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Supporting Information

Phosphine-Catalyzed Sequential Annulation Domino Reaction: Rapid Construction of Bicyclo[4.1.0]heptene Skeletons

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1 General Information

All reactions were carried out with the use of argon atmospheres. Solvents were used from commerically available sources. Yields refer to isolated compounds. Reactions were monitored by TLC using a UV lamp as a visualizing agent. All ^{1}H, ^{13}C nuclear magnetic resonance spectra were recorded in $CDCl_3$. The ^{1}H NMR was recorded at 400MHz, ^{13}C NMR was recorded at 100MHz. All shifts are reported in ppm as downfield from TMS as standard. Multiplicity is indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br s (broad singlet). Coupling constants J are reported in Hz. HRMS were obtained on an IonSpec FT-ICR mass spectrometer with ESI resource. Melting points were measured on a RY-I apparatus and are reported uncorrected. Dienes were prepared according to the literature.[1]

2 General Procedure for the Synthesis of Bicyclo[4.1.0]heptenes

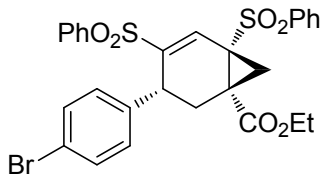
Tris(4-fluorophenyl)phosphine (20 mol %) was added to a mixture of dienic sulfones **1** (1.0 eq) and MBH carbonates **2** (2.0 eq) in $CHCl_3$ (5.0 mL). The resulting suspension was maintained at 60 ^{o}C for the desired time under argon atmosphere. The residue was purified by column chromatography on silica gel (gradient eluant: petroleum ether/ethyl acetate 15:1-5:1) to afford bicyclo[4.1.0]heptenes **3**.

3 Reference

1 J. J. Murphy, A. Quintard, P. McArdle, A. Alexakis and J. C. Stephens, *Angew. Chem., Int. Ed.,* 2011, **50**, 5095.

4 Spectral Data for 3a-3t

(1R,3R,6S)-ethyl 3-(4-bromophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3a)



White solid; mp: 162-164 °C;

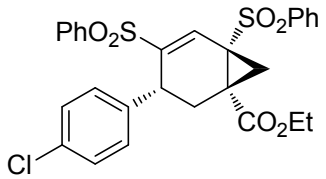
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.4 Hz, 2H), 7.78 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.8 Hz, 2H), 7.58 (d, *J* = 0.8 Hz, 1H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.30 – 7.26 (m, 2H), 7.26 – 7.21 (m, 2H), 6.93 (d, *J* = 8.3 Hz, 2H), 6.49 (d, *J* = 8.3 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.76 (t, *J* = 6.1 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.52 (dd, *J* = 14.7, 5.7 Hz, 1H), 2.32 (dd, *J* = 14.7, 6.9 Hz, 1H), 1.46 (d, *J* = 5.6 Hz, 1H), 1.10 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.82, 144.54, 138.99, 138.18, 136.66, 134.48, 134.05, 133.20, 130.99, 130.21, 129.58, 129.19, 128.84, 127.74, 120.99, 62.25, 48.49, 37.39, 37.19, 33.82, 28.25, 13.62.

IR (KBr): 3062, 2921, 2850, 1735, 1447, 1320, 1152, 1086, 733, 605, 556 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{28}H_{25}BrO_6S_2NH_4$ 618.0614, found 618.0608.

(1R,3R,6S)-ethyl 3-(4-chlorophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3b)



White solid; mp: 164-166 °C;

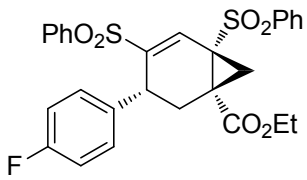
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.7 Hz, 2H), 7.79 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.7 Hz, 2H), 7.58 (s, 1H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.28 (t, *J* = 6.1 Hz, 2H), 7.23 (t, *J* = 7.7 Hz, 2H), 6.78 (d, *J* = 8.3 Hz, 2H), 6.54 (d, *J* = 8.4 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.78 (t, *J* = 6.2 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.53 (dd, *J* = 14.7, 5.7 Hz, 1H), 2.32 (dd, *J* = 14.7, 6.9 Hz, 1H), 1.46 (d, *J* = 5.6 Hz, 1H), 1.10 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.81, 144.68, 138.97, 138.14, 136.21, 134.50, 134.00, 133.24, 132.75, 129.82, 129.58, 129.18, 128.83, 128.01, 127.75, 62.21, 48.53, 37.55, 37.08, 33.72, 28.25, 13.61.

IR (KBr): 3063, 2923, 2851, 1736, 1447, 1321, 1153, 1087, 734, 609, 540 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{28}H_{25}ClO_6S_2NH_4$ 574.1119, found 574.1121.

(1R,3R,6S)-ethyl 3-(4-fluorophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3c)



White solid; mp: 163-165 °C;

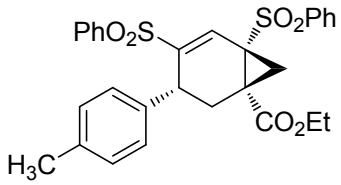
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.8 Hz, 2H), 7.78 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.7 Hz, 2H), 7.58 (s, 1H), 7.43 (t, *J* = 7.2 Hz, 1H), 7.28 (t, *J* = 7.3 Hz, 2H), 7.23 (t, *J* = 7.6 Hz, 2H), 6.62 – 6.55 (m, 2H), 6.51 (t, *J* = 8.5 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.80 (t, *J* = 6.1 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.53 (dd, *J* = 14.7, 5.6 Hz, 1H), 2.32 (dd, *J* = 14.7, 6.9 Hz, 1H), 1.46 (d, *J* = 5.6 Hz, 1H), 1.10 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.87, 162.81, 160.36, 144.89, 139.10, 138.19, 134.46, 133.90, 133.42, 133.40, 133.24, 130.10, 130.02, 129.57, 129.19, 128.77, 127.75, 114.85, 114.63, 62.17, 48.53, 37.76, 36.99, 33.74, 28.22, 13.65.

IR (KBr): 3064, 2921, 2850, 1736, 1509, 1447, 1321, 1154, 739, 620, 543 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{28}H_{25}FO_6S_2NH_4$ 558.1415, found 558.1420.

(1R,3R,6S)-ethyl 4,6-bis(phenylsulfonyl)-3-(*p*-tolyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3d)



White solid; mp: 153-154 °C;

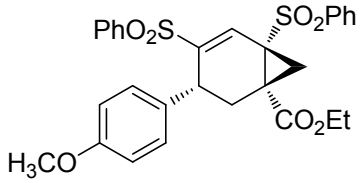
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.4 Hz, 2H), 7.77 (t, *J* = 7.5 Hz, 1H), 7.65 (t, *J* = 7.7 Hz, 2H), 7.59 (d, *J* = 1.4 Hz, 1H), 7.42 – 7.36 (m, 1H), 7.22 – 7.13 (m, 4H), 6.61 (d, *J* = 7.8 Hz, 2H), 6.48 (d, *J* = 7.9 Hz, 2H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.69 (dd, *J* = 7.0, 6.0 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.53 (dd, *J* = 14.6, 7.1 Hz, 1H), 2.33 (dd, *J* = 14.6, 7.0 Hz, 1H), 2.17 (s, 3H), 1.53 (d, *J* = 5.6 Hz, 1H), 1.14 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.98, 144.58, 139.36, 138.25, 136.51, 134.37, 134.25, 134.00, 132.75, 129.50, 129.13, 128.58, 128.54, 127.61, 62.16, 48.27, 37.39, 36.64, 34.81, 27.27, 20.95, 13.66.

IR (KBr): 3062, 2985, 1735, 1447, 1319, 1153, 1086, 733, 689, 621, 543 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{29}H_{28}O_6S_2NH_4$ 554.1666, found 554.1670.

(1R,3R,6S)-ethyl 3-(4-methoxyphenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3e)

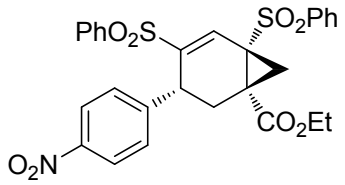


White solid; mp: 133-134 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.6 Hz, 2H), 7.76 (t, *J* = 7.3 Hz, 1H), 7.65 (t, *J* = 7.7 Hz,

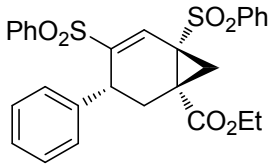
2H), 7.57 (d, J = 0.9 Hz, 1H), 7.42 – 7.37 (m, 1H), 7.24 – 7.16 (m, 4H), 6.54 (d, J = 8.4 Hz, 2H), 6.35 (d, J = 8.5 Hz, 2H), 4.14 (q, J = 7.1 Hz, 2H), 3.73 – 3.67 (m, 4H), 2.68 (d, J = 5.6 Hz, 1H), 2.52 (dd, J = 14.6, 7.1 Hz, 1H), 2.33 (dd, J = 14.6, 6.9 Hz, 1H), 1.52 (d, J = 5.6 Hz, 1H), 1.15 (t, J = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 169.00, 158.43, 144.69, 139.45, 138.27, 134.36, 133.90, 132.89, 129.74, 129.53, 129.28, 129.12, 128.62, 127.57, 113.33, 62.17, 55.20, 48.23, 37.01, 36.71, 34.76, 27.31, 13.71.
IR (KBr): 3063, 2921, 1735, 1512, 1447, 1319, 1153, 1086, 736, 689, 621, 544 cm^{-1}.
HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{29}H_{28}O_7S_2NH_4$ 570.1615, found 570.1617.

(1R,3R,6S)-ethyl 3-(4-nitrophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3f)



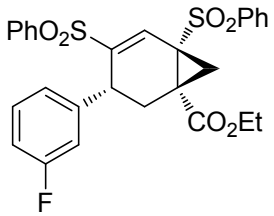
White solid; mp: 173-175 °C;
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 – 7.95 (m, 2H), 7.84 (t, J = 7.5 Hz, 1H), 7.73 – 7.66 (m, 4H), 7.60 (s, 1H), 7.47 – 7.38 (m, 3H), 7.24 (t, J = 7.9 Hz, 2H), 6.81 (d, J = 8.7 Hz, 2H), 4.03 (q, J = 7.1 Hz, 2H), 3.97 (dd, J = 6.7, 4.0 Hz, 1H), 2.70 (d, J = 5.6 Hz, 1H), 2.60 (dd, J = 14.8, 4.0 Hz, 1H), 2.33 (dd, J = 14.8, 6.9 Hz, 1H), 1.40 (d, J = 5.6 Hz, 1H), 1.04 (t, J = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.62, 146.61, 145.57, 144.68, 138.48, 138.05, 134.71, 134.23, 133.77, 129.70, 129.28, 129.16, 129.03, 128.06, 123.05, 62.27, 48.91, 38.72, 37.43, 32.60, 29.43, 13.59.
IR (KBr): 3066, 2921, 1737, 1521, 1348, 1322, 1154, 854, 735, 690, 607 cm^{-1}.
HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{28}H_{25}NO_8S_2NH_4$ 585.1360, found 585.1361.

(1R,3R,6S)-ethyl 3-phenyl-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3g)



White solid; mp: 191-192 °C;
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, J = 7.4 Hz, 2H), 7.77 (t, J = 7.5 Hz, 1H), 7.65 (t, J = 7.8 Hz, 2H), 7.61 (d, J = 1.1 Hz, 1H), 7.38 (t, J = 7.3 Hz, 1H), 7.26 – 7.21 (m, 2H), 7.17 (t, J = 7.8 Hz, 2H), 6.97 (t, J = 7.4 Hz, 1H), 6.81 (t, J = 7.7 Hz, 2H), 6.57 (d, J = 7.5 Hz, 2H), 4.09 (q, J = 7.1 Hz, 2H), 3.78 (t, J = 6.4 Hz, 1H), 2.69 (d, J = 5.6 Hz, 1H), 2.56 (dd, J = 14.6, 6.2 Hz, 1H), 2.34 (dd, J = 14.6, 7.0 Hz, 1H), 1.49 (d, J = 5.6 Hz, 1H), 1.09 (t, J = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.90, 144.71, 139.19, 138.24, 137.49, 134.38, 134.01, 133.04, 129.52, 129.18, 128.68, 128.49, 127.96, 127.74, 126.89, 62.10, 48.50, 37.77, 37.43, 34.23, 27.83, 13.64.
IR (KBr): 3063, 2923, 1736, 1448, 1320, 1266, 1153, 1086, 734, 600, 555 cm^{-1}.
HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{28}H_{26}O_6S_2NH_4$ 540.1509, found 540.1514.

(1R,3R,6S)-ethyl 3-(3-fluorophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3h)



White solid; mp: 174-176 °C;

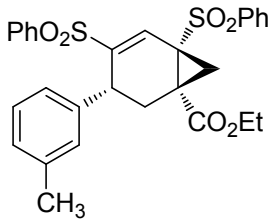
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.7 Hz, 2H), 7.77 (t, *J* = 7.5 Hz, 1H), 7.65 (t, *J* = 7.7 Hz, 2H), 7.59 (s, 1H), 7.41 (t, *J* = 7.4 Hz, 1H), 7.32 (d, *J* = 7.4 Hz, 2H), 7.22 (t, *J* = 7.8 Hz, 2H), 6.83 (dd, *J* = 14.0, 7.8 Hz, 1H), 6.68 (td, *J* = 8.4, 1.8 Hz, 1H), 6.44 (d, *J* = 7.5 Hz, 1H), 6.29 (d, *J* = 9.8 Hz, 1H), 4.07 (q, *J* = 7.1 Hz, 2H), 3.83 (t, *J* = 6.0 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.54 (dd, *J* = 14.7, 5.3 Hz, 1H), 2.32 (dd, *J* = 14.7, 7.0 Hz, 1H), 1.44 (d, *J* = 5.6 Hz, 1H), 1.06 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.76, 163.36, 160.91, 144.57, 140.34, 140.27, 138.89, 138.07, 134.61, 134.03, 133.42, 129.60, 129.43, 129.35, 129.06, 128.80, 127.81, 124.26, 124.23, 115.44, 115.22, 114.02, 113.81, 62.10, 48.62, 37.87, 37.37, 33.49, 28.47, 13.54.

IR (KBr): 3065, 2987, 1736, 1448, 1321, 1265, 1152, 1086, 754, 690, 609, 561 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{28}H_{25}FO_6S_2NH_4$ 558.1415, found 558.1418.

(1R,3R,6S)-ethyl 4,6-bis(phenylsulfonyl)-3-(*m*-tolyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3i)



White solid; mp: 174-175 °C;

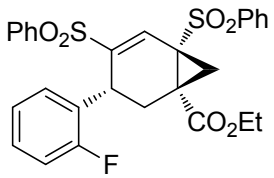
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 7.5 Hz, 2H), 7.77 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.7 Hz, 2H), 7.57 (d, *J* = 1.5 Hz, 1H), 7.38 (dt, *J* = 6.4, 2.1 Hz, 1H), 7.23 – 7.14 (m, 4H), 6.80 (d, *J* = 7.6 Hz, 1H), 6.75 (t, *J* = 7.5 Hz, 1H), 6.54 (s, 1H), 6.46 (d, *J* = 7.3 Hz, 1H), 4.20 – 4.05 (m, 2H), 3.69 (td, *J* = 7.2, 1.3 Hz, 1H), 2.65 (d, *J* = 5.6 Hz, 1H), 2.55 (dd, *J* = 14.6, 7.5 Hz, 1H), 2.35 (dd, *J* = 14.6, 7.0 Hz, 1H), 2.01 (s, 3H), 1.54 (d, *J* = 5.7 Hz, 1H), 1.13 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.00, 144.23, 139.39, 138.32, 137.44, 137.09, 134.41, 134.14, 132.93, 129.57, 129.50, 129.04, 128.50, 127.86, 127.60, 126.05, 62.16, 48.12, 37.78, 36.47, 35.09, 27.32, 21.14, 13.66.

IR (KBr): 3062, 2921, 1735, 1447, 1319, 1151, 1086, 755, 689, 605, 558 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{29}H_{28}O_6S_2NH_4$ 554.1666, found 554.1672.

(1R,3R,6S)-ethyl 3-(2-fluorophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3j)



White solid; mp: 169-171 °C;

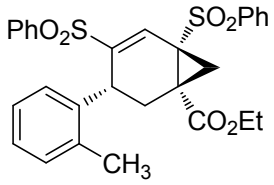
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.5 Hz, 2H), 7.78 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.7 Hz, 2H), 7.60 (s, 1H), 7.44 – 7.38 (m, 3H), 7.23 (t, *J* = 7.8 Hz, 2H), 6.98 (td, *J* = 7.3, 1.2 Hz, 1H), 6.76 (t, *J* = 9.2 Hz, 1H), 6.45 (t, *J* = 7.3 Hz, 1H), 6.36 – 6.25 (m, 1H), 4.11 (s, 1H), 4.07 – 3.96 (m, 2H), 2.72 – 2.59 (m, 2H), 2.22 (dd, *J* = 14.7, 6.8 Hz, 1H), 1.42 (d, *J* = 5.5 Hz, 1H), 1.01 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.75, 161.40, 158.96, 144.47, 138.54, 138.27, 134.41, 134.14, 133.47, 129.76, 129.56, 129.17, 128.85, 128.75, 128.67, 127.98, 125.00, 124.87, 123.59, 123.56, 114.93, 114.71, 62.03, 48.65, 36.61, 33.47, 30.79, 28.77, 13.55.

IR (KBr): 3066, 2922, 1737, 1491, 1448, 1321, 1154, 1087, 757, 689, 602, 566 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{28}H_{25}FO_6S_2NH_4$ 558.1415, found 558.1417.

(1R,3R,6S)-ethyl 4,6-bis(phenylsulfonyl)-3-(*o*-tolyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3k)



White solid; mp: 214-216 °C;

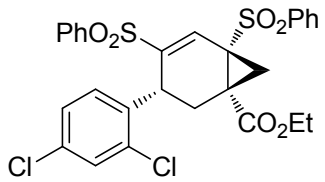
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.6 Hz, 2H), 7.76 (t, *J* = 7.4 Hz, 1H), 7.69 – 7.61 (m, 3H), 7.35 (t, *J* = 7.2 Hz, 1H), 7.20 (d, *J* = 7.3 Hz, 2H), 7.14 (t, *J* = 7.7 Hz, 2H), 6.97 (d, *J* = 6.8 Hz, 1H), 6.83 (t, *J* = 7.0 Hz, 1H), 6.26 (t, *J* = 6.8 Hz, 1H), 6.01 (d, *J* = 7.2 Hz, 1H), 4.14 – 4.00 (m, 3H), 2.70 (d, *J* = 5.3 Hz, 1H), 2.45 (dd, *J* = 14.4, 5.4 Hz, 1H), 2.37 – 2.23 (m, 4H), 1.50 (d, *J* = 5.2 Hz, 1H), 1.07 (t, *J* = 6.8 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.01, 145.21, 139.28, 138.32, 135.64, 135.33, 134.36, 134.17, 133.02, 130.08, 129.50, 129.18, 128.60, 127.99, 127.60, 126.87, 125.55, 62.09, 48.48, 36.20, 34.01, 32.89, 28.12, 19.60, 13.63.

IR (KBr): 3064, 2984, 1735, 1447, 1318, 1153, 1086, 732, 689, 602, 544 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{29}H_{28}O_6S_2NH_4$ 554.1666, found 554.1667.

(1R,3R,6S)-ethyl 3-(2,4-dichlorophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3l)



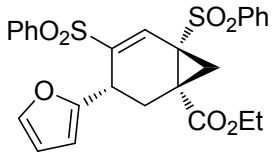
White solid; mp: 167-168 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 7.6 Hz, 2H), 7.80 (t, *J* = 7.4 Hz, 1H), 7.68 (t, *J* = 7.7 Hz, 2H), 7.56 (s, 1H), 7.52 (d, *J* = 7.4 Hz, 2H), 7.45 (t, *J* = 7.5 Hz, 1H), 7.27 (t, *J* = 7.6 Hz, 2H), 7.20 (s, 1H), 6.47 (d, *J* = 7.6 Hz, 1H), 6.30 (d, *J* = 7.9 Hz, 1H), 4.33 (d, *J* = 4.4 Hz, 1H), 4.07 – 3.87 (m, 2H), 2.66 – 2.57 (m, 2H), 2.16 (dd, *J* = 14.9, 6.5 Hz, 1H), 1.30 (d, *J* = 5.1 Hz, 1H), 0.96 (t, *J* = 6.8 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.66, 145.75, 138.16, 134.62, 134.10, 133.75, 133.62, 133.47, 133.17, 130.43, 129.66, 129.26, 129.06, 128.73, 128.21, 126.49, 62.03, 48.99, 37.61, 33.48, 31.73, 30.32, 13.46.

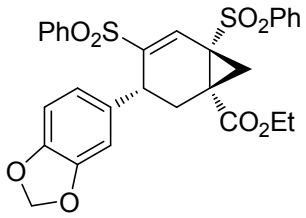
IR (KBr): 2920, 2850, 1737, 1471, 1323, 1264, 1153, 1072, 750, 688, 611, 553 cm^{-1}.
HRMS (ESI/$[M+NH_4]^+$) Cacld. for: $C_{28}H_{24}Cl_2O_6S_2NH_4$ 608.0730, found 608.0733.

(1R,3R,6S)-ethyl 3-(furan-2-yl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3m)



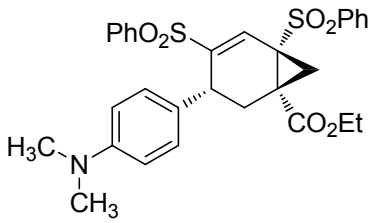
White solid; mp: 139-141 °C;
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.88 (m, 2H), 7.72 (t, *J* = 7.5 Hz, 1H), 7.59 (t, *J* = 7.8 Hz, 2H), 7.55 (d, *J* = 0.7 Hz, 1H), 7.53 – 7.47 (m, 3H), 7.40 – 7.34 (m, 2H), 6.83 (d, *J* = 1.1 Hz, 1H), 5.84 (dd, *J* = 3.2, 1.9 Hz, 1H), 5.14 (d, *J* = 3.2 Hz, 1H), 4.22 – 4.05 (m, 2H), 3.85 (t, *J* = 5.7 Hz, 1H), 2.76 (dd, *J* = 14.5, 5.6 Hz, 1H), 2.70 (d, *J* = 5.6 Hz, 1H), 2.07 (dd, *J* = 14.5, 5.9 Hz, 1H), 1.41 (d, *J* = 5.6 Hz, 1H), 1.19 (t, *J* = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.68, 149.74, 143.90, 141.57, 138.72, 138.22, 134.41, 134.16, 133.32, 129.33, 129.29, 128.92, 127.95, 110.14, 108.42, 62.17, 48.82, 35.34, 33.85, 31.57, 27.97, 13.84.
IR (KBr): 2985, 1735, 1447, 1320, 1152, 1086, 910, 735, 688, 608, 590, 552 cm^{-1}.
HRMS (ESI/$[M+NH_4]^+$) Cacld. for: $C_{26}H_{24}O_7S_2NH_4$ 530.1302, found 530.1305.

(1R,3R,6S)-ethyl 3-(benzo[*d*][1,3]dioxol-5-yl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3n)



White solid; mp: 116-118 °C;
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.4 Hz, 2H), 7.76 (t, *J* = 7.4 Hz, 1H), 7.65 (t, *J* = 7.7 Hz, 2H), 7.57 (d, *J* = 1.2 Hz, 1H), 7.42 (t, *J* = 7.1 Hz, 1H), 7.32 – 7.21 (m, 4H), 6.30 (d, *J* = 8.0 Hz, 1H), 6.14 (dd, *J* = 8.0, 1.5 Hz, 1H), 6.07 (d, *J* = 1.5 Hz, 1H), 5.80 (dd, *J* = 19.2, 1.1 Hz, 2H), 4.15 (q, *J* = 7.1 Hz, 2H), 3.68 (t, *J* = 6.4 Hz, 1H), 2.68 (d, *J* = 5.6 Hz, 1H), 2.50 (dd, *J* = 14.6, 6.6 Hz, 1H), 2.32 (dd, *J* = 14.6, 7.0 Hz, 1H), 1.49 (d, *J* = 5.6 Hz, 1H), 1.17 (t, *J* = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.98, 147.03, 146.56, 144.58, 139.36, 138.15, 134.53, 133.93, 133.04, 131.19, 129.58, 129.05, 128.59, 127.67, 122.35, 108.86, 107.57, 100.89, 62.21, 48.29, 37.37, 36.92, 34.40, 27.64, 13.68.
IR (KBr): 2985, 2921, 1735, 1488, 1446, 1318, 1152, 1086, 1038, 732, 689, 612, 557 cm^{-1}.
HRMS (ESI/$[M+NH_4]^+$) Cacld. for: $C_{29}H_{26}O_8S_2NH_4$ 584.1407, found 584.1407.

(1R,3R,6S)-ethyl 3-(4-(dimethylamino)phenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3o)



Yellow solid; mp: 95-98 °C;

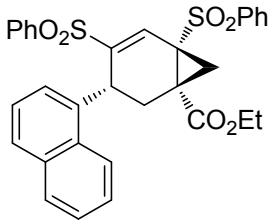
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 – 8.00 (m, 2H), 7.75 (t, *J* = 7.5 Hz, 1H), 7.65 (t, *J* = 7.7 Hz, 2H), 7.56 (d, *J* = 1.7 Hz, 1H), 7.38 – 7.32 (m, 1H), 7.21 – 7.12 (m, 4H), 6.50 (d, *J* = 8.7 Hz, 2H), 6.19 (d, *J* = 8.7 Hz, 2H), 4.19 (tt, *J* = 7.2, 3.6 Hz, 2H), 3.59 (t, *J* = 7.0 Hz, 1H), 2.83 (s, 6H), 2.67 (d, *J* = 5.6 Hz, 1H), 2.51 (dd, *J* = 14.5, 8.6 Hz, 1H), 2.34 (dd, *J* = 14.5, 7.0 Hz, 1H), 1.59 (d, *J* = 5.7 Hz, 1H), 1.20 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.13, 149.65, 144.41, 139.84, 138.41, 134.24, 133.95, 132.56, 129.58, 129.50, 129.06, 128.51, 127.40, 124.39, 112.21, 62.21, 47.88, 40.59, 37.00, 35.87, 35.50, 26.41, 13.79.

IR (KBr): 2920, 2850, 1734, 1521, 1446, 1317, 1151, 733, 689, 618, 547 cm^{-1}.

HRMS (ESI/[M+H]$^+$) Cacld. for: $C_{30}H_{31}NO_6S_2H$ 566.1666, found 566.1668.

(1R,3R,6S)-ethyl 3-(naphthalen-1-yl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3p)



White solid; mp: 218-220 °C;

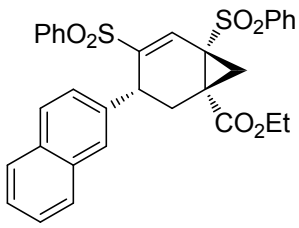
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.5 Hz, 2H), 7.86 (d, *J* = 8.4 Hz, 1H), 7.84 – 7.79 (m, 1H), 7.76 (d, *J* = 7.8 Hz, 1H), 7.73 – 7.64 (m, 3H), 7.57 – 7.50 (m, 1H), 7.50 – 7.42 (m, 2H), 7.31 (d, *J* = 7.6 Hz, 2H), 7.24 (d, *J* = 7.7 Hz, 1H), 7.01 (t, *J* = 7.4 Hz, 2H), 6.54 (t, *J* = 7.6 Hz, 1H), 6.18 (d, *J* = 7.0 Hz, 1H), 4.78 (d, *J* = 5.5 Hz, 1H), 3.86 – 3.66 (m, 2H), 2.78 – 2.65 (m, 2H), 2.35 (dd, *J* = 14.4, 6.7 Hz, 1H), 1.38 (d, *J* = 5.0 Hz, 1H), 0.66 (t, *J* = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.67, 146.86, 138.71, 138.35, 134.47, 133.78, 133.43, 133.04, 130.42, 129.56, 129.41, 129.06, 128.58, 128.13, 127.36, 126.49, 125.76, 125.42, 124.90, 122.17, 61.65, 49.38, 38.49, 32.70, 32.07, 30.28, 13.21.

IR (KBr): 3061, 2921, 2850, 1735, 1447, 1320, 1154, 1086, 753, 689, 599, 563 cm^{-1}.

HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{32}H_{28}O_6S_2NH_4$ 590.1666, found 590.1668.

(1R,3R,6S)-ethyl 3-(naphthalen-2-yl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3q)



White solid; mp: 133-134 °C;

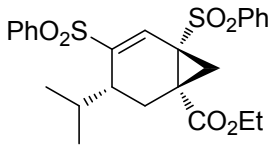
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 7.4 Hz, 2H), 7.80 (t, *J* = 7.5 Hz, 1H), 7.70 (t, *J* = 7.7 Hz, 2H), 7.66 (d, *J* = 7.9 Hz, 1H), 7.60 (d, *J* = 1.1 Hz, 1H), 7.48 (d, *J* = 7.9 Hz, 1H), 7.43 – 7.36 (m, 2H), 7.36 – 7.29 (m, 2H), 7.15 – 7.08 (m, 3H), 6.90 (t, *J* = 7.8 Hz, 2H), 6.82 (dd, *J* = 8.5, 1.5 Hz, 1H), 4.11 – 3.96 (m, 2H), 3.92 (t, *J* = 6.8 Hz, 1H), 2.73 – 2.65 (m, 2H), 2.43 (dd, *J* = 14.6, 6.9 Hz, 1H), 1.57 – 1.54 (m, 1H), 0.94 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.01, 144.37, 139.18, 138.38, 134.50, 134.10, 132.90, 132.81, 132.36, 129.65, 129.06, 128.40, 128.28, 127.92, 127.56, 127.53, 127.23, 126.43, 125.98, 125.81, 62.18, 48.22, 37.95, 36.54, 34.91, 27.79, 13.46.

IR (KBr): 3060, 2922, 1734, 1447, 1319, 1151, 1086, 737, 689, 613, 480 cm^{-1}.

HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{32}H_{28}O_6S_2NH_4$ 590.1666, found 590.1670.

(1R,3R,6S)-ethyl 3-isopropyl-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3r)



White solid; mp: 145-148 °C;

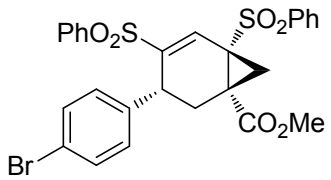
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 – 7.83 (m, 2H), 7.79 – 7.73 (m, 2H), 7.70 – 7.60 (m, 2H), 7.58 – 7.50 (m, 4H), 7.17 (s, 1H), 4.27 (qq, *J* = 10.8, 7.1 Hz, 2H), 2.69 (d, *J* = 5.4 Hz, 1H), 2.47 (dd, *J* = 14.6, 3.3 Hz, 1H), 2.06 (ddd, *J* = 8.5, 4.7, 3.5 Hz, 1H), 1.67 (qd, *J* = 13.3, 6.6 Hz, 1H), 1.42 – 1.31 (m, 4H), 1.05 (d, *J* = 5.4 Hz, 1H), 0.72 (d, *J* = 6.4 Hz, 3H), 0.41 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.52, 150.67, 139.72, 137.69, 134.34, 133.68, 133.05, 129.36, 129.14, 129.10, 128.08, 62.31, 49.87, 39.65, 34.84, 33.82, 30.07, 29.40, 21.24, 20.54, 13.87.

IR (KBr): 3065, 2967, 2935, 1733, 1447, 1320, 1152, 1083, 1023, 914, 734, 689, 608, 597, 554 cm^{-1}.

HRMS (MALDI/[M+Na]$^+$) Cacld. for: $C_{25}H_{28}O_6S_2Na$ 511.12, found 511.1222.

(1R,3R,6S)-methyl 3-(4-bromophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3s)



White solid; mp: 182-183 °C;

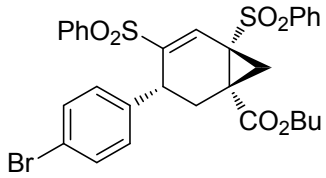
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 – 7.95 (m, 2H), 7.79 (t, *J* = 7.5 Hz, 1H), 7.66 (t, *J* = 7.7 Hz, 2H), 7.61 (d, *J* = 1.1 Hz, 1H), 7.45 (ddd, *J* = 8.6, 5.9, 3.1 Hz, 1H), 7.26 – 7.22 (m, 4H), 6.92 (d, *J* = 8.4 Hz, 2H), 6.46 (d, *J* = 8.4 Hz, 2H), 3.73 (t, *J* = 6.4 Hz, 1H), 3.66 (s, 3H), 2.70 (d, *J* = 5.7 Hz, 1H), 2.52 (dd, *J* = 14.7, 6.4 Hz, 1H), 2.32 (dd, *J* = 14.7, 7.0 Hz, 1H), 1.50 (d, *J* = 5.7 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.32, 144.36, 139.02, 138.05, 136.54, 134.54, 134.11, 133.18, 130.92, 130.25, 129.59, 129.15, 128.85, 127.62, 120.98, 53.10, 48.34, 37.10, 36.79, 33.99, 27.72.

IR (KBr): 2921, 2850, 1739, 1446, 1320, 1265, 1152, 1086, 752, 689, 605, 556 cm^{-1}.

HRMS (ESI/[M+NH$_4$]$^+$) Cacld. for: $C_{27}H_{23}BrO_6S_2NH_4$ 604.0458, found 604.0454.

(1R,3R,6S)-butyl 3-(4-bromophenyl)-4,6-bis(phenylsulfonyl)bicyclo[4.1.0]hept-4-ene-1-carboxylate (3t)



White solid; mp: 189-190 °C;

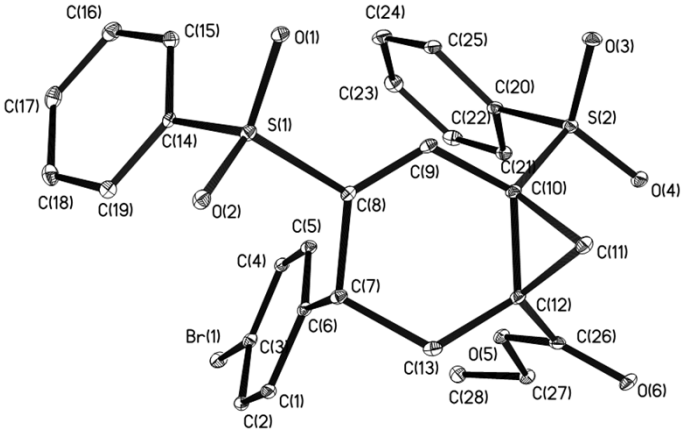
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.6 Hz, 2H), 7.79 (t, *J* = 7.5 Hz, 1H), 7.66 (t, *J* = 7.8 Hz, 2H), 7.57 (s, 1H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.29 (d, *J* = 7.1 Hz, 2H), 7.23 (t, *J* = 7.7 Hz, 2H), 6.94 (d, *J* = 8.4 Hz, 2H), 6.51 (d, *J* = 8.4 Hz, 2H), 4.10 – 3.96 (m, 2H), 3.78 (t, *J* = 6.1 Hz, 1H), 2.67 (d, *J* = 5.6 Hz, 1H), 2.53 (dd, *J* = 14.7, 5.5 Hz, 1H), 2.32 (dd, *J* = 14.7, 7.0 Hz, 1H), 1.49 – 1.36 (m, 3H), 1.30 – 1.15 (m, 2H), 0.87 (t, *J* = 7.3 Hz, 3H).

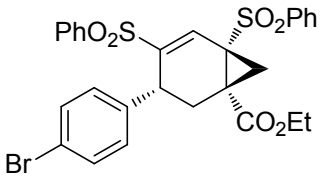
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.92, 144.68, 138.96, 138.15, 136.81, 134.50, 133.90, 133.21, 131.00, 130.17, 129.58, 129.17, 128.85, 127.76, 120.95, 66.18, 48.60, 37.51, 37.12, 33.57, 30.09, 28.46, 18.97, 13.70.

IR (KBr): 2960, 2923, 1734, 1487, 1447, 1321, 1153, 1086, 1012, 726, 688, 606, 540 cm^{-1}.

HRMS (ESI/[M+NH_4]$^+$) Cacld. for: $C_{30}H_{29}BrO_6S_2NH_4$ 646.0927, found 646.0923.

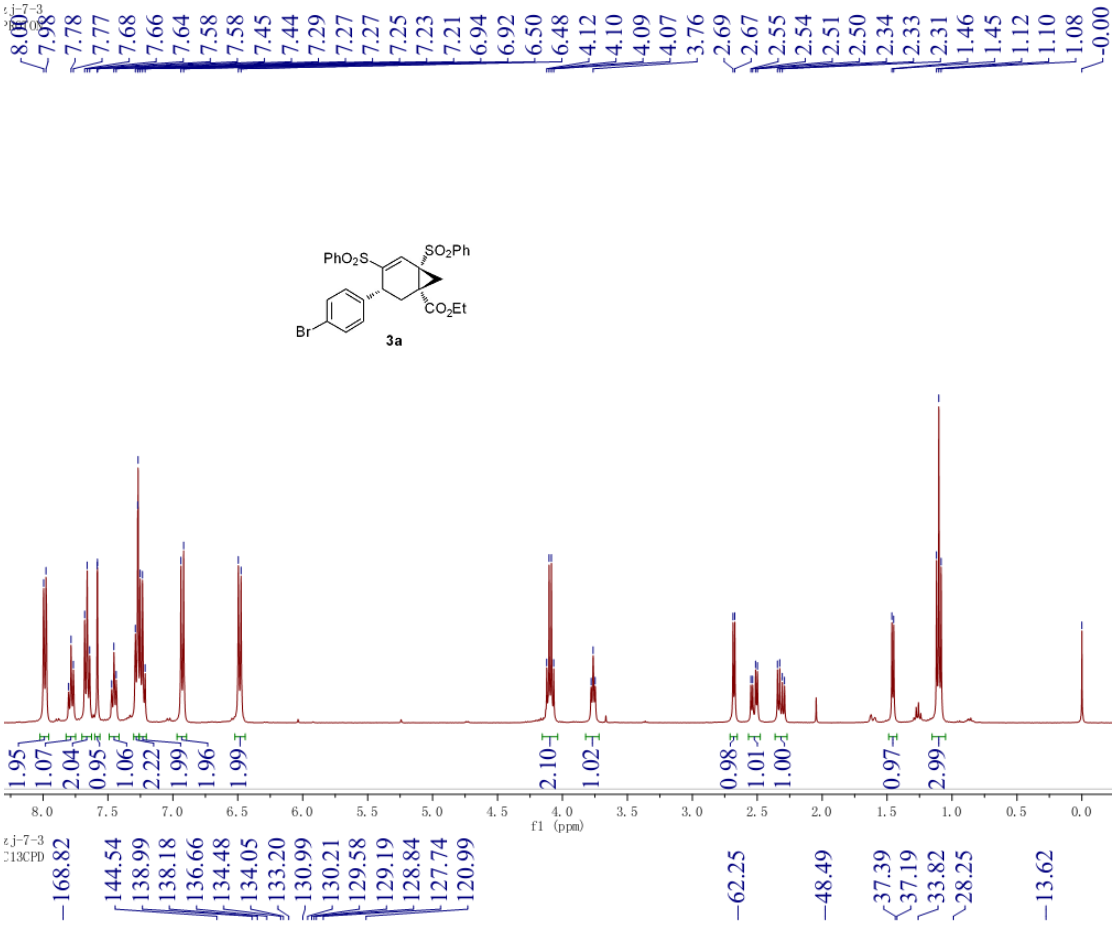
5 X-Ray Crystallography Data

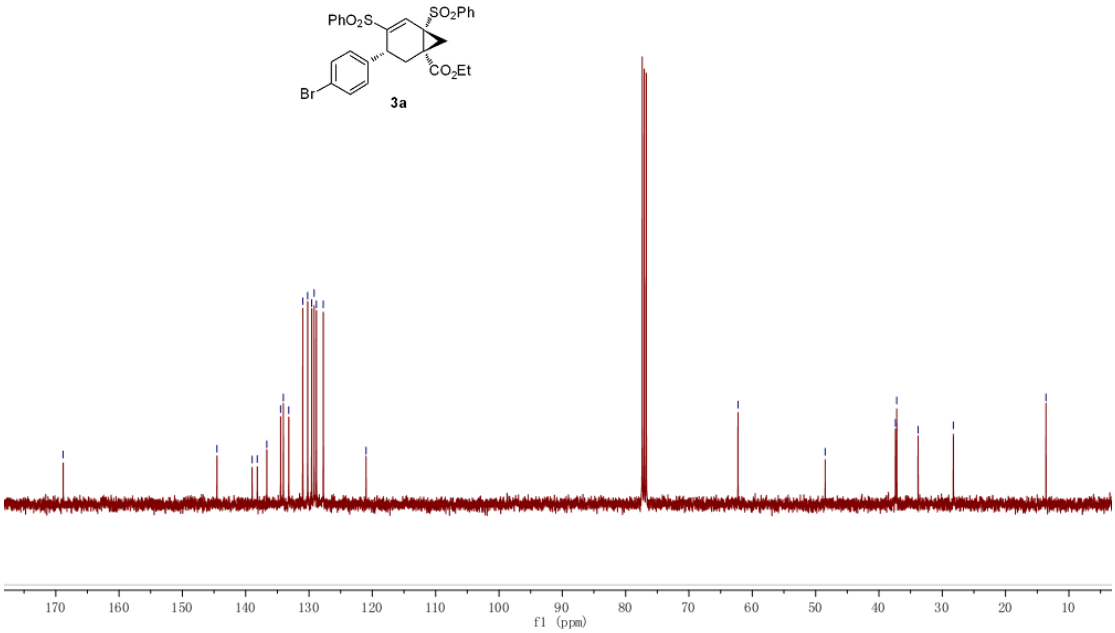


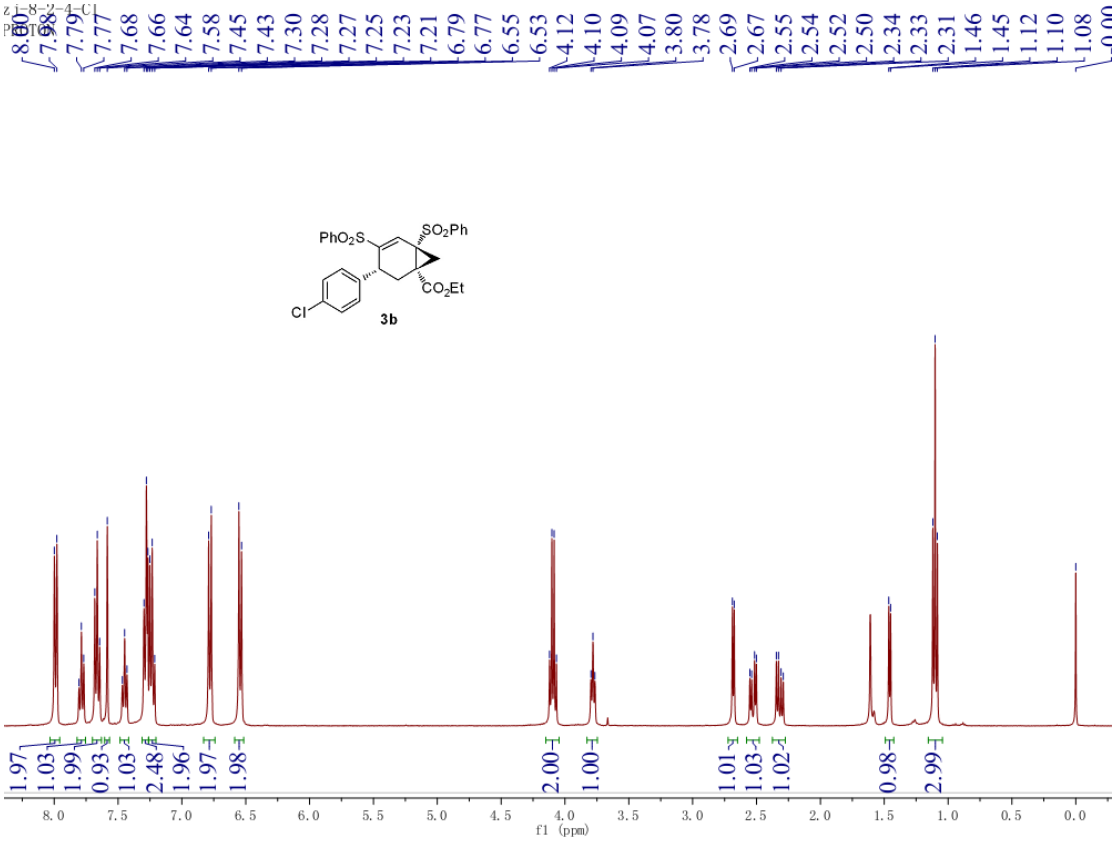


CCDC 972350

6 ^{1}H and ^{13}C Spectra of Compound 3a-3t



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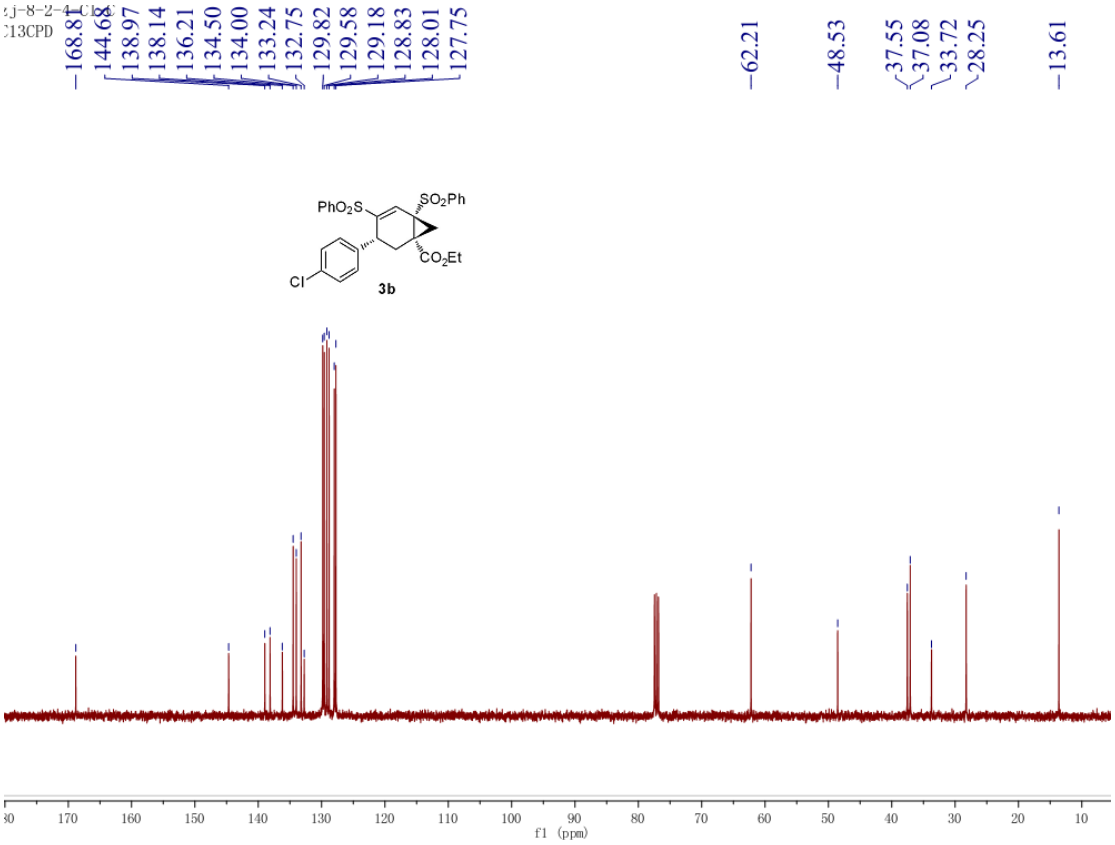
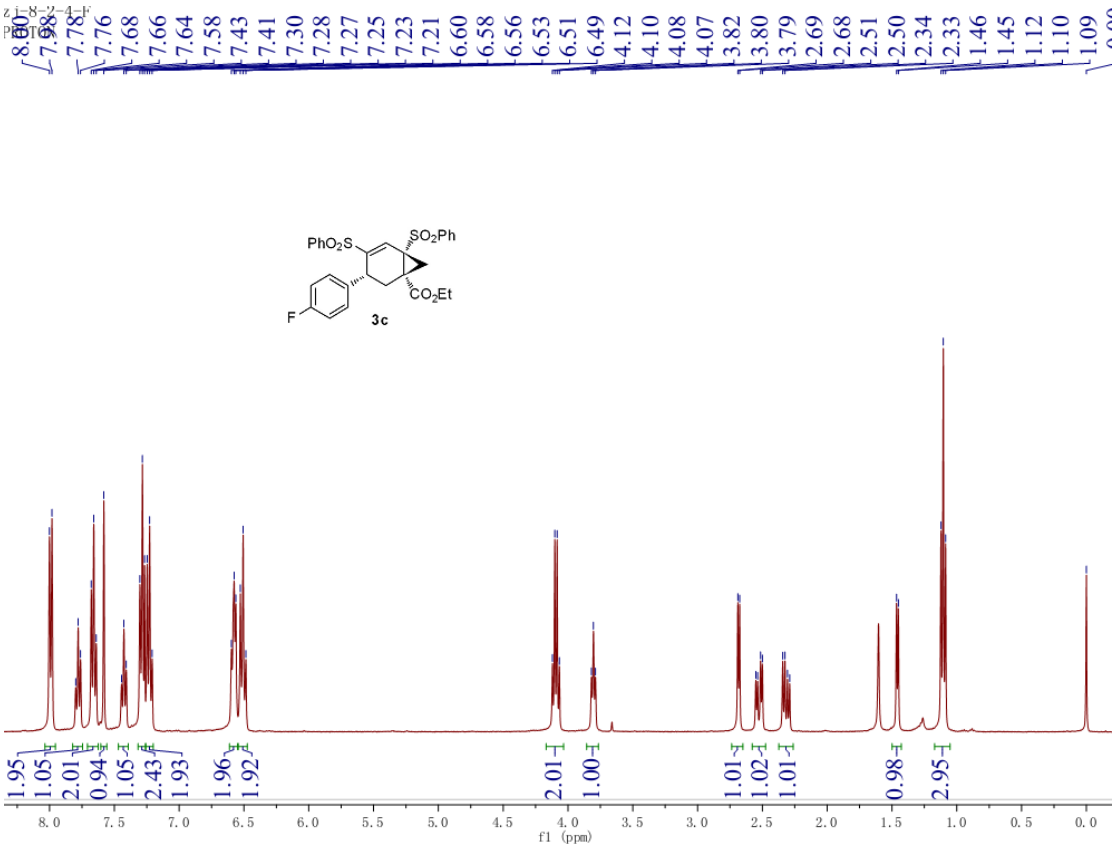
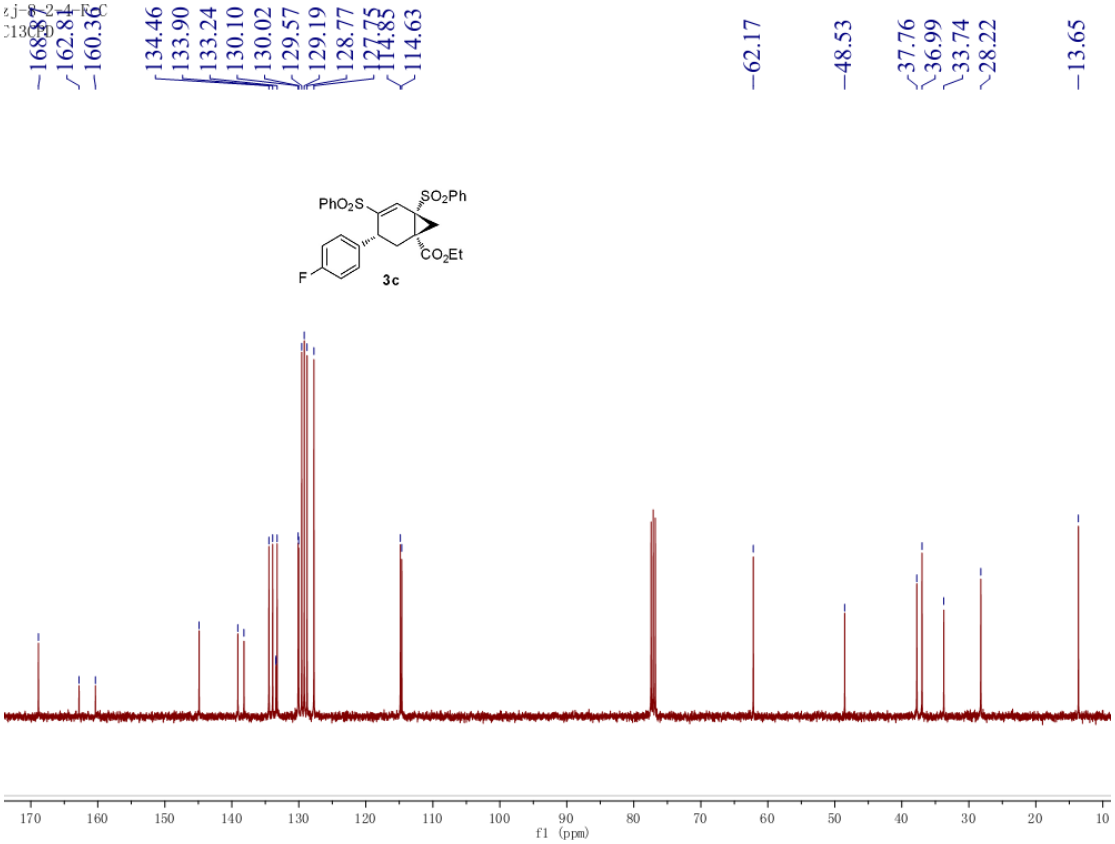
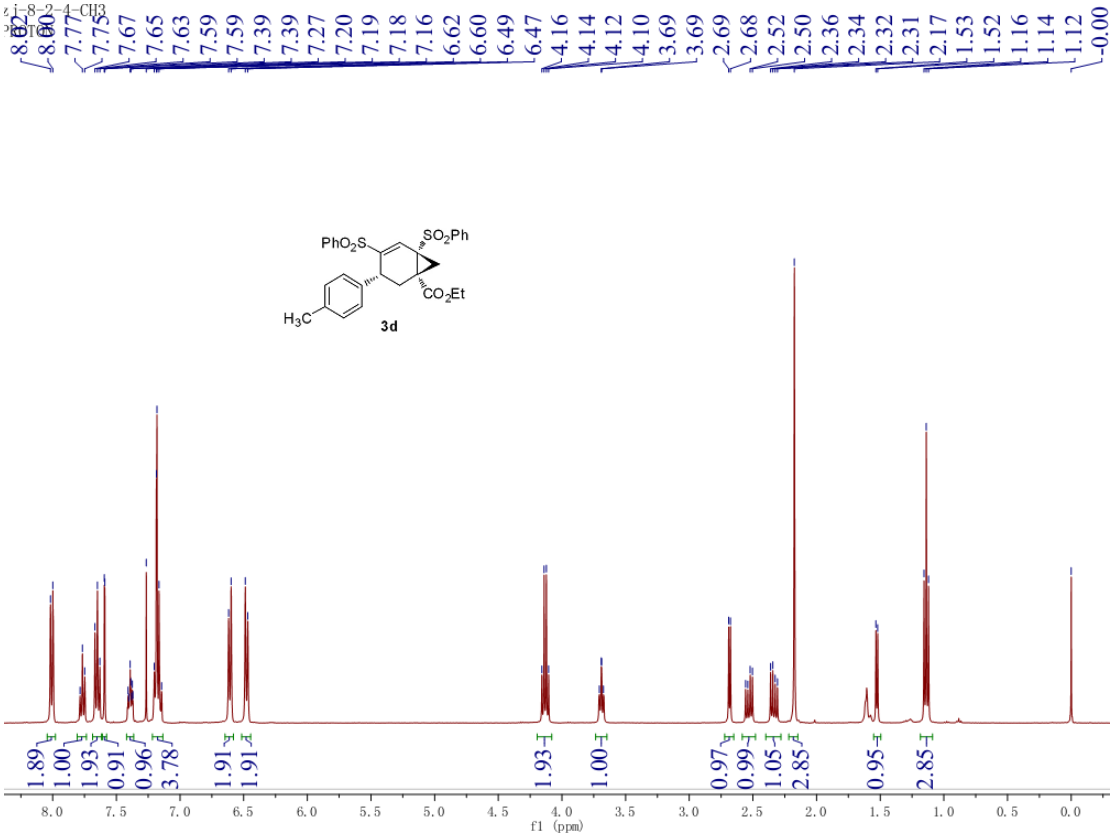
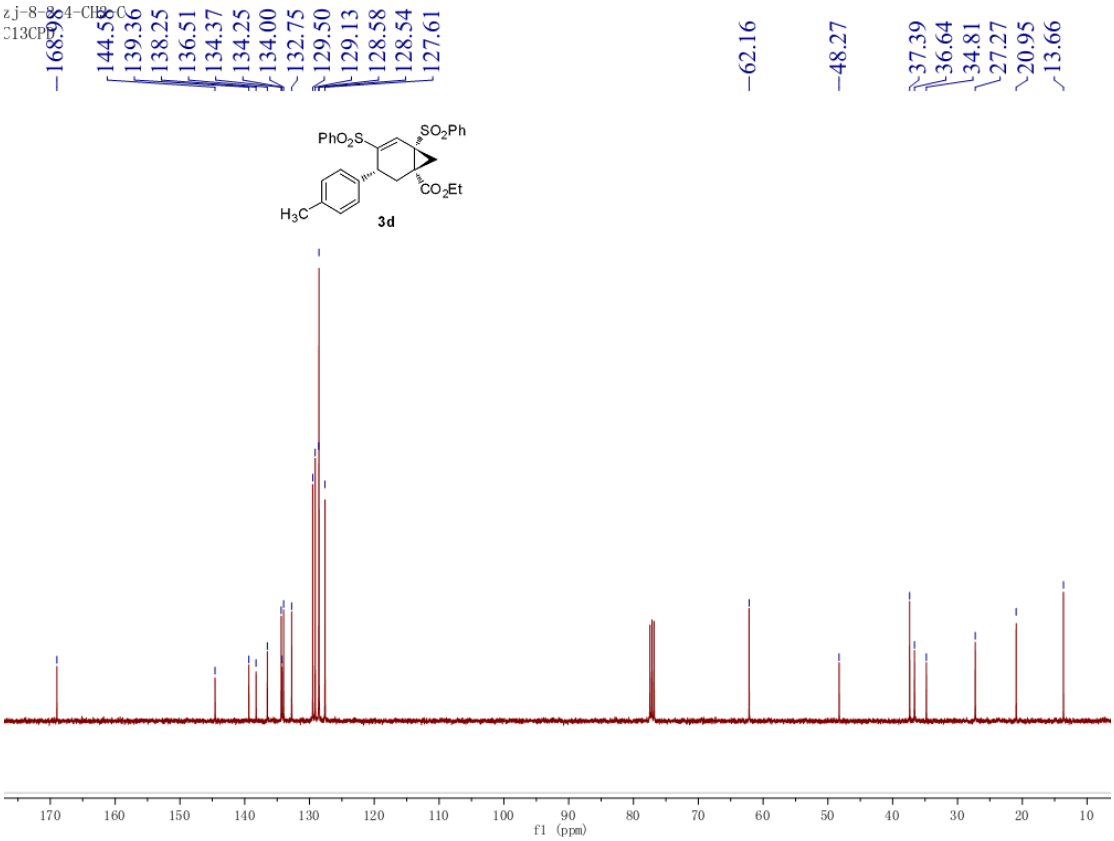
1.96
1.97
1.98
2.00
1.00
1.01
1.03
1.02
0.98
2.99
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

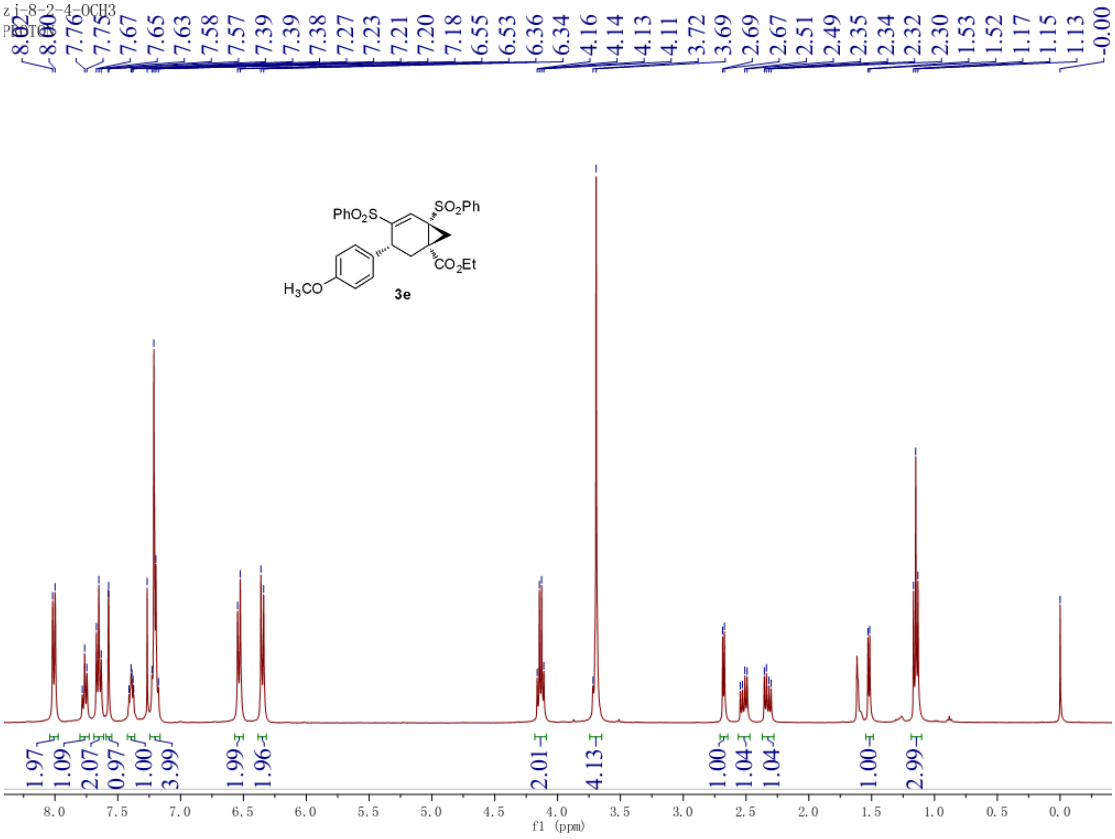

zj-8-2-4-Cl
C13CPD
168.81
144.68
138.97
138.14
136.21
134.50
134.00
133.24
132.75
129.82
129.58
129.18
128.83
128.01
127.75
62.21
48.53
37.55
37.08
33.72
28.25
13.61
PhO2S
SO2Ph
CO2Et
Cl
3b
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

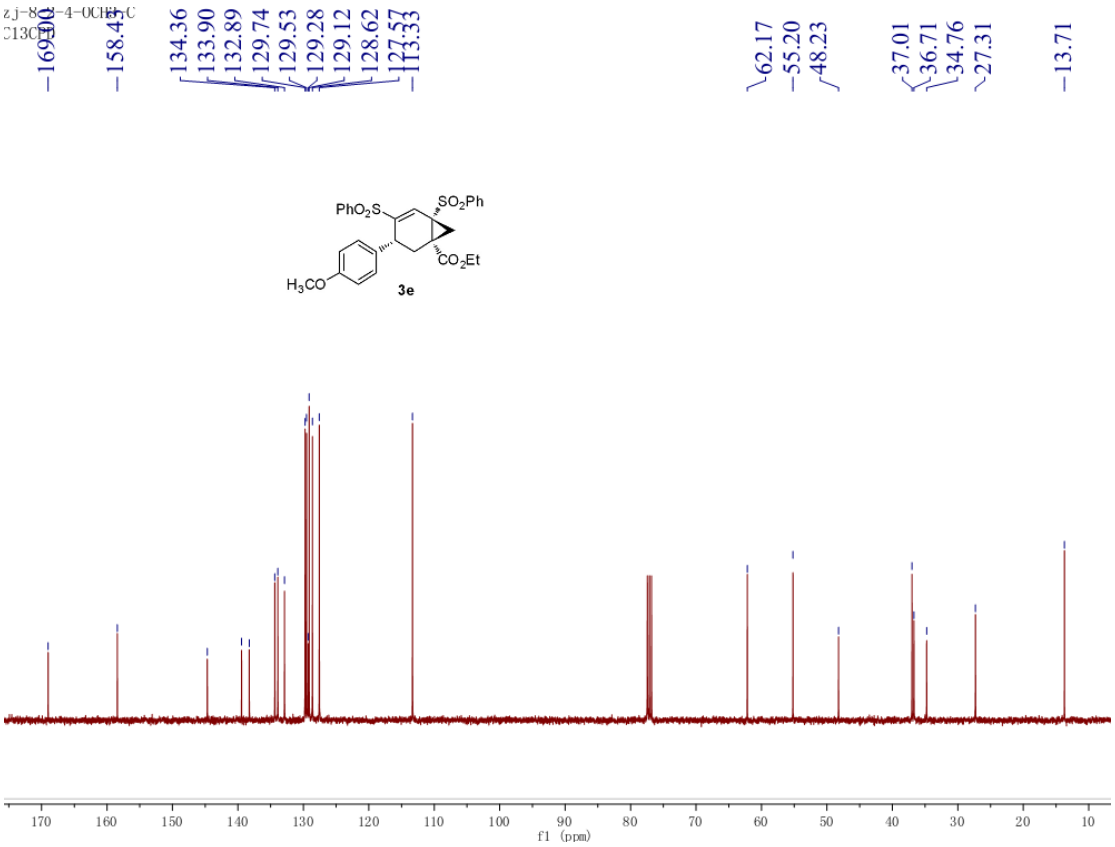

zj-8-2-4-F
PROTON
8.00
7.98
7.78
7.76
7.68
7.66
7.64
7.58
7.43
7.41
7.30
7.28
7.27
7.25
7.23
7.21
6.60
6.58
6.56
6.53
6.51
6.49
4.12
4.10
4.08
4.07
3.82
3.80
3.79
2.69
2.68
2.51
2.50
2.34
2.33
1.46
1.45
1.12
1.10
1.09
PhO2S
SO2Ph
CO2Et
F
3c
1.95
1.05
2.01
0.94
1.05
2.43
1.93
1.96
1.92
2.01
1.00
1.01
1.02
1.01
0.98
2.95
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

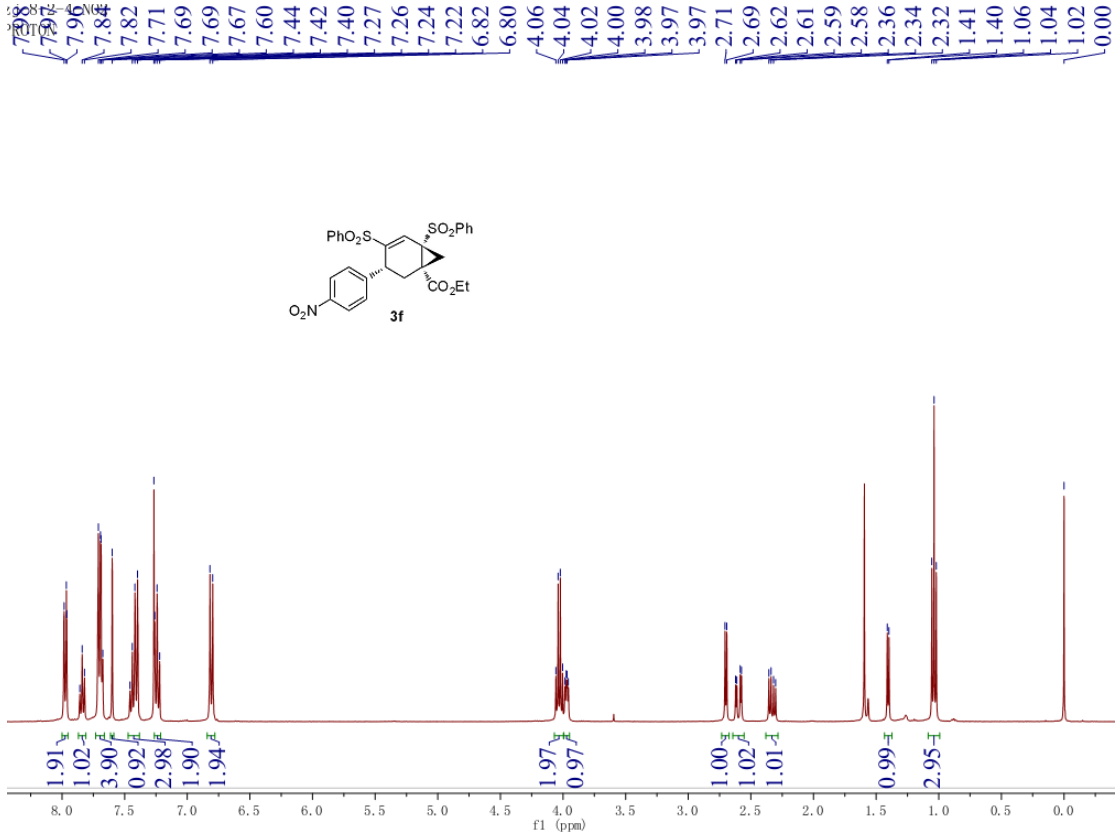

zj-8-2-4-F-C
C13CPD
168.87
162.81
160.36
134.46
133.90
133.24
130.10
130.02
129.57
129.19
128.77
127.75
114.85
114.63
62.17
48.53
37.76
36.99
33.74
28.22
13.65
PhO2S
SO2Ph
CO2Et
F
3c
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

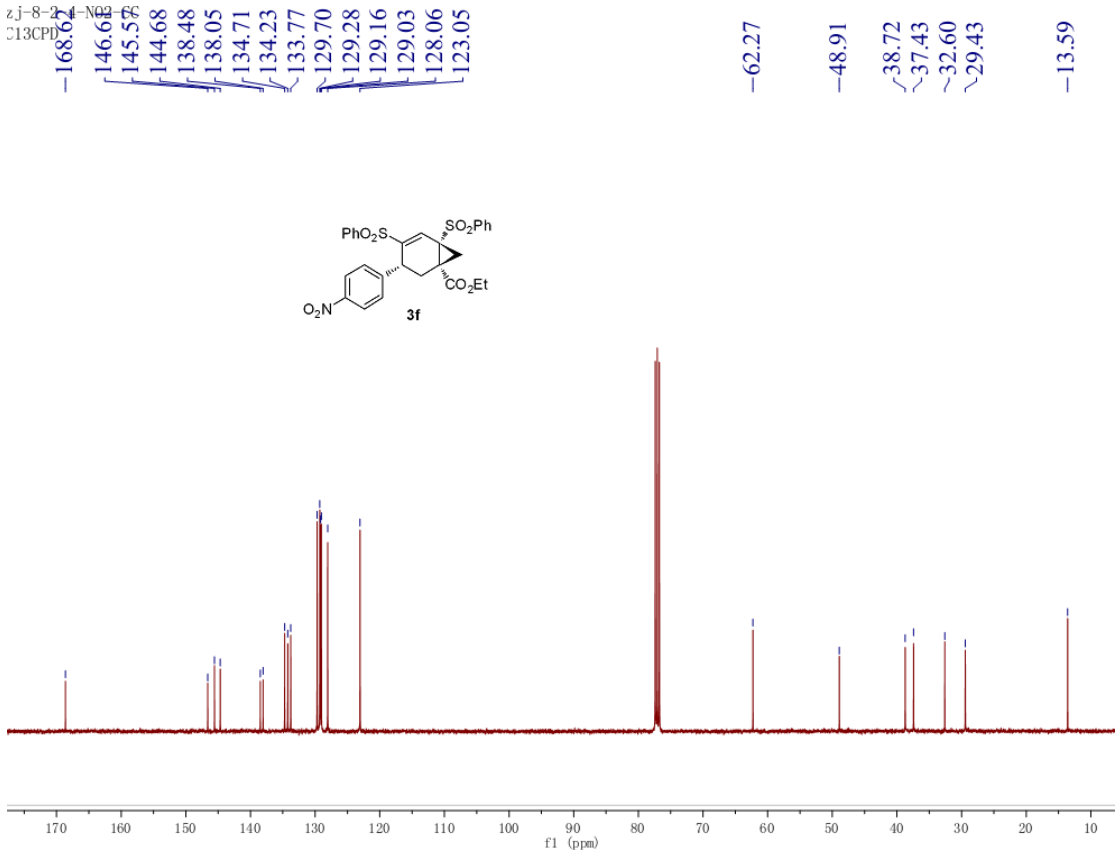

zj-8-2-4-CH3
PhO2S
SO2Ph
CO2Et
H3C
3d
8.02
8.00
7.77
7.75
7.67
7.65
7.63
7.59
7.59
7.39
7.39
7.27
7.20
7.19
7.18
7.16
6.62
6.60
6.49
6.47
4.16
4.14
4.12
4.10
3.69
3.69
2.69
2.68
2.52
2.50
2.36
2.34
2.32
2.31
2.17
1.53
1.52
1.16
1.14
1.12
-0.00
1.89
1.00
1.93
0.91
0.96
3.78
1.91
1.91
1.93
1.00
0.97
0.99
1.05
2.85
0.95
2.85
f1 (ppm)

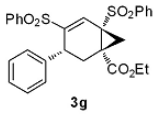

zj-8-8-4-CH3-C
C13CPD
168.98
144.58
139.36
138.25
136.51
134.37
134.25
134.00
132.75
129.50
129.13
128.58
128.54
127.61
62.16
48.27
37.39
36.64
34.81
27.27
20.95
13.66
PhO2S
SO2Ph
CO2Et
H3C
3d
f1 (ppm)


zj-8-2-4-OCH3
PROTON
8.62
8.60
7.76
7.75
7.67
7.65
7.63
7.58
7.57
7.39
7.39
7.38
7.27
7.23
7.21
7.20
7.18
6.55
6.53
6.36
6.34
4.16
4.14
4.13
4.11
3.72
3.69
2.69
2.67
2.51
2.49
2.35
2.34
2.32
2.30
1.53
1.52
1.17
1.15
1.13
-0.00
PhO2S
SO2Ph
CO2Et
H3CO
3e
1.97
1.09
2.07
0.97
1.00
3.99
1.99
1.96
2.01
4.13
1.00
1.04
1.04
1.00
2.99
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

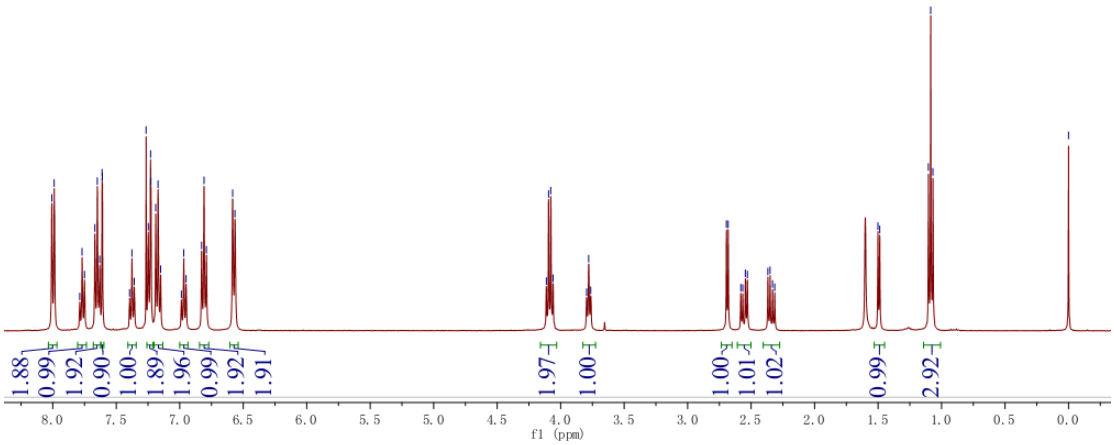

zj-8-2-4-OCH3-C
C13CPD
169.01
158.45
134.36
133.90
132.89
129.74
129.53
129.28
129.12
128.62
127.57
113.33
62.17
55.20
48.23
37.01
36.71
34.76
27.31
13.71
PhO2S
SO2Ph
CO2Et
H3CO
3e
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

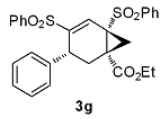

PhO2S
SO2Ph
CO2Et
O2N
3f
f1 (ppm)


PhO2S
SO2Ph
CO2Et
O2N
3f
f1 (ppm)

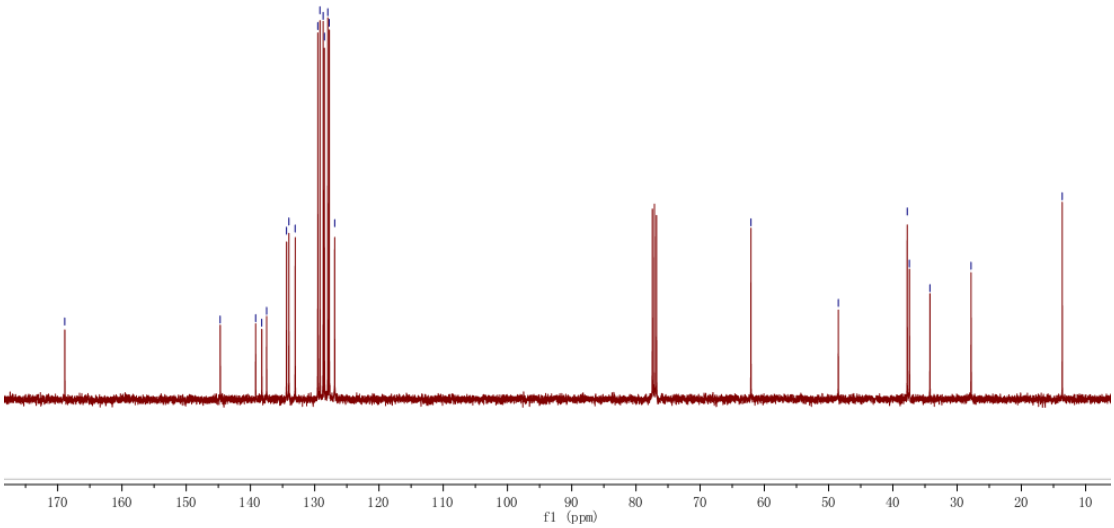


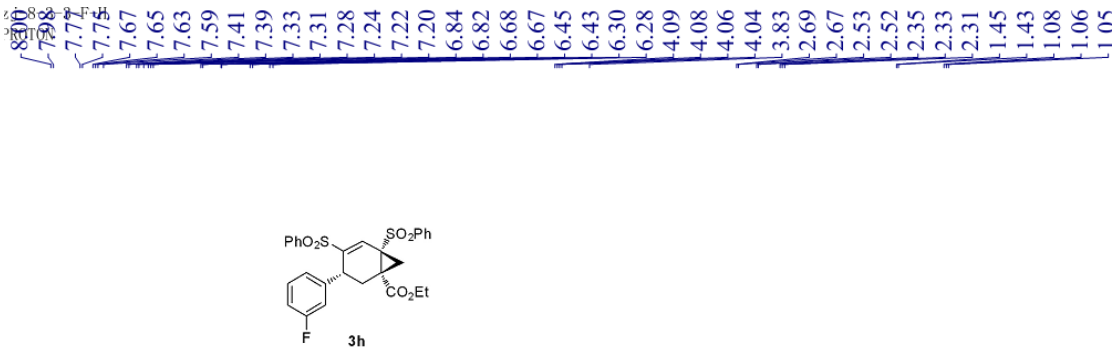
3g

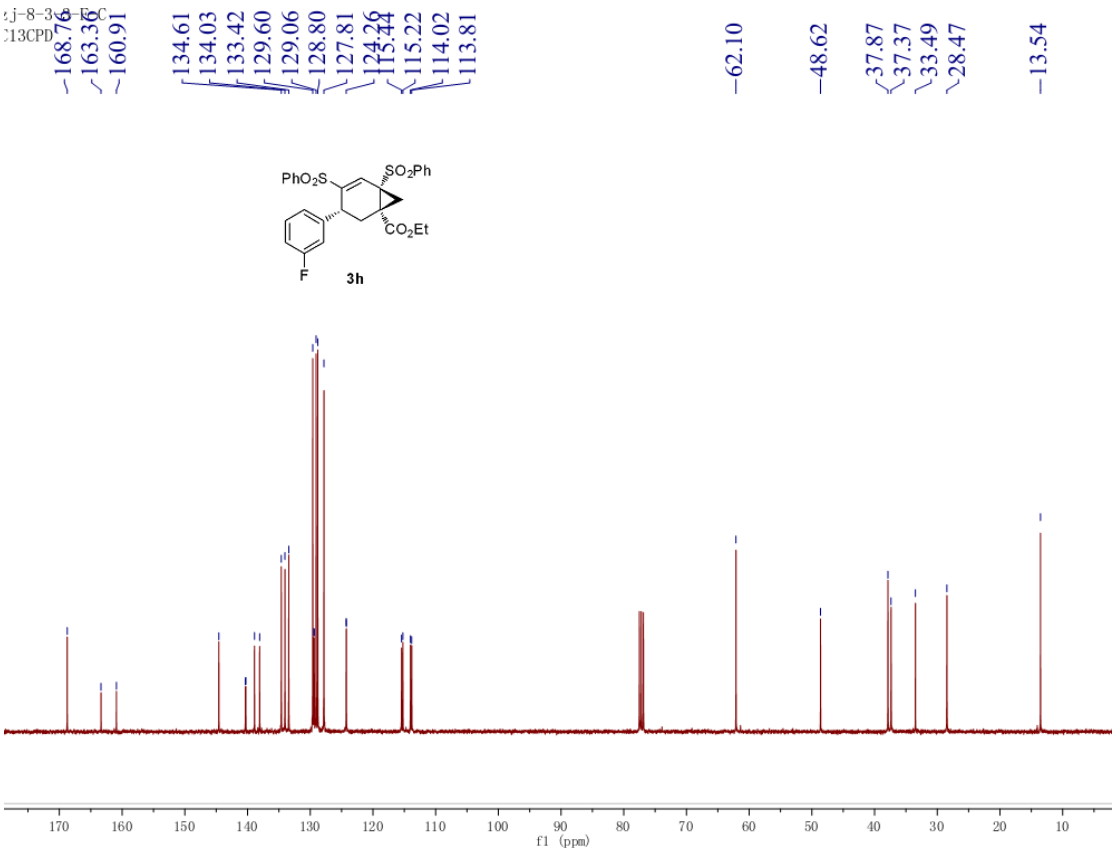


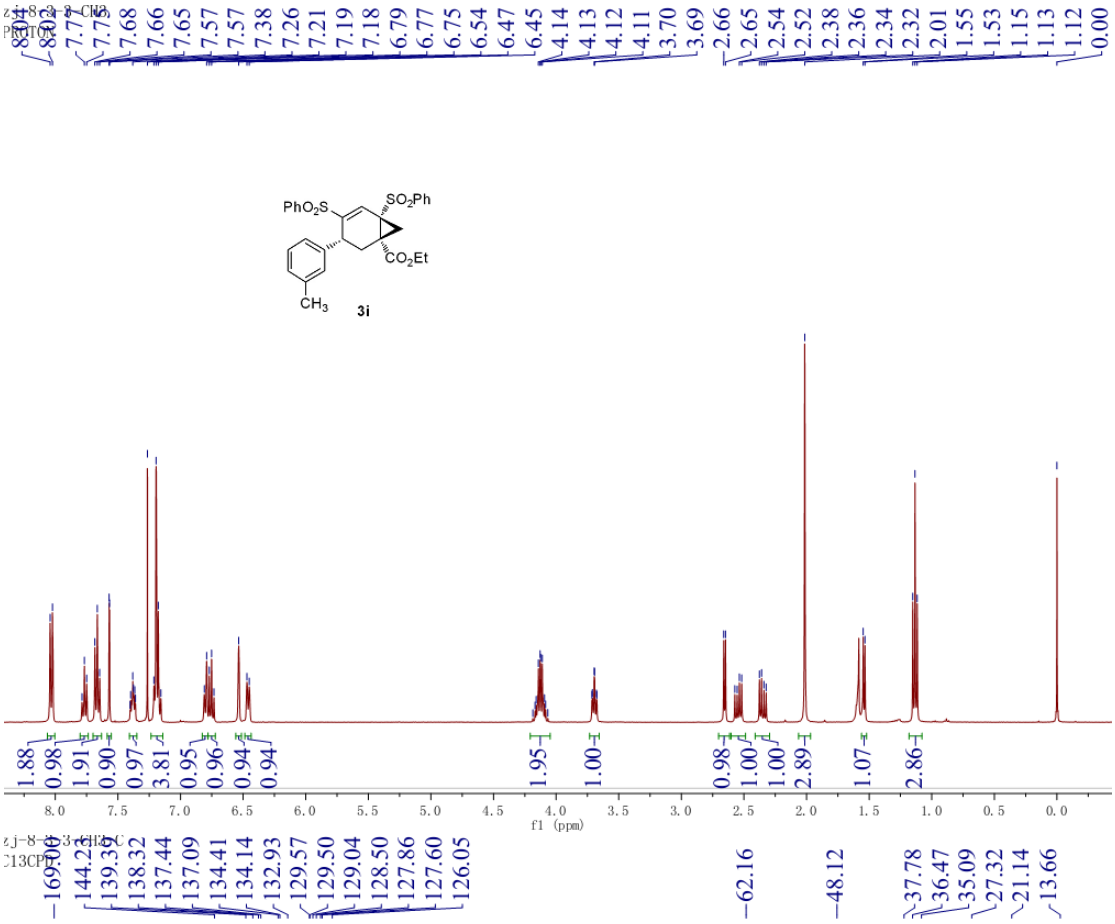


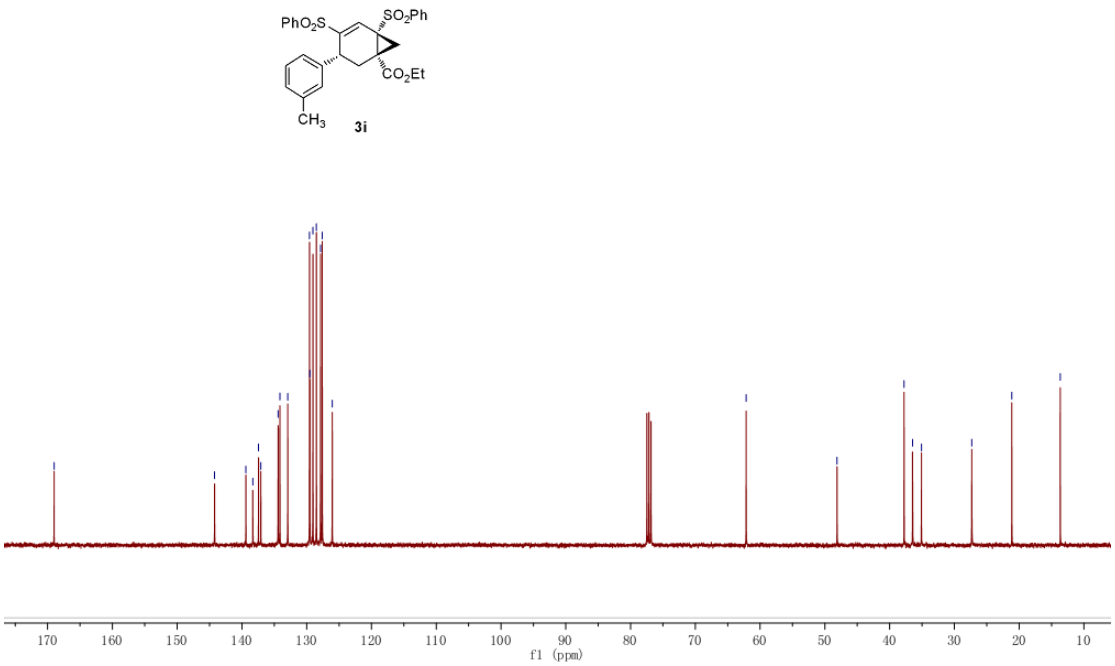
3g

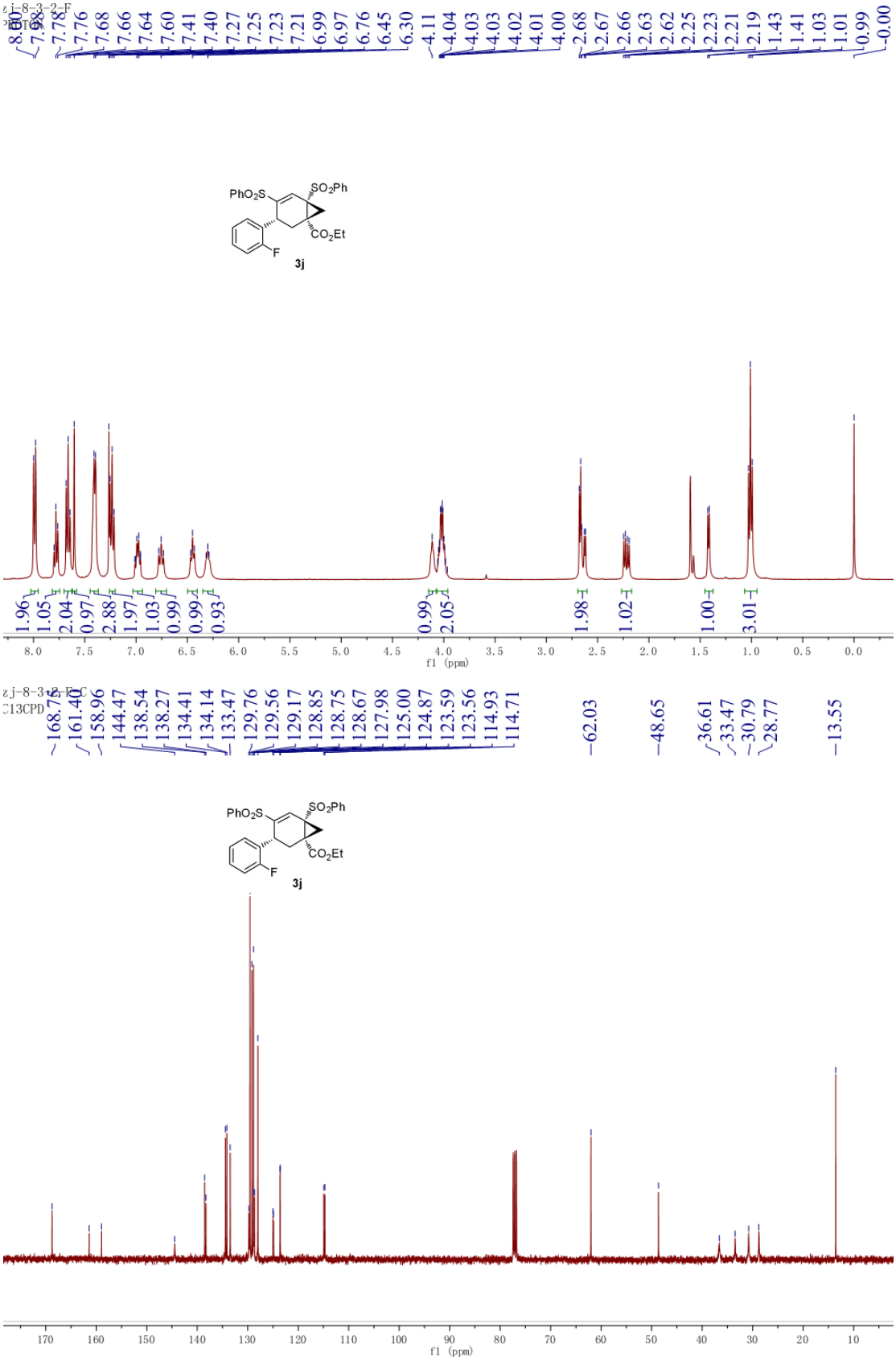



PhO2S
SO2Ph
CO2Et
F
3h
f1 (ppm)

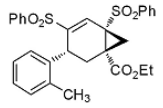

PhO2S
SO2Ph
CO2Et
F
3h
f1 (ppm)


PhO2S
SO2Ph
CO2Et
CH3
3i
f1 (ppm)

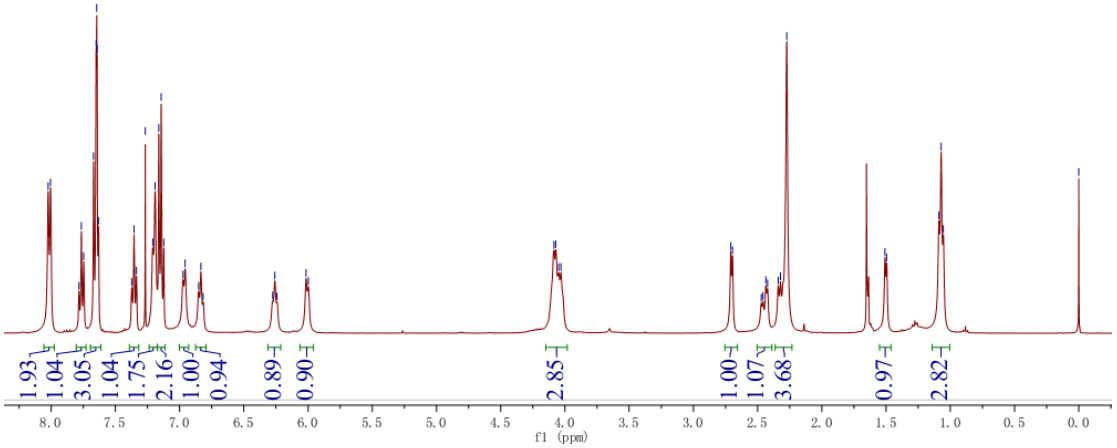

PhO2S
SO2Ph
CO2Et
CH3
3i
f1 (ppm)


zj-8-3-2-F
8.01
7.98
7.78
7.76
7.68
7.66
7.64
7.60
7.41
7.40
7.27
7.25
7.23
7.21
6.99
6.97
6.76
6.45
6.30
4.11
4.04
4.03
4.03
4.02
4.01
4.00
2.68
2.67
2.66
2.63
2.62
2.25
2.23
2.21
2.19
1.43
1.41
1.03
1.01
0.99
-0.00
PhO2S
SO2Ph
CO2Et
F
3j
1.96
1.05
2.04
0.97
2.88
1.97
1.03
0.99
0.99
0.93
0.99
2.05
1.98
1.02
1.00
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
zj-8-3-2-F-C
C13CPD
168.75
161.40
158.96
144.47
138.54
138.27
134.41
134.14
133.47
129.76
129.56
129.17
128.85
128.75
128.67
127.98
125.00
124.87
123.59
123.56
114.93
114.71
62.03
48.65
36.61
33.47
30.79
28.77
13.55
PhO2S
SO2Ph
CO2Et
F
3j
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

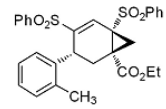
zj-8-3-2-CH3-H
PROTON
8.82
8.80
7.76
7.75
7.67
7.65
7.65
7.64
7.63
7.37
7.35
7.34
7.27
7.21
7.19
7.16
7.14
7.12
6.97
6.96
6.83
6.26
6.02
6.00
4.09
4.07
4.05
4.03
2.71
2.70
2.44
2.42
2.34
2.32
2.27
1.51
1.50
1.09
1.07
1.05
0.00


PhO2S
SO2Ph
CO2Et
CH3

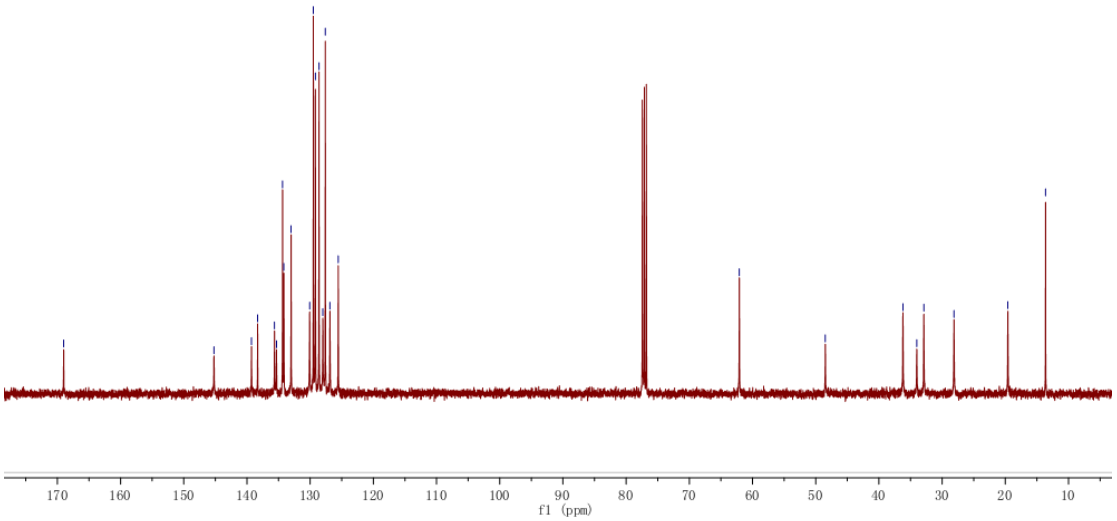
3k

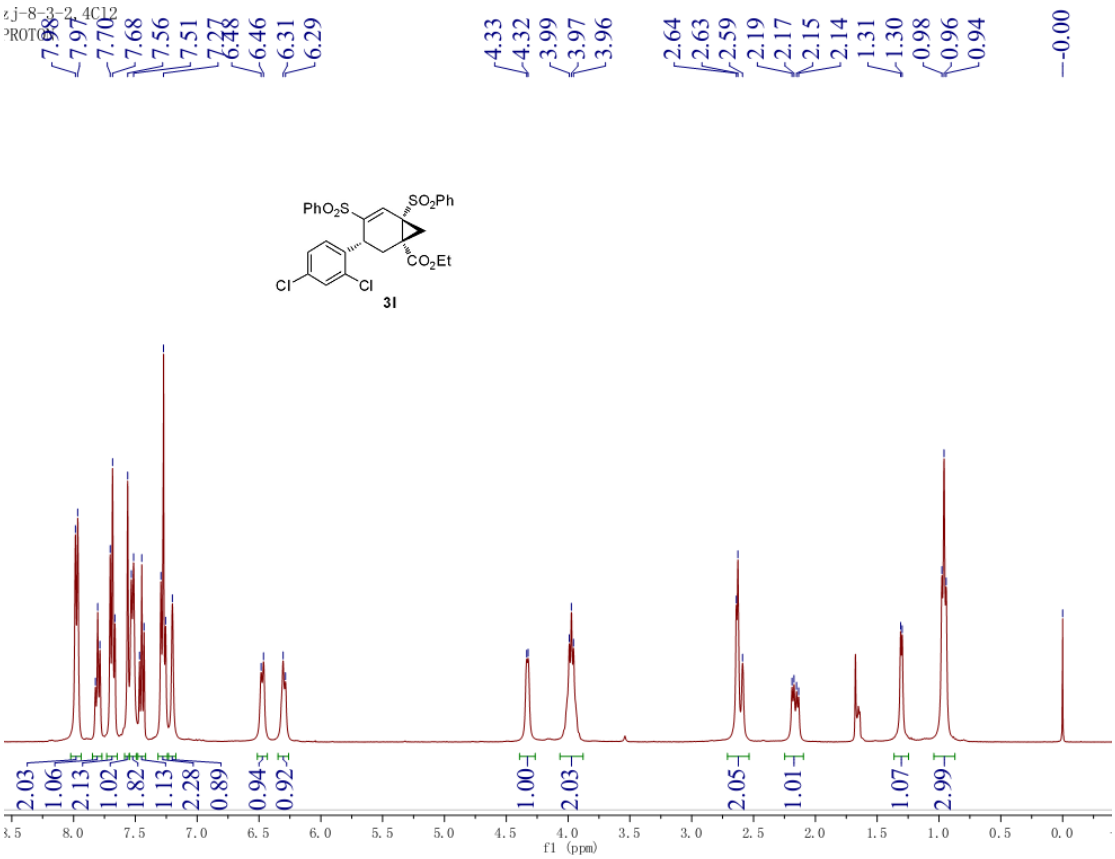

1.93
1.04
3.05
1.04
1.75
2.16
1.00
0.94
0.89
0.90
2.85
1.00
1.07
3.68
0.97
2.82
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

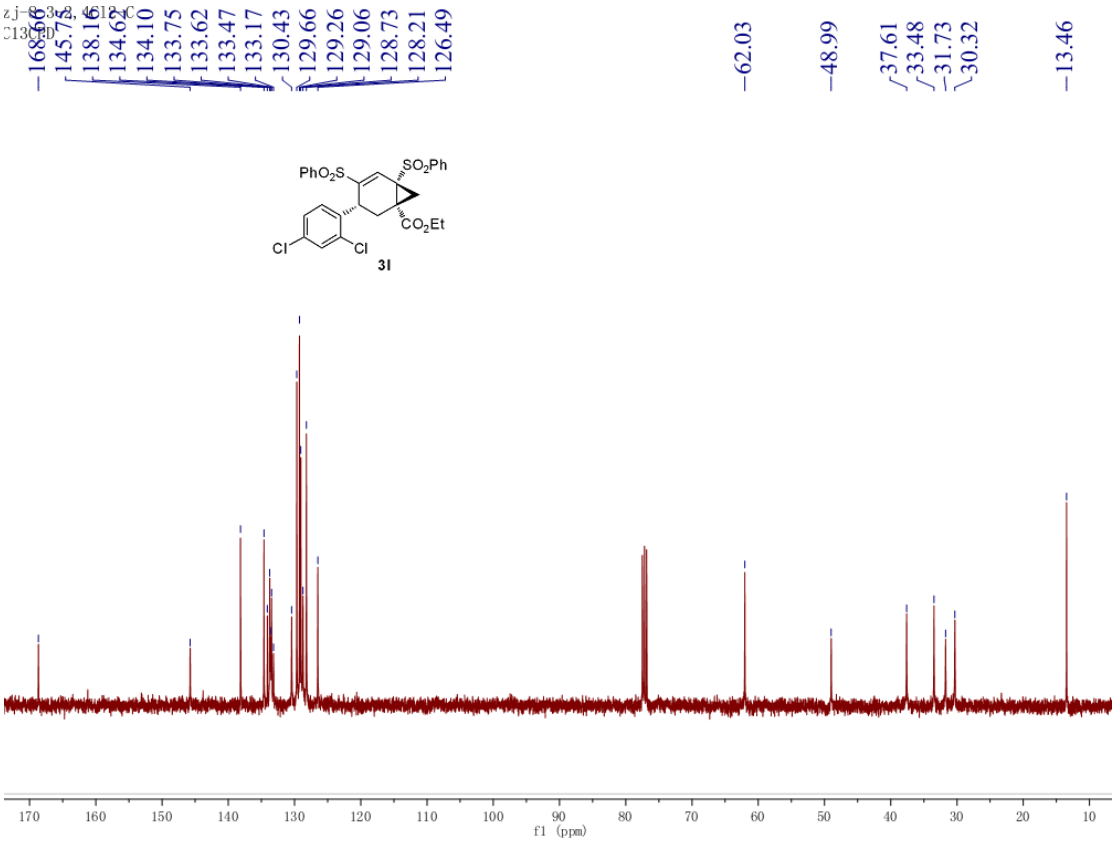
zj-8-3-2CH3-6
C13CPD
169.01
145.21
139.28
138.32
135.64
135.33
134.36
134.17
133.02
130.08
129.50
129.18
128.60
127.99
127.60
126.87
125.55
62.09
48.48
36.20
34.01
32.89
28.12
19.60
13.63

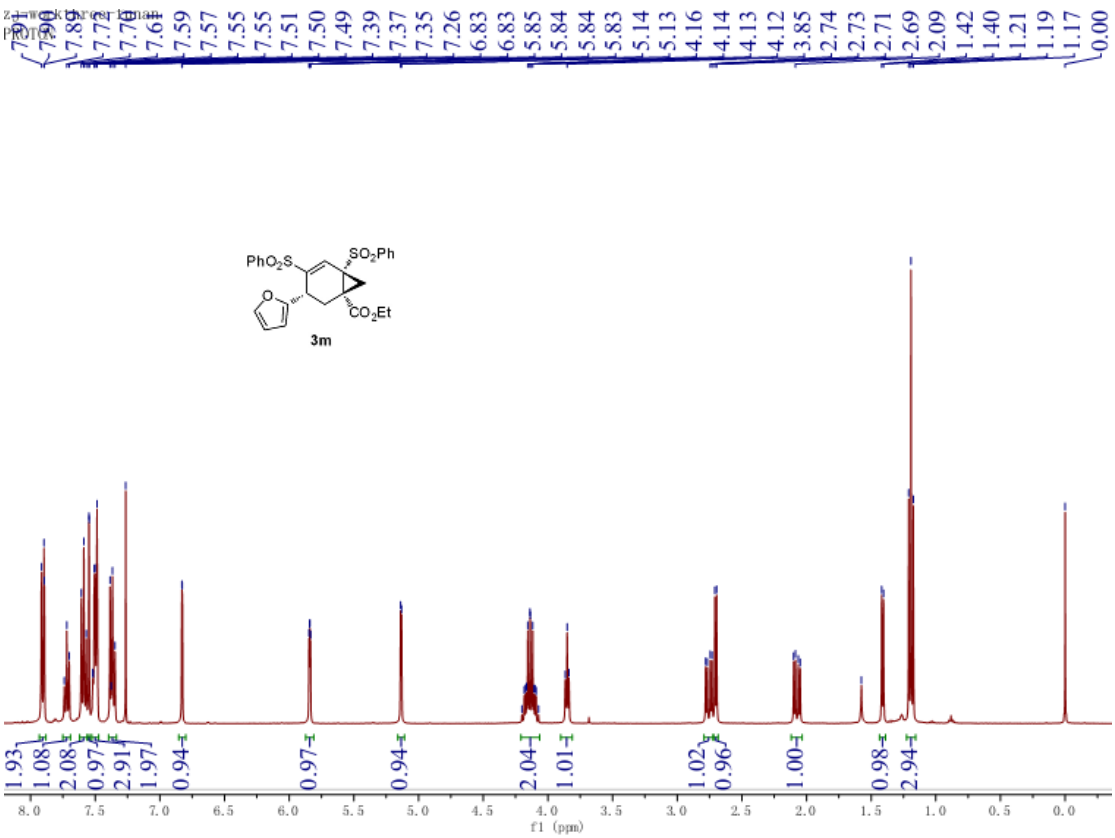

PhO2S
SO2Ph
CO2Et
CH3

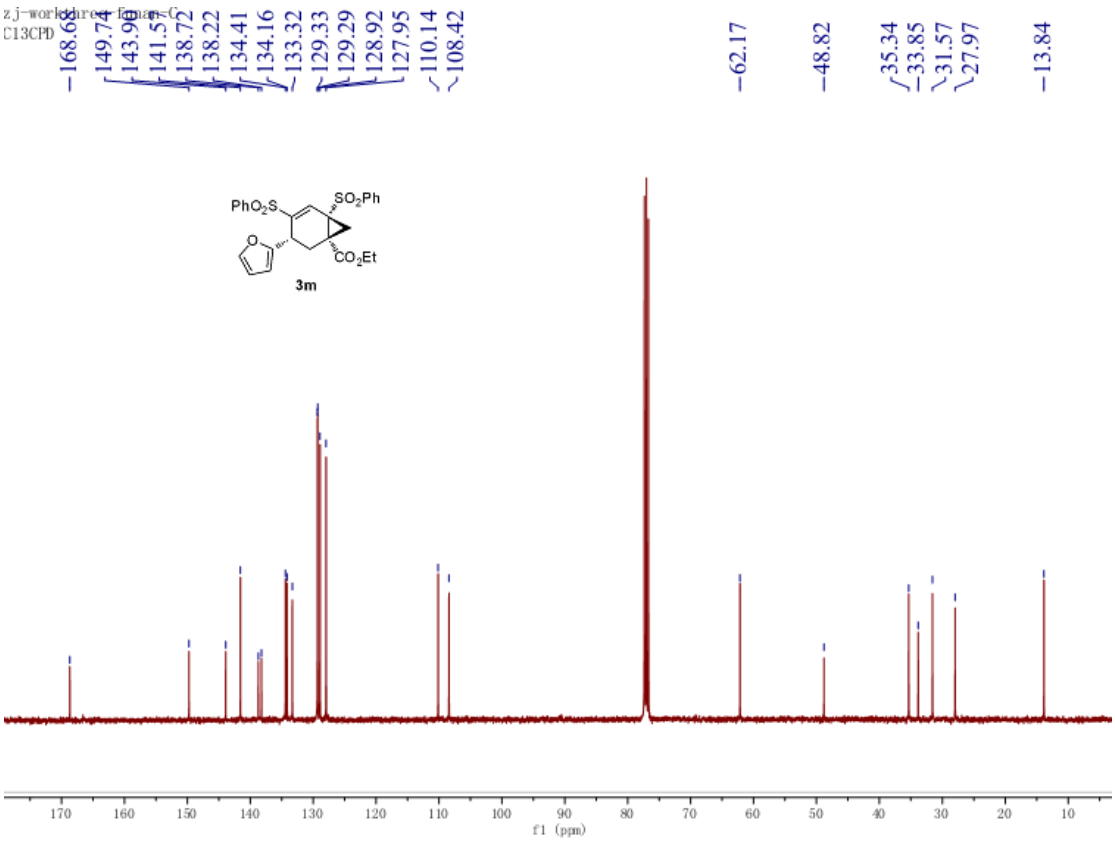
3k


170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

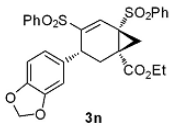

zj-8-3-2.4C12
PROTON
7.98
7.97
7.70
7.68
7.56
7.51
7.27
6.48
6.46
6.31
6.29
4.33
4.32
3.99
3.97
3.96
2.64
2.63
2.59
2.19
2.17
2.15
2.14
1.31
1.30
0.98
0.96
0.94
-0.00
PhO2S
SO2Ph
CO2Et
Cl
Cl
3l
2.03
1.06
2.13
1.02
1.82
1.13
2.28
0.89
0.94
0.92
1.00
2.03
2.05
1.01
1.07
2.99
f1 (ppm)


zj-8-3-2.4C12-C
C13CPD
168.66
145.72
138.16
134.62
134.10
133.75
133.62
133.47
133.17
130.43
129.66
129.26
129.06
128.73
128.21
126.49
62.03
48.99
37.61
33.48
31.73
30.32
13.46
PhO2S
SO2Ph
CO2Et
Cl
Cl
3l
f1 (ppm)

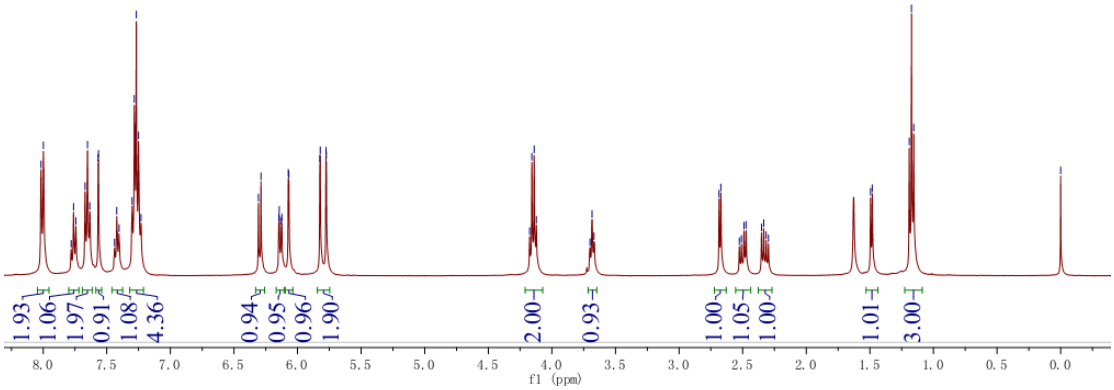

PhO2S
SO2Ph
CO2Et
3m
f1 (ppm)


PhO2S
SO2Ph
CO2Et
3m
f1 (ppm)

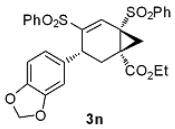
zj-8-4-hujiaoquan
8.82
8.80
7.76
7.74
7.67
7.65
7.63
7.57
7.56
7.42
7.30
7.28
7.27
7.25
7.23
6.31
6.29
6.15
6.14
6.13
6.12
6.07
6.07
5.82
5.82
5.78
5.77
4.16
4.14
4.12
3.68
2.69
2.67
2.47
2.33
1.49
1.48
1.19
1.17
1.15
-0.00


PhO2S
SO2Ph
CO2Et
O
O

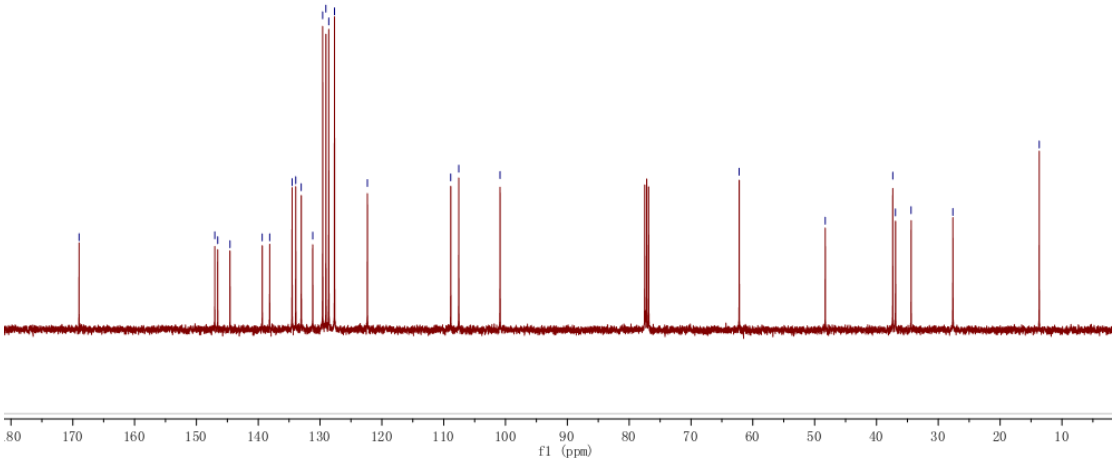
3n

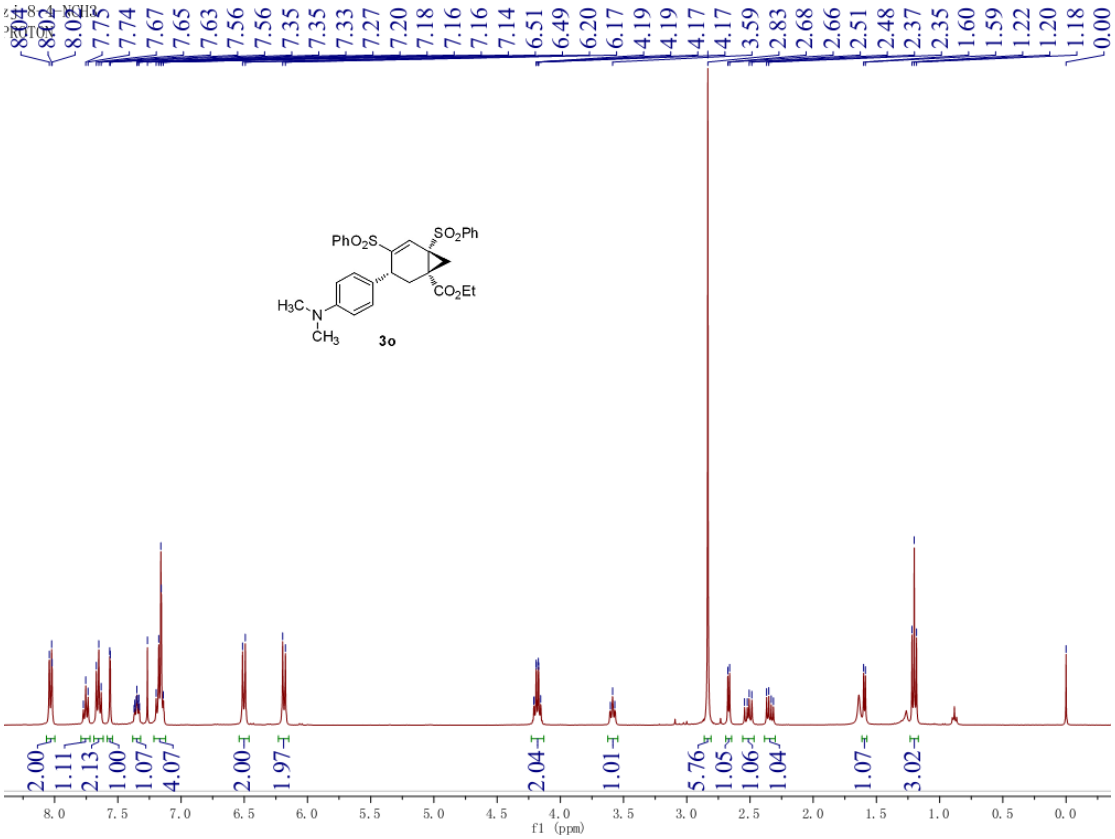

1.93
1.06
1.97
0.91
1.08
4.36
0.94
0.95
0.96
1.90
2.00
0.93
1.00
1.05
1.00
1.01
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

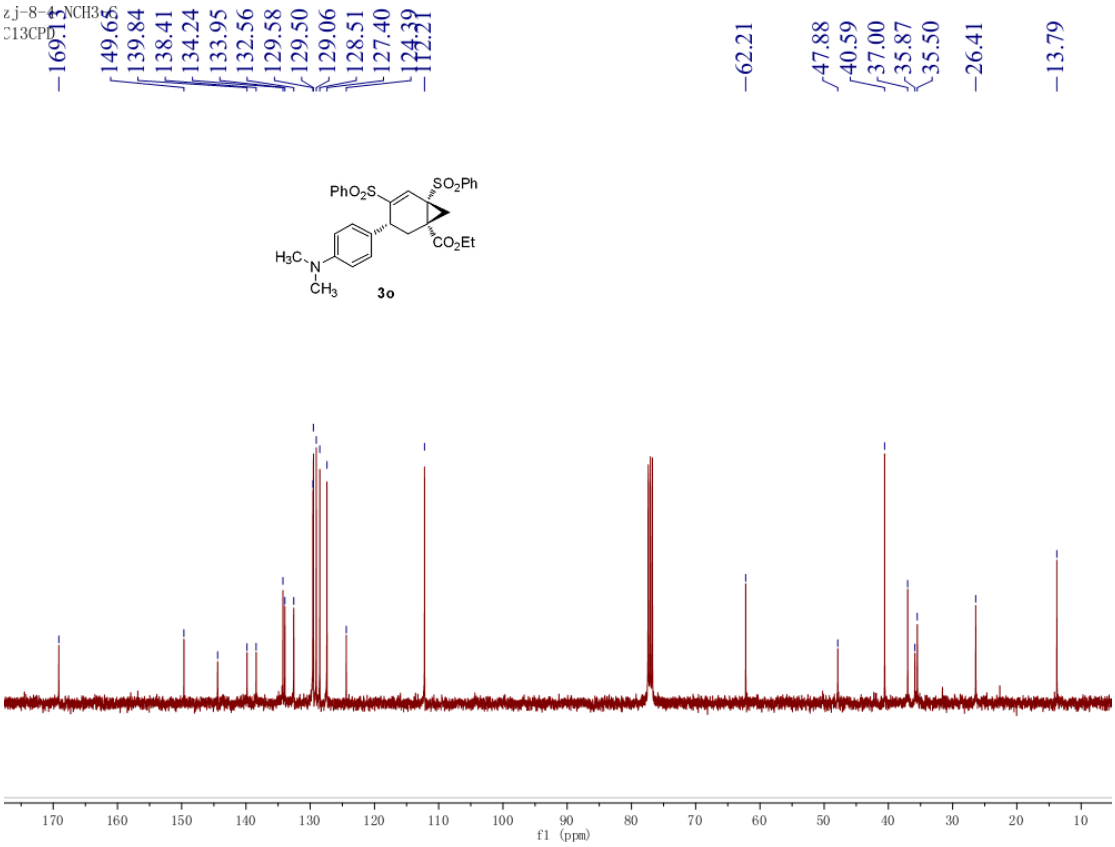
zj-8-4-hujiaoquan-c
C13CPD
168.98
147.03
139.36
138.15
134.53
133.93
133.04
131.19
129.58
129.05
128.59
127.67
122.35
108.86
107.57
100.89
62.21
48.29
37.37
36.92
34.40
27.64
13.68


PhO2S
SO2Ph
CO2Et
O
O

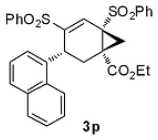
3n

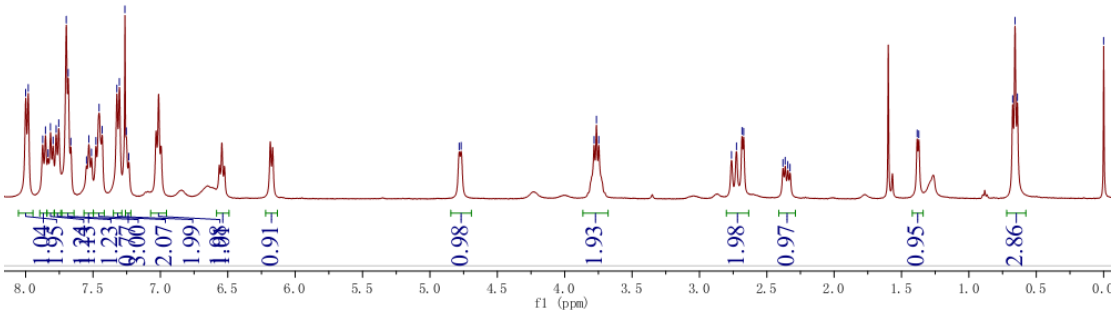

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

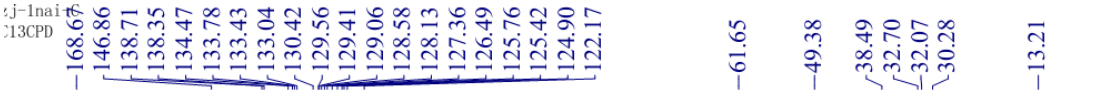

PhO2S
SO2Ph
CO2Et
H3C
N
CH3
3o
f1 (ppm)

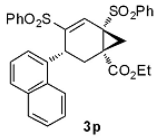

PhO2S
SO2Ph
CO2Et
H3C
N
CH3
3o
f1 (ppm)

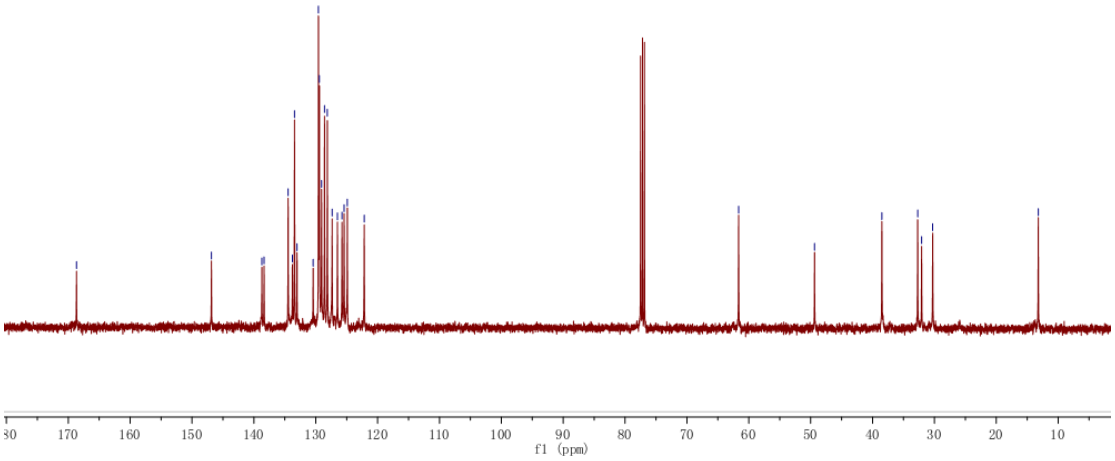
zj-8-10 1nai
8.00
7.98
7.87
7.85
7.83
7.82
7.80
7.77
7.75
7.70
7.68
7.67
7.55
7.53
7.51
7.48
7.45
7.43
7.32
7.30
7.26
7.25
7.23
4.78
4.77
3.78
3.76
3.75
2.76
2.72
2.68
2.67
2.38
2.36
2.34
1.38
1.37
0.68
0.66
0.64
0.00

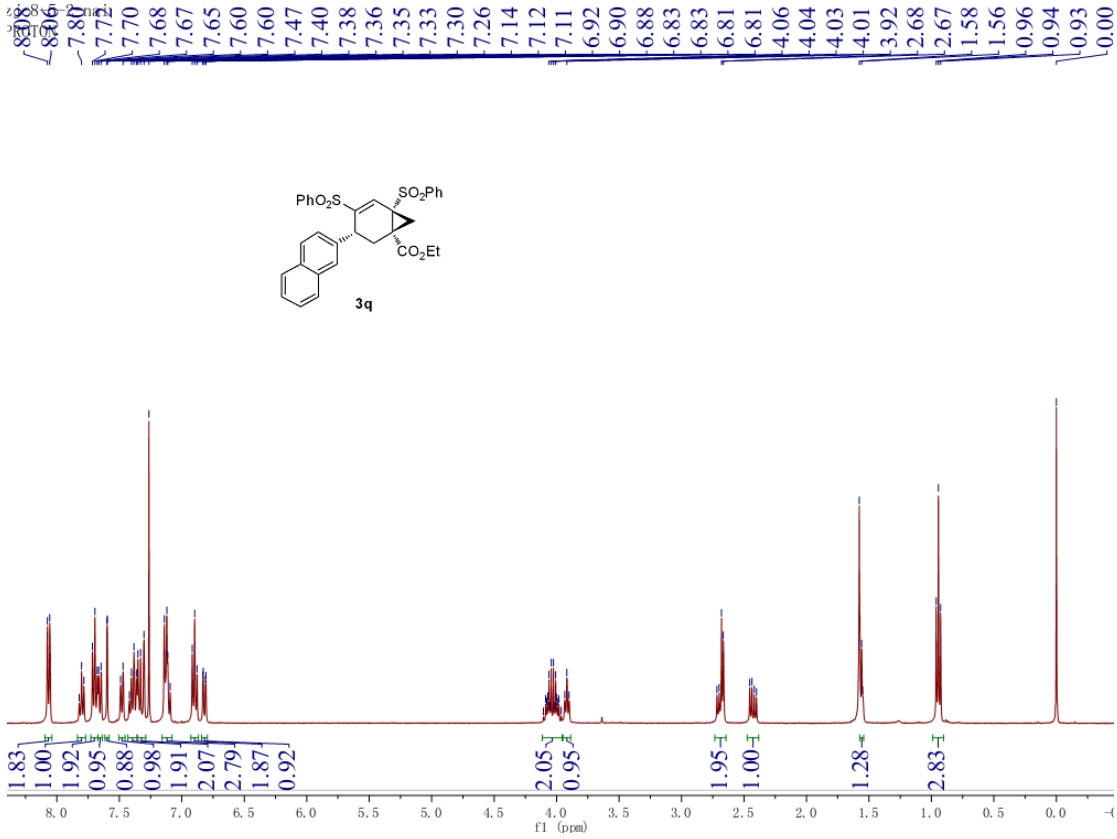

PhO2S
SO2Ph
CO2Et
3p

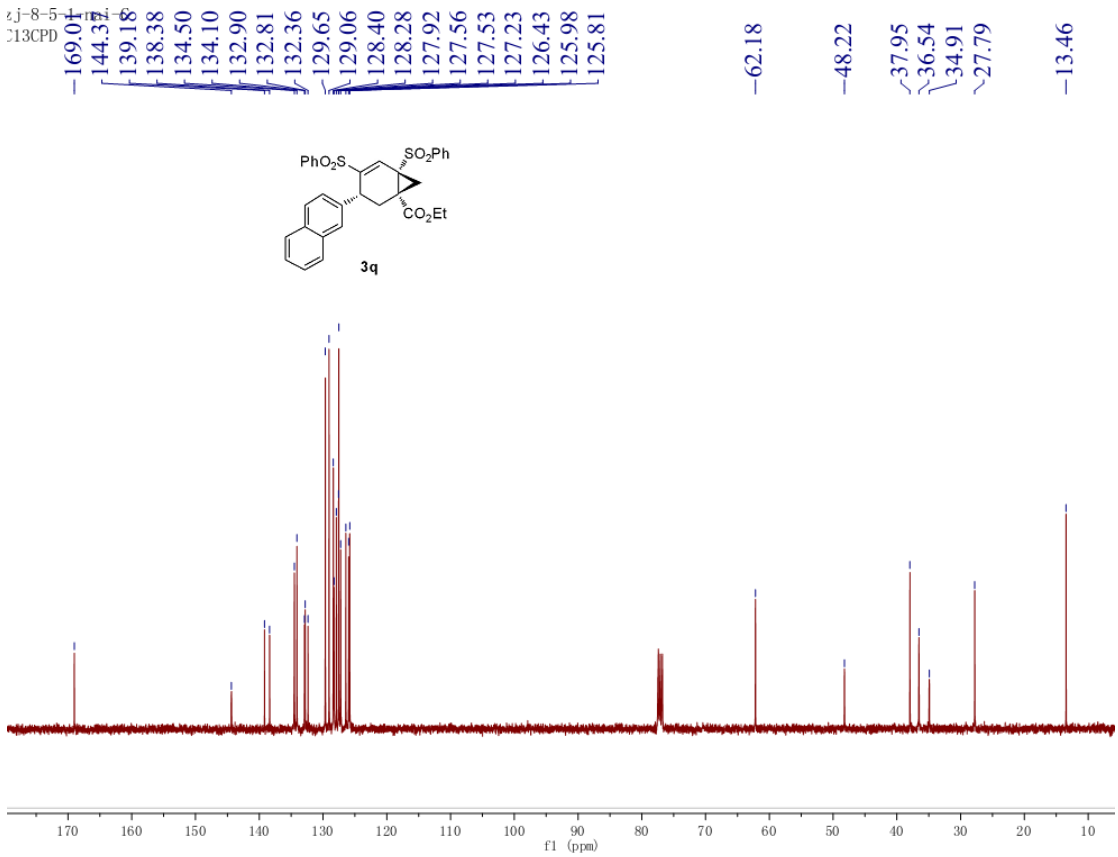

1.04
1.95
1.34
1.23
0.77
3.00
2.07
1.99
1.08
1.01
0.91
0.98
1.93
1.98
0.97
0.95
2.86
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

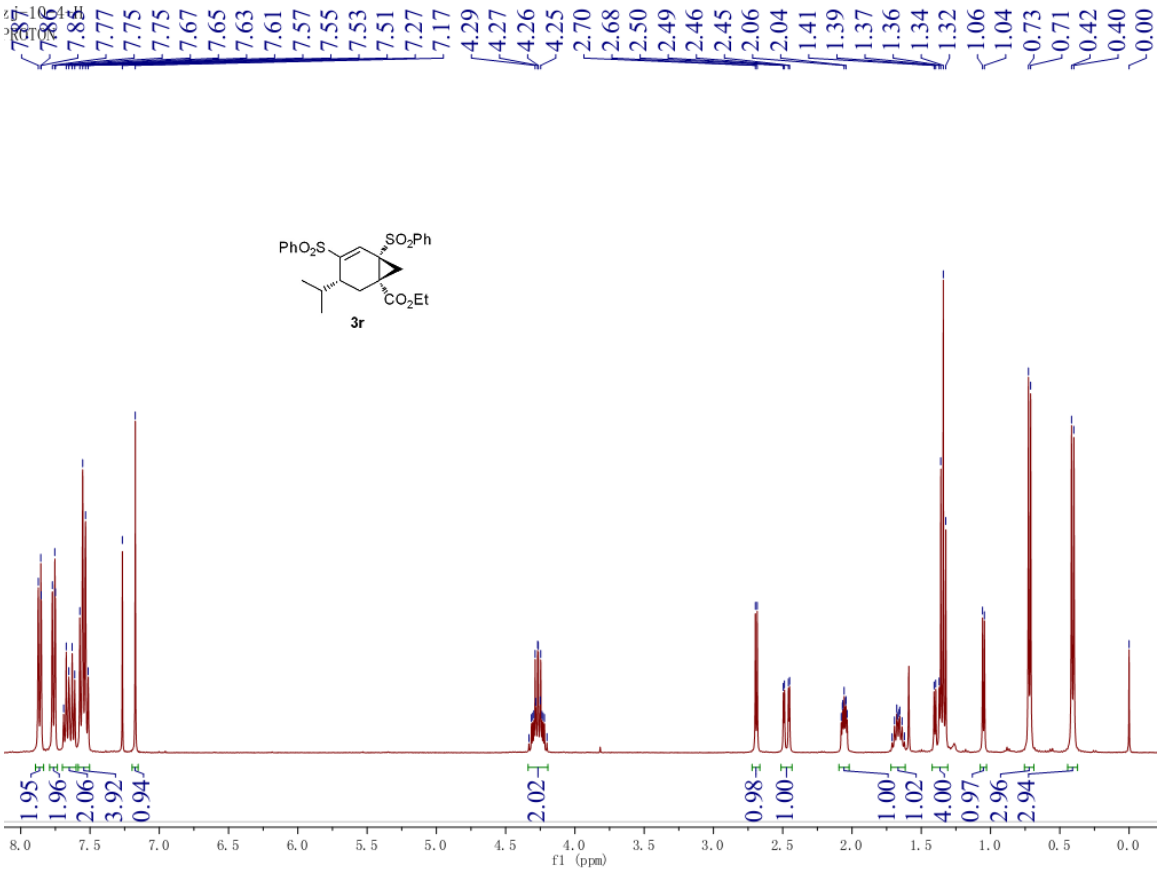

zj-1nai-C
C13CPD
168.67
146.86
138.71
138.35
134.47
133.78
133.43
133.04
130.42
129.56
129.41
129.06
128.58
128.13
127.36
126.49
125.76
125.42
124.90
122.17
61.65
49.38
38.49
32.70
32.07
30.28
13.21

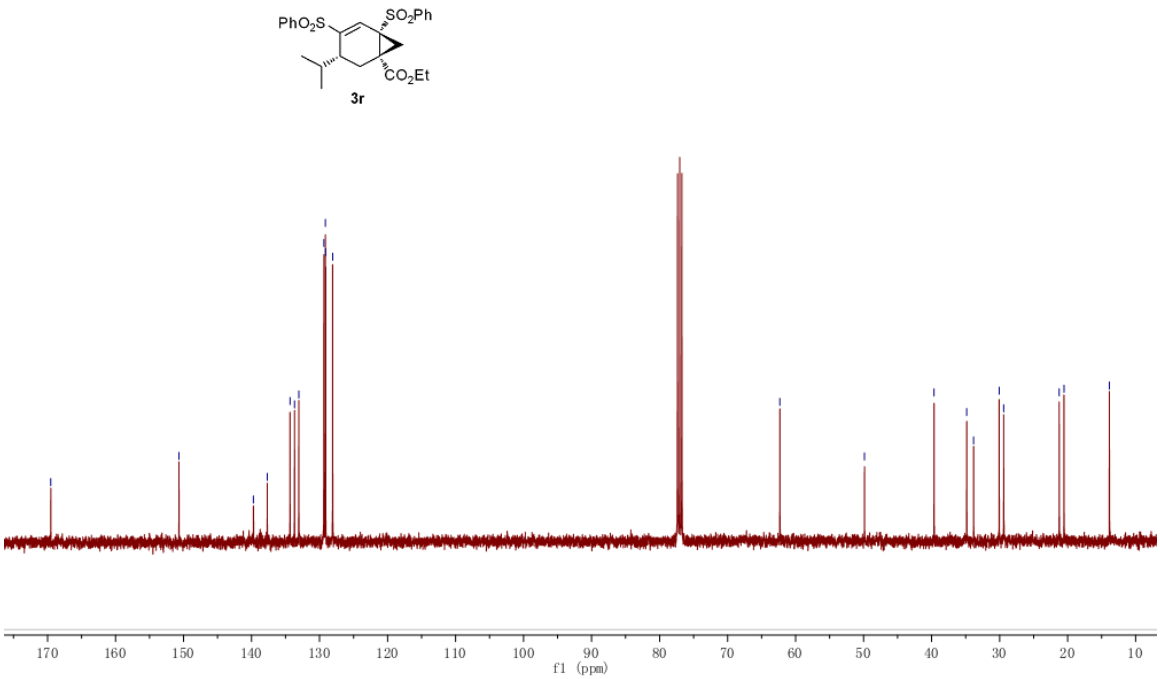

PhO2S
SO2Ph
CO2Et
3p

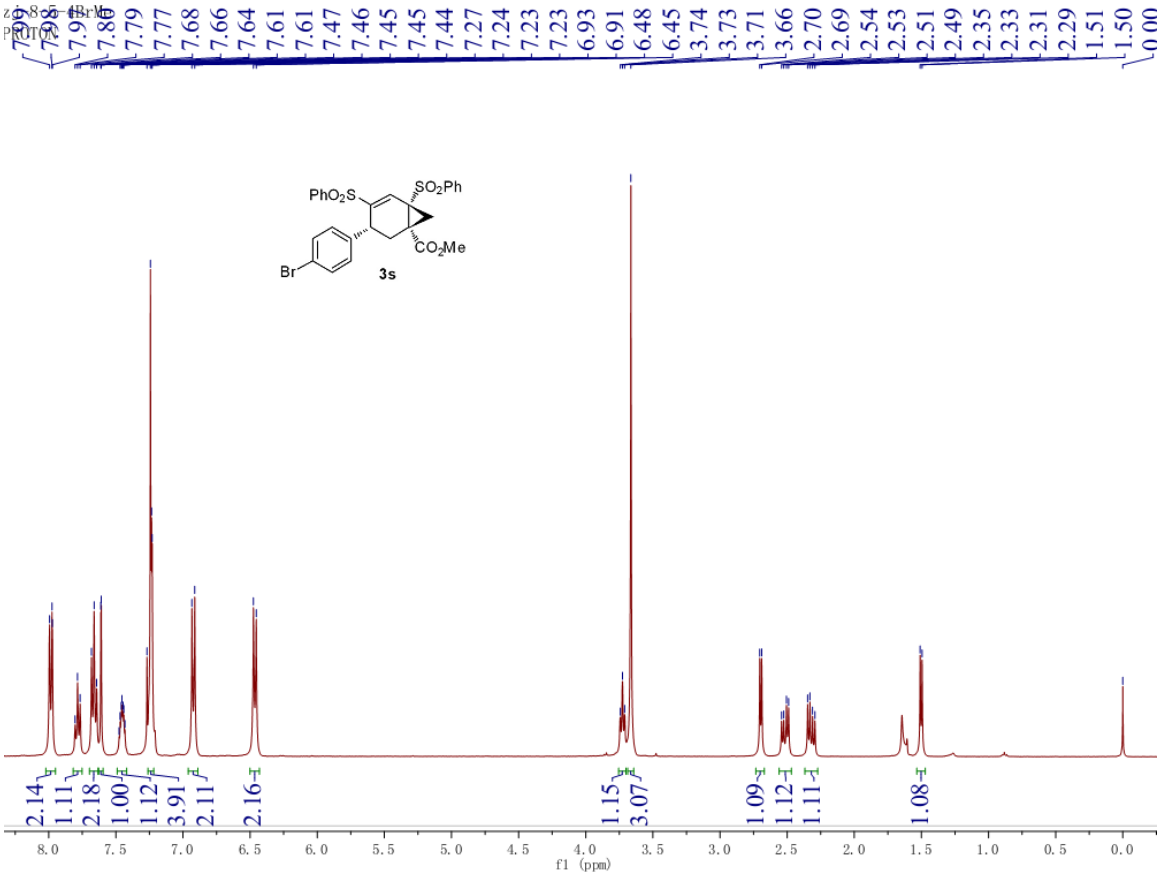

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

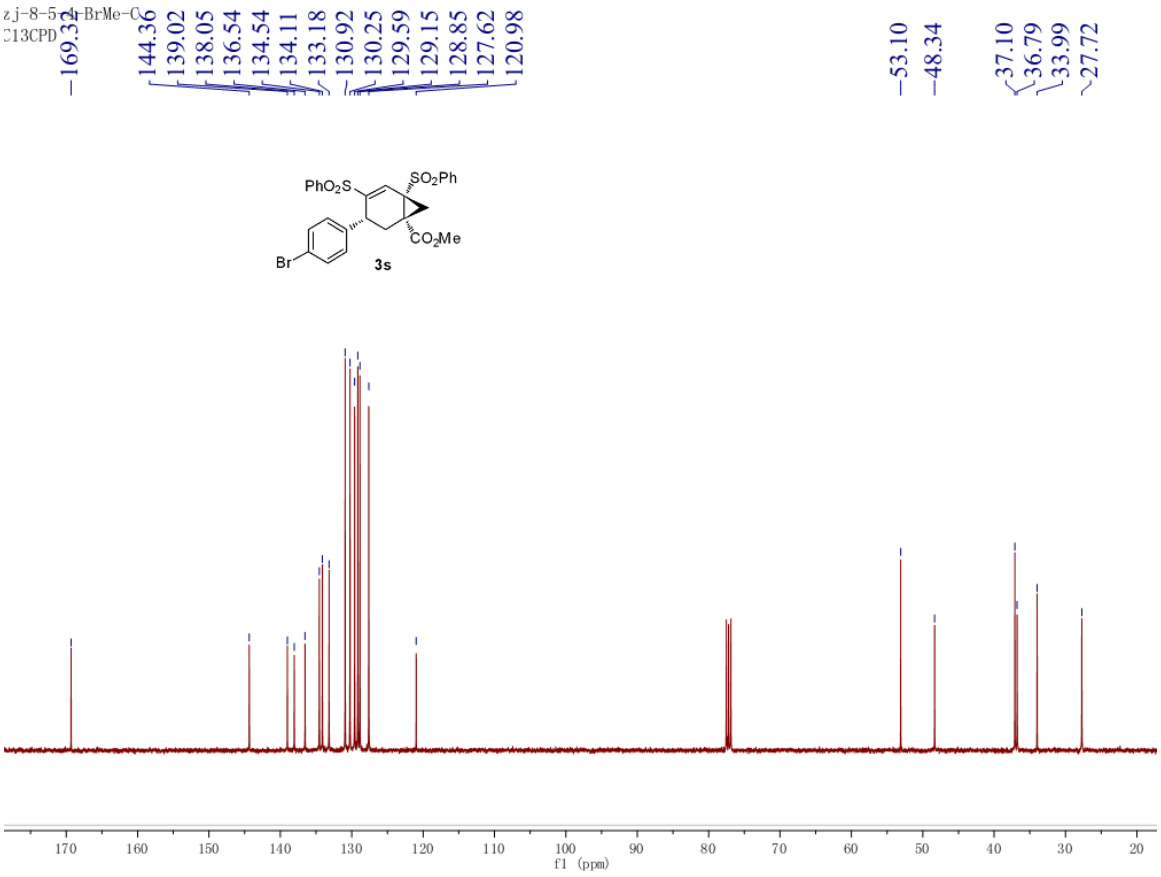

PhO2S
SO2Ph
CO2Et
3q
f1 (ppm)

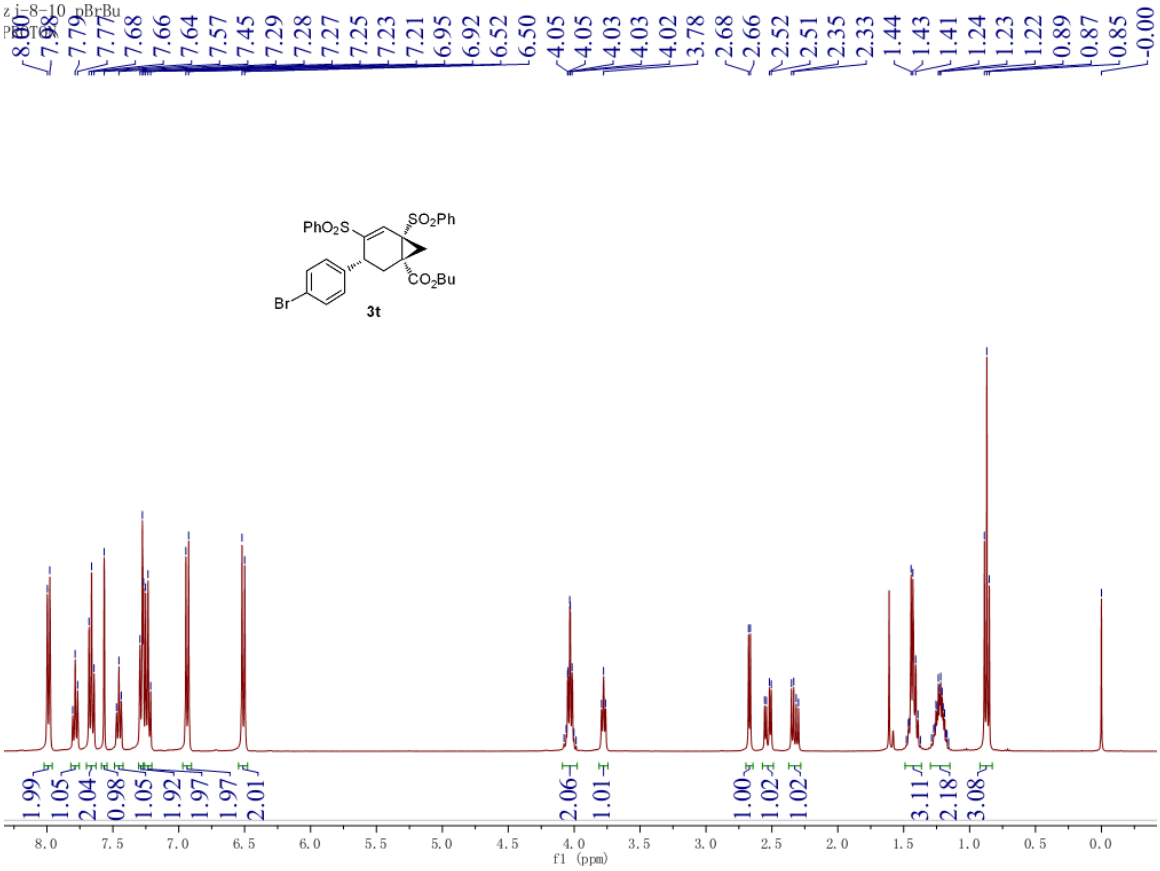

PhO2S
SO2Ph
CO2Et
3q
f1 (ppm)

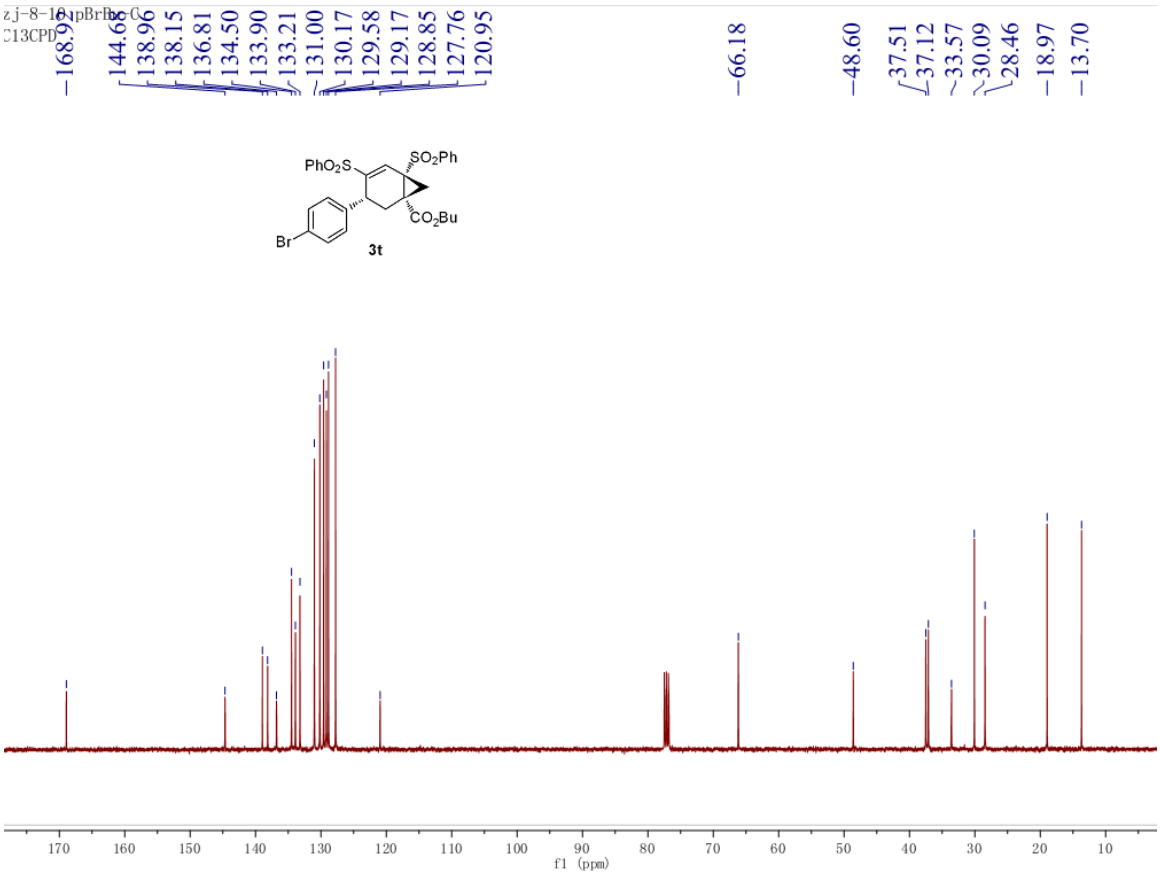

3r
f1 (ppm)


3r
f1 (ppm)


zj-8-5-4BrMe
PROTON
7.98
7.98
7.80
7.79
7.77
7.68
7.66
7.64
7.61
7.61
7.47
7.46
7.45
7.45
7.44
7.27
7.24
7.23
7.23
6.93
6.91
6.48
6.45
3.74
3.73
3.71
3.66
2.70
2.69
2.54
2.53
2.51
2.49
2.35
2.33
2.31
2.29
1.51
1.50
0.00
PhO2S
SO2Ph
CO2Me
Br
3s
2.14
1.11
2.18
1.00
1.12
3.91
2.11
2.16
1.15
3.07
1.09
1.12
1.11
1.08
f1 (ppm)


zj-8-5-4-BrMe-C
C13CPD
169.32
144.36
139.02
138.05
136.54
134.54
134.11
133.18
130.92
130.25
129.59
129.15
128.85
127.62
120.98
53.10
48.34
37.10
36.79
33.99
27.72
PhO2S
SO2Ph
CO2Me
Br
3s
f1 (ppm)


zj-8-10 pBrBu
PhO2S
SO2Ph
CO2Bu
Br
3t
f1 (ppm)


zj-8-10 pBrBu-C
C13CPD
PhO2S
SO2Ph
CO2Bu
Br
3t
f1 (ppm)