : $\text{C}_{18}\text{H}_{18}\text{NaO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 321.0920, found 321.0927.

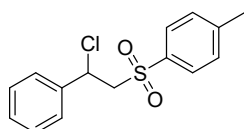


1-methyl-4-((2-phenylpent-2-en-1-yl)sulfonyl)benzene (**8**), by silica gel column chromatography (hexane/ethyl acetate = 5:1), 16.8 mg, 28% yield, Yellow solid (mp 71-73 °C), ^1H NMR (400 MHz, CDCl_3) δ : 7.61 (d, $J = 8.2$ Hz, 2H), 7.21 – 7.13 (m,

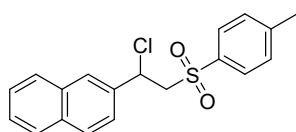
7H), 5.95 (t, $J = 7.4$ Hz, 1H), 4.34 (s, 2H), 2.36 (s, 3H), 2.12-2.04 (m, 2H), 0.96 (t, $J = 7.5$ Hz, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.4, 140.9, 140.2, 136.0, 129.4, 128.5, 128.2, 127.3, 126.9, 126.4, 57.7, 22.7, 21.5, 13.6; HRMS (ESI-TOF) m/z : $\text{C}_{18}\text{H}_{20}\text{NaO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 323.1076, found 323.1079.



(E)-2-bromo-1-(3-chloro-4-tosylbut-1-en-1-yl)-4-fluorobenzene (**9**), by silica gel column chromatography (hexane/ethyl acetate = 10:1), 34.1 mg, 41% yield, Yellow oil, ^1H NMR (400 MHz, CDCl_3) δ : 7.76 (d, $J = 8.2$ Hz, 2H), 7.34 – 7.26 (m, 4H), 6.97 (td, $J = 8.4, 2.5$ Hz, 1H), 6.89 (d, $J = 15.5$ Hz, 1H), 5.93 (dd, $J = 15.5, 9.0$ Hz, 1H), 4.93 (td, $J = 8.8, 5.4$ Hz, 1H), 3.77-3.66 (m, 2H), 2.37 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 162.1 (d, $J = 251.5$ Hz, 1C), 145.2, 135.9, 131.7, 131.4 (d, $J = 3.6$ Hz, 1C), 129.9, 128.7 (d, $J = 1.9$ Hz, 1C), 128.4, 128.3 (3C), 123.9 (d, $J = 9.4$ Hz, 1C), 120.0 (d, $J = 24.3$ Hz, 1C), 114.9 (d, $J = 21.3$ Hz, 1C), 62.9, 54.2, 21.5; ^{19}F NMR (376 MHz, CDCl_3) δ -110.7 (s, 1F); HRMS (ESI-TOF) m/z : $\text{C}_{17}\text{H}_{15}\text{BrClFO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 438.9541, found 438.9555.



1-((2-chloro-2-phenylethyl)sulfonyl)-4-methylbenzene (**11'**), by silica gel column chromatography (hexane/ethyl acetate = 15:1), 51.8 mg, 88% yield, Yellow oil, ^1H NMR (400 MHz, CDCl_3) δ : 7.63 (d, $J = 8.3$ Hz, 2H), 7.27 (s, 5H), 7.23 (d, $J = 8.1$ Hz, 2H), 5.33 (t, $J = 6.9$ Hz, 1H), 3.94 (dd, $J = 14.8, 6.9$ Hz, 1H), 3.84 (dd, $J = 14.8, 6.9$ Hz, 1H), 2.40 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.9, 138.5, 136.1, 129.7, 129.0, 128.8, 128.1, 127.1, 64.0, 55.1, 21.6; HRMS (ESI-TOF) m/z : $\text{C}_{15}\text{H}_{15}\text{ClNaO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 317.0373, found 317.0375.



2-(1-chloro-2-tosylethyl)naphthalene (**13'**), by silica gel column chromatography

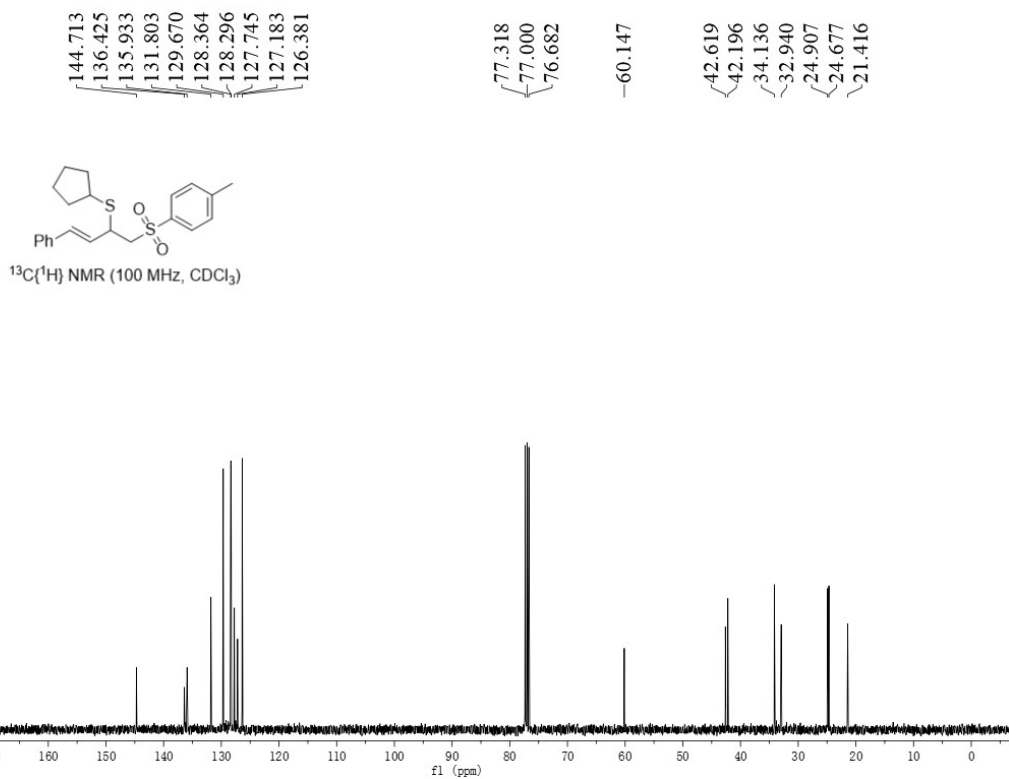
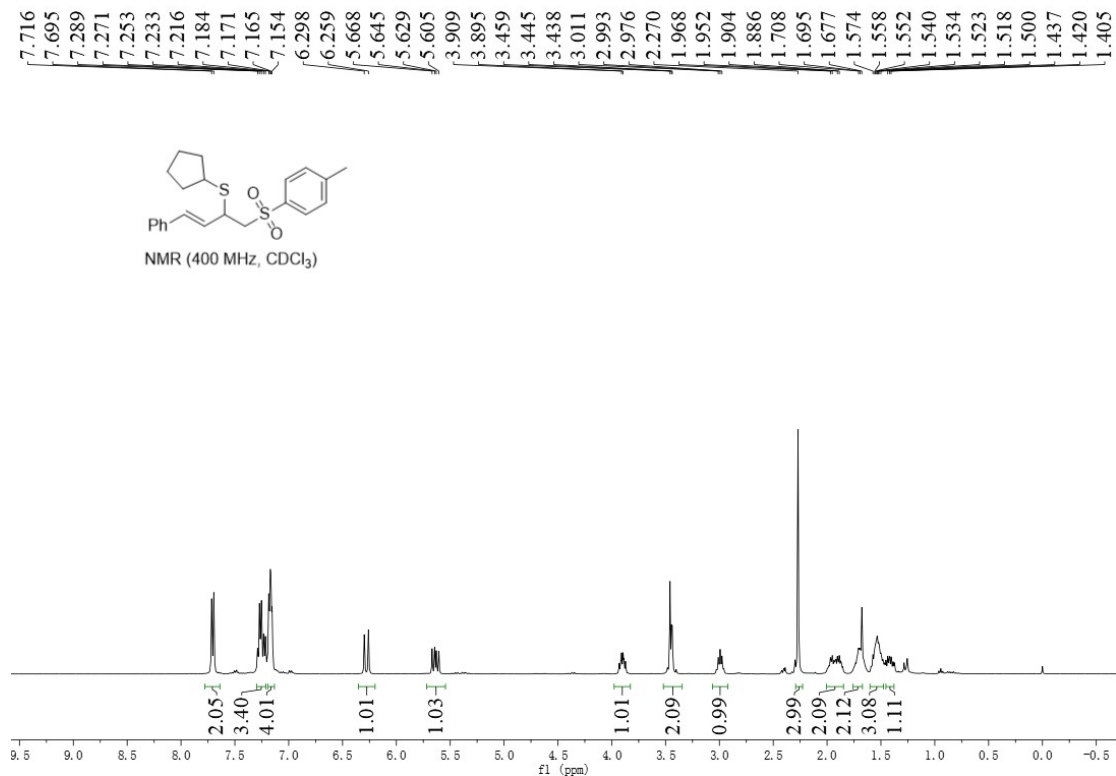
(hexane/ethyl acetate = 12:1), 46.1 mg, 67% yield, Yellow oil, ^1H NMR (400 MHz, CDCl_3) δ : 7.78 – 7.69 (m, 2H), 7.69 – 7.62 (m, 2H), 7.50-7.47 (m, 4H), 7.29 (dd, J = 8.5, 1.5 Hz, 1H), 6.97 (d, J = 8.1 Hz, 2H), 5.48 (t, J = 7.0 Hz, 1H), 4.14 – 3.90 (m, 2H), 2.20 (s, 3H); $^{13}\text{C}\{^1\text{H}\}$ NMR (100 MHz, CDCl_3) δ : 144.7, 135.7, 135.1, 133.3, 132.7, 129.4 (2C), 129.0, 128.0, 127.9, 127.5, 126.9, 126.6, 123.9, 63.7, 55.5, 21.3; HRMS (ESI-TOF) m/z : $\text{C}_{19}\text{H}_{17}\text{ClNaO}_2\text{S}^+$ ($\text{M} + \text{Na}$) $^+$ calcd for 367.0530, found 367.0535.

7. References

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- [5] H. Mo, D. Chen, L. Xu, D. Chen, F. Pan, J. Yang, *Synthesis*, **2015**, *47*, 209-215.

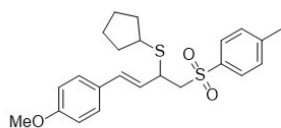
8. NMR Spectra

(*E*)-cyclopentyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (**4a**)

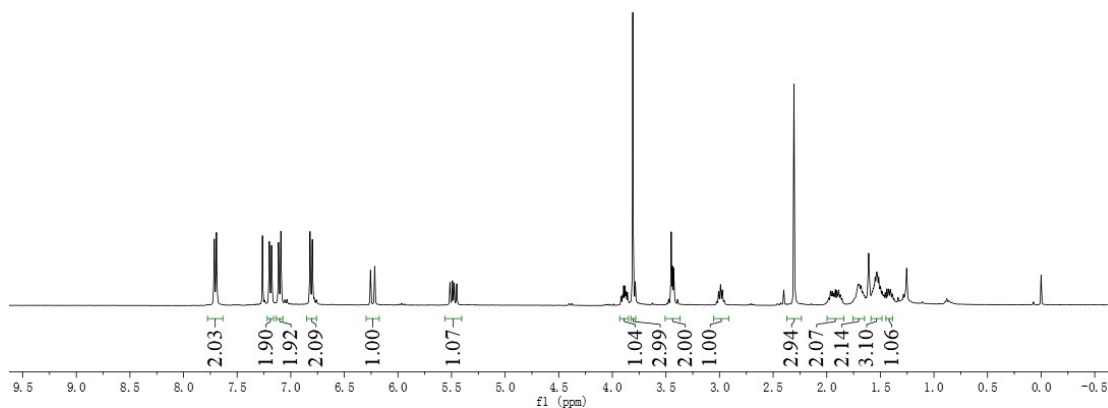


(E)-cyclopentyl(4-(4-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (**4b**)

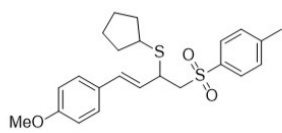
7.713
7.693
7.199
7.179
7.114
7.092
6.820
6.799
6.256
6.217
5.515
5.491
5.476
5.452
3.895
3.882
3.809
3.450
3.438
3.427
3.008
2.991
2.974
2.306
1.966
1.949
1.919
1.906
1.888
1.708
1.701
1.694
1.681
1.548
1.538
1.532
1.525
1.515
1.499
1.483
1.438
1.422
1.406
0.000



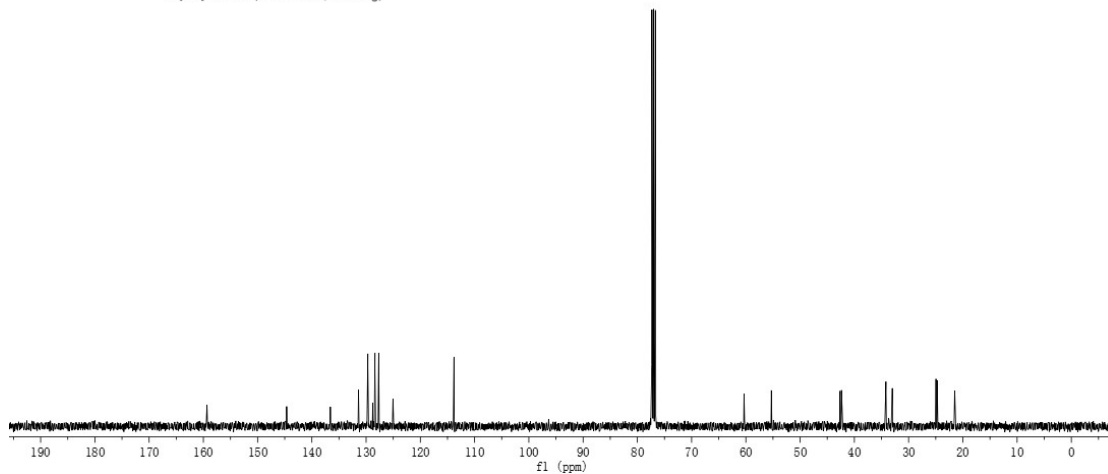
NMR (400 MHz, CDCl₃)



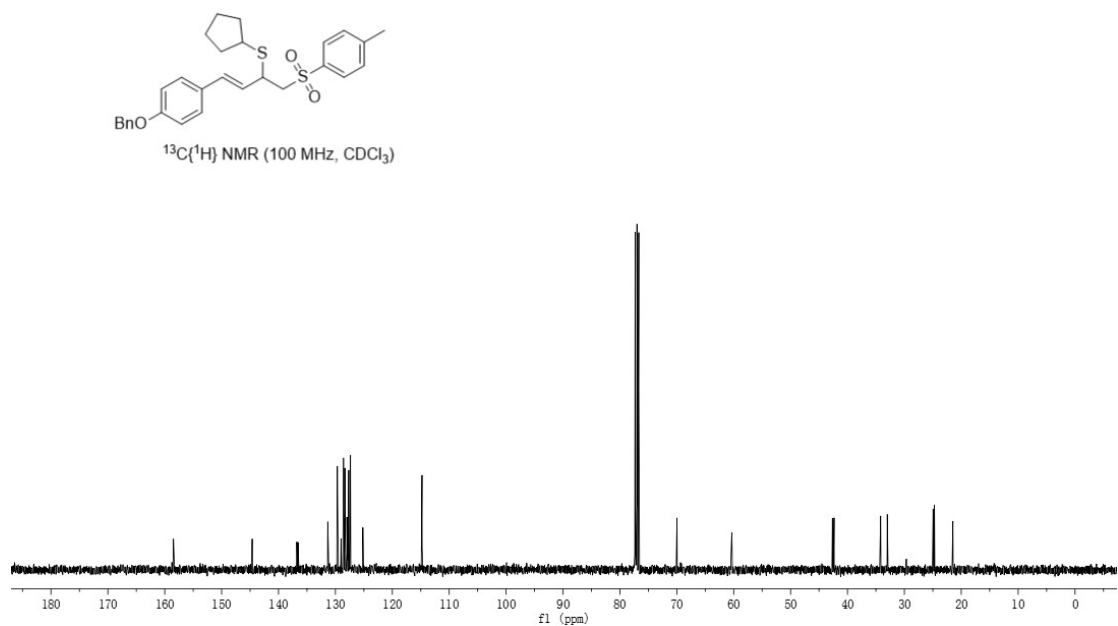
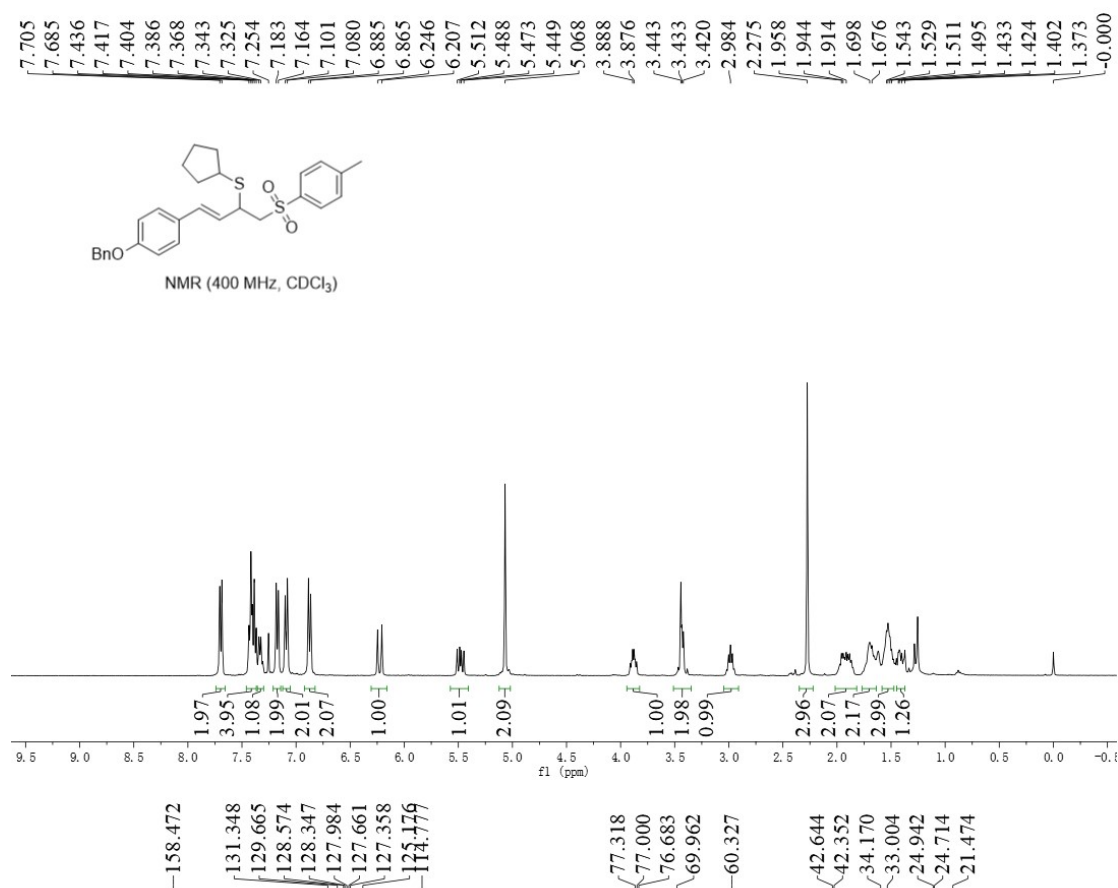
159.333
144.641
136.587
131.407
129.680
128.783
128.368
127.671
125.044
113.805
77.318
77.000
76.683
60.336
55.301
42.647
42.377
34.182
33.006
24.956
24.728
21.506



¹³C{¹H} NMR (100 MHz, CDCl₃)

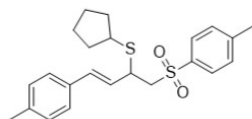


(E)-4-(4-(benzyloxy)phenyl)-1-tosylbut-3-en-2-yl(cyclopentyl)sulfane (**4c**)

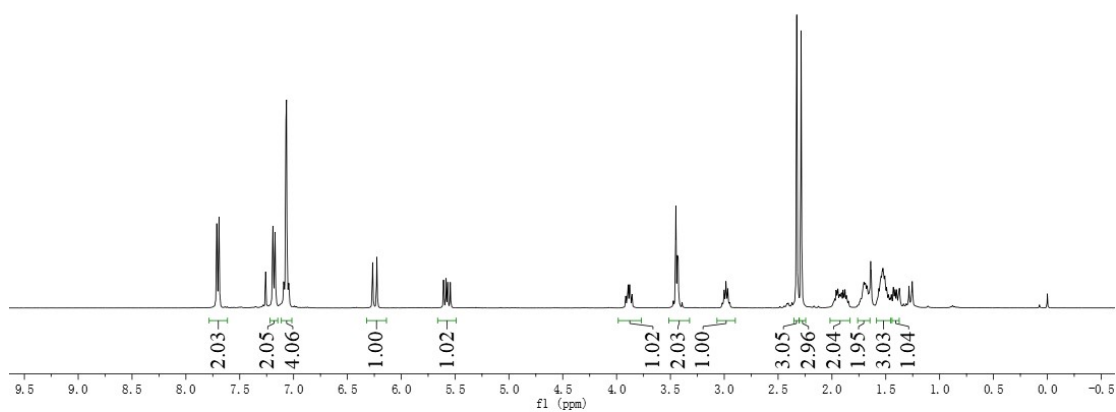


(E)-cyclopentyl(4-(p-tolyl)-1-tosylbut-3-en-2-yl)sulfane (4d)

7.713
7.693
7.259
7.192
7.172
7.092
7.070
7.066
7.044
6.265
6.226
5.607
5.583
5.568
5.544
3.893
3.879
3.450
3.436
3.428
3.002
2.984
2.967
2.327
2.286
1.944
1.897
1.879
1.711
1.703
1.696
1.689
1.676
1.566
1.550
1.544
1.533
1.526
1.509
1.493
1.430
1.413
1.400
1.373

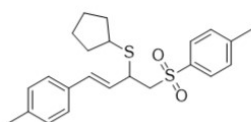


NMR (400 MHz, CDCl₃)

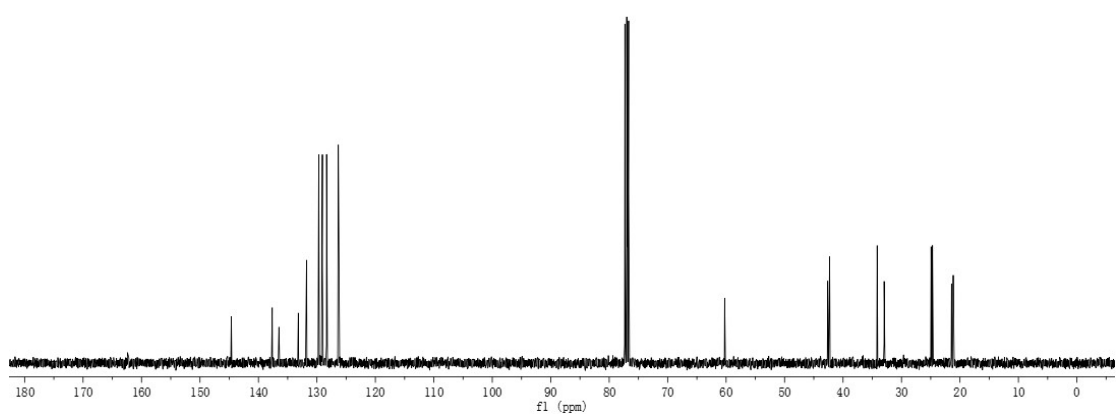


144.641
137.643
136.494
133.181
131.769
129.678
129.064
128.336
126.343
126.183

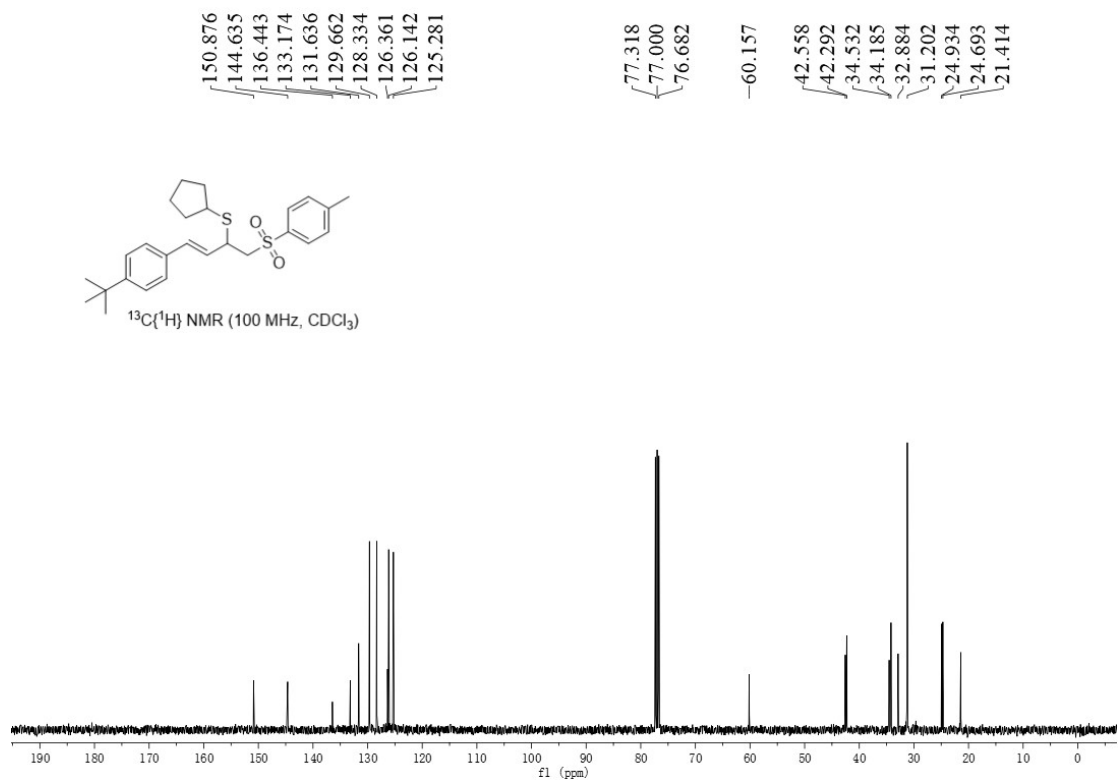
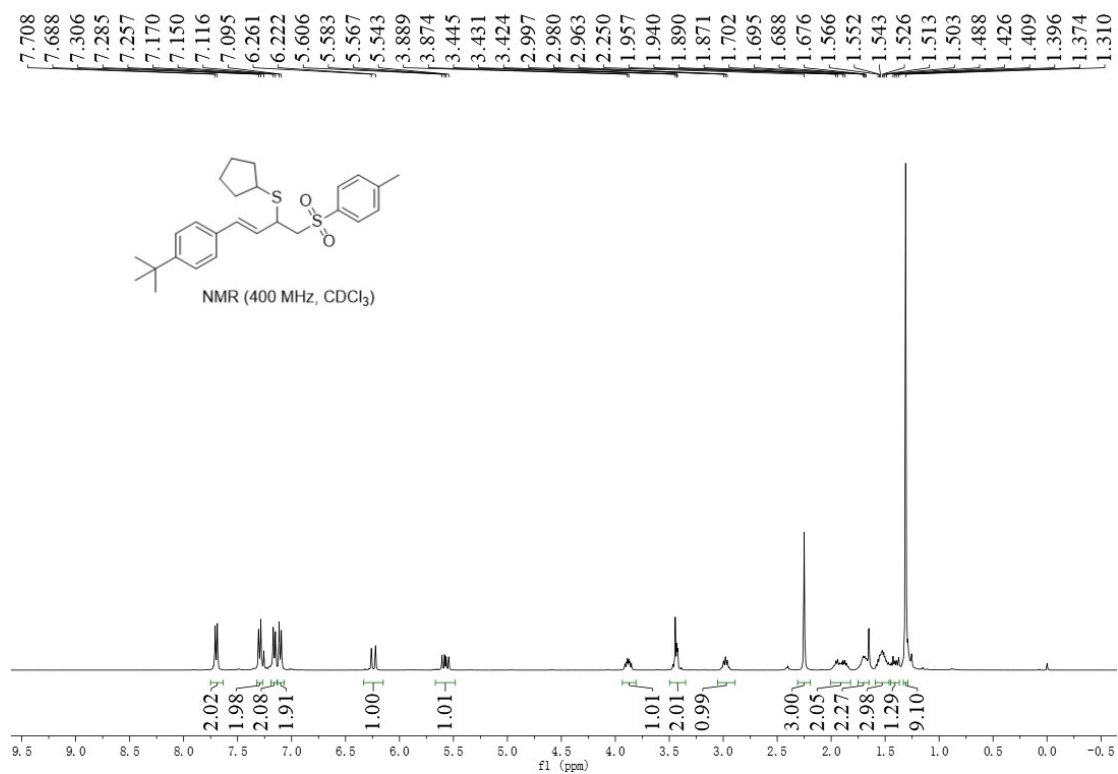
77.317
77.000
76.682
60.246
42.625
42.297
34.158
32.968
24.932
24.700
21.439
21.151



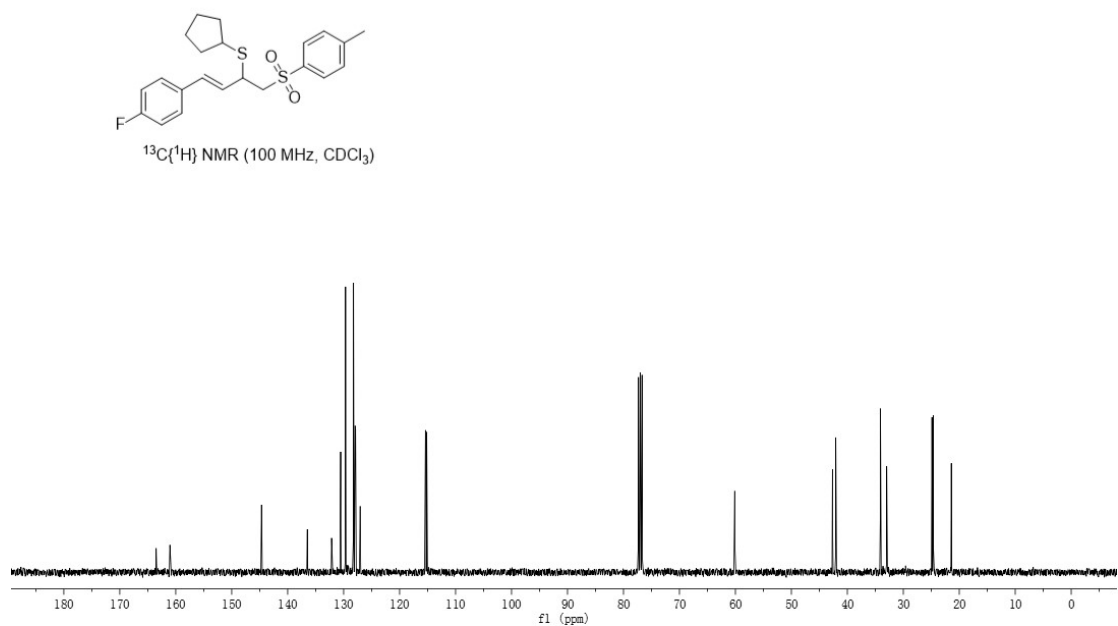
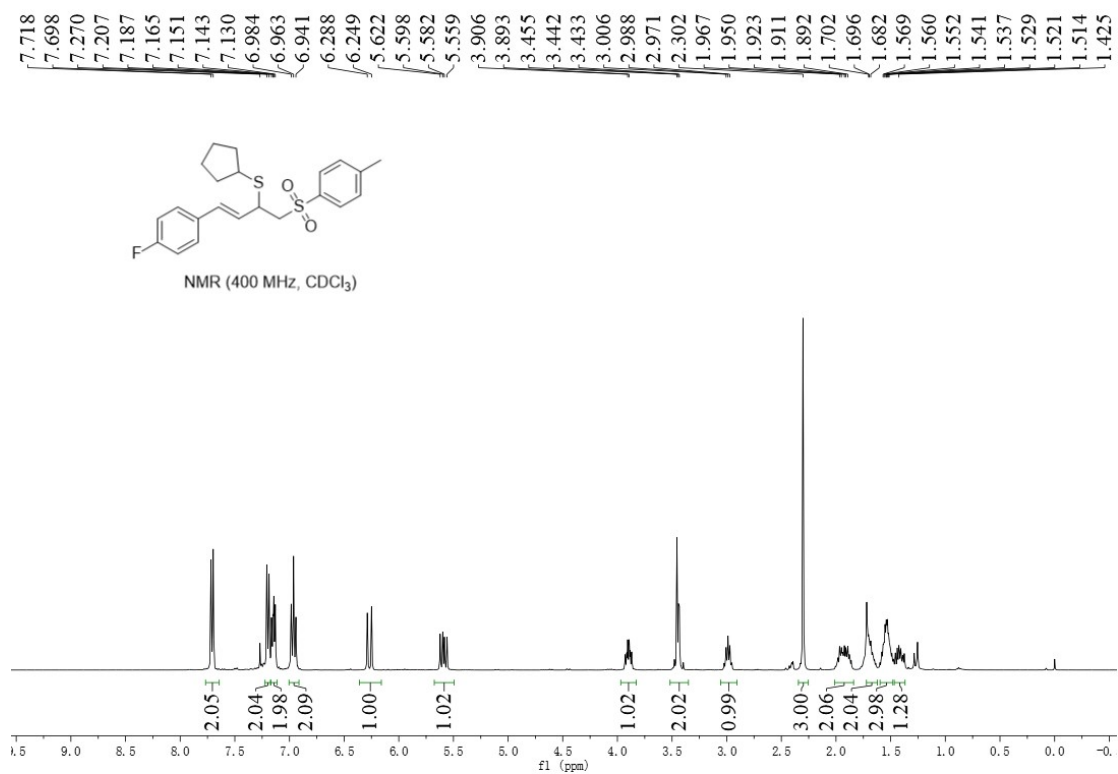
¹³C{¹H} NMR (100 MHz, CDCl₃)

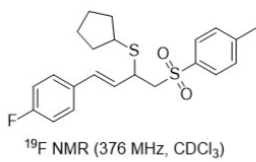


(E)-4-(4-(tert-butyl)phenyl)-1-tosylbut-3-en-2-yl(cyclopentyl)sulfane (4e)

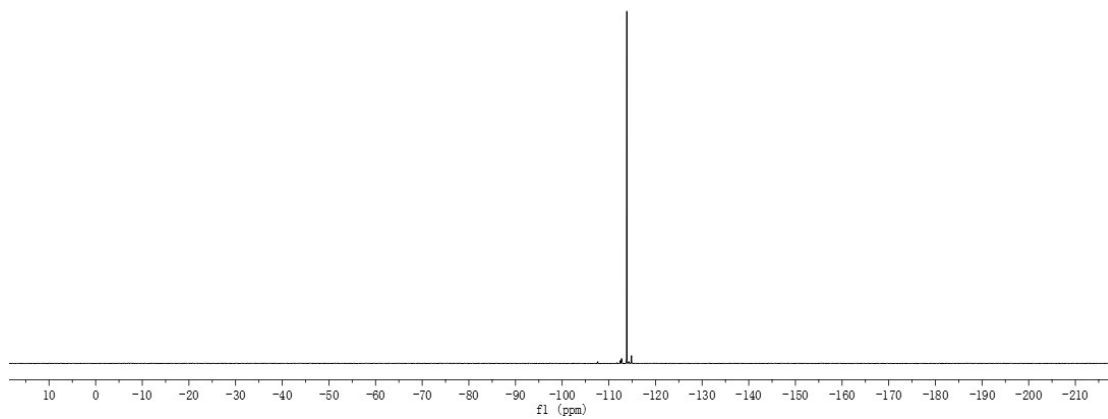


(E)-cyclopentyl(4-(4-fluorophenyl)-1-tosylbut-3-en-2-yl)sulfane (**4f**)



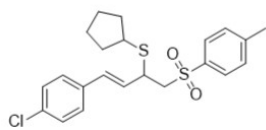


--113.849

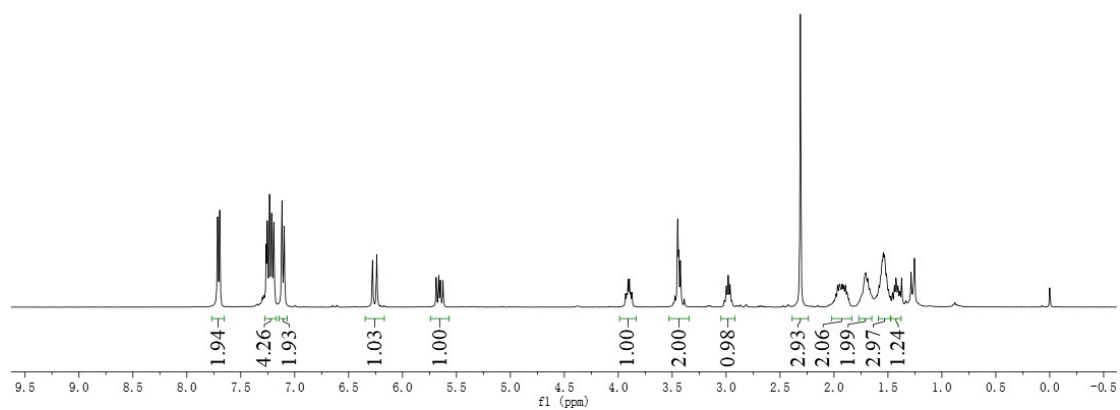


(E)-(4-(4-chlorophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4g**)

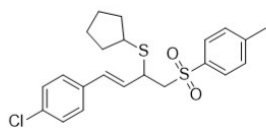
7.715
7.695
7.265
7.254
7.233
7.213
7.193
7.118
7.097
6.278
6.239
5.688
5.664
5.649
5.625
3.909
3.897
3.886
3.449
3.439
3.425
3.425
2.998
2.981
2.964
2.312
2.312
1.967
1.950
1.925
1.912
1.893
1.706
1.686
1.670
1.583
1.553
1.542
1.532
1.514
1.495
1.439
1.426
1.407
1.373
0.000



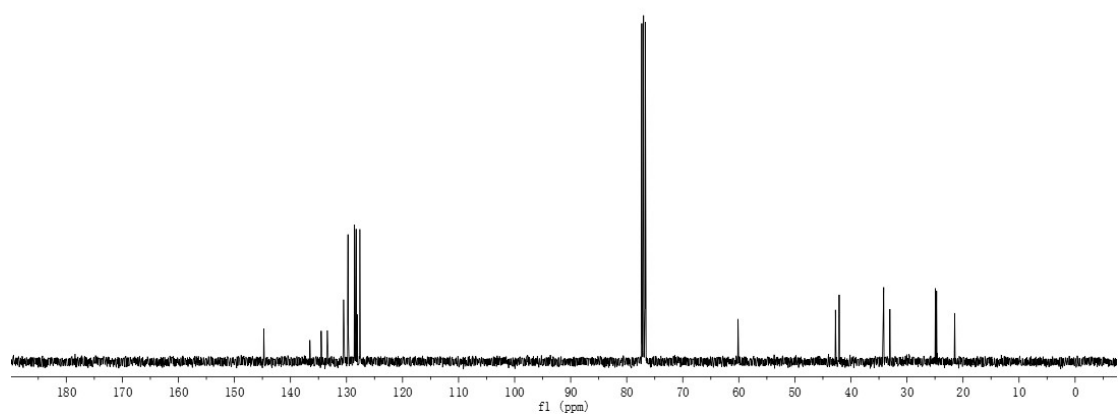
NMR (400 MHz, CDCl₃)



144.763
136.539
134.513
133.425
130.518
129.738
128.571
128.287
128.058
127.615
77.317
77.000
76.682
-60.139
42.758
42.093
34.150
33.043
24.929
24.709
21.482

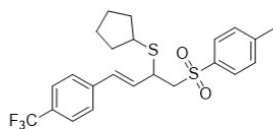


¹³C{¹H} NMR (100 MHz, CDCl₃)

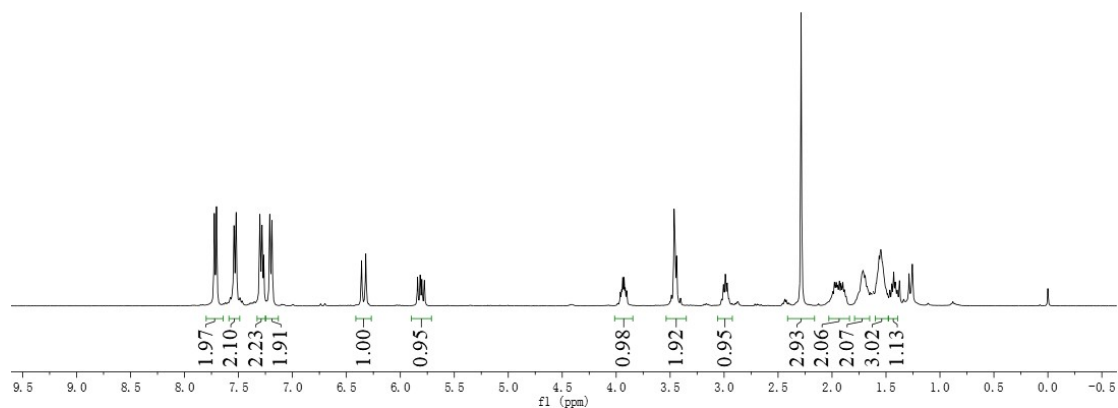


(E)-3-(3-(cyclopentylthio)-4-tosylbut-1-en-1-yl)thiophene (**4h**)

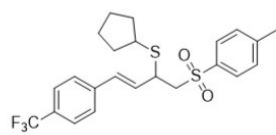
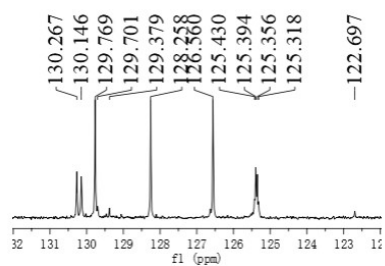
7.724
7.703
7.541
7.521
7.301
7.281
7.266
7.210
7.190
6.359
6.320
5.840
5.816
5.801
5.777
3.949
3.939
3.927
3.916
3.463
3.452
3.440
3.006
2.989
2.972
2.287
1.978
1.961
1.949
1.931
1.918
1.899
1.713
1.693
1.677
1.631
1.563
1.548
1.541
1.500
1.446
1.428
1.414
0.000



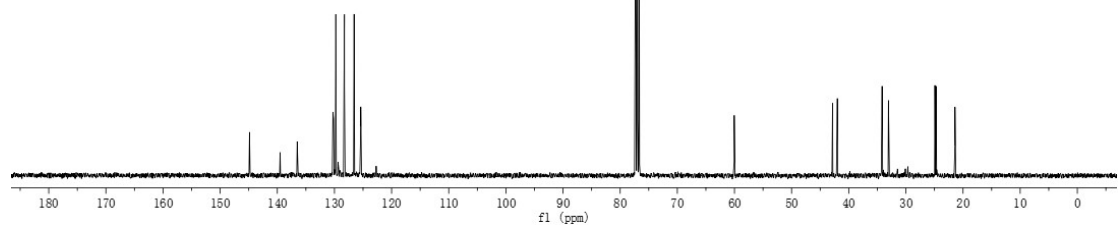
NMR (400 MHz, CDCl₃)



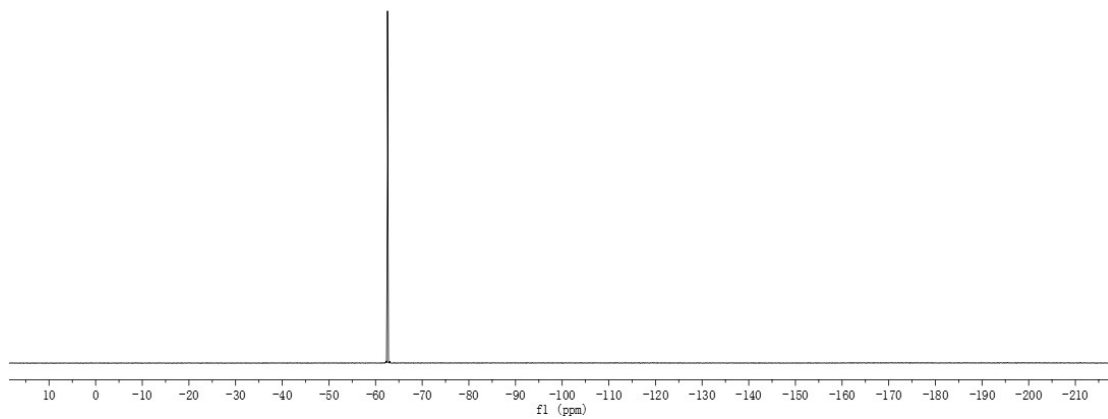
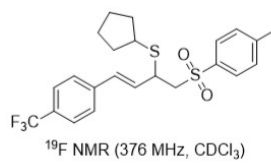
144.864
139.509
136.516
130.267
130.146
130.024
129.769
129.701
129.379
129.058
128.258
126.560
125.430
125.394
125.356
125.318
122.697
77.318
77.000
76.683
60.035
42.832
41.993
34.161
33.056
24.921
24.704
21.410



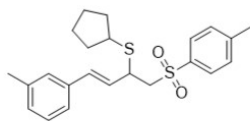
¹³C{¹H} NMR (100 MHz, CDCl₃)



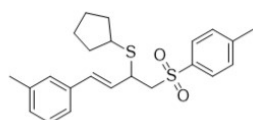
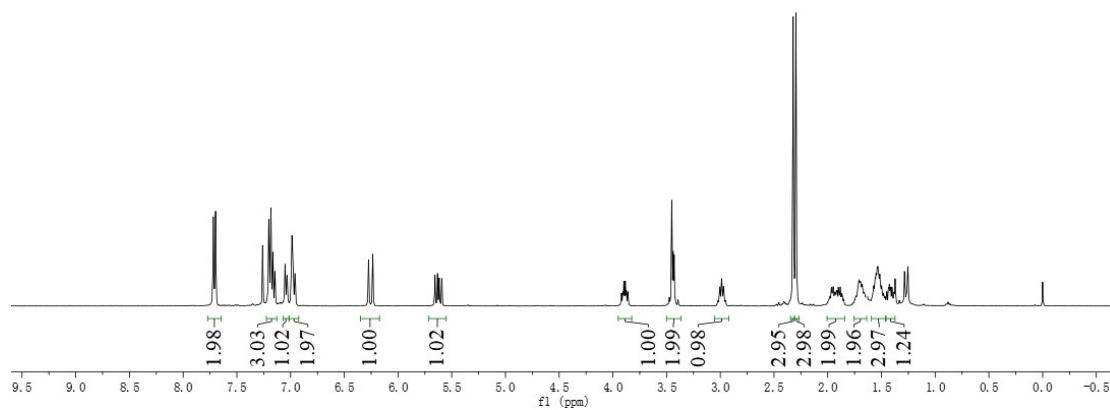
--62.560



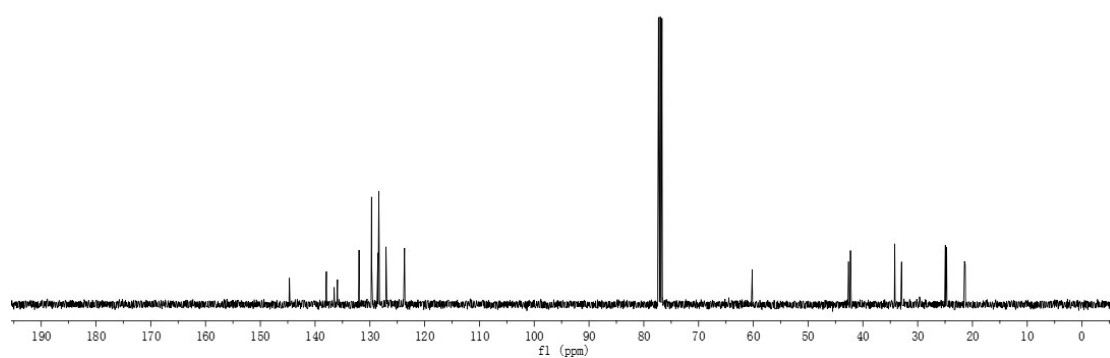
(E)-cyclopentyl(4-(*m*-tolyl)-1-tosylbut-3-en-2-yl)sulfane (**4i**)



NMR (400 MHz, CDCl₃)

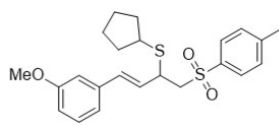


¹³C{¹H} NMR (100 MHz, CDCl₃)

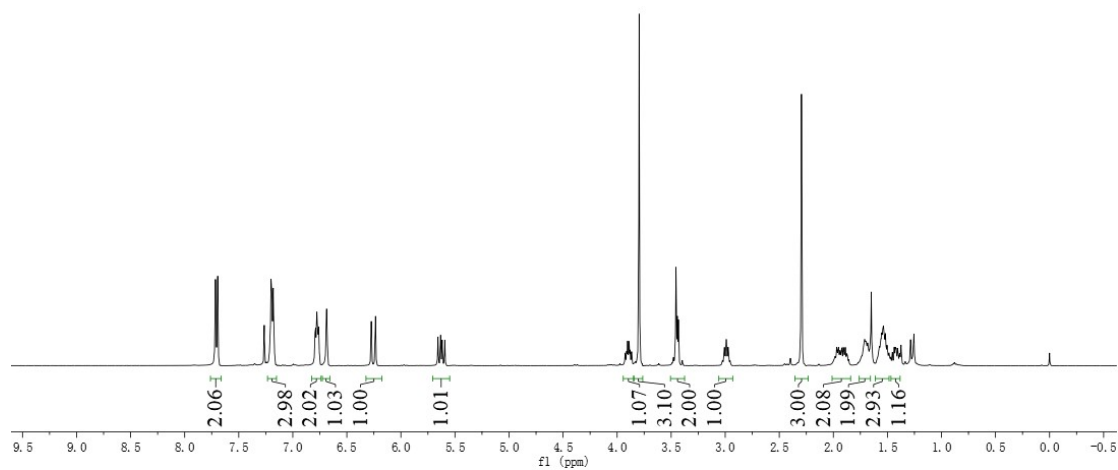


(E)-cyclopentyl(4-(3-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (**4j**)

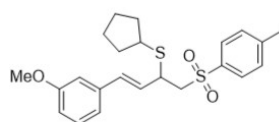
7.715
7.695
7.264
7.211
7.201
7.192
7.181
7.172
6.794
6.788
6.777
6.768
6.760
6.687
6.274
6.235
5.657
5.633
5.618
5.594
3.903
3.889
3.796
3.456
3.443
3.433
2.990
2.973
2.295
1.969
1.952
1.710
1.703
1.698
1.684
1.574
1.560
1.553
1.543
1.536
1.518
1.503
1.437
1.427



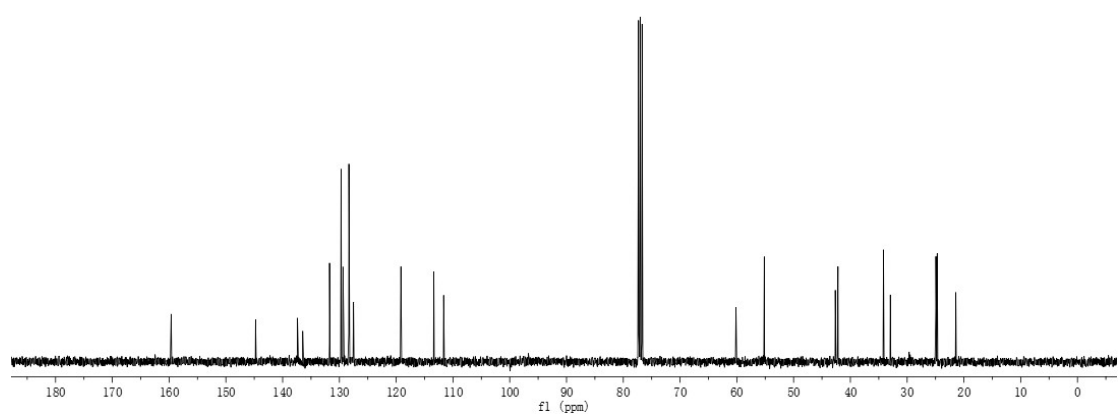
NMR (400 MHz, CDCl₃)



159.634
144.761
137.389
136.464
131.739
129.705
129.371
128.334
127.517
119.171
113.377
111.639
77.318
77.000
76.683
60.151
55.163
42.655
42.186
34.167
32.957
24.936
24.704
21.427

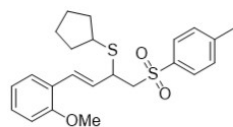


¹³C{¹H} NMR (100 MHz, CDCl₃)

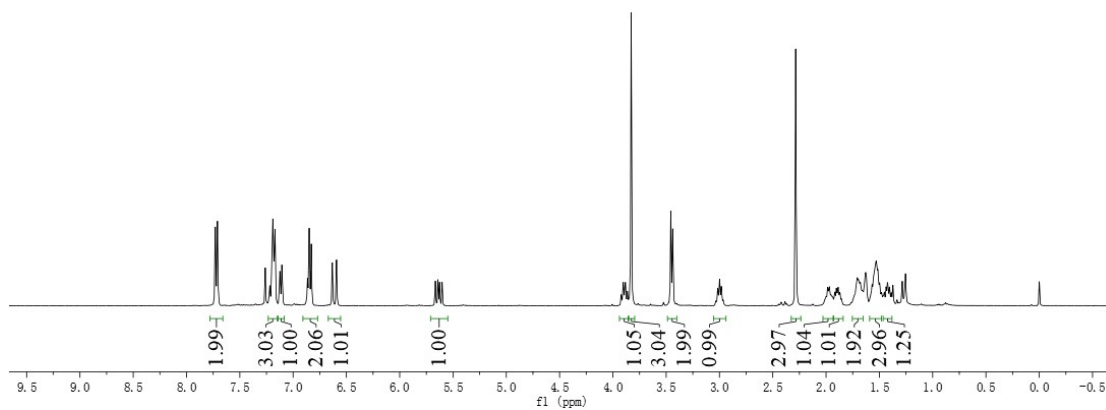


(E)-cyclopentyl(4-(2-methoxyphenyl)-1-tosylbut-3-en-2-yl)sulfane (4k)

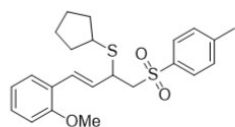
7.730
7.710
7.218
7.190
7.170
7.124
7.106
6.865
6.849
6.829
6.632
6.592
5.665
5.641
5.626
5.602
3.903
3.882
3.863
3.828
3.456
3.439
3.016
2.999
2.982
2.285
1.986
1.969
1.917
1.904
1.886
1.707
1.697
1.679
1.660
1.568
1.529
1.513
1.497
1.453
1.437
1.424
1.405
-0.000



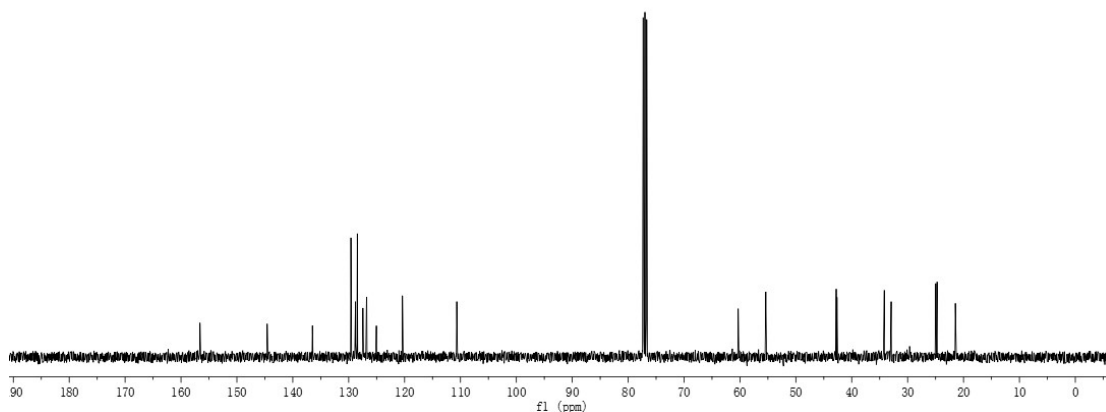
NMR (400 MHz, CDCl₃)



156.604
144.581
136.488
129.603
128.787
128.457
127.456
126.813
126.772
110.381
77.318
77.000
76.682
60.316
55.374
42.776
42.636
34.182
32.941
24.964
24.734
21.461

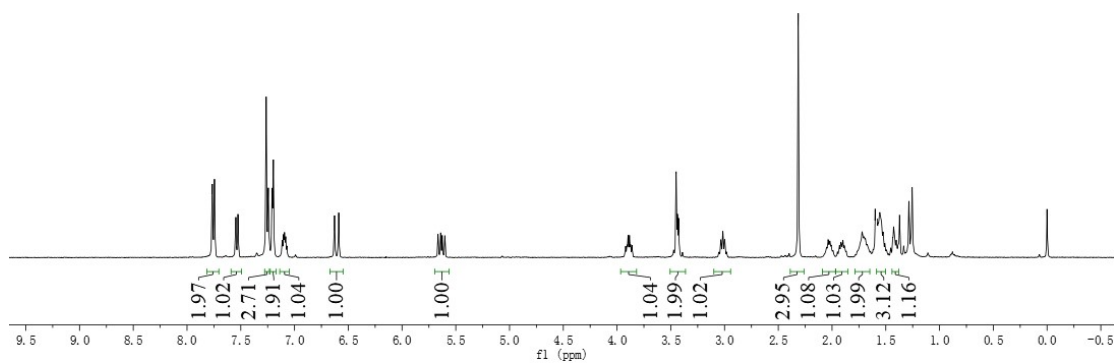
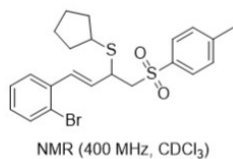


¹³C{¹H} NMR (100 MHz, CDCl₃)

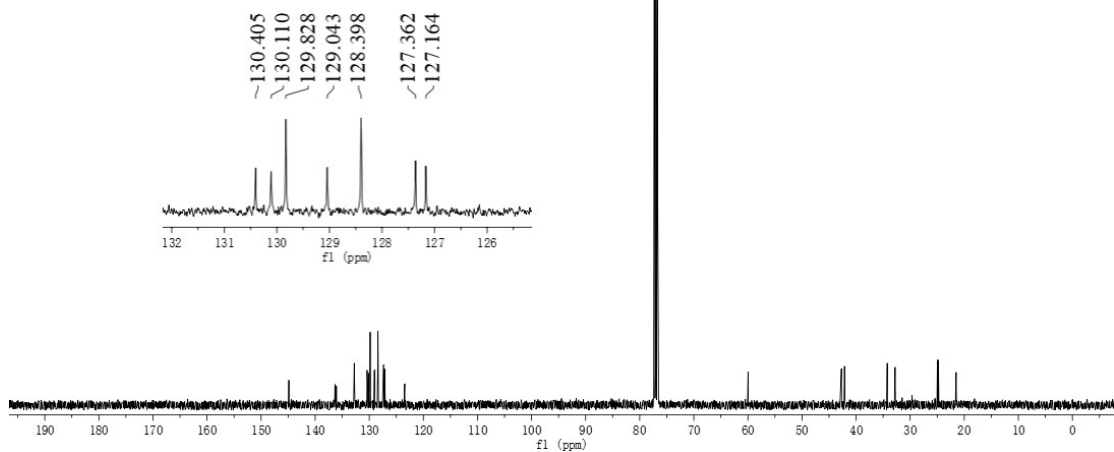
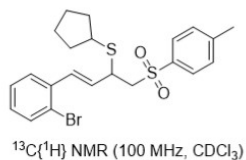


(E)-(4-(2-bromophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4I**)

7.765
7.745
7.546
7.526
7.263
7.244
7.207
7.197
7.114
7.102
7.093
7.082
6.628
6.589
5.665
5.641
5.626
5.602
3.907
3.898
3.885
3.875
3.450
3.438
3.427
3.034
3.016
2.999
2.314
2.036
2.020
2.008
1.930
1.917
1.899
1.721
1.703
1.674
1.556
1.525
1.427
1.403
1.385
0.000

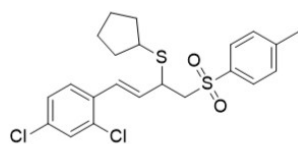


144.873
136.347
136.081
132.781
130.405
130.110
129.828
129.043
128.398
127.362
127.164
123.441
77.317
77.000
76.682
-59.969
42.708
42.142
34.241
33.106
32.782
24.964
24.772
21.501

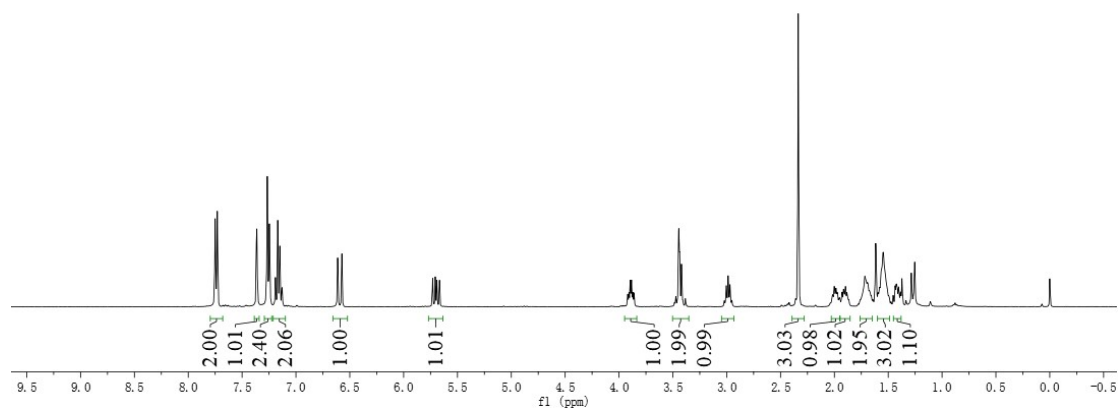


(E)-cyclopentyl(4-(2,4-dichlorophenyl)-1-tosylbut-3-en-2-yl)sulfane (**4m**)

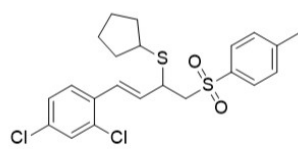
7.750
7.730
7.363
7.266
7.247
7.190
7.169
7.150
7.128
6.613
6.574
5.730
5.706
5.667
3.908
3.896
3.884
3.872
3.445
3.437
3.420
3.004
2.987
2.969
2.336
2.001
1.985
1.973
1.928
1.915
1.897
1.884
1.717
1.693
1.674
1.594
1.581
1.549
1.436
1.426
1.403
1.385
0.000



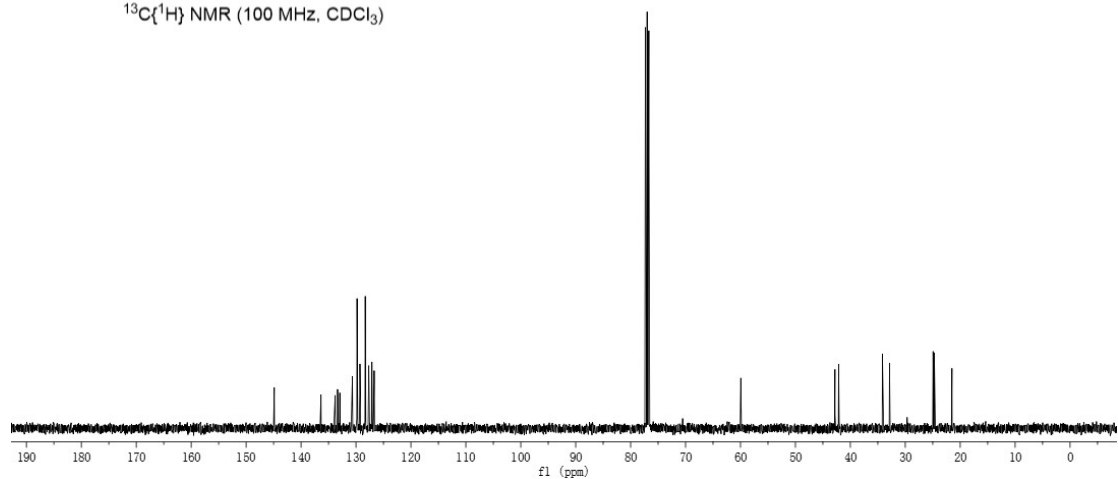
NMR (400 MHz, CDCl₃)



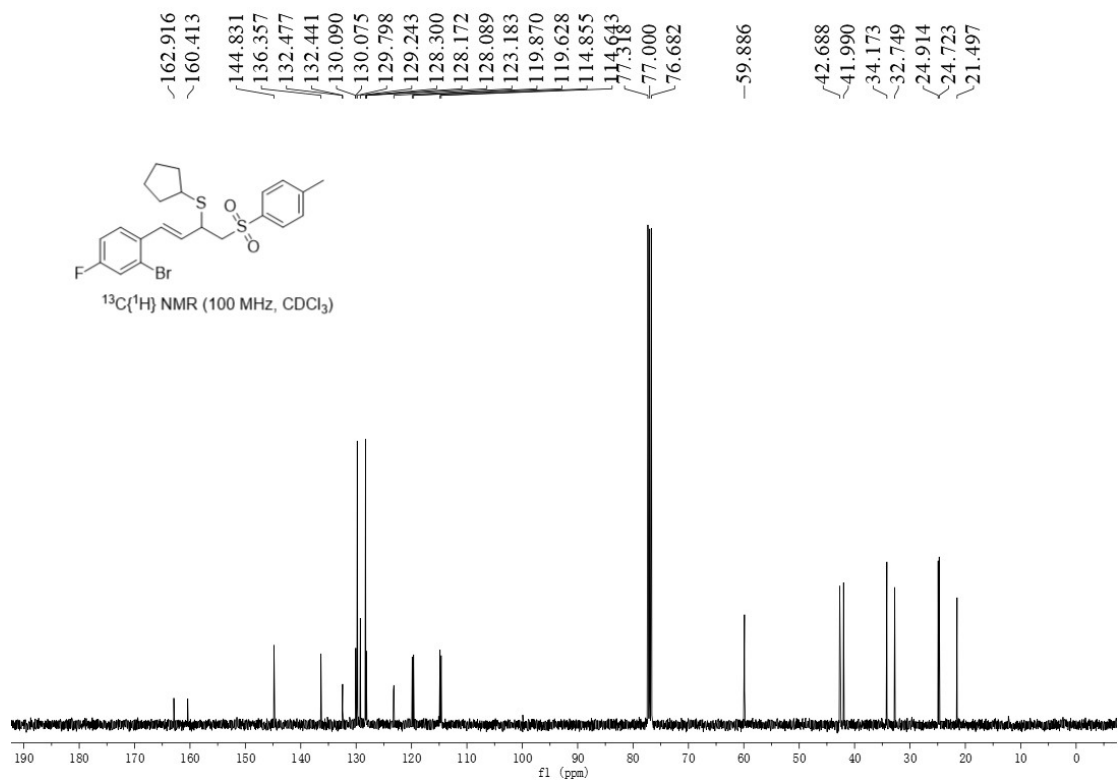
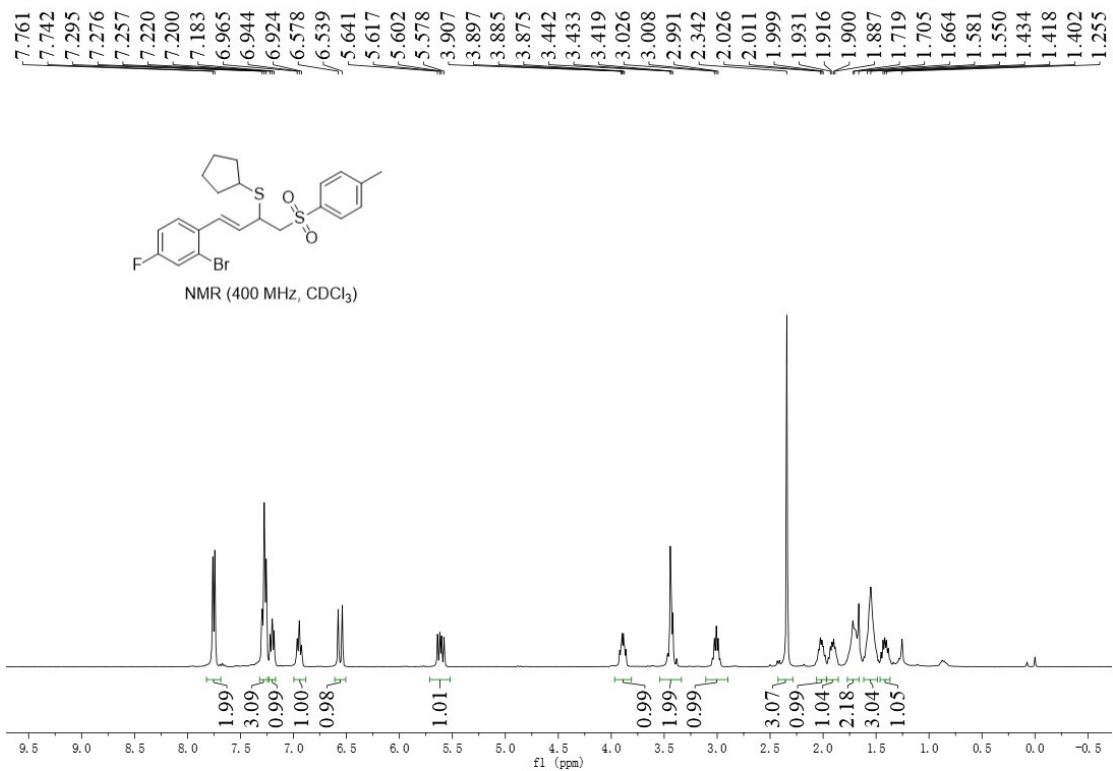
144.876
136.372
133.786
133.352
132.952
130.653
129.811
129.278
128.316
127.669
127.101
126.691
77.318
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76.683
59.946
42.800
42.132
34.161
32.870
24.935
24.723
21.502

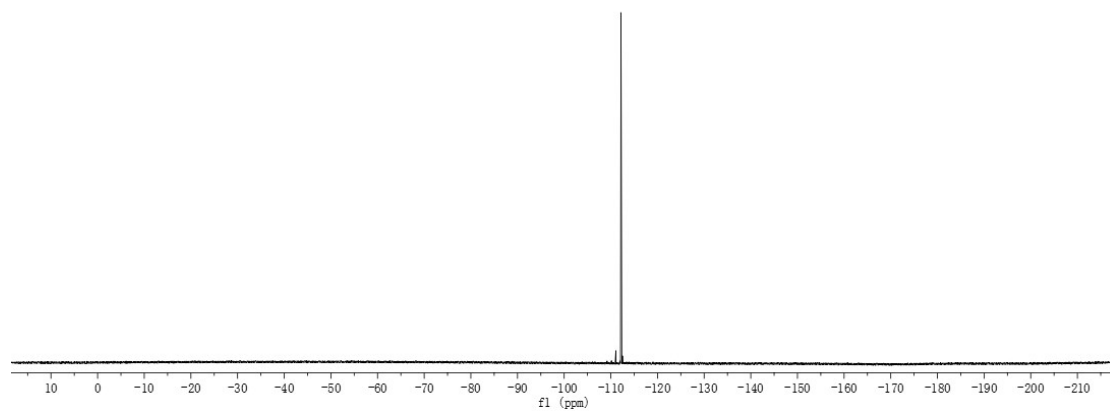
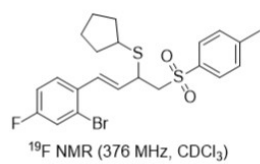


¹³C{¹H} NMR (100 MHz, CDCl₃)



(E)-(4-(2-bromo-4-fluorophenyl)-1-tosylbut-3-en-2-yl)(cyclopentyl)sulfane (**4n**)

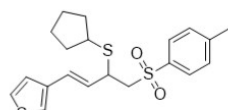




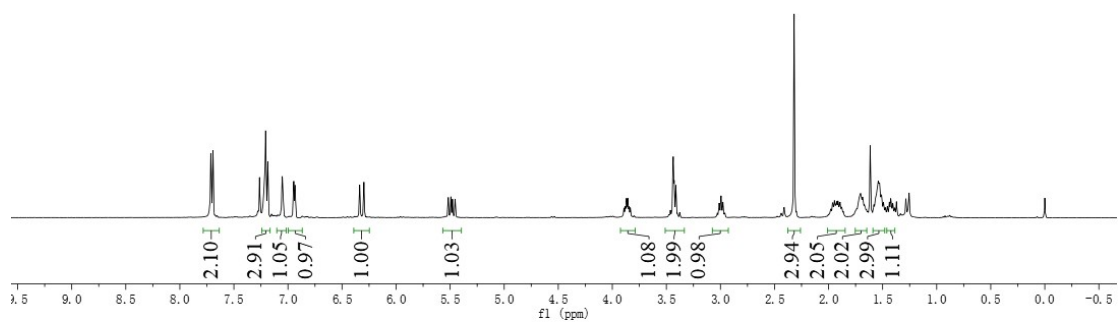
-112.179

(E)-3-(3-(cyclopentylthio)-4-tosylbut-1-en-1-yl)thiophene (**4o**)

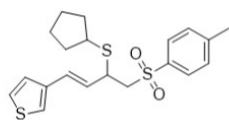
7.714
7.694
7.263
7.225
7.206
7.187
7.053
6.946
6.934
6.336
6.297
5.517
5.493
5.478
5.454
3.880
3.869
3.857
3.846
3.437
3.428
3.413
3.012
2.994
2.977
2.977
1.964
1.946
1.925
1.913
1.894
1.881
1.704
1.685
1.669
1.581
1.540
1.531
1.511
1.493
1.456
1.438
1.425
1.406
0.000



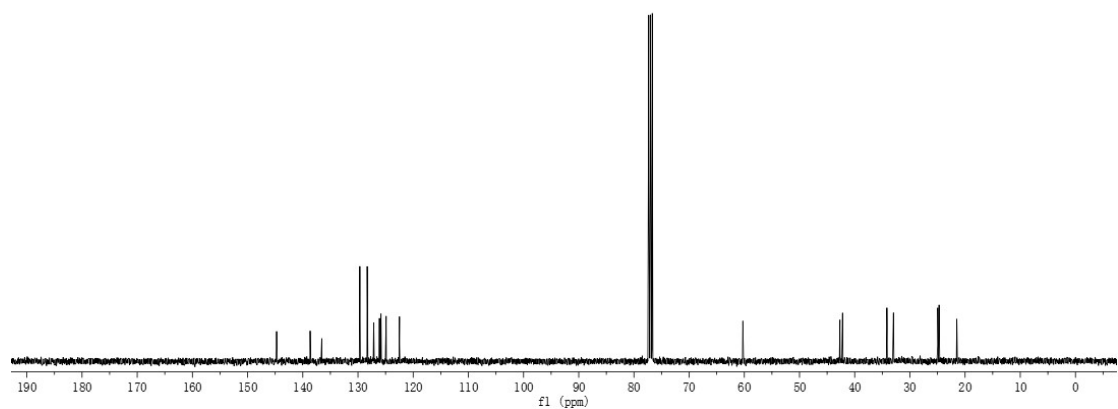
NMR (400 MHz, CDCl₃)



144.745
138.667
136.565
129.659
128.330
127.149
126.117
125.830
124.893
122.479
77.318
77.000
76.683
60.266
42.675
42.200
34.162
32.979
24.941
24.716
21.499

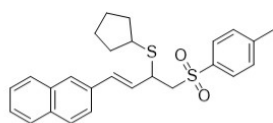


¹³C{¹H} NMR (100 MHz, CDCl₃)

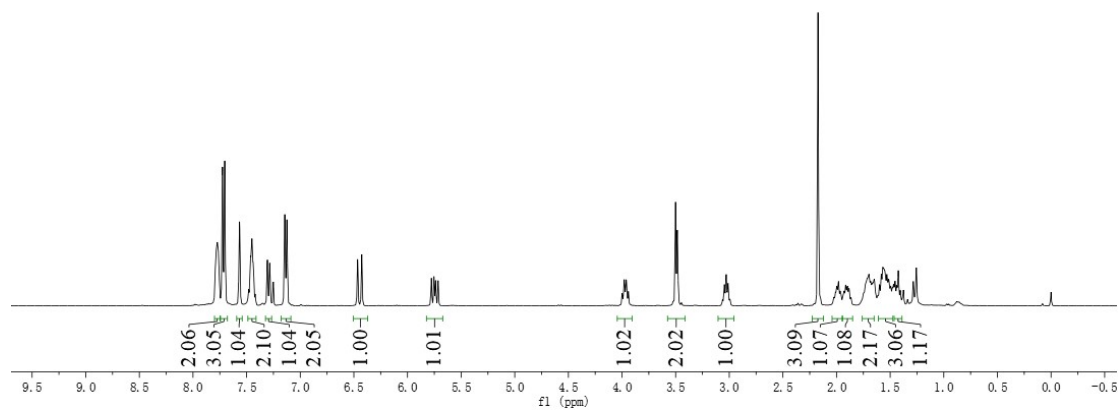


(E)-cyclopentyl(4-(naphthalen-2-yl)-1-tosylbut-3-en-2-yl)sulfane (**4p**)

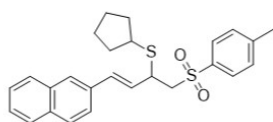
7.773
7.725
7.704
7.566
7.463
7.450
7.306
7.285
7.251
7.144
7.124
6.465
6.426
5.777
5.753
5.738
5.714
3.979
3.961
3.501
3.484
3.045
3.028
3.011
2.173
2.198
1.981
1.915
1.898
1.698
1.682
1.666
1.649
1.599
1.583
1.568
1.530
1.514
1.495
1.480
1.468
1.454
1.438
1.424



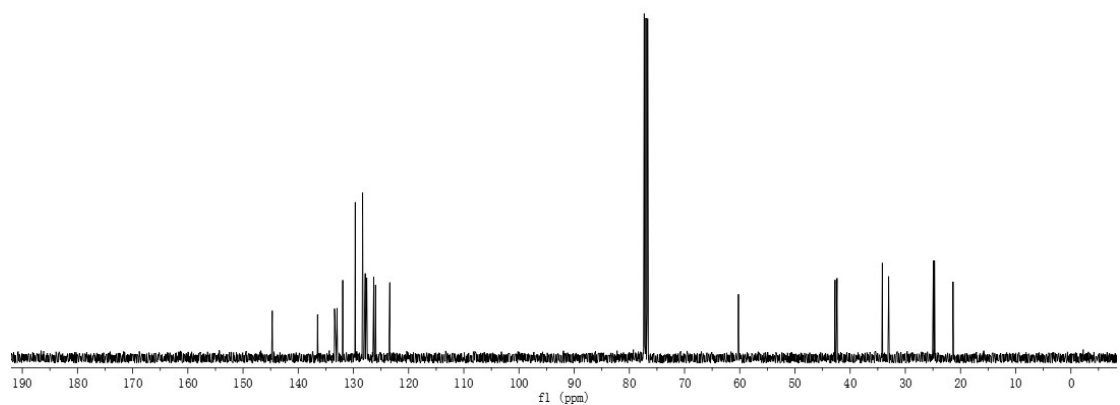
NMR (400 MHz, CDCl₃)



144.695
136.504
133.422
133.360
132.968
131.935
129.678
128.327
127.957
127.862
127.642
127.575
126.423
126.314
126.001
123.417
77.318
77.000
76.682
-60.234
42.730
42.367
34.176
33.017
24.925
24.706
21.350

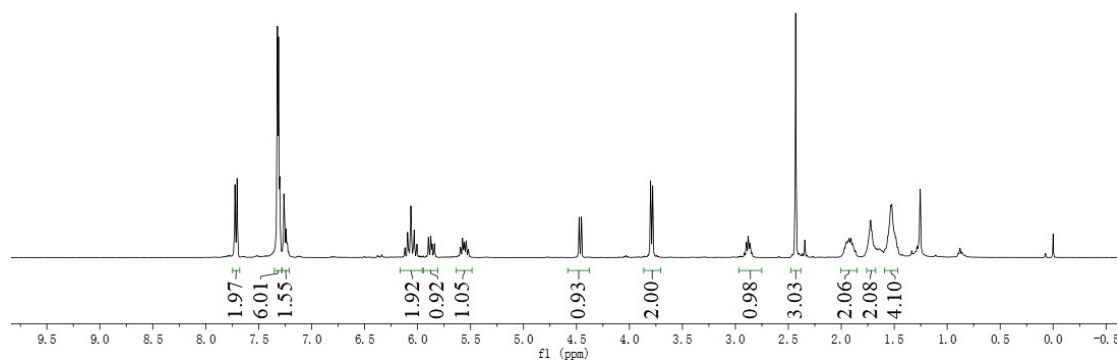
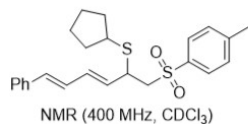


¹³C{¹H} NMR (100 MHz, CDCl₃)

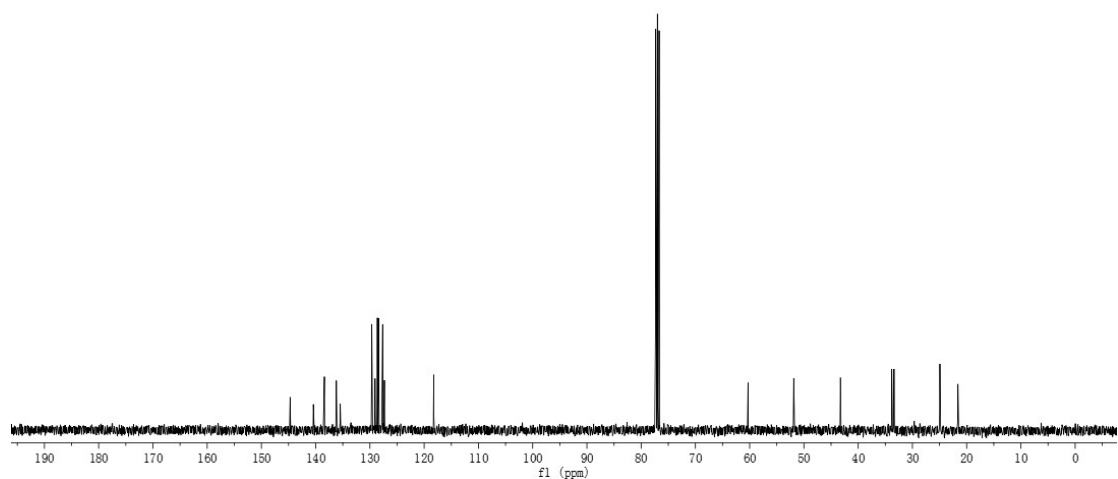
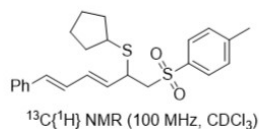


Cyclopentyl((3*E*,5*E*)-6-phenyl-1-tosylhexa-3,5-dien-2-yl)sulfane (**4q**)

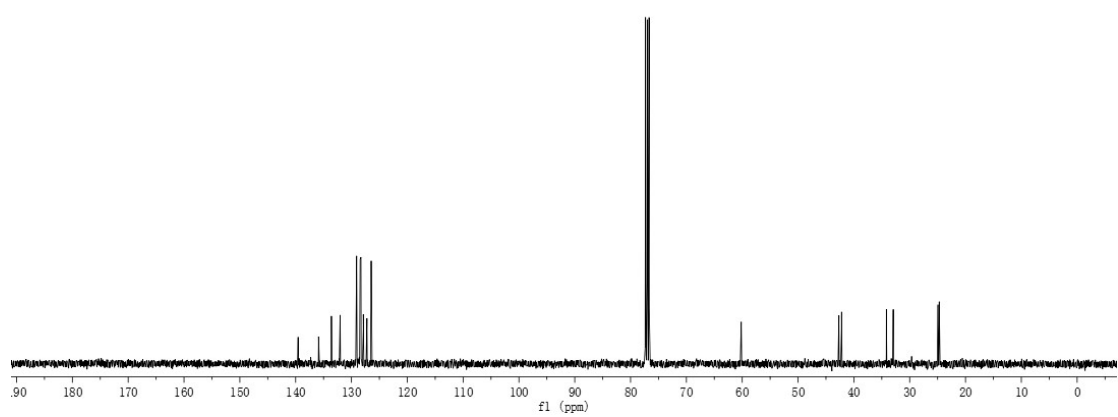
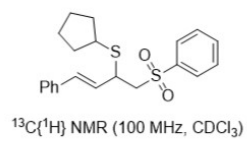
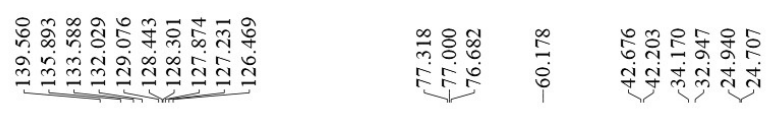
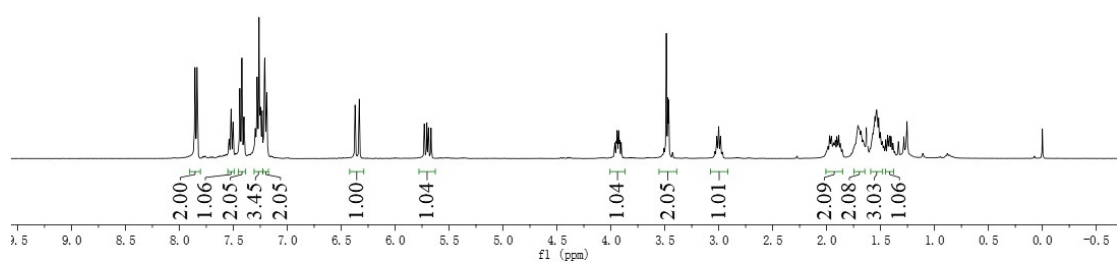
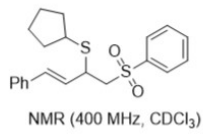
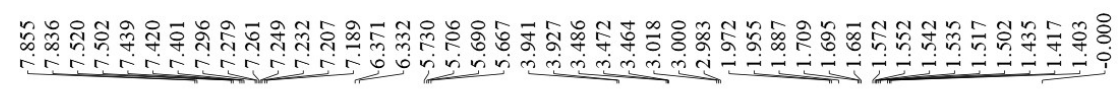
7.724
7.704
7.323
7.313
7.302
7.262
7.252
7.241
7.231
6.120
6.094
6.084
6.063
6.032
6.006
5.897
5.875
5.862
5.840
5.595
5.576
5.558
5.540
5.521
4.475
4.453
3.801
3.781
2.896
2.879
2.861
2.431
1.970
1.950
1.938
1.926
1.909
1.894
1.866
1.723
1.534
1.524
1.485
0.000



144.702
140.423
138.389
136.185
135.468
129.658
128.626
128.400
127.649
127.322
118.233
77.318
77.000
76.683
60.298
51.873
43.265
33.811
33.390
24.933
24.843
21.616

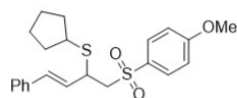


(*E*)-cyclopentyl(4-phenyl-1-(phenylsulfonyl)but-3-en-2-yl)sulfane (**4r**)

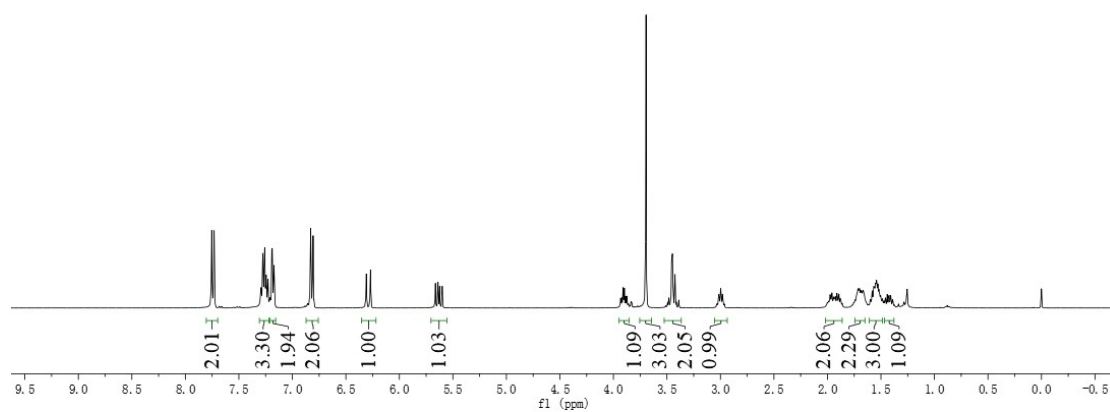


(E)-cyclopentyl(1-((4-methoxyphenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4s**)

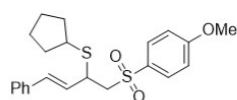
7.753
7.748
7.746
7.736
7.731
7.293
7.277
7.272
7.264
7.258
7.249
7.245
7.241
7.228
7.192
7.188
7.172
6.829
6.824
6.811
6.806
6.309
6.270
5.663
5.639
5.624
5.600
3.909
3.897
3.695
3.456
3.448
3.425
2.998
1.715
1.706
1.700
1.567
1.559
1.552
1.547
1.541
1.528
1.519
0.000



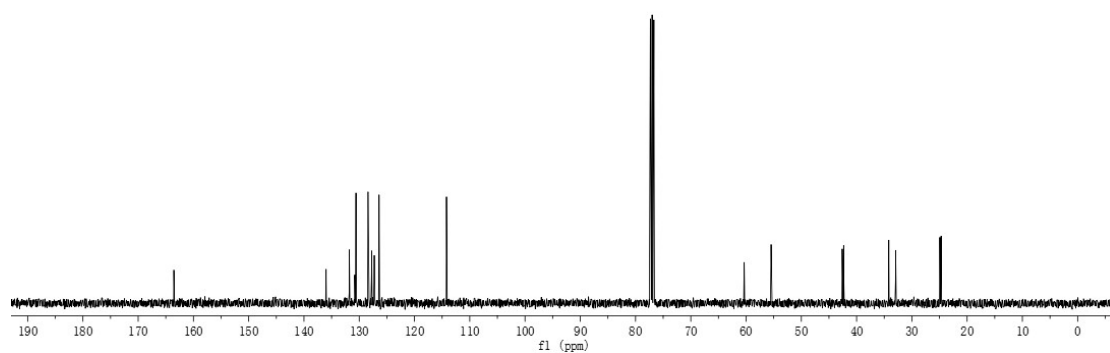
NMR (400 MHz, CDCl₃)



163.543
135.998
131.796
130.803
130.587
128.407
127.757
127.280
126.410
114.209
77.318
77.000
76.682
60.339
55.469
42.601
42.340
34.176
32.937
24.933
24.702

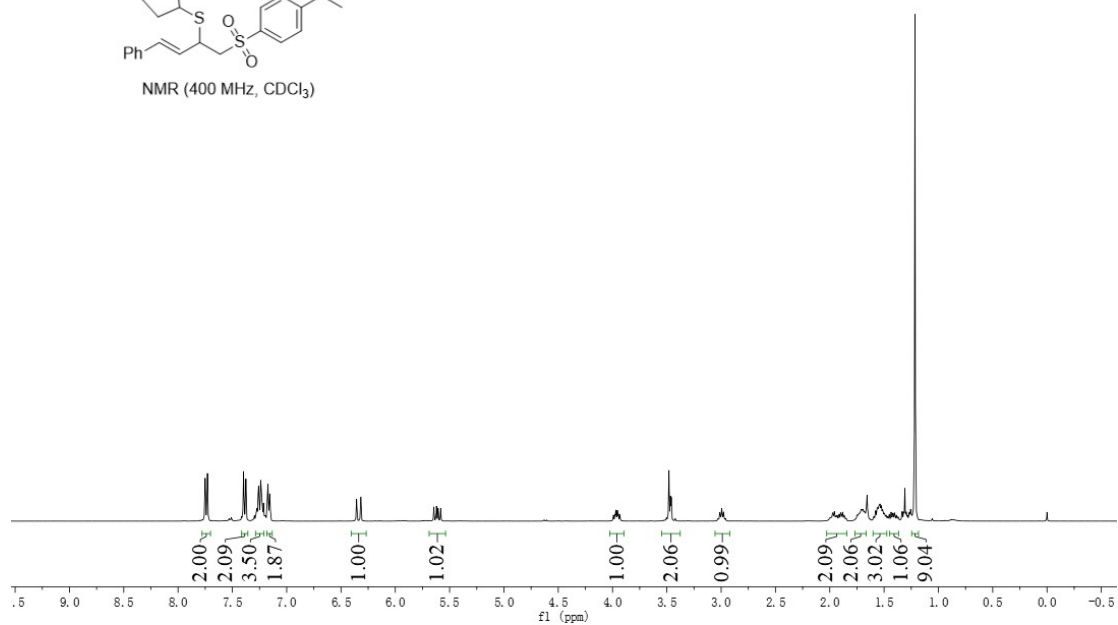
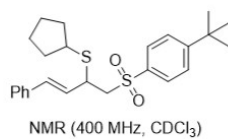


¹³C{¹H} NMR (100 MHz, CDCl₃)

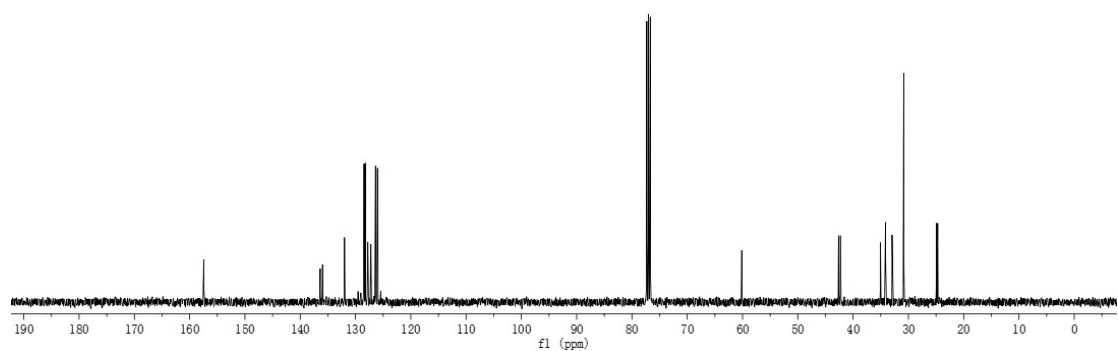
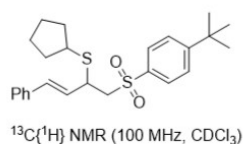


(E)-1-((4-(*tert*-butyl)phenyl)sulfonyl)-4-phenylbut-3-en-2-yl)(cyclopentyl)sulfane (**4t**)

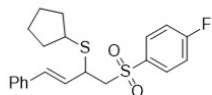
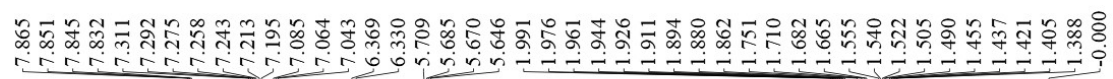
7.751
7.729
7.397
7.376
7.279
7.274
7.261
7.258
7.239
7.230
7.213
7.176
7.172
7.156
6.356
6.317
5.645
5.621
5.606
5.582
3.969
3.955
3.481
3.467
3.459
3.012
2.995
2.978
1.957
1.882
1.710
1.702
1.695
1.683
1.578
1.564
1.555
1.543
1.538
1.525
1.515
1.435
1.216
0.000



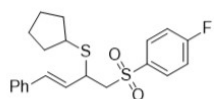
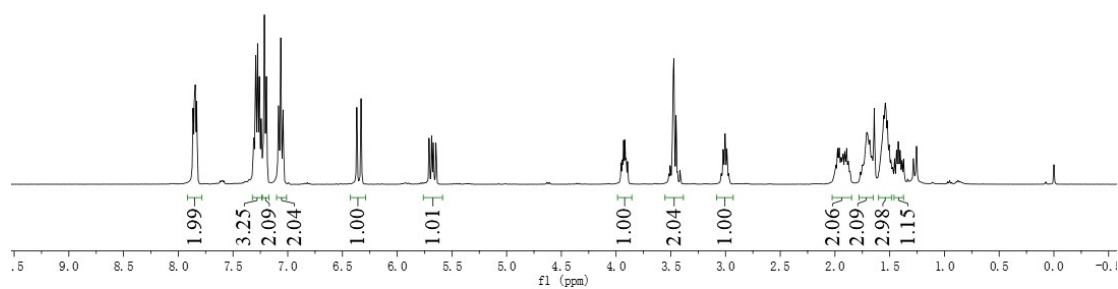
157.448
136.386
135.958
131.987
128.456
128.225
127.774
127.217
126.377
126.021
77.318
77.000
76.683
60.139
42.626
42.295
35.050
34.144
32.954
30.843
24.929
24.698



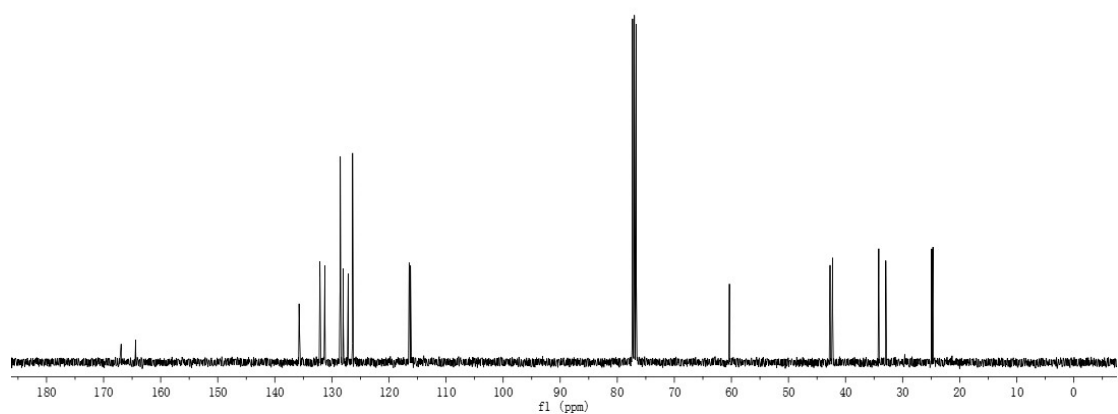
(E)-cyclopentyl(1-((4-fluorophenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4u**)

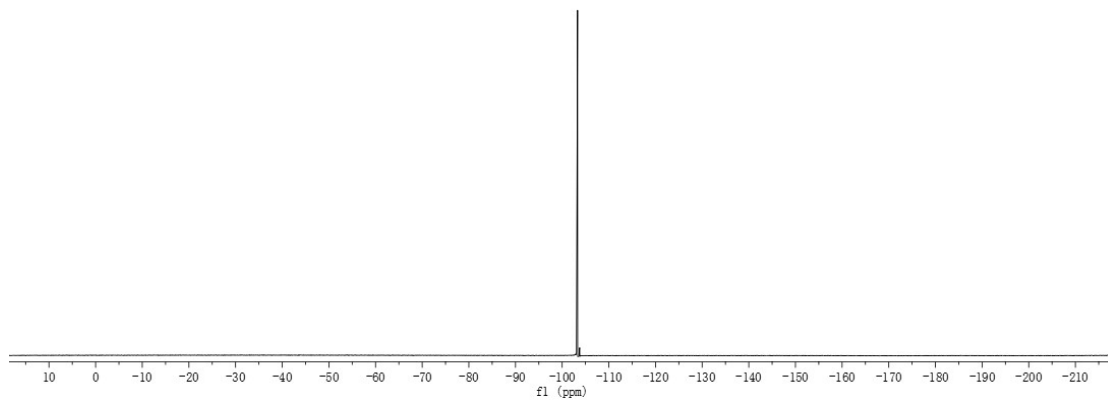
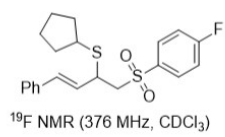


NMR (400 MHz, CDCl₃)

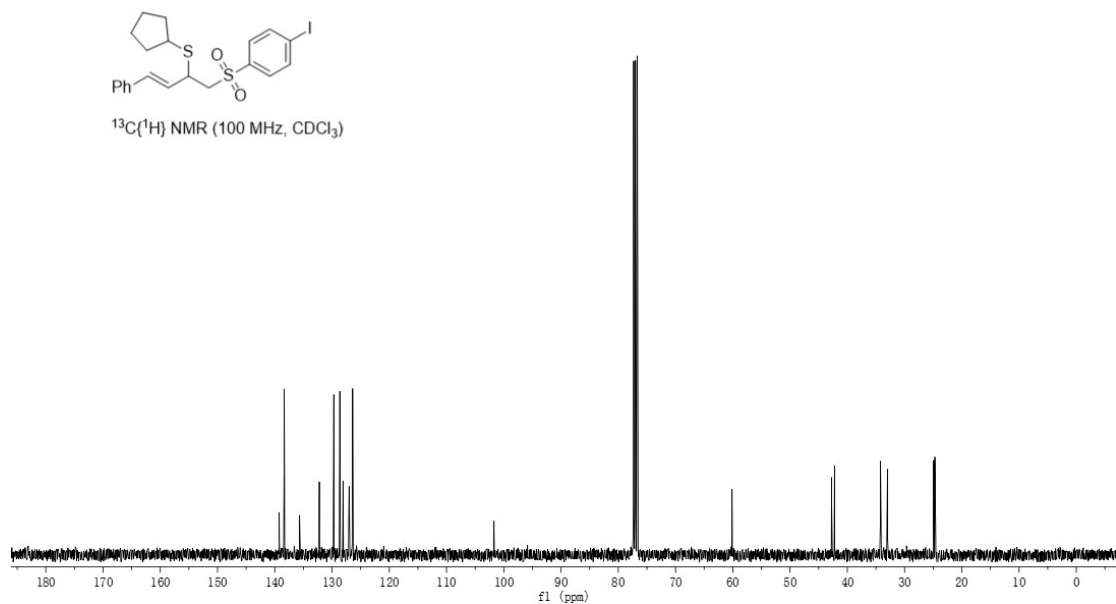
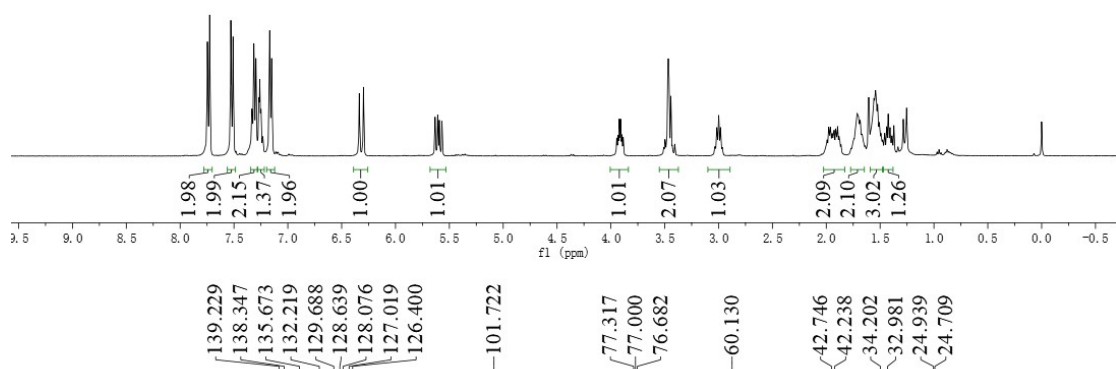
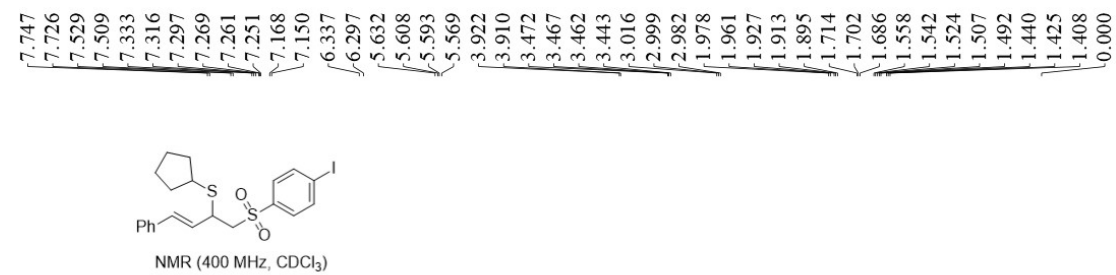


¹³C{¹H} NMR (100 MHz, CDCl₃)

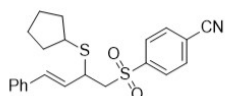
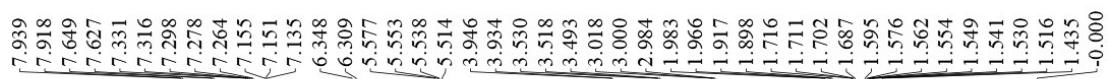




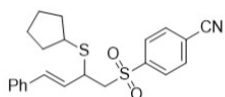
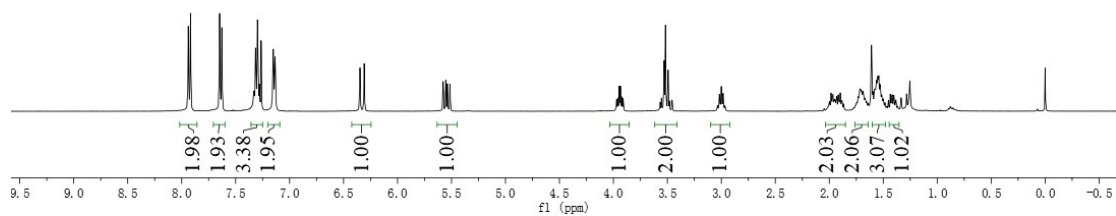
(E)-cyclopentyl(1-((4-iodophenyl)sulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4v**)



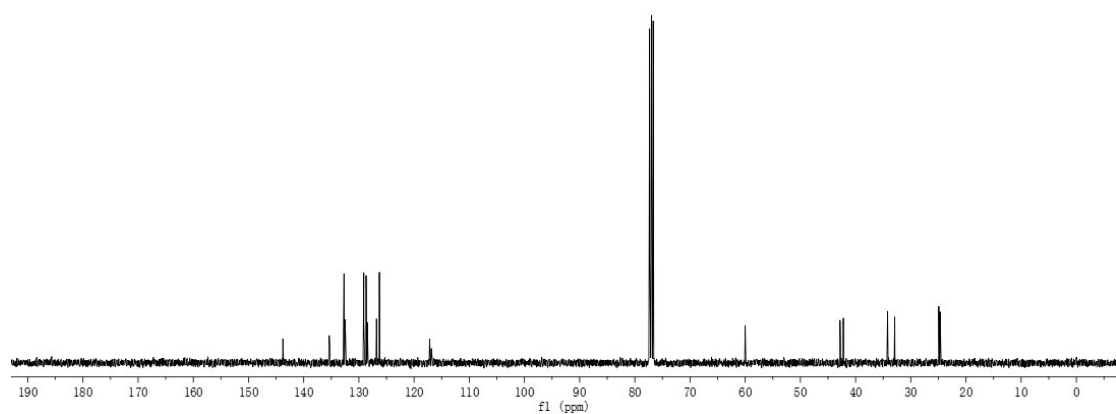
(E)-4-((2-(cyclopentylthio)-4-phenylbut-3-en-1-yl)sulfonyl)benzonitrile (**4w**)



NMR (400 MHz, CDCl₃)

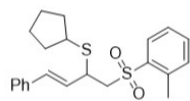


¹³C{¹H} NMR (100 MHz, CDCl₃)

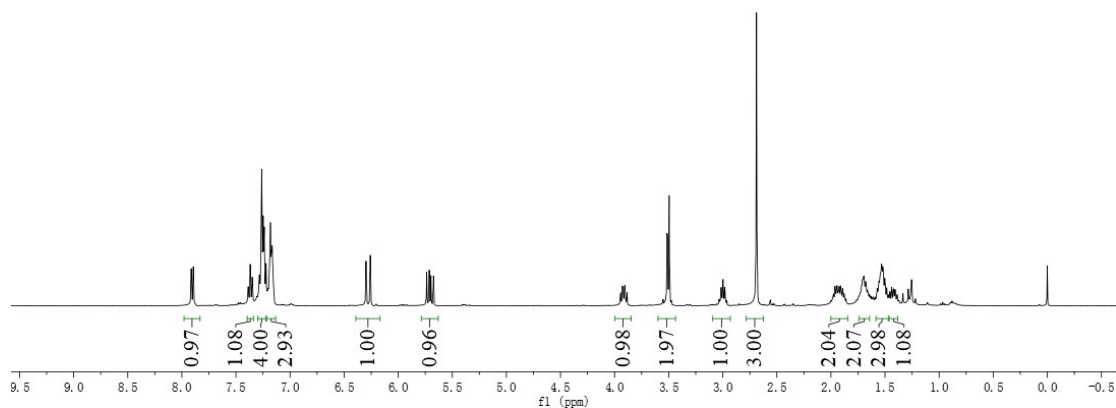


(E)-cyclopentyl(4-phenyl-1-(o-tolylsulfonyl)but-3-en-2-yl)sulfane (4x)

7.914
7.911
7.894
7.891
7.368
7.365
7.349
7.346
7.288
7.283
7.279
7.266
7.261
7.248
7.242
7.238
7.185
7.181
7.174
7.165
7.155
6.297
6.258
6.257
5.737
5.713
5.698
5.674
3.905
3.515
3.511
3.495
2.998
2.688
1.710
1.704
1.696
1.679
1.556
1.544
1.532
1.521
1.517
1.502
0.000



NMR (400 MHz, CDCl₃)

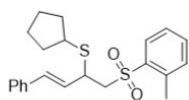


137.699
137.631
135.950
133.591
132.538
132.011
130.639
128.403
127.828
127.137
126.453

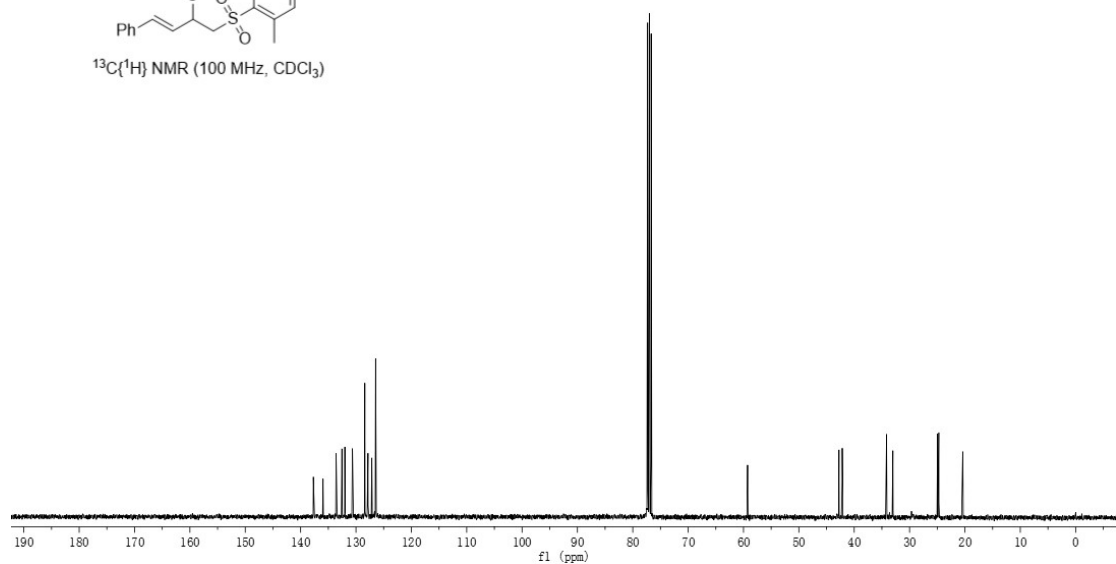
77.317
77.000
76.682

-59.258

42.749
42.159
34.156
33.013
24.946
24.715
20.385

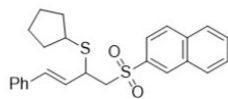


¹³C{¹H} NMR (100 MHz, CDCl₃)

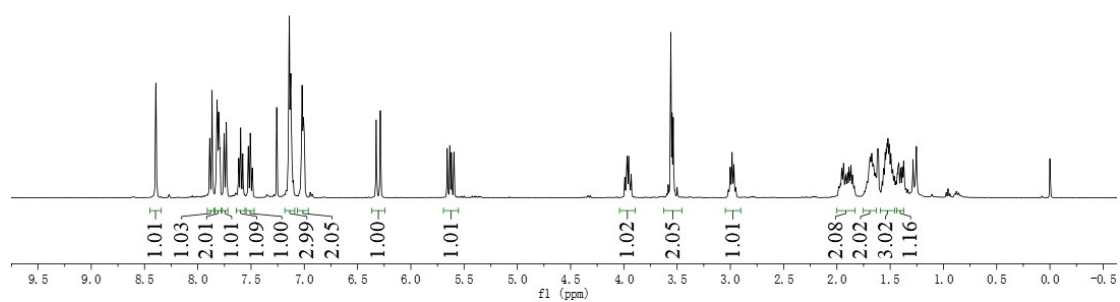


(E)-cyclopentyl(1-(naphthalen-2-ylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (4y)

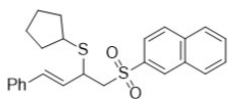
8.393
7.888
7.866
7.824
7.819
7.814
7.804
7.798
7.793
7.753
7.732
7.615
7.598
7.578
7.526
7.508
7.259
7.140
7.131
7.126
7.024
7.021
7.008
7.002
6.325
6.286
5.658
5.634
5.619
5.595
3.968
3.955
3.559
3.547
3.536
2.984
1.687
1.673
1.547
1.537
1.529
1.520
1.506
1.493



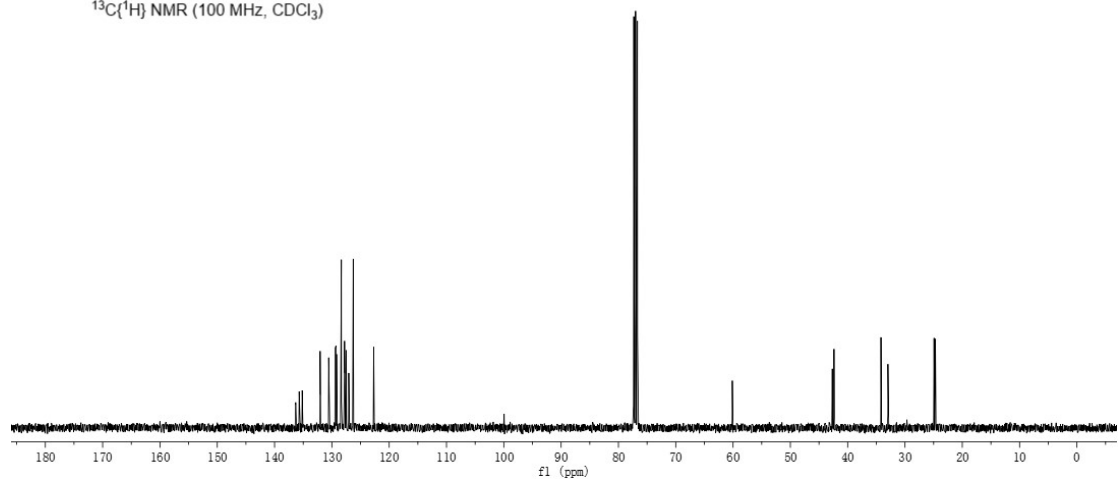
NMR (400 MHz, CDCl₃)



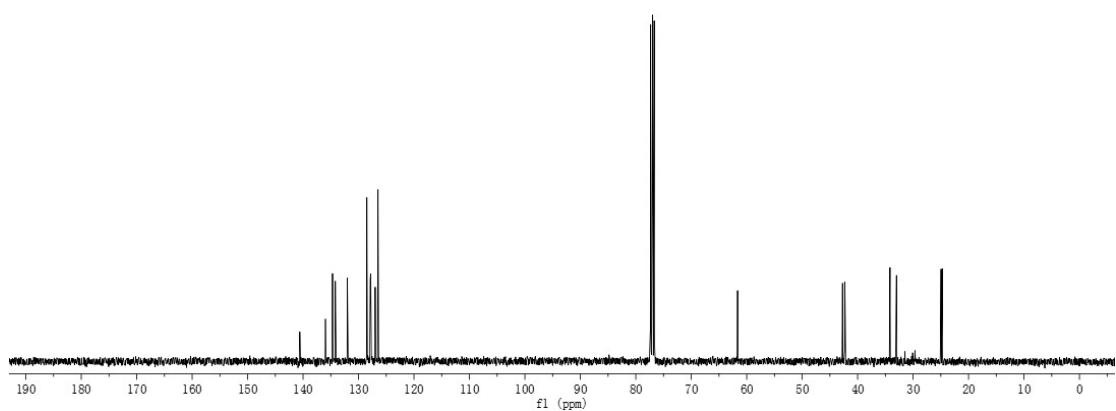
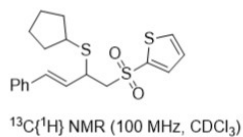
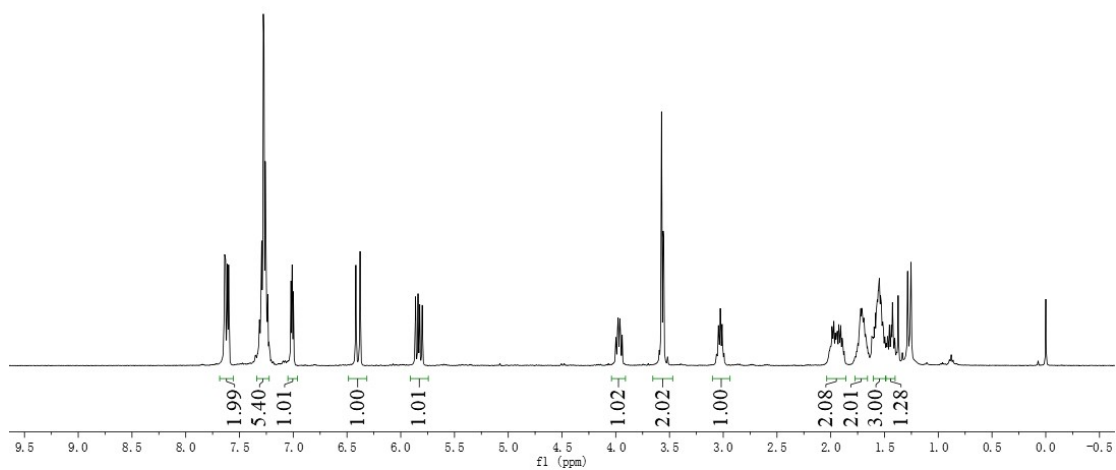
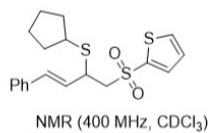
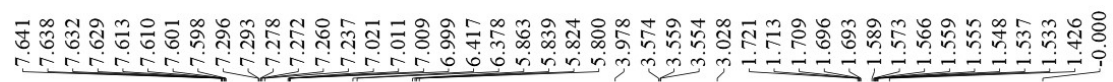
136.311
135.709
135.180
132.044
131.992
130.559
129.429
129.284
129.186
128.343
127.786
127.739
127.515
127.054
126.276
122.704
77.318
77.000
76.683
60.126
42.683
42.379
34.189
32.970
24.926
24.695



¹³C{¹H} NMR (100 MHz, CDCl₃)

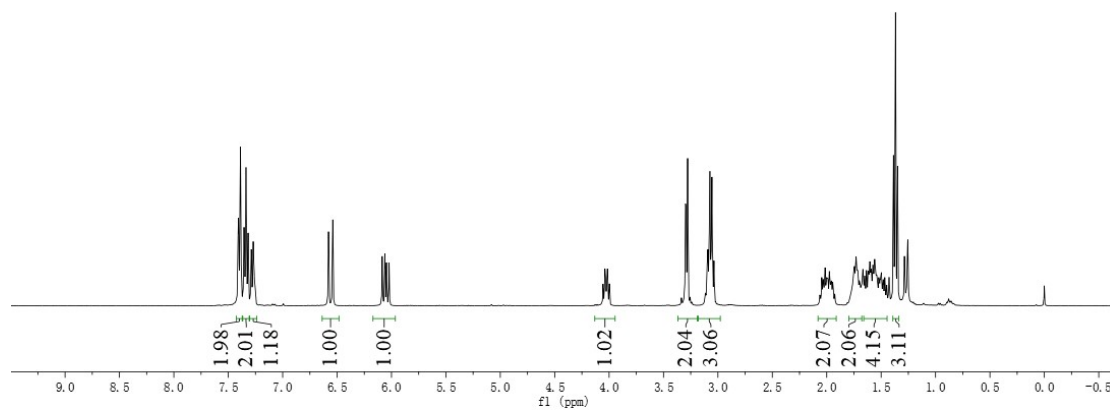
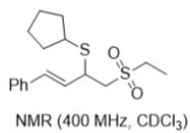


(E)-2-((2-(cyclopentylthio)-4-phenylbut-3-en-1-yl)sulfonyl)thiophene (**4z**)



(*E*)-cyclopentyl(1-(ethylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4zb**)

7.406
7.388
7.355
7.337
7.318
7.288
7.271
7.262
6.579
6.540
6.085
6.061
6.046
6.022
4.038
4.015
3.298
3.293
3.278
3.092
3.074
3.055
3.036
2.045
2.015
1.976
1.756
1.745
1.730
1.716
1.668
1.651
1.635
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1.386
1.368
1.349

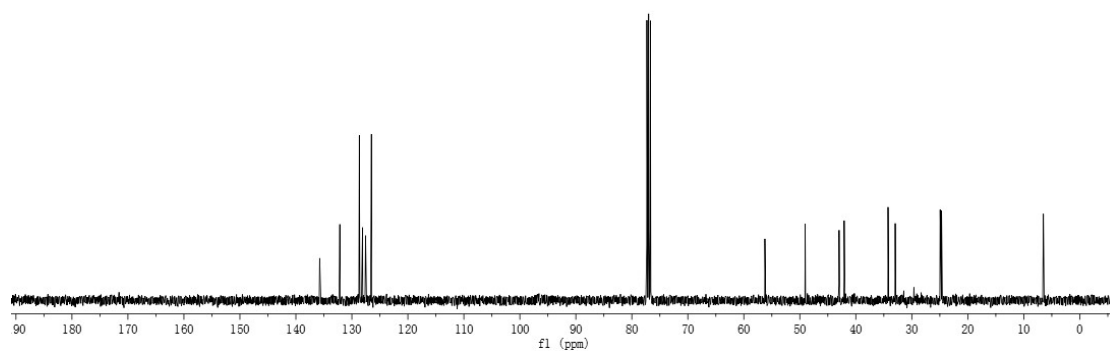
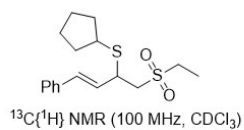


135.754
132.155
128.672
128.100
127.559
126.509

77.317
77.000
76.682

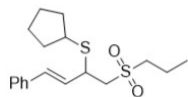
56.241
49.046
42.986
42.079
34.243
32.966
24.935
24.686

6.504

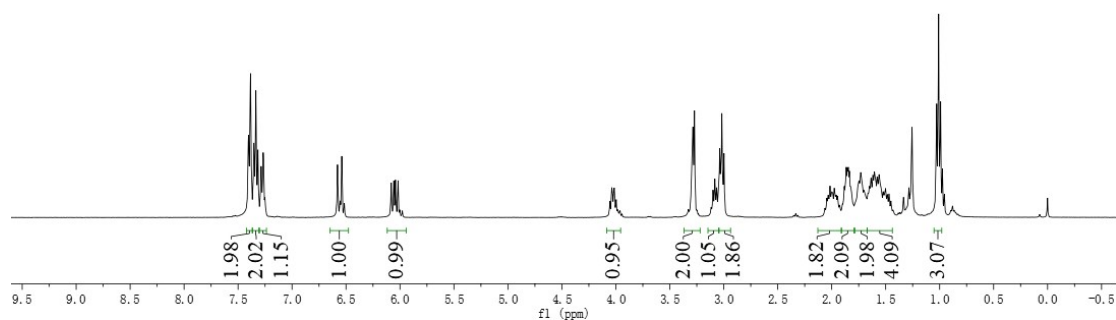


(E)-cyclopentyl(4-phenyl-1-(propylsulfonyl)but-3-en-2-yl)sulfane (4zc)

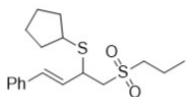
7.403
7.385
7.353
7.335
7.316
7.286
7.267
6.579
6.539
6.081
6.057
6.042
6.018
4.037
4.015
3.291
3.286
3.272
3.083
3.065
3.048
3.037
3.028
3.018
2.998
2.016
1.977
1.883
1.865
1.854
1.846
1.836
1.826
1.746
1.732
1.652
1.636
1.619
1.605
1.579
1.561
1.028
1.009
0.991



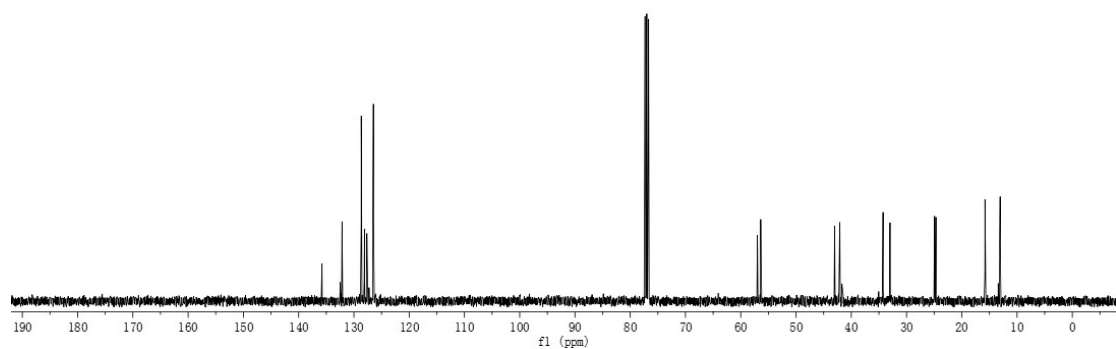
NMR (400 MHz, CDCl₃)



135.777
132.148
128.671
128.092
127.659
126.475
77.317
77.000
76.682
56.988
56.384
43.006
42.077
34.246
32.988
24.935
24.686
15.803
13.062

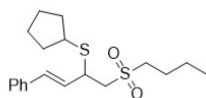


¹³C{¹H} NMR (100 MHz, CDCl₃)

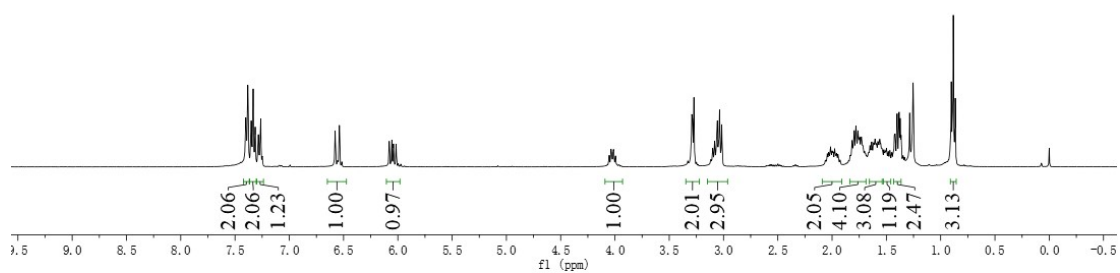


(E)-(1-(butylsulfonyl)-4-phenylbut-3-en-2-yl)(cyclopentyl)sulfane (4zd)

7.401
7.382
7.351
7.333
7.314
7.285
7.266
7.263
6.578
6.539
6.079
6.055
6.040
6.016
3.292
3.287
3.273
3.273
3.082
3.064
3.057
3.037
3.016
1.815
1.796
1.781
1.762
1.745
1.730
1.635
1.619
1.604
1.592
1.578
1.561
1.552
1.427
1.419
1.401
1.382
1.373
1.364
0.902
0.884
0.865



NMR (400 MHz, CDCl₃)

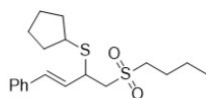


135.769
132.176
128.673
128.113
127.666
126.485

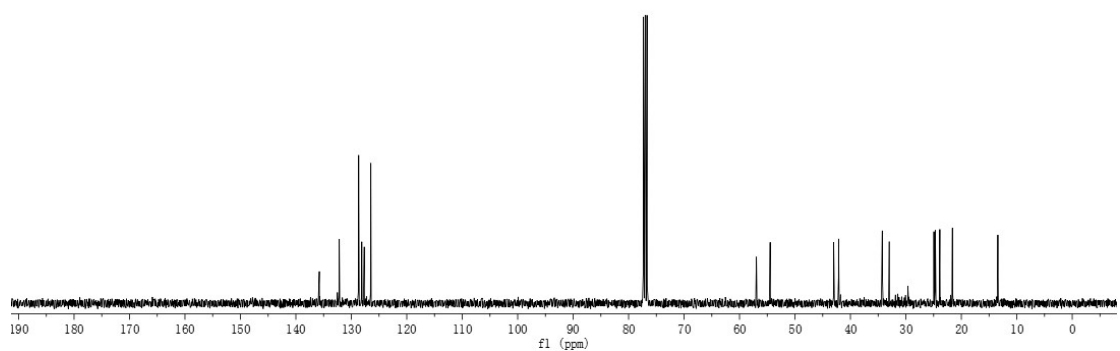
77.317
77.000
76.682

56.954
54.473

43.022
42.131
34.257
32.997
24.947
24.694
23.877
21.605
13.409

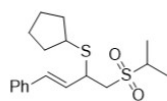


¹³C{¹H} NMR (100 MHz, CDCl₃)

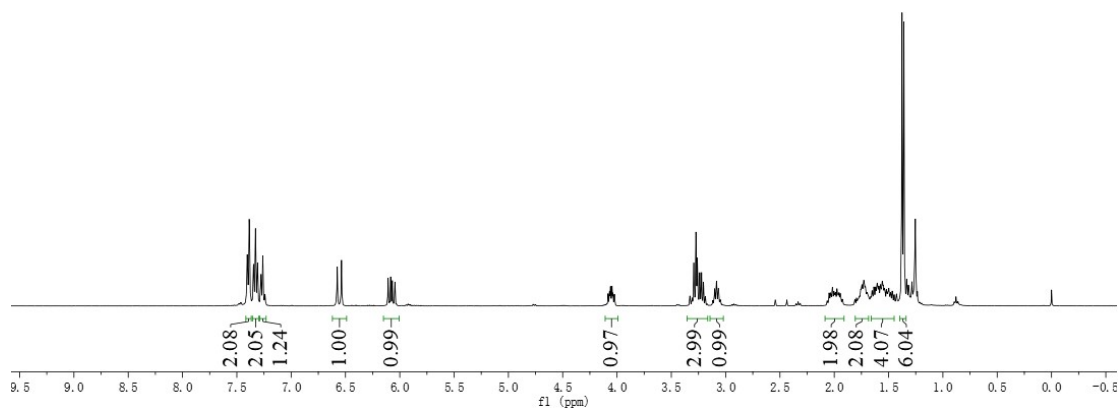


(*E*)-cyclopentyl(1-(isopropylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (**4ze**)

7.404
7.386
7.346
7.328
7.309
7.277
7.261
6.576
6.537
6.108
6.084
6.069
6.045
4.060
4.046
3.293
3.273
3.261
3.239
3.222
3.204
3.101
3.084
3.066
2.017
1.975
1.756
1.744
1.728
1.714
1.652
1.636
1.620
1.604
1.589
1.574
1.558
1.549
1.538
1.520
1.498
1.376
1.359
-0.000



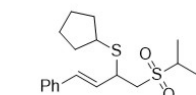
NMR (400 MHz, CDCl₃)



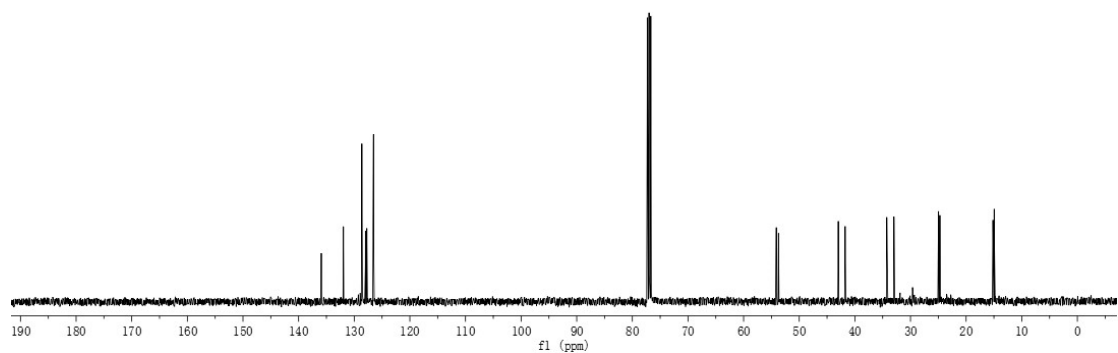
135.917
131.947
128.627
127.983
127.736
126.534

77.318
77.000
76.682

54.118
53.726
42.977
41.743
34.264
32.974
24.954
24.710
15.174
14.955

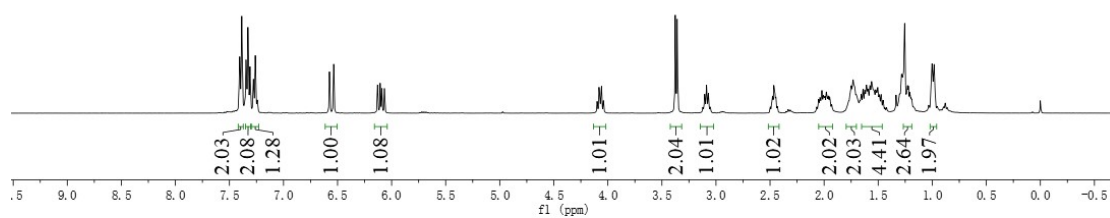
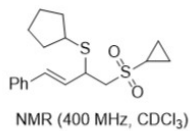


¹³C{¹H} NMR (100 MHz, CDCl₃)



(E)-cyclopentyl(1-(cyclopropylsulfonyl)-4-phenylbut-3-en-2-yl)sulfane (4zf)

7.405
7.386
7.347
7.329
7.310
7.278
7.261
6.575
6.536
6.130
6.106
6.091
6.067
4.082
4.059
3.377
3.359
3.087
2.465
2.021
1.980
1.749
1.732
1.719
1.640
1.625
1.608
1.594
1.577
1.561
1.542
1.523
1.504
1.284
1.278
1.271
1.255
1.228
1.221
1.006
1.002
0.995
0.986
0.982



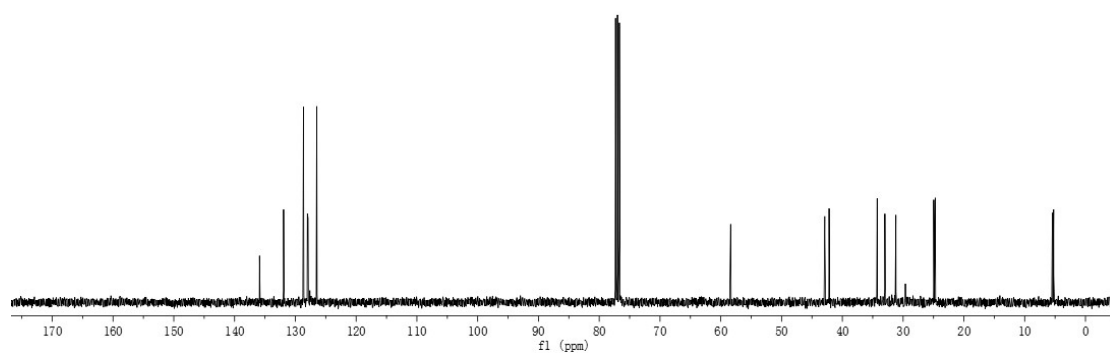
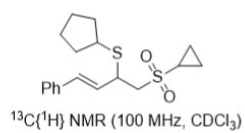
135.895
131.930
128.669
128.019
127.907
126.476

77.318
77.000
76.683

-58.377

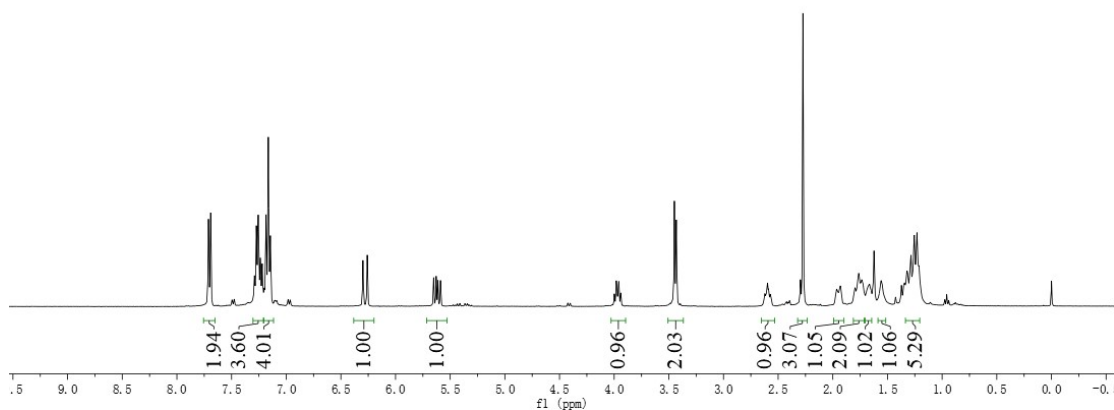
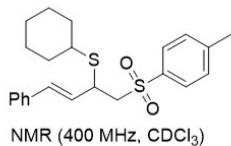
42.892
42.182
34.269
32.996
31.191
24.961
24.720

5.442
5.232

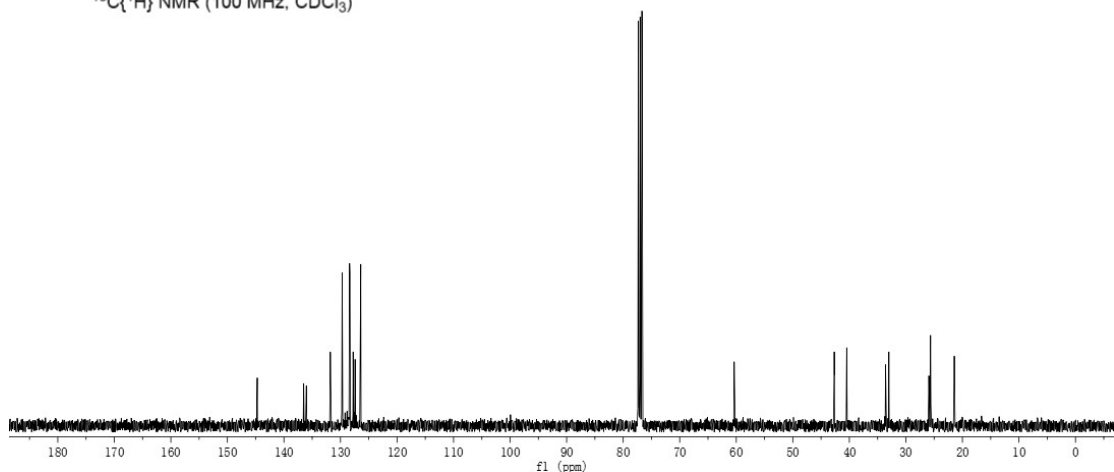


(E)-cyclohexyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zg)

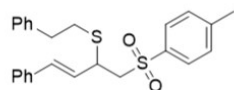
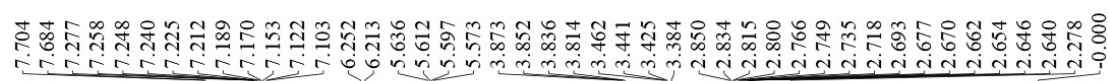
7.711
7.691
7.291
7.273
7.256
7.237
7.220
7.184
7.164
7.145
6.298
6.259
5.652
5.628
5.613
5.589
3.999
3.980
3.958
3.940
3.449
3.431
2.623
2.613
2.597
2.589
2.572
2.563
2.274
1.964
1.931
1.796
1.764
1.735
1.674
1.664
1.559
1.525
1.320
1.285
1.254
1.230
1.213
-0.000



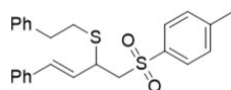
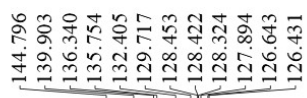
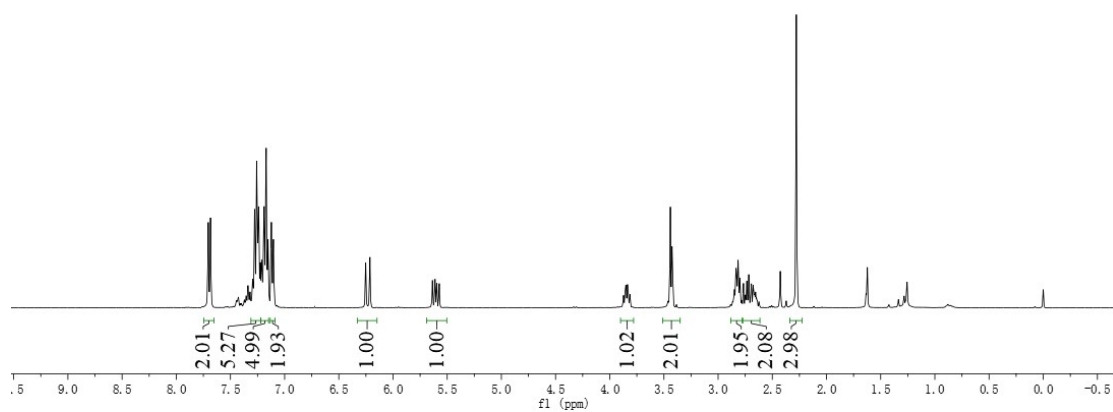
144.719
136.509
136.031
131.795
129.700
128.387
128.324
127.763
127.414
126.414
77.318
77.000
76.683
-60.366
42.672
40.457
33.595
33.008
25.935
25.637
25.605
21.442



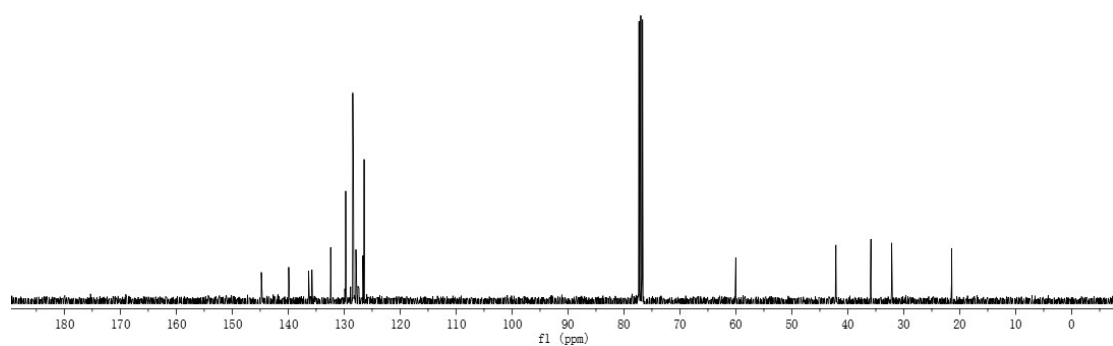
(E)-phenethyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zh)



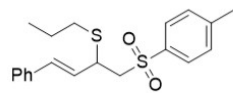
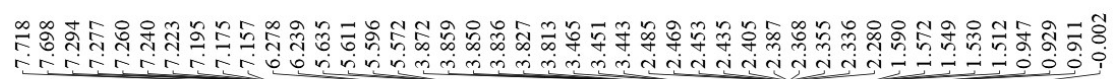
NMR (400 MHz, CDCl₃)



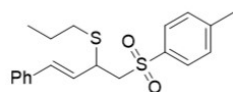
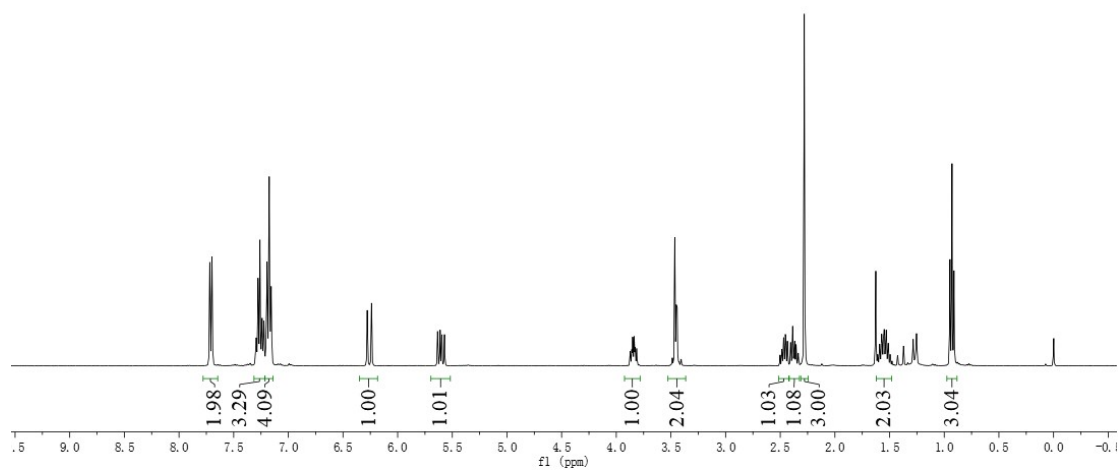
¹³C{¹H} NMR (100 MHz, CDCl₃)



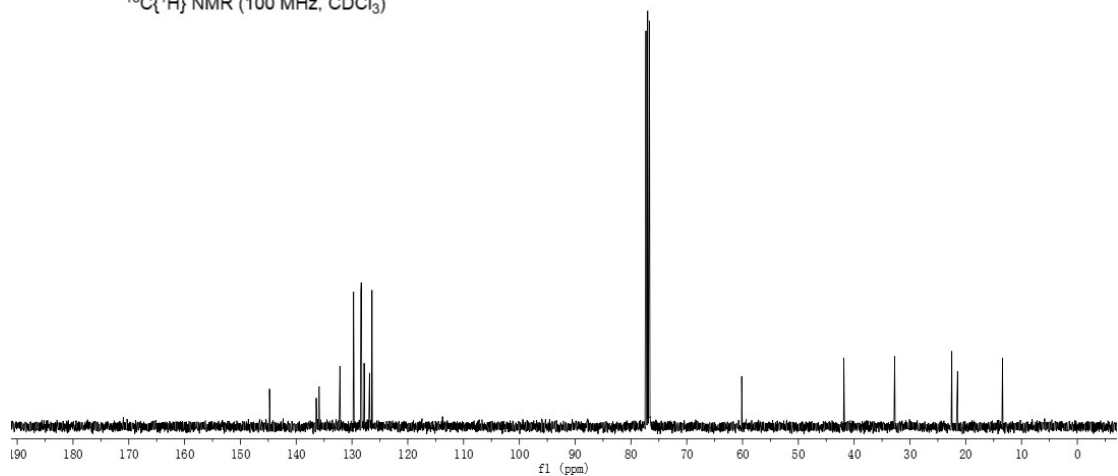
(E)-(4-phenyl-1-tosylbut-3-en-2-yl)(propyl)sulfane (**4zi**)



NMR (400 MHz, CDCl₃)

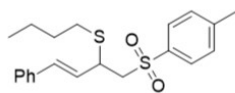


¹³C{¹H} NMR (100 MHz, CDCl₃)

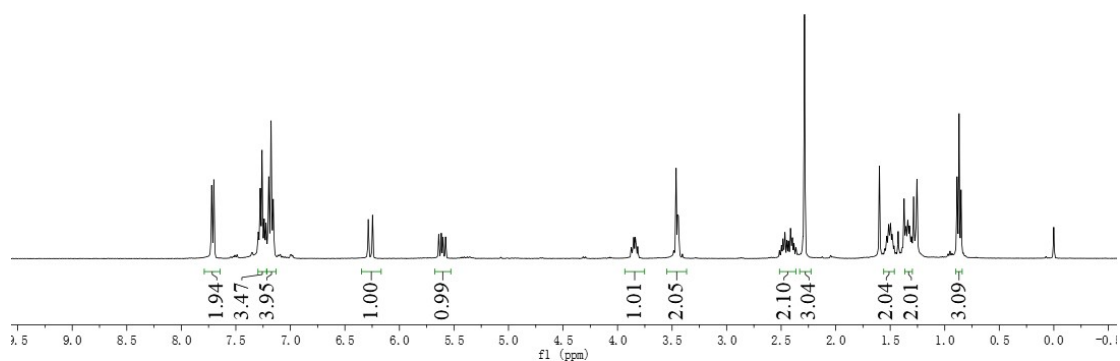


(E)-butyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zj)

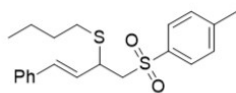
7.722 7.702 7.294 7.276 7.260 7.240 7.223 7.198 7.177 7.157 6.286 6.246 5.640 5.616 5.601 5.577 2.515 2.497 2.483 2.465 2.448 2.434 2.414 2.396 2.383 2.364 2.286 1.514 1.498 1.373 1.339 0.887 0.869 0.852 0.000



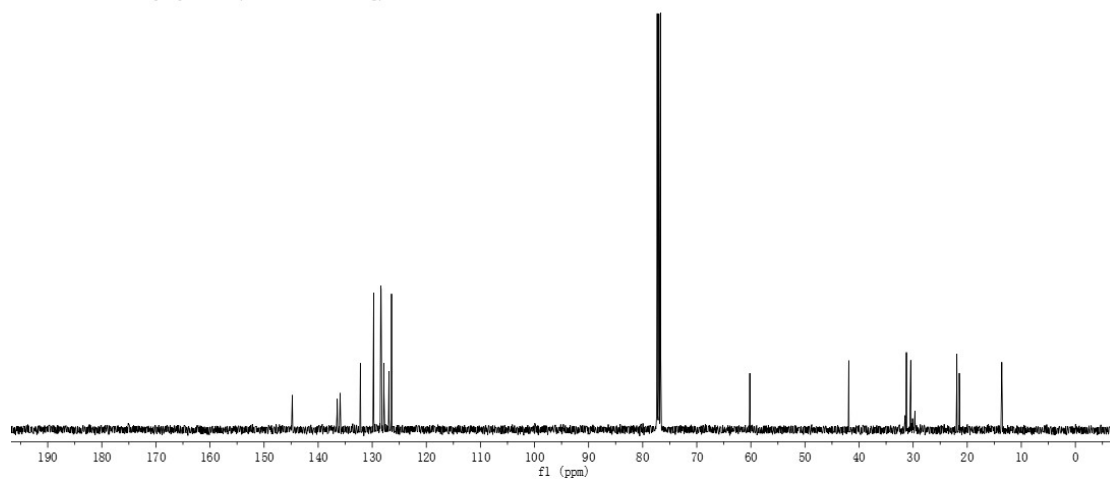
NMR (400 MHz, CDCl₃)



144.779 136.476 135.940 132.194 129.730 128.420 128.363 127.829 126.904 126.434 77.318 77.000 76.683 60.201 41.898 31.242 30.439 21.918 21.463 13.603

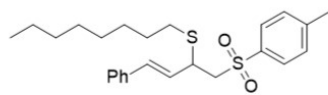


¹³C{¹H} NMR (100 MHz, CDCl₃)

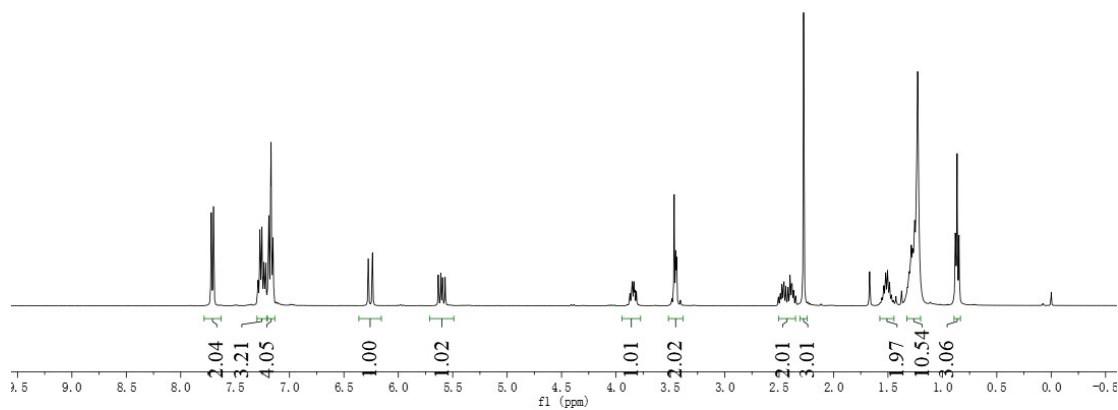


(E)-octyl(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zk)

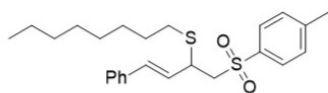
7.719
7.698
7.272
7.254
7.235
7.218
7.190
7.170
7.152
6.276
6.237
5.632
5.609
5.593
5.570
2.507
2.487
2.475
2.459
2.455
2.439
2.418
2.400
2.386
2.380
2.368
2.348
2.275
2.275
1.557
1.538
1.521
1.504
1.485
1.467
1.322
1.306
1.285
1.272
1.254
1.227
0.881
0.865
0.847
-0.000



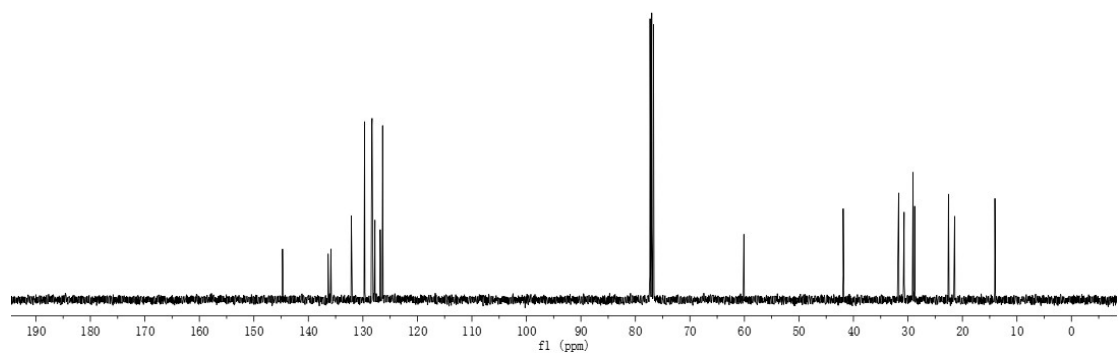
NMR (400 MHz, CDCl₃)



144.737
136.373
135.863
132.124
129.683
128.367
128.312
127.782
126.813
126.381
77.317
77.000
76.682
60.096
41.874
31.697
30.700
29.127
29.061
29.048
28.767
22.553
21.426
14.043

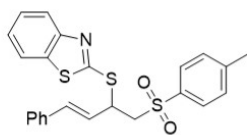


¹³C{¹H} NMR (100 MHz, CDCl₃)

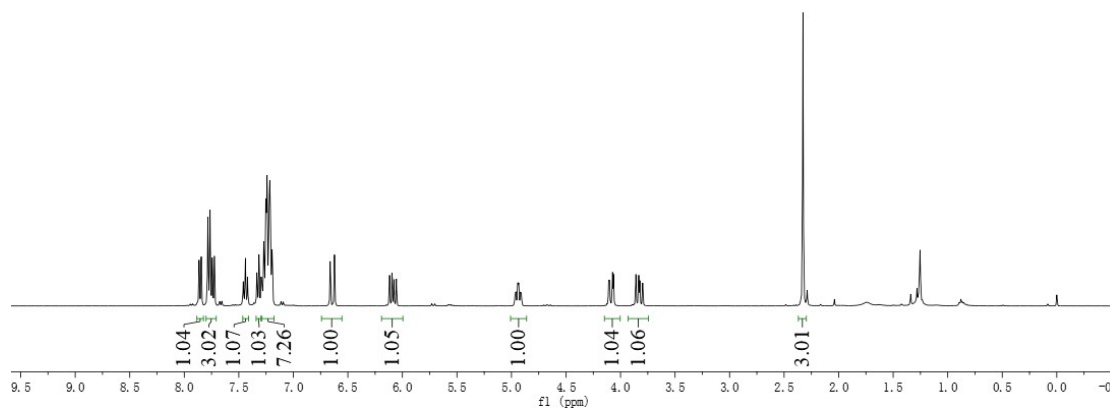


(E)-2-((4-phenyl-1-tosylbut-3-en-2-yl)thio)benzo[d]thiazole (**4zI**)

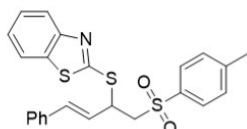
7.844, 7.784, 7.764, 7.744, 7.724, 7.315, 7.271, 7.252, 7.241, 7.216, 7.195, 6.662, 6.623, 6.117, 6.095, 6.055, 4.958, 4.942, 4.934, 4.918, 4.100, 4.073, 4.064, 3.859, 3.833, 3.823, 3.797, -2.327, -0.082, -0.000



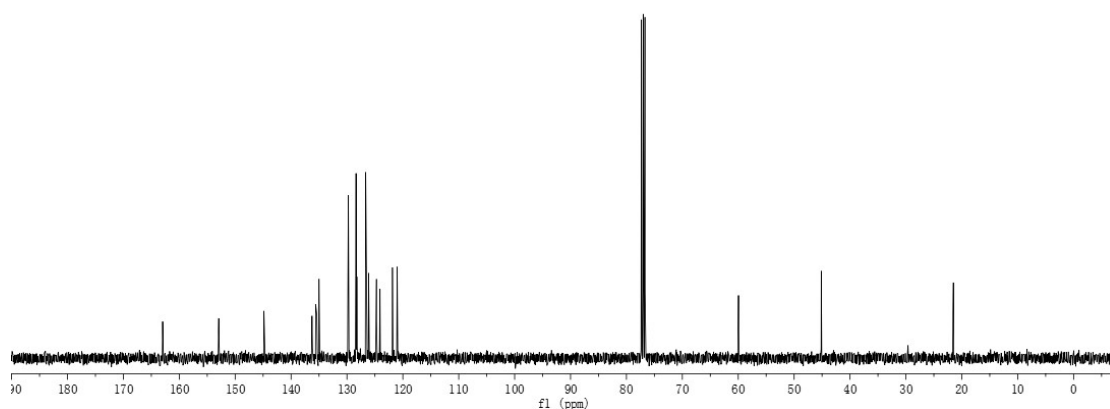
NMR (400 MHz, CDCl₃)



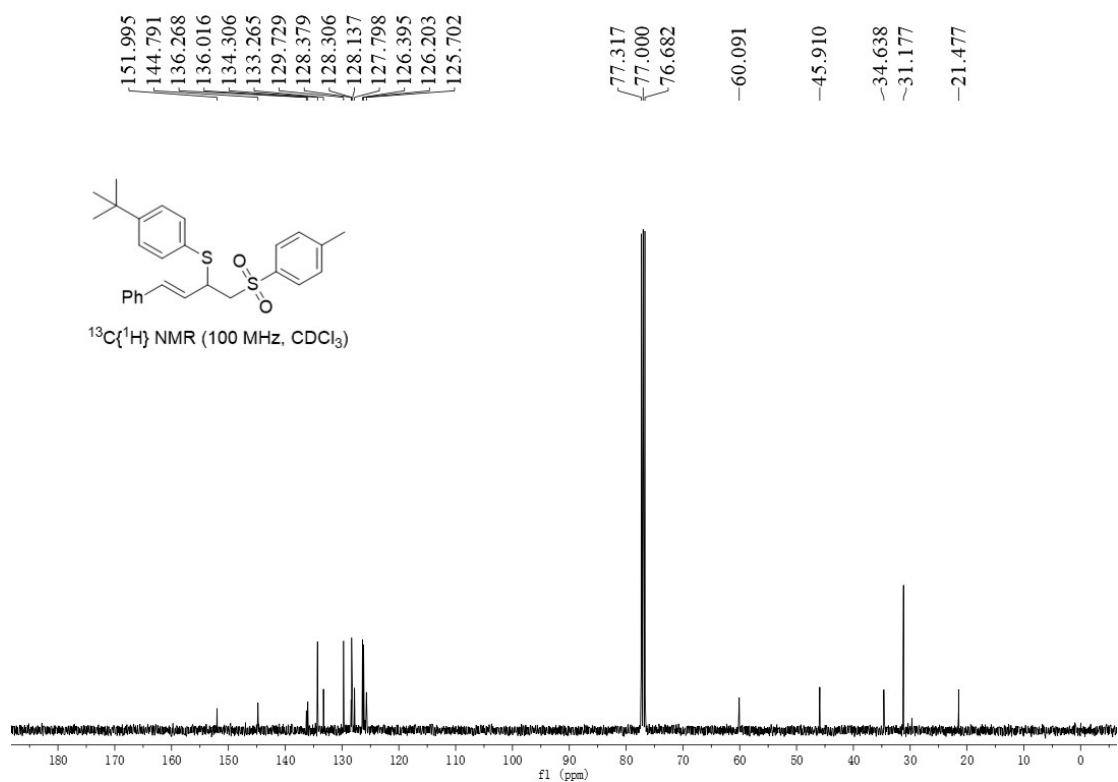
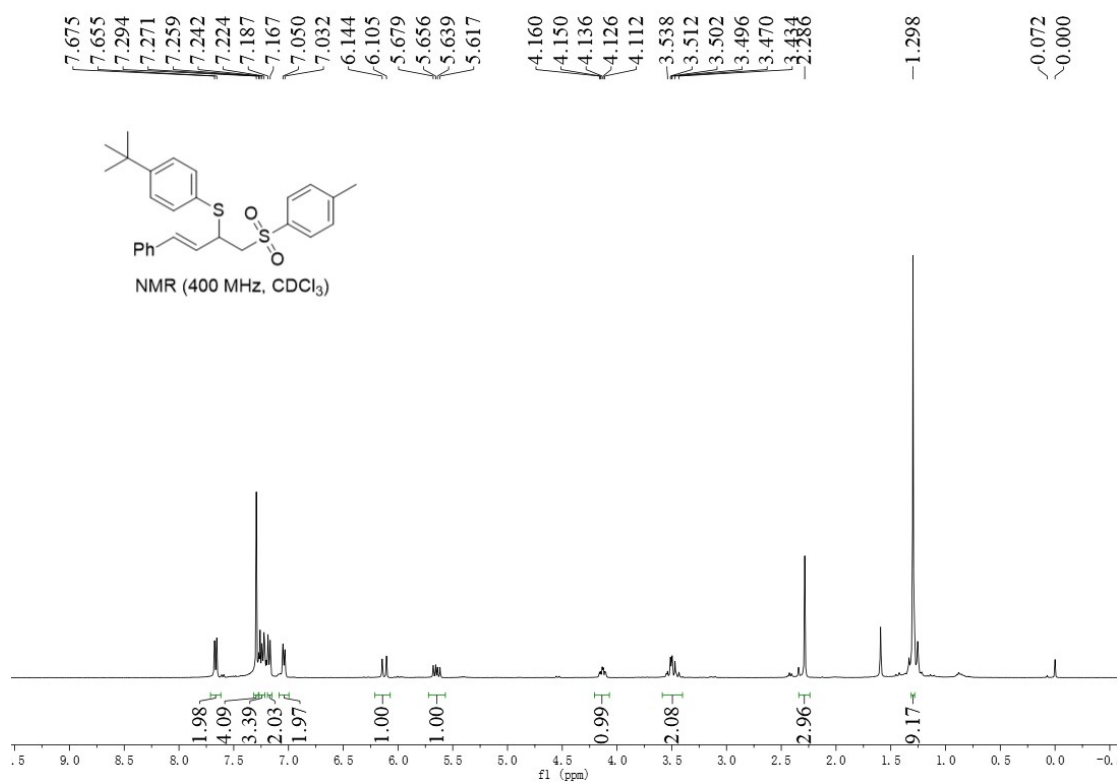
162.976, 152.935, 144.860, 136.257, 135.597, 135.391, 135.008, 129.759, 128.422, 128.371, 128.237, 126.652, 126.126, 124.722, 124.092, 121.863, 121.019, 77.318, 77.000, 76.682, -59.954, -45.139, -21.506



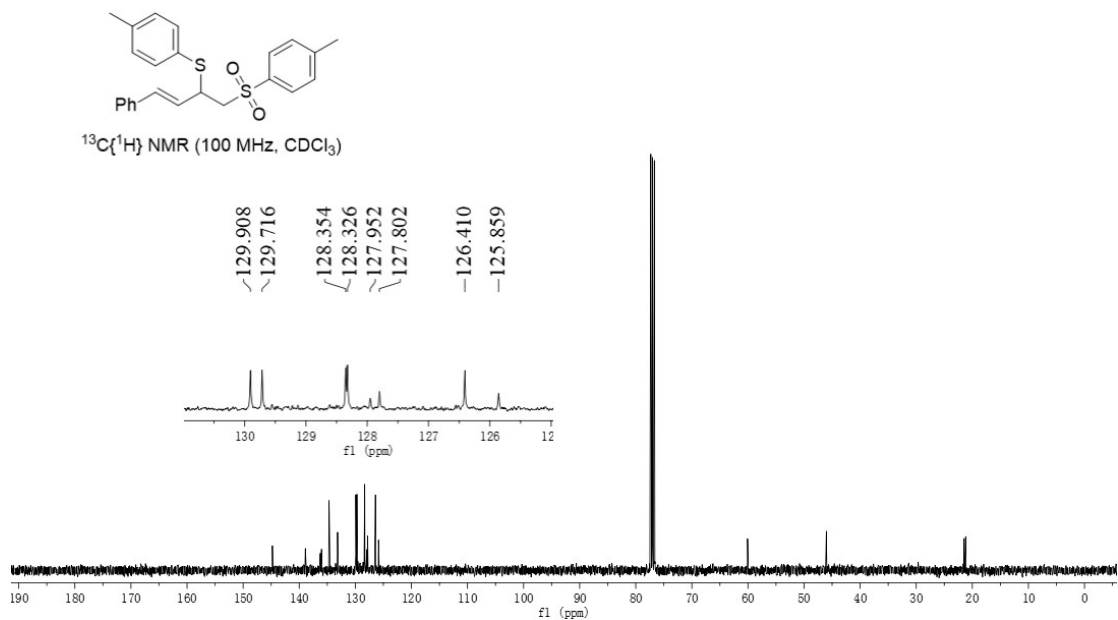
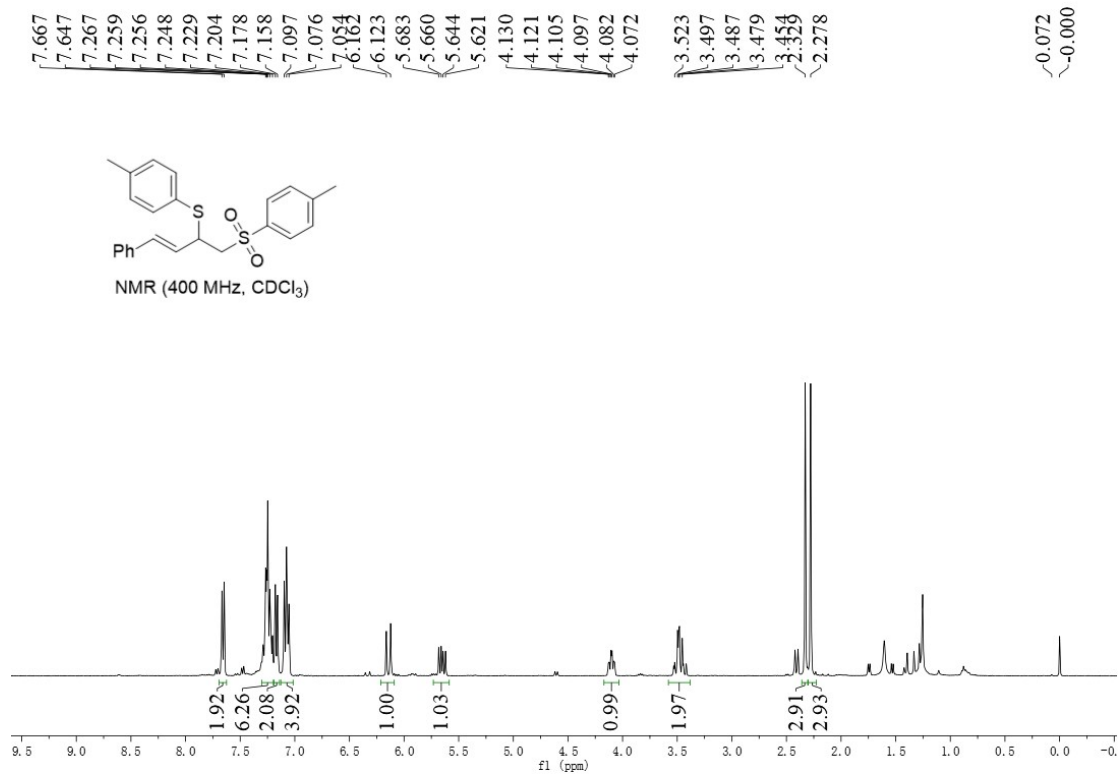
¹³C{¹H} NMR (100 MHz, CDCl₃)



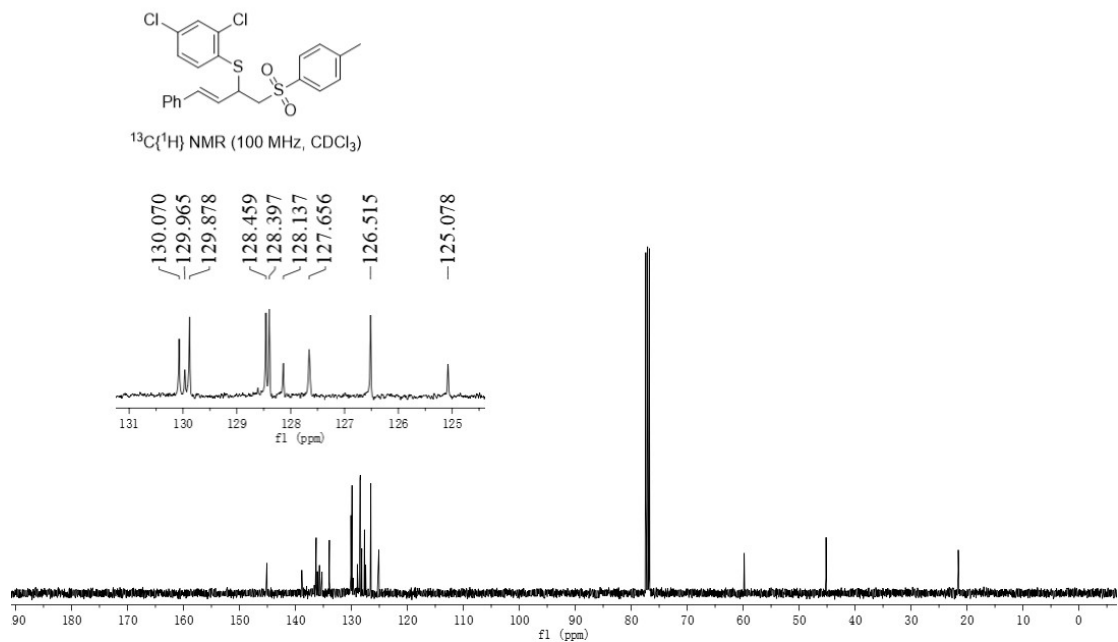
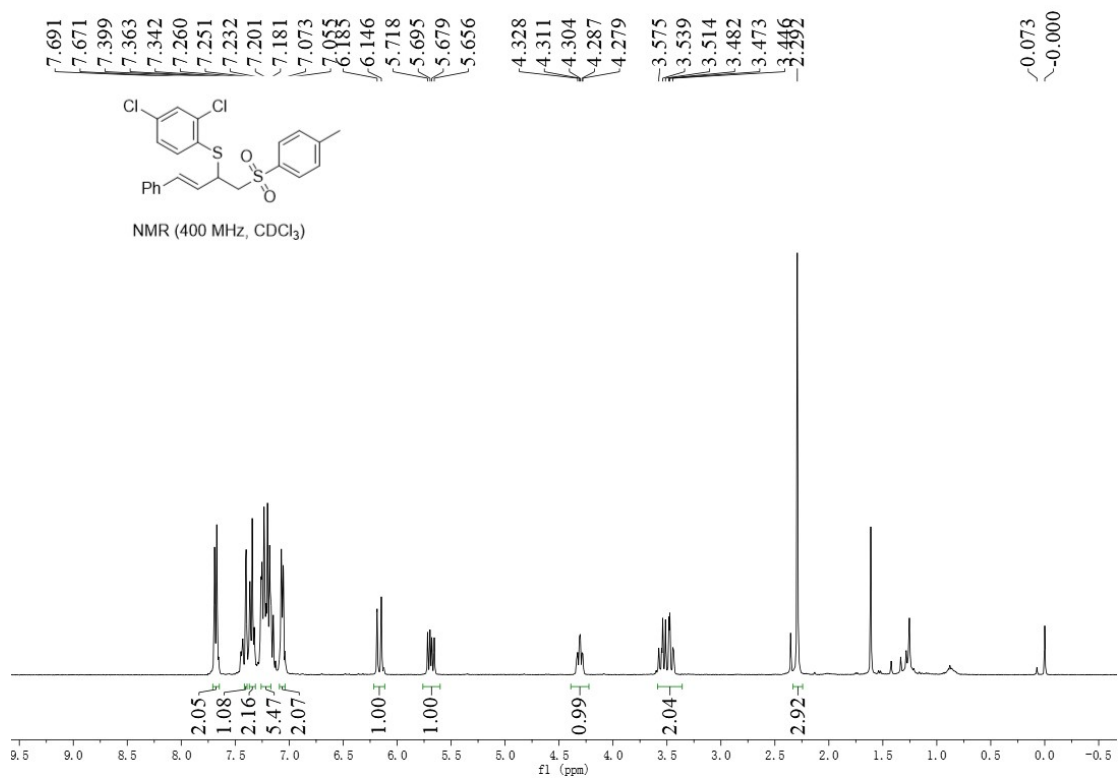
(E)-(4-(tert-butyl)phenyl)(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zm)



(E)-(4-phenyl-1-tosylbut-3-en-2-yl)(p-tolyl)sulfane (4zn)



(E)-(2,4-dichlorophenyl)(4-phenyl-1-tosylbut-3-en-2-yl)sulfane (4zo)

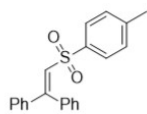


(2-tosylethene-1,1-diyl)dibenzene (5)

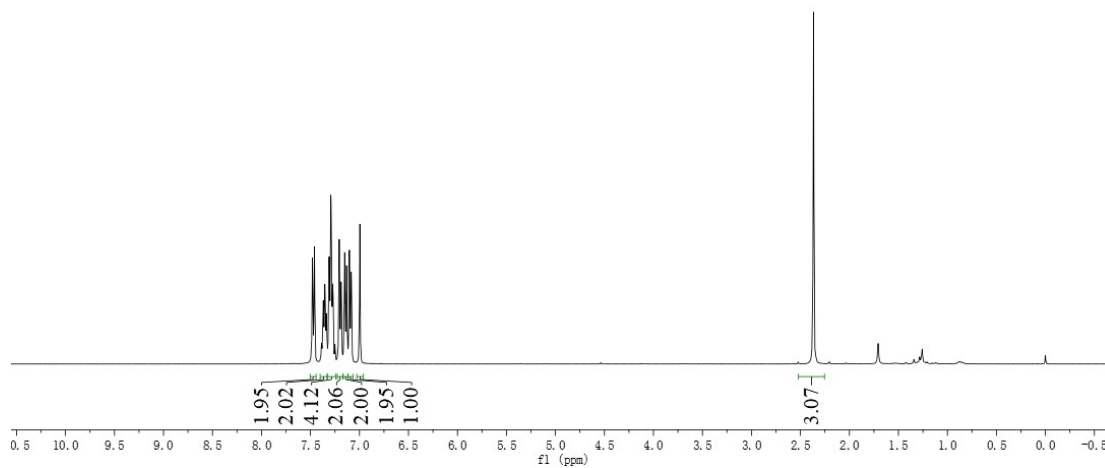
7.480
7.459
7.369
7.354
7.337
7.309
7.292
7.273
7.206
7.188
7.151
7.131
7.103
7.085
6.996

-2.366

-0.084
-0.000



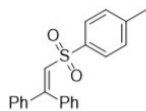
NMR (400 MHz, CDCl₃)



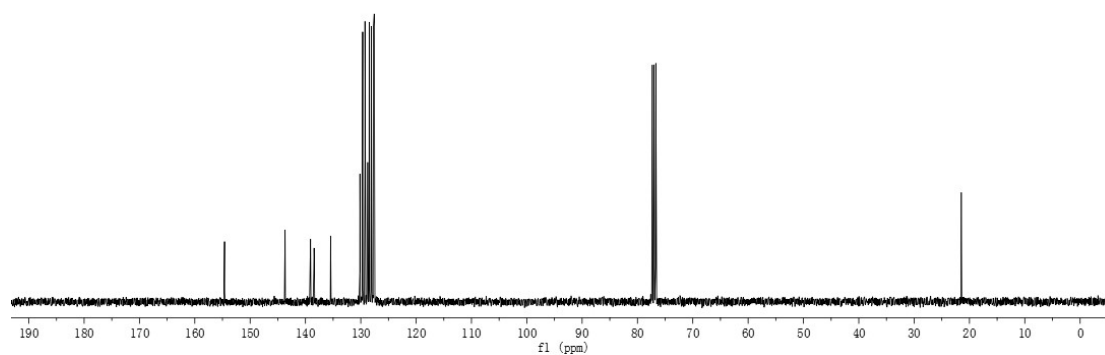
154.624
143.685
139.081
138.435
135.454
130.154
129.659
129.243
128.815
128.750
128.477
128.104
127.707
127.573

77.318
77.000
76.682

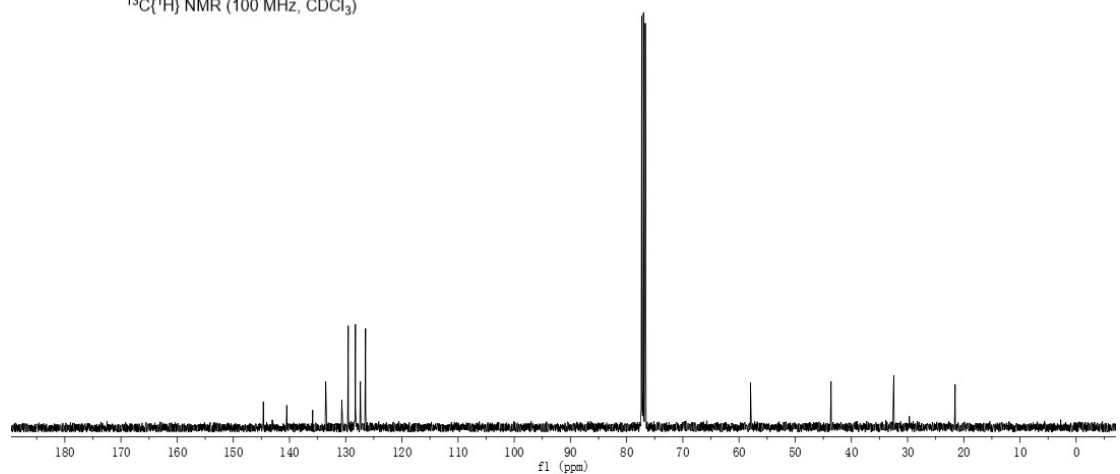
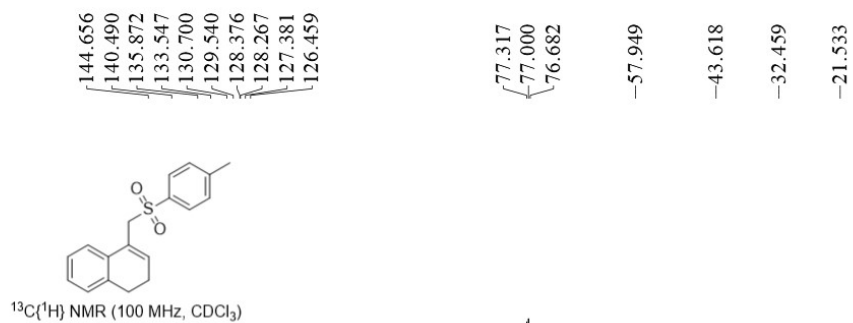
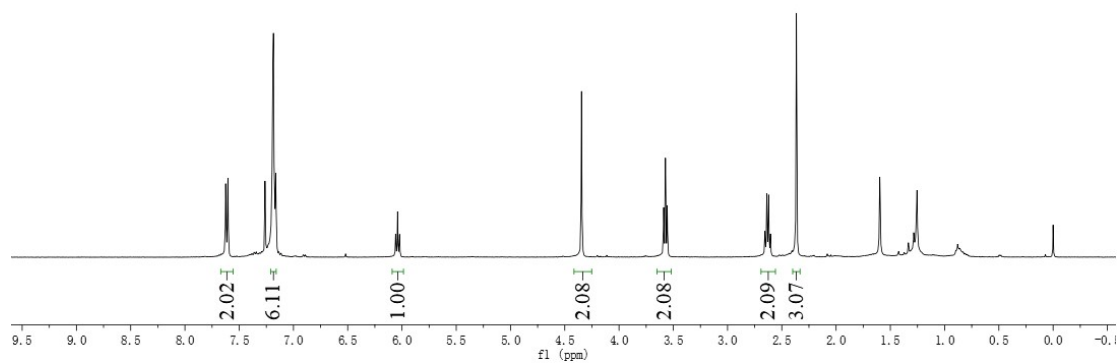
-21.476



¹³C{¹H} NMR (100 MHz, CDCl₃)

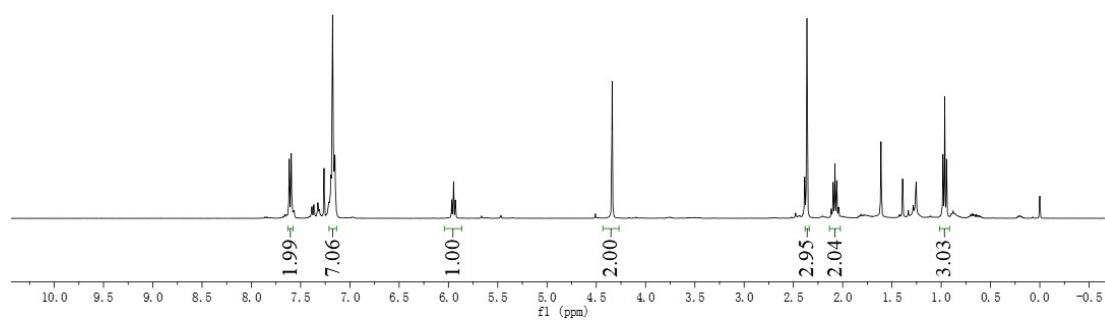
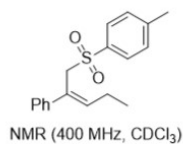


4-(tosylmethyl)-1,2-dihydronaphthalene (7)



1-methyl-4-((2-phenylpent-2-en-1-yl)sulfonyl)benzene (**8**)

7.615
7.595
7.262
7.212
7.193
7.175
7.152
5.966
5.948
5.930
-4.339
2.362
2.116
2.097
2.079
2.060
2.041
0.983
0.964
0.946
-0.071
-0.000



144.375
140.857
140.213
135.961
129.383
128.465
128.179
127.307
126.936
126.371
77.318
77.000
76.682
-57.656
22.679
21.512
-13.560

