Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

For

Applicable β-Sulfonium Carbanions: Facile Construction of Thiophene Derivatives

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Table of contents

1. General information

Tetrahydrofuran was dried with Na and distilled freshly before use. Et_3N was dried with NaH and distilled freshly before use. Other materials and solvents were purchased from commercial suppliers and used without additional purification. NMR spectra were measured in $CDCl_3$ and recorded on Bruker Avance spectrometers operating for ^1H NMR at 400 MHz, for ^{13}C NMR at 100 MHz and for ^{31}P at 160 MHz. Chemical shifts were calibrated using TMS for ^1H NMR and ^{13}C NMR, and 85% H_3PO_4 for ^{31}P NMR. Mass spectroscopy data of the products were collected with an HRMS-TOF instrument GCT Premier, which is produced by WATERS company, and the collision energy is 70eV. Infrared spectra were recorded with a Bruker ATRFTIR spectrometer.

2. General experimental procedures

Typical procedure for the synthesis of 3: To a 25mL Schlenk with $Pd(PPh_3)_2Cl_2$ (0.02 mmol) and CuI (0.03 mmol) was added acyl chloride (1.2 mmol) in tetrahydrofuran (10.0 mL) under N_2 atmosphere. The mixture was stirred at room temperature for 10 minutes. Then alkyne (1.0 mmol) was added at room temperature and the mixture was stirred for 10 minutes. Triethylamine (3.0 mmol) was added at room temperature and the reaction was monitored by TLC until completion. Then the reaction was quenched with water (30 mL), extracted with ethyl acetate (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

The procedure for the synthesis of **3g**: To a 25mL Schlenk with 4-(2-(allylthio)phenyl)-4-methoxybut-2-yn-1-ol (1.0 mmol) was added DMP (1.2 mmol) in DCM (10.0 mL) under N_2 atmosphere at 0°C. The reaction was monitored by TLC until completion. Then the reaction was quenched with saturated $Na_2S_2O_3$ solution (30 mL), extracted with DCM (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

The procedure for the synthesis of **3m**: To a 25mL Schlenk with allyl(2-(1-

methoxyprop-2-ynyl)phenyl)sulfane (1.0 mmol) was added Methyl magnesium bromide (1.2 mmol) in THF (5.0 mL) under N_2 atmosphere at -78^{o}C for 1h. Then the mixture was added to the solution of methyl chloroformate (1.3 mmol) in THF (5.0 mL) under N_2 atmosphere at -78^{o}C for 3h. The reaction was monitored by TLC until completion and the reaction was quenched with saturated NH_4Cl solution (30 mL), extracted with ethyl acetate (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

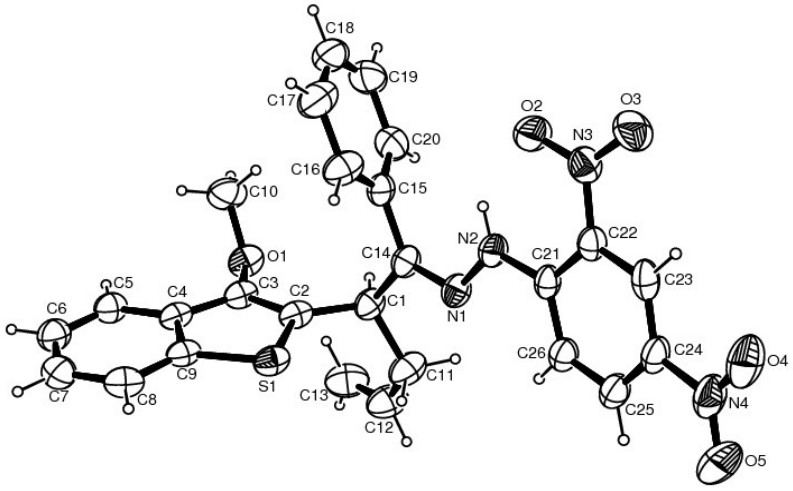
Typical procedure for the synthesis of 5: To a solution of alcohol (1.0 mmol) in tetrahydrofuran (10.0 mL) was added triethylamine (3.0 mmol) under N_2 atmosphere at -78^{o}C. The resulting mixture was stirred at -78^{o}C for 10 minutes. Then diphenylphosphinous chloride (1.2 mmol) was added at -78^{o}C and the reaction was monitored by TLC until completion. Then the reaction was quenched with water (30 mL), extracted with ethyl acetate (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

Typical procedure for the synthesis of 6: To a solution of **5a** (1.0 mmol) in tetrahydrofuran (10.0 mL) was added NaH (1.0 mmol) under N_2 atmosphere at 0^{o}C. The resulting mixture was stirred at room temperature for 1 hour. Then aldehyde (1.0 mmol) was added and the reaction was monitored by TLC until completion, the reaction was quenched with water (30 mL), extracted with ethyl acetate (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

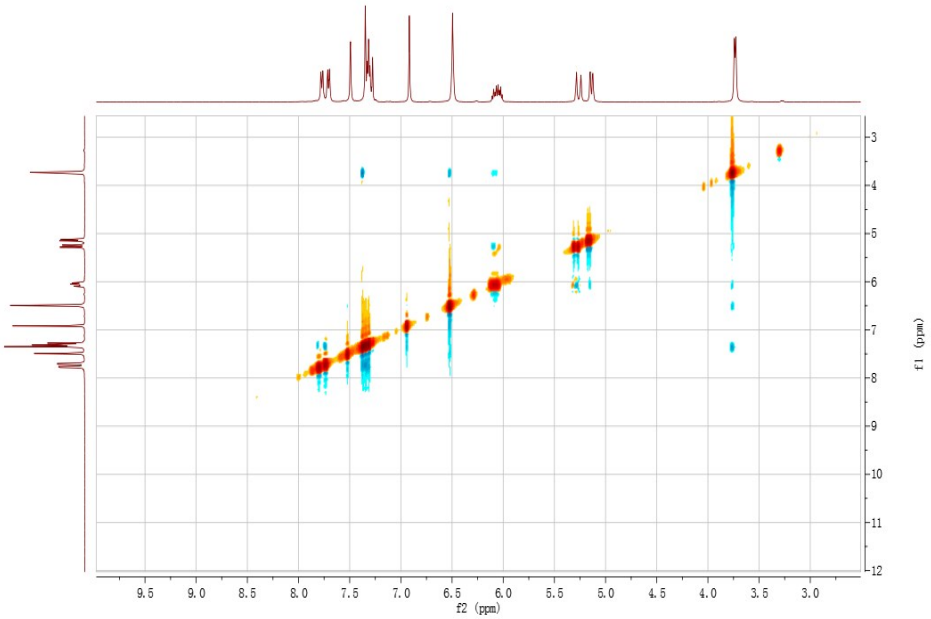
Typical procedure for the synthesis of 9: To a 25mL Schlenk with $Pd(PPh_3)_2Cl_2$ (0.02 mmol) and CuI (0.03 mmol) was added 1-iodo-4-methoxybenzene (1.2 mmol) in tetrahydrofuran (10.0 mL) under N_2 atmosphere. The mixture was stirred at room temperature for 10 minutes. Then allyl(2-(1-methoxyprop-2-ynyl)phenyl)sulfane (1.0 mmol) was added at room temperature and the mixture was stirred for 10 minutes. Triethylamine (3.0 mmol) was added at room temperature and the reaction was monitored by TLC until completion. Then the reaction was quenched with water (30

mL), extracted with ethyl acetate (3 × 20 mL), dried with anhydrous Na_2SO_4. After evaporation, chromatography on silica gel of the reaction mixture afforded desired product.

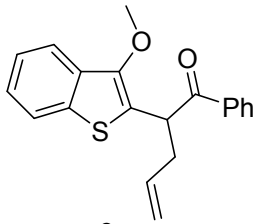
ORTEP Representation (2, 4-dinitrophenyl)hydrazone of 3a.



The noesy of 6c.

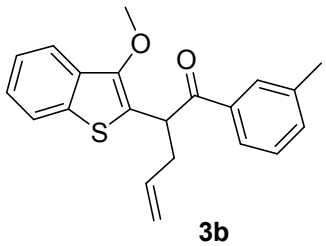


3. Characterization data



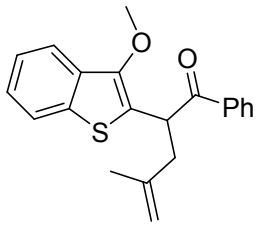
3a

2-(3-methoxybenzo[b]thiophen-2-yl)-1-phenylpent-4-en-1-one (3a): Colorless oil; 274 mg, 85% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8.0 Hz, 2H), 7.68 (d, *J* = 8.0 Hz, 2H), 7.51 (t, *J* = 7.2 Hz, 1H), 7.42 (t, *J* = 7.5 Hz, 2H), 7.34–7.25 (m, 2H), 5.85–5.73 (m, 1H), 5.24 (t, *J* = 7.4 Hz, 1H), 5.11 (d, *J* = 16.0 Hz, 1H), 5.01 (d, *J* = 12.0 Hz, 1H), 3.99 (s, 3H), 2.93 (dd, *J* = 14.0, 6.0 Hz, 1H), 2.73 (dd, *J* = 12.0, 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 147.9, 137.0, 136.0, 135.4, 133.4, 132.8, 128.7, 126.8, 124.6, 124.0, 123.2, 120.7, 117.5, 62.1, 44.8, 37.8; IR (neat) 2935, 1683, 736; MS (EI) *m/z* 322 (M^+), 217 (100%); HRMS (EI) calcd for $C_{20}H_{18}O_2S$ 322.1028, found 322.1026.



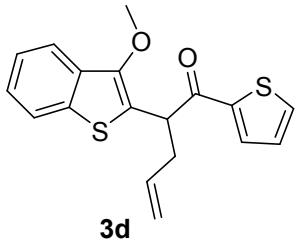
3b

2-(3-methoxybenzo[b]thiophen-2-yl)-1-(m-tolyl)pent-4-en-1-one (3b): Colorless oil; 272 mg, 81% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.0 Hz, 2H), 7.72–7.65 (m, 2H), 7.33–7.24 (m, 4H), 5.85–5.72 (m, 1H), 5.23 (t, *J* = 7.4 Hz, 1H), 5.11 (d, *J* = 16.0 Hz, 1H), 5.01 (d, *J* = 12.0 Hz, 1H), 3.98 (s, 3H), 2.93 (dd, *J* = 12.0, 8.0 Hz, 1H), 2.70 (dd, *J* = 12.0, 8.0 Hz, 1H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.5, 147.9, 138.4, 137.0, 136.1, 135.4, 134.2, 132.8, 129.2, 128.5, 126.9, 125.9, 124.5, 124.0, 123.2, 120.7, 117.4, 62.0, 44.8, 37.9, 21.4; IR (neat) 2934, 1681, 736; MS (EI) *m/z* 336 (M^+), 217 (100%); HRMS (EI) calcd for $C_{21}H_{20}O_2S$ 336.1184, found 336.1180.



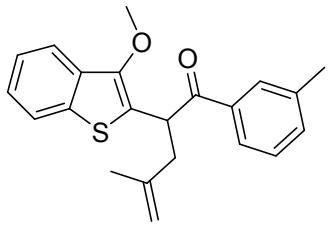
3c

2-(3-methoxybenzo[b]thiophen-2-yl)-4-methyl-1-phenylpent-4-en-1-one (3c): Colorless oil; 259 mg, 77% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15–8.08 (m, 2H), 7.72–7.65 (m, 2H), 7.51 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.5 Hz, 2H), 7.33–7.23 (m, 2H), 5.42 (t, *J* = 7.2 Hz,1H), 4.72 (d, *J* = 16.0 Hz, 2H), 3.98 (s, 3H), 2.99 (dd, *J* = 14.0, 8.0 Hz, 1H), 2.62 (dd, *J* = 14.0, 8.0 Hz, 1H), 1.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.5, 147.8, 142.5, 137.0, 136.2, 133.3, 132.8, 128.7, 128.6, 127.1, 124.5, 124.0, 123.2, 120.7, 112.8, 62.0, 43.3, 41.7, 22.9; IR (neat) 2936, 1683, 733; MS (EI) *m/z* 336 (M^+), 173 (100%); HRMS (EI) calcd for $C_{21}H_{20}O_2S$ 336.1184, found 336.1181.



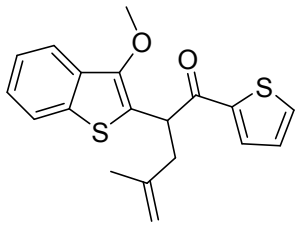
3d

2-(3-methoxybenzo[b]thiophen-2-yl)-1-(thiophen-2-yl)pent-4-en-1-one (3d): Colorless oil; 217 mg, 66% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 3.8, 0.9 Hz, 1H), 7.69 (d, *J* = 8.0 Hz, 2H), 7.61–7.56 (m, 1H), 7.35–7.22 (m, 2H), 7.10–7.04 (m, 1H), 5.86–5.73 (m, 1H), 5.17–4.98 (m, 3H), 4.00 (s, 3H), 2.92 (dd, *J* = 14.0, 8.0 Hz, 1H), 2.73 (dd, *J* = 12.0, 4.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.0, 148.0, 143.4, 137.0, 135.1, 134.6, 132.9, 132.7, 128.3, 126.9, 124.7, 124.1, 123.3, 120.7, 117.6, 62.2, 46.2, 37.6; IR (neat) 2936, 1659, 728; MS (EI) *m/z* 328 (M^+), 217 (100%); HRMS (EI) calcd for $C_{18}H_{16}O_2S_2$ 328.0592, found 328.0594.



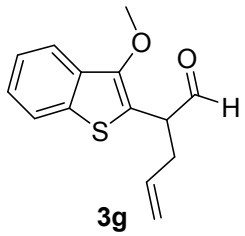
3e

2-(3-methoxybenzo[b]thiophen-2-yl)-4-methyl-1-(m-tolyl)pent-4-en-1-one (3e): Colorless oil; 284 mg, 81% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98–7.86 (m, 2H), 7.68 (dd, *J* = 7.7, 3.3 Hz, 2H), 7.34–7.24 (m, 4H), 5.41 (t, *J* = 7.2 Hz, 1H), 4.72 (d, *J* = 12.0 Hz, 2H), 3.98 (s, 3H), 2.99 (dd, *J* = 12.0, 8.0 Hz, 1H), 2.60 (dd, *J* = 12.0, 4.0 Hz, 1H), 2.37 (s, 3H), 1.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.6, 147.7, 142.6, 138.5, 137.0, 136.2, 134.1, 132.8, 129.2, 128.5, 127.2, 125.8, 124.5, 123.9, 123.2, 120.7, 112.7, 61.9, 43.3, 41.7, 22.9, 21.4; IR (neat) 2935, 1682, 734; MS (EI) *m/z* 350 (M^+), 231 (100%); HRMS (EI) calcd for $C_{22}H_{22}O_2S$ 350.1341, found 350.1344.



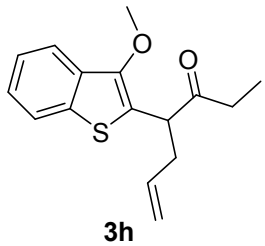
3f

2-(3-methoxybenzo[b]thiophen-2-yl)-4-methyl-1-(thiophen-2-yl)pent-4-en-1-one (3f): Colorless oil; 229 mg, 67 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 4.0 Hz, 1H), 7.70 (d, *J* = 8.0 Hz, 2H), 7.62 (d, *J* = 8.0 Hz, 1H), 7.36–7.27 (m, 2H), 7.17–7.07 (m, 1H), 5.23 (t, *J* = 7.3 Hz, 1H), 4.75 (d, *J* = 4.0 Hz, 2H), 4.01 (s, 3H), 2.98 (dd, *J* = 16.0, 8.0 Hz, 1H), 2.61 (dd, *J* = 14.0, 8.0 Hz, 1H), 1.79 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ191.1, 161.3, 147.9, 143.5, 142.3, 137.0, 134.5, 132.7, 128.3, 127.2, 124.6, 124.0, 123.2, 120.7, 112.9, 62.0, 44.8, 41.4, 22.8; IR (neat) 2932, 1662, 733; MS (EI) *m/z* 342 (M^+), 231 (100%); HRMS (EI) calcd for $C_{19}H_{18}O_2S_2$ 342.0748, found 342.0745.



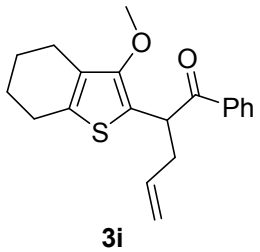
3g

2-(3-methoxybenzo[b]thiophen-2-yl)pent-4-enal (3g): Colorless oil; 202 mg, 82 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.72 (s, 1H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.42–7.30 (m, 2H), 5.84–5.70 (m, 1H), 5.14 (d, *J* = 16.0 Hz, 1H), 5.05 (d, *J* = 8.0 Hz, 1H), 4.14 (m, 1H), 3.95 (s, 3H), 2.95–2.83 (m, 1H), 2.62–2.49 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.2, 149.6, 136.9, 134.3, 133.0, 124.9, 124.3, 123.2, 120.8, 117.8, 62.2, 50.6, 34.0; IR (neat) 2935, 1725, 737; MS (EI) *m/z* 246 (M^+), 217 (100%); HRMS (EI) calcd for $C_{14}H_{14}O_2S$ 246.0715, found 246.0715.



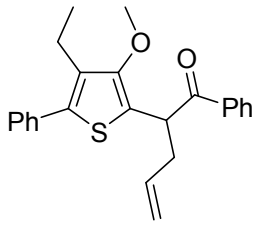
3h

4-(3-methoxybenzo[b]thiophen-2-yl)hept-6-en-3-one (3h): Colorless oil; 206 mg, 75 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.0 Hz, 2H), 7.40–7.28 (m, 2H), 5.81–5.69 (m, 1H), 5.09 (d, *J* = 16.0 Hz, 1H), 5.00 (d, *J* = 12.0 Hz, 1H), 4.05–3.90 (m, 3H), 3.97 (s, 3H), 2.83 (dd, *J* = 16.0, 8.0 Hz, 1H), 2.60–2.37 (m, 3H), 1.01 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.0, 148.6, 136.7, 135.2, 132.9, 126.5, 124.7, 124.2, 123.2, 120.7, 117.3, 61.9, 49.8, 36.3, 34.9, 7.8; IR (neat) 2936, 1717, 736; MS (EI) *m/z* 274 (M^+), 217 (100%); HRMS (EI) calcd for $C_{16}H_{18}O_2S$ 274.1028, found 274.1032.



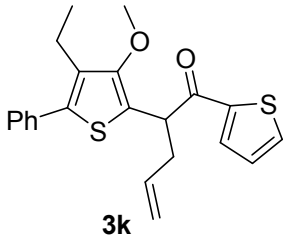
3i

2-(3-methoxy-4,5,6,7-tetrahydrobenzo[b]thiophen-2-yl)-1-phenylpent-4-en-1-one (3i): Colorless oil; 238 mg, 73 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.0 Hz, 2H), 7.51 (d, *J* = 8.0 Hz, 1H), 7.43 (t, *J* = 7.4 Hz, 2H), 5.85–5.71 (m, 1H), 5.14–4.97 (m, 3H), 3.75 (s, 3H), 2.87 (dd, *J* = 16.0, 8.0 Hz, 1H), 2.65–2.55 (m, 3H), 2.47 (s, 2H), 1.77 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.8, 151.8, 136.3, 135.9, 134.3, 133.1, 128.7, 128.6, 121.4, 116.9, 61.2, 44.2, 38.2, 25.5, 23.6, 23.3, 22.3; IR (neat) 2934, 1683, 737; MS (EI) *m/z* 326 (M^+), 221 (100%); HRMS (EI) calcd for $C_{20}H_{22}O_2S$ 326.1341, found 326.1341.



3j

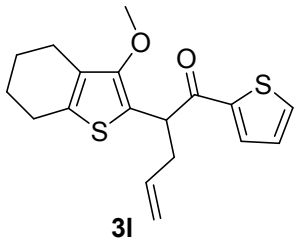
2-(4-ethyl-3-methoxy-5-phenylthiophen-2-yl)-1-phenylpent-4-en-1-one (3j): Colorless oil; 278 mg, 74 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.0 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 2H), 7.41–7.32 (m, 4H), 7.32–7.27 (m, 1H), 5.90–5.75 (m, 1H), 5.16 – 5.07 (m, 2H), 5.02 (d, *J* = 8.0 Hz, 1H), 3.85 (s, 3H), 2.95 (dd, *J* = 16.0, 8.0 Hz, 1H), 2.71–2.54 (m, 3H), 1.10 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.7, 153.4, 136.3, 136.0, 135.7, 135.1, 133.3, 133.2, 128.7, 128.6, 128.5, 127.4, 125.1, 117.2, 100.0, 62.4, 44.6, 38.6, 19.8, 14.5; IR (neat) 2971, 1684, 700; MS (EI) *m/z* 376 (M^+), 271 (100%); HRMS (EI) calcd for $C_{24}H_{24}O_2S$ 376.1497, found 376.1495.



3k

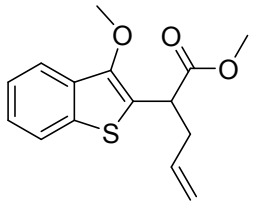
2-(4-ethyl-3-methoxy-5-phenylthiophen-2-yl)-1-(thiophen-2-yl)pent-4-en-1-one (3k): Colorless oil; 252 mg, 66 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 4.0 Hz, 1H), 7.64 (d, *J* = 4.0 Hz, 1H), 7.42–7.34 (m, 4H), 7.30 (d, *J* = 8.0 Hz, 1H), 7.18–7.07 (m, 1H), 5.88 – 5.78 (m, 1H), 5.13 (d, *J* = 16.0 Hz, 1H), 5.03 (d, *J* = 8.0 Hz,

1H), 4.92 (t, *J* = 7.5 Hz, 1H), 3.86 (s, 3H), 2.92 (dd, *J* = 14.0, 8.0 Hz, 1H), 2.72–2.56 (m, 3H), 1.11 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.5, 135.6, 143.7, 135.4, 135.0, 134.4, 133.3, 132.7, 128.8, 128.5, 128.3, 127.4, 125.1, 117.4, 100.0, 62.4, 46.1, 38.3, 19.8, 14.5; IR (neat) 2970, 1663, 731; MS (EI) *m/z* 382 (M^+), 271 (100%); HRMS (EI) calcd for $C_{22}H_{22}O_2S_2$ 382.1061, found 382.1063.



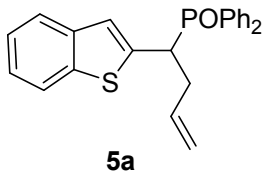
3l

2-(3-methoxy-4,5,6,7-tetrahydrobenzo[b]thiophen-2-yl)-1-(thiophen-2-yl)pent-4-en-1-one (3l): Colorless oil; 213 mg, 64 % yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 4.0 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.10 (s, 1H), 5.83–5.72 (m, 1H), 5.10 (d, *J* = 16.0 Hz, 1H), 5.01(d, *J* = 12.0 Hz, 1H), 4.85 (t, *J* = 7.5 Hz, 1H), 3.76 (s, 3H), 2.94–2.79 (m, 1H), 2.65–2.54 (m, 3H), 2.48 (s, 2H), 1.79 (d, *J* = 4.0 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.7, 135.6, 134.4, 134.2, 132.7, 128.8, 128.2, 121.5, 117.1, 61.3, 45.7, 37.9, 25.5, 23.6, 23.3, 22.3; IR (neat) 2931, 1663, 732; MS (EI) *m/z* 332 (M^+), 221 (100%); HRMS (EI) calcd for $C_{18}H_{20}O_2S_2$ 332.0905, found 332.0906.



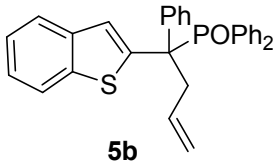
3m

methyl 2-(3-methoxybenzo[b]thiophen-2-yl)pent-4-enoate (3m): Colorless oil; 198mg, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77–7.67 (m, 2H), 7.33 (m, 2H), 5.76 (m, 1H), 5.13 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.08–4.99 (m, 1H), 4.31 (t, *J* = 7.8 Hz, 1H), 3.96 (s, 3H), 3.71 (s, 3H), 2.84 (m, 1H), 2.65–2.55 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.7, 148.5, 136.6, 134.5, 132.8, 126.1, 124.7, 124.1, 123.1, 120.7, 117.7, 62.0, 52.3, 43.2, 37.8; IR (neat) 2930, 1668, 736; MS (EI) *m/z* 276 (M^+), 217 (100%); HRMS (EI) calcd for $C_{15}H_{16}O_3S$ 276.0820, found 276.0822.



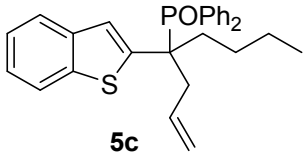
5a

(1-(benzo[b]thiophen-2-yl)but-3-en-1-yl)diphenylphosphine oxide (5a): White solid; 322 mg, 83% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96–7.87 (m, 2H), 7.69 (d, *J* = 4.0 Hz, 1H), 7.65–7.49 (m, 6H), 7.34–7.32 (m, 1H), 7.31–7.22 (m, 4H), 7.18 (d, *J* = 4.0 Hz, 1H), 5.74–5.60 (m, 1H), 4.96 (dd, *J* = 17.0, 1.4 Hz, 1H), 4.91 (d, *J* = 10.0 Hz, 1H), 3.92–3.82 (m, 1H), 2.92–2.80 (m, 1H), 2.74–2.66 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.7, 138.7 (d, *J* = 6.0 Hz), 134.8 (d, *J* = 14.0 Hz), 132.6, 132.0 (d, *J* = 2.0 Hz), 131.7 (d, *J* = 2.0 Hz), 131.4 (d, *J* = 9.0 Hz), 131.1 (d, *J* = 9.0 Hz), 129.0, 128.9 (d, *J* = 12.0 Hz), 128.3 (d, *J* = 12.0 Hz), 124.2, 124.1, 123.8, 123.2, 122.0, 117.4, 43.1 (d, *J* = 67.0 Hz), 34.8; ^{31}P NMR (160 MHz, $CDCl_3$) δ 31.6; IR (neat) 3057, 1186, 697; MS (EI) *m/z* 388 (M^+), 201 (100%); HRMS (EI) calcd for $C_{24}H_{21}OPS$ 388.1051, found 388.1050.



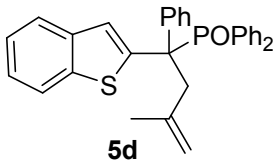
5b

(1-(benzo[b]thiophen-2-yl)-1-phenylbut-3-en-1-yl)diphenylphosphine oxide (5b): White solid; 362 mg, 78% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, *J* = 8.0 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.48 (t, *J* = 9.0 Hz, 3H), 7.44–7.38 (m, 2H), 7.37–7.27 (m, 7H), 7.27–7.18 (m, 6H), 5.58–5.42 (m, 1H), 5.00 (d, *J* = 16.0 Hz, 1H), 4.85 (d, *J* = 12.0 Hz, 1H), 3.52–3.43 (m, 1H), 3.20–3.04 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6 (d, *J* = 3.0 Hz), 144.0, 139.0, 136.5, 133.5 (d, *J* = 8.0 Hz), 133.2 (d, *J* = 8.0 Hz), 132.5 (d, *J* = 11.0 Hz), 132.0 (d, *J* = 2.0 Hz), 131.9 (d, *J* = 2.0 Hz), 131.1 (d, *J* = 5.0 Hz), 128.1, 127.9 (d, *J* = 6.0 Hz), 127.8, 127.7, 126.4 (d, *J* = 6.0 Hz), 124.2, 124.1, 123.5, 121.9, 118.6, 55.5 (d, *J* = 63.0 Hz), 39.8; ^{31}P NMR (160 MHz, $CDCl_3$) δ 36.0; IR (neat) 3056, 1175, 696; MS (EI) *m/z* 464 (M^+), 263 (100%); HRMS (EI) calcd for $C_{30}H_{25}OPS$ 464.1364, found 464.1366.



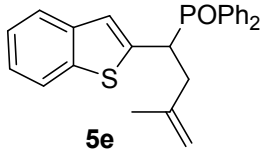
5c

(4-(benzo[b]thiophen-2-yl)oct-1-en-4-yl)diphenylphosphine oxide (5c): White solid; 298 mg, 67% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79–7.65 (m, 5H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.54–7.47 (m, 2H), 7.42–7.26 (m, 6H), 6.64 (d, *J* = 4.0 Hz, 1H), 6.02–5.87 (m, 1H), 5.11 (d, *J* = 16.0 Hz, 1H), 5.05 (d, *J* = 10.0 Hz, 1H), 3.24–3.13 (m, 1H), 2.95–2.76 (m, 1H), 2.43–2.31 (m, 1H), 2.08–1.89 (m, 1H), 1.66–1.48 (m, 1H), 1.31–1.17 (m, 3H), 0.80 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.8, 139.2 (d, *J* = 4.0 Hz), 133.2 (d, *J* = 7.0 Hz), 132.9 (d, *J* = 7.0 Hz), 131.8, 130.8, 129.9, 128.2, 128.0, 124.5, 124.3, 124.2 (d, *J* = 15.0 Hz), 123.3, 121.9, 118.4, 48.9 (d, *J* = 65.0 Hz), 38.5, 34.0, 25.3 (d, *J* = 6.0 Hz), 23.2, 13.9; ^{31}P NMR (160 MHz, $CDCl_3$) δ 35.1; IR (neat) 3058, 1182, 699; MS (EI) *m/z* 444 (M^+), 243 (100%); HRMS (EI) calcd for $C_{28}H_{29}OPS$ 444.1677, found 444.1669.



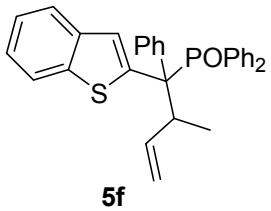
5d

(1-(benzo[b]thiophen-2-yl)-3-methyl-1-phenylbut-3-en-1-yl)diphenylphosphine oxide (5d): White solid; 349 mg, 73% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.0 Hz, 1H), 7.68 (d, *J* = 4.0 Hz, 1H), 7.48 (t, *J* = 6.0 Hz, 2H), 7.44–7.35 (m, 4H), 7.35–7.26 (m, 7H), 7.24–7.16 (m, 3H), 7.12–7.06 (m, 2H), 4.60 (s, 1H), 4.36 (s, 1H), 3.55 (dd, *J* = 16.0, 8.0 Hz, 1H), 3.07 (dd, *J* = 16.0, 8.0 Hz, 1H), 1.55 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.7, 139.7, 139.4, 139.2, 139.0, 136.0, 133.6 (d, *J* = 8.0 Hz), 133.2 (d, *J* = 9.0 Hz), 131.9, 131.3, 131.1, 128.0, 127.9 (d, *J* = 6.0 Hz), 127.7, 127.5, 126.6, 124.2, 124.1, 123.5, 121.8, 115.4, 55.7 (d, *J* = 59.0 Hz), 41.0, 25.2; ^{31}P NMR (160 MHz, $CDCl_3$) δ 36.0; IR (neat) 3057, 1179, 699; MS (EI) *m/z* 478 (M^+), 277 (100%); HRMS (EI) calcd for $C_{31}H_{27}OPS$ 478.1520, found 478.1516.



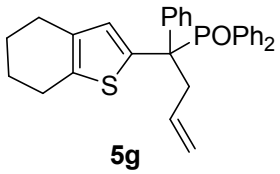
5e

(1-(benzo[b]thiophen-2-yl)-3-methyl-1-phenylbut-3-en-1-yl)diphenylphosphine oxide (5e): White solid; 314 mg, 78% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00–7.88 (m, 2H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.64–7.49 (m, 6H), 7.39–7.33 (m, 1H), 7.29–7.18 (m, 4H), 7.13 (d, *J* = 4.0 Hz, 1H), 4.63 (d, *J* = 12.0 Hz, 2H), 4.02 (dd, *J* = 16.0, 6.0 Hz, 1H), 2.90–2.76 (m, 1H), 2.74–2.60 (m, 1H), 1.61 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.5, 141.3, 139.6, 138.8, 132.0 (d, *J* = 8.0 Hz), 131.8, 131.7, 131.4 (d, *J* = 8.0 Hz), 131.1 (d, *J* = 9.0 Hz), 130.9, 128.9 (d, *J* = 11.0 Hz), 128.2 (d, *J* = 11.0 Hz), 124.1 (d, *J* = 7.0 Hz), 124.0, 123.7, 123.2, 122.0, 113.4, 41.7 (d, *J* = 67.0 Hz), 38.3, 22.1; ^{31}P NMR (160 MHz, $CDCl_3$) δ 32.1; IR (neat) 3058, 1185, 697; MS (EI) *m/z* 402 (M^+), 201 (100%); HRMS (EI) calcd for $C_{25}H_{23}OPS$ 402.1207, found 402.1209.



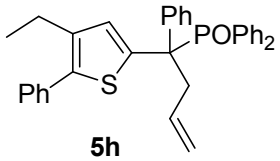
5f

(1-(benzo[b]thiophen-2-yl)-2-methylbut-3-en-1-yl)diphenylphosphine oxide (5f): White solid; 220 mg, 46% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (s, 1H), 7.75 (t, *J* = 7.0 Hz, 2H), 7.52 (m, 3H), 7.48–7.39 (m, 2H), 7.40–7.26 (m, 8H), 7.22–7.14 (m, 4H), 6.47–6.30 (m, 1H), 5.01 (d, *J* = 12.0 Hz, 1H), 4.74 (d, *J* = 16.0 Hz, 1H), 3.39 (dd, *J* = 14.0, 8.0 Hz, 1H), 1.02 (d, *J* = 4.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.9, 140.1 (d, *J* = 4.0 Hz), 139.7, 138.7, 136.8, 134.0 (d, *J* = 8.0 Hz), 133.5, 133.3, 132.8, 132.4, 131.8, 131.5 (d, *J* = 3.0 Hz), 128.3 (d, *J* = 6.0 Hz), 128.1, 127.7 (d, *J* = 5.0 Hz), 127.6 (d, *J* = 4.0 Hz), 127.0 (d, *J* = 2.0 Hz), 124.2, 124.0, 123.6, 121.6, 114.6, 59.2 (d, *J* = 61.0 Hz), 42.6, 18.5 (d, *J* = 8.0 Hz); ^{31}P NMR (160 MHz, $CDCl_3$) δ 35.2; IR (neat) 3057, 1179, 698; MS (EI) *m/z* 478 (M^+), 277 (100%); HRMS (EI) calcd for $C_{31}H_{27}OPS$ 478.1520, found 478.1524.



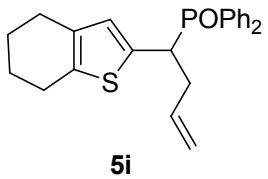
5g

diphenyl(1-phenyl-1-(4,5,6,7-tetrahydrobenzo[b]thiophen-2-yl)but-3-en-1-yl)phosphine oxide (5g): White solid; 309 mg, 66% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.0 Hz, 2H), 7.49–7.34 (m, 4H), 7.34–7.28 (m, 3H), 7.28–7.18 (m, 6H), 6.55 (d, *J* = 2.0 Hz, 1H), 5.54–5.39 (m, 1H), 4.99 (d, *J* = 16.0 Hz, 1H), 4.90 (d, *J* = 8.0 Hz, 1H), 3.26 (dd, *J* = 12.0, 8.0 Hz, 1H), 3.17 (dd, *J* = 14.0, 6.0 Hz, 1H), 2.70 (s, 2H), 2.48 (s, 2H), 1.88–1.73 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.9, 137.6, 135.6 (d, *J* = 3.0 Hz), 134.5 (d, *J* = 3.0 Hz), 133.5, 133.4 (d, *J* = 8.0 Hz), 133.3, 133.1, 131.6, 130.8, 130.7, 130.5 (d, *J* = 5.0 Hz), 129.7, 129.5, 127.8, 127.7, 127.5 (d, *J* = 2.0 Hz), 118.2, 54.4 (d, *J* = 65.0 Hz), 40.0, 25.4, 24.8, 23.7, 23.0; ^{31}P NMR (160 MHz, $CDCl_3$) δ 36.7; IR (neat) 3059, 1177, 699; MS (EI) *m/z* 468 (M^+), 267 (100%); HRMS (EI) calcd for $C_{30}H_{29}OPS$ 468.1677, found 468.1678.



5h

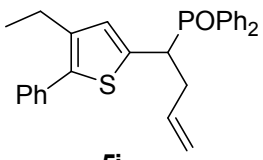
(1-(4-ethyl-5-phenylthiophen-2-yl)-1-phenylbut-3-en-1-yl)diphenylphosphine oxide (5h): White solid; 352 mg, 68% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72–7.63 (m, 2H), 7.60–7.53 (m, 2H), 7.49–7.43 (m, 1H), 7.41–7.35 (m, 4H), 7.30 (d, *J* = 8.0 Hz, 6H), 7.23–7.11 (m, 2H), 7.04 (d, *J* = 2.0 Hz, 2H), 6.94 (d, *J* = 2.0 Hz, 2H), 5.88–5.78 (m, 1H), 5.20 (d, *J* = 12.0 Hz, 2H), 3.07 (dd, *J* = 14.0, 8.0 Hz, 1H), 2.90 (dd, *J* = 14.0, 8.0 Hz, 1H), 1.95 (dd, *J* = 18.0, 8.0 Hz, 1H), 1.78 (dd, *J* = 16.0, 8.0 Hz, 1H), 0.97 (t, *J* = 7.0, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.5, 142.3, 133.1, 132.1 (d, *J* = 4.0 Hz), 132.0 (d, *J* = 3.0 Hz), 131.4, 131.2, 130.1 (d, *J* = 5.0 Hz), 128.5, 128.3, 128.2, 128.0, 127.9, 127.3, 127.2, 126.7, 125.6 (d, *J* = 6.0 Hz), 118.6, 69.5, 40.1, 21.9, 12.0; ^{31}P NMR (160 MHz, $CDCl_3$) δ 27.4; IR (neat) 3056, 1185, 697; MS (EI) *m/z* 518 (M^+), 317 (100%); HRMS (EI) calcd for $C_{34}H_{31}OPS$ 518.1833, found 518.1829.



5i

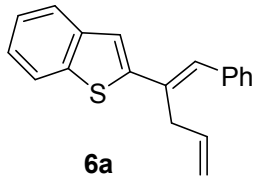
diphenyl(1-(4,5,6,7-tetrahydrobenzo[b]thiophen-2-yl)but-3-en-1-yl)phosphine oxide (5i): White solid; 251 mg, 64% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92–7.81

(m, 2H), 7.79–7.68 (m, 1H), 7.61–7.49 (m, 4H), 7.45–7.38 (m, 1H), 7.34 (d, J = 8.0 Hz, 2H), 6.47 (s, 1H), 5.79–5.61 (m, 1H), 5.07–4.84 (m, 2H), 3.80–3.67 (m, 1H), 2.72–2.56 (m, 4H), 2.48–2.39 (m, 2H), 1.80–1.62 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.3, 140.1, 135.5, 135.0, 134.9, 134.7, 132.7, 131.8, 131.4 (d, J = 9.0 Hz), 131.3, 128.7 (d, J = 9.0 Hz), 128.1, 128.0, 117.0, 42.4 (d, J = 67.0 Hz), 34.6, 25.1, 24.8, 23.6, 22.8; ^{31}P NMR (160 MHz, $CDCl_3$) δ 31.9; IR (neat) 3056, 1183, 699; MS (EI) *m/z* 392 (M^+), 201 (100%); HRMS (EI) calcd for $C_{24}H_{25}OPS$ 392.1364, found 392.1359.



5j

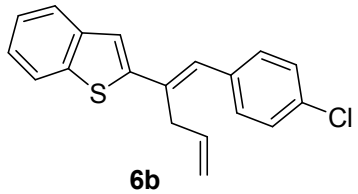
(1-(4-ethyl-5-phenylthiophen-2-yl)but-3-en-1-yl)diphenylphosphine oxide (5j): White solid; 314 mg, 71% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97–7.84 (m, 2H), 7.62–7.52 (m, 5H), 7.45–7.39 (m, 1H), 7.38–7.27 (m, 7H), 6.69 (s, 1H), 5.79–5.70 (m, 1H), 4.99 (t, J = 15.0 Hz, 2H), 3.76 (t, J = 8.0 Hz, 1H), 2.82–2.64 (m, 2H), 2.54 (dd, J =16.0, 8.0 Hz, 2H), 1.06 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.4, 139.7, 135.5, 135.3, 134.6, 132.0, 131.5 (d, J = 9.0 Hz), 129.6 (d, J = 5.0 Hz), 129.1, 128.8 (d, J = 11.0 Hz), 128.4, 128.2, 128.0, 127.1, 117.2, 100.0, 42.9 (d, J = 69.0 Hz), 34.5, 22.0, 15.4; ^{31}P NMR (160 MHz, $CDCl_3$) δ 31.9; IR (neat) 3056, 1183, 699; MS (EI) *m/z* 442 (M^+), 241 (100%); HRMS (EI) calcd for $C_{28}H_{27}OPS$ 442.1520, found 442.1525.



6a

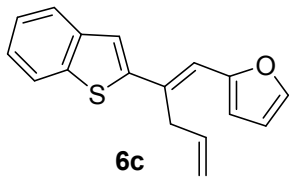
(E)-2-(1-phenylpenta-1,4-dien-2-yl)benzo[b]thiophene (6a): Colorless oil; 185 mg, 67% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, J = 8.0 Hz, 1H), 7.69 (d, J = 8.0 Hz, 1H), 7.45–7.34 (m, 4H), 7.34–7.25 (m, 4H), 7.19 (s, 1H), 6.16–6.05 (m, 1H), 5.28–5.16 (m, 2H), 3.52 (d, J = 8.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.5, 140.5, 138.7, 136.9, 135.7, 133.0, 130.2, 128.8, 128.4, 127.3, 124.6, 124.4, 123.5,

122.0, 120.9, 116.7, 34.5; IR (neat) 3059, 1600, 747; MS (EI) *m/z* 276 (M^+), 199 (100%); HRMS (EI) calcd for $C_{19}H_{16}S$ 276.0973, found 276.0974.



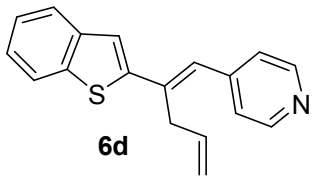
6b

(E)-2-(1-(4-chlorophenyl)penta-1,4-dien-2-yl)benzo[b]thiophene (6b): Colorless oil; 229 mg, 74% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.69 (dd, *J* = 6.0, 2.0 Hz, 1H), 7.40–7.27 (m, 7H), 7.11 (s, 1H), 6.14–6.02 (m, 1H), 5.27–5.15 (m, 2H), 3.54–3.43 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.1, 140.4, 138.8, 135.4, 135.3, 133.6, 133.1, 130.1, 128.9, 128.6, 124.7, 124.5, 123.6, 122.0, 121.2, 116.9, 34.4; IR (neat) 3061, 1488, 744; MS (EI) *m/z* 310 (M^+), 199 (100%); HRMS (EI) calcd for $C_{19}H_{15}ClS$ 310.0583, found 310.0587.



6c

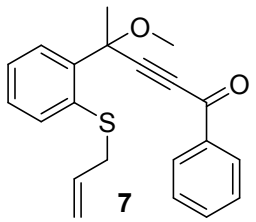
(E)-2-(2-(benzo[b]thiophen-2-yl)penta-1,4-dien-1-yl)furan (6c): Colorless oil; 202 mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79–7.71 (m, 1H), 7.68 (dd, *J* = 6.5, 2.1 Hz, 1H), 7.46 (d, *J* = 2.0 Hz, 1H), 7.34–7.24 (m, 3H), 6.89 (s, 1H), 6.50–6.44 (m, 2H), 6.08–5.97 (m, 1H), 5.23 (dd, *J* = 18.0, 2.0 Hz, 1H), 5.11 (dd, *J* = 12.0, 2.0 Hz, 1H), 3.71 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.3, 146.3, 142.5, 140.6, 138.8, 135.0, 130.9, 124.6, 124.4, 123.5, 122.0, 120.9, 117.3, 116.2, 111.8, 111.2, 35.2; IR (neat) 3061, 1440, 738; MS (EI) *m/z* 266 (M^+), 199 (100%); HRMS (EI) calcd for $C_{17}H_{14}OS$ 266.0765, found 266.0768.



6d

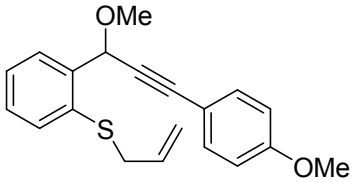
(E)-4-(2-(benzo[b]thiophen-2-yl)penta-1,4-dien-1-yl)pyridine (6d): Colorless oil; 177 mg, 64% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.0 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.34–7.30 (m, 3H), 7.26 (s,1H), 7.08 (s, 3H), 6.50 (s, 1H), 5.98–5.87

(m, 1H), 5.26–5.12 (m, 2H), 3.32 (d, J = 8.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.8, 141.4, 140.1, 139.6, 138.5, 134.5, 127.5, 124.6, 124.4, 123.9, 123.7, 123.4, 122.2, 117.9, 115.9, 44.6; IR (neat) 3062, 1594, 748; MS (EI) *m/z* 277 (M^+), 199 (100%); HRMS (EI) calcd for $C_{18}H_{15}NS$ 277.0925, found 277.0928.



7

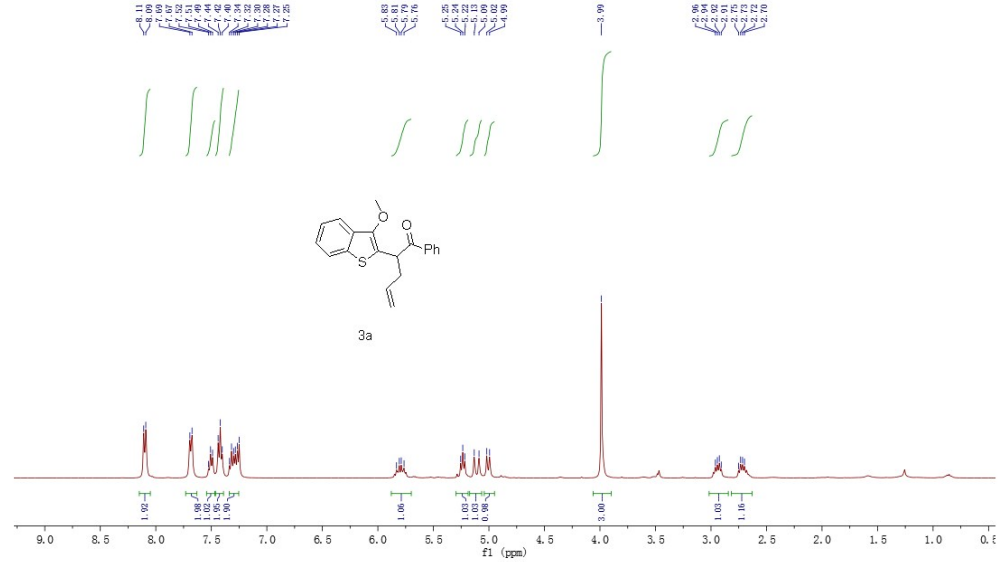
4-(2-(allylthio)phenyl)-4-methoxy-1-p-tolylpent-2-yn-1-one (7): Colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (m, 1H), 7.62–7.56 (m, 2H), 7.39 (dd, J = 11.4, 4.5 Hz, 2H), 7.34 (dd, J = 4.9, 3.6 Hz, 1H), 7.29 (dd, J = 7.9, 1.0 Hz, 1H), 7.23–7.18 (m, 1H), 7.10 (t, J = 7.5 Hz, 1H), 5.89 (m, 1H), 5.26 (dd, J = 17.0, 1.4 Hz, 1H), 5.11 (dd, J = 10.1, 1.1 Hz, 1H), 3.58 (dd, J = 6.7, 1.1 Hz, 2H), 3.26 (s, 3H), 1.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.4, 140.5, 138.9, 135.4, 133.2, 128.6, 128.4, 128.3, 128.1, 127.7, 126.7, 124.7, 118.1, 91.2, 87.3, 78.2, 52.5, 36.2, 27.9; MS (EI) *m/z* 336 (M^+), 231 (100%); IR (neat) 3058, 1186, 696; HRMS (EI) calcd for $C_{21}H_{20}O_2S$ 336.1184, found 336.1182.

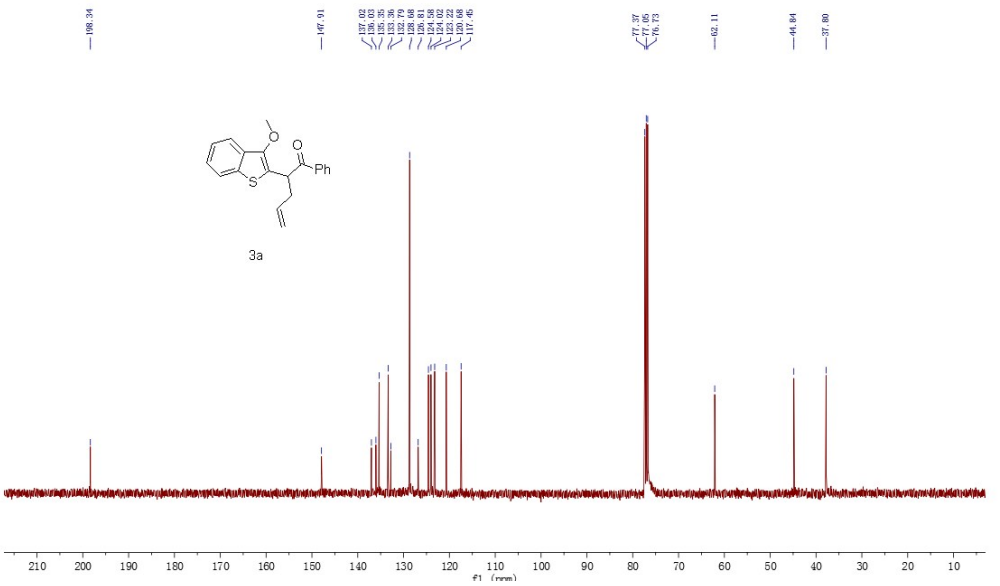


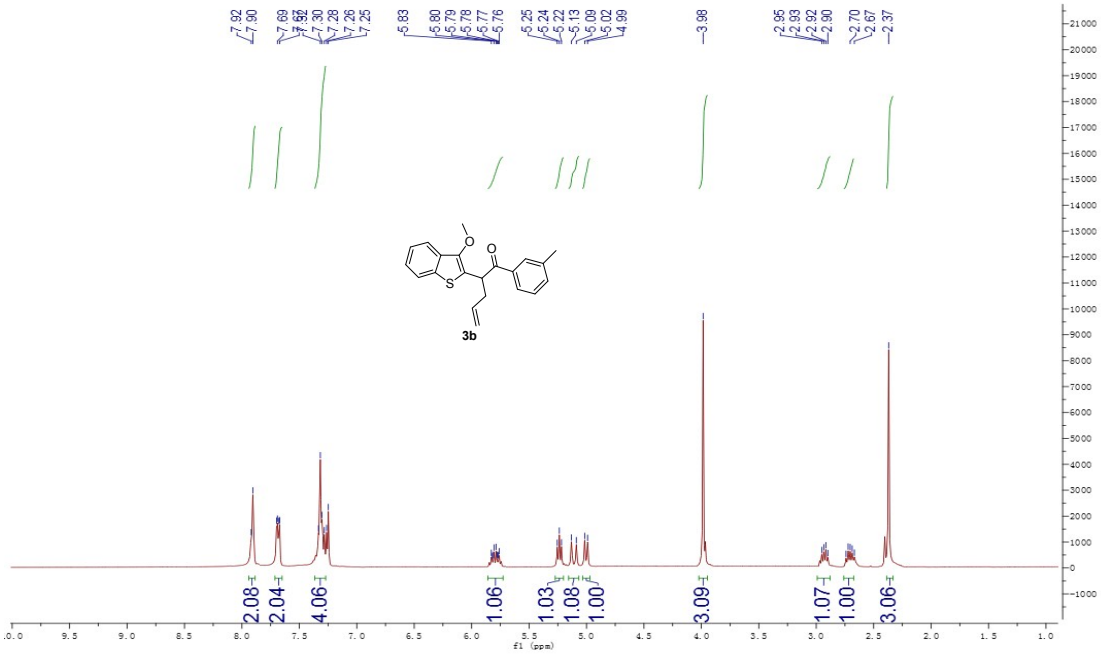
9

allyl(2-(1-methoxy-3-(4-methoxyphenyl)prop-2-ynyl)phenyl)sulfane (9): Colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.78 (m, 1H), 7.42 (m, 3H), 7.31 – 7.27 (m, 2H), 6.85 – 6.82 (m, 2H), 5.93 – 5.82 (m, 1H), 5.80 (s, 1H), 5.12 – 5.03 (m, 2H), 3.80 (s, 3H), 3.56 (dd, J = 7.0, 1.0 Hz, 2H), 3.52 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.7, 139. 7, 134.8, 133.4, 133.3, 131.6, 128.7, 128.1, 127.1, 117.9, 114.7, 113.9, 87.6, 85.3, 71.0, 56.3, 55.3, 38.2; IR (neat) 3067, 1196, 786; MS (EI) *m/z* 324 (M^+), 217 (100%); HRMS (EI) calcd for $C_{20}H_{20}O_2S$ 324.1184, found 324.1183.

4. The ^{1}H and ^{13}C NMR spectra of compounds



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2.08
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3.06
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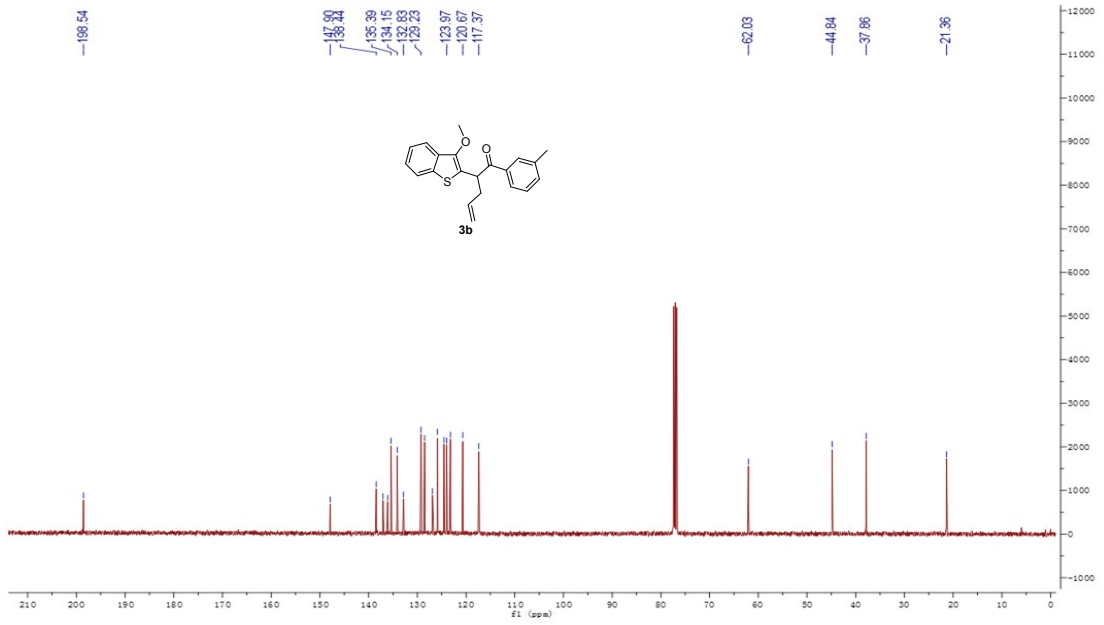
3b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f1 (ppm)
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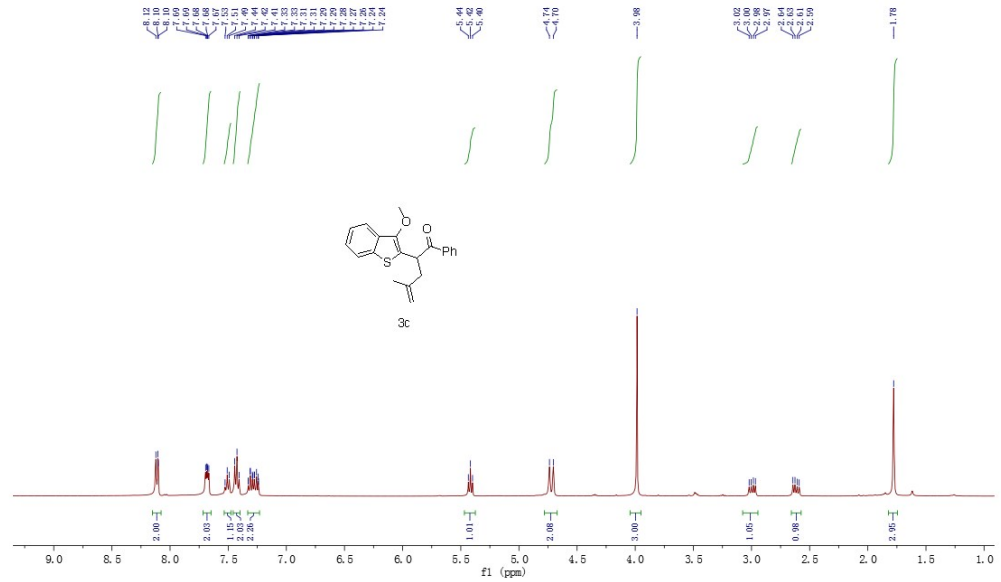
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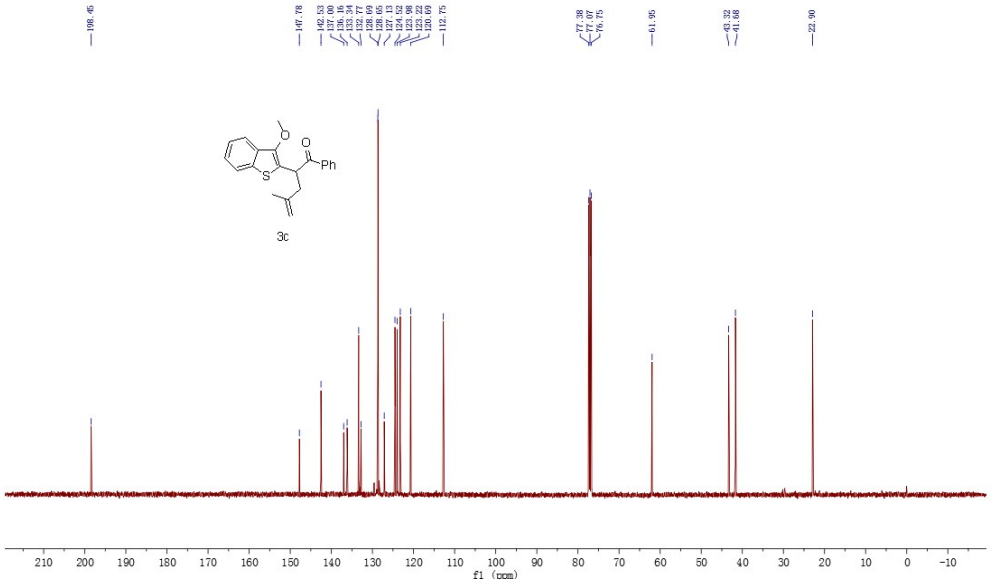
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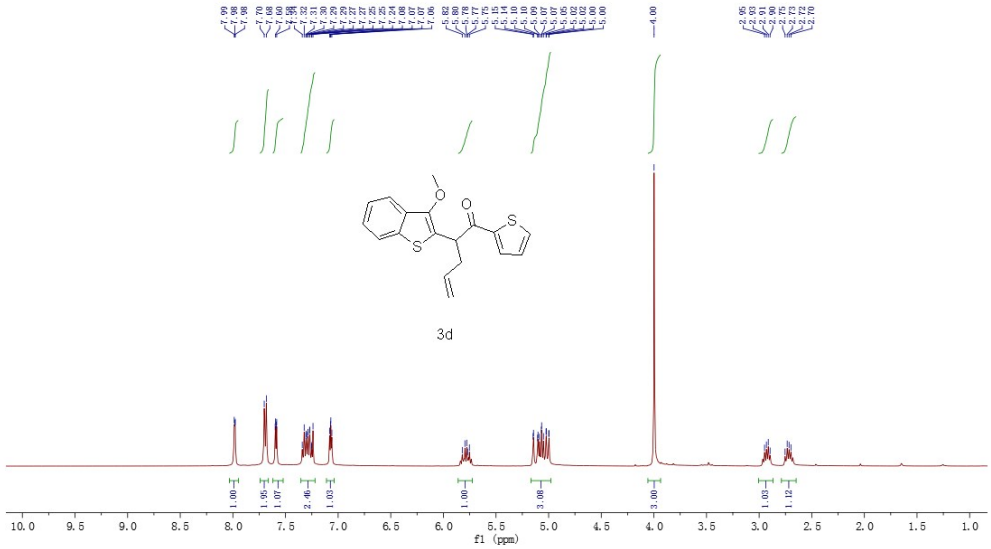
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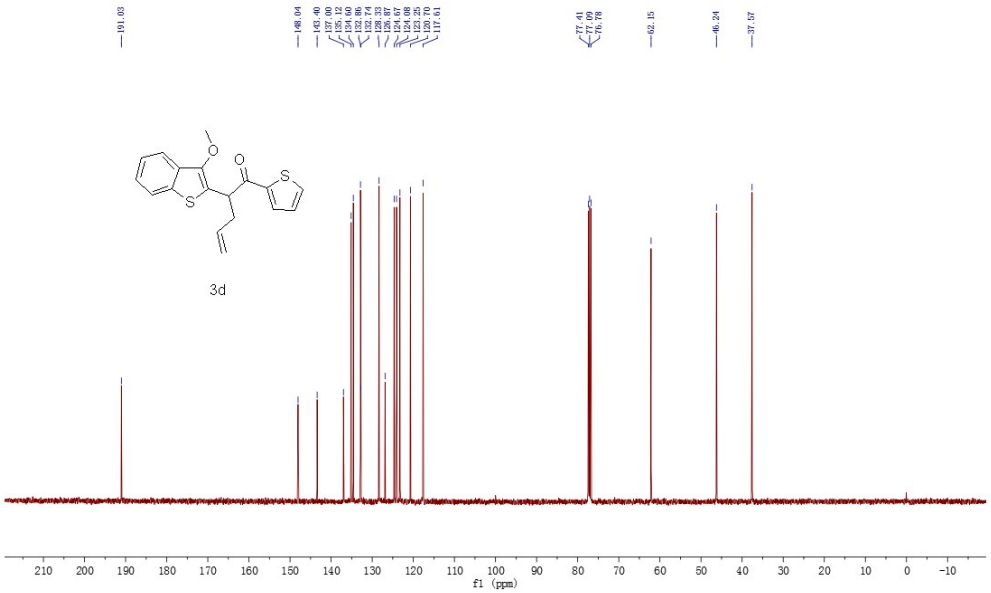
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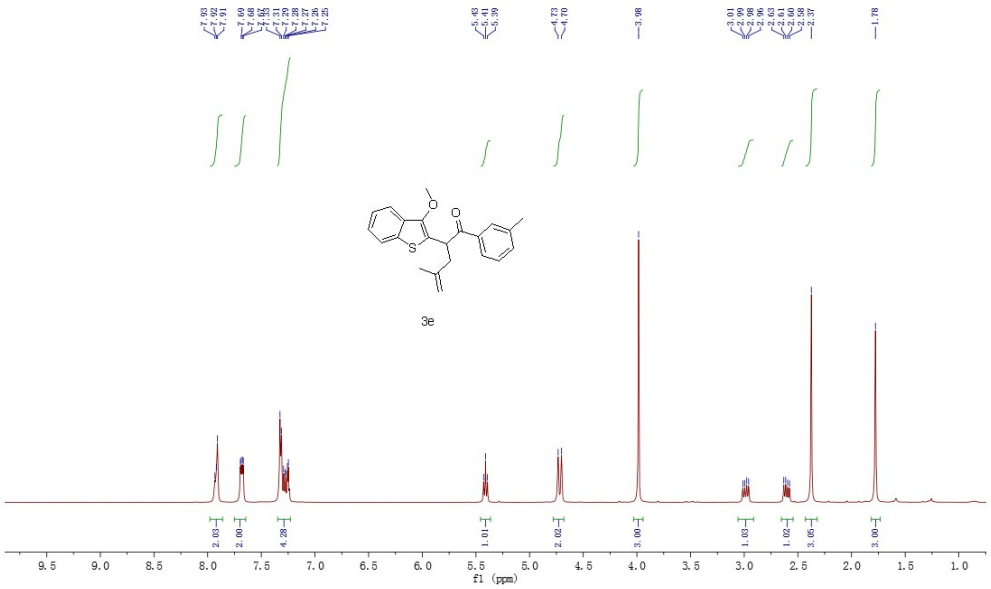
f1 (ppm)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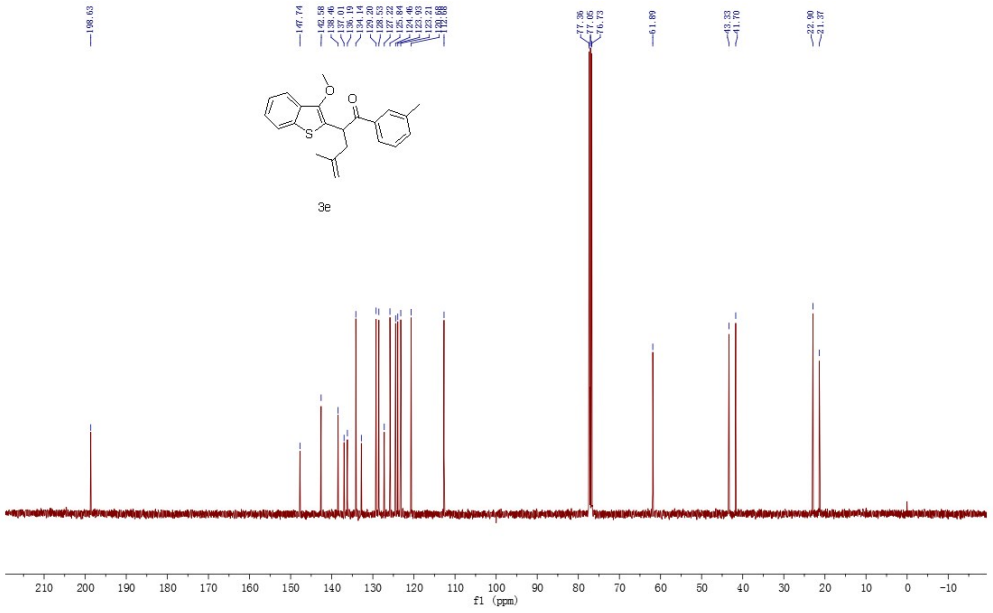
f1 (ppm)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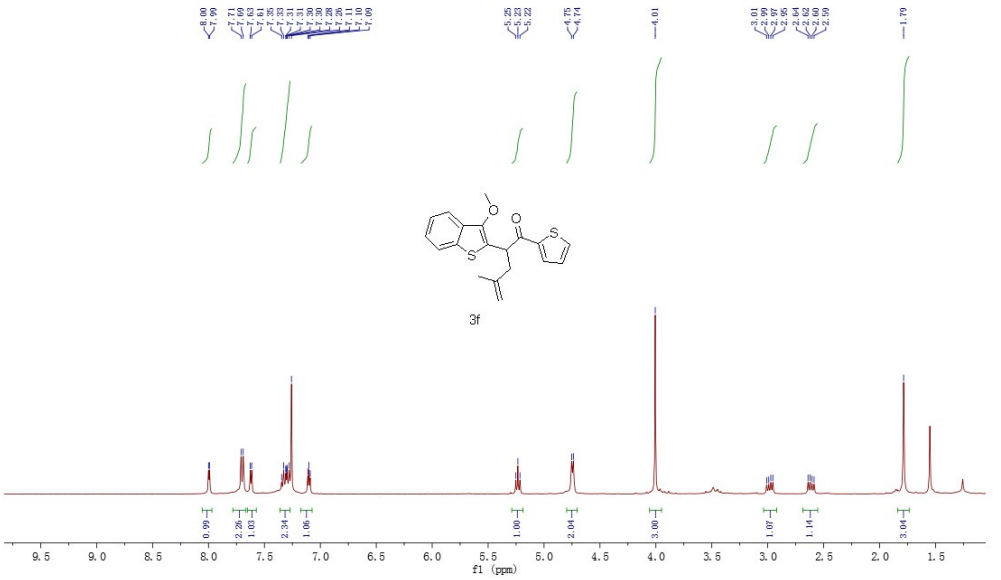
f1 (ppm)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2.97
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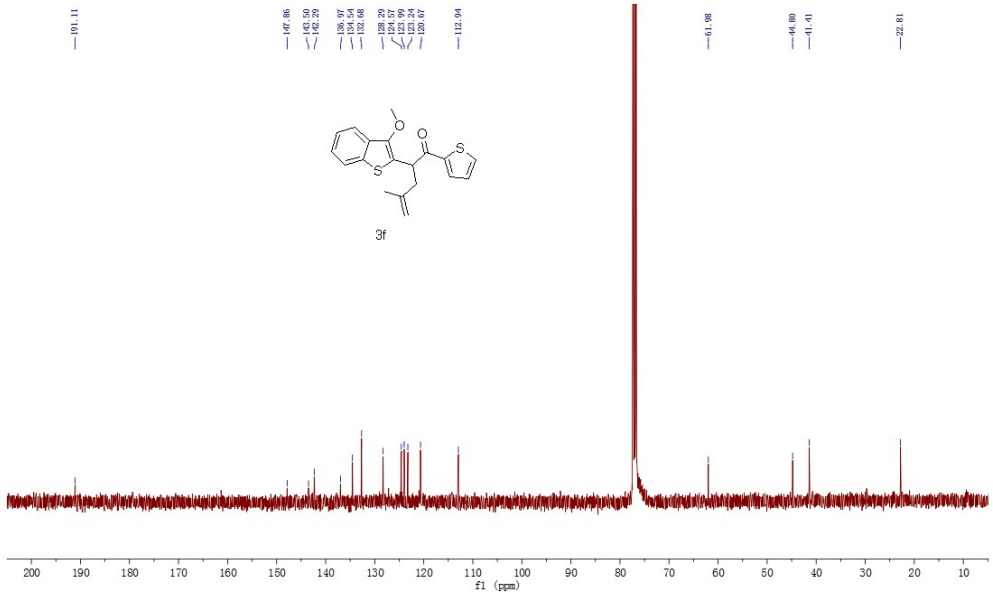
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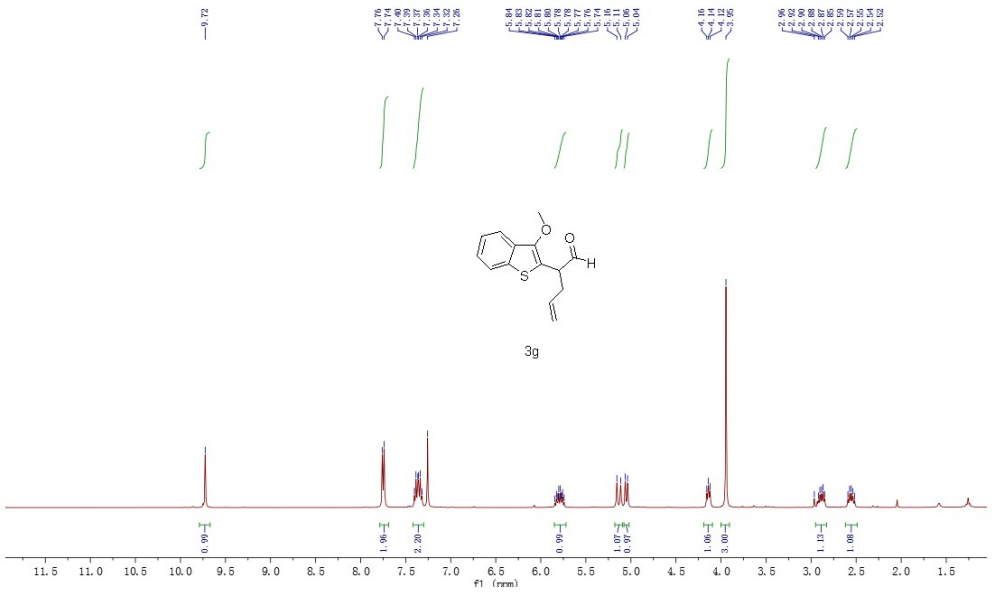
f1 (ppm)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0.97
1.06
3.00
1.13
1.08
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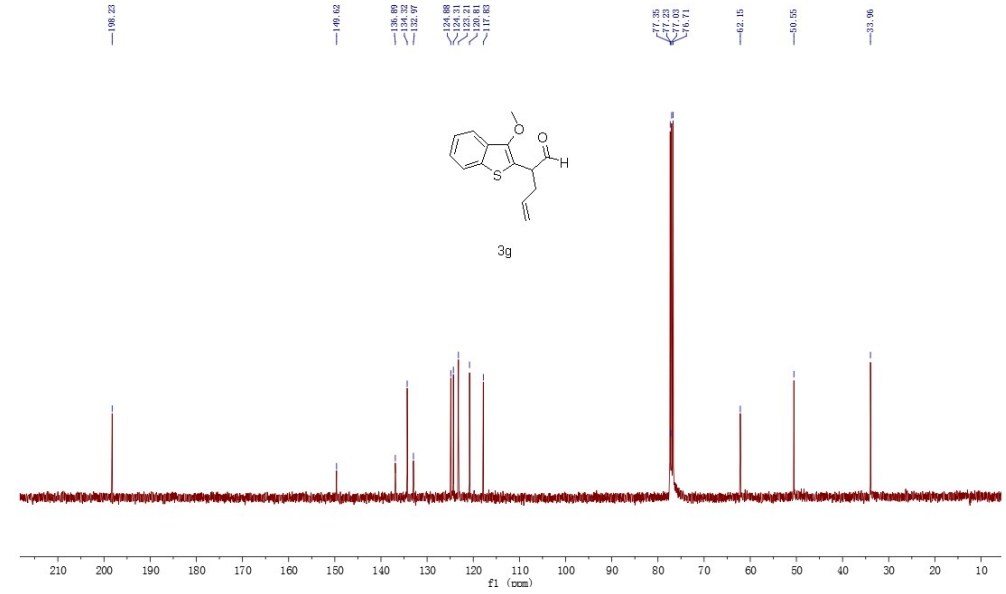
f1 (ppm)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33.96
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H
S
3g
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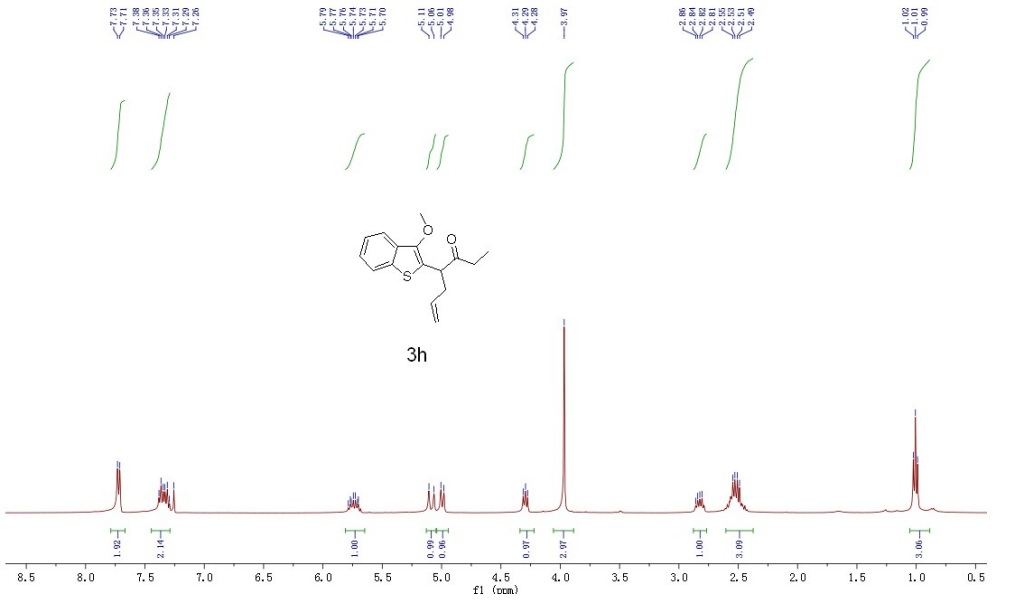
f1 (ppm)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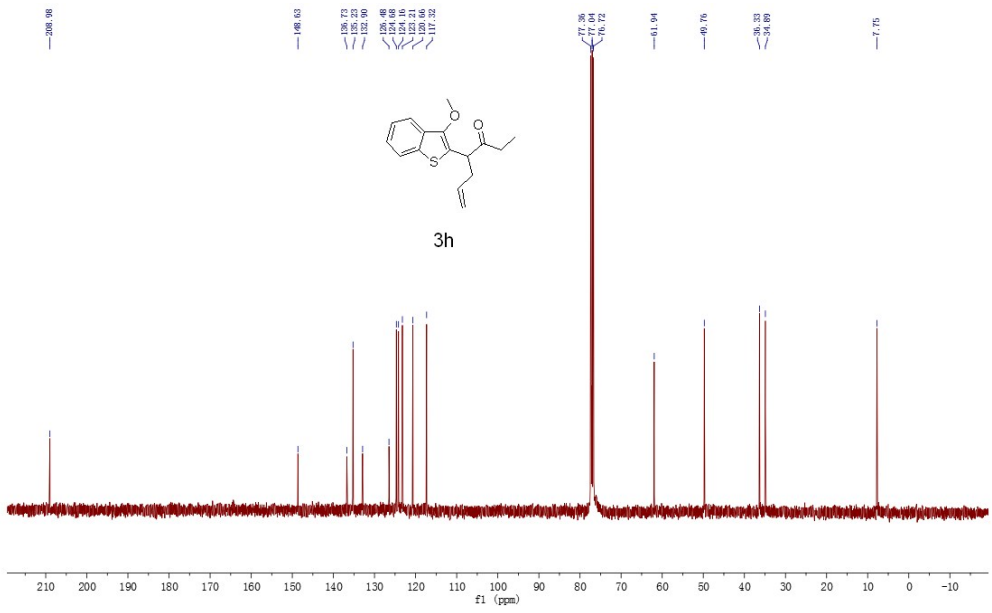
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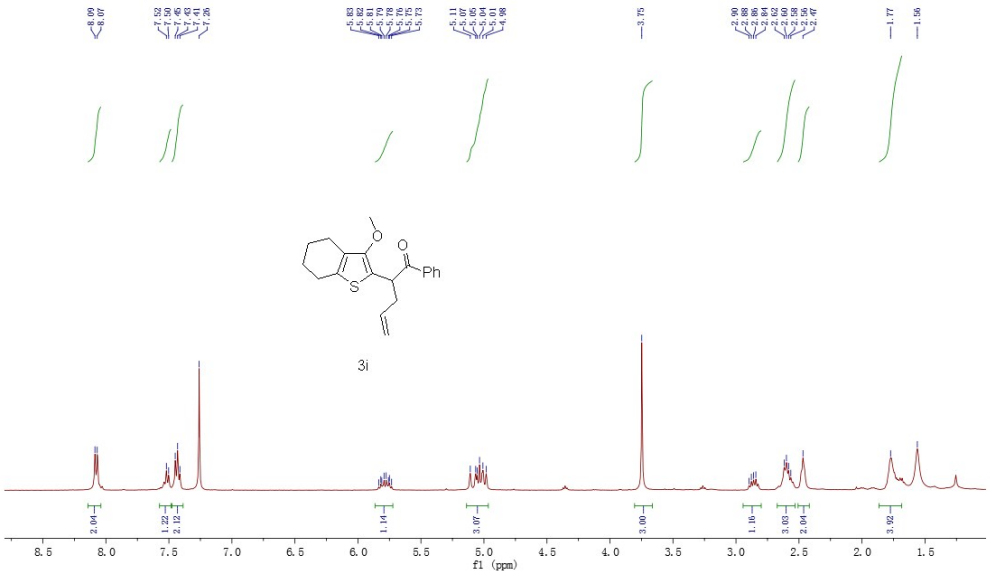
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S
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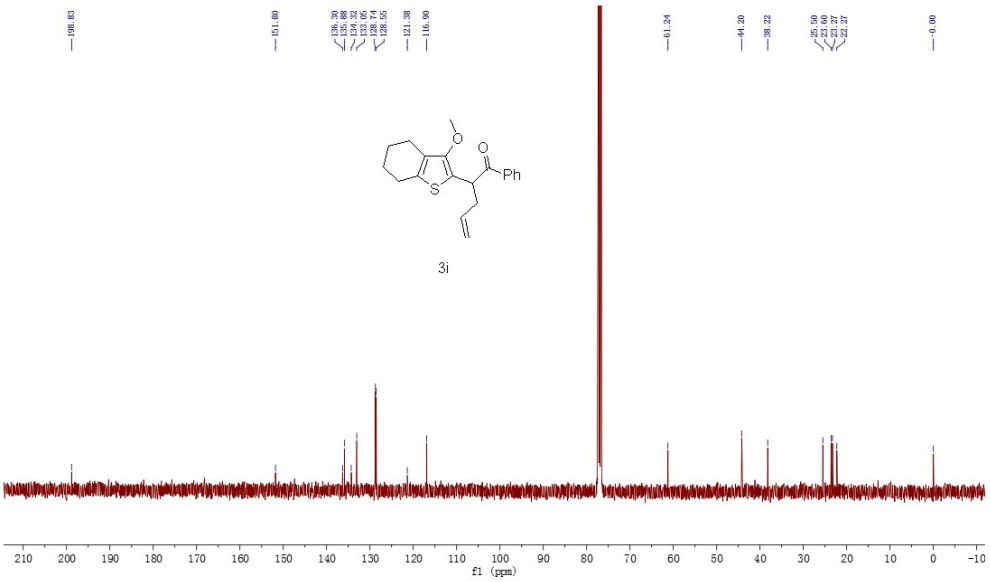
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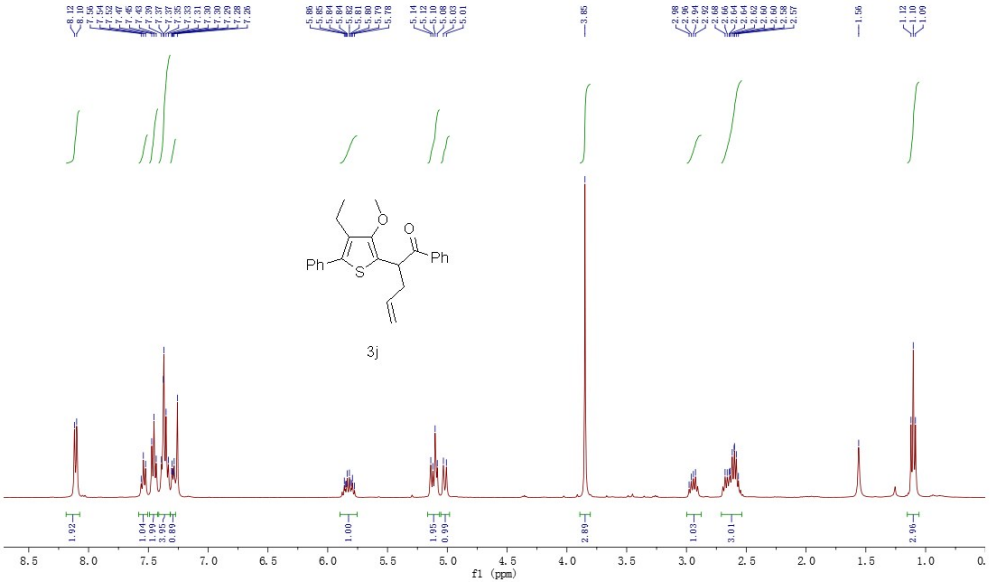
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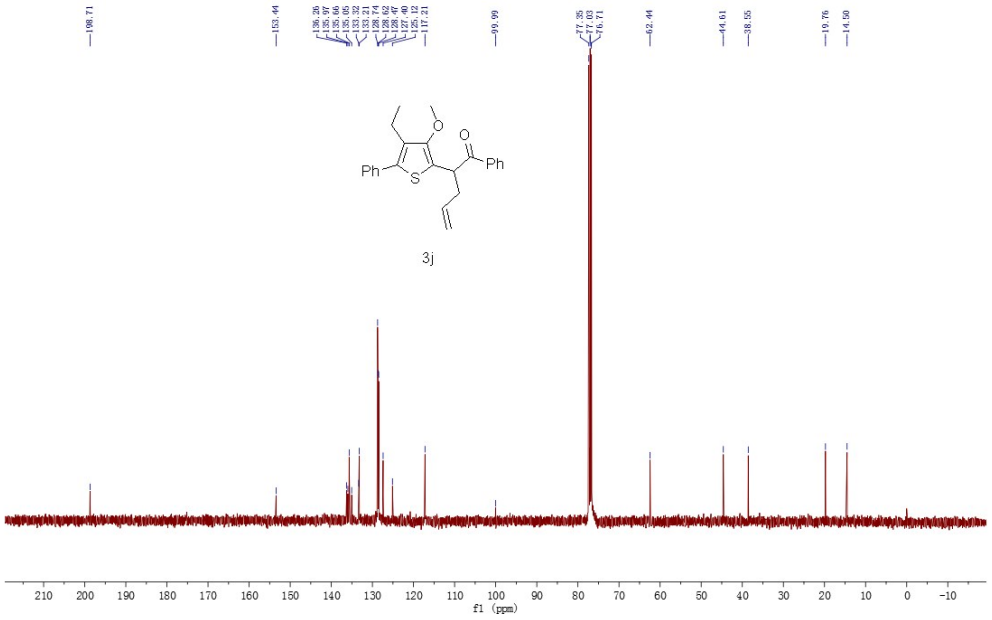
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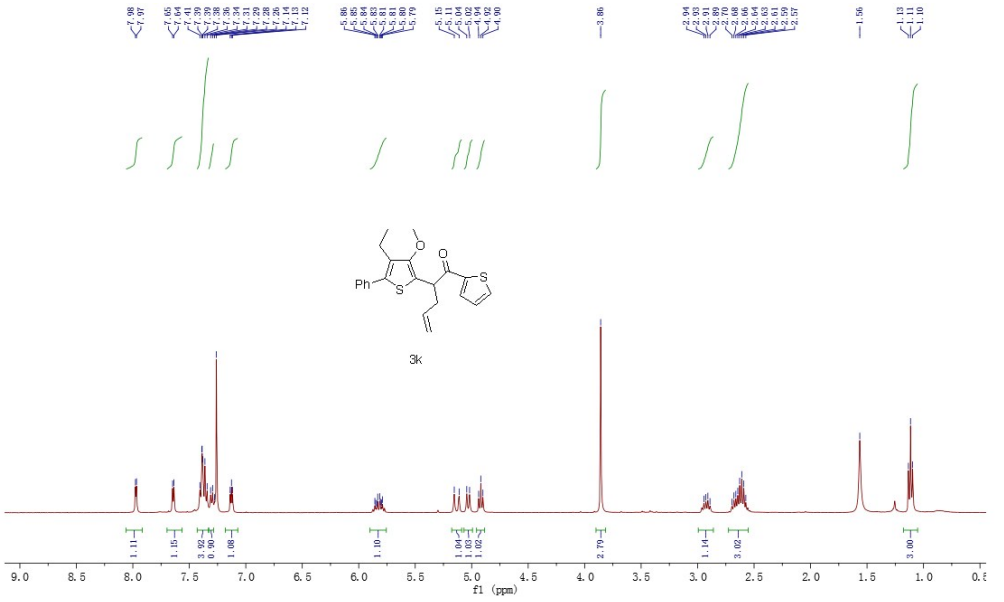
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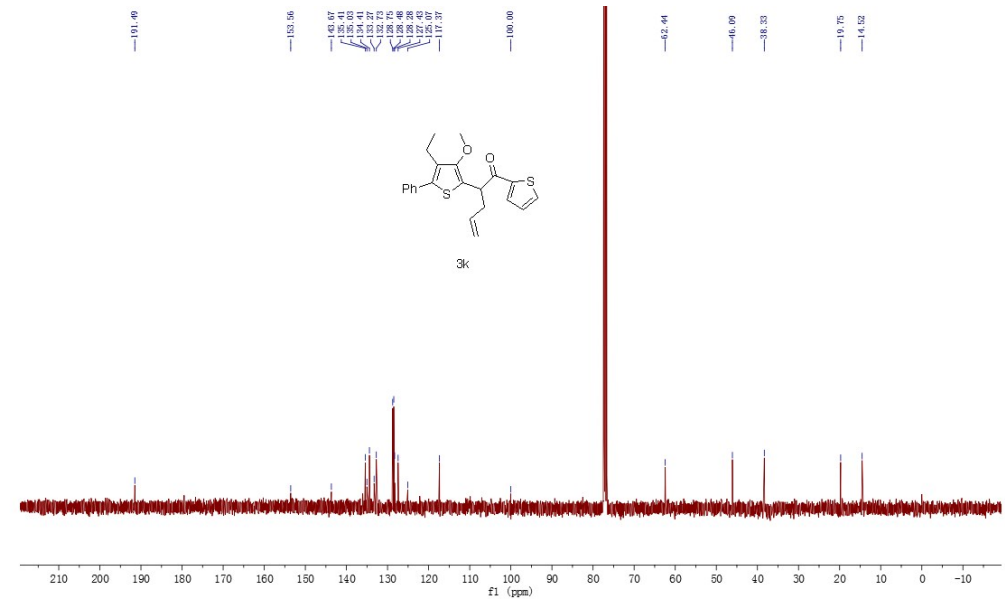
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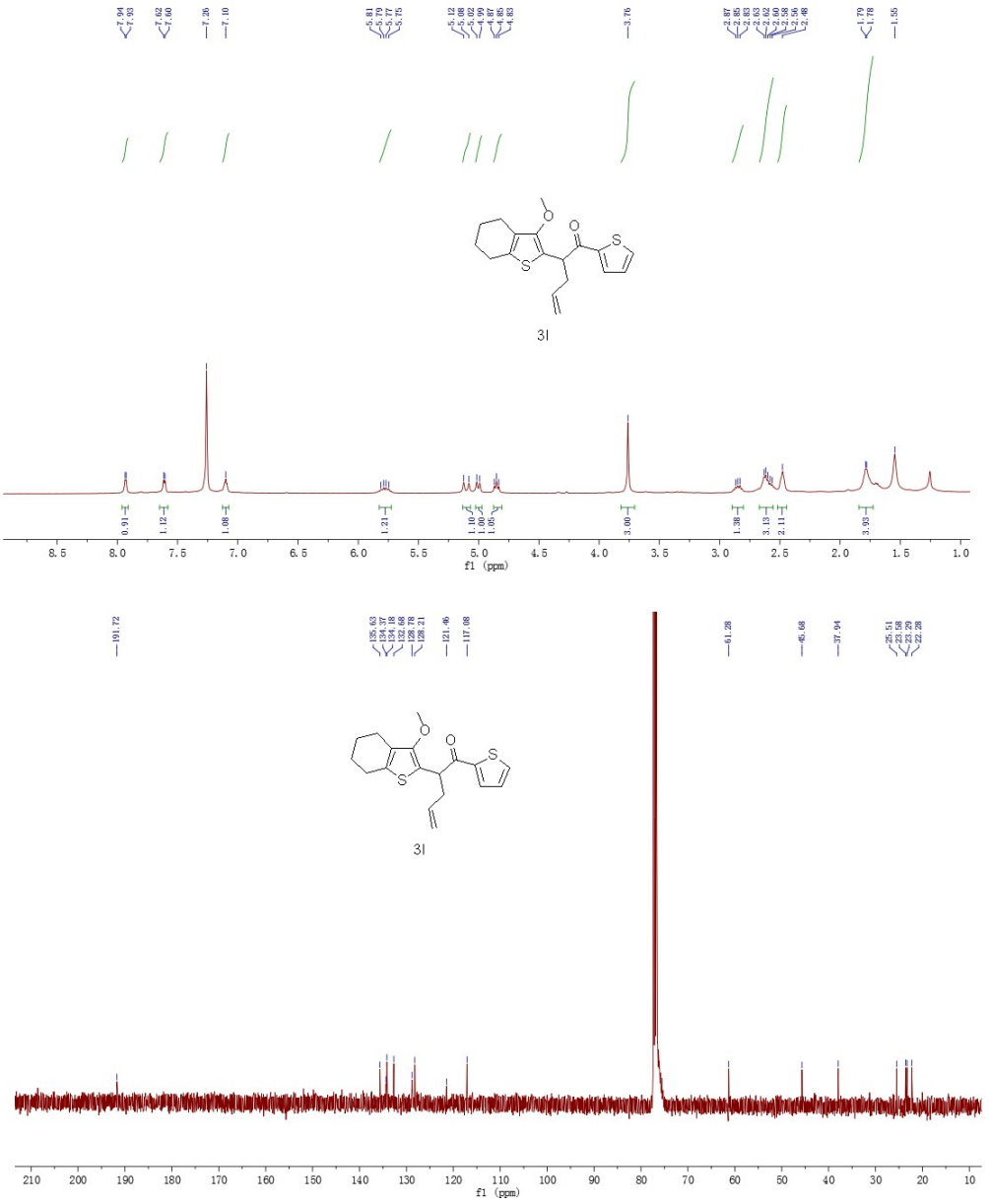
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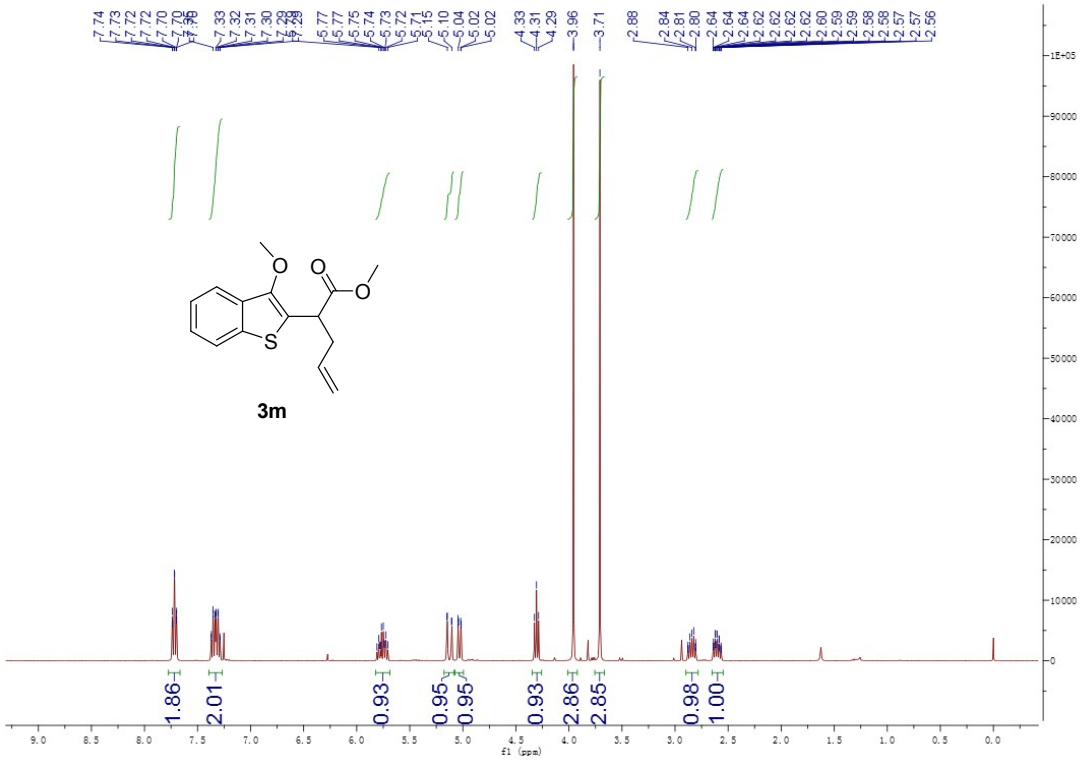
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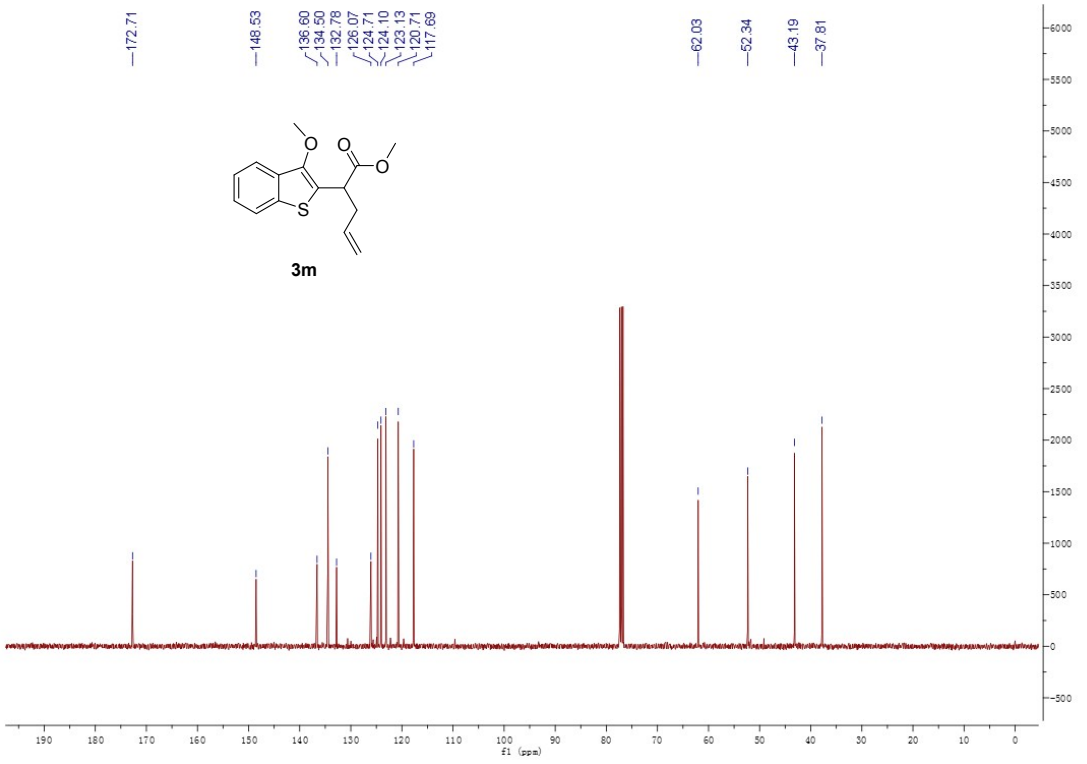
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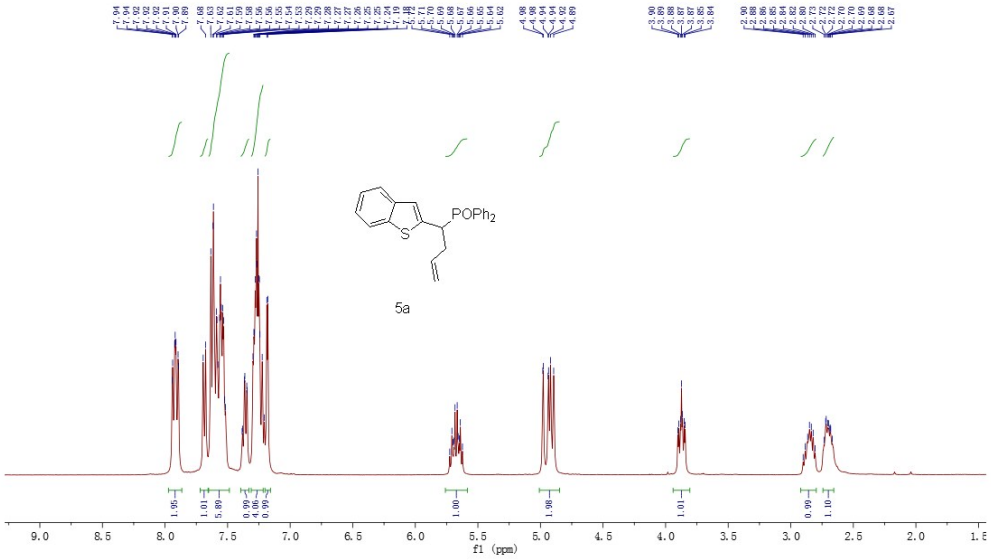
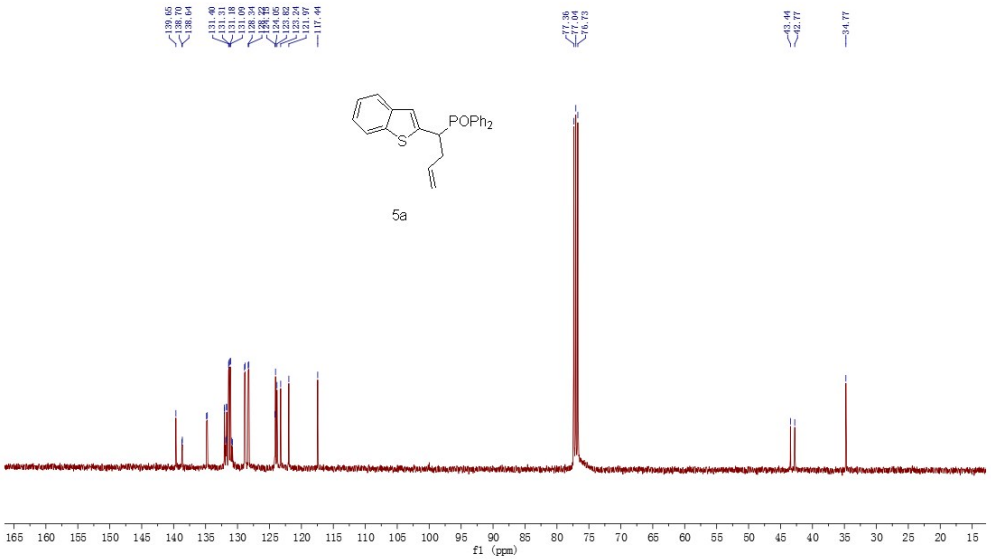

POPh2
5a
f1 (ppm)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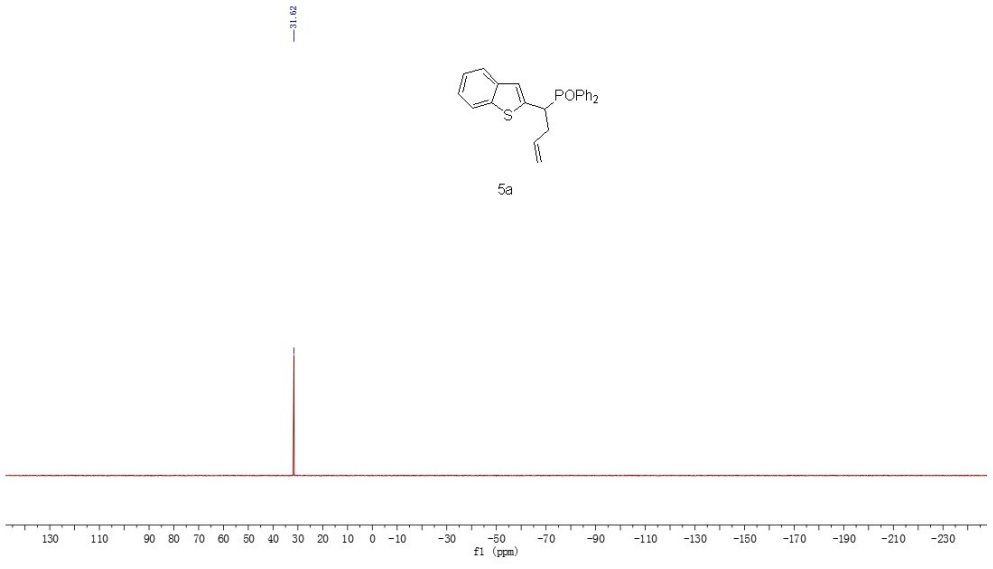
f1 (ppm)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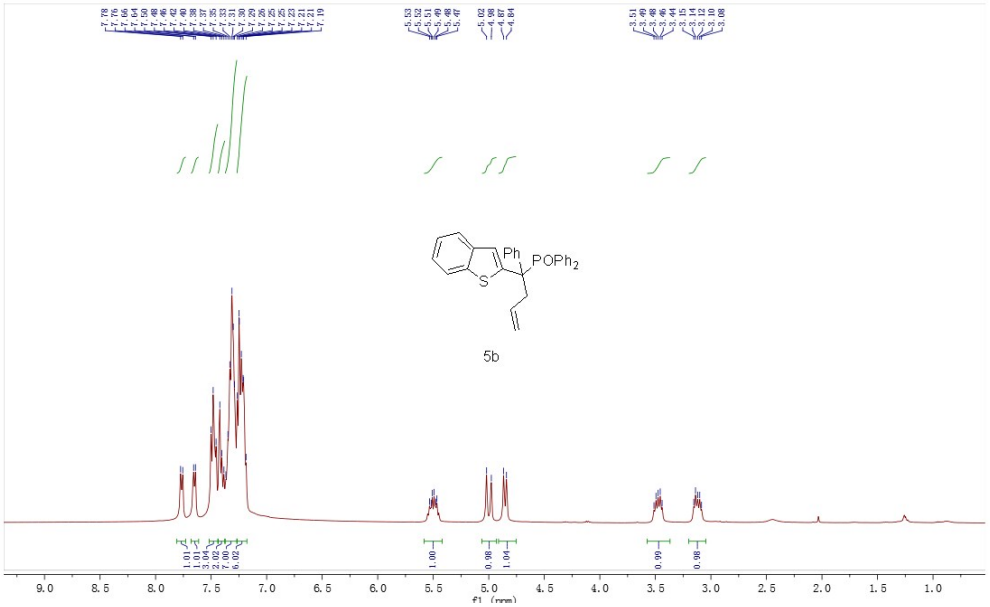
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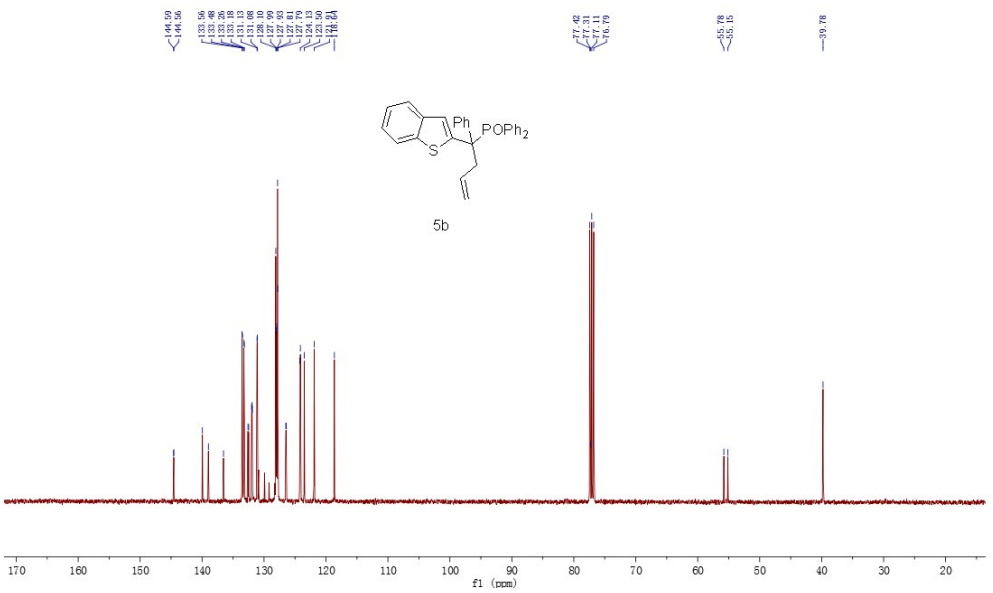
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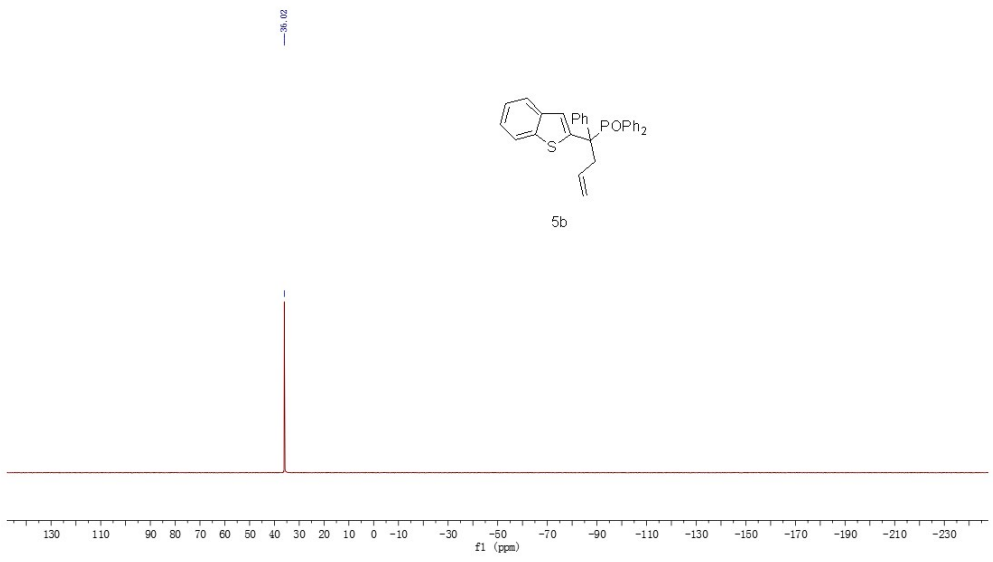
f1 (ppm)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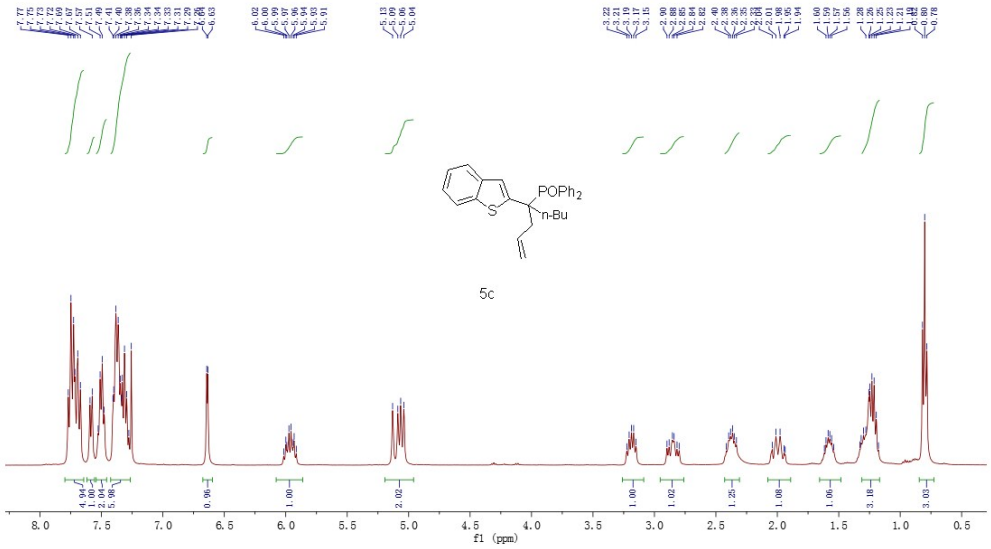

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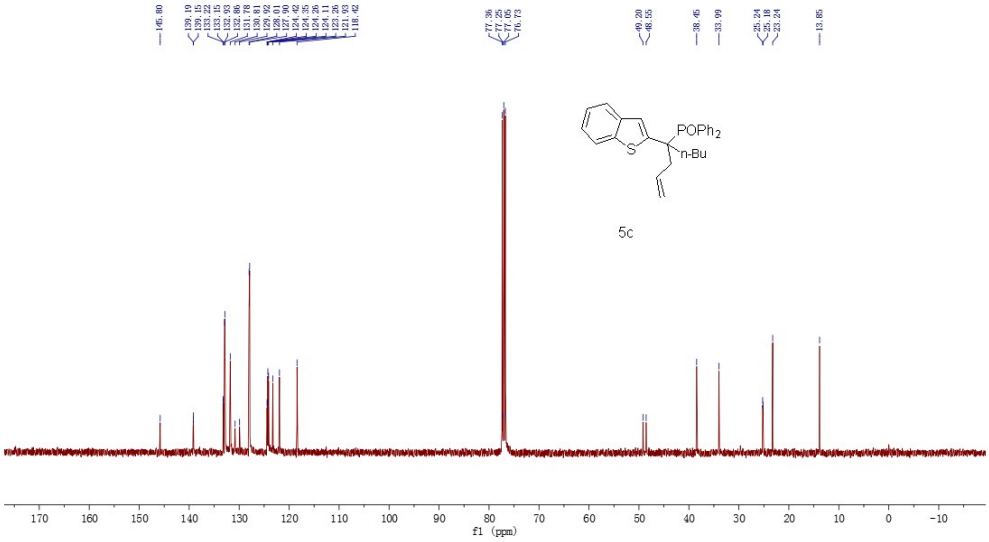

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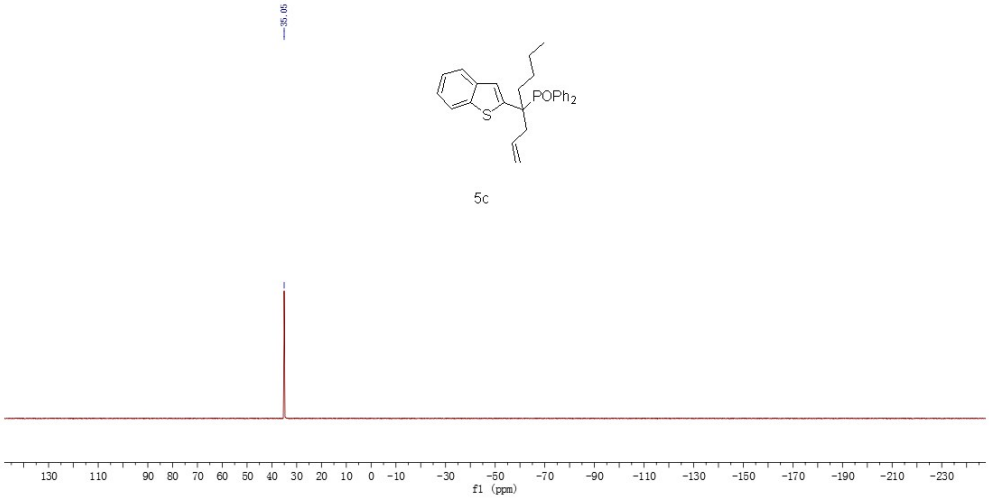

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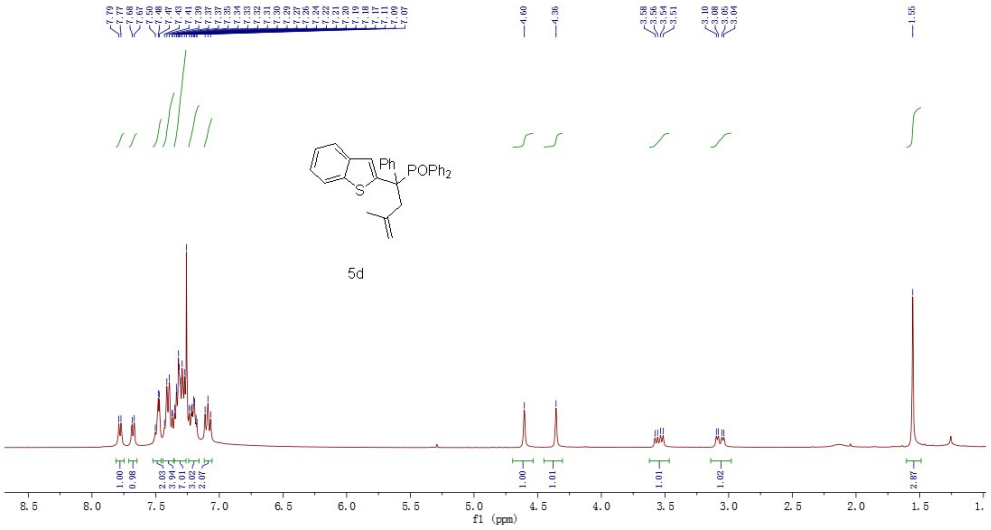
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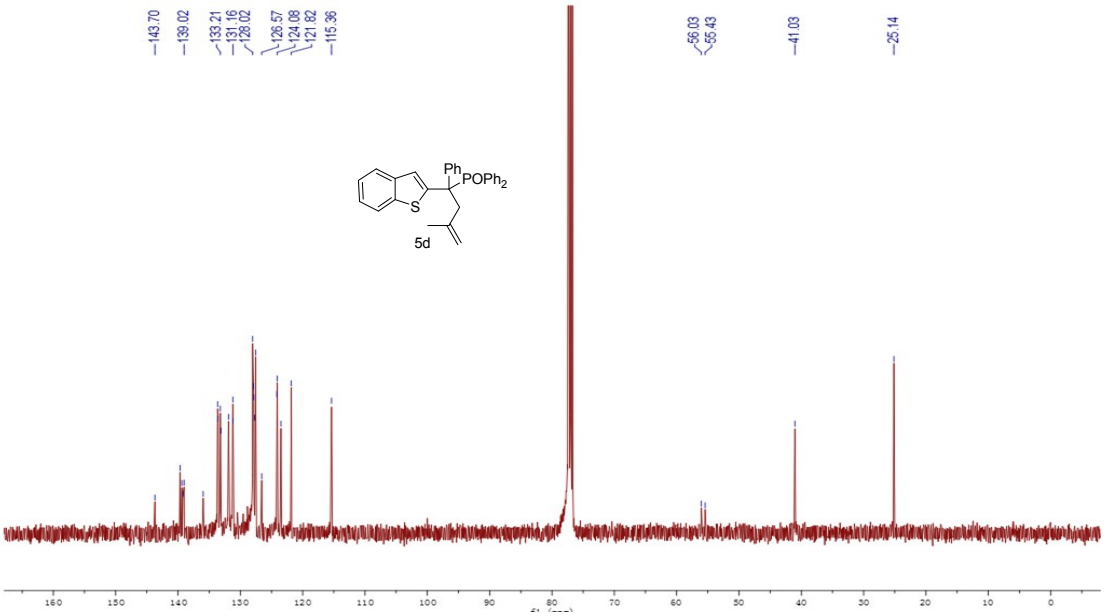
f1 (ppm)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56.03
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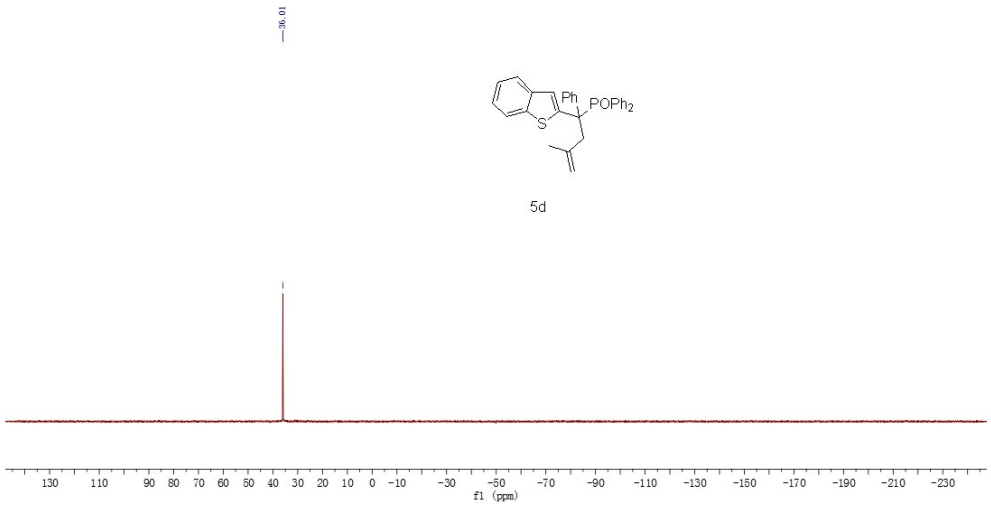
41.03
25.14
Ph
POPh2
S
5d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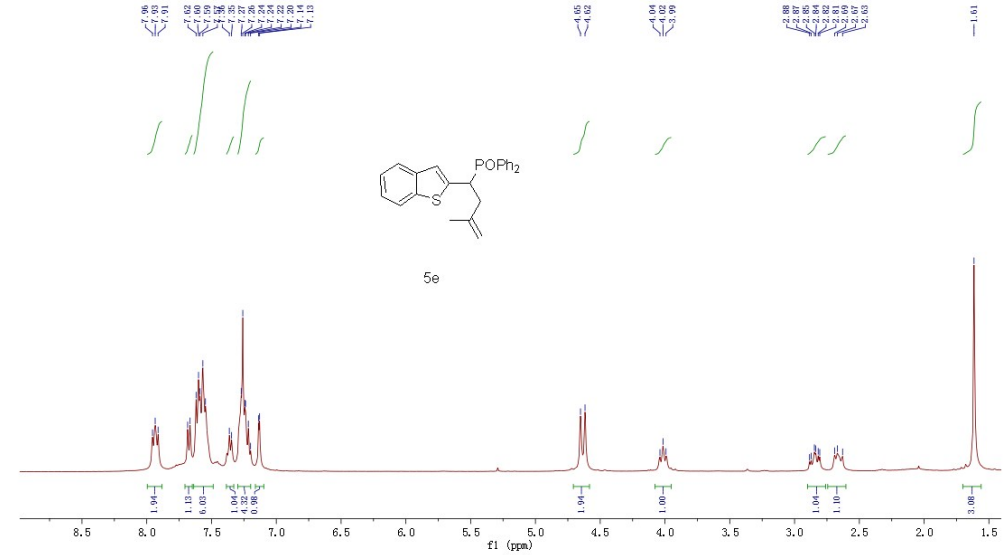
5d
f1 (ppm)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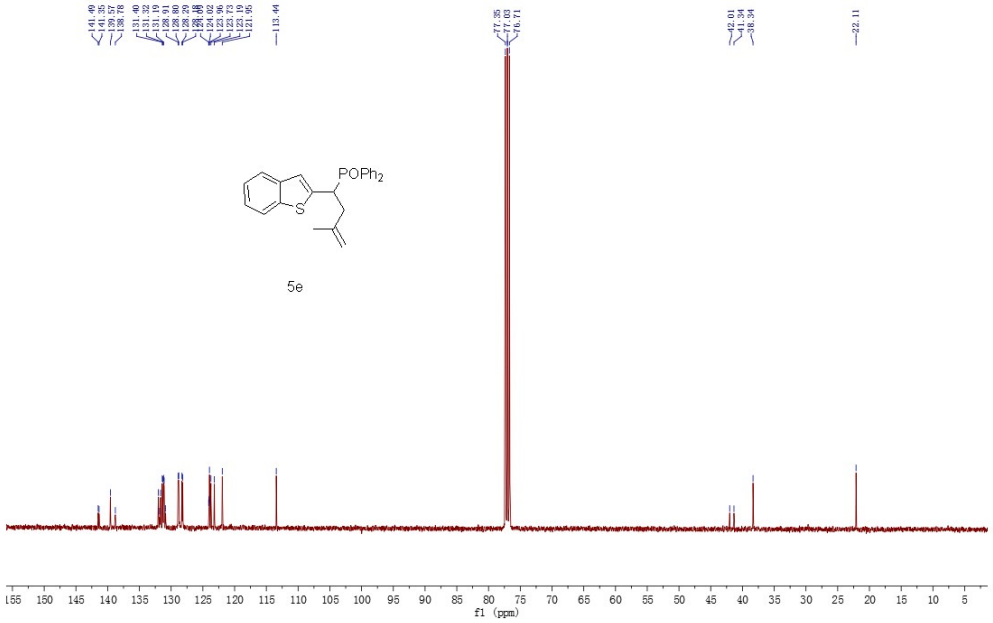
5e
f1 (ppm)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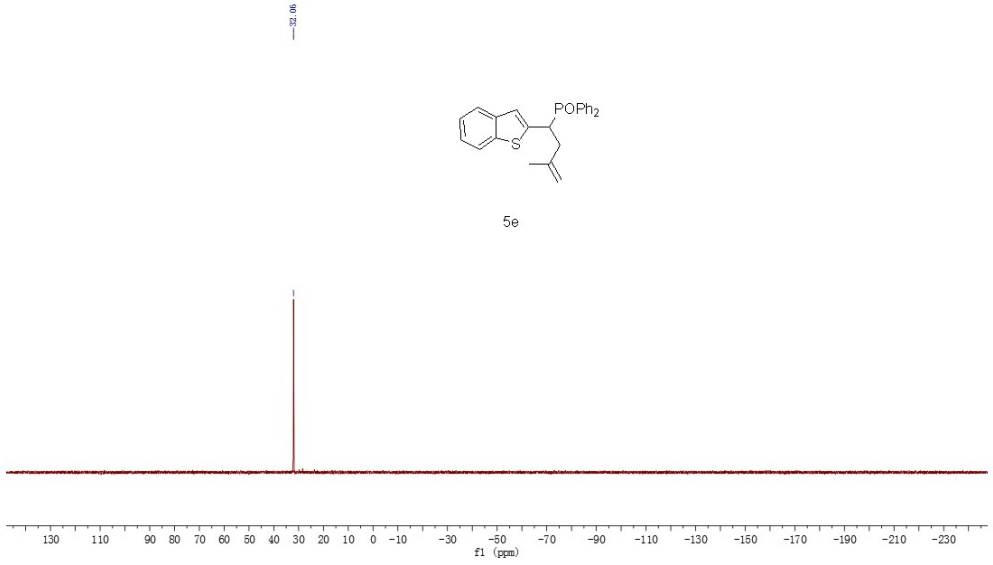
f1 (ppm)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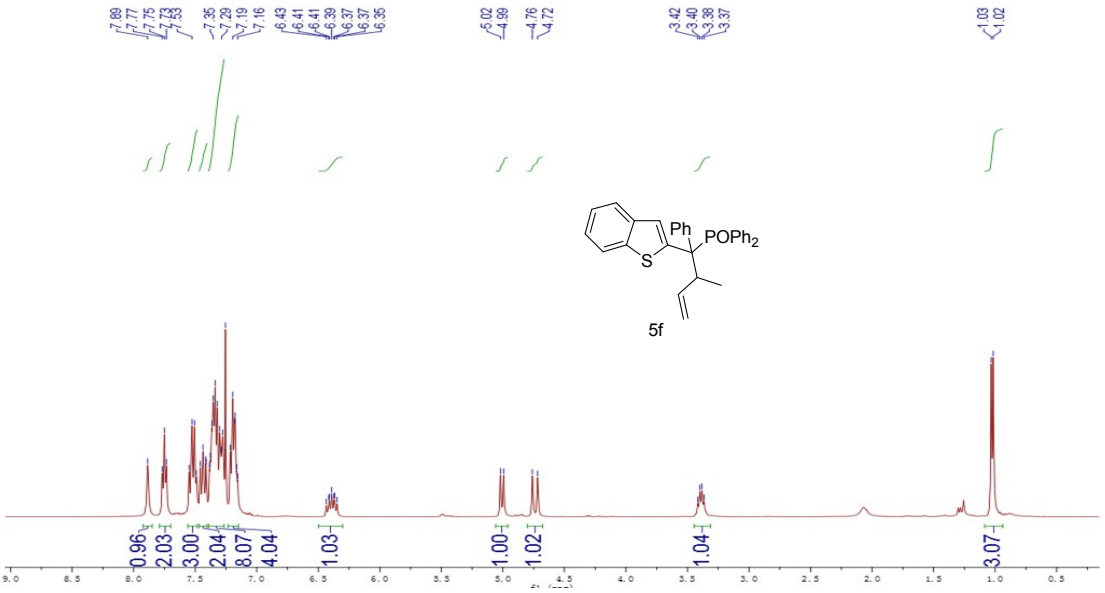
5e
f1 (ppm)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7.16
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6.41
6.41
6.39
6.37
6.37
6.35
5.02
4.99
4.76
4.72
3.42
3.40
3.38
3.37
1.03
1.02
Ph
POPh2
S
5f
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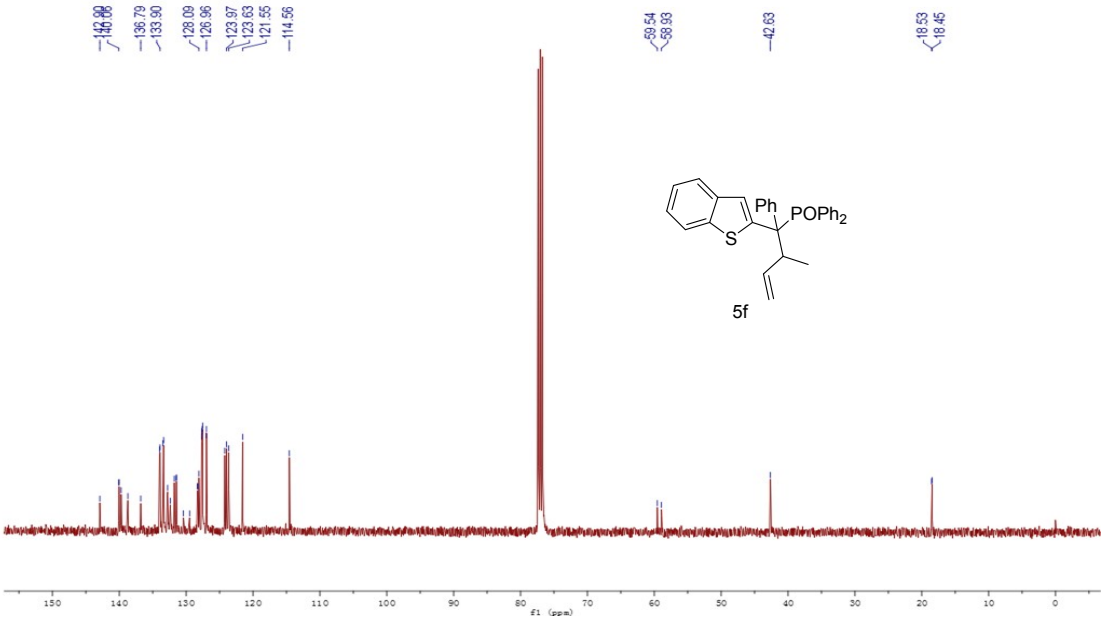
3.00
2.04
8.07
4.04
1.03
1.00
1.02
1.04
3.07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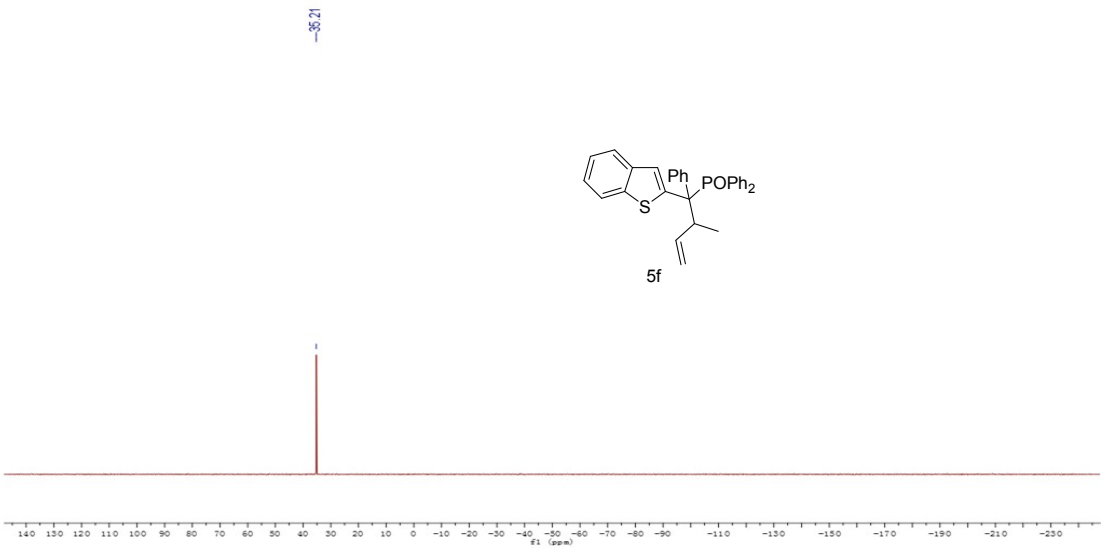
42.63
18.53
18.45
Ph
POPh2
S
5f
f1 (ppm)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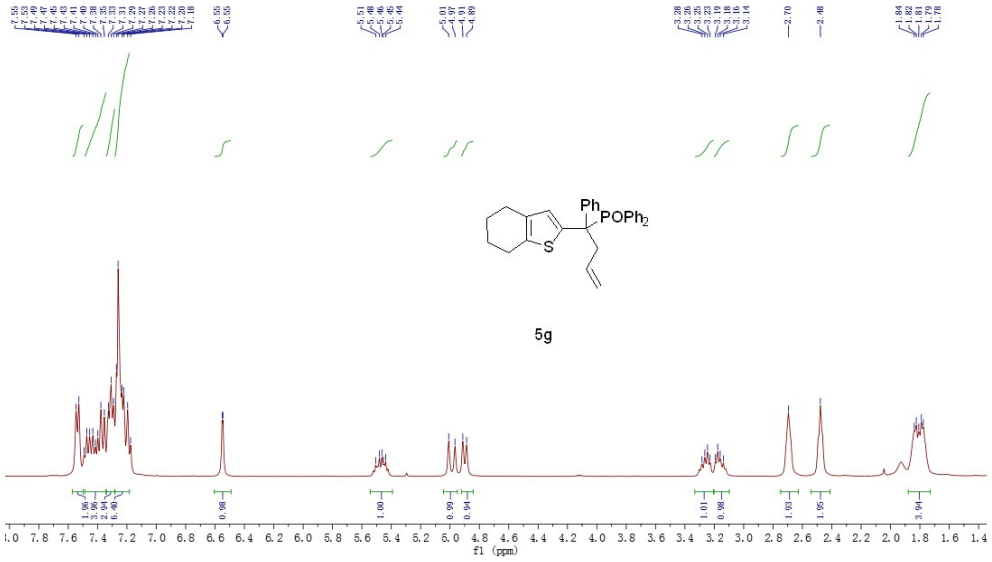
S
5f
f1 (ppm)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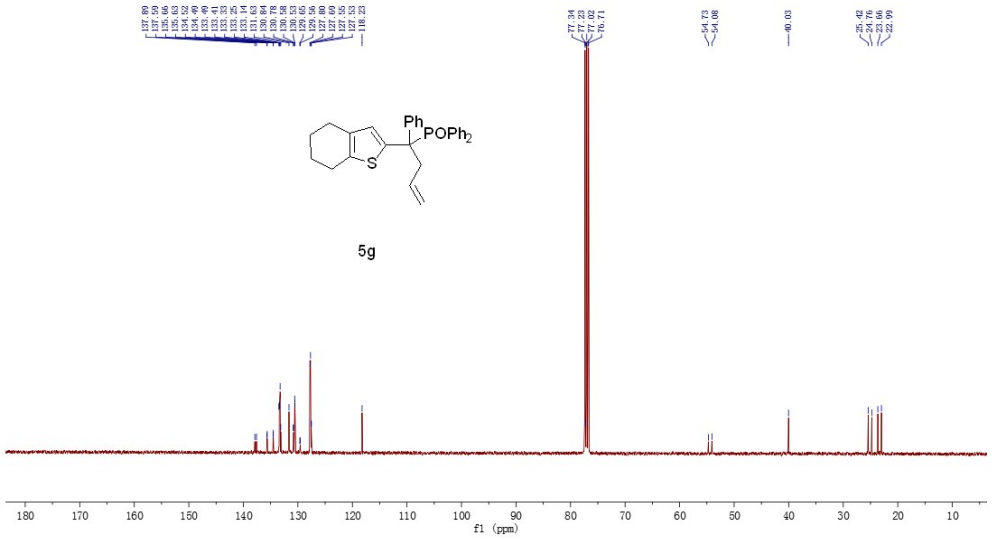
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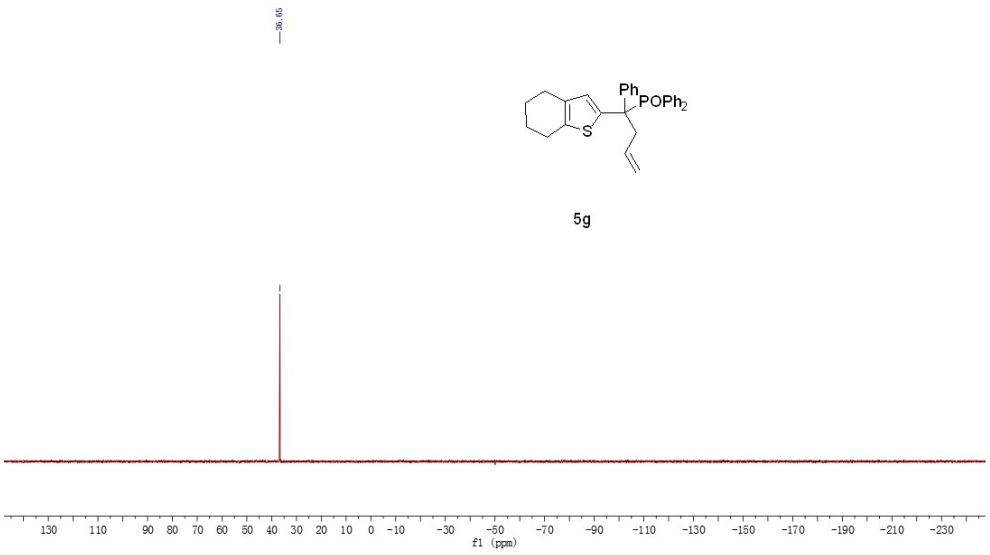
S
5g
f1 (ppm)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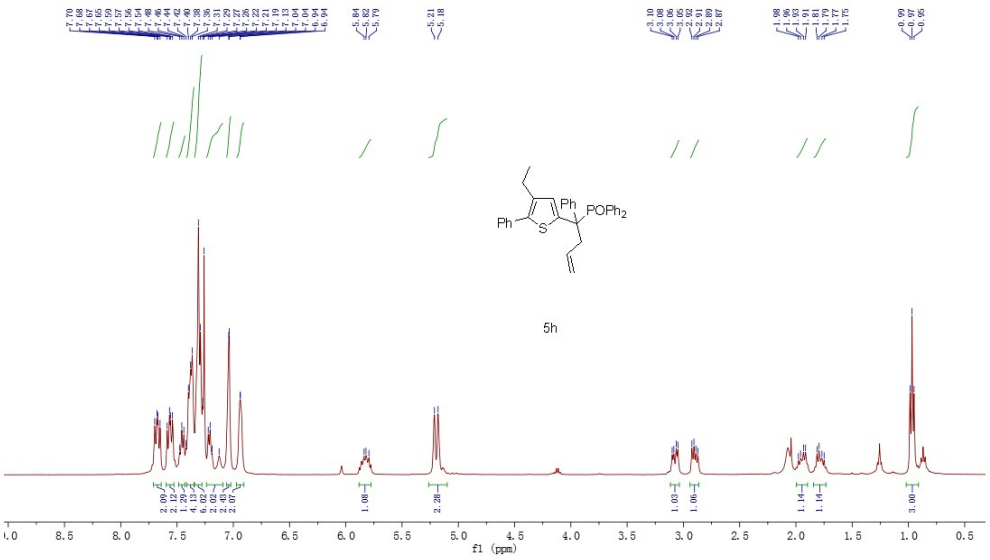
S
5g
f1 (ppm)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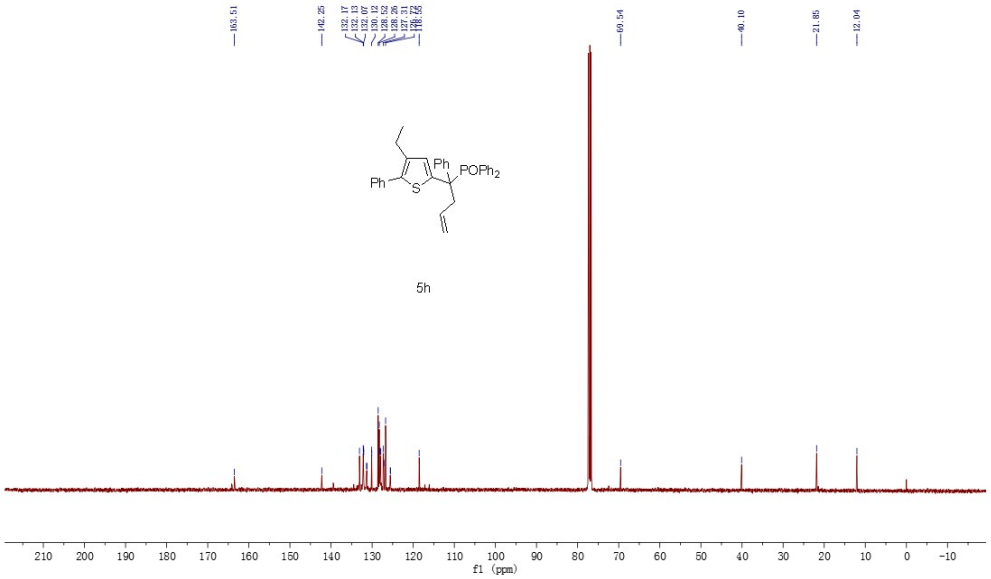
S
5h
f1 (ppm)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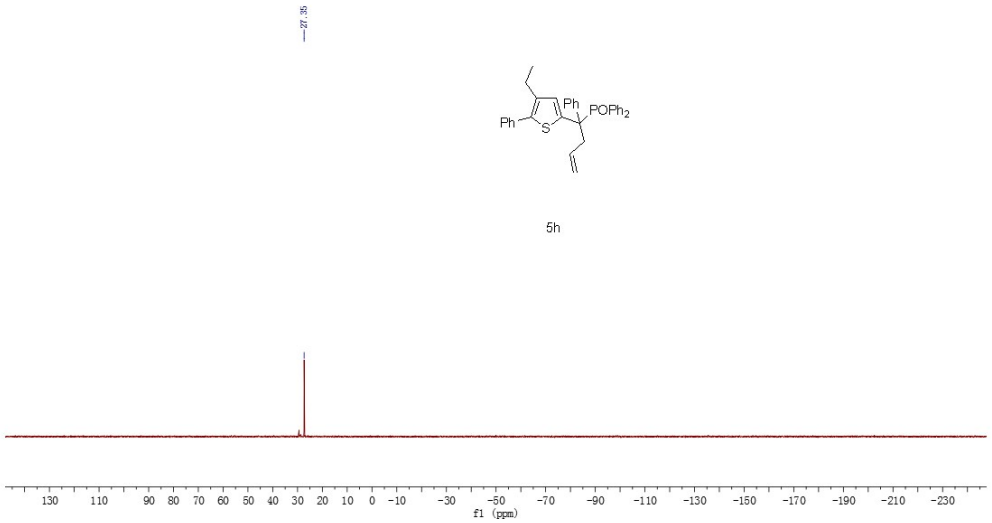
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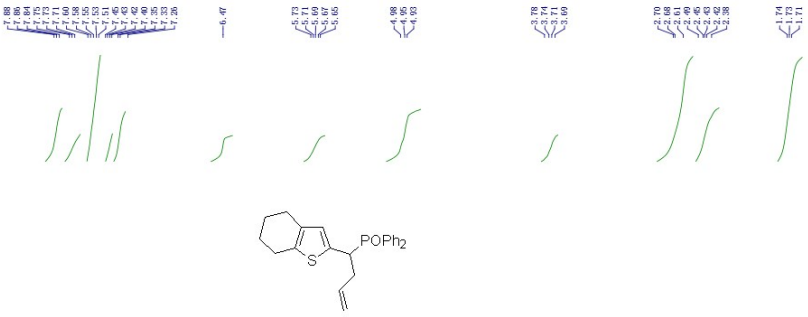

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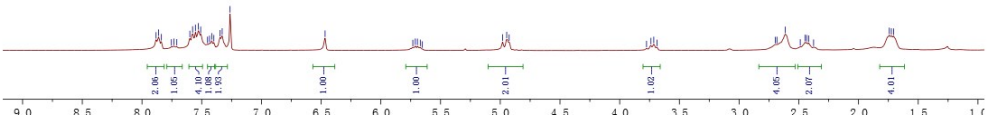

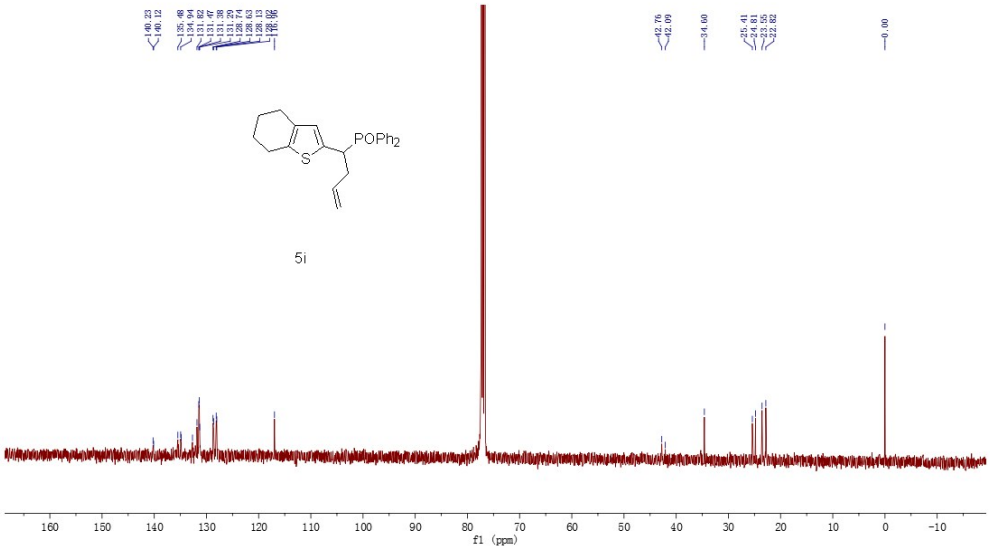

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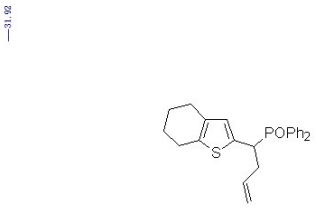

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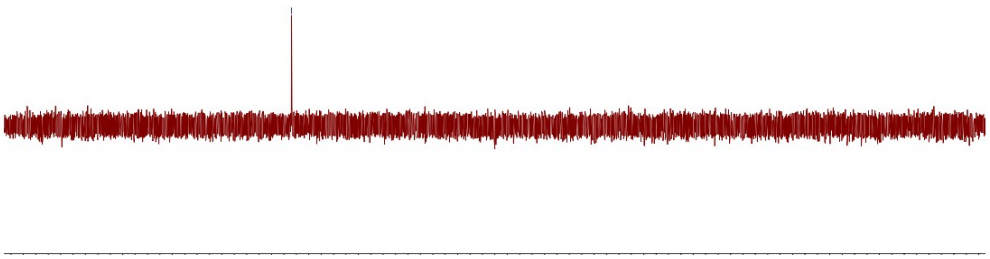

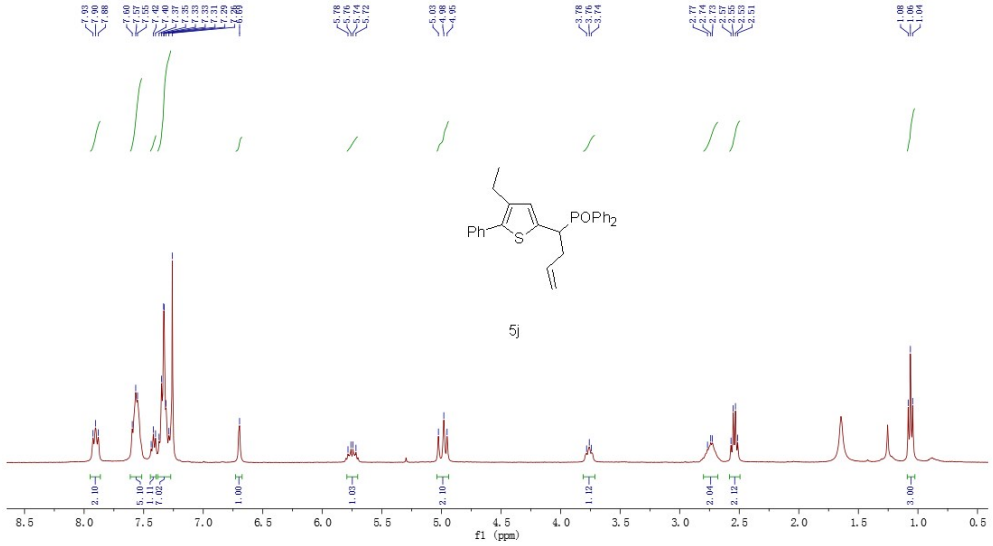
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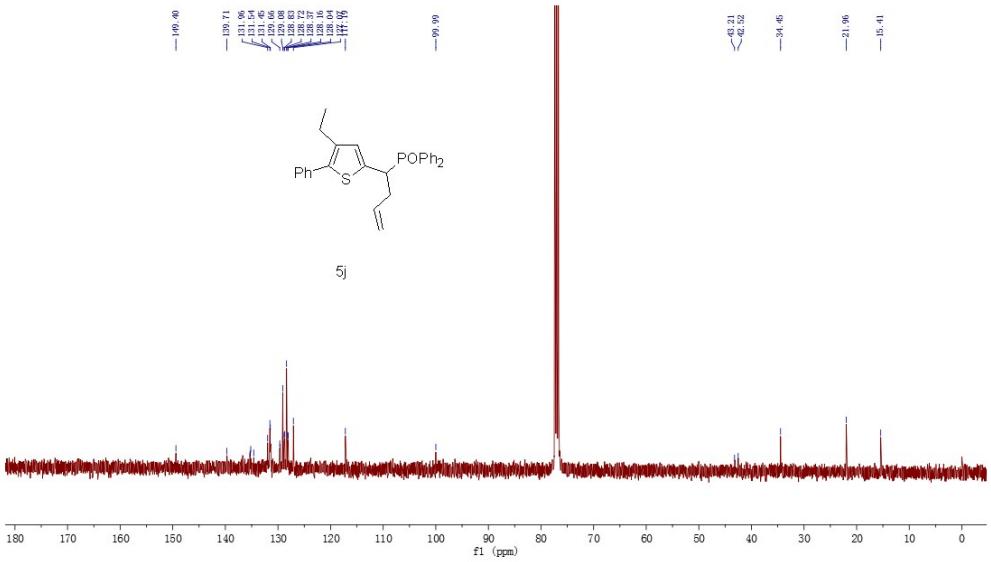
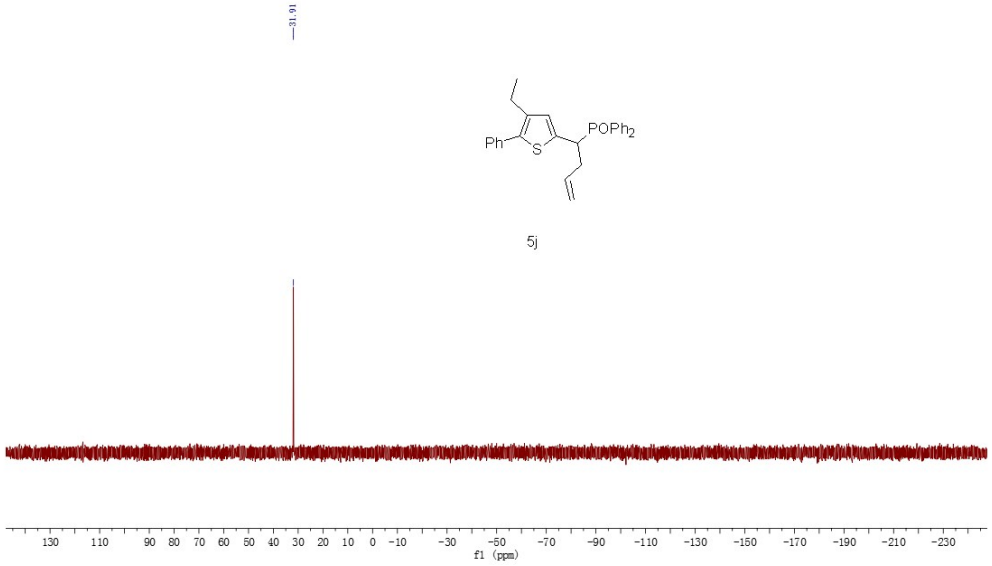
S
POPh2
5j
f1 (ppm)


Ph
S
POPh2
5j
f1 (ppm)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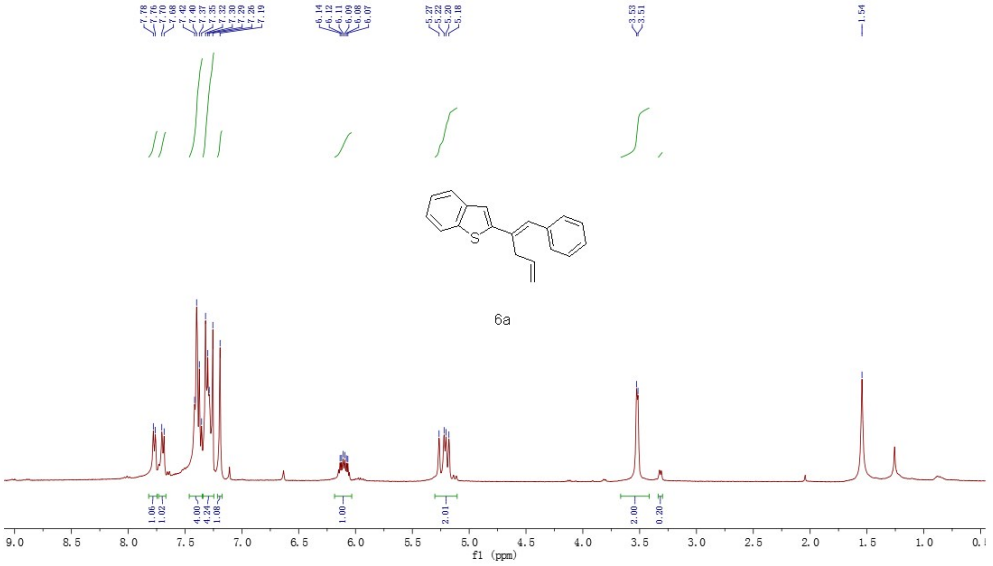
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7.19
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6.12
6.11
6.09
6.08
6.07
5.27
5.23
5.22
5.20
5.18
3.53
3.51
1.54
6a
1.06
1.02
4.00
4.24
1.08
1.00
2.01
2.00
0.20
9.0
8.5
8.0
7.5
7.0
6.5
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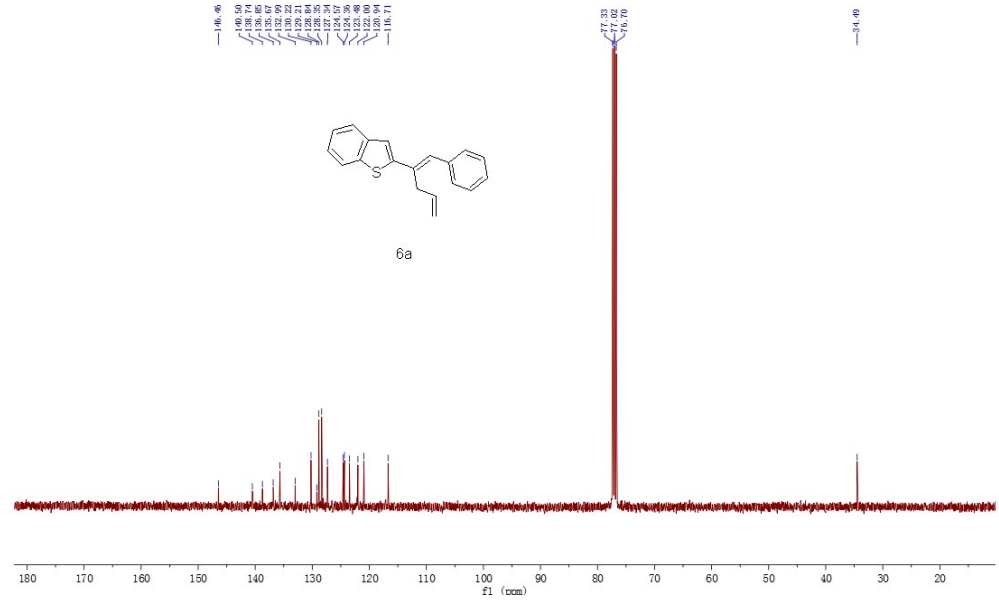
f1 (ppm)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129.21
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128.35
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124.57
124.36
123.48
122.06
120.94
110.71
77.33
77.02
76.70
34.49
6a
180
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70
60
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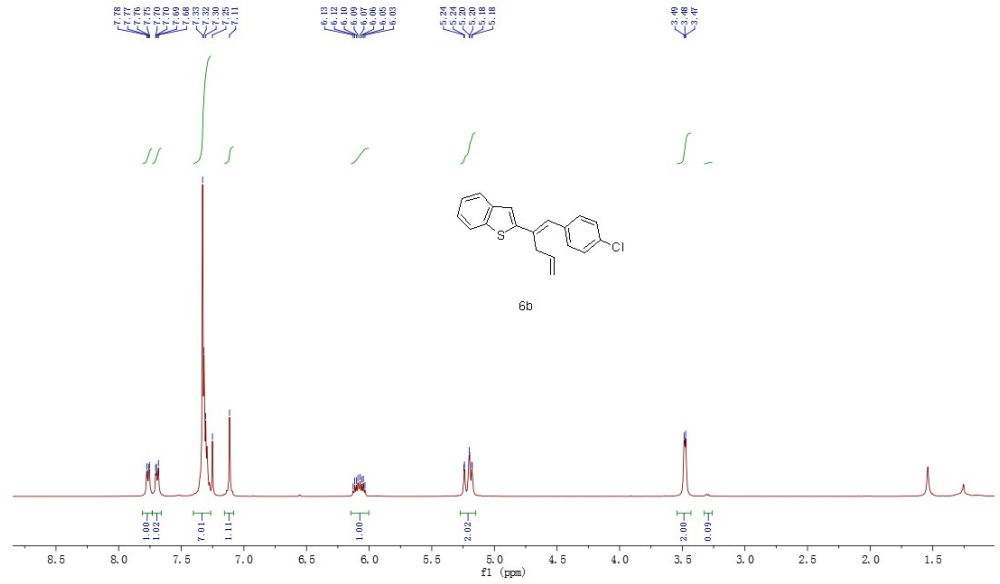
30
20
f1 (ppm)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7.11
6.13
6.12
6.10
6.09
6.07
6.06
6.05
6.03
5.24
5.24
5.20
5.20
5.18
5.18
3.49
3.48
3.47
S
Cl
6b
1.00
1.02
7.01
1.11
1.00
2.02
2.00
0.09
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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4.0
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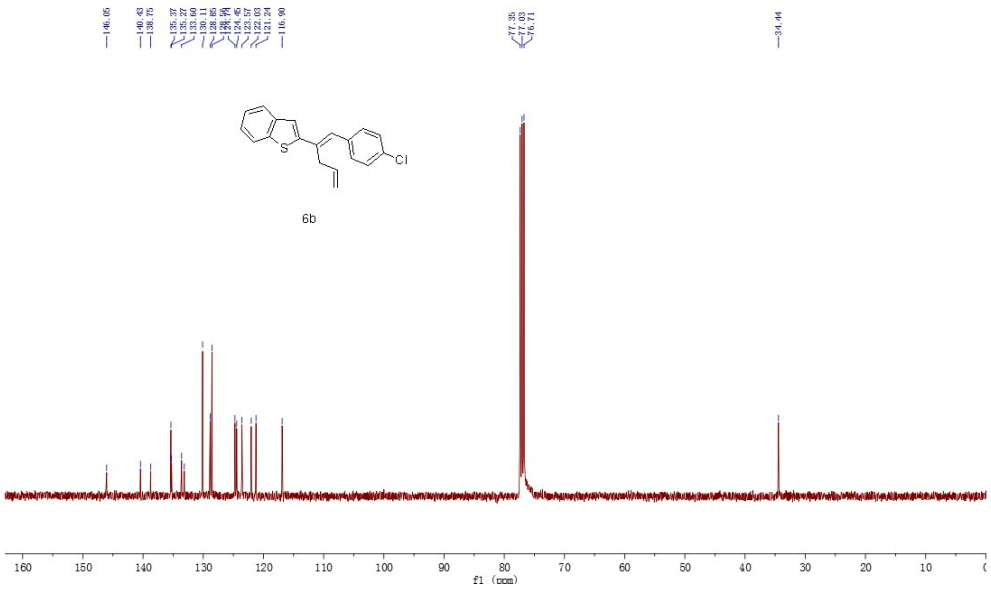
2.5
2.0
1.5
f1 (ppm)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122.03
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116.90
77.35
77.03
76.71
34.44
S
Cl
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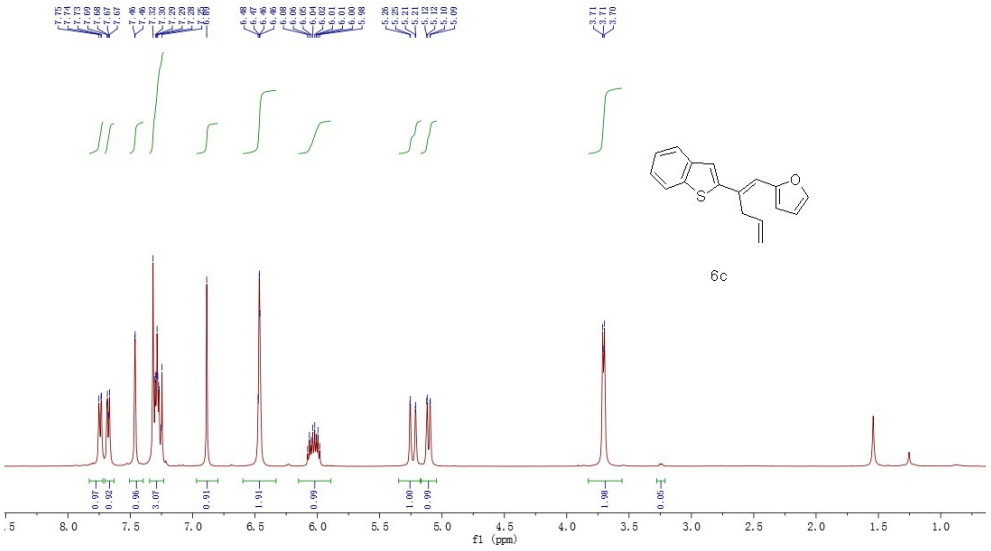
10
f1 (ppm)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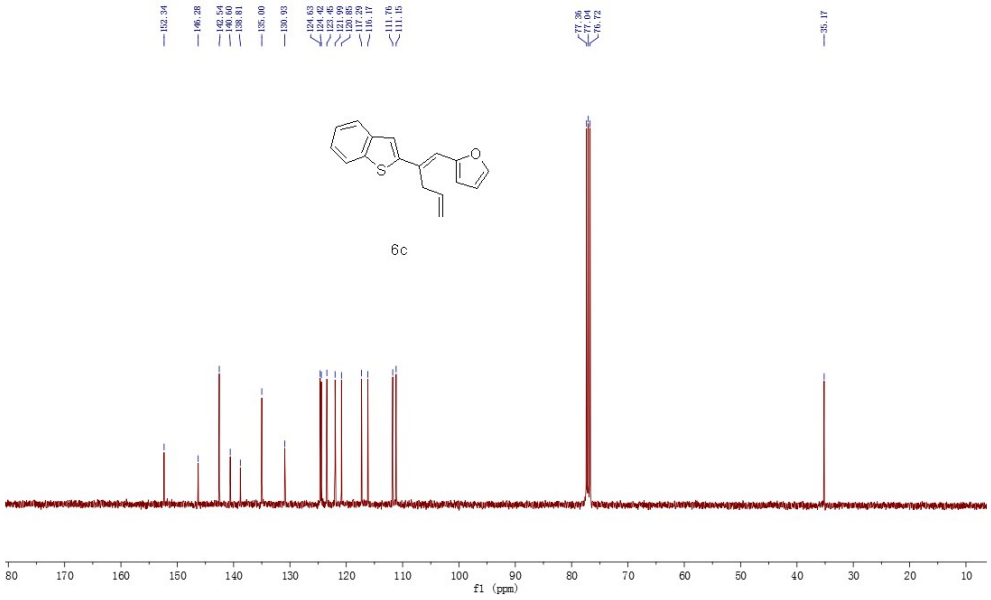
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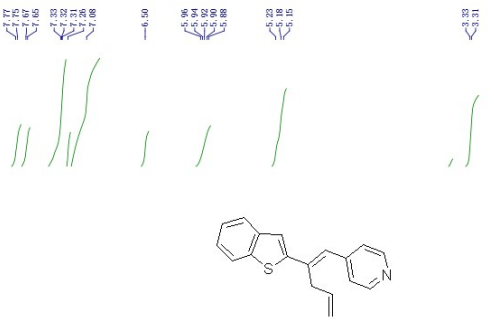
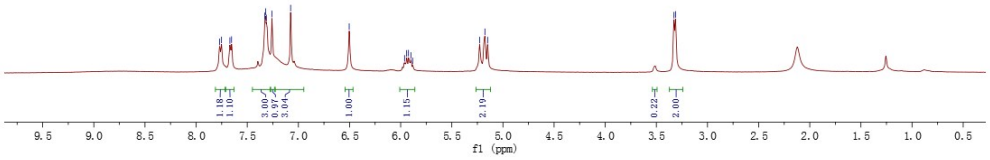
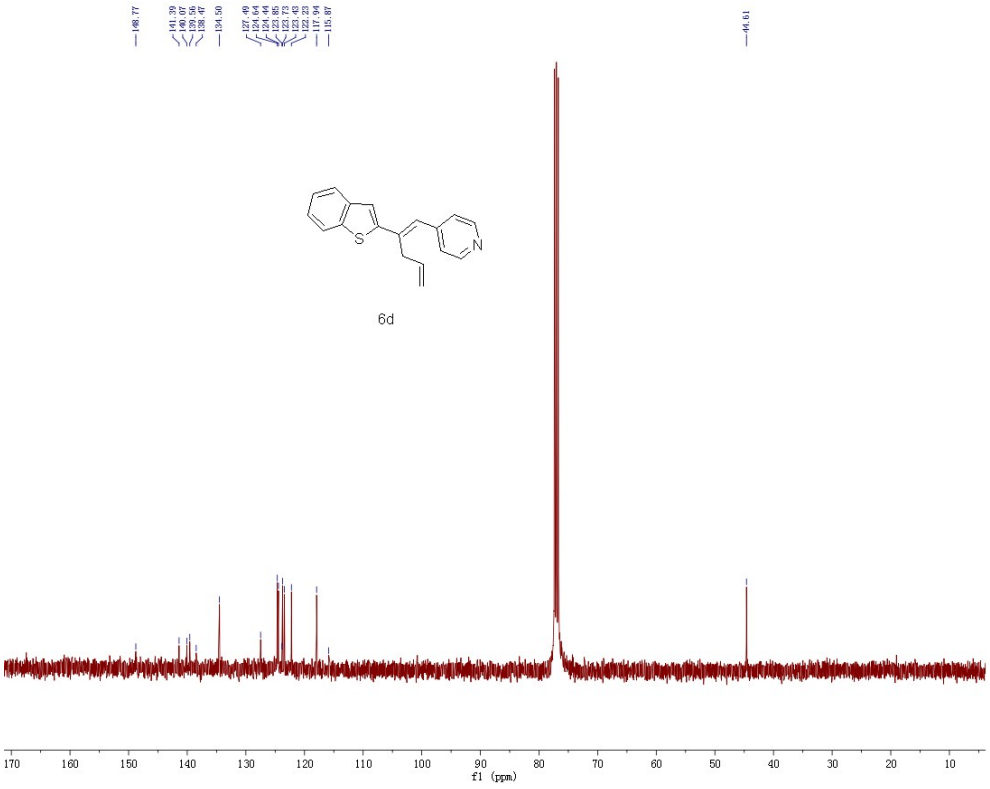
f1 (ppm)



6d





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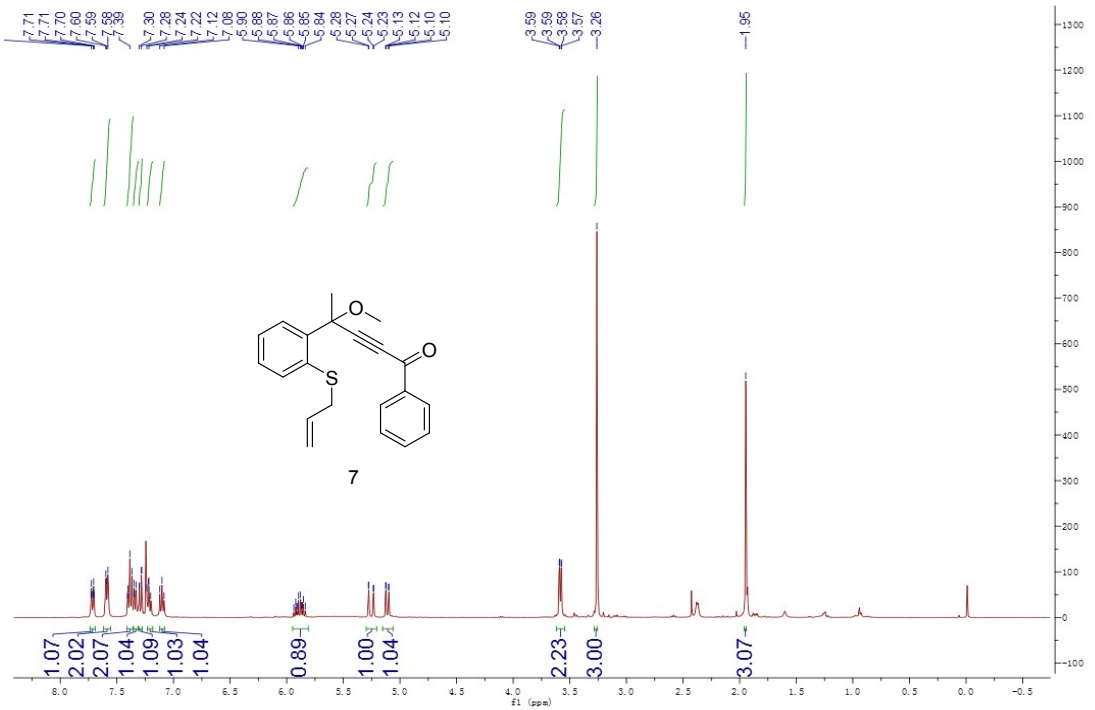
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5.23
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5.12
5.10
5.10
3.59
3.59
3.58
3.57
3.26
1.95
O
O
S
7
1.07
2.02
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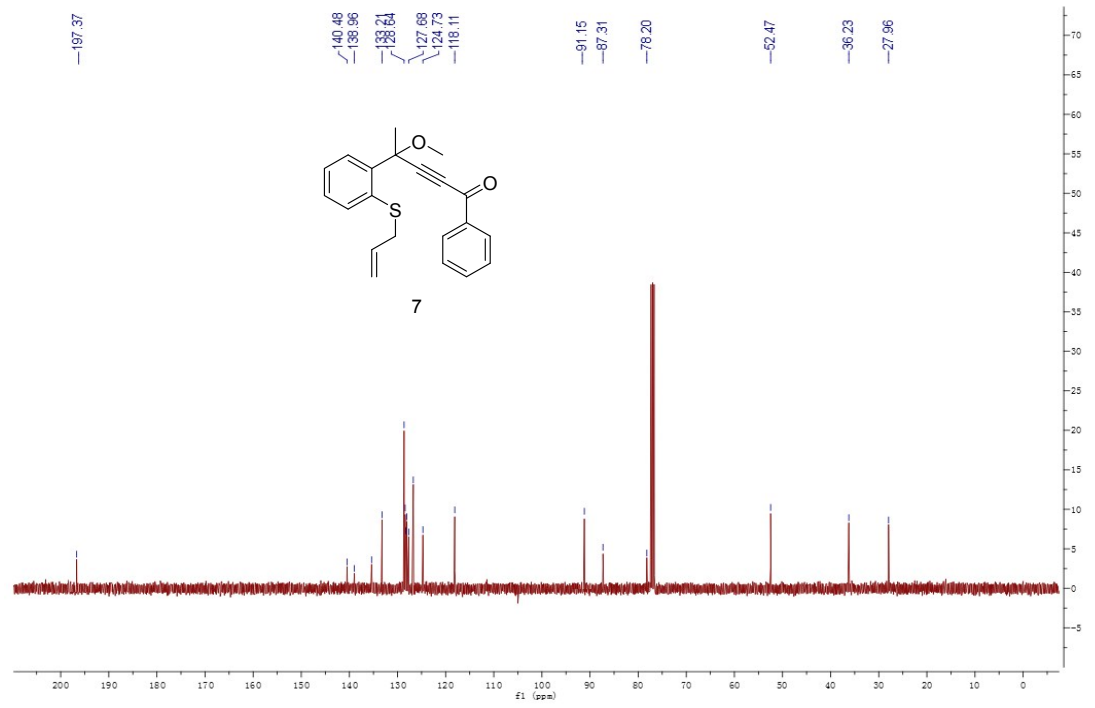
1.03
1.04
0.89
1.00
1.04
2.23
3.00
3.07
f1 (ppm)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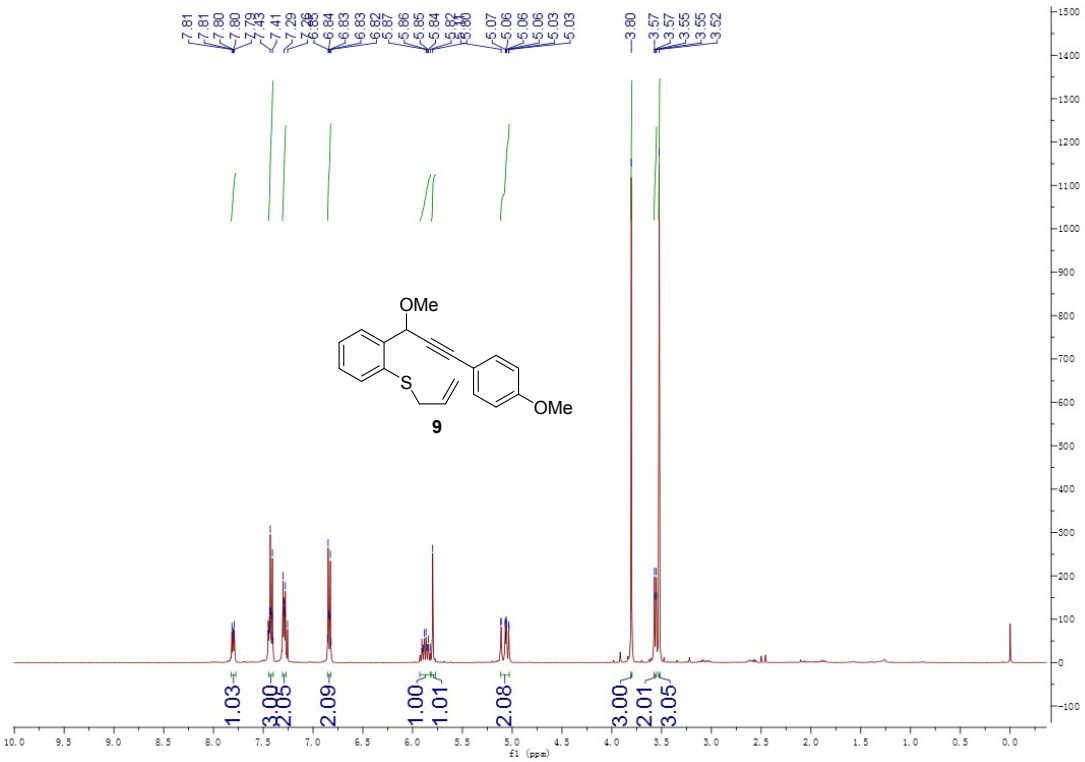
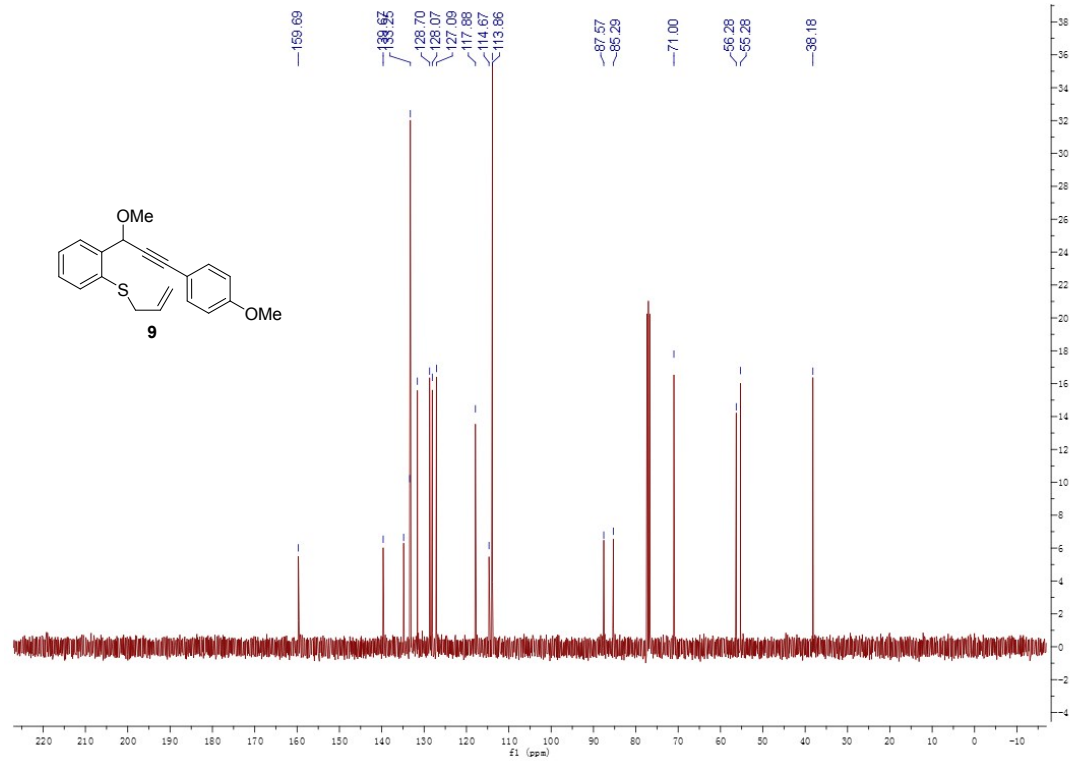
36.23
27.96
O
O
S
7
f1 (ppm)


OMe
S
OMe
9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OMe
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