Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

For

Sulfone Promoted Rh(III)−Catalyzed C−H Activation and Base Assisted 1, 5−H Shift Strategy For the Construction of Seven−Memebered Rings

Dianpeng Chen, [a] *Gangdong Xing,* [a] *and Hongwei Zhou* [*,a,b]

[a] Department of Chemistry, Zhejiang University (Campus Xixi), Hangzhou 310028, People's Republic of China

[b] College of Biological, Chemical Sciences and Engineering, Jiaxing University, Jiaxing 314001, People's Republic of China

Fax: (+ 86)-571-8892-0271; e-mail: zhouhw@zju.edu.cn

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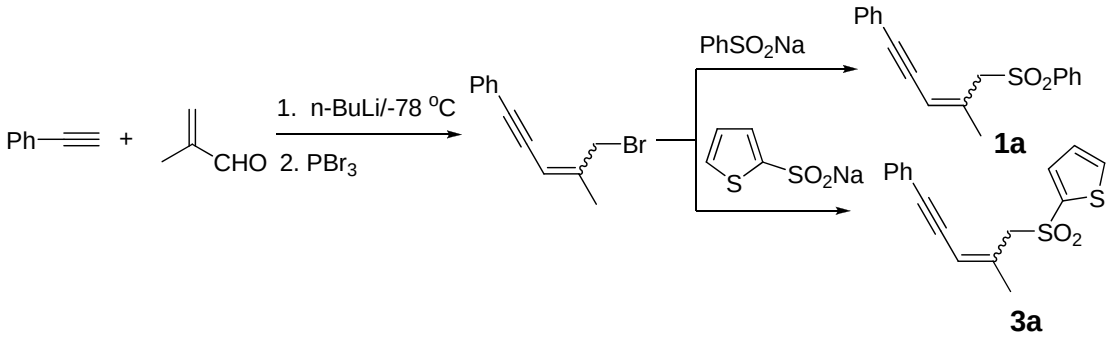
1. General information

All the Rhodium-catalyzed reactions were carried out in oven-dried glassware sealed with rubber septa under nitrogen condition. All solvents were distilled under nitrogen atmosphere prior to use. DCE was dried over calcium hydride. Purification of products was conducted by flash chromatography on silica gel (200-300 mesh). NMR spectra were measured in $CDCl_3$ and recorded on Bruker Avance spectrometers operating for ^1H NMR at 400 MHz and for ^{13}C NMR at 100 MHz. Chemical shifts are expressed in ppm and J values are given in Hz. Mass spectroscopy data of the products were collected with an HRMS-TOF instrument. Infrared spectra were recorded with a Bruker ATRFTIR spectrometer. Melting points were measured on a microscopic apparatus and were uncorrected.

2. General procedure for the synthesis of substrates 1a and 3a



To a solution of the phenylacetylene (2.6 g, 25 mmol) in THF (50 mL) was added *n*-BuLi (10 mL, 2.5 M) at -78^{o}C under argon. The resulting solution was stirred for 1 h at room temperature. Then a solution of methacrylaldehyde (1.8 g, 25 mmol) in THF (20 mL) was added slowly and the mixture was stirred for 1 h. The reaction was quenched with water, extracted with ethyl acetate and dried over anhydrous Na_2SO_4. After removal of solvent, the residue was used directly as crude product in the next step.

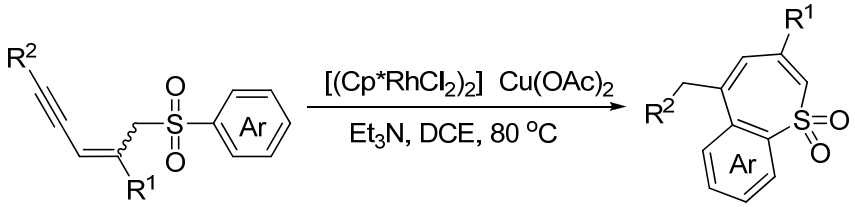
To the solution of the crude product in ethyl ether (40 mL) was slowly added PBr_3 (3.3 g, 12 mmol, in 40 mL of ethyl ether) at 0^{o}C. The resulting mixture was stirred for 3 h at room temperature and quenched with water, extracted with ethyl ether and dried over anhydrous Na_2SO_4. After removal of solvent, the residue was directly used in the next step.

To the crude bromide (1 g, 4.2 mmol) in DMF (10 mL) was charged $PhSO_2Na$ (0.8 g, 5mmol) at room temperature. The resulting mixture was stirred for 4 h and diluted with water, extracted with ether (3 × 20 mL), dried over anhydrous Na_2SO_4. After evaporation, chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 6:1) of the crude mixture afforded **1a** (1.0g, 81%). White solid; ^1H NMR (400 MHz,

$CDCl_3$) δ 7.89 (d, *J* = 8.2 Hz, 2H), 7.67 (t, *J* = 6.9 Hz, 1H), 7.58 (t, *J* = 7.7 Hz, 2H), 7.44 – 7.36 (m, 2H), 7.35 – 7.28 (m, 3H), 5.39 (s, 1H), 3.87 (s, 2H), 2.08 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.30, 137.59, 133.96, 131.46, 129.21, 128.50, 128.47, 128.37, 123.05, 114.70, 95.87, 85.88, 65.16, 20.10; IR (neat) 2963, 1658, 3305cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}O_2S$ 296.0871, found 296.0873.

To the crude bromide (1 g, 4.2 mmol) in DMF (10 mL) was charged sodium thiophene-2-sulfinate (0.85 g, 5mmol) at room temperature. The resulting mixture was stirred for 8 h and diluted with water, extracted with ether (3 × 20 mL), dried over anhydrous Na_2SO_4. After evaporation, chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 6:1) of the crude mixture afforded **3a** (0.95 g, 75%). White solid; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (dt, *J* = 10.9, 5.4 Hz, 1H), 7.71 – 7.65 (m, 1H), 7.42 (dd, *J* = 6.5, 2.8 Hz, 2H), 7.31 (dd, *J* = 11.7, 8.4 Hz, 3H), 7.18 (dd, *J* = 4.7, 4.0 Hz, 1H), 5.48 (s, 1H), 3.96 (s, 2H), 2.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.06, 137.64, 134.85, 134.52, 131.49, 128.53, 128.40, 127.96, 123.02, 114.85, 96.04, 85.92, 66.42, 20.03; IR (neat) 2958, 1657, 3308cm^{-1}; HRMS (EI-TOF) calcd for $C_{16}H_{14}O_2S_2$ 302.0435, found 302.0431.

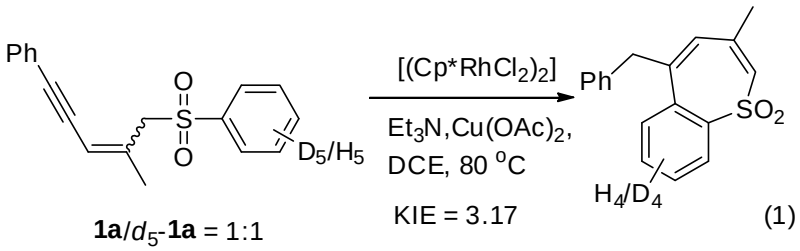
3. General procedure for the Rh-catalyzed reaction



[(Cp*$RhCl_2$)$_2$] (3.1mg, 0.005 mmol, 2.5%mol), $Cu(OAc)_2$(10.0 mg, 0.05 mmol, 25% mol), substrates (0.2 mmol, 1 equiv) were successively added to a 10 mL vial equipped with a stir bar. Dry DCE (2.0 mL) and Et_3N (84 uL, 0.6 mmol) was charged using a syringe. The reaction mixture was stirred at 80 ^oC for 36 h. After evaporation, chromatography on silica gel (eluent: hexane/EtOAc = 6:1) of the crude mixture afforded desired product.

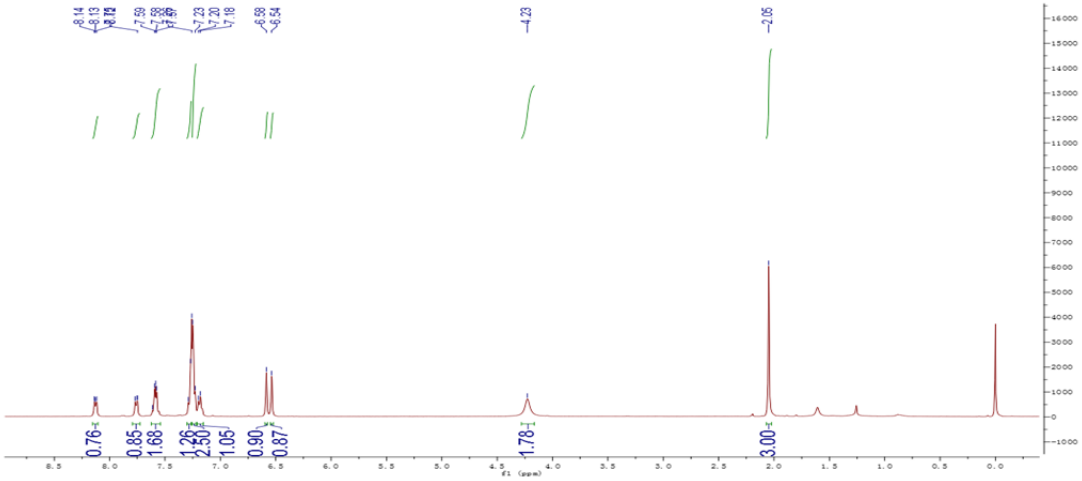
4. Deuteration Experiments

(1) The KIE study

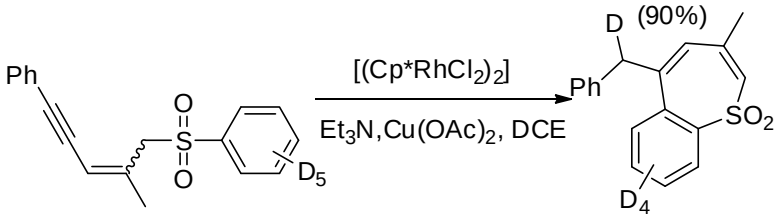


1a/d_5-**1a** = 1:1

29mg of **1a** (0.01 mmol) and 29mg of d_5-**1a** (0.01 mmol) were dissolved in 2mL dry DCE in a screw cap vial and [(Cp*$RhCl_2$)$_2$] (3.1 mg, 0.005 mmol), $Cu(OAc)_2$ (10 mg, 0.05 mmol) and Et_3N (84 uL) were added. The solution was heated at 80 ^oC for 6 hours. After evaporation, chromatography on silica gel (eluent: hexane/EtOAc = 6:1) of the crude mixture afforded 5 mg of the product mixture as light yellow solid. The KIE value (K_H/K_D= 3.17) was determined from the ^1H NMR.

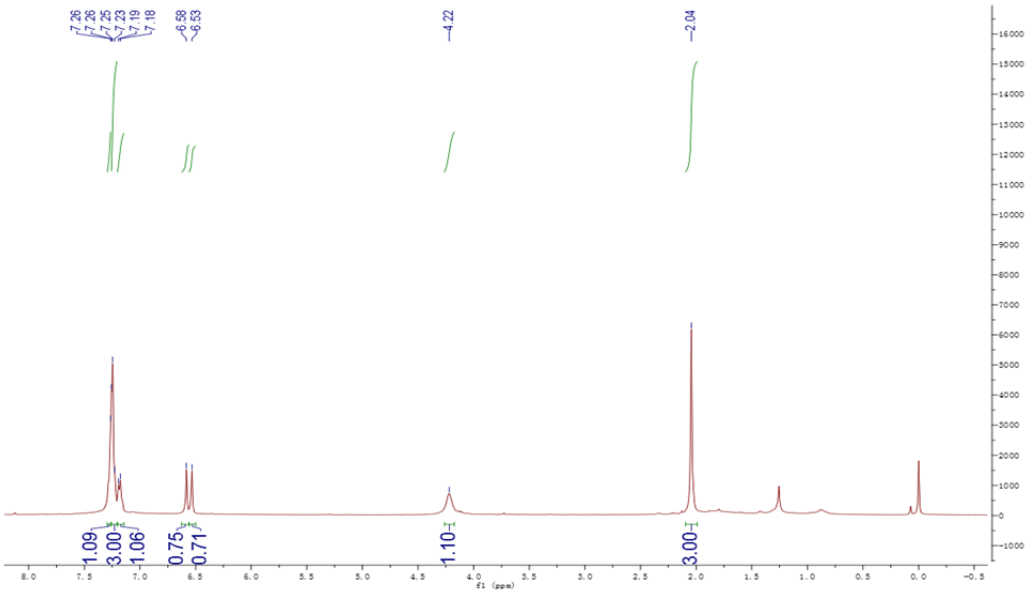


(2) Deuterium shift experiment

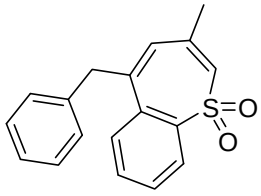


d_5-**1a** d_5-**2a**

[(Cp*$RhCl_2$)$_2$] (3.1mg, 0.005mmol), $Cu(OAc)_2$ (10.0mg, 0.05mmol) and d_5-**1a** (0.2mmol) were successively added to a 10 mL vial equipped with a stir bar. Dry DCE (2.0 mL) and Et_3N (84 uL) were added to the mixture using a syringe. The reaction was stirred at 80 ^oC for 36h. The deuterated ratio is 90% analysised by ^1H NMR.

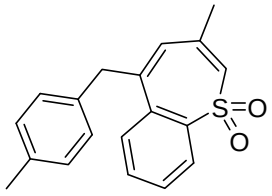


5. Characterization data



2a

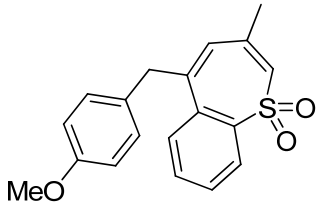
3-Methyl-5-benzyl-1-benzothiepin,1,1-dioxide(2a): Pale yellow solid, 48 mg, 82% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.09 (m, 1H), 7.79 – 7.72 (m, 1H), 7.60 – 7.52 (m, 2H), 7.29 – 7.20 (m, 4H), 7.20 – 7.12 (m, 1H), 6.58 (s, 1H), 6.52 (s, 1H), 4.22 (s, 2H), 2.03 (d, *J* = 0.8 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.2, 145.6, 141.7, 138.3, 134.6, 131.9, 131.3, 130.6, 129.8, 129.2, 128.6, 128.1, 126.6, 124.9, 44.9, 23.1; IR (neat) 2924,1312,1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}O_2S$ 296.0871, found 296.0867.



2b

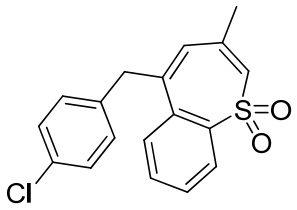
3-Methyl-5-(4-methyl)-benzyl-1-benzothiepin,1,1-dioxide(2b): Pale yellow solid, 55 mg, 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 – 7.99 (m, 1H), 7.75 – 7.63 (m, 1H), 7.54 – 7.46 (m, 2H), 7.05 (d, *J* = 7.8 Hz, 2H), 7.00 (d, *J* = 7.6 Hz, 2H), 6.50 (s, 1H), 6.45(s, 1H), 4.10 (s, 2H), 2.20 (s, 3H), 1.97 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 146.2, 144.9, 140.6, 135.0, 134.2, 133.6, 130.9, 130.1, 129.4, 128.7, 128.3, 128.0,

127.1, 123.9, 43.5, 22.1, 20.0; IR (neat) 2921,1310,1162 cm^{-1}; HRMS (EI-TOF) calcd for $C_{19}H_{18}O_2S$ 310.1028, found 310.1030.



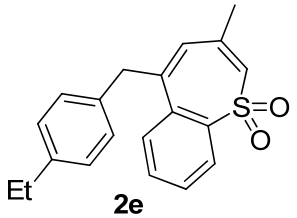
2c

3-Methyl-5-(4-methoxy)-benzyl-1-benzothiepin,1,1-dioxide(2c): Pale yellow solid, 51 mg, 78% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 8.09 (m, 1H), 7.79 – 7.73 (m, 1H), 7.61 – 7.55 (m, 2H), 7.14 (d, *J* = 8.1 Hz, 2H), 6.80 (d, *J* = 8.2 Hz, 2H), 6.56 (s, 1H), 6.52 (s, 1H), 4.17 (s, 2H), 3.75 (s, 3H), 2.04 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 158.3, 147.2, 146.1, 141.7, 134.6, 131.9, 131.0, 130.5, 130.3, 130.2, 129.8, 128.1, 124.9, 114.1, 55.2, 44.1, 23.1; IR (neat) 2925,1512,1248 cm^{-1}; HRMS (EI-TOF) calcd for $C_{19}H_{18}O_3S$ 326.0977, found 326.0977.



2d

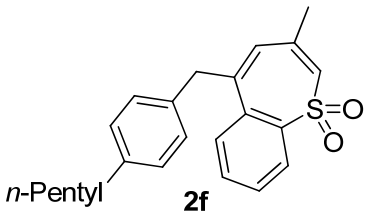
3-Methyl-5-(4-chloro)-benzyl-1-benzothiepin,1,1-dioxide(2d): Pale yellow solid, 56 mg, 85% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 8.09 (m, 1H), 7.75 – 7.69 (m, 1H), 7.63 – 7.55 (m, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.4 Hz, 2H), 6.59 (s, 1H), 6.55 (s, 1H), 4.21 (s, 2H), 2.05 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.0, 145.1, 136.7, 134.2, 132.5, 132.0, 131.4, 130.9, 130.5, 129.9, 128.8, 127.9, 125.1, 44.3, 23.1; IR (neat) 2925,1311,1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{15}ClO_2S$ 330.0481, found 330.0482.



2e

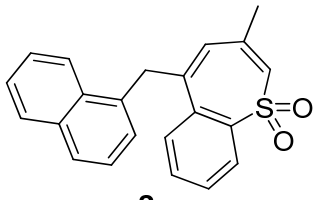
3-Methyl-5-(4-ethyl)-benzyl-1-benzothiepin,1,1-dioxide(2e): Pale yellow solid, 57 mg, 88% yield;^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 – 8.09 (m, 1H), 7.81 – 7.73 (m, 1H), 7.59 (dd, *J* = 9.0, 5.1 Hz, 2H), 7.15 (d, *J* = 7.9 Hz, 2H), 7.10 (d, *J* = 8.1 Hz, 2H), 6.57 (s, 1H), 6.52 (s, 1H), 4.18 (s, 2H), 2.58 (q, *J* = 7.6 Hz, 2H), 2.04 (s, 3H), 1.19 (t, *J* = 7.6 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.2, 145.8, 142.5, 141.6, 135.5,

134.7, 131.9, 131.2, 130.5, 129.8, 129.1, 128.1, 124.9, 44.6, 28.4, 23.1, 15.4; IR (neat) 2964, 1311, 1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{20}H_{20}O_2S$ 324.1184, found 324.1183.



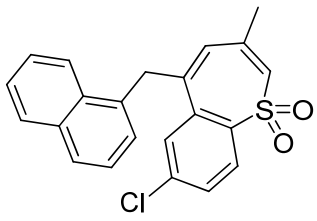
2f

3-Methyl-5-(4-n-amyl)-benzyl-1-benzothiepin,1,1-dioxide(2f): Yellow amorphous solid; 61 mg, 83% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (dd, *J* = 5.9, 3.2 Hz, 1H), 7.76 (dd, *J* = 5.2, 2.3 Hz, 1H), 7.66 – 7.51 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 7.08 (d, *J* = 7.9 Hz, 2H), 6.56 (s, 1H), 6.52 (s, 1H), 4.16 (d, *J* = 12.1 Hz, 2H), 2.61 – 2.46 (q, *J* = 8.0 Hz, 2H), 2.04 (s, 3H), 1.58 (m, 3H), 1.35 – 1.28 (m, 3H), 0.87 (t, *J* = 6.6 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.2, 145.9, 141.6, 141.3, 135.4, 134.7, 131.9, 131.2, 130.4, 129.8, 128.9, 128.7, 128.2, 124.9, 44.5, 35.5, 31.5, 31.1, 23.1, 22.5, 14.0; IR (neat) 2927,1313,1164 cm^{-1}; HRMS (EI-TOF) calcd for $C_{23}H_{26}O_2S$ 366.1654, found 366.1662.



2g

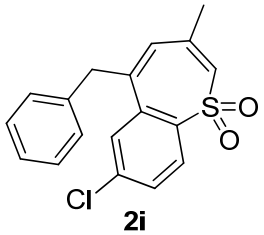
3-Methyl-5-(naphthalen-1-ylmethyl)-1-benzothiepin,1,1-dioxide(2g): Pale yellow solid, 55mg, 80% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20 (dd, *J* = 7.5, 1.6 Hz, 1H), 7.97 – 7.86 (m, 3H), 7.78 (dd, *J* = 6.2, 2.7 Hz, 1H), 7.68 – 7.61 (m, 2H), 7.54 – 7.48 (m, 2H), 7.45 – 7.40 (m, 2H), 6.50 (s, 1H), 6.35 (s, 1H), 4.62 (s, 2H), 1.92 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.3, 145.4, 141.6, 135.1, 134.1, 133.9, 132.1, 131.9, 131.1, 130.3, 129.9, 128.7, 127.9, 127.9, 127.8, 126.5, 125.9, 125.6, 125.1, 124.2, 41.6, 23.1; IR (neat) 3055,1311,1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{18}O_2S$ 346.1028, found 346.1032.



2h

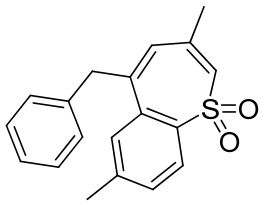
3-Methyl-5-(naphthalen-1-ylmethyl)-7-chloro-1-benzothiepin,1,1-dioxide(2h):
Pale yellow solid, 59mg, 78% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.5

Hz, 1H), 7.92 – 7.85 (m, 3H), 7.81 (s, 1H), 7.63 (d, *J* = 8.5 Hz, 1H), 7.52 (d, *J* = 5.9 Hz, 2H), 7.43 (s, 2H), 6.49 (s, 1H), 6.29 (s, 1H), 4.57 (s, 2H), 1.89 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 147.5, 144.3, 138.6, 133.9, 133.4, 131.8, 130.6, 130.0, 128.7, 128.2, 128.1, 127.8, 126.8, 126.6, 126.1, 125.6, 124.3, 41.4, 23.1; IR (neat) 2924, 1720, 1265 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}ClO_2S$ 380.0638, found 380.0639.



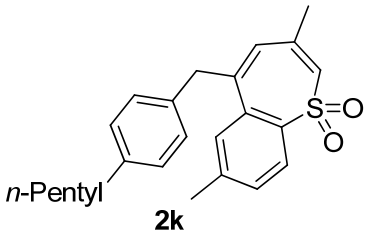
2i

3-Methyl-5-benzyl-7-chloro-1-benzothiepin,1,1-dioxide(2i): Pale yellow solid, 50mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.5 Hz, 1H), 7.72 (d, *J* = 1.6 Hz, 1H), 7.54 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.32 – 7.26 (m, 2H), 7.21 (dd, *J* = 15.1, 7.1 Hz, 3H), 6.58 (s, 1H), 6.54 (s, 1H), 4.18 (s, 2H), 2.04 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ147.3,144.5,140.2,138.4, 137.7, 136.1, 132.1, 130.9,129.9,129.2,128.8,128.0, 126.9,126.7, 44.7, 23.1; IR (neat) 2922,1314,1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{15}ClO_2S$ 330.0481, found 330.0486.



2j

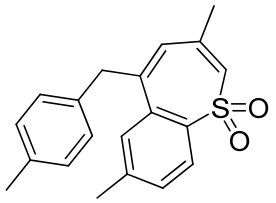
3-Methyl-5-benzyl-7-methyl-1-benzothiepin,1,1-dioxide(2j): Pale yellow solid, 53mg, 86% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.1 Hz, 1H), 7.54 (s, 1H), 7.38 (d, *J* = 8.1 Hz, 1H), 7.26(t, *J* = 3.4 Hz, 4H), 7.19(dd, *J* =5.4, 2.9 Hz, 1H) , 6.52 (d, *J* = 3.1 Hz, 2H), 4.20 (s, 2H), 2.41 (s, 3H), 2.01 (d, *J* = 0.9 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 146.8, 145.6, 142.5, 139.4, 138.4, 134.6, 131.1, 130.7, 130.6, 129.2, 128.6, 128.4, 126.6, 125.0, 44.8, 23.1, 21.7; IR (neat) 2922, 1309, 1129 cm^{-1}; HRMS (EI-TOF) calcd for $C_{19}H_{18}O_2S$ 310.1028, found 310.1034.



2k

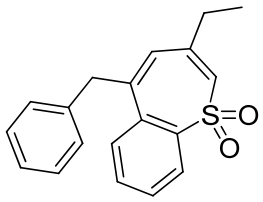
3-Methyl-5-(4-n-amyl)-benzyl-7-methyl-1-benzothiepin,1,1-dioxide(2k): Yellow amorphous solid; 64mg, 85% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.1 Hz, 1H), 7.55 (s, 1H), 7.39 (d, *J* = 8.1 Hz, 1H), 7.14 (d, *J* = 7.9 Hz, 2H), 7.08 (d, *J* = 7.9

Hz, 2H), 6.50 (s, 2H), 4.16 (s, 2H), 2.57 – 2.50 (m, 2H), 2.41 (s, 3H), 2.01 (s, 3H), 1.58 (m, 3H), 1.33 – 1.29 (m, 3H), 0.87 (t, J = 6.7 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 146.8, 145.9, 142.5, 141.2, 139.3, 135.5, 134.7, 131.0, 130.6, 129.1, 128.7, 128.5, 125.0, 44.4, 35.5, 31.5, 31.1, 23.1, 22.5, 21.7, 14.0; IR (neat) 2926, 1312, 1156 cm^{-1}; HRMS (EI-TOF) calcd for $C_{24}H_{28}O_2S$ 380.1810, found 380.1812.



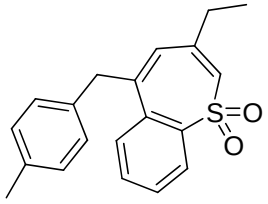
2l

3-Methyl-5-(4-methyl)-benzyl-7-methyl-1-benzothiepin,1,1-dioxide(2l): Pale yellow solid, 53mg, 82% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, J = 8.1 Hz, 1H), 7.55 (s, 1H), 7.38 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 7.9 Hz, 2H), 7.07 (d, J = 7.8 Hz, 2H), 6.51 (s, 2H), 4.16 (s, 2H), 2.41 (s, 3H), 2.28 (s, 3H), 2.01 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 146.8, 145.8, 142.5, 139.4, 136.1, 135.2, 134.66, 130.9, 130.6, 129.3, 129.1, 128.4, 125.0, 44.4, 23.1, 21.7, 21.0; IR (neat) 2923, 1311, 1160 cm^{-1}; HRMS (EI-TOF) calcd for $C_{20}H_{20}O_2S$ 324.1184, found 324.1183.



2m

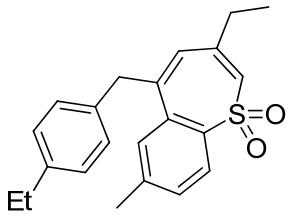
3-Ethyl-5-benzyl-1-benzothiepin,1,1-dioxide(2m): Pale yellow solid, 50mg, 81% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 – 8.10 (m, 1H), 7.80 – 7.71 (m, 1H), 7.62 – 7.55 (m, 2H), 7.29 – 7.26 (m, 2H), 7.23 (s, 2H), 7.18 (t, J = 6.6 Hz, 1H), 6.61 (s, 1H), 6.52 (s, 1H), 4.23 (s, 2H), 2.36 (dd, J = 14.4, 7.2 Hz, 2H), 1.06 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.5, 145.9, 141.7, 138.4, 134.6, 131.9, 130.9, 129.8, 129.1, 128.7, 128.1, 126.6, 125.0, 45.0, 29.9, 12.4; IR (neat) 2968, 1720, 1265 cm^{-1}; HRMS (EI-TOF) calcd for $C_{19}H_{18}O_2S$ 310.1028, found 310.1026.



2n

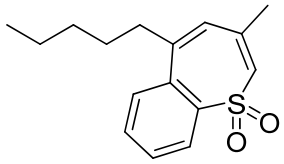
3-Ethyl-5-(4-methyl)-benzyl-1-benzothiepin,1,1-dioxide(2n): Pale yellow solid, 49mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 – 8.09 (m, 1H), 7.80 – 7.73 (m,

1H), 7.59 (dt, *J* = 5.8, 3.8 Hz, 2H), 7.13 (d, *J* = 7.9 Hz, 2H), 7.07 (d, *J* = 7.9 Hz, 2H), 6.60 (s, 1H), 6.51 (s, 1H), 4.19 (s, 2H), 2.35 (dd, *J* = 14.5, 7.4 Hz, 2H), 2.28 (s, 3H), 1.06 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 152.6, 146.1, 141.7, 136.2, 135.3, 134.7, 131.9, 130.7, 129.7, 129.4, 128.9, 128.2, 124.9, 44.7, 29.9, 21.0, 12.4; IR (neat) 2923, 1311, 1163 cm^{-1}; HRMS (EI-TOF) calcd for $C_{20}H_{20}O_2S$ 324.1184, found 324.1187.



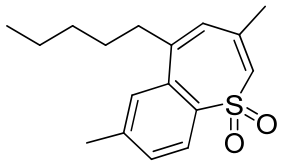
2o

3-Ethyl-5-(4-ethyl)-benzyl-7-methyl-1-benzothiepin,1,1-dioxide(2o): Pale yellow solid; 56mg, 80% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.1 Hz, 1H), 7.55 (s, 1H), 7.39 (d, *J* = 8.1 Hz, 1H), 7.16 (d, *J* = 7.7 Hz, 2H), 7.11 (d, *J* = 7.9 Hz, 2H), 6.53 (s, 1H), 6.50 (s, 1H), 4.17 (s, 2H), 2.59 (dd, *J* = 15.0, 7.5 Hz, 2H), 2.42 (s, 3H), 2.32 (dd, *J* = 14.3, 7.1 Hz, 2H), 1.20 (t, *J* = 7.6 Hz, 3H), 1.04 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 152.2, 146.1, 142.5, 139.4, 135.7, 134.8, 130.6, 130.6, 129.1, 128.5, 128.1, 125.0, 44.5, 29.8, 28.4, 21.7, 15.4, 12.4; IR (neat) 2966, 1309, 1138 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{24}O_2S$ 352.1497, found 352.1500.



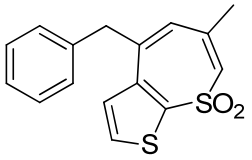
2p

3-Methyl-5-n-amyl-1-benzothiepin,1,1-dioxide(2p): Yellow oil; 30mg, 53% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (dd, *J* = 7.3, 1.7 Hz, 1H), 7.77 (d, *J* = 7.1 Hz, 1H), 7.65 (m, 2H), 6.58 (s, 1H), 6.48 (s, 1H), 2.83 (s, 2H), 2.04 (s, 3H), 1.52 – 1.44 (m, 2H), 1.28 (m, 4H), 0.84 (t, *J* = 6.8 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 148.2, 147.4, 142.0, 134.5, 131.9, 130.1, 129.7, 128.6, 127.9, 124.9, 39.7, 31.4, 28.6, 23.2, 22.4, 13.9; IR (neat) 2924, 1720, 1265 cm^{-1}; HRMS (EI-TOF) calcd for $C_{16}H_{20}O_2S$ 276.1184, found 276.1189.



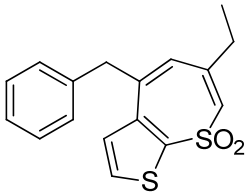
2q

3-Methyl-5-n-amyl-7-methyl-1-benzothiepin,1,1-dioxide(2q): Yellow oil; 30mg, 52% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.1 Hz, 1H), 7.54 (s, 1H), 7.43 (d, *J* = 8.1 Hz, 1H), 6.55 (s, 1H), 6.47 (s, 1H), 2.84 (s, 2H), 2.49 (s, 3H), 2.02 (s, 3H), 1.48 (m, 2H), 1.35 – 1.25 (m, 4H), 0.85 (t, *J* = 6.7 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 148.0, 146.9, 142.5, 139.8, 134.5, 130.5, 130.3, 128.5, 128.3, 124.9, 39.6, 31.4, 28.6, 23.1, 22.4, 21.7, 13.9; IR (neat) 2928, 1311, 1157 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{22}O_2S$ 290.1341, found 290.1349.



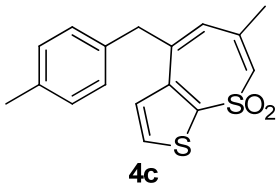
4a

4-Benzyl-6-methyl-thieno[2,3-b]thiepine,8,8-dioxide(4a): Yellow solid, 54mg, 90% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 5.2 Hz, 1H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.23 (dd, *J* = 9.7, 6.3 Hz, 2H), 7.18 (d, *J* = 7.5 Hz, 2H), 6.61 (s, 1H), 6.57 (s, 1H), 4.13 (s, 2H), 2.15 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 145.2, 141.0, 139.6, 138.1, 131.3, 128.9, 128.8, 128.7, 127.5, 127.5, 126.8, 44.8, 24.1; IR (neat) 2924, 1314, 1153 cm^{-1}; HRMS (EI-TOF) calcd for $C_{16}H_{14}O_2S_2$ 302.0435, found 302.0441.



4b

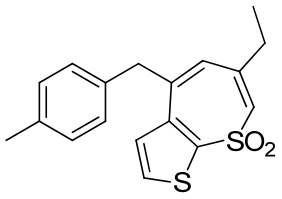
4-Benzyl-6-ethyl-thieno[2,3-b]thiepine,8,8-dioxide(4b): Pale yellow solid, 56mg, 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 5.2 Hz, 1H), 7.37 – 7.29 (m, 3H), 7.27 – 7.23 (m, 2H), 7.21 (d, *J* = 7.4 Hz, 2H), 6.65 (s, 1H), 6.58 (s, 1H), 4.16 (s, 2H), 2.47 (dd, *J* = 14.8, 7.4 Hz, 2H), 1.15 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 150.6, 141.2, 139.7, 138.2, 130.9, 128.9, 128.8, 128.7, 127.5, 126.8, 126.2, 44.9, 30.9, 13.1; IR (neat) 2970, 1313, 1149 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{16}O_2S_2$ 316.0592, found 316.0598.



4c

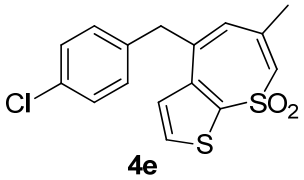
4-(4-Methyl)-benzyl-6-methyl-thieno[2,3-b]thiepine,8,8-dioxide(4c): Pale yellow solid, 58mg, 92% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 5.2 Hz, 1H), 7.24 (s, 1H), 7.09 (d, *J* = 8.0 Hz ,2H), 7.06 (d, *J* = 8.1 Hz, 2H) , 6.60 (s, 1H), 6.56 (s, 1H), 4.08 (s, 2H), 2.30 (s, 3H), 2.15 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 145.2, 141.2,

139.7, 136.4, 134.9, 131.1, 129.5, 128.9, 128.6, 127.5, 127.4, 44.4, 24.1, 21.0; IR (neat) 2923, 1315, 1153 cm^{-1}; HRMS (EI) calcd for $C_{17}H_{16}O_2S_2$ 316.0592, found 316.0587.



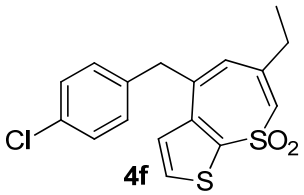
4d

4-(4-Methyl)-benzyl-6-ethyl-thieno[2,3-b]thiepine,8,8-dioxide(4d): Yellow amorphous solid; 58mg, 88% yield; ^1H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 5.2 Hz, 1H), 7.24 (d, *J* = 5.3 Hz, 1H), 7.10 (d, *J* = 8.1 Hz, 2H), 7.06 (d, *J* = 8.1Hz, 2H), 6.62 (s, 1H), 6.54 (s, 1H), 4.09 (s, 2H), 2.44 (dd, *J* = 14.8, 7.3 Hz, 2H), 2.30 (s, 3H), 1.12 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 150.6, 141.5, 139.8, 136.4, 135.0, 130.7, 129.5, 128.9, 128.6, 127.5, 126.1, 44.5, 30.9, 21.0, 13.1; IR (neat) 2925, 1314, 1150 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{18}O_2S_2$ 330.0748, found 330.0757.



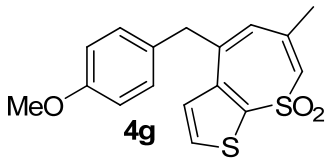
4e

4-(4-Chloro)-benzyl-6-methyl-thieno[2,3-b]thiepine,8,8-dioxide(4e): Pale yellow solid, 61mg, 91% yield; ^1H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 5.2 Hz, 1H), 7.26 – 7.24 (m, 1H), 7.24-7.21 (m, 2H), 7.10 (d, *J* = 8.2 Hz, 2H), 6.61 (s, 1H), 6.58 (s, 1H), 4.09 (s, 2H), 2.15 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 145.1, 141.5, 140.4, 139.3, 136.5, 132.7, 131.3, 130.1, 129.1, 128.9, 127.9, 127.2, 44.2, 24.0; IR (neat) 2970, 1313, 1150 cm^{-1}; HRMS (EI-TOF) calcd for $C_{16}H_{13}ClO_2S_2$ 336.0045, found 336.0041.



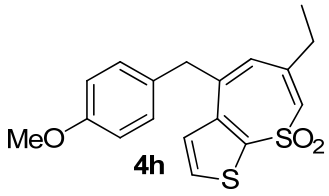
4f

4-(4-Chloro)-benzyl-6-ethyl-thieno[2,3-b]thiepine,8,8-dioxide(4f): Pale yellow solid, 65mg, 93% yield; ^1H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 5.1 Hz, 1H), 7.24 (s, 1H), 7.24-7.20 (m, 2H), 7.10 (d, J = 8.0 Hz), 7.10 (d, *J* = 8.0 Hz, 2H), 6.62 (s, 1H), 6.56 (s, 1H), 4.10 (s, 2H), 2.45 (dd, *J* = 14.6, 7.2 Hz, 2H), 1.13 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 150.5, 141.5, 140.7, 139.3, 136.6, 132.7, 130.9, 130.0, 129.2, 128.9, 127.2, 126.6, 44.2, 30.8, 13.0; IR (neat) 2923, 1314, 1153 cm^{-1}; HRMS (EI) calcd for $C_{17}H_{15}ClO_2S_2$ 350.0202, found 350.0207.



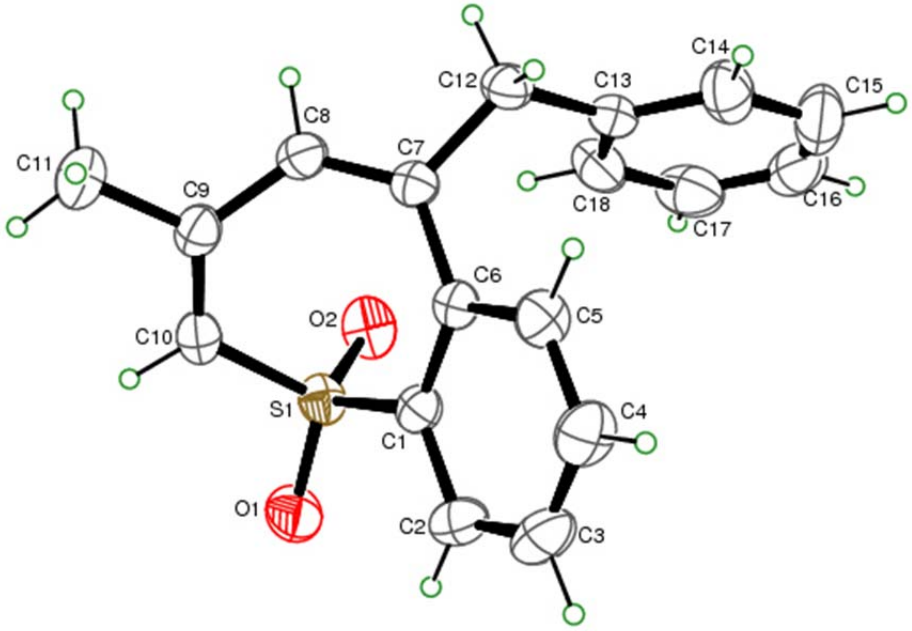
4g

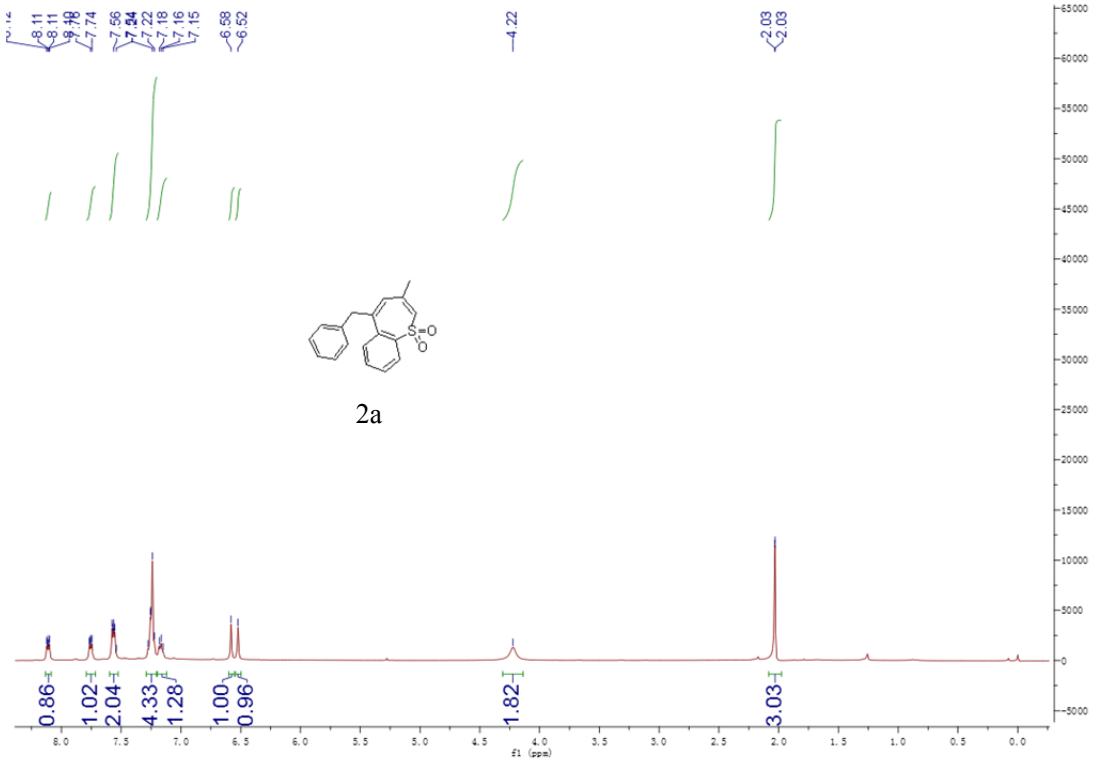
4-(4-Methoxy)-benzyl-6-methyl-thieno[2,3-b]thiepine,8,8-dioxide(4g): Yellow solid, 54mg, 82% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 5.2 Hz, 1H), 7.25 – 7.23 (m, 1H), 7.08 (d, *J* = 8.4 Hz, 2H), 6.82 (d, *J* = 8.5 Hz, 2H), 6.59 (s, 1H), 6.56 (s, 1H), 4.06 (s, 2H), 3.77 (s, 3H), 2.14 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 158.4, 145.2, 141.4, 139.7, 130.9, 129.8, 129.8, 128.9, 127.5, 127.4, 114.2, 55.2, 43.9, 24.1; IR (neat) 2924, 1314, 1154 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{16}O_3S_2$ 332.0541, found 332.0540.



4h

4-(4-Methoxy)-benzyl-6-ethyl-thieno[2,3-b]thiepine,8,8-dioxide(4h): Yellow solid, 55mg, 80% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 5.2 Hz, 1H), 7.24 (s, 1H), 7.09 (d, *J* = 8.5 Hz, 2H), 6.83 (d, *J* = 8.6 Hz, 2H), 6.60 (s, 1H), 6.54 (s, 1H), 4.07 (s, 2H), 3.77 (s, 3H), 2.44 (dd, *J* = 14.6, 7.2 Hz, 2H), 1.12 (t, *J* = 7.4 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 150.6, 141.7, 130.6, 129.8, 128.9, 127.5, 126.1, 114.2, 55.2, 44.1, 30.9, 13.1; IR (neat) 2924, 1306, 1150 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{18}O_3S_2$ 346.0697, found 346.0695.


C14
C12
C13
C15
C8
C7
C11
C9
C18
C16
C17
C6
C5
O2
C10
S1
C4
C1
O1
C2
C3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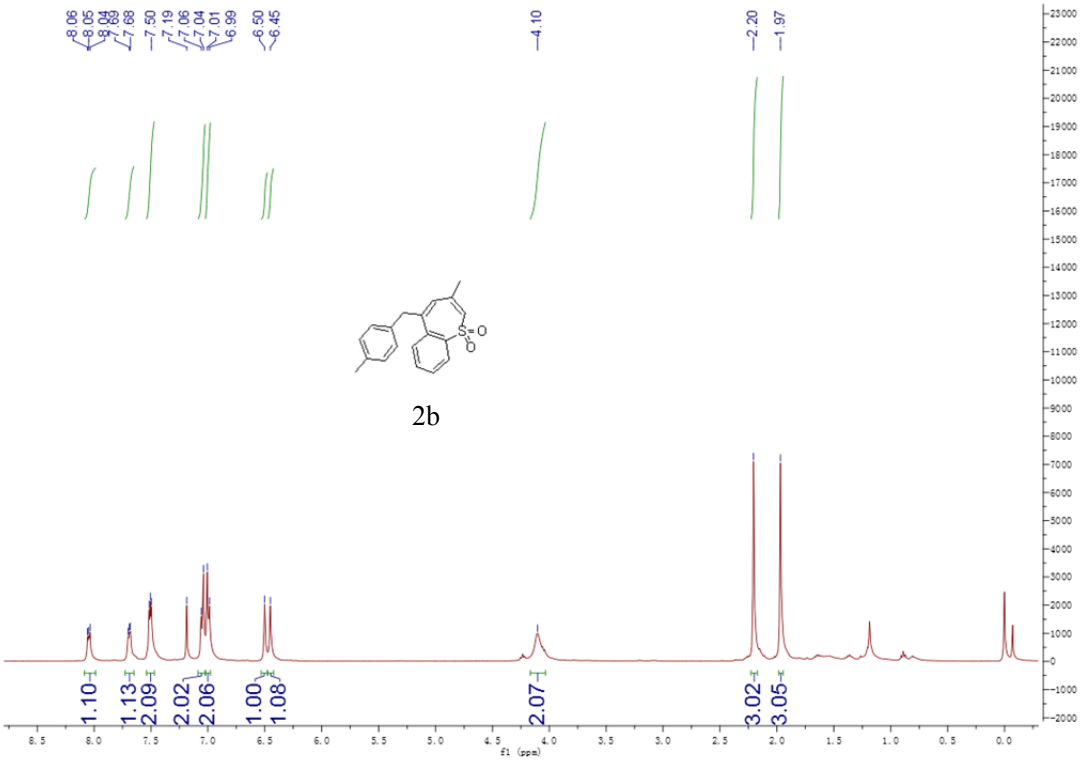
7.18
7.16
7.15
6.58
6.52
4.22
2.03
2.03
0.86
1.02
2.04
4.33
1.28
1.00
0.96
1.82
3.03
f1 (ppm)

2a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7.04
7.01
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6.50
6.45
4.10
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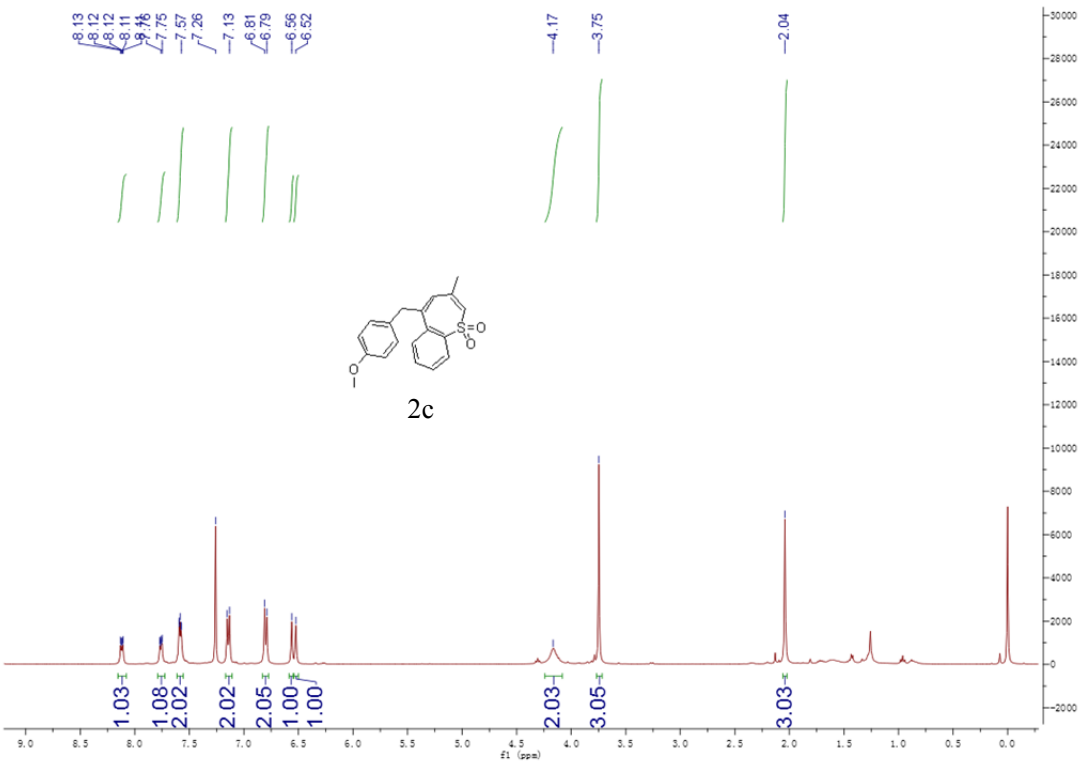
1.97
1.10
1.13
2.09
2.02
2.06
1.00
1.08
2.07
3.02
3.05
f1 (ppm)

2b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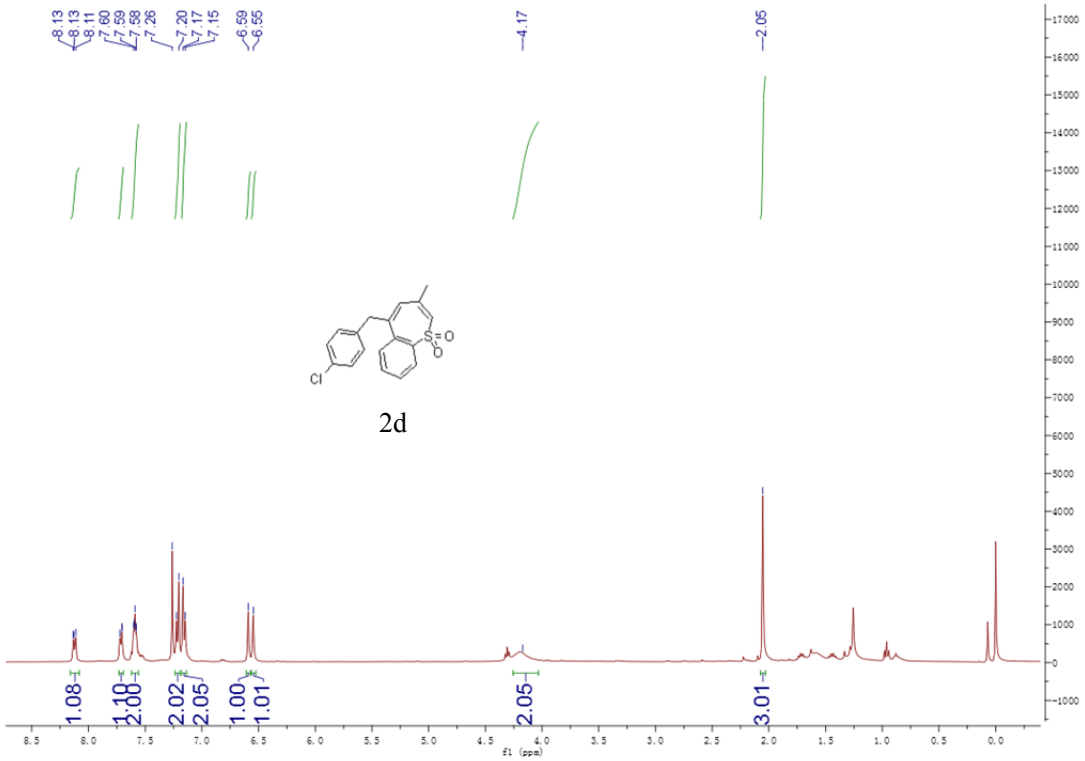
2.03
3.05
3.03
f1 (ppm)

2c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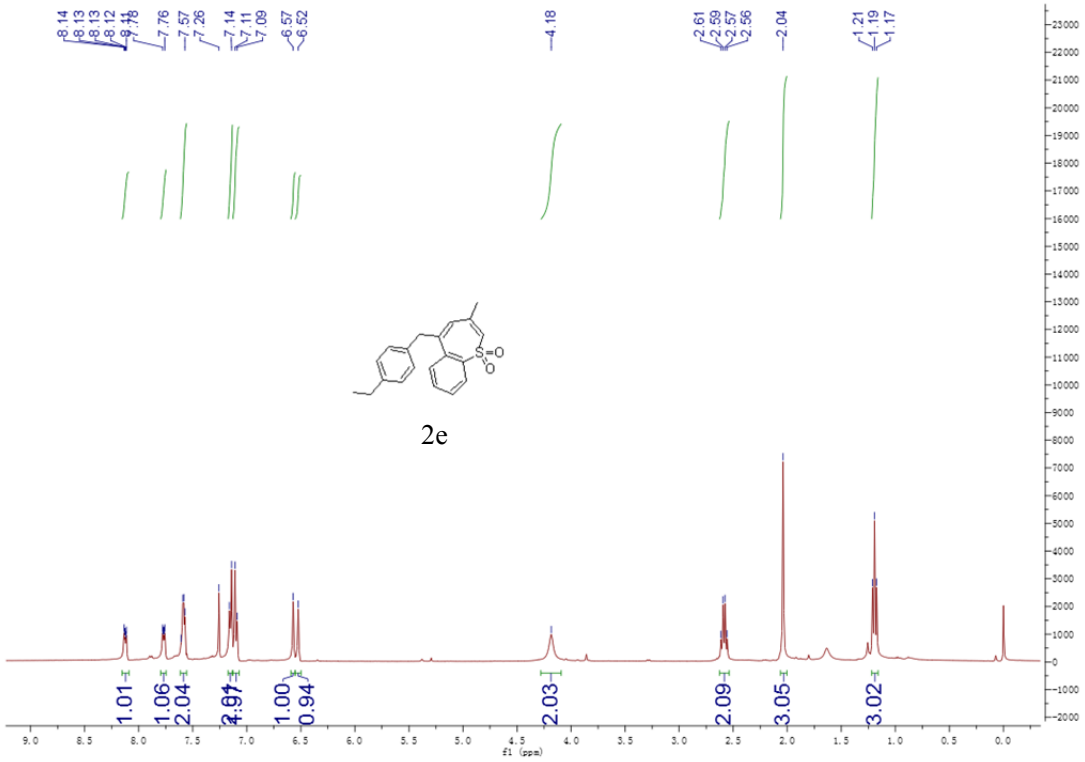
1.01
2.05
3.01
f1 (ppm)

2d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7.09
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2.61
2.59
2.57
2.56
2.04
1.21
1.19
1.17
1.01
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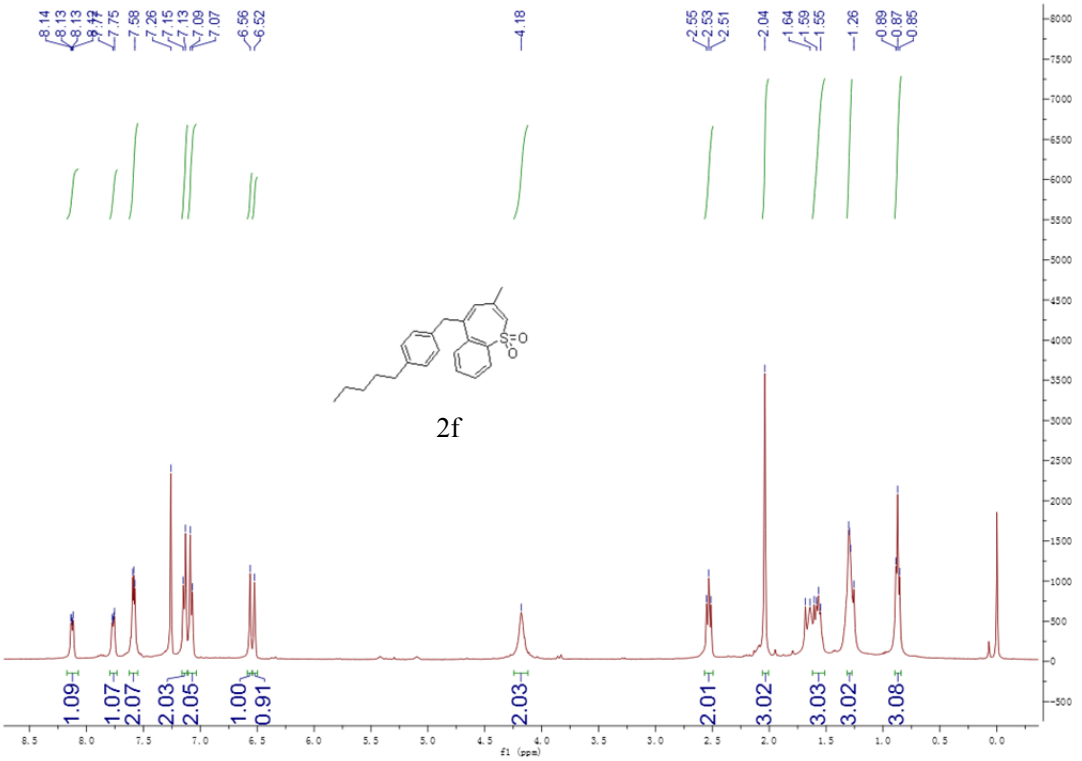
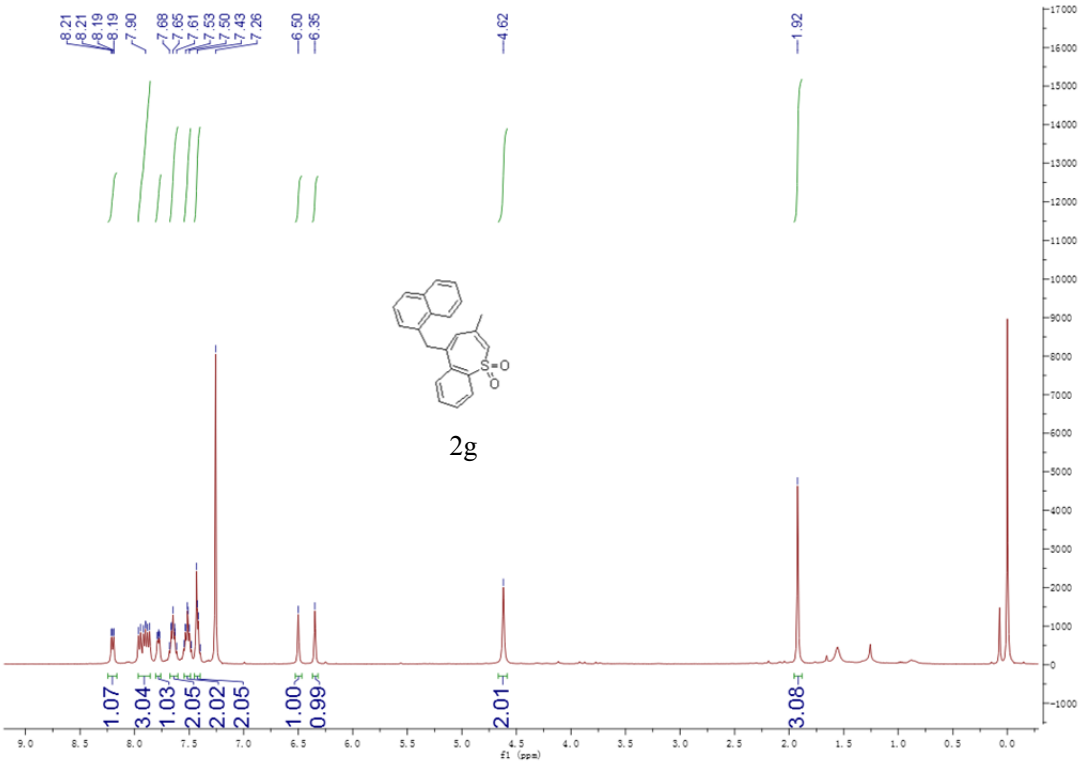
2.04
1.00
0.94
2.03
2.09
3.05
3.02
f1 (ppm)

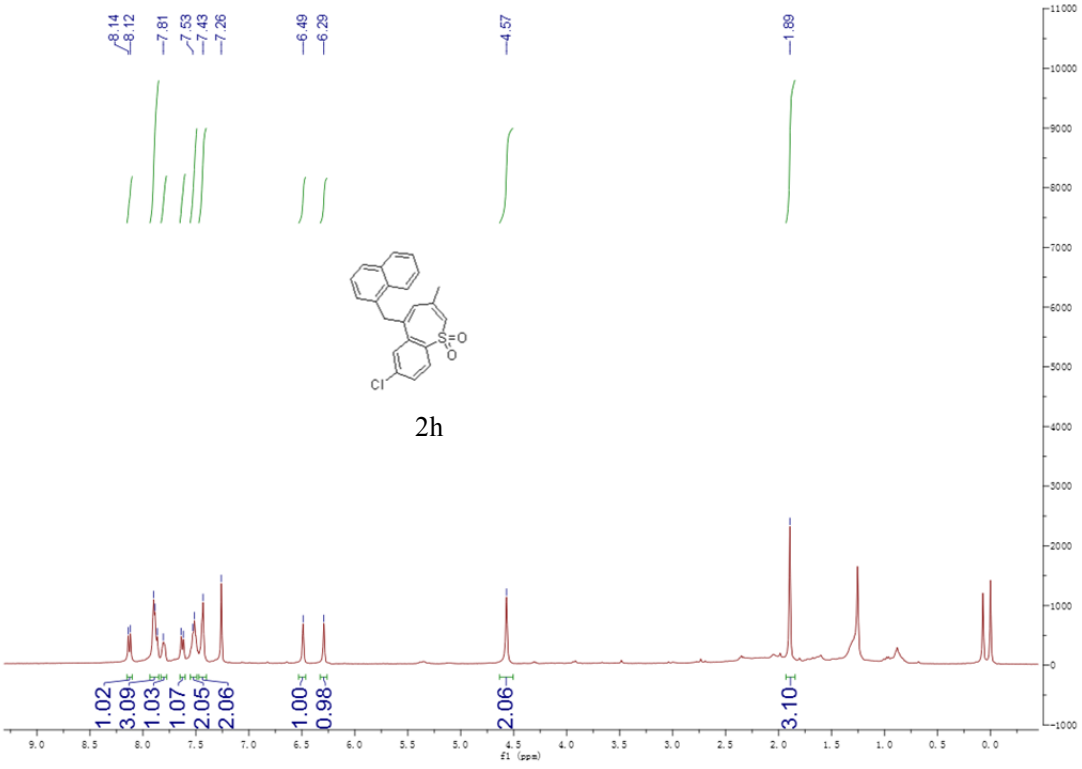
2e



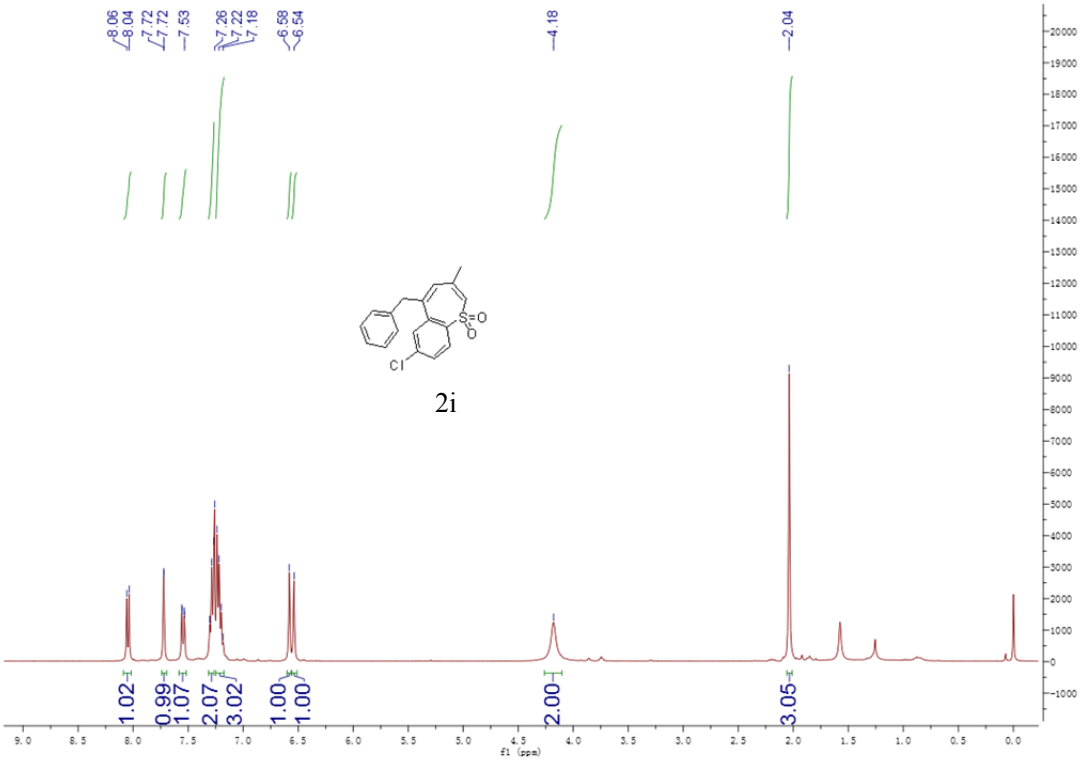
2f



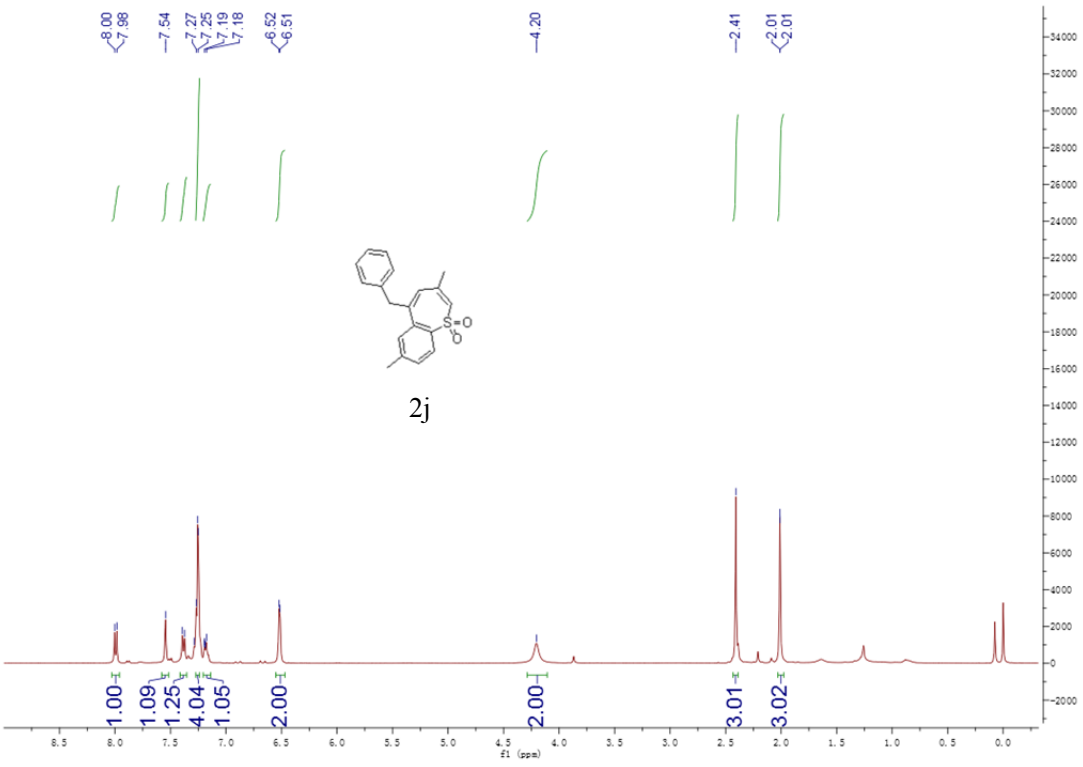
2g


8.14
8.12
7.81
7.53
7.43
7.26
6.49
6.29
4.57
1.89
S
O
O
Cl
1.02
3.09
1.03
1.07
2.05
2.06
1.00
0.98
2.06
3.10
f1 (ppm)

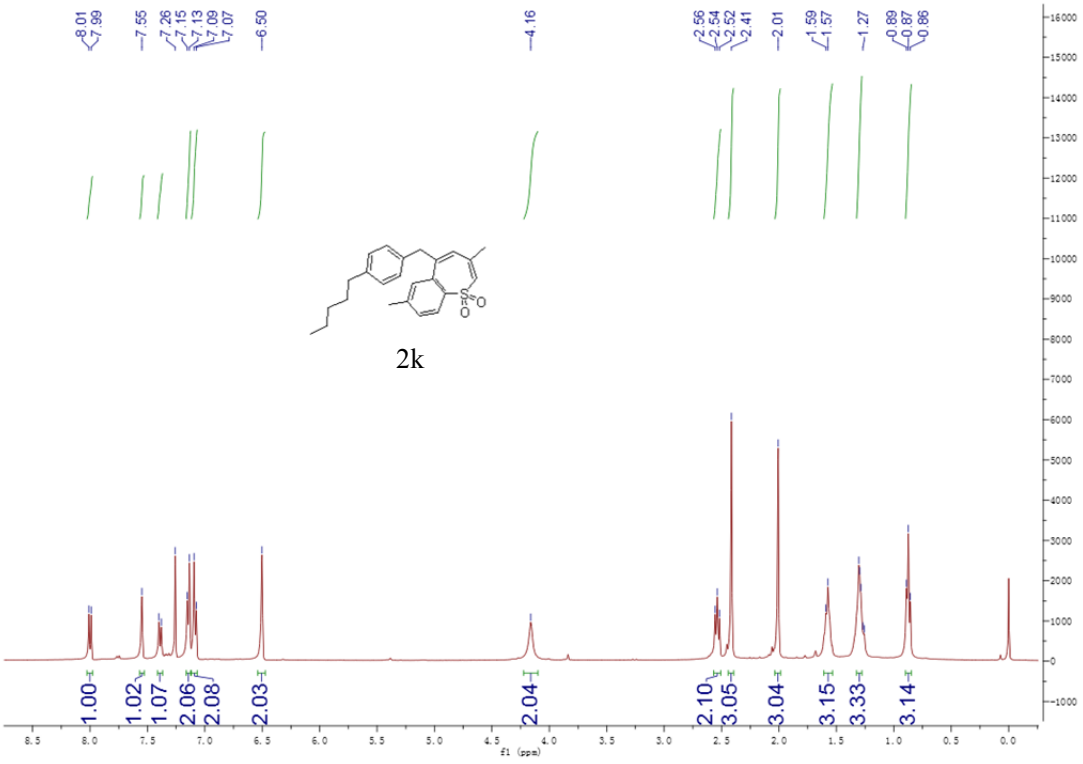
2h


8.06
8.04
7.72
7.72
7.53
7.26
7.22
7.18
6.58
6.54
4.18
2.04
S
O
O
Cl
1.02
0.99
1.07
2.07
3.02
1.00
1.00
2.00
3.05
f1 (ppm)

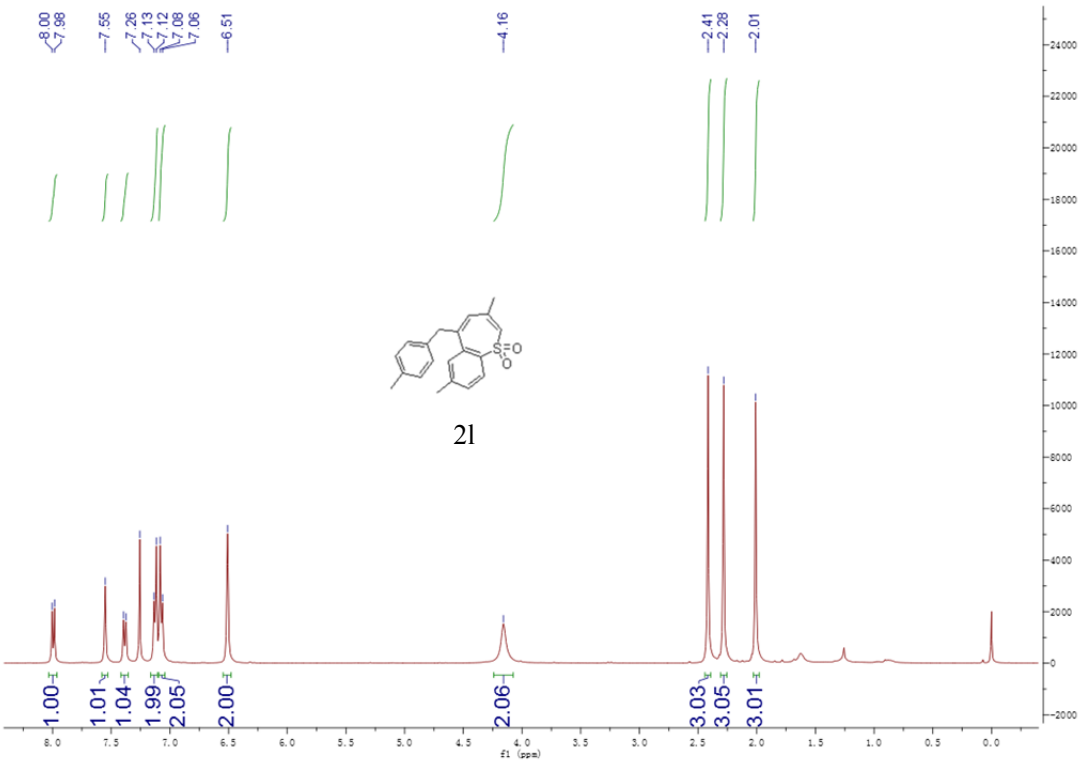
2i


8.00
7.98
7.54
7.27
7.25
7.19
7.18
6.52
6.51
4.20
2.41
2.01
2.01
1.00
1.09
1.25
4.04
1.05
2.00
2.00
3.01
3.02
f1 (ppm)

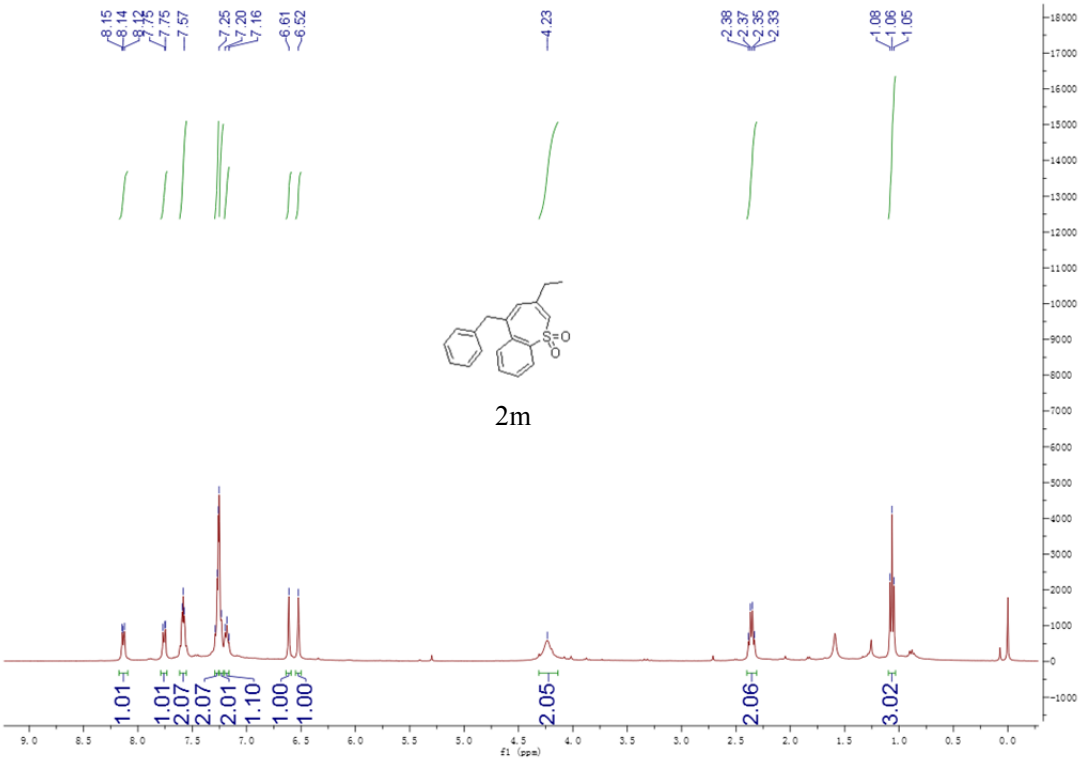
2j


8.01
7.99
7.55
7.26
7.15
7.13
7.09
7.07
6.50
4.16
2.56
2.54
2.52
2.41
2.01
1.59
1.57
1.27
0.89
0.87
0.86
1.00
1.02
1.07
2.06
2.08
2.03
2.04
2.10
3.05
3.04
3.15
3.33
3.14
f1 (ppm)

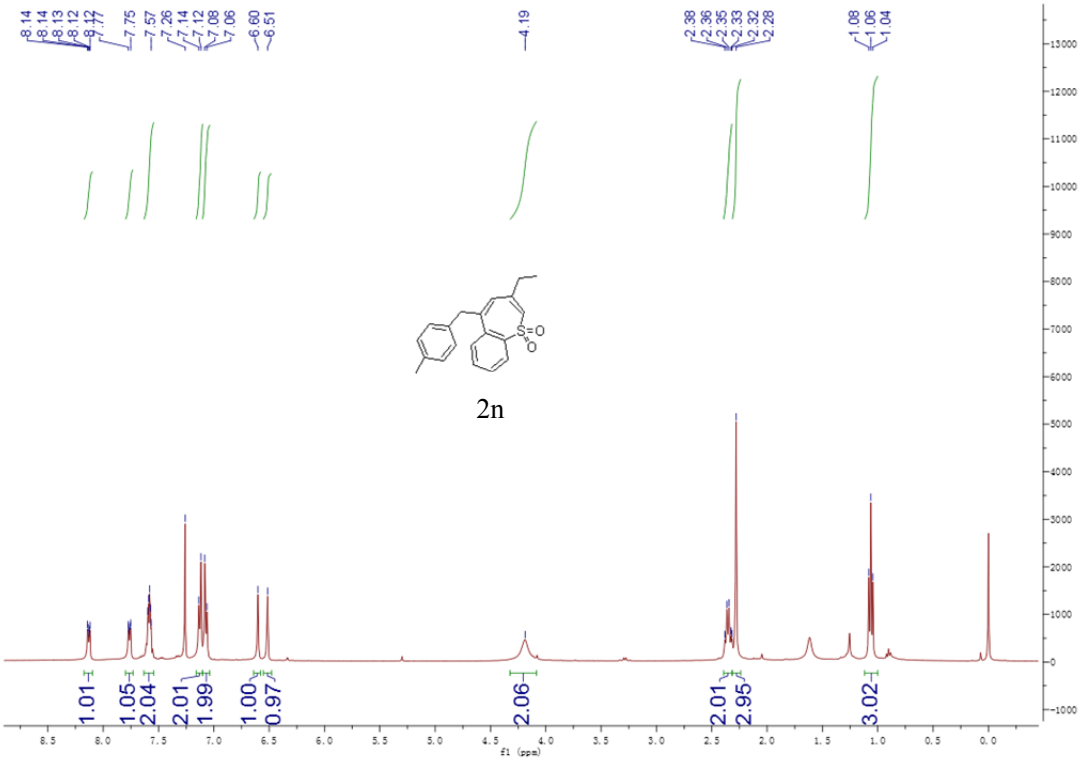
2k


8.00
7.98
7.55
7.26
7.13
7.12
7.08
7.06
6.51
4.16
2.41
2.28
2.01
1.00
1.01
1.04
1.99
2.05
2.00
2.06
3.03
3.05
3.01
f1 (ppm)

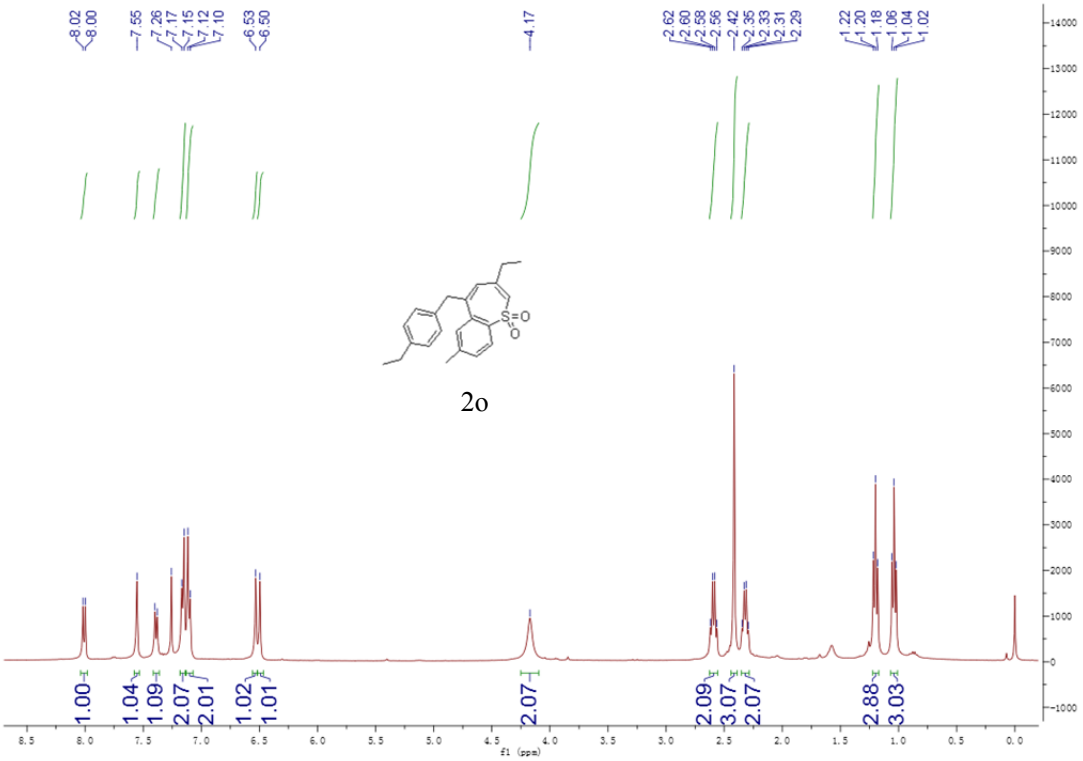
2l


8.15
8.14
8.12
7.75
7.75
7.57
7.25
7.20
7.16
6.61
6.52
4.23
2.38
2.37
2.35
2.33
1.08
1.06
1.05
1.01
1.01
2.07
2.01
1.10
1.00
1.00
2.05
2.06
3.02
f1 (ppm)

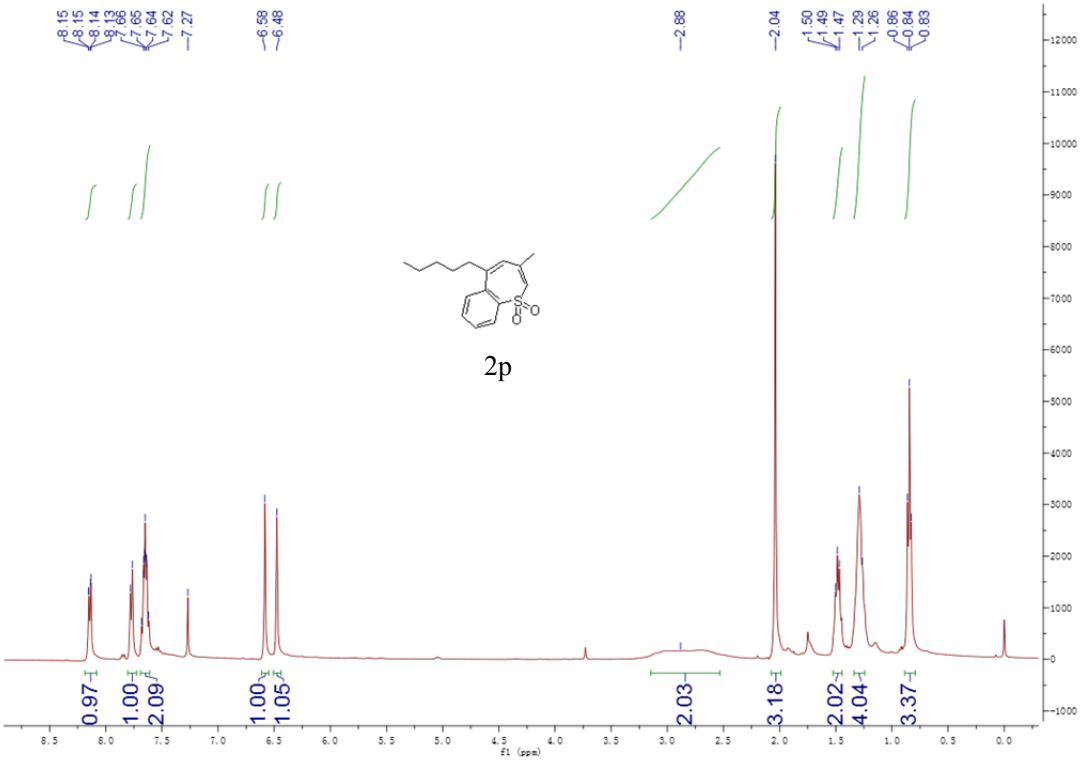
2m



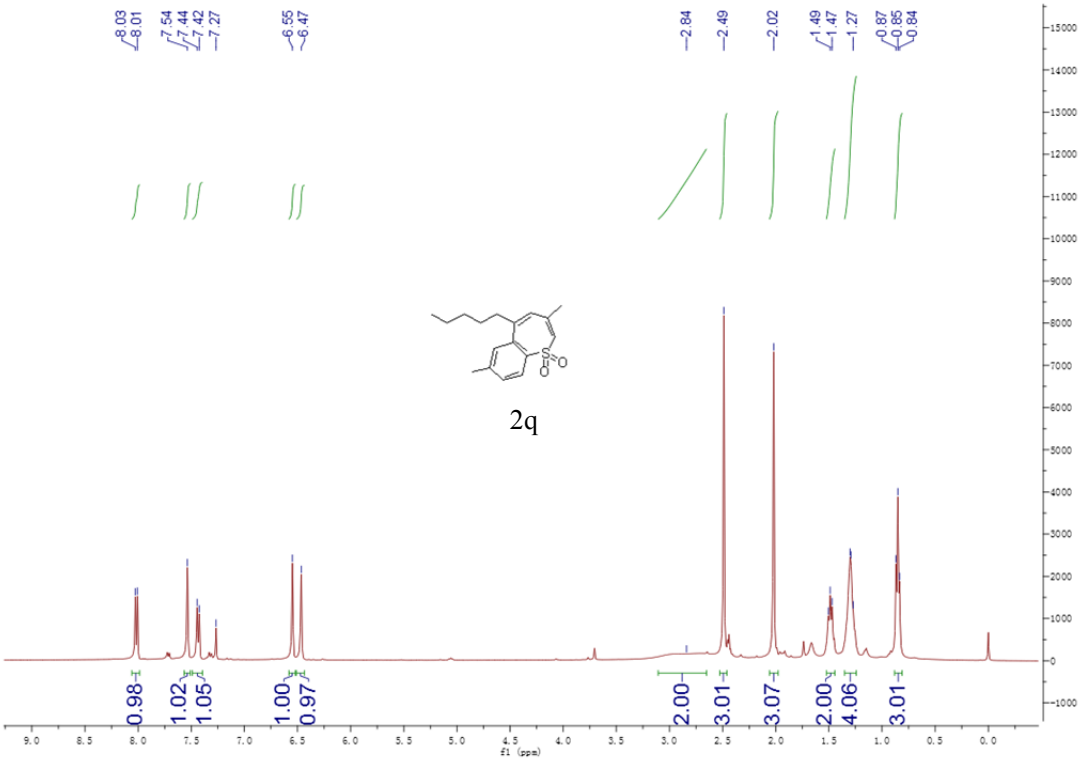
2n



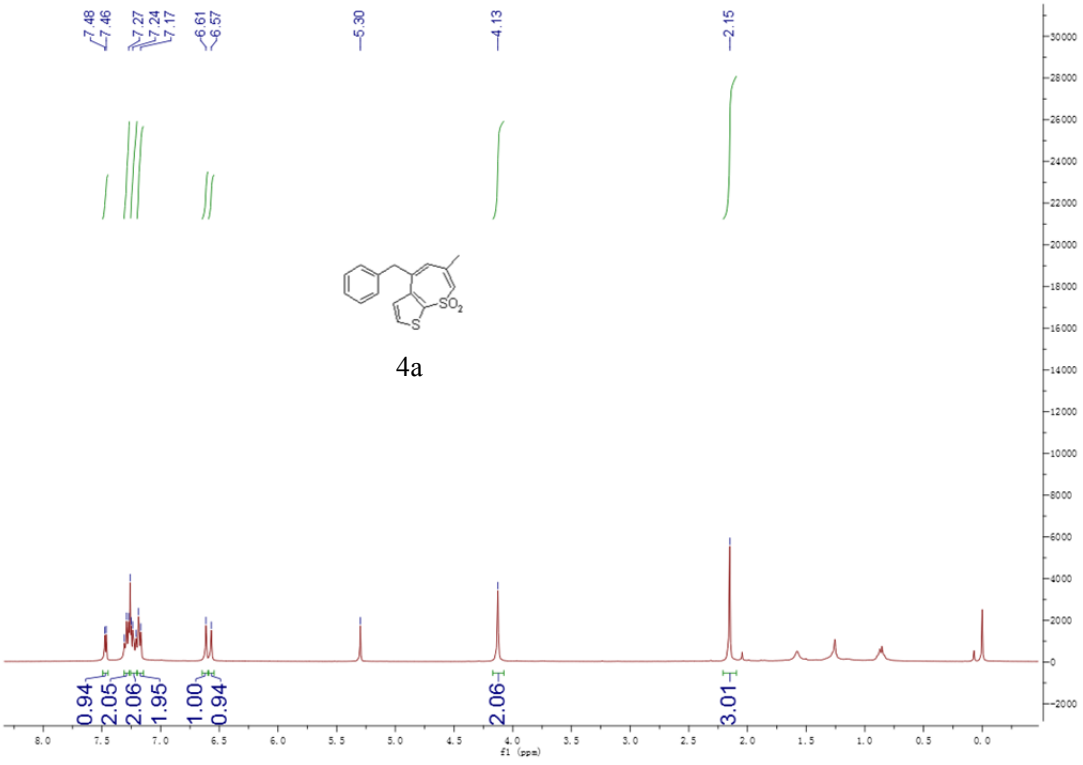
2o


8.15
8.15
8.14
8.13
7.66
7.65
7.64
7.62
7.27
6.58
6.48
2.88
2.04
1.50
1.49
1.47
1.29
1.26
0.86
0.84
0.83
0.97
1.00
2.09
1.00
1.05
2.03
3.18
2.02
4.04
3.37
f1 (ppm)

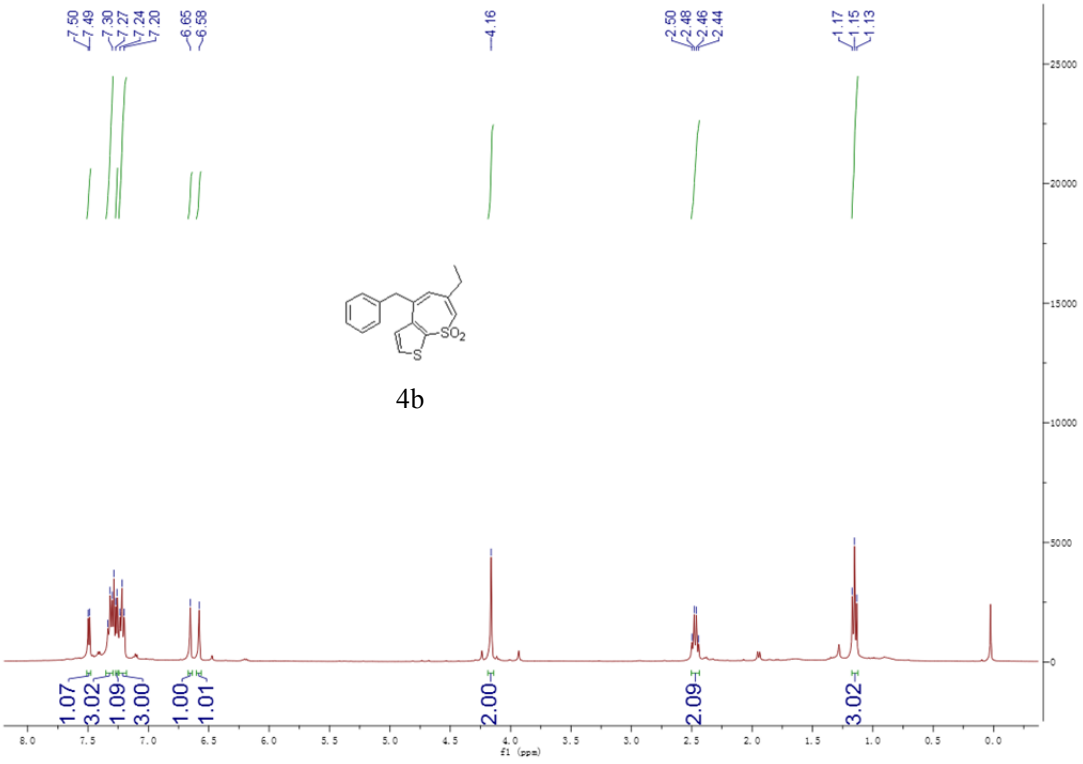
2p


8.03
8.01
7.54
7.44
7.42
7.27
6.55
6.47
2.84
2.49
2.02
1.49
1.47
1.27
0.87
0.85
0.84
0.98
1.02
1.05
1.00
0.97
2.00
3.01
3.07
2.00
4.06
3.01
f1 (ppm)

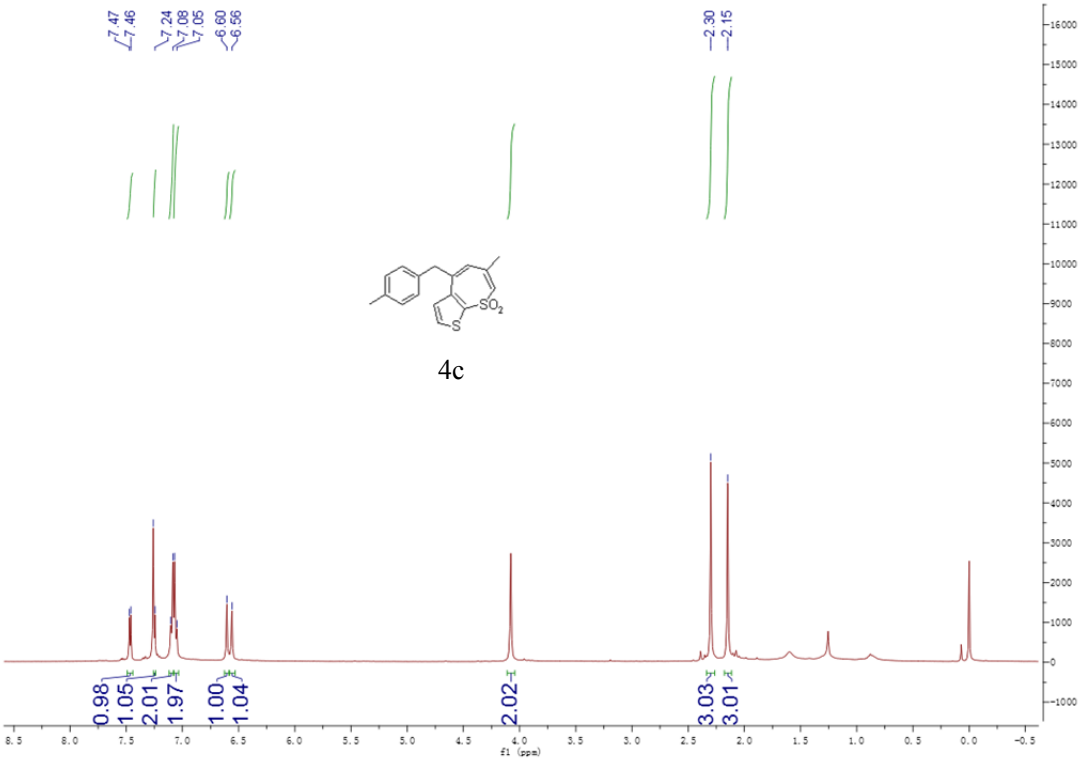
2q


7.48
7.46
7.27
7.24
7.17
6.61
6.57
5.30
4.13
2.15
SO2
S
0.94
2.05
2.06
1.95
1.00
0.94
2.06
3.01
f1 (ppm)

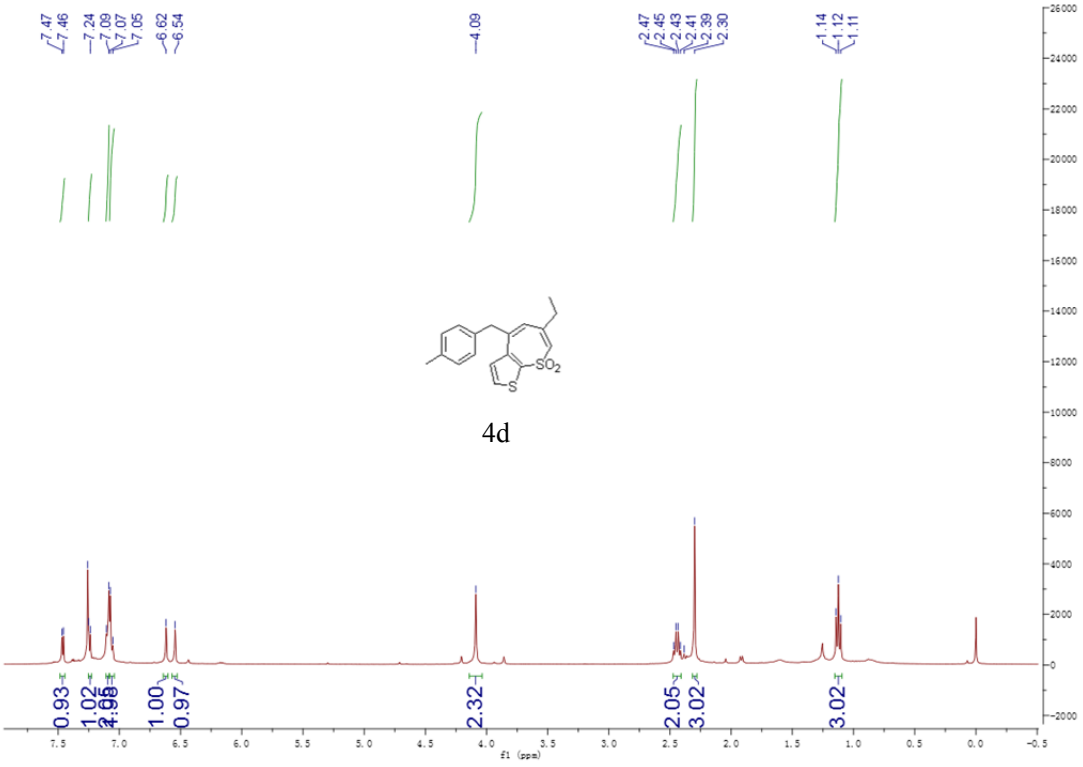
4a


7.50
7.49
7.30
7.27
7.24
7.20
6.65
6.58
4.16
2.50
2.48
2.46
2.44
1.17
1.15
1.13
SO2
S
1.07
3.02
1.09
3.00
1.00
1.01
2.00
2.09
3.02
f1 (ppm)

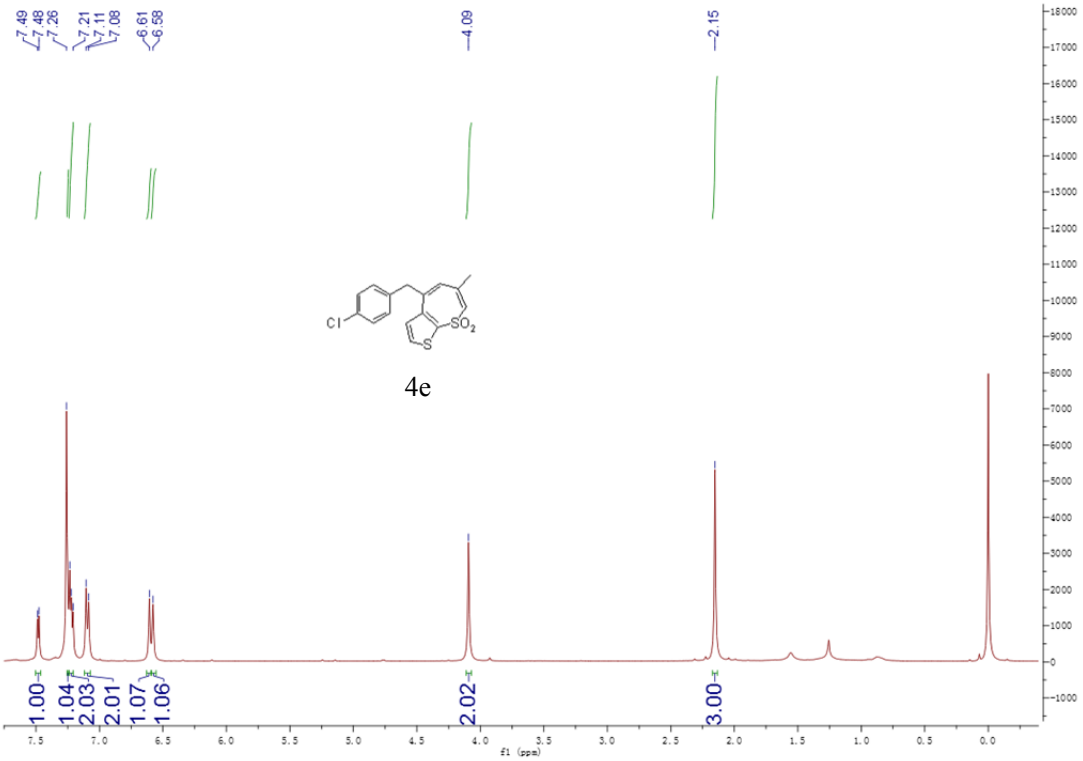
4b


7.47
7.46
7.24
7.08
7.05
6.60
6.56
2.30
2.15
0.98
1.05
2.01
1.97
1.00
1.04
2.02
3.03
3.01
f1 (ppm)

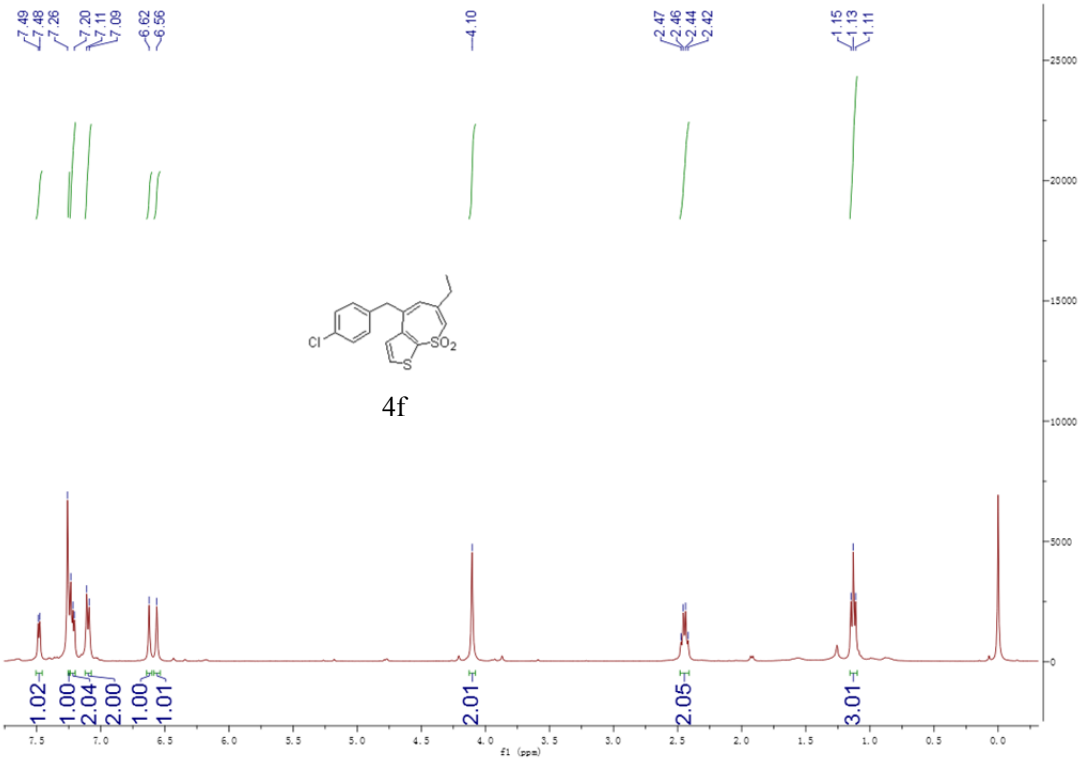
4c


7.47
7.46
7.24
7.09
7.07
7.05
6.62
6.54
4.09
2.47
2.45
2.43
2.41
2.39
2.30
1.14
1.12
1.11
0.93
1.02
1.00
0.97
2.32
2.05
3.02
3.02
f1 (ppm)

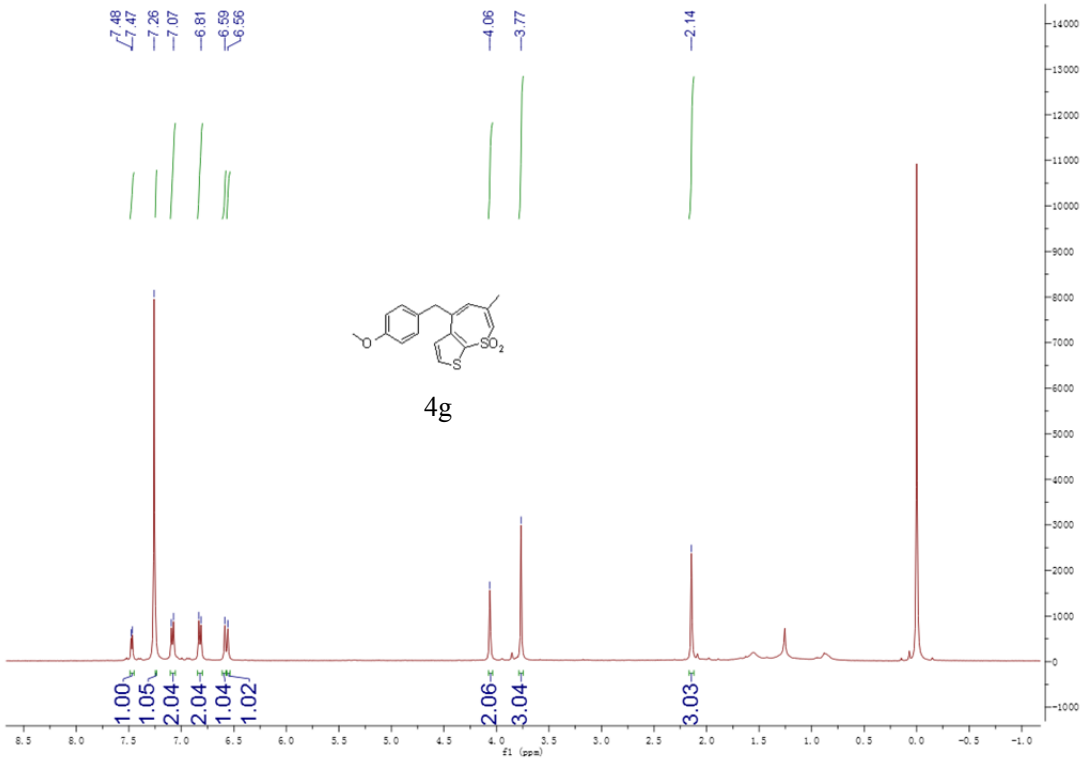
4d


7.49
7.48
7.26
7.21
7.11
7.08
6.61
6.58
4.09
2.15
Cl
SO2
S
1.00
1.04
2.03
2.01
1.07
1.06
2.02
3.00
f1 (ppm)

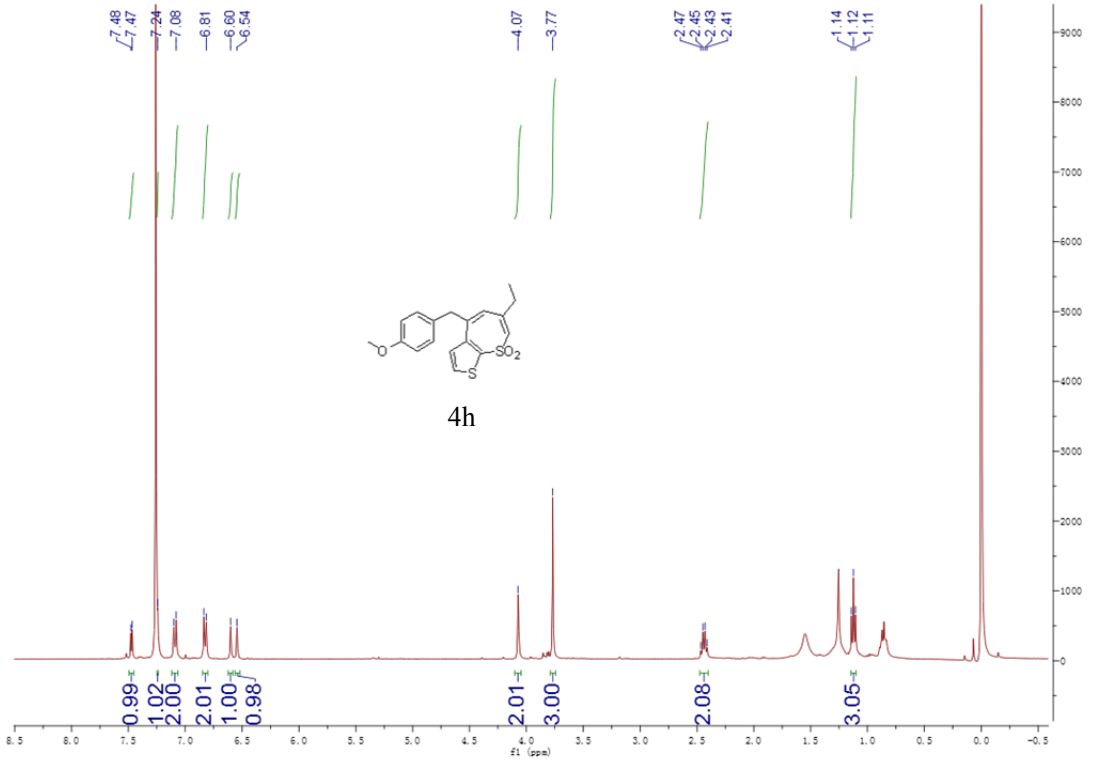
4e


7.49
7.48
7.26
7.20
7.11
7.09
6.62
6.56
4.10
2.47
2.46
2.44
2.42
1.15
1.13
1.11
Cl
SO2
S
1.02
1.00
2.04
2.00
1.00
1.01
2.01
2.05
3.01
f1 (ppm)

4f


7.48
7.47
7.26
7.07
6.81
6.59
6.56
4.06
3.77
2.14
1.00
1.05
2.04
2.04
1.04
1.02
2.06
3.04
3.03
f1 (ppm)

4g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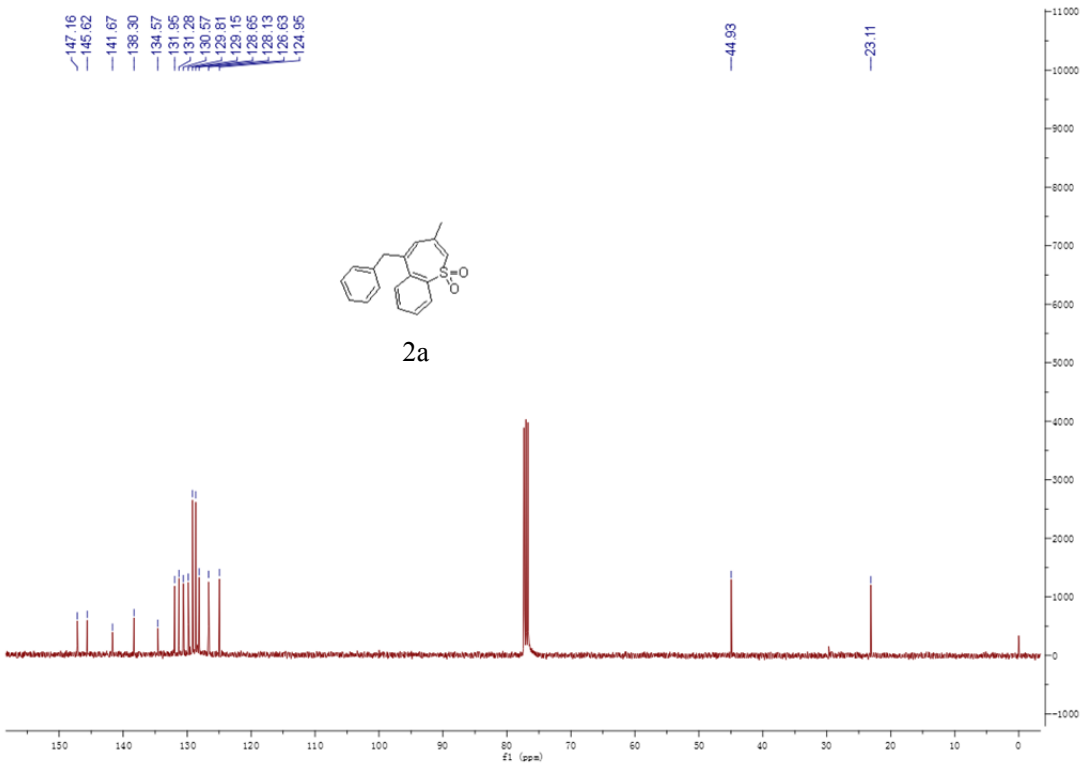
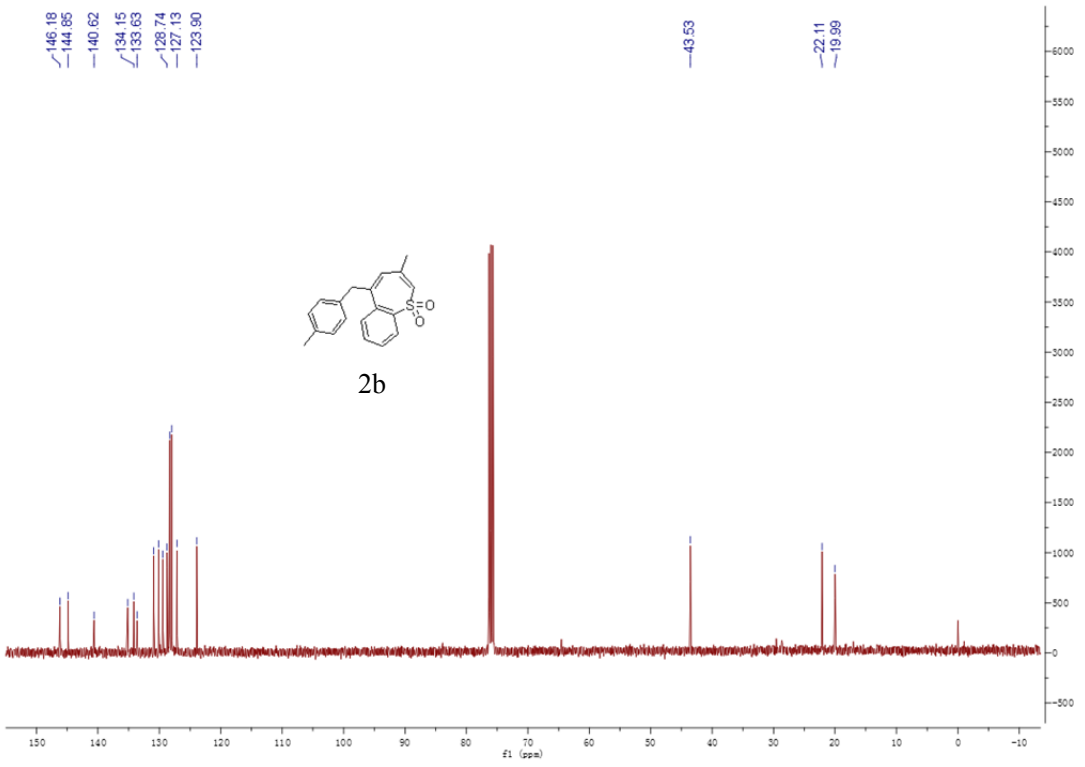
7.47
7.24
7.08
6.81
6.60
6.54
4.07
3.77
2.47
2.45
2.43
2.41
1.14
1.12
1.11
0.99
1.02
2.00
2.01
1.00
0.98
2.01
3.00
2.08
3.05
f1 (ppm)

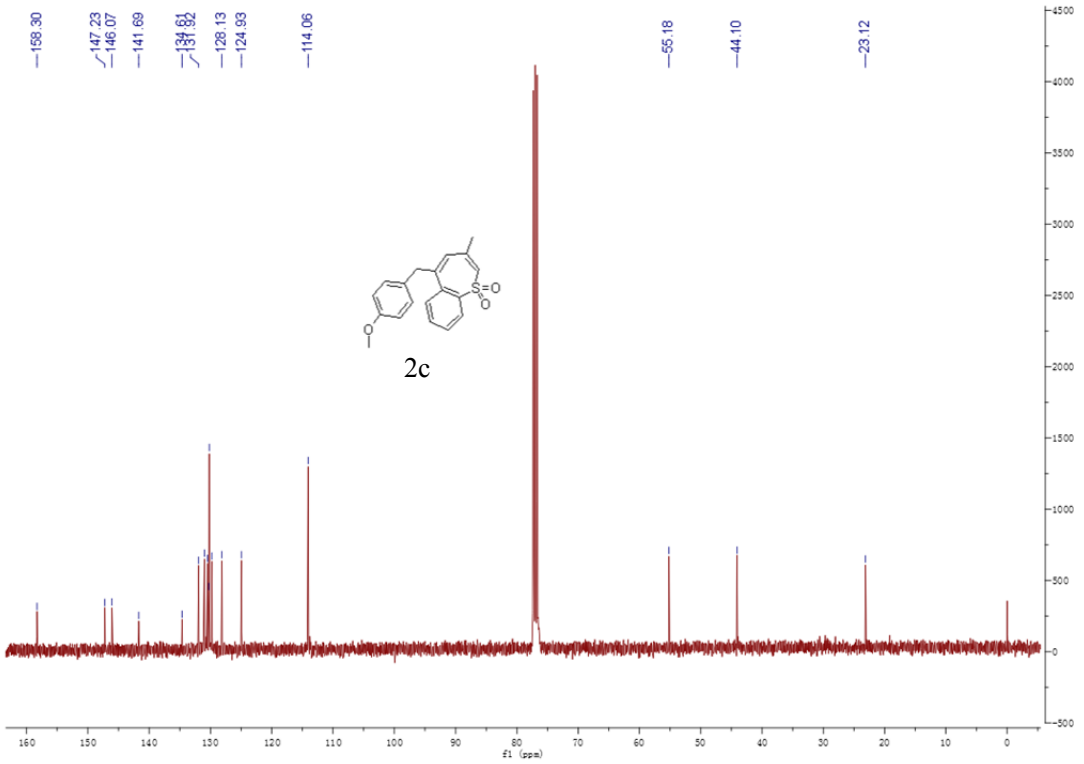
4h


147.16
145.62
141.67
138.30
134.57
131.95
131.28
130.57
129.81
129.15
128.65
128.13
126.63
124.95
44.93
23.11
f1 (ppm)

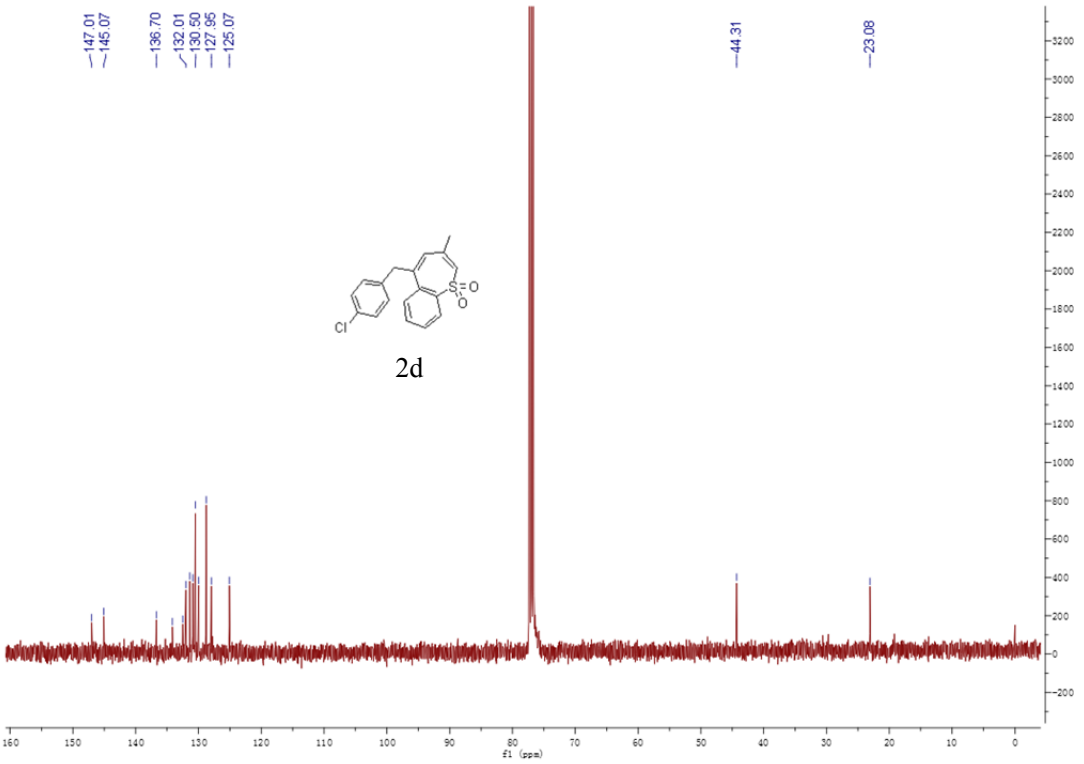
2a


146.18
144.85
140.62
134.15
133.63
128.74
127.13
123.90
43.53
22.11
19.99
f1 (ppm)

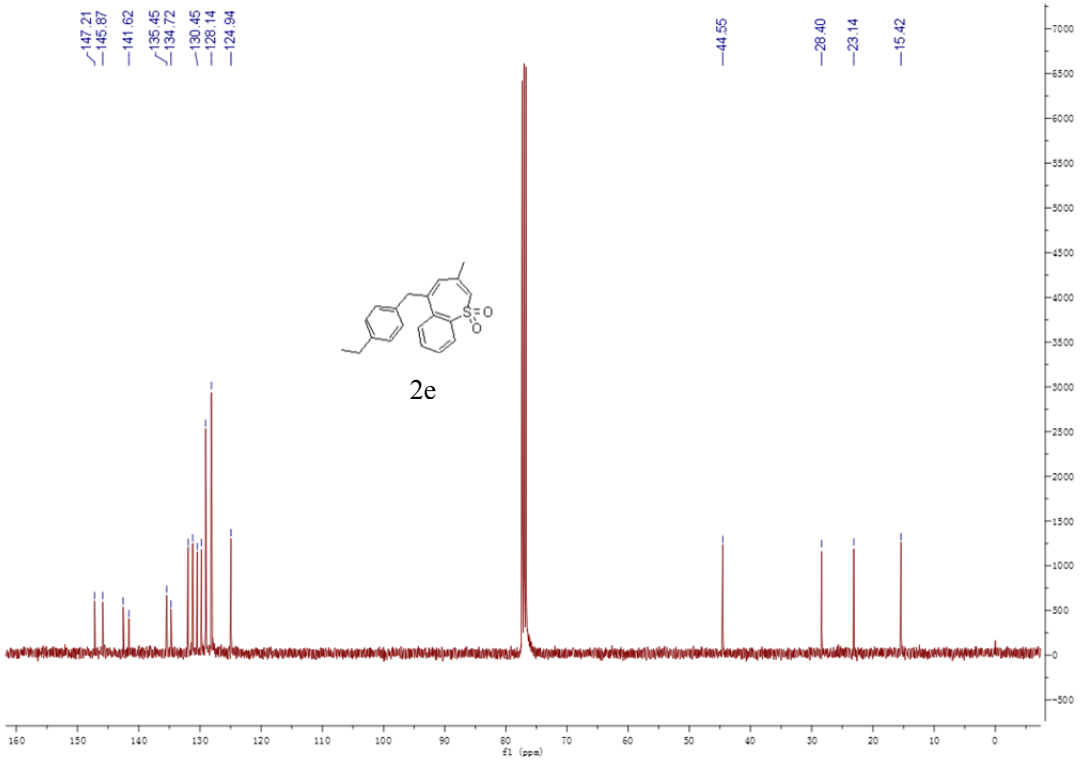
2b


158.30
147.23
146.07
141.69
134.61
131.92
128.13
124.93
114.06
55.18
44.10
23.12
O
S
O
f1 (ppm)

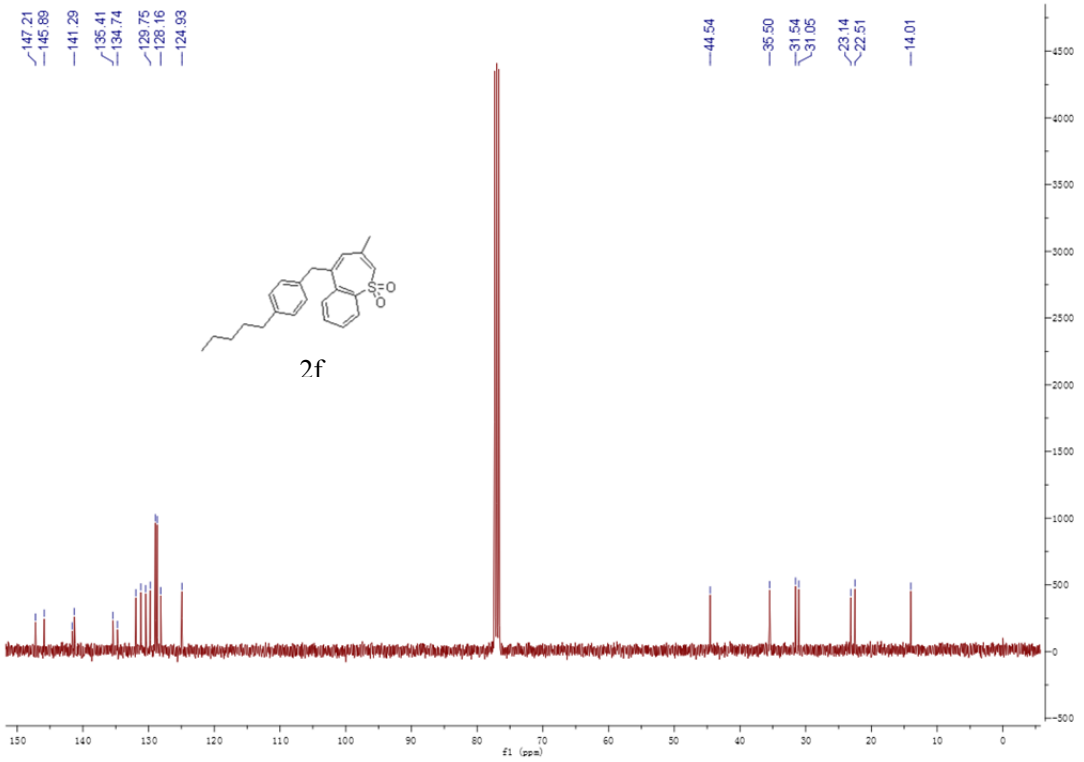
2c


147.01
145.07
136.70
132.01
130.50
127.95
125.07
44.31
23.08
Cl
S
O
O
f1 (ppm)

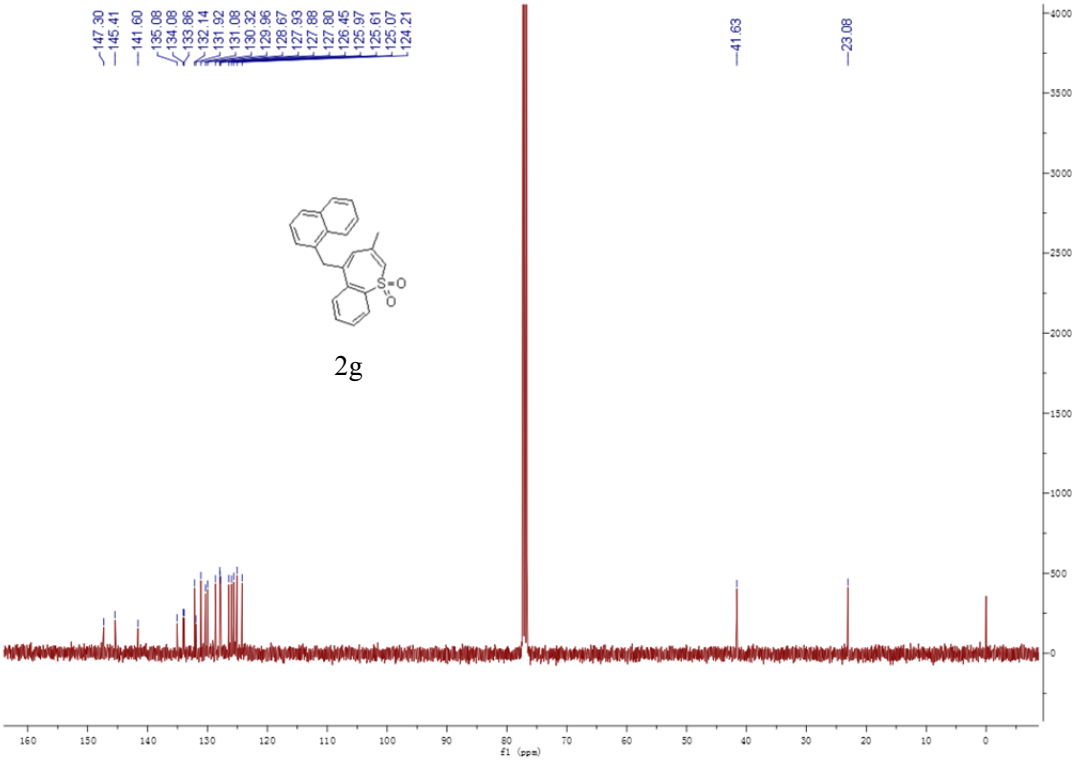
2d


147.21
145.87
141.62
135.45
134.72
130.45
128.14
124.94
44.55
28.40
23.14
15.42
f1 (ppm)

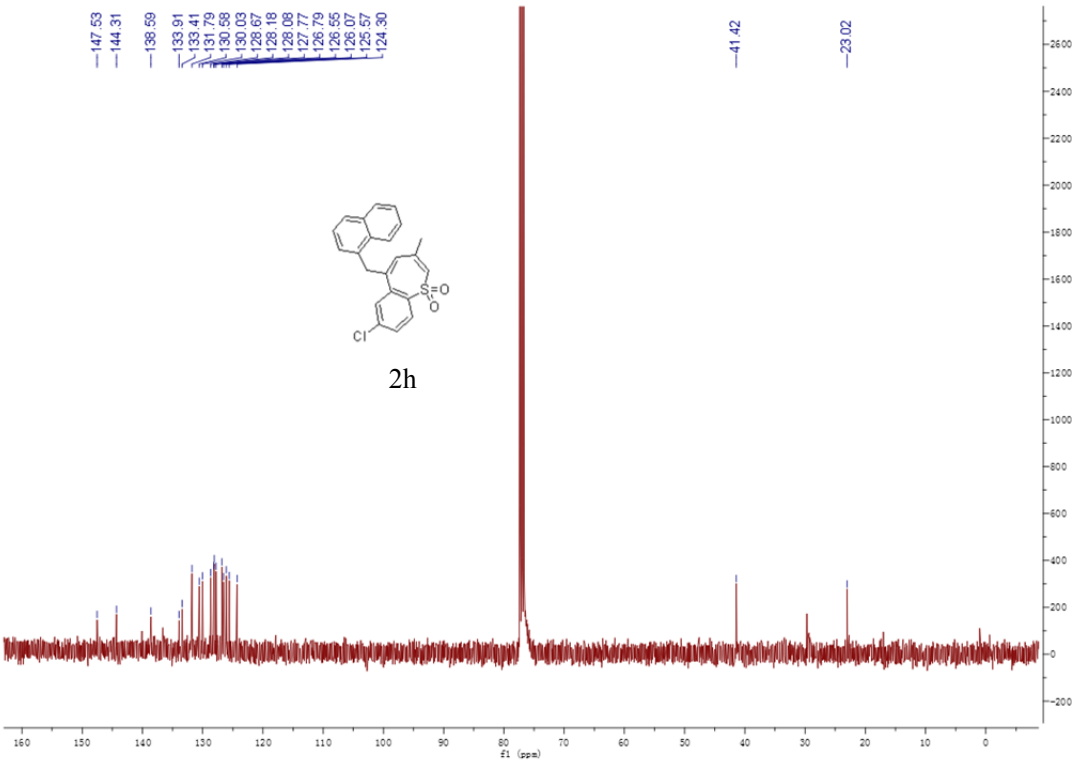
2e


147.21
145.89
141.29
135.41
134.74
129.75
128.16
124.93
44.54
35.50
31.54
31.05
23.14
22.51
14.01
f1 (ppm)

2f


147.30
145.41
141.60
135.08
134.08
133.86
132.14
131.92
131.08
130.32
129.96
128.67
127.93
127.88
127.80
126.45
125.97
125.61
125.07
124.21
41.63
23.08
S
O
O

2g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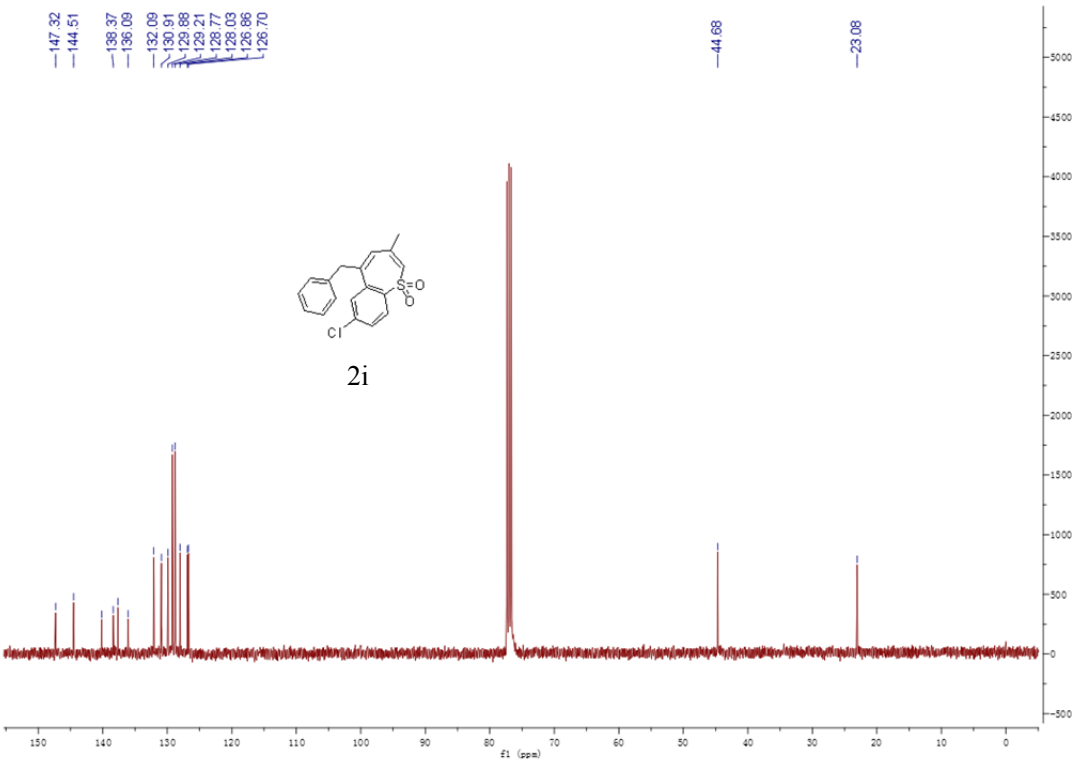
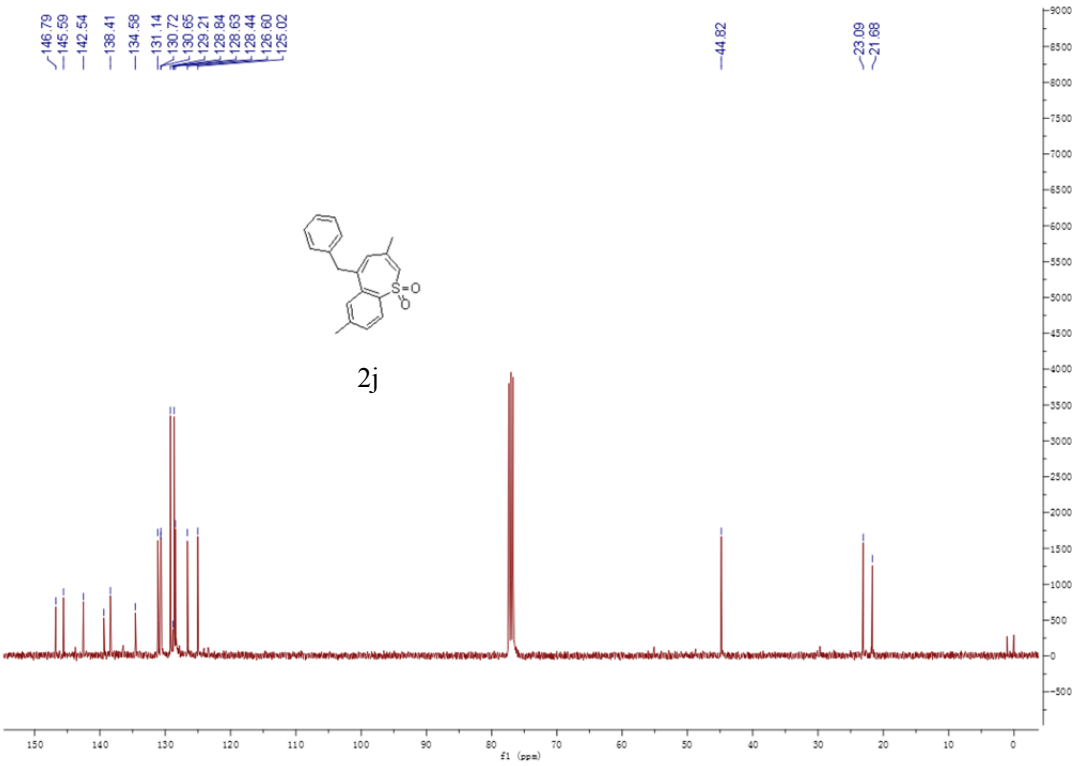
144.31
138.59
133.91
133.41
131.79
130.58
130.03
128.67
128.18
128.08
127.77
126.79
126.55
126.07
125.57
124.30
41.42
23.02
S
O
O
Cl

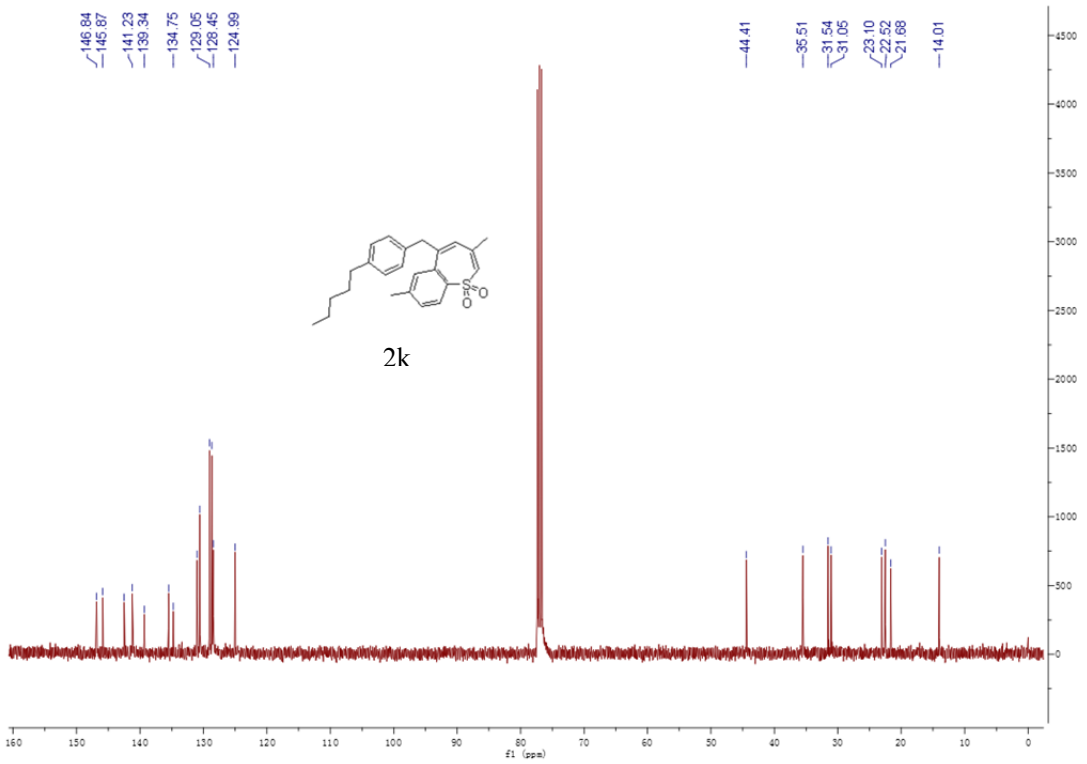
2h


147.32
144.51
138.37
136.09
132.09
130.91
129.88
129.21
128.77
128.03
126.86
126.70
44.68
23.08
Cl
S
O
O
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

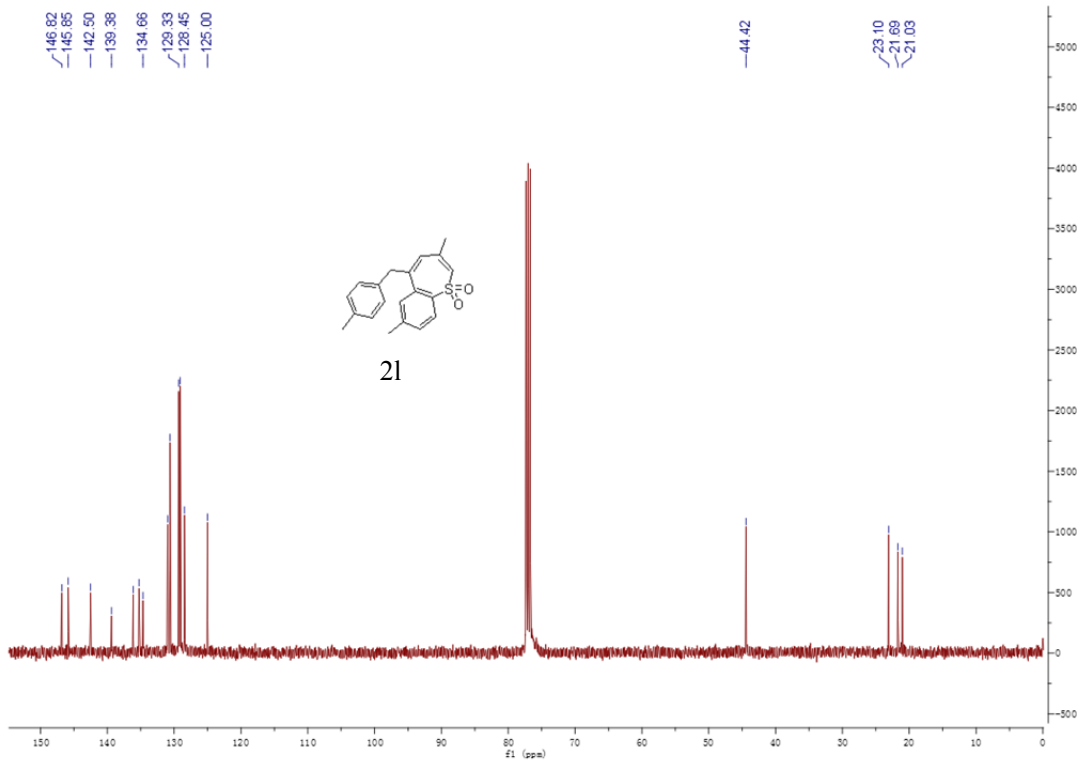
2i


146.79
145.59
142.54
138.41
134.58
131.14
130.72
130.65
129.21
128.84
128.63
128.44
126.60
125.02
44.82
23.09
21.68
S
O
O
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

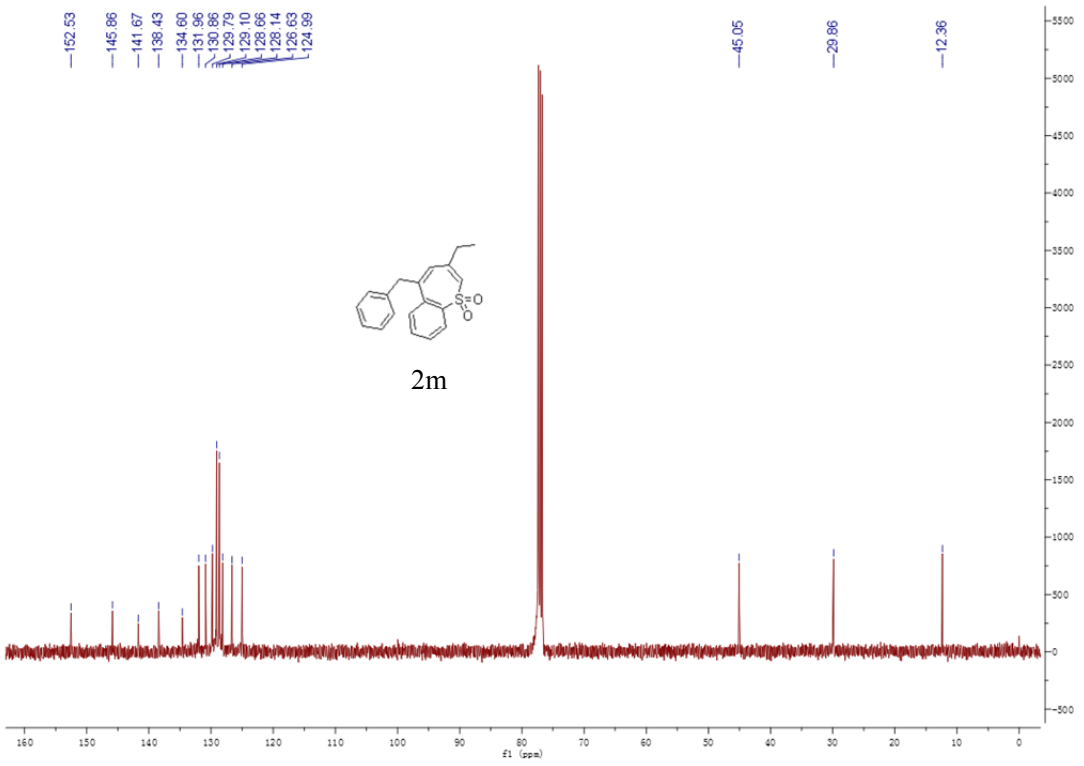
2j


146.84
145.87
141.23
139.34
134.75
129.05
128.45
124.99
44.41
35.51
31.54
31.05
23.10
22.52
21.68
14.01
f1 (ppm)

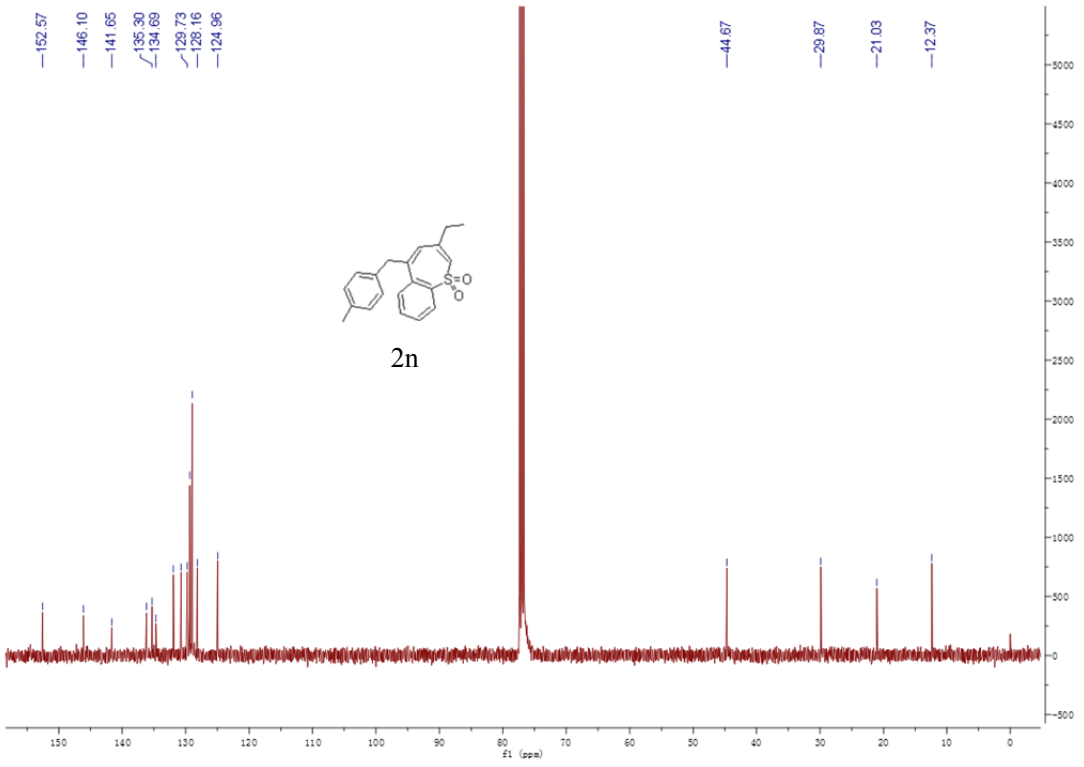
2k


146.82
145.85
142.50
139.38
134.66
129.33
128.45
125.00
44.42
23.10
21.69
21.03
f1 (ppm)

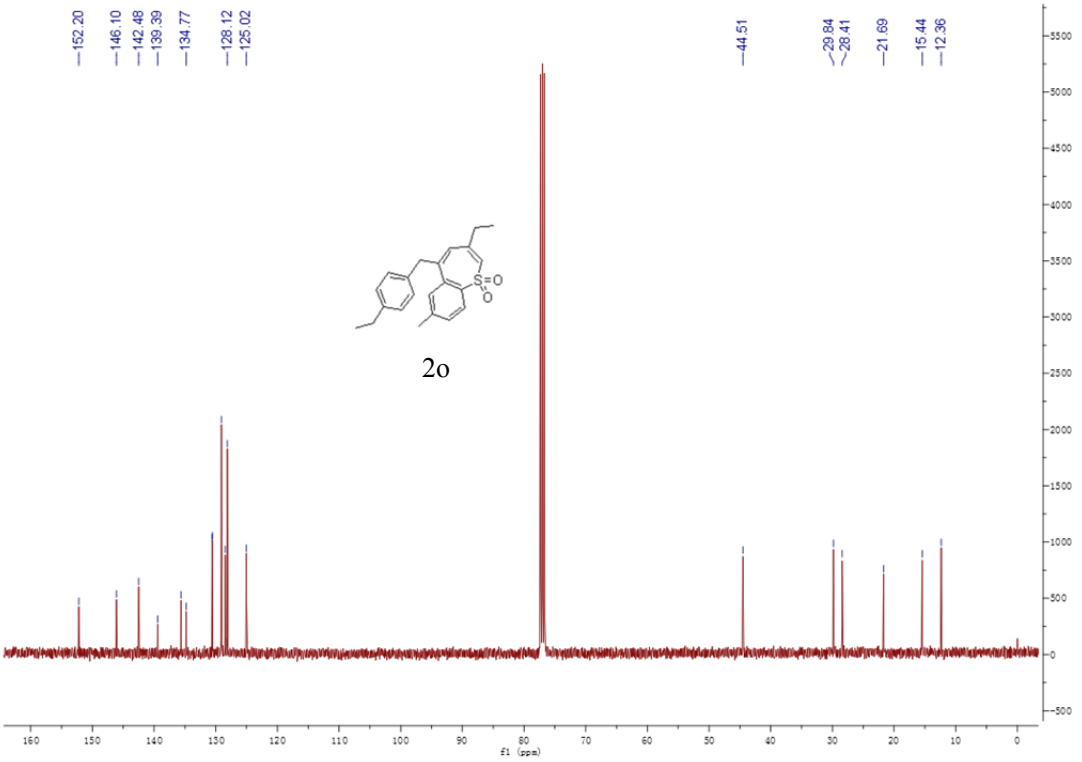
2l


152.53
145.86
141.67
138.43
134.60
131.96
130.86
129.79
129.10
128.66
128.14
126.63
124.99
45.05
29.86
12.36
f1 (ppm)

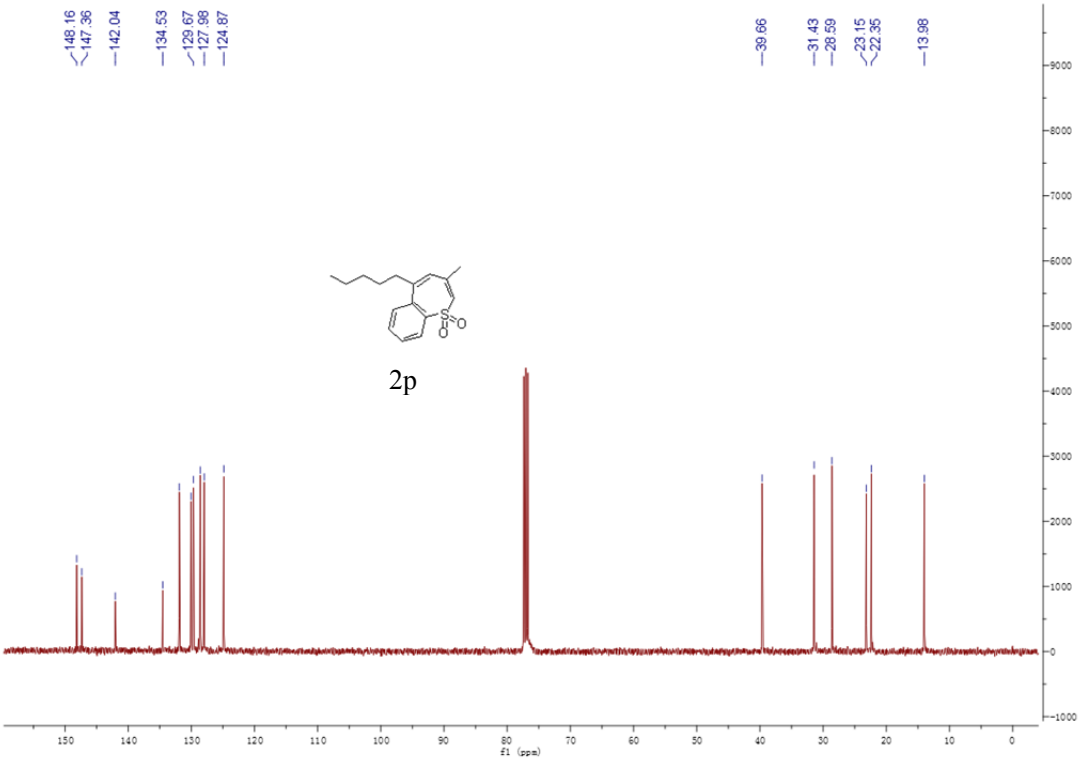
2m


152.57
146.10
141.65
135.30
134.69
129.73
128.16
124.96
44.67
29.87
21.03
12.37
f1 (ppm)

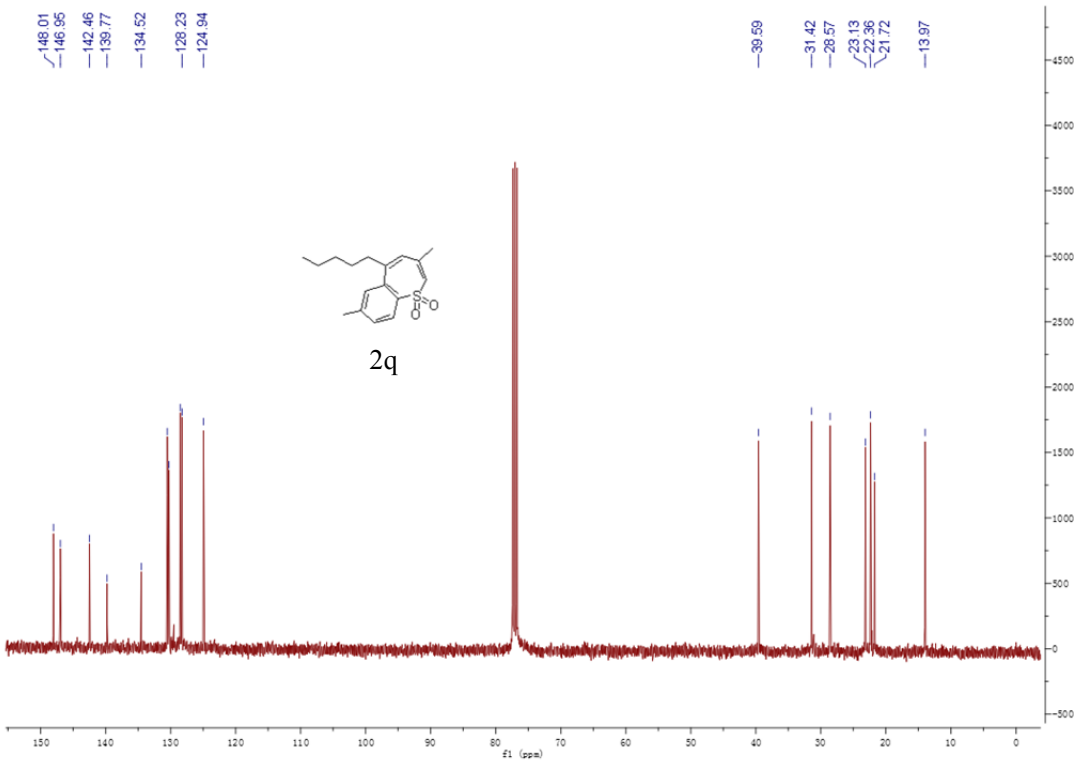
2n


152.20
146.10
142.48
139.39
134.77
128.12
125.02
44.51
29.84
28.41
21.69
15.44
12.36
f1 (ppm)

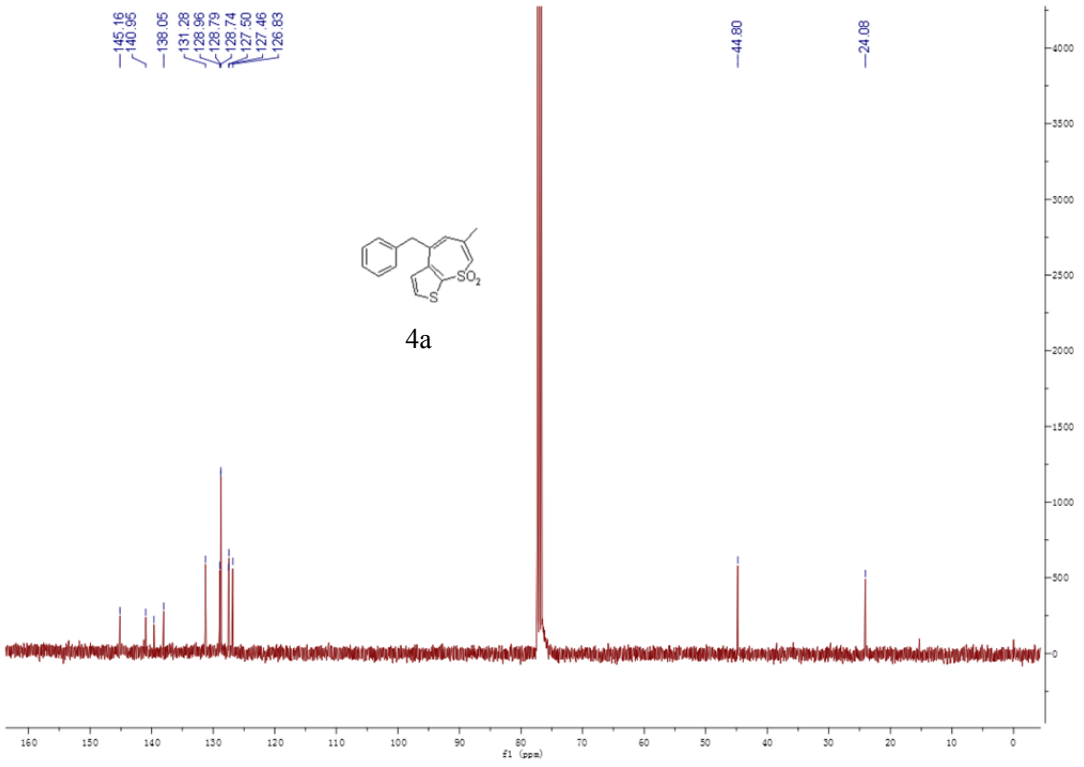
2o


148.16
147.36
142.04
134.53
129.67
127.98
124.87
39.66
31.43
28.59
23.15
22.35
13.98
f1 (ppm)

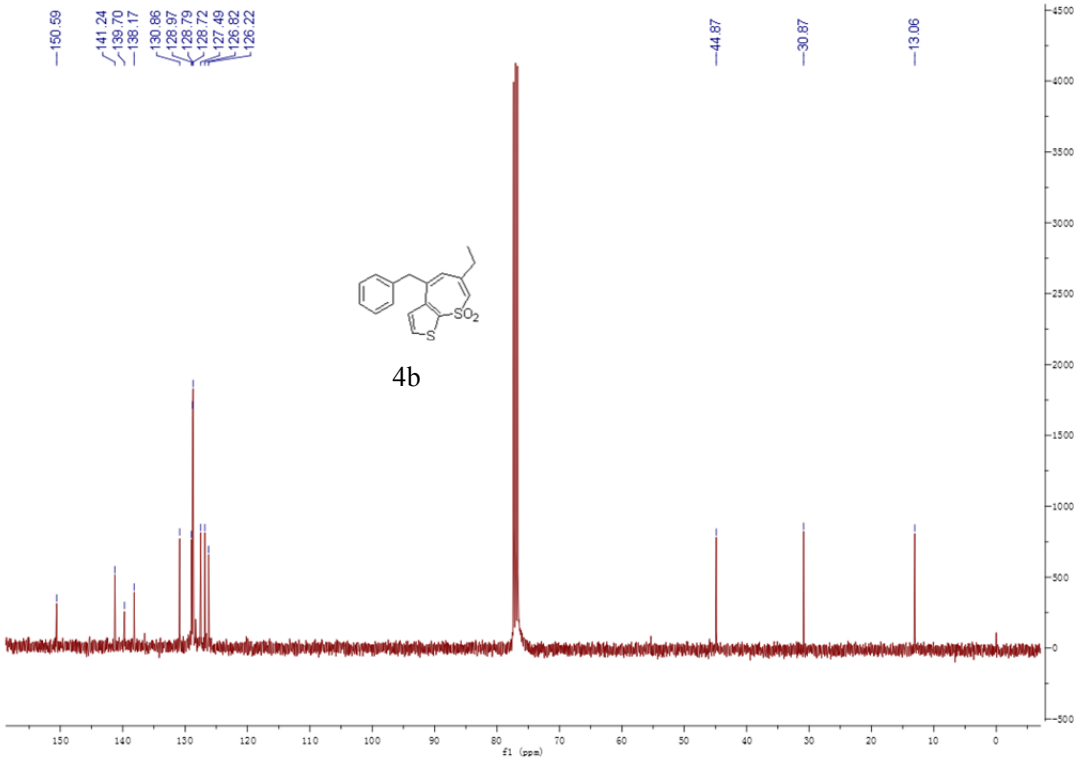
2p


148.01
146.95
142.46
139.77
134.52
128.23
124.94
39.59
31.42
28.57
23.13
22.36
21.72
13.97

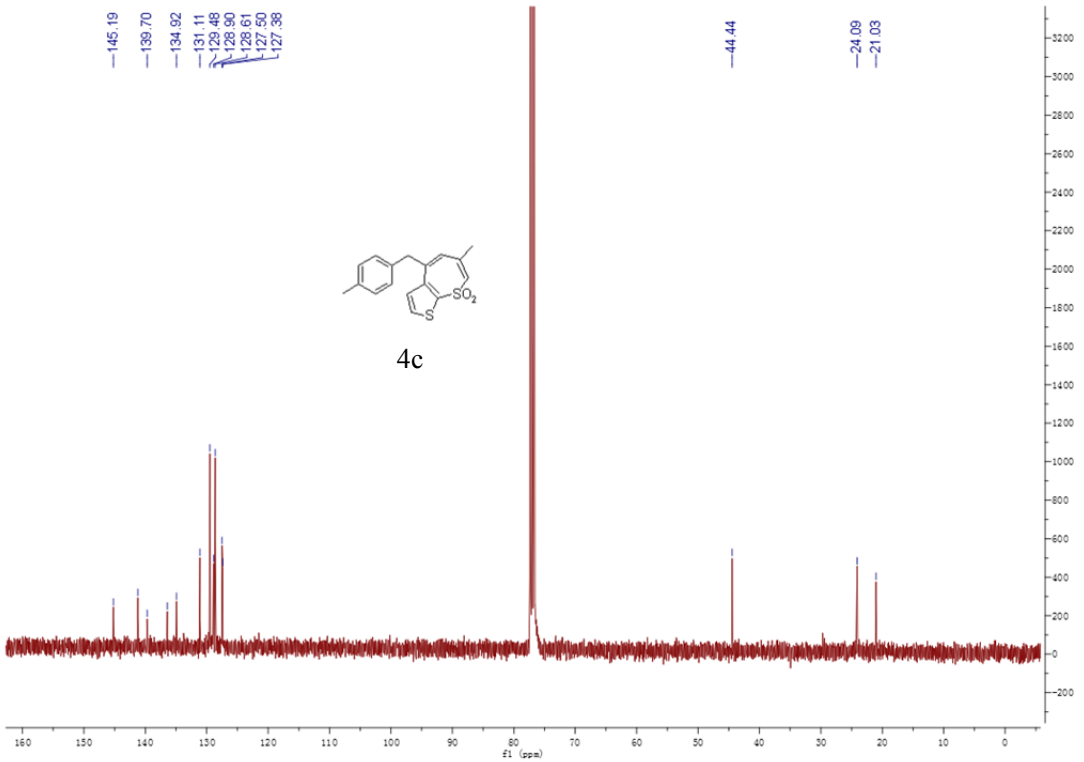
2q


145.16
140.95
138.05
131.28
128.96
128.79
128.74
127.50
127.46
126.83
44.80
24.08

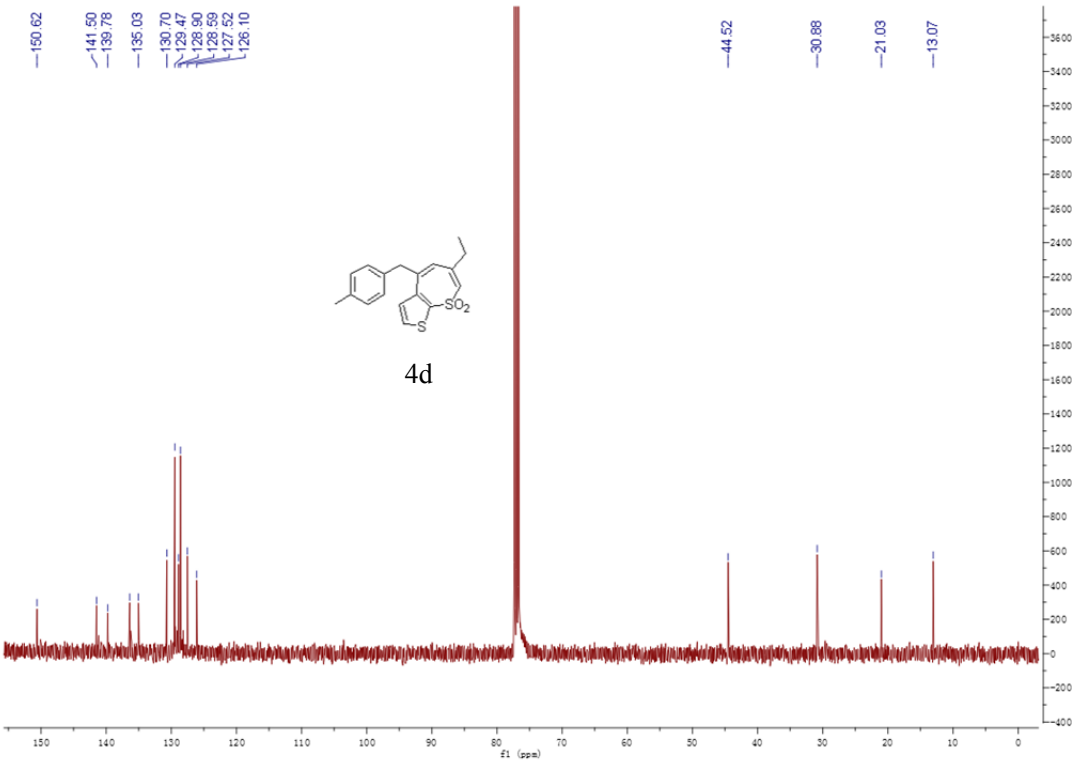
4a


150.59
141.24
139.70
138.17
130.86
128.97
128.79
128.72
127.49
126.82
126.22
44.87
30.87
13.06
SO2
S
f1 (ppm)

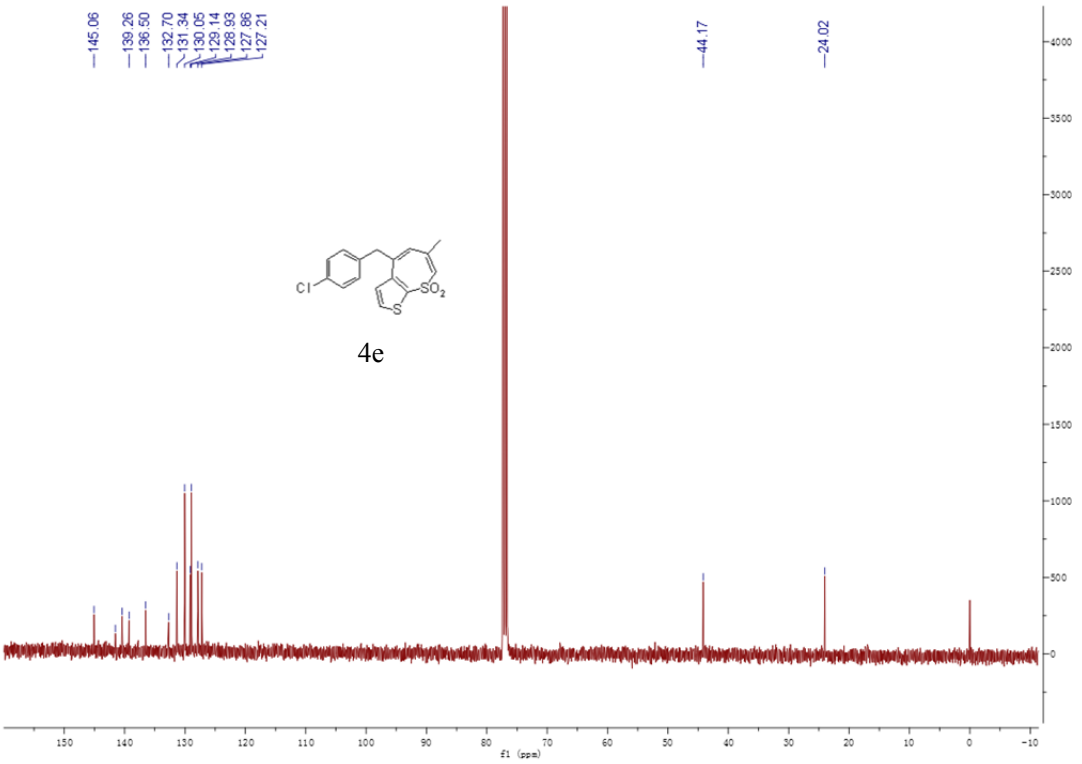
4b


145.19
139.70
134.92
131.11
129.48
128.90
128.61
127.50
127.38
44.44
24.09
21.03
SO2
S
f1 (ppm)

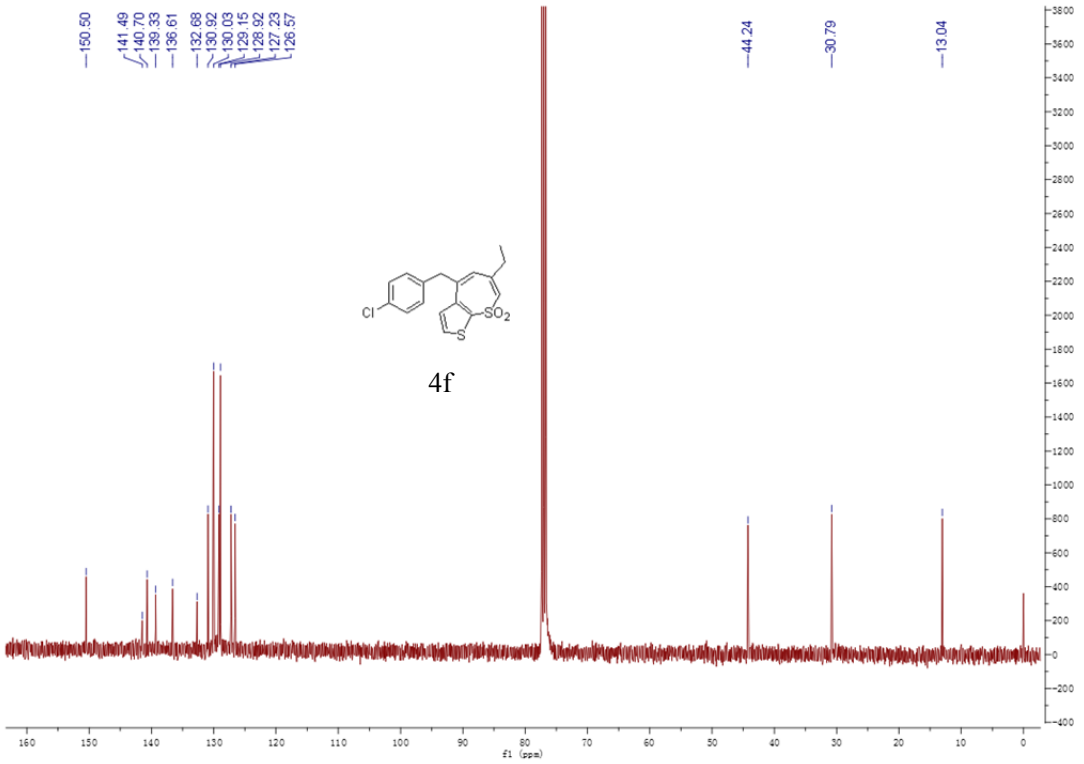
4c


150.62
141.50
139.78
135.03
130.70
129.47
128.90
128.59
127.52
126.10
44.52
30.88
21.03
13.07
SO2
S
f1 (ppm)

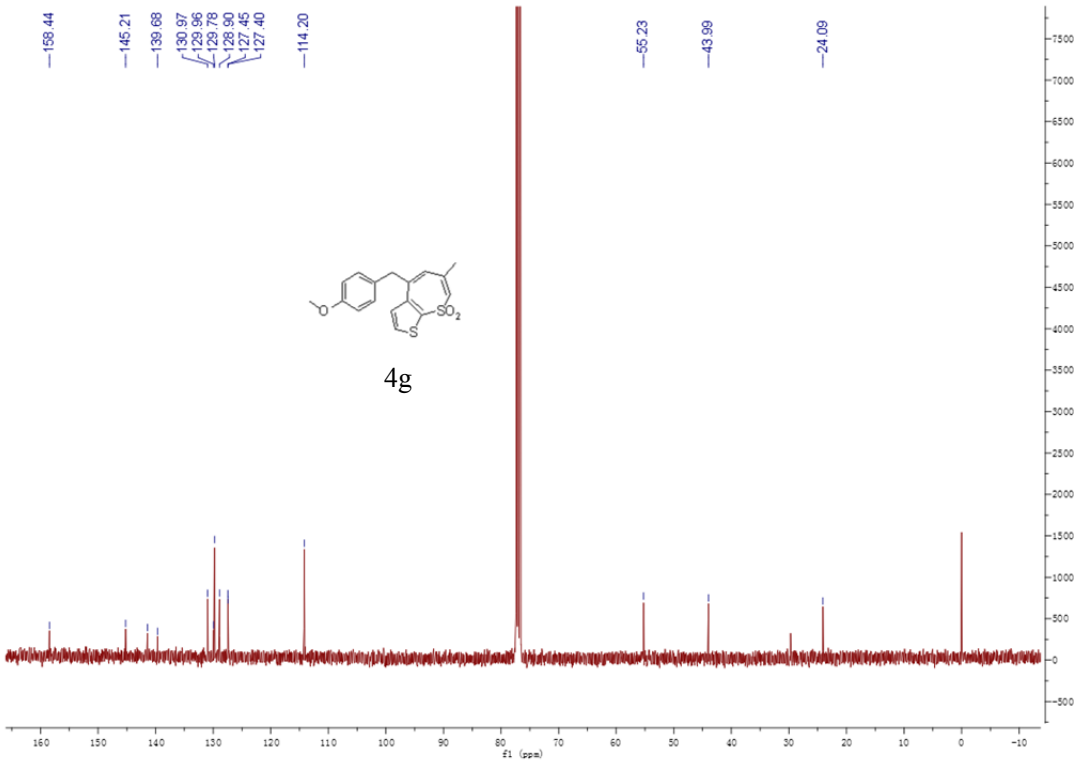
4d


145.06
139.26
136.50
132.70
131.34
130.05
129.14
128.93
127.86
127.21
44.17
24.02
Cl
SO2
S
f1 (ppm)

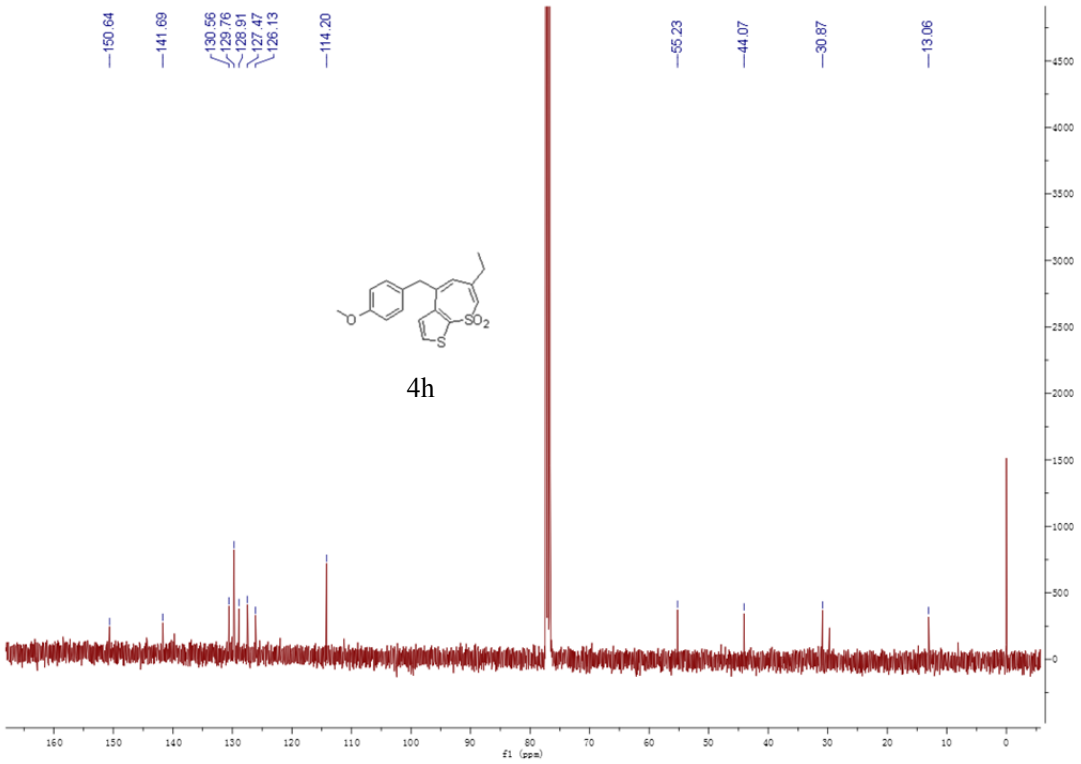
4e


150.50
141.49
140.70
139.33
136.61
132.68
130.92
130.03
129.15
128.92
127.23
126.57
44.24
30.79
13.04
Cl
SO2
S
f1 (ppm)

4f


158.44
145.21
139.68
130.97
129.96
129.78
128.90
127.45
127.40
114.20
55.23
43.99
24.09
O
SO2
S
f1 (ppm)

4g


150.64
141.69
130.56
129.76
128.91
127.47
126.13
114.20
55.23
44.07
30.87
13.06
O
SO2
S
f1 (ppm)

4h