

## Supporting Information

### Chiral amine-catalyzed asymmetric conjugate addition of aldehydes to $\alpha$ -phenylselenoenones as formal *Z*-allylating agents

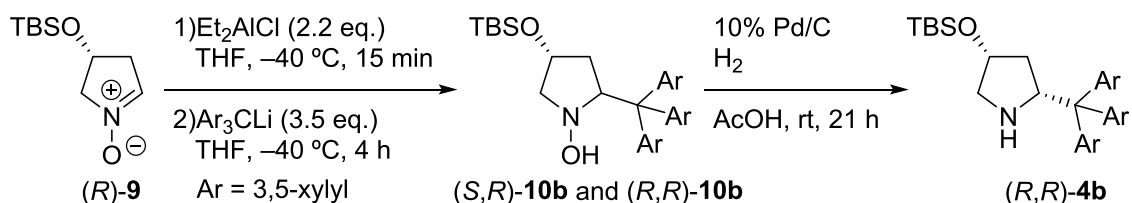
Taichi Kano\*, Hiroki Maruyama, Chihiro Homma and Keiji Maruoka\*

*Department of Chemistry, Graduate School of Science, Kyoto University*  
Sakyo, Kyoto 606-8502, Japan

**General Information.** Infrared (IR) spectra were recorded on a Shimadzu IRPrestige-21 spectrometer. <sup>1</sup>H NMR spectra were measured on a JEOL JNM-FX400 (400 MHz) spectrometer and a JEOL JNM-ECA500 (500 MHz) spectrometer. Data were reported as follows: chemical shifts in ppm from the residual solvent as an internal standard ( $\delta$  7.26 for CDCl<sub>3</sub> and  $\delta$  0.00 for TMS), integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, AB q = AB quartet, m = multiplet, br = broad, and app = apparent), and coupling constants (Hz). <sup>13</sup>C NMR spectra were measured on a JEOL JNM-FX500 (125 MHz) spectrometer with complete proton decoupling. Chemical shifts were reported in ppm from the residual solvent as an internal standard ( $\delta$  77.16 for CDCl<sub>3</sub>). High performance liquid chromatography (HPLC) was performed on Shimadzu 10A instruments using a Daicel CHIRALPAK AD-3, AS-H, IC, IC-3, ID, IE, IF and IG, 4.6 mm  $\times$  25 cm column. High-resolution mass spectra (HRMS) were performed on Thermo Scientific Exactive Plus. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter. For thin layer chromatography (TLC) analysis throughout this work, Merck precoated TLC plates (silica gel 60 GF<sub>254</sub>, 0.25 mm) were used. The products were purified by flash column chromatography on silica gel 60 (Merck 1.09386.9025, 230-400 mesh). For purification with preparative thin layer chromatography (PLC), Merck precoated PLC plates (silica gel 60 GF<sub>254</sub>, 0.5 mm) were used.

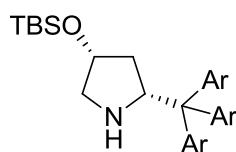
In experiments requiring dry solvents, tetrahydrofuran (THF) diethyl ether (Et<sub>2</sub>O), and dichloromethane (CH<sub>2</sub>Cl<sub>2</sub>) were purchased from Kanto Chemical Co. Inc. as “Dehydrated”. Commercially available aldehydes were distilled and stored under argon atmosphere at -20 °C. 1-Phenyl-2-phenylselanylbut-2-en-1-one (**1a**),<sup>1</sup> 3-(phenylselanyl)but-3-en-2-one<sup>1</sup> and catalysts (*S*)-**3**,<sup>2</sup> (*S,R*)-**4a**,<sup>3</sup> (*R,R*)-**4a**,<sup>3</sup> and nitrene (*R*)-**9**<sup>4</sup> were prepared according to the literature procedure.

### Preparation of catalyst (*R,R*)-**4b**<sup>3</sup>



To a solution of tris(3,5-xylyl)methane (3.5 mmol) in THF (3 mL) at  $0\text{ }^\circ\text{C}$  was added a 1.6 M hexane solution of *n*-butyllithium (2.2 mL) and the mixture was stirred for 2 h. In another round-bottom flask, a 1M hexane solution of  $\text{Et}_2\text{AlCl}$  (2.2 mL) was added to a solution of (*R*)-**9** (216 mg, 1 mmol) in THF (10 mL) at  $-40\text{ }^\circ\text{C}$  and the mixture was stirred for 15 min. To the solution of the deprotonated tris(3,5-xylyl)methane was added the solution containing (*R*)-**9** at  $-40\text{ }^\circ\text{C}$ . After stirring for 4 h, the mixture was quenched by aqueous  $\text{NH}_4\text{Cl}$  and aqueous Rochelle salt, and extracted with  $\text{Et}_2\text{O}$ . The organic phase was dried with  $\text{Na}_2\text{SO}_4$  and concentrated *in vacuo*. The crude mixture was roughly purified by silica gel column chromatography to give the mixture of (*S,R*)-**10b** and (*R,R*)-**10b**, which was immediately used for the next reaction to prevent the decomposition.

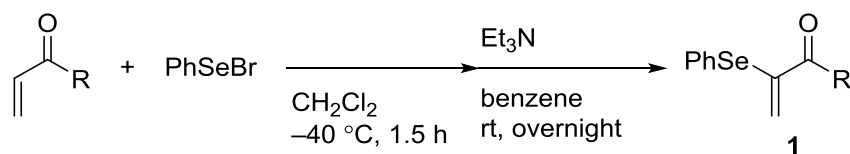
A solution of (*S,R*)-**10b**, (*R,R*)-**10b** and palladium 10% on carbon (68 mg) in acetic acid (12 mL) was stirred under  $\text{H}_2$  atmosphere at room temperature for 21 h. The mixture was filtered through celite with EtOAc and the filtrate was evaporated under reduced pressure. The residue was neutralized with saturated  $\text{NaHCO}_3$  and extracted with EtOAc. The organic phase was dried with  $\text{Na}_2\text{SO}_4$  and concentrated *in vacuo*. The residue was purified by silica gel chromatography (hexane/EtOAc = 10/1 as eluent) to yield (*R,R*)-**4b** (47.5 mg, 0.09 mmol, 9% yield) and (*S,R*)-**4b** (43% NMR yield), respectively, as white solid.



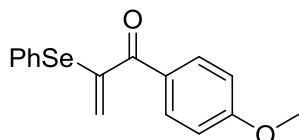
(*R,R*)-**4b** (Ar = 3,5-xylyl)

**Catalyst (*R,R*)-**4b****:  $[\alpha]_D^{21} = 13.0$  (*c* 0.8,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  6.96 (6H, s), 6.80 (3H, s), 4.50 (1H, dd,  $J = 9.7, 7.3$  Hz), 4.31–4.26 (1H, m), 2.77 (1H, dd,  $J = 11.2, 5.4$  Hz), 2.39 (1H, dd,  $J = 11.2, 3.7$  Hz), 2.28 (1H, dd,  $J = 13.5, 6.8$  Hz), 2.23 (18H, s), 1.50–1.43 (1H, m), 0.74 (9H, s),  $-0.09$  (6H, s);  $^{13}\text{C NMR}$  (125 MHz,  $\text{CDCl}_3$ )  $\delta$  136.6, 127.6 (3 peaks overlapped), 72.9, 62.9, 60.0, 55.6, 39.1, 25.7, 21.6, 17.9,  $-4.8$ ; IR (neat) 2952, 2926, 1596, 1472, 1251, 1065, 907, 836, 775, 733  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{35}\text{H}_{50}\text{NOSi}$ : 528.3656 ( $[\text{M} + \text{H}]^+$ ), Found: 528.3652 ( $[\text{M} + \text{H}]^+$ ).

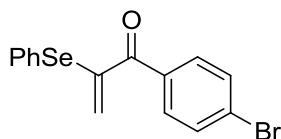
### General procedure for preparation of $\alpha$ -selenoenones



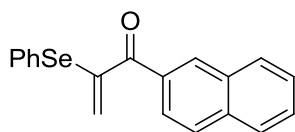
To a solution of phenylselenenyl bromide (20 mmol) in  $\text{CH}_2\text{Cl}_2$  (30 mL) was added a vinyl ketone (20 mmol) in  $\text{CH}_2\text{Cl}_2$  (10 mL) at  $-40\text{ }^\circ\text{C}$ . After stirring for 1.5 h, a solution of triethylamine (25 mmol) in benzene (40 mL) was added at  $-40\text{ }^\circ\text{C}$ . The mixture was stirred overnight at room temperature. Filtration and evaporation of solvents gave a crude product, which was purified by silica gel column chromatography. The obtained  $\alpha$ -selenoenones **1** were stored at  $-78\text{ }^\circ\text{C}$  under Ar atmosphere.



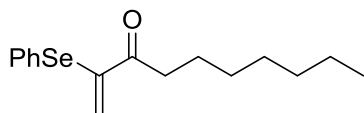
**1-(4-Methoxyphenyl)-2-(phenylselenanyl)prop-2-en-1-one**: 411 mg, 1.30 mmol, 24% yield;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.81 (2H, app d,  $J = 8.7$  Hz), 7.66-7.64 (2H, m), 7.40-7.33 (3H, m), 6.92 (2H, app d,  $J = 8.9$  Hz), 6.13 (1H, d,  $J = 1.2$  Hz), 5.66 (1H, d,  $J = 1.2$  Hz), 3.87 (3H, s);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  193.2, 163.5, 143.5, 136.4, 132.0, 129.6, 128.9, 128.8, 127.5, 124.5, 113.6, 55.5; IR (neat) 1642, 1597, 1508, 1253, 1174, 1134, 1023, 971, 844, 785, 742, 692  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{16}\text{H}_{14}\text{NaO}_2\text{Se}$ : 341.0051 ( $[\text{M} + \text{Na}]^+$ ), Found: 341.0056 ( $[\text{M} + \text{Na}]^+$ ).



**1-(4-Bromophenyl)-2-(phenylselenanyl)prop-2-en-1-one**: 452 mg, 1.23 mmol, 35% yield;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.65-7.62 (4H, m), 7.59-7.57 (2H, m), 7.40-7.36 (3H, m), 6.16 (1H, d,  $J = 1.5$  Hz), 5.72 (1H, d,  $J = 1.5$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  193.5, 143.7, 136.6, 135.0, 131.7, 131.0, 129.7, 129.1, 127.7, 126.9, 126.3; IR (neat) 1651, 1581, 1397, 1282, 1068, 971, 740  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{15}\text{H}_{11}\text{BrNaOSe}$ : 388.9051 ( $[\text{M} + \text{Na}]^+$ ), Found: 388.9047 ( $[\text{M} + \text{Na}]^+$ ).

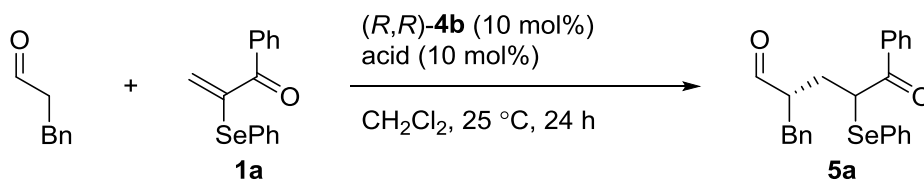


**1-(Naphthalen-2-yl)-2-(phenylselanyl)prop-2-en-1-one:** 150 mg, 0.44 mmol, 9% yield;  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.28 (1H, s), 7.94-7.84 (4H, m), 7.70 (2H, dd,  $J = 7.2, 2.1$  Hz), 7.61 (1H, app td,  $J = 7.5, 1.1$  Hz), 7.56 (1H, app t,  $J = 7.5$  Hz), 7.41-7.36 (3H, m), 6.27 (1H, d,  $J = 1.4$  Hz), 5.78 (1H, d,  $J = 1.1$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  194.5, 144.0, 136.6, 135.3, 133.5, 132.2, 131.1, 129.7, 129.4, 129.0, 128.4, 128.3, 127.8, 127.2, 126.8, 126.2, 125.2; IR (neat) 1644, 1625, 1279, 1112, 939, 764, 741  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{19}\text{H}_{14}\text{NaOSe}$ : 361.0102 ( $[\text{M} + \text{Na}]^+$ ), Found: 361.0108 ( $[\text{M} + \text{Na}]^+$ ).



**2-(Phenylselanyl)dec-1-en-3-one:** 1.30 g, 4.20 mmol, 48% yield;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.59 (2H, app dd,  $J = 7.6, 1.8$  Hz), 7.39-7.36 (3H, m), 6.46 (1H, d,  $J = 1.7$  Hz), 5.47 (1H, d,  $J = 1.7$  Hz), 2.75 (2H, t,  $J = 7.4$  Hz), 1.68-1.61 (2H, m), 1.30-1.27 (8H, m), 0.88 (3H, t,  $J = 6.8$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  199.0, 146.3, 136.8, 129.7, 128.9, 127.2, 123.2, 37.7, 31.6, 29.2, 29.0, 24.5, 22.6, 14.1; IR (neat) 2925, 1675, 1590, 740, 692  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{16}\text{H}_{22}\text{NaOSe}$ : 333.0728 ( $[\text{M} + \text{Na}]^+$ ), Found: 333.0731 ( $[\text{M} + \text{Na}]^+$ ).

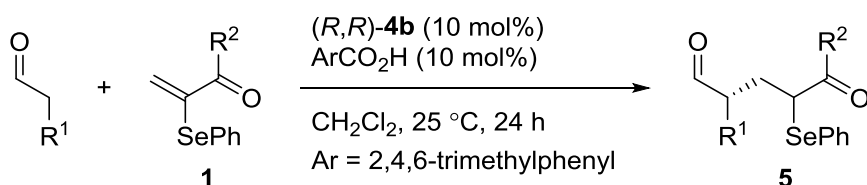
### Screening of acid catalyst for the amine-catalyzed conjugate addition to $\alpha$ -selenoenone **1a**



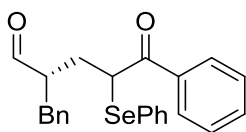
entry	acid	Yield [%] <sup>ab</sup>	dr <sup>c</sup>	ee [%] <sup>d</sup>
1	benzoic acid	66	3.8/1	99/85
2	acetic acid	57	3.0/1	98/92
3	4-nitrobenzoic acid	59	2.6/1	90/48
4	4-nitrophenol	76	2.0/1	95/85
5	2,4,6-trimethylbenzoic acid	75	2.4/1	98/88

<sup>a</sup> The reaction of 3-phenylpropanal (0.3 mmol) with  $\alpha$ -selenoenone **1a** (0.1 mmol) was carried out in the presence of (*R,R*)-**4b** (0.01 mmol) and an acid (0.01 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (0.1 mL) at 25 °C. <sup>b</sup> <sup>1</sup>H-NMR yield utilizing mesitylene as an internal standard. <sup>c</sup> Determined by <sup>1</sup>H-NMR. <sup>d</sup> Determined by HPLC analysis using a chiral column.

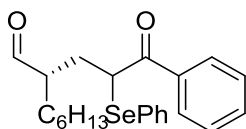
### General procedure for the asymmetric conjugate addition catalyzed by chiral amine (*R,R*)-**4b**



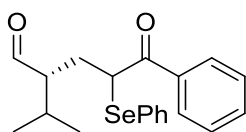
To a solution of amine catalyst (*R,R*)-**4b** (0.01 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (0.1 mL) in a test tube were added an aldehyde (0.3 mmol) and  $\alpha$ -selenoenone **1** (0.1 mmol) at 25 °C under Ar atmosphere. After capping the test tube, the mixture was stirred for 24 h. All volatiles were subsequently removed *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel to afford the corresponding product **5** as an inseparable diastereomeric mixture.



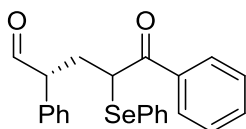
**2-Benzyl-5-oxo-5-phenyl-4-(phenylselanyl)pentanal (5a)** (Table 2, entry 1): 35.4 mg, 0.084 mmol, 84% yield, 2.2/1 dr;  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.73 (0.69H, d,  $J = 1.7$  Hz), 9.65 (0.31H, d,  $J = 1.7$  Hz), 7.75-7.73 (2H, m), 7.52 (1H, app t,  $J = 7.4$  Hz), 7.39 (2H, app t,  $J = 7.9$  Hz), 7.35-7.32 (1H, m), 7.31-7.23 (4H, m), 7.21-7.12 (5H, m), 4.55-4.50 (1H, m), 3.12 (0.69H, dd,  $J = 13.5, 6.1$  Hz), 3.09-3.02 (1H, m), 2.85-2.78 (0.69H, m), 2.67 (0.69H, dd,  $J = 13.5, 8.1$  Hz), 2.36-2.25 (1H, m), 2.18 (0.31H, ddd,  $J = 14.3, 9.2, 4.9$  Hz), 1.92 (0.69H, ddd,  $J = 14.9, 8.7, 4.5$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  203.6, 195.0, 138.3, 136.6, 135.8, 132.9, 129.12, 129.06 (2 peaks overlapped), 128.8, 128.4, 128.3, 126.7, 125.9, 51.7, 43.5, 35.7, 29.1; minor diastereomer  $\delta$  203.9, 195.2, 137.9, 136.4, 136.0, 133.0, 128.9, 128.7, 128.5, 128.2, 126.5, 126.1, 51.4, 42.6, 36.0, 30.5 (aromatic 2 peaks overlapped); IR (neat) 1721, 1669, 1447, 1240, 741, 701,  $691\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{24}\text{H}_{22}\text{NaO}_2\text{Se}$ : 445.0677 ( $[\text{M} + \text{Na}]^+$ ), Found: 445.0683 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IC, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 12.2 min and 13.0 min (major), minor diastereomer 11.0 min (major) and 14.6 min.



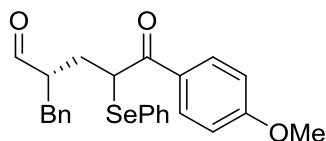
**2-(3-Oxo-3-phenyl-2-(phenylselanyl)propyl)octanal (5b)** (Table 2, entry 2): 28.8 mg, 0.069 mmol, 69% yield, 2.2/1 dr;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  9.61 (0.69H, d,  $J = 2.2$  Hz), 9.59 (0.31H, d,  $J = 1.9$  Hz), 7.85 (2H, major diastereomer d,  $J = 7.5$  Hz), 7.53 (1H, app t,  $J = 7.4$  Hz), 7.44-7.33 (5H, m), 7.28-7.24 (2H, m), 4.62 (1H, major diastereomer dd,  $J = 8.8, 5.9$  Hz), 2.78-2.71 (0.69H, m), 2.33-2.23 (1.62H, m), 1.96-1.89 (0.69H, m), 1.72-1.63 (1H, m), 1.50-1.43 (1H, m), 1.29-1.26 (8H, m), 0.89-0.85 (3H, m);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  204.6, 195.5, 136.5, 135.9, 132.9, 129.1 (2 peaks overlapped), 128.5, 128.3, 126.4, 50.0, 43.7, 31.5, 29.32 (2 peaks overlapped), 29.28, 26.9, 22.5, 14.0; minor diastereomer  $\delta$  204.7, 195.3, 136.3, 136.2, 133.0, 129.1, 128.5, 128.4, 126.8, 50.8, 42.5, 31.5, 30.7, 29.6, 29.2, 26.8 (aromatic 1 peak and aliphatic 2 peaks overlapped); IR (neat) 2926, 2855, 1721, 1670, 1447, 1438, 1236, 740,  $690\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{23}\text{H}_{28}\text{NaO}_2\text{Se}$ : 439.1147 ( $[\text{M} + \text{Na}]^+$ ), Found: 439.1151 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IF, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 7.6 min and 8.8 min (major), minor diastereomer 6.5 min (major) and 7.0 min.



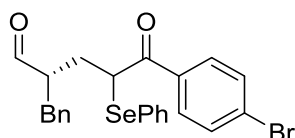
**2-Isopropyl-5-oxo-5-phenyl-4-(phenylselanyl)pentanal (5c)** (Table 2, entry 3): 27.7 mg, 0.074 mmol, 74% yield, 2.4/1 dr;  $^1\text{H NMR}$  (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.70 (0.71 H, d,  $J = 2.0$  Hz), 9.65 (0.29 H, d,  $J = 2.3$  Hz), 7.85 (1.4H, d,  $J = 7.1$ Hz), 7.80 (0.58H, d,  $J = 7.1$  Hz), 7.55-7.51 (1 H, m), 7.45-7.32 (5H, m), 7.28-7.23 (2H, m), 4.67 (0.29H, dd,  $J = 8.4, 6.7$  Hz), 4.59 (0.71H, dd,  $J = 10.2, 4.5$  Hz), 2.78-2.75 (0.71H, m), 2.28 (0.58H, app t,  $J = 7.1$  Hz), 2.25-2.19 (0.71H, m), 2.17-2.08 (1.29H, m), 1.93-1.85 (0.71H, m), 1.01 (3H, d,  $J = 6.8$  Hz), 0.96 (3H, d,  $J = 7.1$  Hz);  $^{13}\text{C NMR}$  (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  205.2, 195.9, 136.4, 136.1, 132.9, 129.12, 129.08, 128.5, 128.4, 126.4, 55.8, 44.4, 28.6, 25.7, 20.3, 19.5; minor diastereomer  $\delta$  205.2, 195.4, 136.0, 133.0, 128.9, 128.5, 128.3, 56.8, 42.8, 28.8, 27.8, 20.0, 19.3 (aromatic 3 peaks overlapped); IR (neat) 2960, 1716, 1671, 1578, 1475, 1447, 1438, 1284, 1250, 741, 709, 691  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{20}\text{H}_{22}\text{NaO}_2\text{S}$ : 397.0677 ( $[\text{M} + \text{Na}]^+$ ), Found: 397.0685 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IC, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 7.9 min and 9.4 min (major), minor diastereomer 6.3 min (major) and 7.1 min.



**5-Oxo-2,5-diphenyl-4-(phenylselanyl)pentanal (5d)** (Table 2, entry 4): 15.4 mg, 0.038 mmol, 38% yield, 1.7/1 dr;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  9.70 (0.37H, s), 9.66 (0.63H, s), 7.73 (0.74H, dd,  $J = 7.4, 1.1$  Hz), 7.67 (1.26H, dd,  $J = 7.4, 1.1$  Hz), 7.54-7.49 (1H, m), 7.38-7.31 (8H, m), 7.26-7.20 (2.74H, m,  $\text{CHCl}_3$  overlapped), 7.07-7.05 (1.26H, m), 4.53 (0.37H, app t,  $J = 7.4$  Hz), 4.39 (0.63H, dd,  $J = 9.2, 6.0$  Hz), 3.90 (0.37H, t,  $J = 7.4$  Hz), 3.79 (0.63H, t,  $J = 7.5$  Hz), 2.82-2.74 (0.63H, m), 2.68-2.60 (0.37H, m), 2.43-2.29 (1H, m);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  199.5, 195.2, 136.4, 136.2, 135.2, 132.9, 129.3, 129.2, 129.12, 129.07, 128.5, 128.3, 128.2, 126.4, 57.2, 42.6, 31.4; minor diastereomer  $\delta$  200.1, 195.1, 136.4, 136.0, 135.5, 129.3, 129.0, 128.0, 126.3, 57.3, 43.0, 31.2 (aromatic 5 peaks overlapped); IR (neat) 1720, 1669, 1447, 1438, 1283, 1231, 741, 702, 690  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{23}\text{H}_{20}\text{NaO}_2\text{Se}$ : 431.0521 ( $[\text{M} + \text{Na}]^+$ ), Found: 431.0516 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IC, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 10.4 min and 11.8 min (major), minor diastereomer 12.9 min (major) and 14.9 min.

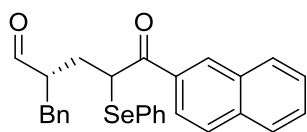


**2-Benzyl-5-(4-methoxyphenyl)-5-oxo-4-(phenylselanyl)pentanal (5e)** (Table 2, entry 5): 26.5 mg, 0.059 mmol, 59% yield, 2.0/1 dr;  $^1\text{H NMR}$  (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.71 (0.66H, app s), 9.63 (0.33H, app s), 7.73 (2H, d,  $J = 8.8$  Hz), 7.39-7.22 (5H,  $\text{CHCl}_3$  overlapped, m), 7.21-7.13 (5H, m), 6.86 (2H, d,  $J = 8.8$  Hz), 4.52-4.45 (1H, m), 3.86 (2H, s), 3.85 (1H, s), 3.09 (0.66H, dd,  $J = 13.7, 6.1$  Hz), 3.04-3.00 (1H, m), 2.81-2.77 (0.66H, m), 2.67 (0.66H, dd,  $J = 13.6, 7.9$  Hz), 2.38-2.32 (0.66H, m), 2.27-2.20 (0.66H, m), 1.95-1.89 (0.66H, m);  $^{13}\text{C NMR}$  (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  203.6, 194.0, 163.4, 138.3, 136.5, 130.6, 129.1, 129.04, 129.00, 128.8, 128.7, 126.6, 113.6, 55.5, 51.8, 43.3, 35.7, 29.5 (aromatic 1 peak overlapped); minor diastereomer  $\delta$  203.9, 194.1, 163.5, 138.0, 136.3, 130.6, 129.1, 128.9, 128.6, 126.3, 113.7, 51.5, 42.4, 36.0, 30.8 (aromatic 3 peaks and aliphatic 1 peak overlapped); IR (neat) 1720, 1661, 1599, 1257, 1171, 741, 693  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{26}\text{H}_{28}\text{NaO}_4\text{Se}$ : 507.1045 ( $[\text{M} + \text{Na} + \text{MeOH}]^+$ ), Found: 507.1047( $[\text{M} + \text{Na} + \text{MeOH}]^+$ ); HPLC analysis: Daicel Chiralpak IF, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 27.1 min and 36.3 min (major), minor diastereomer 20.7 min and 23.4 min (major).

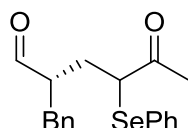


**2-Benzyl-5-(4-bromophenyl)-5-oxo-4-(phenylselanyl)pentanal (5f)** (Table 2, entry 6): 39.7 mg, 0.079 mmol, 79% yield, 2.8/1 dr;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  9.74 (0.74H, d,  $J = 0.7$  Hz), 9.65 (0.26H, d,  $J = 1.0$  Hz), 7.57 (2H, d,  $J = 8.5$  Hz), 7.51 (2H, d,  $J = 8.5$  Hz), 7.37-7.21 (5H,  $\text{CHCl}_3$  overlapped, m), 7.18-7.15 (3.52H, m), 7.09 (1.48H, d,  $J = 7.0$  Hz), 4.43 (1H, dd,  $J = 8.2, 6.3$  Hz), 3.14 (0.74H, dd,  $J = 13.8, 5.8$  Hz), 3.09-3.02 (1H, m), 2.86-2.76 (0.52H, m), 2.66 (0.74H, dd,  $J = 13.5, 8.5$  Hz), 2.35-2.24 (1H, m), 2.19-2.12 (0.26H, m), 1.95-1.88 (0.74H, m);  $^{13}\text{C NMR}$  (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  203.5, 193.9, 138.2, 136.6, 134.6, 131.7, 129.8, 129.3, 129.1, 129.0, 128.9, 127.9, 126.7, 125.7, 51.6, 43.5, 35.7, 29.0; minor diastereomer  $\delta$  203.8, 194.1, 137.9, 136.4, 134.8, 131.7, 129.7, 129.2, 128.9, 128.7, 128.1, 126.3, 51.3, 42.7, 36.0, 30.4 (aromatic 2 peaks overlapped); IR (neat) 3059, 1721, 1669, 1584, 1071, 1009, 742, 701  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{25}\text{H}_{25}\text{NaO}_2\text{Se}$ : 555.0045 ( $[\text{M} + \text{Na} + \text{MeOH}]^+$ ), Found: 555.0039 ( $[\text{M} + \text{Na} + \text{MeOH}]^+$ ); HPLC analysis: Daicel Chiralpak IG, hexane/*i*-PrOH = 8/1, flow rate = 1.0 mL/min, retention time; major diastereomer 17.7 min and 22.2 min (major), minor diastereomer 15.8 min and 19.5 (major) min.

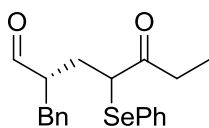




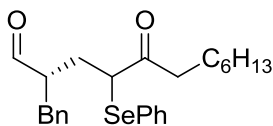
**2-Benzyl-5-(naphthalen-2-yl)-5-oxo-4-(phenylselanyl)pentanal (5g)** (Table 2, entry 7): 32.3 mg, 0.068 mmol, 68% yield, 2.3/1dr;  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.77 (0.70H, d,  $J = 1.4$  Hz), 9.68 (0.30H, d,  $J = 1.7$  Hz), 8.06 (1H, s), 7.89-7.83 (3H, m), 7.79 (1H, d,  $J = 8.2$  Hz), 7.57 (1H, app t,  $J = 7.5$  Hz), 7.51 (1H, app t,  $J = 7.4$  Hz), 7.37 (0.70H, d,  $J = 7.1$  Hz), 7.34-7.26 (2.3H,  $\text{CHCl}_3$  overlapped, m), 7.24-7.20 (2H, m), 7.19-7.15 (5H, m), 4.65-4.60 (1H, m), 3.15 (0.70H, dd,  $J = 13.6, 6.0$  Hz), 3.12-3.07 (1H, m), 2.95-2.89 (0.30H, m), 2.82 (0.30H, dd,  $J = 13.9, 7.1$  Hz), 2.70 (0.70H, dd,  $J = 13.3, 8.2$  Hz), 2.46-2.40 (0.70H, m), 2.39-2.33 (0.30H, m), 2.26-2.20 (0.30H, m), 2.03-1.97 (0.70H, m);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  203.6, 195.0, 138.3, 136.6, 135.5, 133.1, 132.3, 129.7, 129.6, 129.12, 129.07 (2 peaks overlapped), 128.8, 128.4, 128.3, 127.7, 126.7, 126.63, 126.59, 124.3, 51.8, 43.9, 35.7, 29.4; minor diastereomer  $\delta$  203.8, 195.2, 138.0, 136.5, 133.2, 132.3, 129.2, 129.0, 128.7, 128.4, 126.8, 126.4, 124.2, 51.4, 43.1, 36.0, 30.5 (aromatic 7 peaks overlapped); IR (neat) 1720, 1663, 1437, 1279, 760, 738, 700, 692  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{28}\text{H}_{24}\text{NaO}_2\text{Se}$ : 495.0834 ( $[\text{M} + \text{Na}]^+$ ), Found: 495.0834 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IF, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; major diastereomer 22.8 min and 25.7 min (major), minor diastereomer 17.5 min and 20.8 min (major).



**2-Benzyl-5-oxo-4-(phenylselanyl)hexanal (5h)** (Table 2, entry 8): 26.6 mg, 0.074 mmol, 74% yield, 3.5/1 dr;  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.68 (0.78H, app s), 9.62 (0.22H, app s), 7.46 (0.44H, d,  $J = 7.7$  Hz), 7.36 (0.22H, app t,  $J = 6.7$  Hz), 7.33-7.30 (2.34H, m), 7.27-7.18 (5H, m,  $\text{CHCl}_3$  overlapped), 7.16 (1.56H, d,  $J = 7.9$  Hz), 7.12 (0.44H, d,  $J = 7.9$  Hz), 3.67-3.62 (1H, m), 3.09 (0.78H, dd,  $J = 13.7, 6.1$  Hz), 3.03-2.95 (1H, m), 2.78-2.73 (0.44H, m), 2.63 (0.78H, dd,  $J = 13.7, 8.1$  Hz), 2.24 (2.34H, s), 2.23 (0.66H, s), 2.17-2.10 (0.78H, m), 2.07 (0.22H, app t,  $J = 6.8$  Hz), 1.99-1.93 (0.22H, m), 1.72-1.66 (0.78H, m);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  203.5, 203.2, 138.1, 135.8, 129.2, 129.0 (2 peaks overlapped), 128.8, 126.7, 125.8, 51.6, 49.6, 35.6, 28.3, 28.1; minor diastereomer  $\delta$  203.6, 203.4, 136.0, 129.3, 128.9, 128.7, 48.8, 35.7, 29.6 (aromatic 4 peaks and aliphatic 2 peaks overlapped); IR (neat) 1721, 1699, 1454, 1437, 1356, 742, 701, 693  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{20}\text{H}_{24}\text{NaO}_3\text{Se}$ : 415.0783 ( $[\text{M} + \text{Na} + \text{MeOH}]^+$ ), Found: 415.0794 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak AS-H, hexane/*i*-PrOH = 30/1, flow rate = 1.0 mL/min, retention time; major diastereomer 17.5 min (major) and 28.5 min, minor diastereomer 16.3 min and 24.1 min (major).

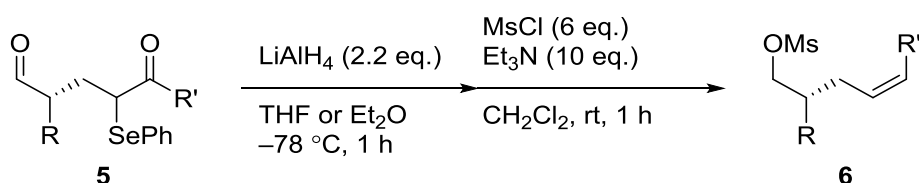


**2-Benzyl-5-oxo-4-(phenylselanyl)heptanal (5i) (Table 2, entry 9):** 20.8 mg, 0.056 mmol, 56% yield, 3.5/1 dr;  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.66 (0.78H, d,  $J = 1.1$  Hz), 9.61 (0.22H, d,  $J = 1.1$  Hz), 7.45 (0.44H, app d,  $J = 8.2$  Hz), 7.37-7.27 (4H, m), 7.26-7.19 (3.56H, m), 7.16-7.11 (2H, m), 3.65 (1H, dd,  $J = 8.8, 6.2$  Hz), 3.07 (0.78H, dd,  $J = 13.6, 6.2$  Hz), 2.99-2.95 (1H, m), 2.85-2.70 (1.44H, m), 2.63 (0.78H, dd,  $J = 13.7, 8.1$  Hz), 2.41-2.28 (1H, m), 2.18-2.12 (0.78H, m), 2.08 (0.22H, dd,  $J = 15.0, 7.4$  Hz), 2.02-1.96 (0.22H, m), 17.3 (0.78H, ddd,  $J = 15.0, 8.9, 4.6$  Hz), 1.05 (3H, td,  $J = 7.2, 0.9$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  206.1, 203.5, 138.1, 136.0, 129.2, 129.0, 128.9, 128.8, 126.7, 126.0, 51.7, 48.5, 35.6, 33.8, 28.5, 8.3; minor diastereomer  $\delta$  206.2, 203.6, 137.9, 135.8, 129.2, 129.0, 128.9, 128.6, 51.6, 47.7, 35.7, 34.0, 29.8 (aromatic 2 peaks and aliphatic 1 peak overlapped); IR (neat) 2935, 1720, 1699, 1455, 1437, 740, 700, 692  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{20}\text{H}_{22}\text{NNaO}_2\text{Se}$ : 397.0677 ( $[\text{M} + \text{Na}]^+$ ), Found: 397.0686 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IC3, hexane/*i*-PrOH = 20/1, flow rate = 0.75 mL/min, retention time; major diastereomer 22.6 min and 25.3 min (major), minor diastereomer 24.3 min (major) and 29.7 min.



**2-Benzyl-5-oxo-4-(phenylselanyl)dodecanal (5j) (Table 2, entry 11):** 26.5 mg, 0.060 mmol, 60% yield, 3.7/1 dr;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  9.66 (0.79H, d,  $J = 1.7$  Hz), 9.61 (0.21H, d,  $J = 1.7$  Hz), 7.45 (0.42H, app d,  $J = 6.8$  Hz), 7.38-7.26 (3.58H, m), 7.26-7.19 (4H, m), 7.16-7.11 (2H, m), 3.63 (1H, dd,  $J = 8.7, 6.3$  Hz), 3.06 (0.79H, dd,  $J = 13.7, 6.4$  Hz), 3.00-2.92 (1H, m), 2.80-2.69 (1H, m), 2.67-2.58 (1.21H, m), 2.43-2.31 (1H, m), 2.14 (0.79H, ddd,  $J = 15.2, 9.0, 6.1$  Hz), 2.08-2.05 (0.21H, m), 2.01-1.94 (0.21H, m), 1.72 (0.79H, ddd,  $J = 14.9, 8.7, 4.4$  Hz), 1.53 (2H, br s,  $\text{H}_2\text{O}$  overlapped), 1.25 (8H, br s), 0.88 (3H, t,  $J = 6.8$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) major diastereomer  $\delta$  205.7, 203.5, 138.1, 136.0, 129.2, 129.0, 128.9, 128.8, 126.7, 126.1, 51.7, 48.7, 40.8, 35.6, 31.7, 29.1, 29.0, 28.5, 24.2, 22.6, 14.1; minor diastereomer  $\delta$  205.8, 203.6, 137.9, 135.8, 129.2, 128.7, 51.6, 48.0, 40.9, 35.7, 29.7, 29.1, 29.0, 24.2 (aromatic 4 peaks and aliphatic 3 peaks overlapped); IR (neat) 2925, 2854, 1721, 1700, 1609, 741, 700, 693  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{25}\text{H}_{32}\text{NaO}_2\text{Se}$ : 467.1460 ( $[\text{M} + \text{Na}]^+$ ), Found: 467.1458 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak ID, hexane/*i*-PrOH = 20/1, flow rate = 1.0 mL/min, retention time; major diastereomer 9.0 min and 12.1 min (major), minor diastereomer 9.6 min (major) and 10.5 min.

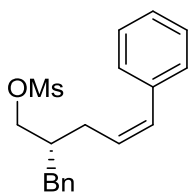
### Typical procedure for the olefination of conjugate adducts **5**



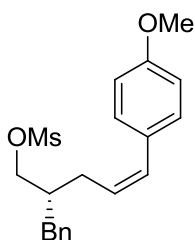
To a solution of conjugate adduct **5** (0.14 mmol) in THF and/or Et<sub>2</sub>O (3 mL; Et<sub>2</sub>O (Table 3, entries 1-2); THF/Et<sub>2</sub>O (1/1) (Table 3, entry 3); THF (Table 3, entries 4-6)) was added LiAlH<sub>4</sub> (11.7 mg, 0.31 mmol) in THF or Et<sub>2</sub>O slowly. After stirring for 1 h, the reaction was quenched with aqueous NH<sub>4</sub>Cl. The resulting mixture was diluted with 4 mL of a mixture of EtOAc/Et<sub>3</sub>N/MeOH (87/10/3). After celite filtration, the filtrate was extracted with EtOAc. The combined organic extracts were washed with brine, dried over Na<sub>2</sub>SO<sub>4</sub> and concentrated *in vacuo*. The crude product was used for the next step without further purification.

The crude alcohol was dissolved in CH<sub>2</sub>Cl<sub>2</sub>. The solution was cooled to -20 °C and added Et<sub>3</sub>N (194 μL, 1.4 mmol) followed by MsCl (65 μL, 0.84 mmol). The reaction mixture was warmed to room temperature and stirred for 1 h. The reaction was quenched with water and the resulting mixture was extracted with CH<sub>2</sub>Cl<sub>2</sub>. The combined organic extracts were dried with Na<sub>2</sub>SO<sub>4</sub> and concentrated *in vacuo*. The crude product was purified by column chromatography on silica gel.

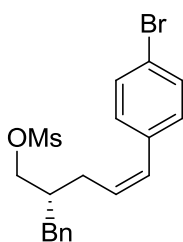
The *Z*-configuration of the olefin **6a** was confirmed by comparing the <sup>1</sup>H-NMR chemical shifts and coupling constants of the olefin moiety (6.56 (1H, d, *J* = 11.6 Hz), 5.66 (1H, dt, *J* = 11.6, 7.4 Hz)) with those of the corresponding *E*-isomer (6.46 (1H, d, *J* = 15.6 Hz), 6.17 (1H, dt, *J* = 15.9, 7.4 Hz)). The *E*-isomer was synthesized by asymmetric allylation of aldehydes according to the Córdoba's procedure. (See S15-S16)



**(Z)-2-Benzyl-5-phenylpent-4-en-1-yl methanesulfonate (6a)** (Table 3, entry 1): Reduction was conducted in Et<sub>2</sub>O. 38.2 mg, 0.116 mmol, 84% yield, *Z/E* = >20/1, 95% ee;  $[\alpha]_{\text{D}}^{25} = 31.3$  (*c* 1.10, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.31-7.27 (3H, m), 7.25-7.20 (5H, m), 7.14-7.12 (2H, m), 6.56 (1H, d, *J* = 11.6 Hz), 5.66 (1H, dt, *J* = 11.6, 7.4 Hz), 4.08 (2H, d, *J* = 5.1 Hz), 2.81 (3H, s), 2.70 (2H, d, *J* = 7.3 Hz), 2.49 (1H, ddd, *J* = 15.0, 7.6, 1.6 Hz), 2.42 (1H, ddd, *J* = 14.9, 6.9, 1.9 Hz), 2.20-2.14 (1H, m); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  138.9, 137.0, 131.4, 129.1, 129.0, 128.7, 128.5, 128.2, 126.8, 126.4, 70.9, 40.7, 36.9 (2 peaks overlapped), 29.1; IR (neat) 1352, 1172, 940, 834, 698 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>19</sub>H<sub>22</sub>NaO<sub>3</sub>S: 353.1182 ([M + Na]<sup>+</sup>), Found: 353.1186 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak IC, hexane/*i*-PrOH = 10/1, flow rate = 1.0 mL/min, retention time; 22.4 min and 24.1 min (major).

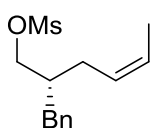


**(Z)-2-Benzyl-5-(4-methoxyphenyl)pent-4-en-1-yl methanesulfonate (6e)** (Table 3, entry 2): Reduction was conducted in Et<sub>2</sub>O. 31.2 mg, 0.087 mmol, 81% yield, *Z/E* = 19/1, 95% ee;  $[\alpha]_{\text{D}}^{25} = 31.8$  (*c* 0.98, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.29-7.28 (2H, m), 7.22 (1H, d, *J* = 7.2 Hz), 7.19-7.13 (4H, m), 6.85 (2H, d, *J* = 8.7 Hz), 6.48 (1H, d, *J* = 11.6 Hz), 5.57 (1H, dt, *J* = 11.6, 7.2 Hz), 4.09 (2H, d, *J* = 5.1 Hz), 3.81 (3H, s), 2.83 (3H, s), 2.71 (2H, d, *J* = 7.2 Hz), 2.49-2.40 (2H, m), 2.19-2.14 (1H, m); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  158.4, 138.9, 130.8, 129.9, 129.7, 129.1, 128.5, 127.3, 126.4, 113.7, 71.1, 55.2, 40.8, 36.95, 36.92, 29.1; IR (neat) 1606, 1510, 1353, 1247, 1172, 1031, 943, 837, 743, 702 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>20</sub>H<sub>24</sub>NaO<sub>4</sub>S: 383.1288 ([M + Na]<sup>+</sup>), Found: 383.1295 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak IG, hexane/EtOH = 5/1, flow rate = 1.0 mL/min, retention time; 14.1 min and 16.2 min (major).

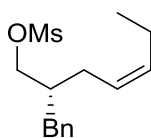


**(Z)-2-Benzyl-5-(4-bromophenyl)pent-4-en-1-yl methanesulfonate (6f) (Table 3, entry 3):**

Reduction was conducted in Et<sub>2</sub>O and THF (1/1). 44.0 mg, 0.107 mmol, 82% yield, *Z/E* = >20/1, 94% ee;  $[\alpha]_{\text{D}}^{25} = 32.60$  (*c* 0.82, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.43 (2H, d, *J* = 8.5 Hz), 7.29-7.25 (2H, m), 7.23-7.19 (1H, m), 7.12 (2H, d, *J* = 8.5 Hz), 7.07 (2H, d, *J* = 8.5 Hz), 6.47 (1H, d, *J* = 11.8 Hz), 5.70 (1H, dt, *J* = 11.6, 7.4 Hz), 4.08 (2H, d, *J* = 5.1 Hz), 2.86 (3H, s), 2.68 (2H, d, *J* = 7.2 Hz), 2.40 (2H, app t, *J* = 7.1 Hz), 2.21-2.12 (1H, m); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  138.7, 135.9, 131.3, 130.3, 130.2, 129.8, 129.1, 128.5, 126.5, 120.7, 70.8, 40.7, 37.0, 36.9, 29.0; IR (neat) 1487, 1352, 1172, 941, 835, 732, 700 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>19</sub>H<sub>21</sub>BrNaO<sub>3</sub>S: 431.0287 ([M + Na]<sup>+</sup>), Found: 431.0293 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak IE, hexane/EtOH = 10/1, flow rate = 1.0 mL/min, retention time; 11.6 min and 12.3 min (major).

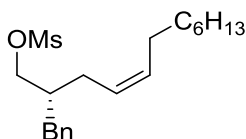


**(Z)-2-Benzylhex-4-en-1-yl methanesulfonate (6h) (Table 3, entry 4):** Reduction was conducted in THF. 21.4 mg, 0.080 mmol, 70% yield, *Z/E* = 10/1, 94% ee;  $[\alpha]_{\text{D}}^{17} = -4.8$  (*c* 1.14, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.30 (2H, app t, *J* = 7.6 Hz), 7.22 (1H, d, *J* = 6.5 Hz), 7.17 (2H, d, *J* = 8.0 Hz), 5.64-5.56 (1H, m), 5.42-5.36 (1H, m), 4.08 (2H, d, *J* = 4.6 Hz), 2.94 (3H, s), 2.70 (2H, d, *J* = 7.0 Hz), 2.19-2.09 (3H, m), 1.60 (3H, d, *J* = 6.8 Hz); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  139.2, 129.1, 128.5, 126.8, 126.7, 126.3, 71.2, 40.4, 37.1, 36.9, 27.8, 12.9; IR (neat) 1353, 1173, 942, 834, 745, 701 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>14</sub>H<sub>20</sub>NaO<sub>3</sub>S: 291.1025 ([M + Na]<sup>+</sup>), Found: 291.1030 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak AS-H, hexane/*i*-PrOH = 20/1, flow rate = 0.5 mL/min, retention time; 17.8 min (major) and 20.3 min.



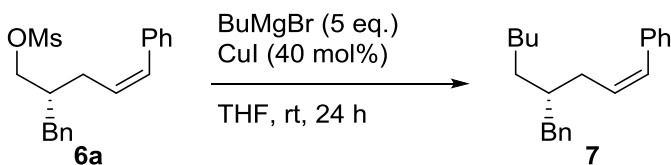
**(Z)-2-Benzylhept-4-en-1-yl methanesulfonate (6i) (Table 3, entry 5):** Reduction was conducted in THF. 23.1 mg, 0.082 mmol, 83% yield, *Z/E* = 11/1, 94% ee;  $[\alpha]_{\text{D}}^{20} = -2.4$  (*c* 1.50, CHCl<sub>3</sub>); <sup>1</sup>H NMR

(400 MHz, CDCl<sub>3</sub>)  $\delta$  7.32-7.28 (2H, m), 7.23-7.19 (1H, m), 7.18-7.16 (2H, m), 5.54-5.48 (1H, m), 5.36-5.30 (1H, m), 4.08 (2H, d,  $J = 4.8$  Hz), 2.95 (3H, s), 2.70 (2H, dd,  $J = 6.9, 3.3$  Hz), 2.20-2.14 (2H, m), 2.12-2.06 (1H, m), 2.02 (2H, app td,  $J = 7.4, 1.4$  Hz), 0.96 (3H, t,  $J = 7.5$  Hz); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  139.2, 134.5, 129.1, 128.5, 126.3, 125.2, 71.2, 40.4, 37.1, 36.9, 28.1, 20.6, 14.1; IR (neat) 1355, 1174, 942, 835, 745, 701 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>15</sub>H<sub>22</sub>NaO<sub>3</sub>S: 305.1182 ([M + Na]<sup>+</sup>), Found: 305.1197 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak AS-H, hexane/*i*-PrOH = 10/1, flow rate = 0.75 mL/min, retention time; 15.4 min (major) and 16.6 min.

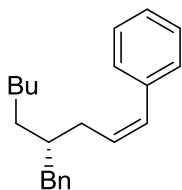


**(Z)-2-Benzyl-dodec-4-en-1-yl methanesulfonate (6j)** (Table 3, entry 6): Reduction was conducted in THF. 27.9 mg, 0.079 mmol, 82% yield,  $Z/E = 8.1/1$ , 96% ee;  $[\alpha]_D^{21} = 0.13$  ( $c$  1.26, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.30 (2H, t,  $J = 7.2$  Hz), 7.21 (1H, t,  $J = 6.8$  Hz), 7.17 (2H, d,  $J = 6.8$  Hz), 5.55-5.48 (1H, m), 5.39-5.33 (1H, m), 4.08 (2H, d,  $J = 4.8$  Hz), 2.95 (3H, m), 2.70-2.68 (2H, m), 2.12-2.06 (1H, m), 1.27 (10H, m), 0.88 (3H, t,  $J = 6.9$  Hz); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  139.2, 133.0, 129.1, 128.5, 126.3, 125.7, 71.2, 40.5, 37.0, 36.9, 31.8, 29.6, 29.3, 29.2, 28.2, 27.4, 22.6, 14.1; IR (neat) 2925, 2854, 1357, 1176, 956, 835, 744, 701 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>20</sub>H<sub>32</sub>NNaO<sub>3</sub>S: 375.1964 ([M + Na]<sup>+</sup>), Found: 375.1975 ([M + Na]<sup>+</sup>); HPLC analysis: Daicel Chiralpak AD-3 and IG, hexane/EtOH = 40/1, flow rate = 0.7 mL/min, retention time; 23.0 min and 23.5 min (major).

#### Synthesis of 7<sup>5</sup>

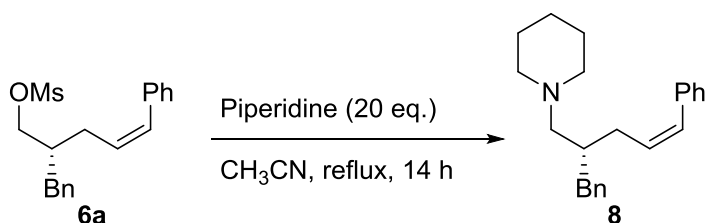


To a solution of **6a** (33.0 mg, 0.1 mmol) in THF (1 mL) were added BuMgBr (1 M solution in THF, 0.5 mL, 0.5 mmol) and CuI (7.6 mg, 0.04 mmol) at  $-78$  °C. The mixture was warmed to room temperature and stirred for 24 h. The reaction was quenched with saturated aqueous NH<sub>4</sub>Cl solution and the resulting mixture was extracted twice with EtOAc. The combined extracts were washed with brine, dried with Na<sub>2</sub>SO<sub>4</sub> and concentrated *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel to afford **7** (22.0 mg, 0.075 mmol, 75%) as a colorless oil.

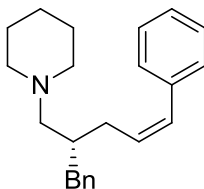


**(Z)-(4-Pentylpent-1-ene-1,5-diyl)dibenzene (7):** 95% ee;  $[\alpha]_D^{25} = 52.5$  (*c* 0.85, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.30-7.24 (3H, m), 7.23-7.19 (4H, m), 7.17-7.13 (1H, m), 7.11-7.09 (2H, m), 6.47 (1H, d, *J* = 11.8 Hz), 5.70 (1H, dt, *J* = 11.8, 7.2 Hz), 2.58 (1H, dd, *J* = 13.4, 6.6 Hz), 2.53 (1H, dd, *J* = 13.3, 7.0 Hz), 2.29 (2H, app tt, *J* = 6.5, 2.3 Hz), 1.77 (1H, br app t, *J* = 6.4 Hz), 1.31-1.17 (8H, m), 0.85 (3H, t, *J* = 7.0 Hz); <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>)  $\delta$  141.2, 137.8, 131.4, 129.9, 129.2, 128.7, 128.1, 128.0, 126.4, 125.6, 40.8, 40.3, 33.2, 32.1, 31.9, 26.4, 22.6, 14.1; IR (neat) 2924, 2854, 1494, 769, 742, 697 cm<sup>-1</sup>; HRMS (ESI-MS) Calcd. for C<sub>22</sub>H<sub>28</sub>Na: 315.2083 ([M + Na]<sup>+</sup>), Found: 315.2088 ([M + Na]<sup>+</sup>).

### Synthesis of 8



To a solution of **6a** (37.0 mg, 0.11 mmol) in CH<sub>3</sub>CN (4 mL) was added piperidine (0.22 mL, 2.2 mmol) at room temperature. The mixture was refluxed for 14 h. The reaction mixture was diluted with brine and extracted with EtOAc. Combined organic extracts were dried with Na<sub>2</sub>SO<sub>4</sub> and concentrated *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel to afford **8** (35 mg, 0.11 mmol, >99%) as a colorless oil.

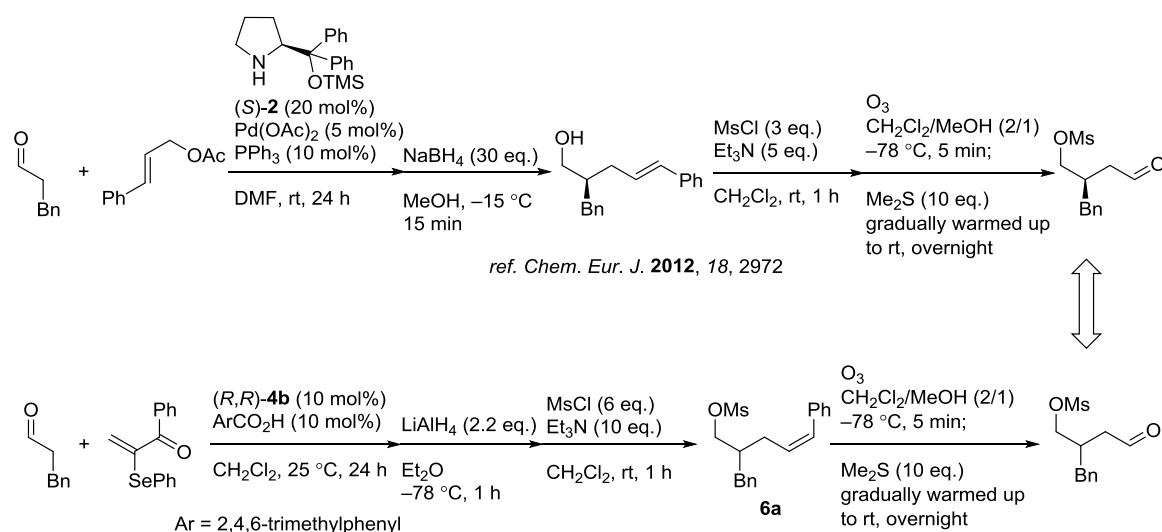


**(Z)-1-(2-Benzyl-5-phenyl-pent-4-en-1-yl)piperidine (8):** 95% ee;  $[\alpha]_D^{23} = 35.7$  (*c* 1.12, CHCl<sub>3</sub>); <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>)  $\delta$  7.29-7.23 (4H, m), 7.21-7.18 (3H, m), 7.14 (1H, app t, *J* = 7.2 Hz), 7.09 (2H, d, *J* = 7.1 Hz), 6.45 (1H, d, *J* = 11.6 Hz), 5.71 (1H, dt, *J* = 11.6, 7.4 Hz), 2.70 (1H, dd, *J* = 13.6, 5.7 Hz), 2.55 (1H, dd, *J* = 13.6, 7.1 Hz), 2.33-2.29 (6H, m), 2.16 (1H, dd, *J* = 12.3, 7.2 Hz), 2.09 (1H,

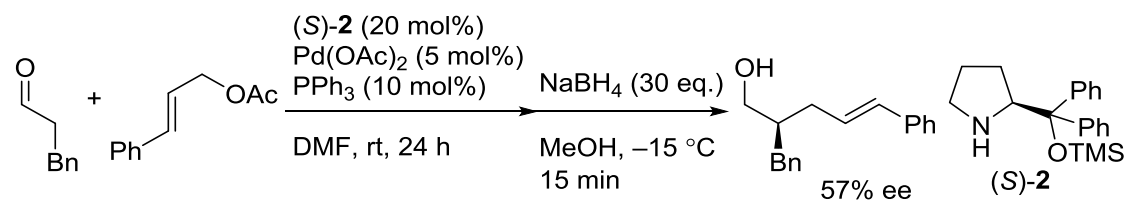
dd,  $J = 12.3, 7.2$  Hz), 2.05-1.99 (1H, m), 1.55-1.51 (4H, m), 1.39 (2H, br);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  140.9, 137.7, 131.4, 129.8, 129.4, 128.8, 128.03, 128.00, 126.3, 125.6, 62.9, 55.0, 38.4 (2 peaks over rapped), 30.7, 26.2, 24.6; IR (neat) 2932, 1494, 1444, 769, 743, 698  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{23}\text{H}_{30}\text{N}$ : 320.2373 ( $[\text{M} + \text{H}]^+$ ), Found: 320.2387 ( $[\text{M} + \text{H}]^+$ ).

### Determination of absolute configuration

The absolute configuration of **6a** was determined to be *S* by conversion to 2-benzyl-4-oxobutyl methanesulfonate as shown below.



### Preparation of (*S,E*)-2-benzyl-5-phenylpent-4-en-1-ol<sup>6</sup>

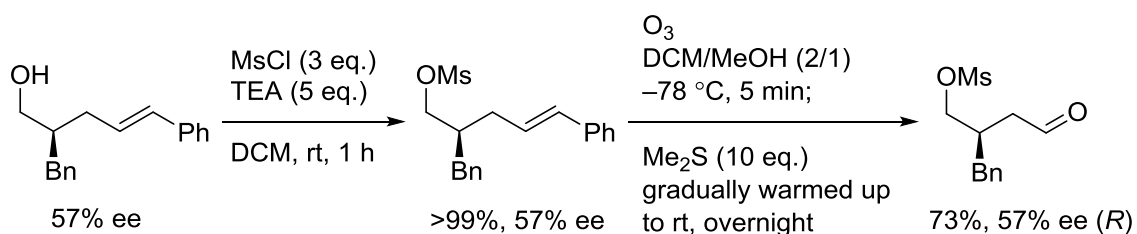


An oven-dried vial containing a magnetic stir bar was charged with  $\text{Pd}(\text{OAc})_2$  (3.4 mg, 0.015 mmol) and  $\text{PPh}_3$  (7.9 mg, 0.03 mmol), fitted with a septum, sealed, and flushed with a stream of  $\text{N}_2$  for 5 min, followed by addition of degassed DMF (300 mL). After 3 min of stirring at room temperature, cinnamyl acetate (50  $\mu\text{L}$ , 0.3 mmol) was added and the mixture was stirred for another 3 min. In parallel to the above procedure, an oven-dried vial was subsequently charged with catalyst (*S*)-**2** (19.5 mg, 0.06 mmol), 3-phenylpropanal (119  $\mu\text{L}$ , 0.9 mmol), fitted with a septum, sealed and flushed with a stream of  $\text{N}_2$  for 5 min, followed by addition of degassed DMF (300 mL). After 3 min



of stirring, this mixture was transferred by a syringe to the vial containing the mixture of Pd and cinnamyl acetate in DMF (final substrate concentration = 0.50 M). The resulting mixture was stirred at room temperature for 24 h. Next, the mixture was cooled to  $-15^{\circ}\text{C}$ , followed by addition of MeOH (1 mL) and  $\text{NaBH}_4$  (341 mg, 9.0 mmol). After stirring for 15 min, the mixture was then transferred to a flask containing a cold mixture of saturated aqueous  $\text{NH}_4\text{Cl}$  and EtOAc at  $0^{\circ}\text{C}$ . The resulting mixture was stirred for 5 min and dried with  $\text{Na}_2\text{SO}_4$ . The volatiles were removed *in vacuo*. The residue was purified by silica gel column chromatography (toluene/EtOAc = 3/1 as eluent) to afford the title compound (12 mg, 0.048 mmol, 16%).

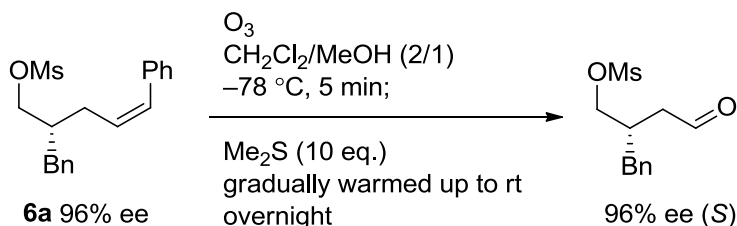
#### Preparation of (*R*)-2-benzyl-4-oxobutyl methanesulfonate



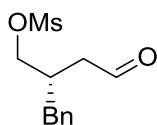
The obtained alcohol (12 mg, 0.048 mmol) was dissolved in  $\text{CH}_2\text{Cl}_2$  (1 mL). The solution was added  $\text{Et}_3\text{N}$  (33.3  $\mu\text{L}$ , 0.24 mmol) at  $-20^{\circ}\text{C}$  followed by  $\text{MsCl}$  (11  $\mu\text{L}$ , 0.14 mmol). The reaction mixture was warmed to room temperature and stirred for 1 h. The reaction was quenched with water and the mixture was extracted with  $\text{CH}_2\text{Cl}_2$ . The combined organic extracts were dried with  $\text{Na}_2\text{SO}_4$  and concentrated *in vacuo*. The residue was roughly purified by column chromatography on silica gel to afford the title compound (>99%).

The obtained mesylate (15.9 mg, 0.048 mmol) was dissolved in  $\text{CH}_2\text{Cl}_2$  (1 mL) and MeOH (0.5 mL). Ozone was bubbled through this solution at  $-78^{\circ}\text{C}$  until complete consumption of the mesylate was observed by TLC analysis (around 5 min). The mixture was then flushed with nitrogen and added dimethyl sulfide (38  $\mu\text{L}$ , 0.5 mmol). The reaction mixture was gradually warmed up to room temperature and stirred overnight. All volatiles were removed *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel to afford the title compound (9 mg, 0.035 mmol, 73%, 57% ee (*R*)).

### Preparation of 2-benzyl-4-oxobutyl methanesulfonate from **6a**



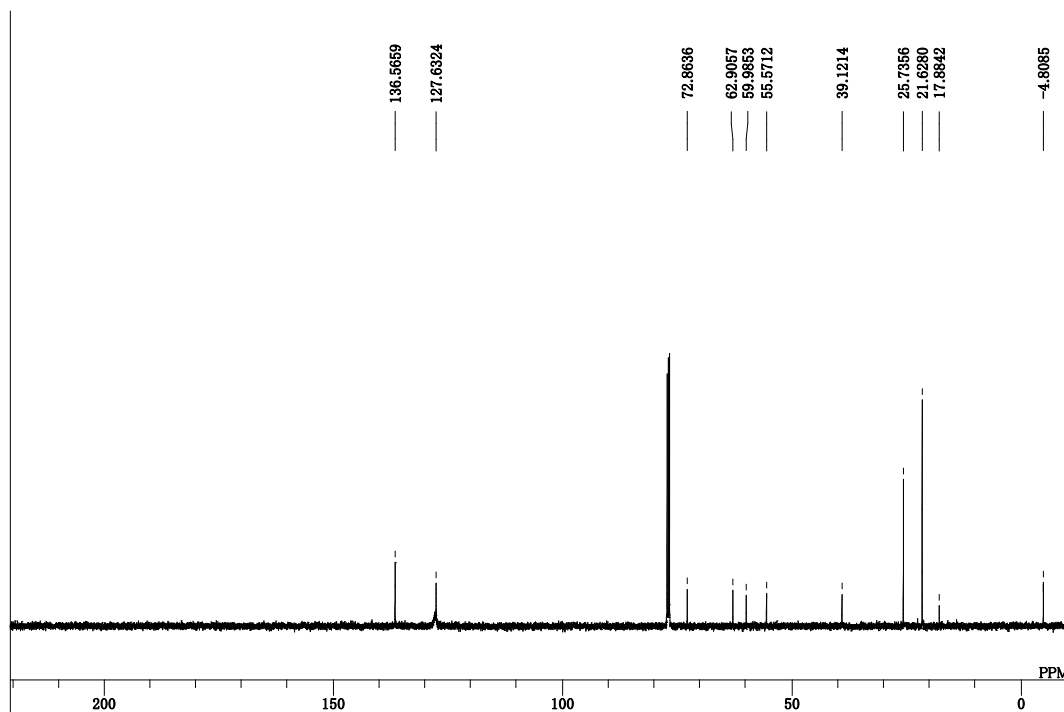
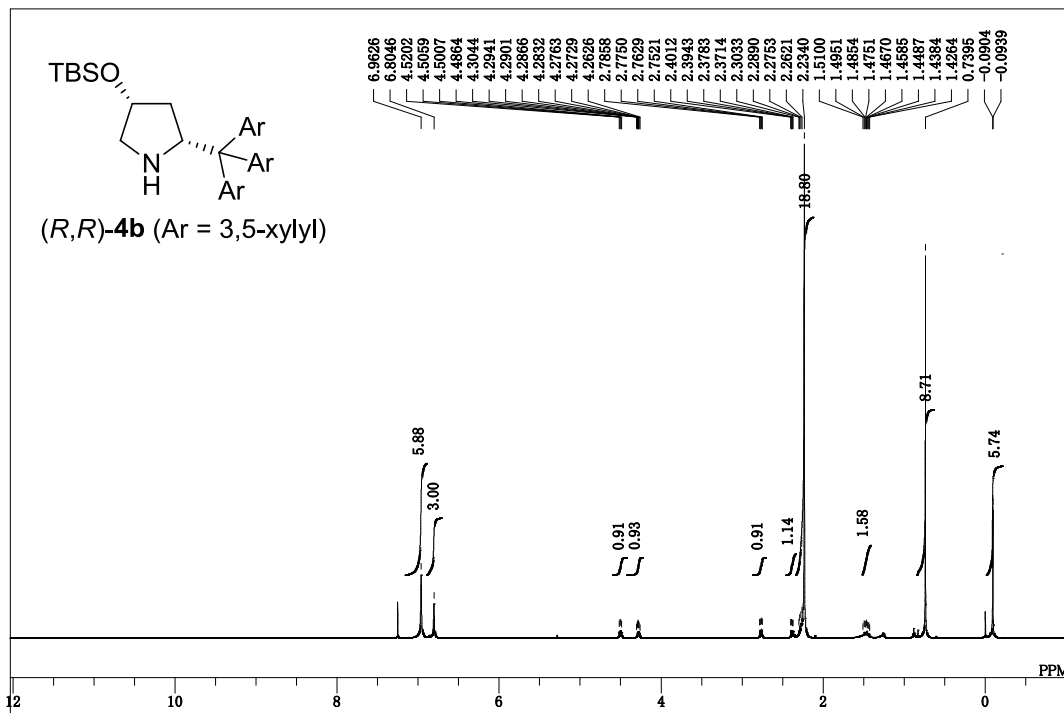
Mesylate **6a** (17.5 mg, 0.053 mmol) was dissolved in  $\text{CH}_2\text{Cl}_2$  (1 mL) and MeOH (0.5 mL). Ozone was bubbled through this solution at  $-78\text{ }^\circ\text{C}$  until complete consumption of **6a** was observed by TLC analysis (around 5 min). The mixture was then flushed with nitrogen and added dimethyl sulfide (48  $\mu\text{L}$ , 0.65 mmol). The reaction mixture was gradually warmed up to room temperature and stirred overnight. All volatiles were removed *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel to afford the title compound (10.7 mg, 0.042 mmol, 79%, 96% ee (S)).



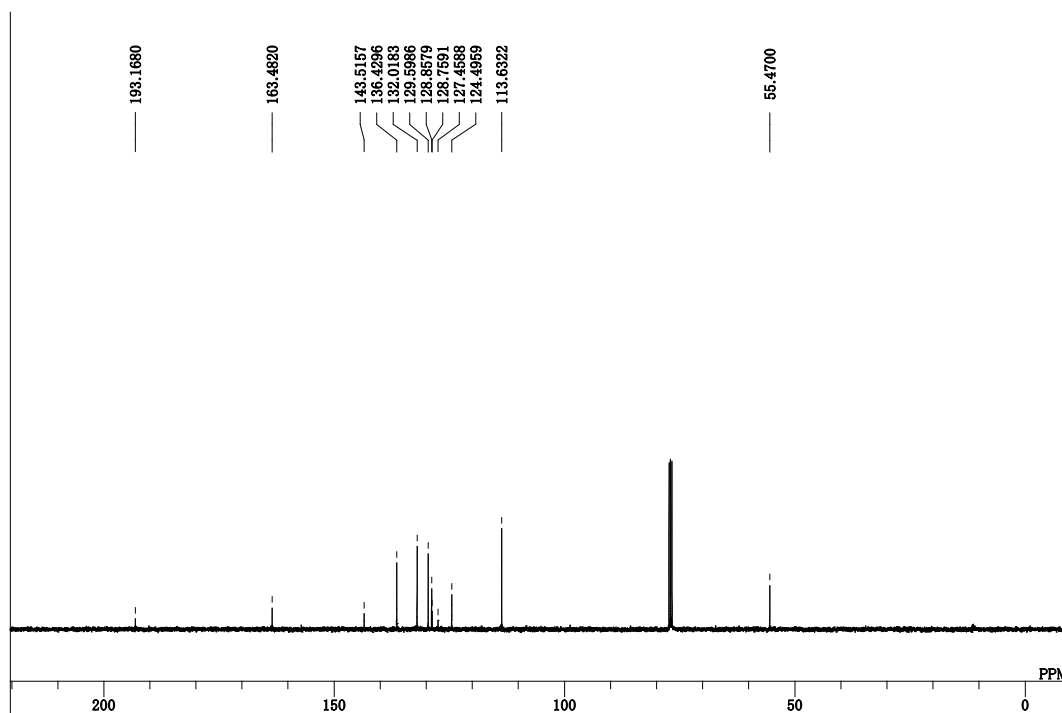
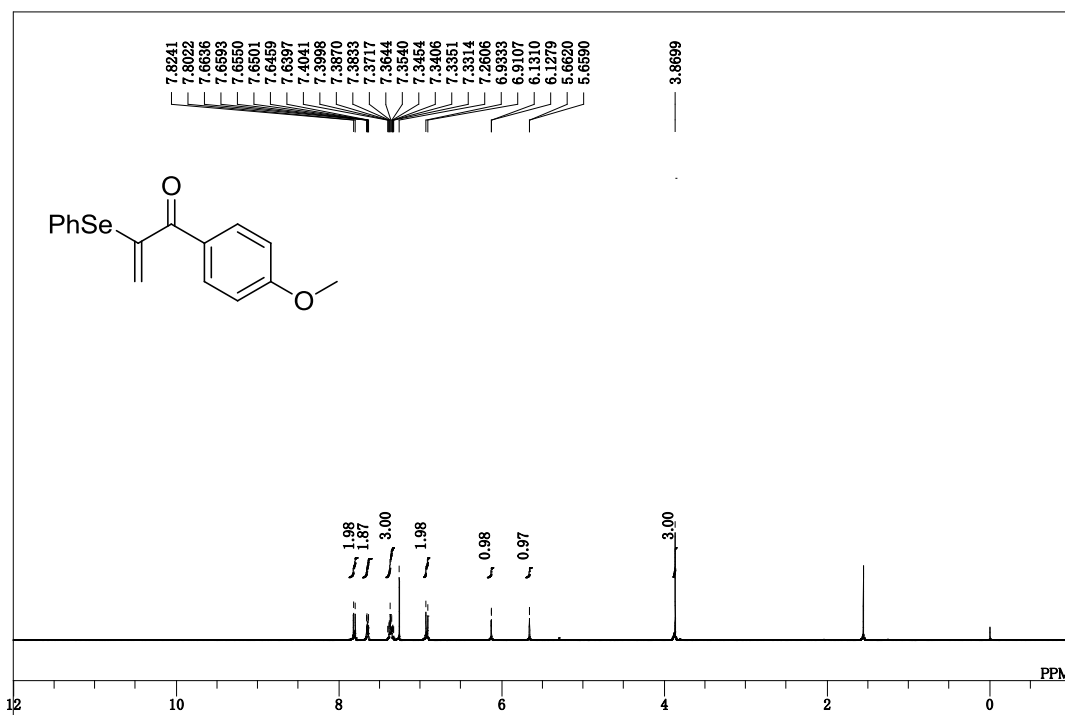
(S)-2-Benzyl-4-oxobutyl methanesulfonate: 96% ee;  $[\alpha]_{\text{D}}^{24} = -13.8$  (*c* 0.84,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.74 (1H, app s), 7.32 (2H, app t,  $J = 7.4$  Hz), 7.24 (1H, app t,  $J = 7.4$  Hz), 7.18 (2H, d,  $J = 7.1$  Hz), 4.22 (1H, dd,  $J = 9.9, 4.0$  Hz), 4.12 (1H, dd,  $J = 9.8, 4.7$  Hz), 2.98 (3H, s), 2.79-2.61 (4H, m), 2.54 (1H, dd,  $J = 18.0, 4.1$  Hz);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  200.4, 138.1, 129.1, 128.7, 126.8, 71.0, 44.5, 37.2, 36.9, 34.7; IR (neat) 1718, 1349, 1170, 945, 818, 747, 702  $\text{cm}^{-1}$ ; HRMS (ESI-MS) Calcd. for  $\text{C}_{12}\text{H}_{16}\text{NaO}_4\text{S}$ : 279.0662 ( $[\text{M} + \text{Na}]^+$ ), Found: 279.0664 ( $[\text{M} + \text{Na}]^+$ ); HPLC analysis: Daicel Chiralpak IG, hexane/*i*-PrOH = 5/1, flow rate = 1.0 mL/min, retention time; 23.3 min (major) and 31.7 min.

### References

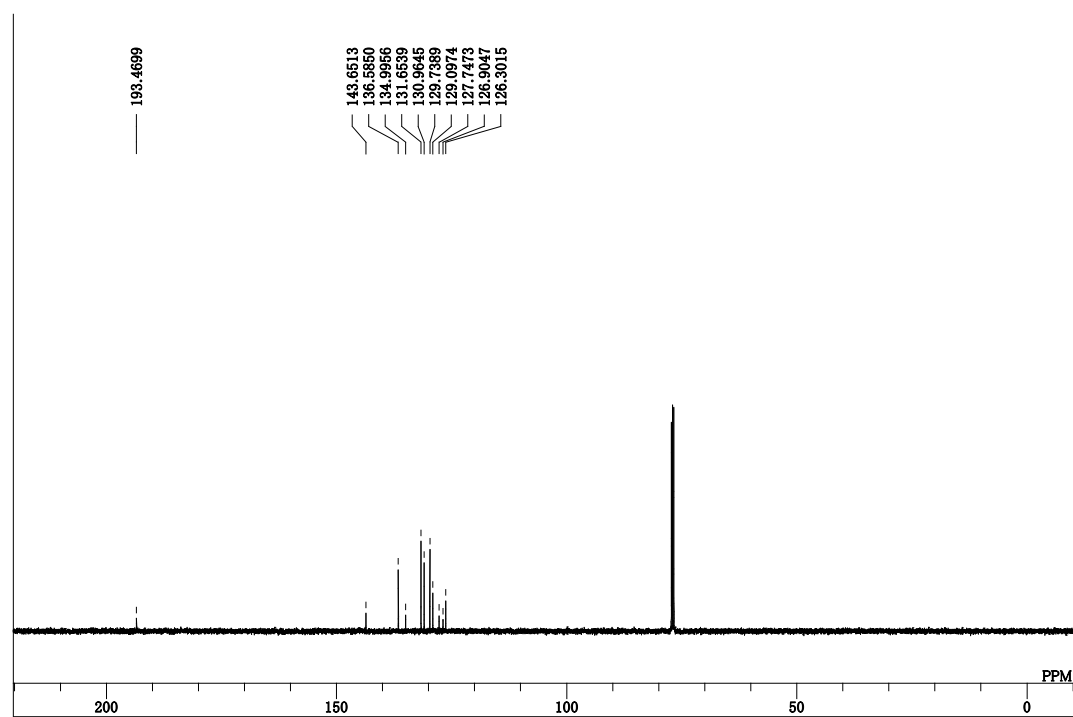
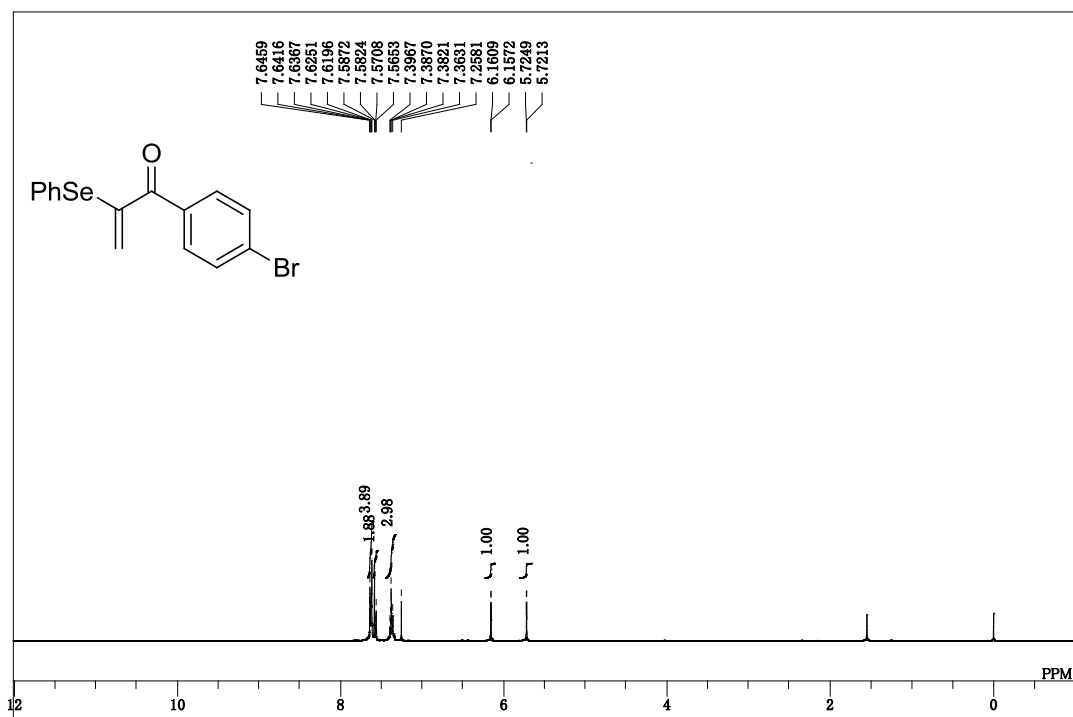
- (1) Z. Janousek, S. Piettre, F. Gorissen-Hervens, H. G. Viehe, *J. Orgmet. Chem.* **1983**, 250, 197.
- (2) T. Kano, H. Mii, K. Maruoka, *J. Am. Chem. Soc.* **2009**, 131, 3450.
- (3) M. Shimogaki, H. Maruyama, S. Tsuji, C. Homma, T. Kano, K. Maruoka, *J. Org. Chem.* DOI: 10.1021/acs.joc.7b02562.
- (4) H. Ohtake, Y. Imada, S.-I. Murahashi, *Bull. Chem. Soc. Jpn.* **1999**, 72, 2737.
- (5) H. S. Tae, J. Hines, A. R. Schneekloth, C. M. Crews, *Org. Lett.* **2010**, 12, 4308.
- (6) S. Afewerki, I. Ibrahim, J. Rydfjord, P. Breistein, A. Córdova, *Chem. Eur. J.* **2012**, 18, 2972.



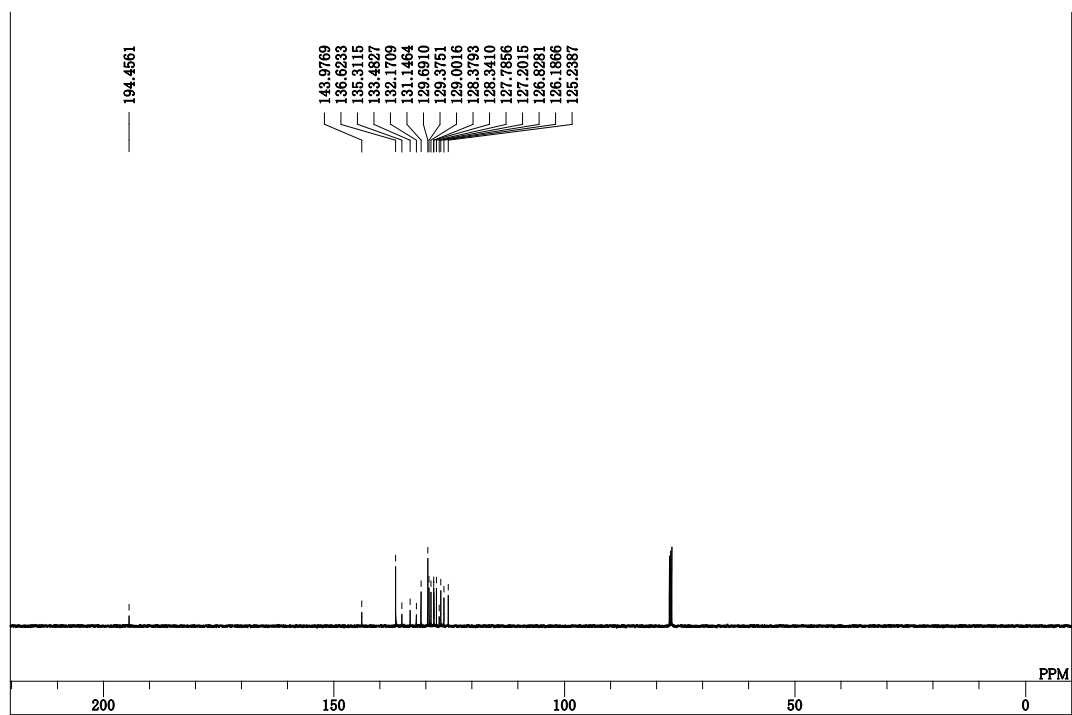
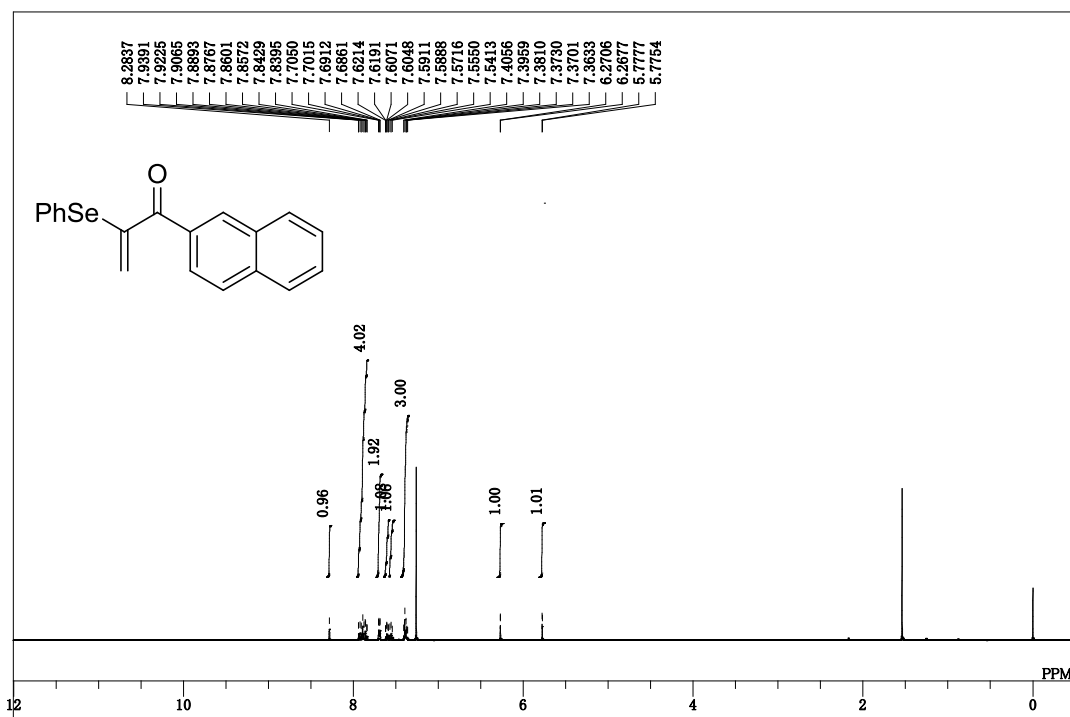
# 1-(4-Methoxyphenyl)-2-(phenylselanyl)prop-2-en-1-one



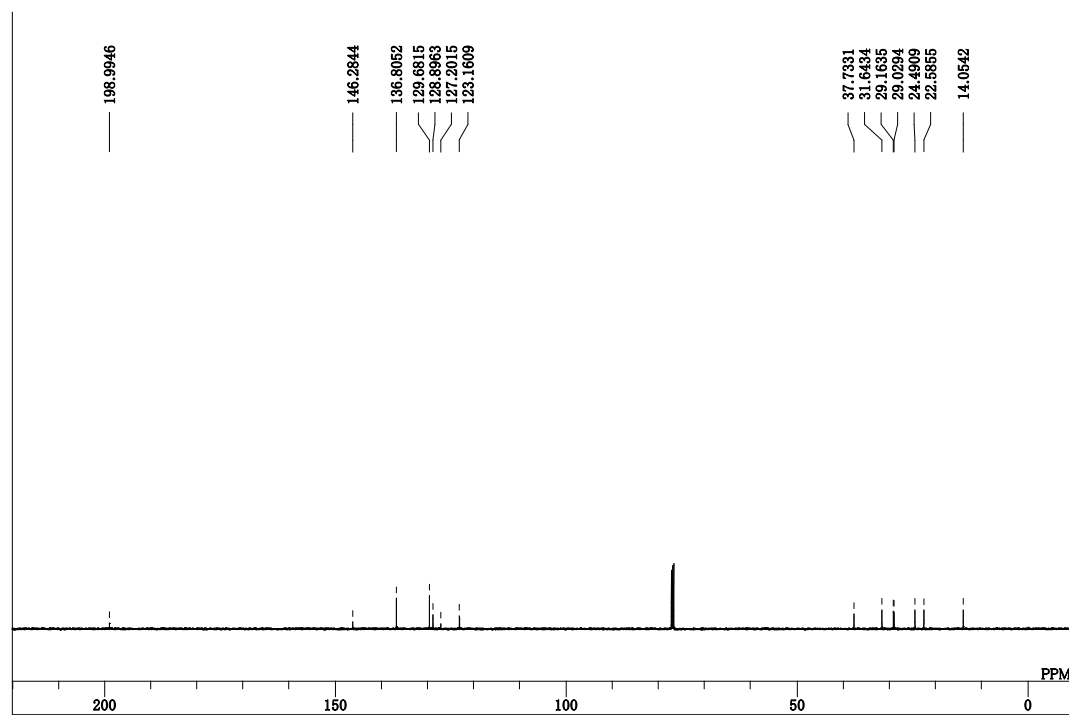
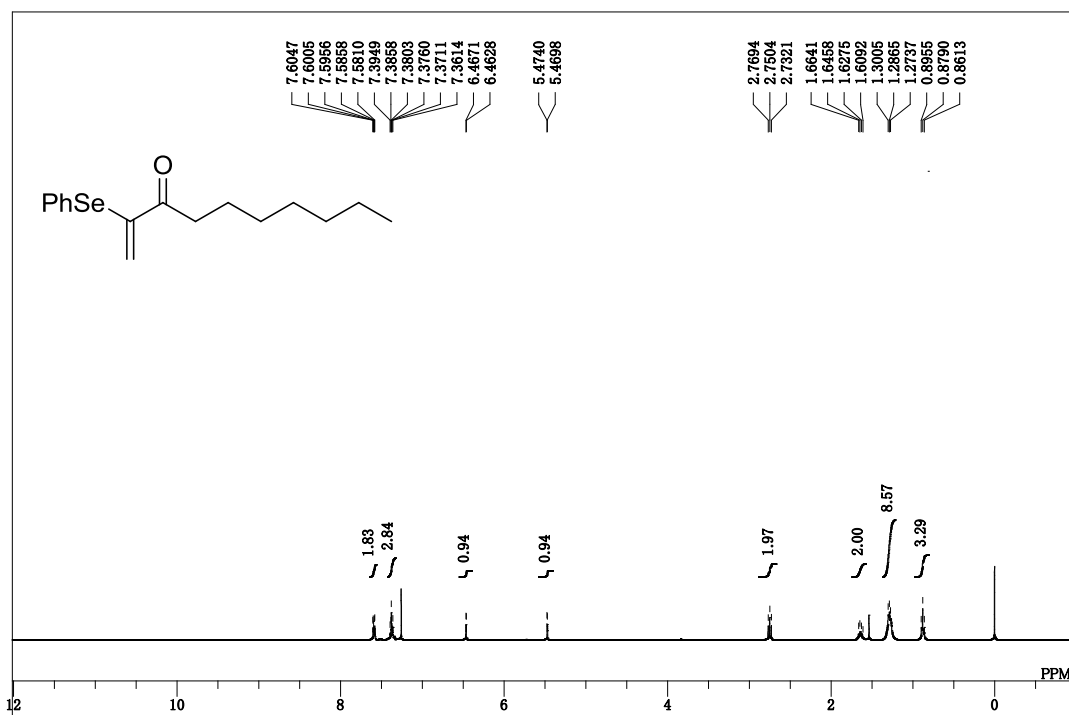
# 1-(4-Bromophenyl)-2-(phenylselanyl)prop-2-en-1-one



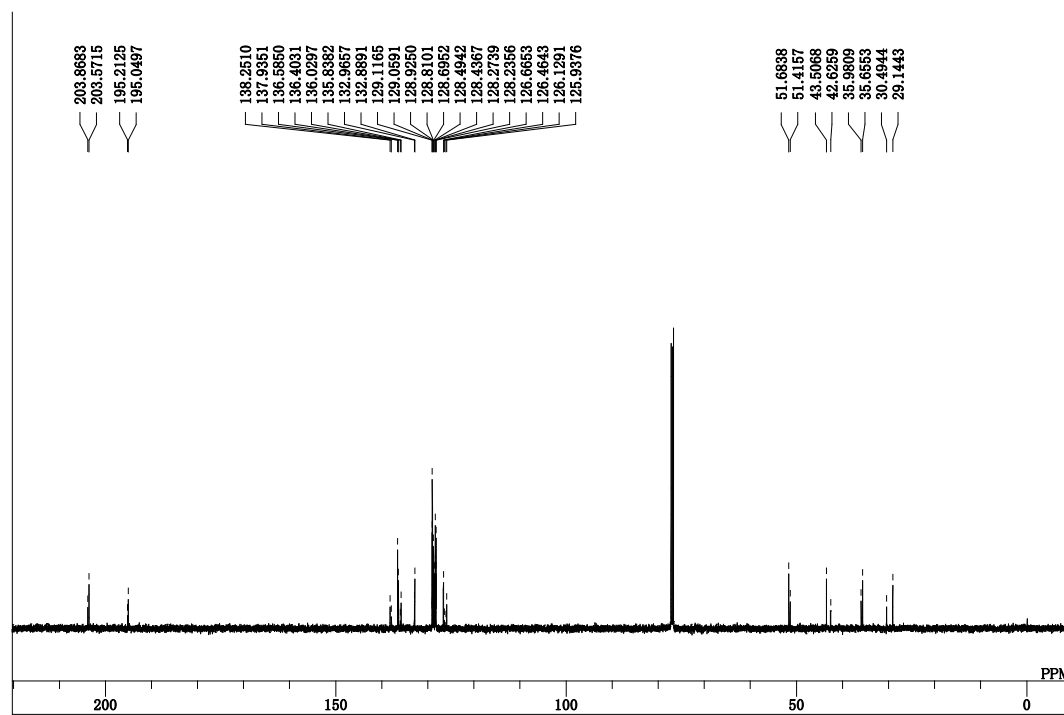
# 1-(Naphthalen-2-yl)-2-(phenylselanyl)prop-2-en-1-one



# 2-(Phenylselanyl)dec-1-en-3-one

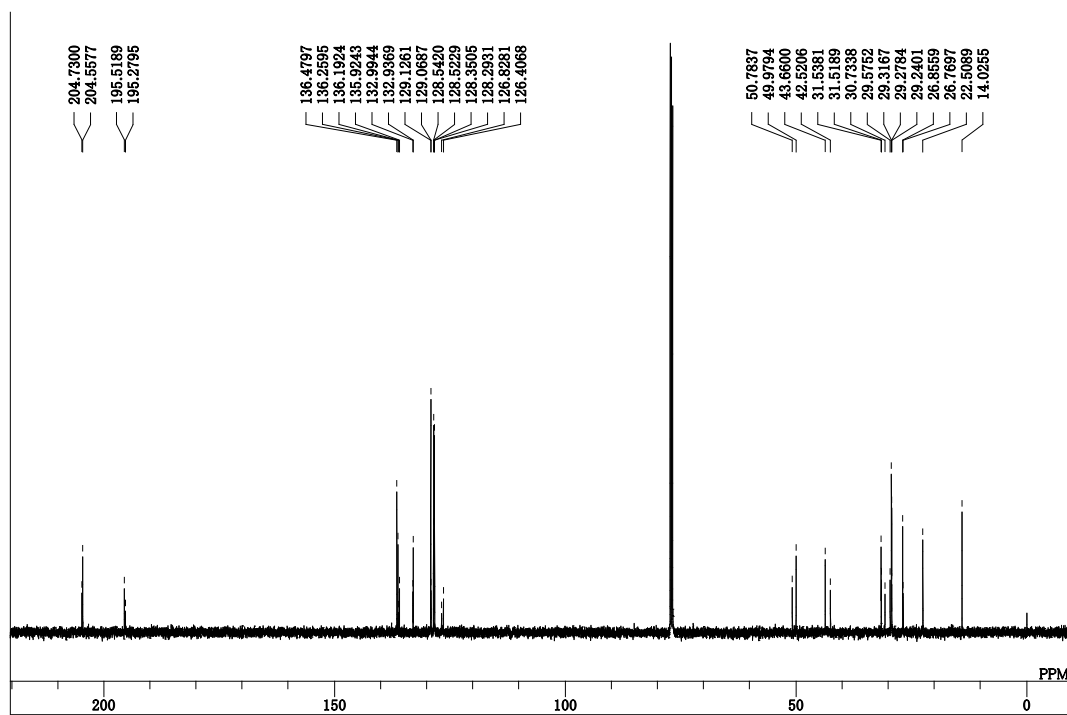
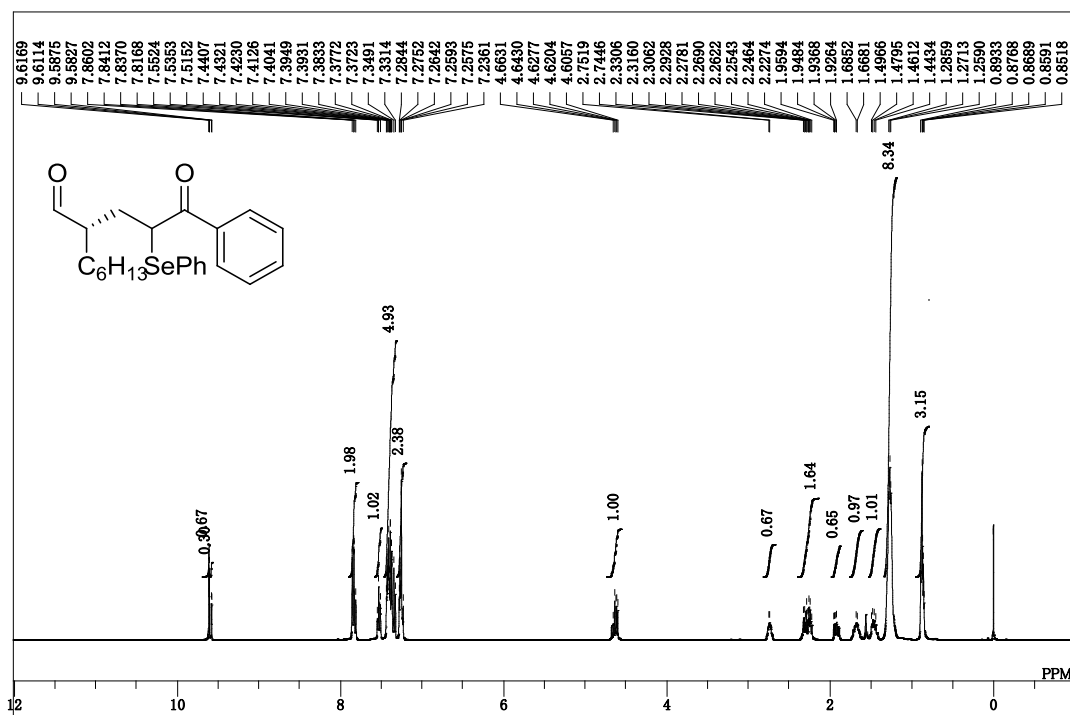


2-Benzyl-5-oxo-5-phenyl-4-(phenylselanyl)pentanal (Table 2, entry 1)

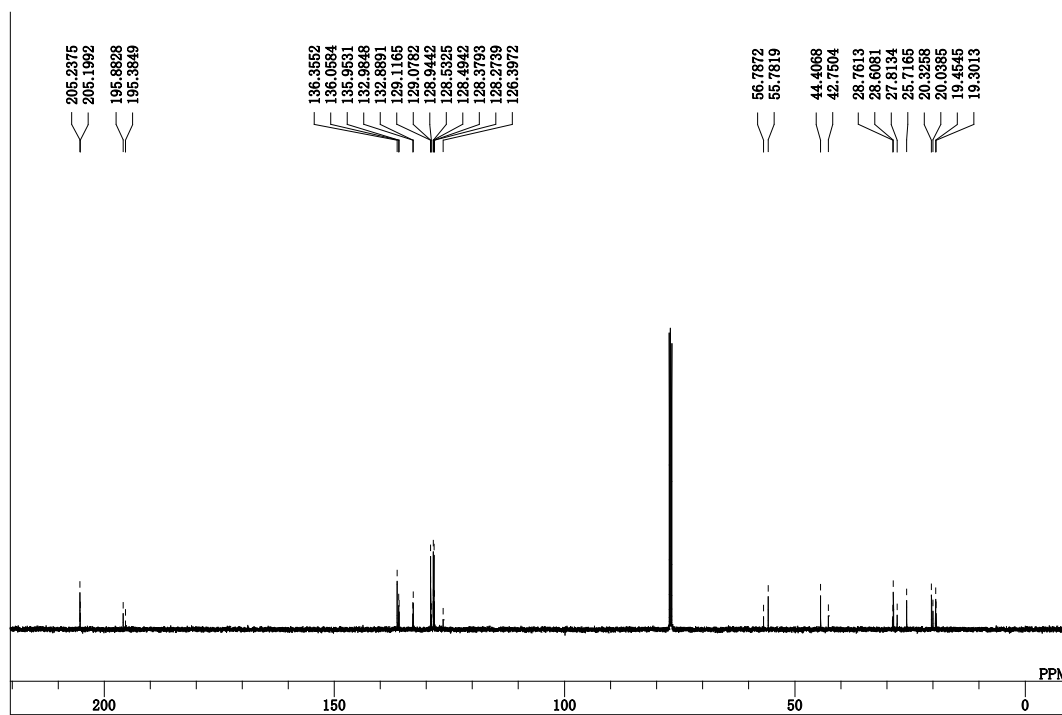




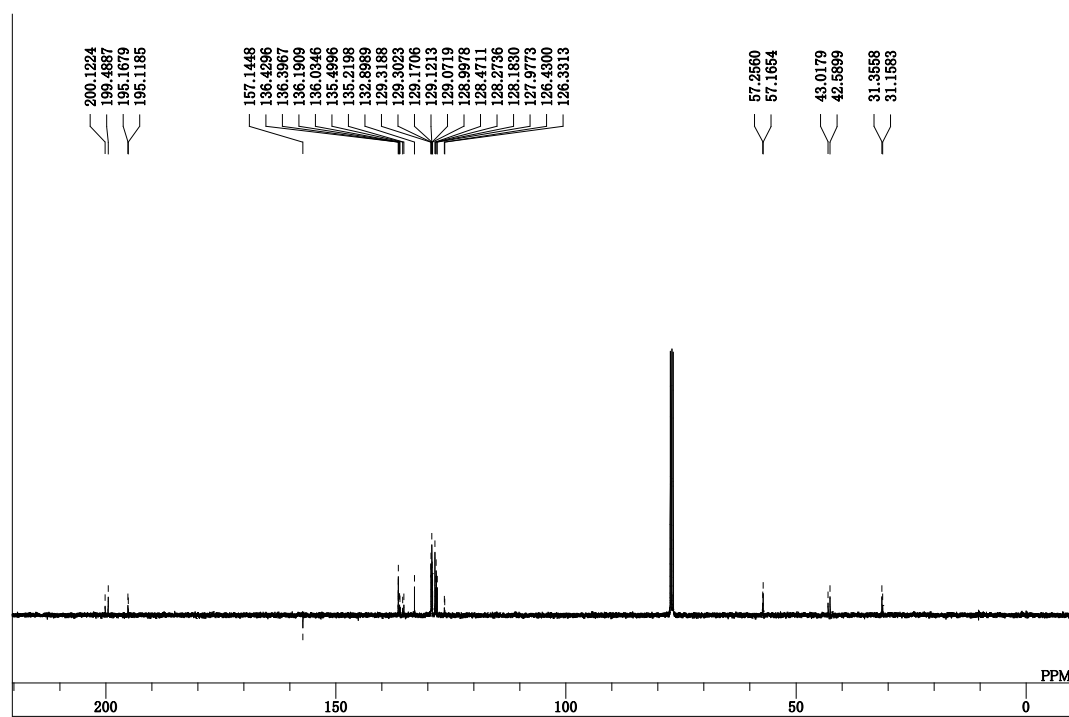
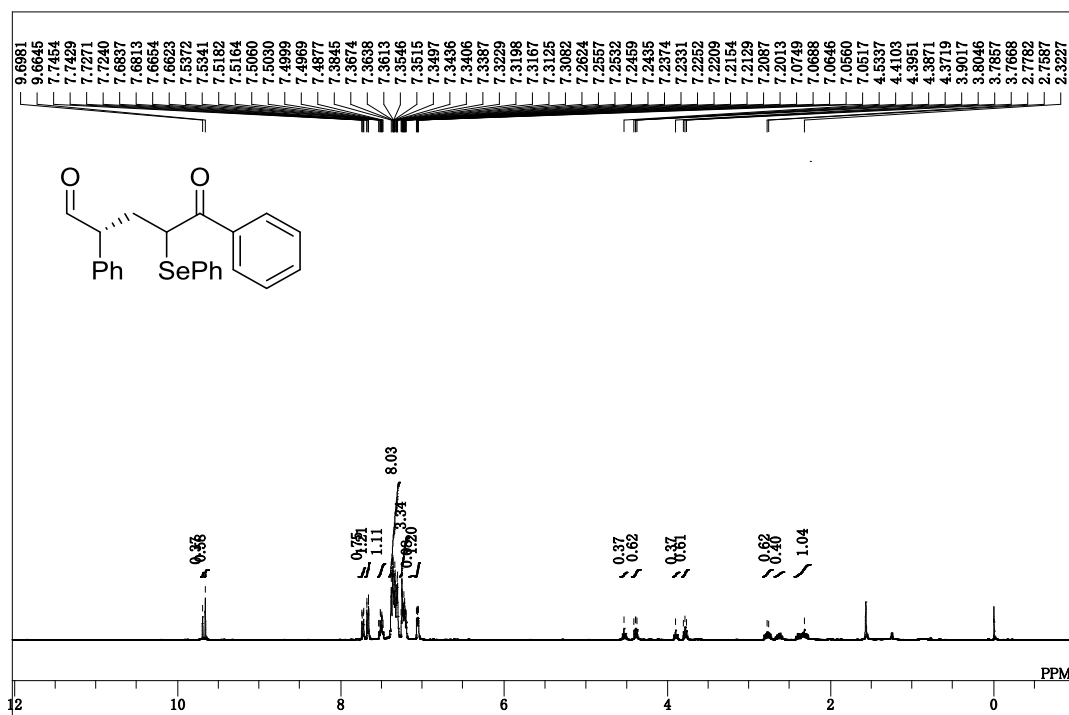
2-(3-Oxo-3-phenyl-2-(phenylselanyl)propyl)octanal (Table 2, entry 2)



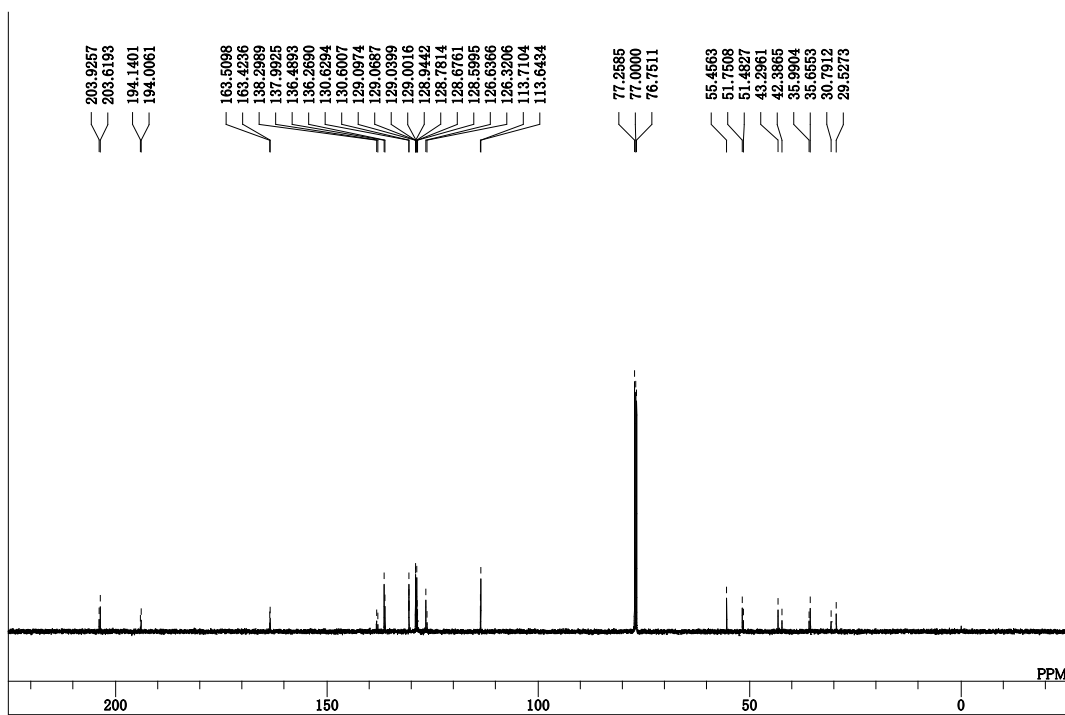
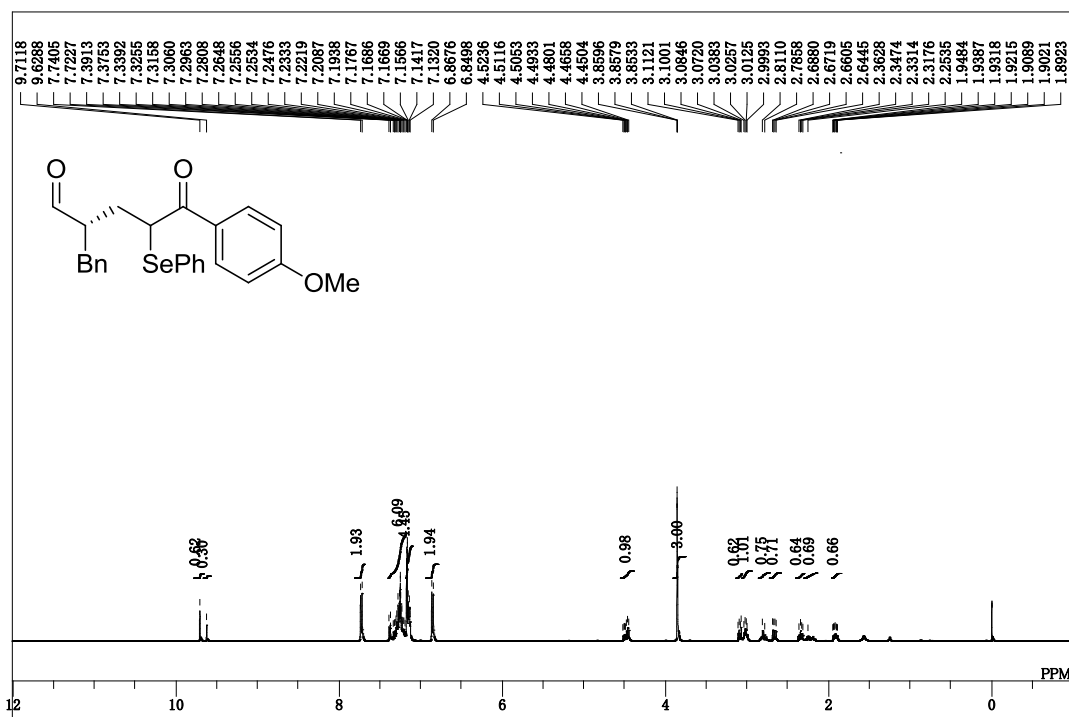
2-Isopropyl-5-oxo-5-phenyl-4-(phenylselanyl)pentanal (Table 2, entry 3)



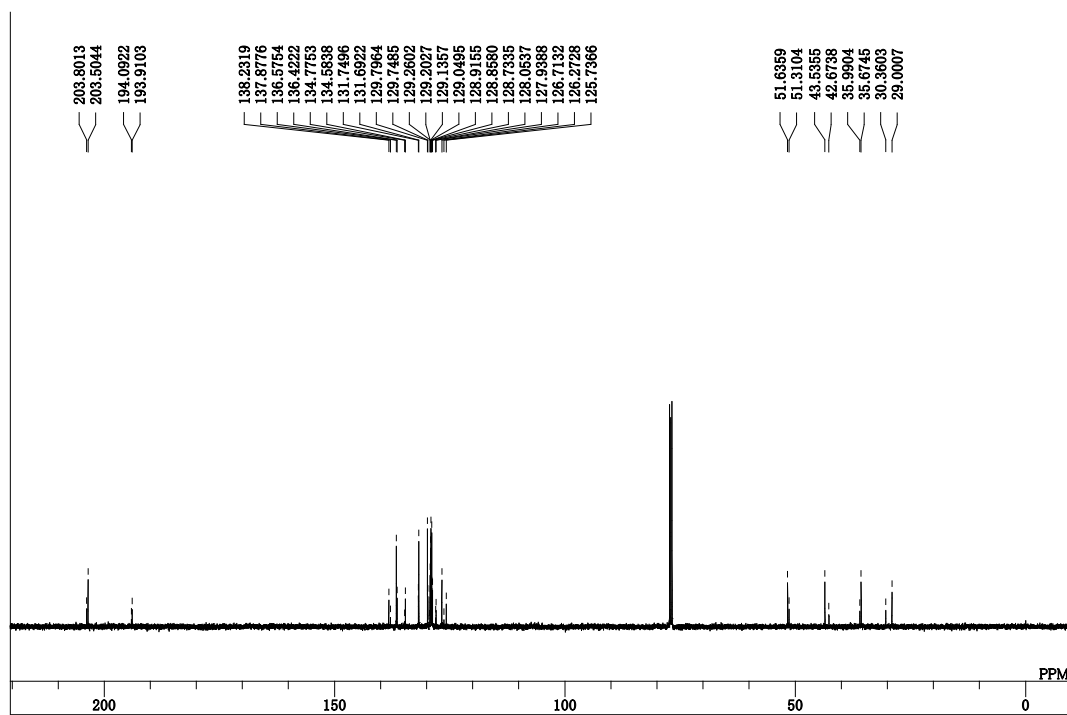
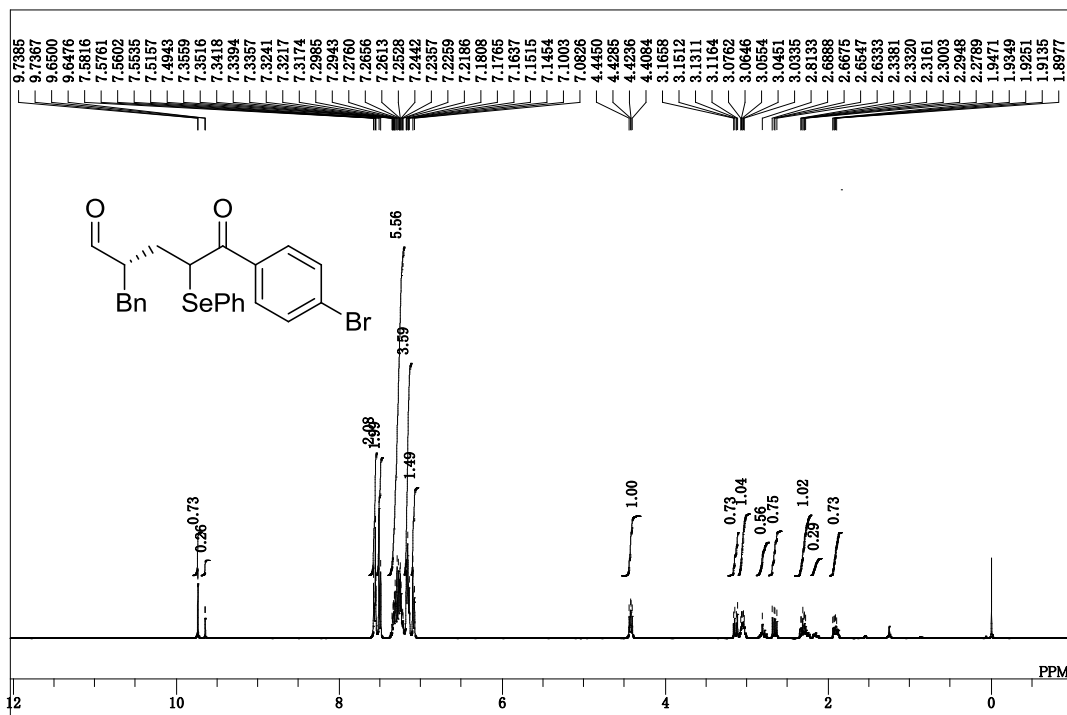
5-Oxo-2,5-diphenyl-4-(phenylselanyl)pentanal (Table 2, entry 4)



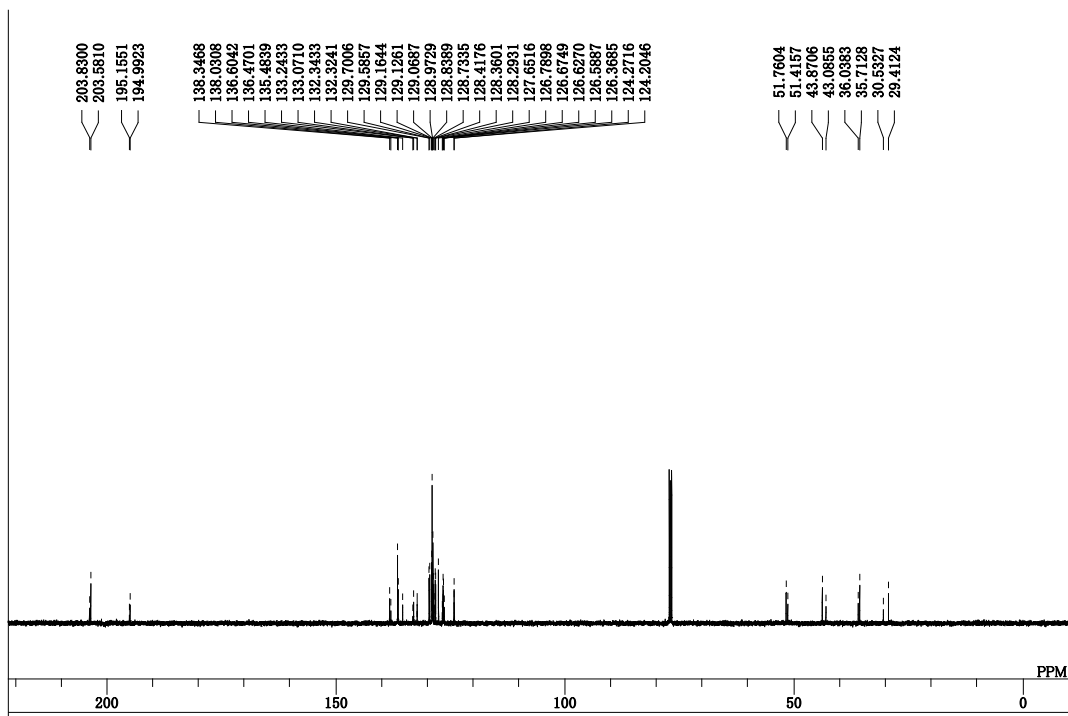
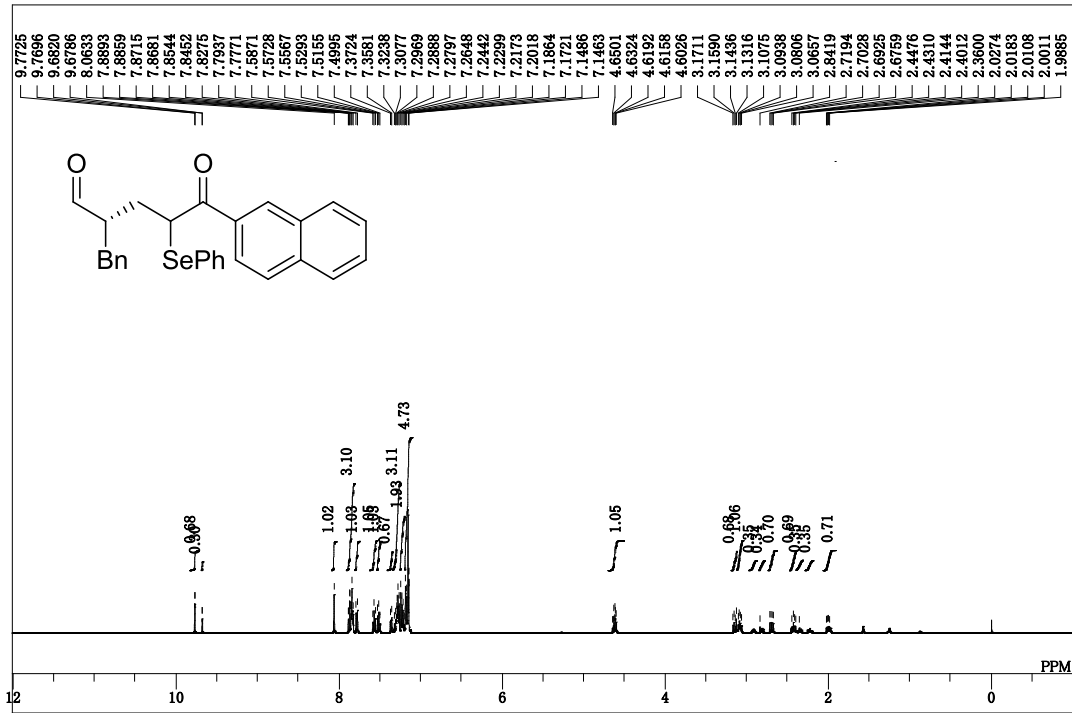
2-Benzyl-5-(4-methoxyphenyl)-5-oxo-4-(phenylselanyl)pentanal (Table 2, entry 5)



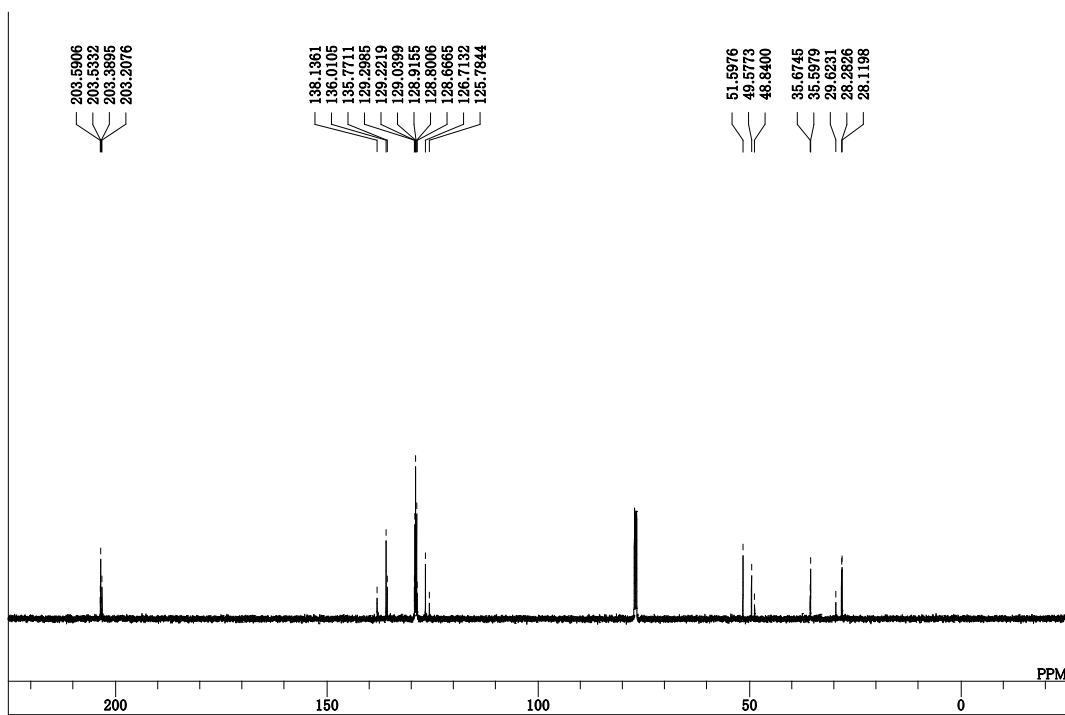
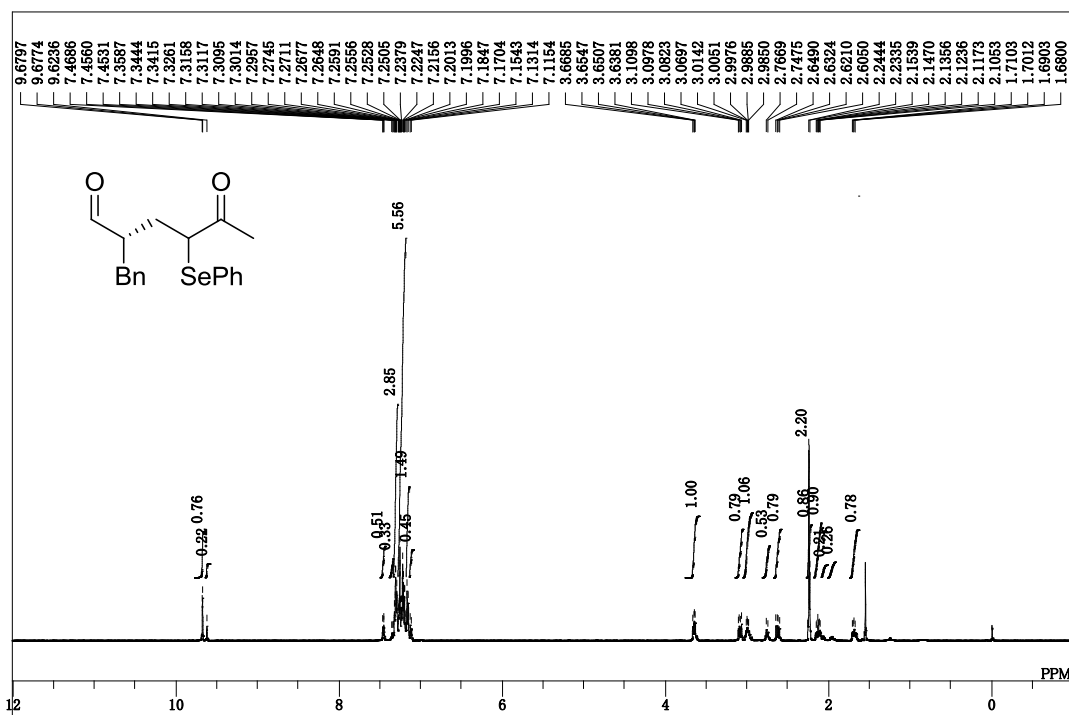
2-Benzyl-5-(4-bromophenyl)-5-oxo-4-(phenylselanyl)pentanal (Table 2, entry 6)



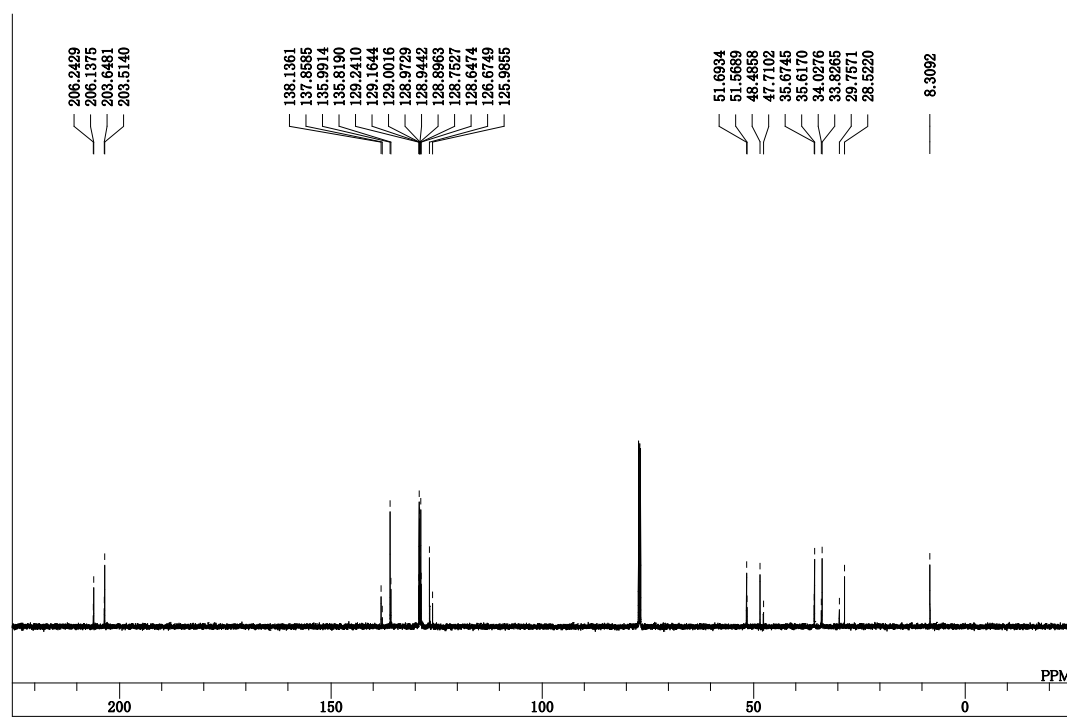
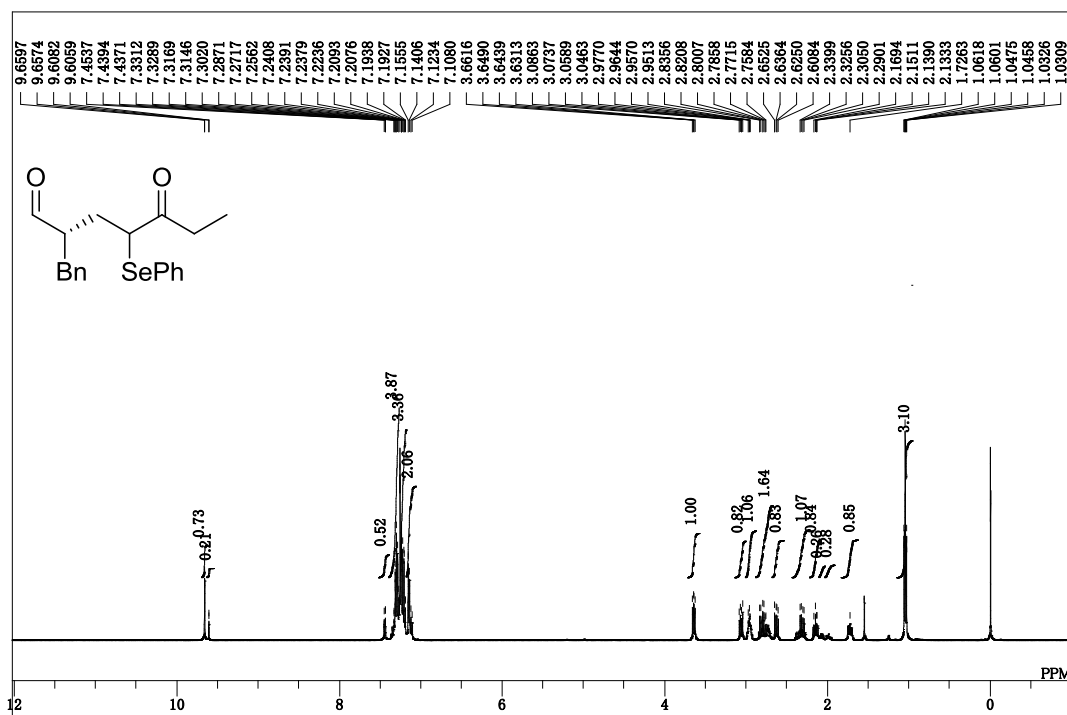
2-Benzyl-5-(naphthalen-2-yl)-5-oxo-4-(phenylselanyl)pentanal (Table 2, entry 7)



2-Benzyl-5-oxo-4-(phenylselanyl)hexanal (Table 2, entry 8)

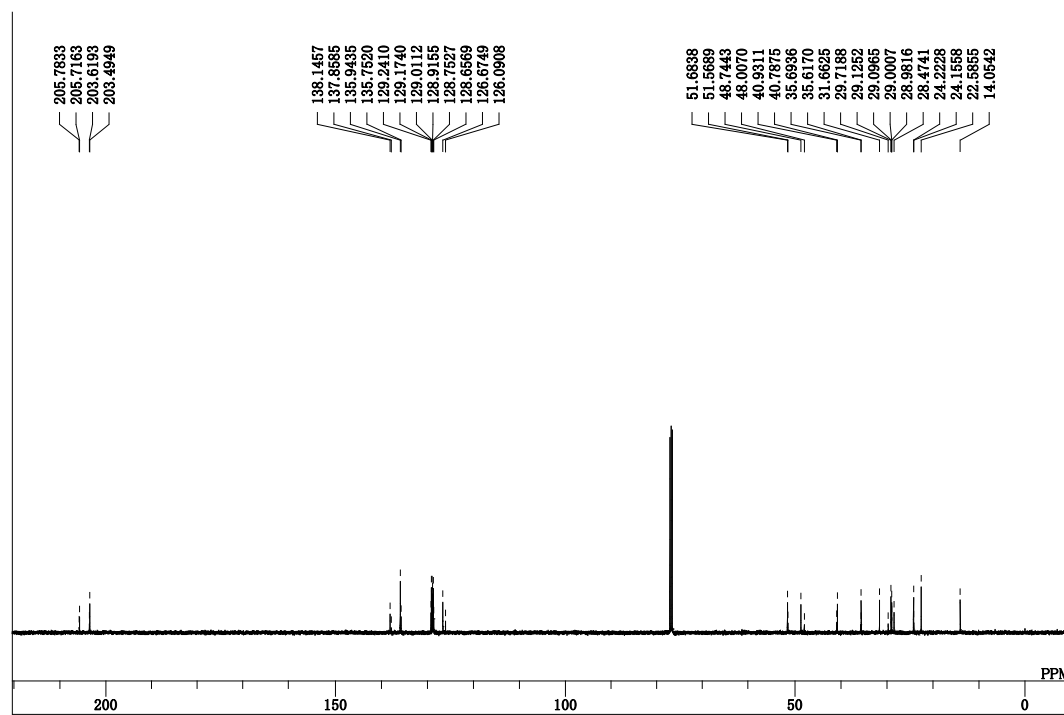
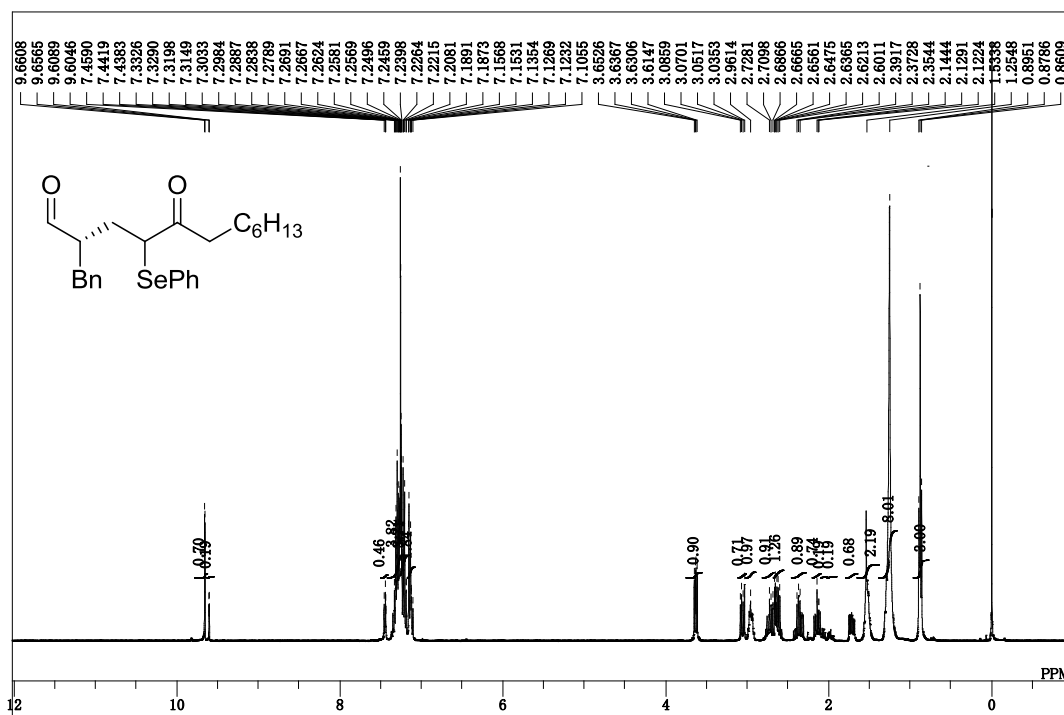


2-Benzyl-5-oxo-4-(phenylselanyl)heptanal (Table 2, entry 9)

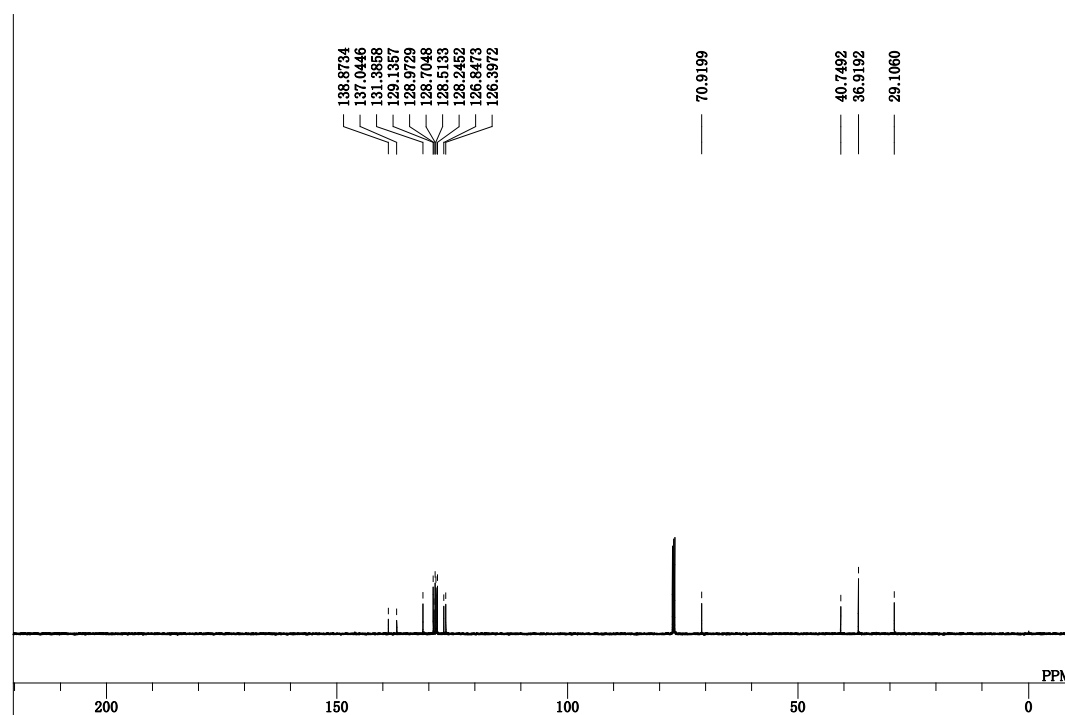
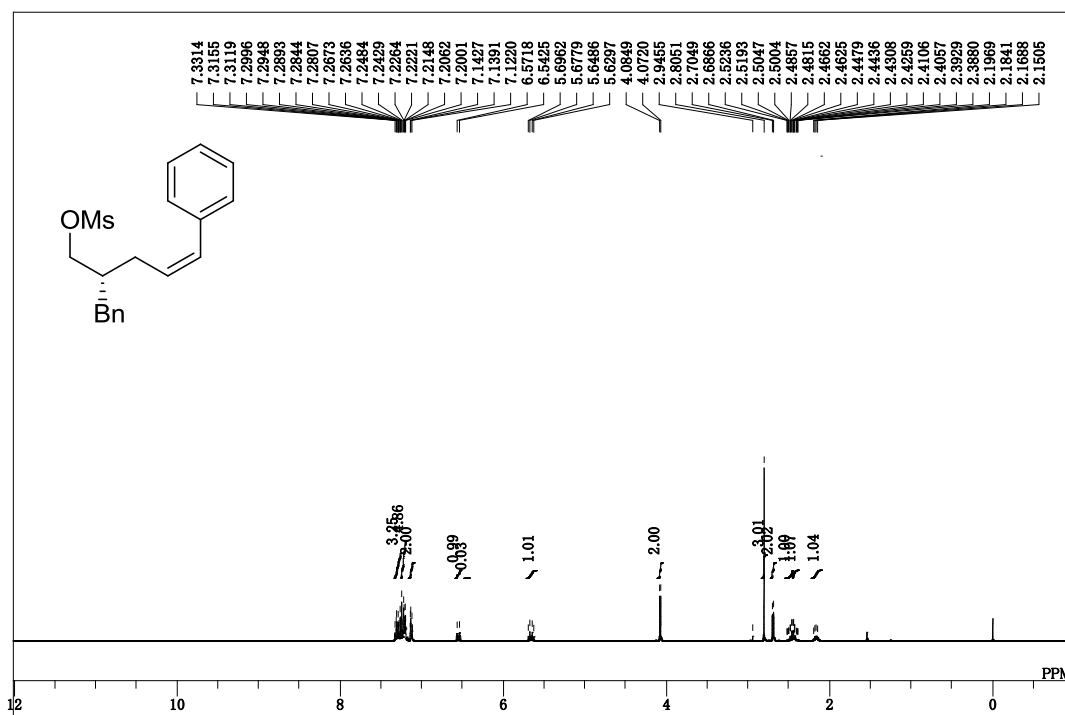




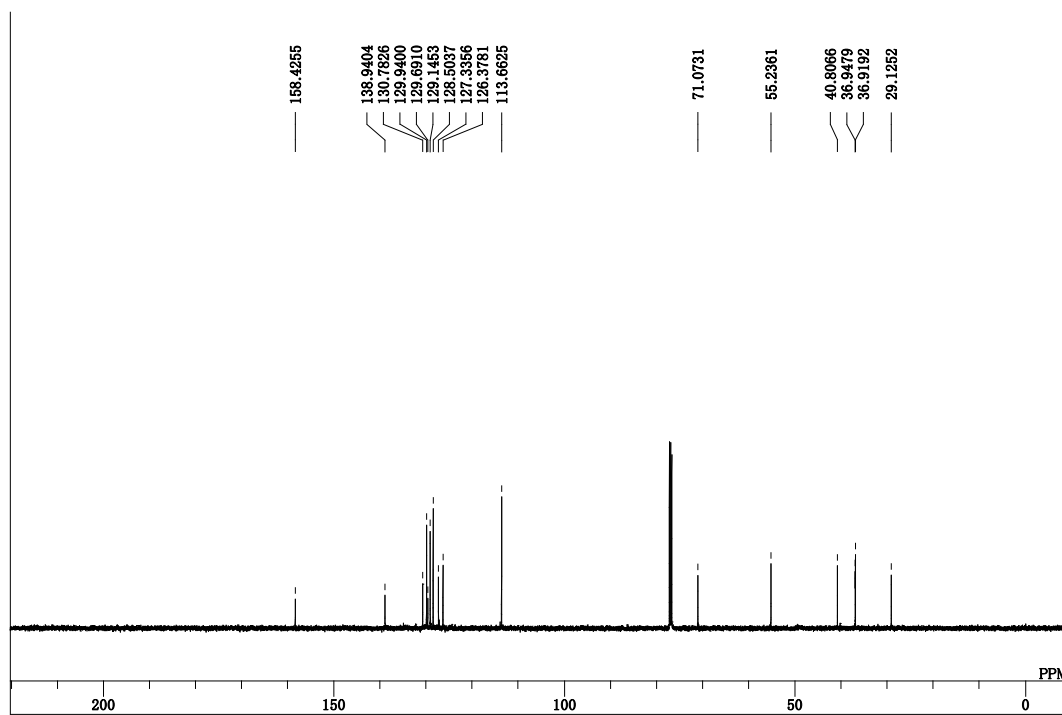
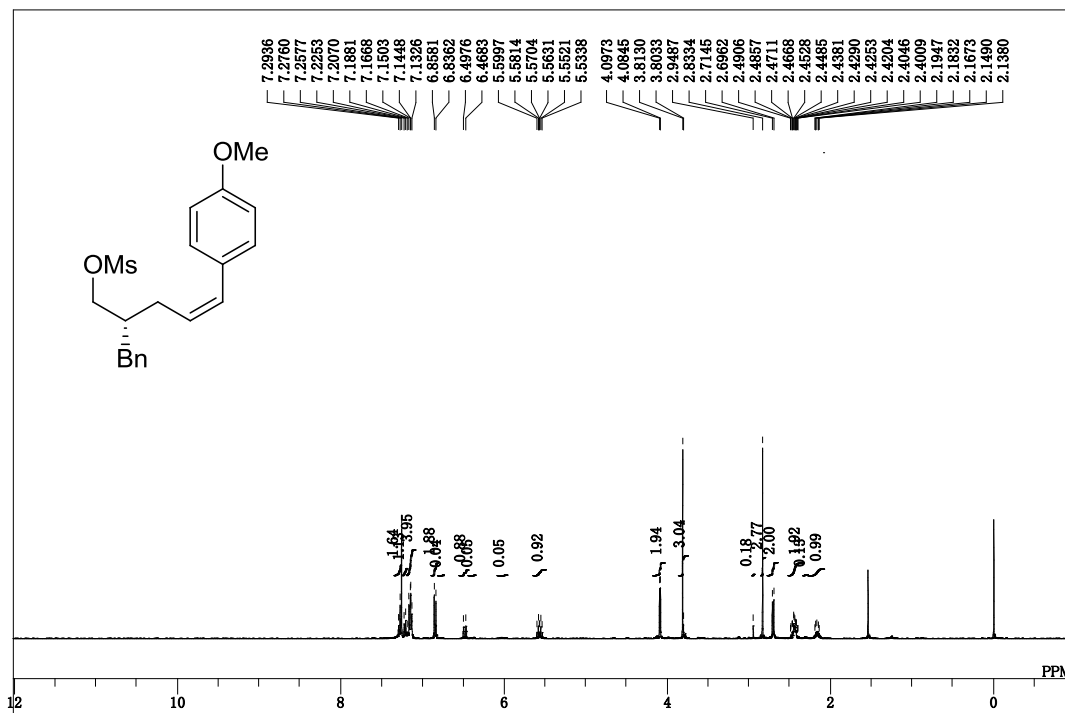
2-Benzyl-5-oxo-4-(phenylselanyl)dodecanal (Table 2, entry 11)



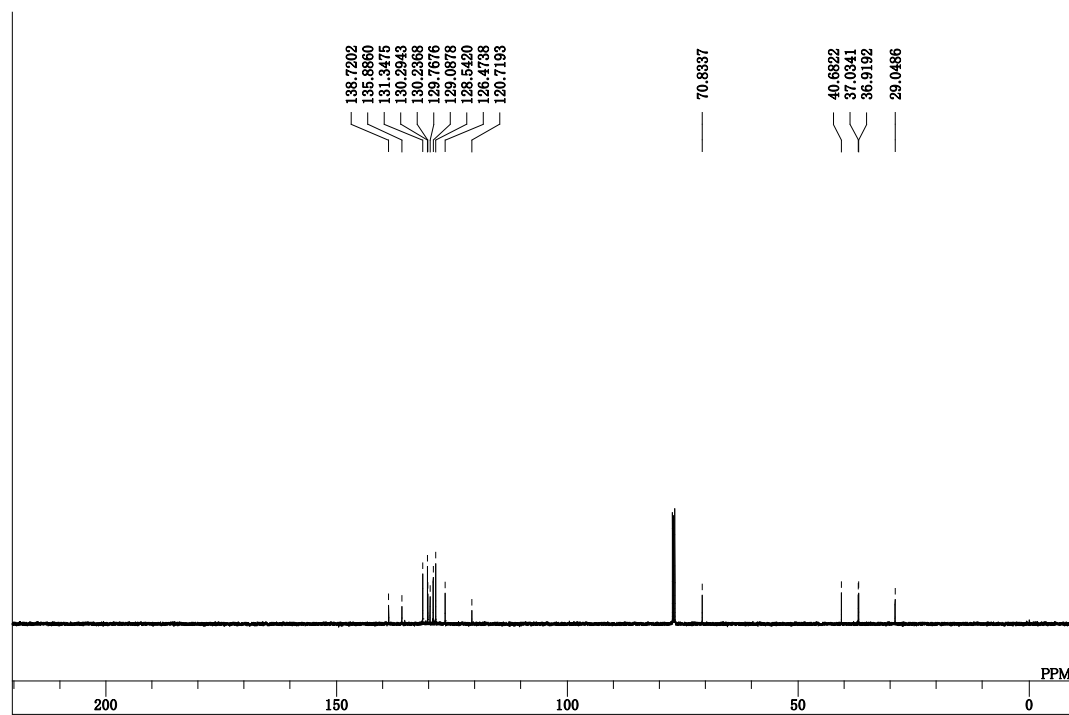
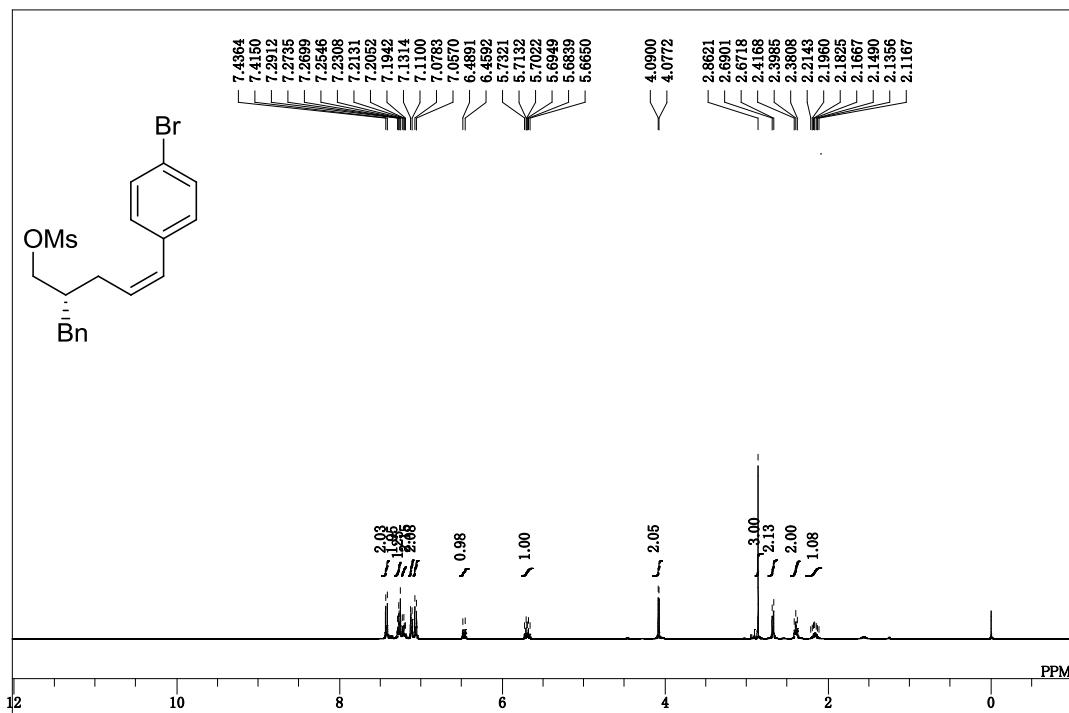
(Z)-2-Benzyl-5-phenylpent-4-en-1-yl methanesulfonate (Table 3, entry 1)



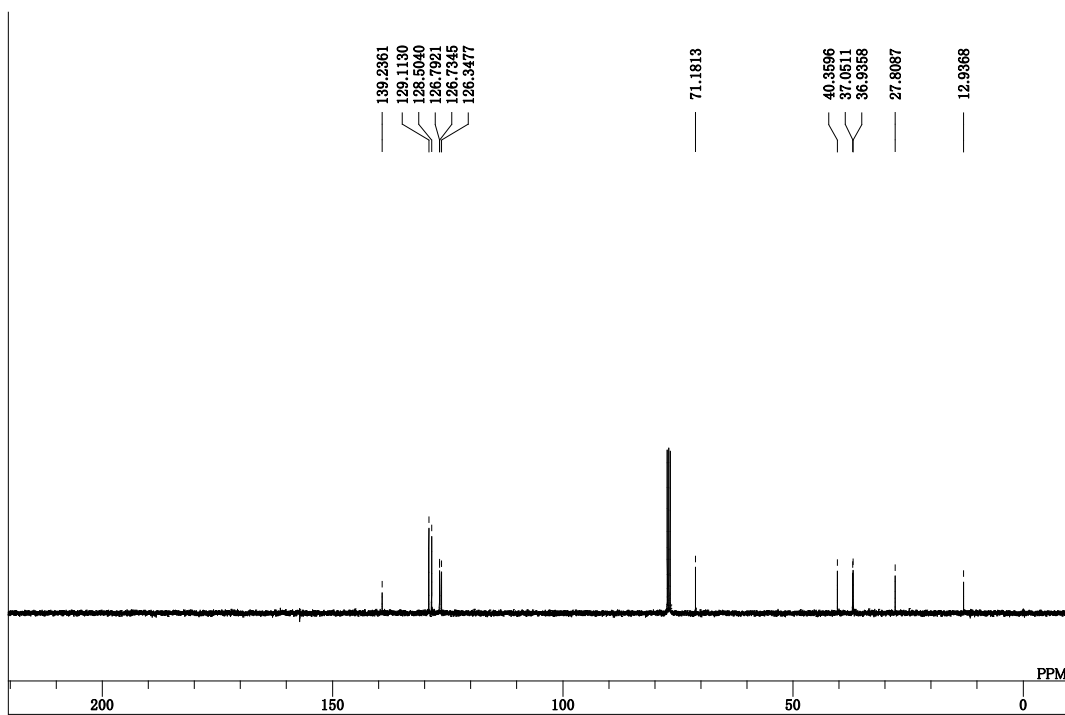
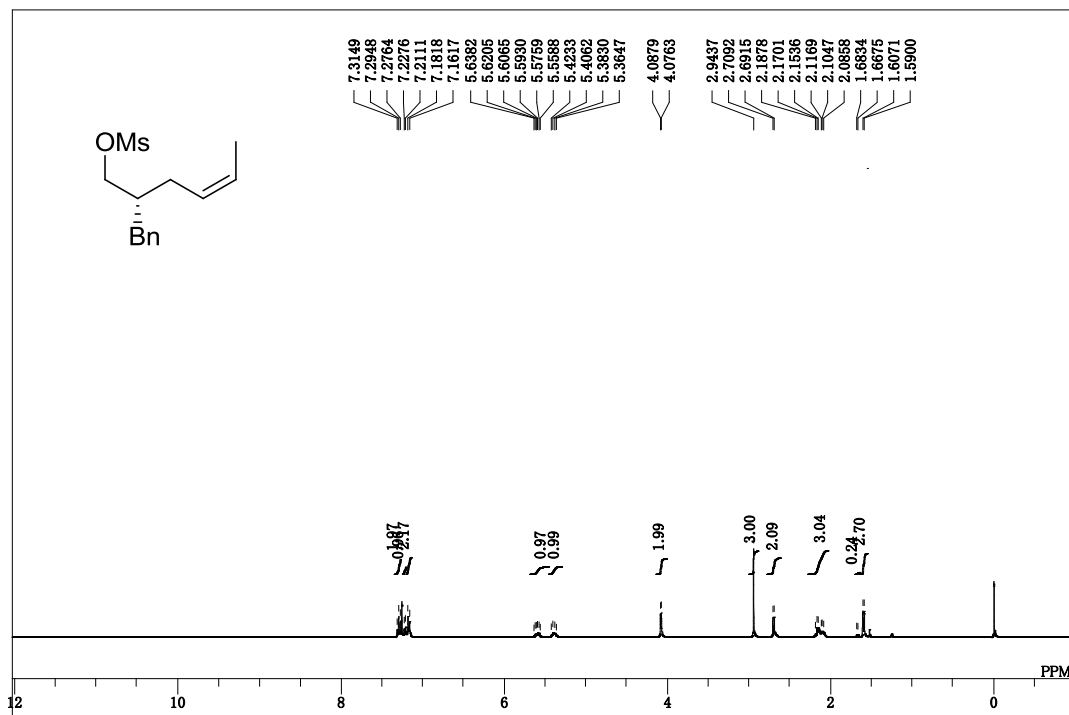
**(Z)-2-Benzyl-5-(4-methoxyphenyl)pent-4-en-1-yl methanesulfonate (Table 3, entry 2)**



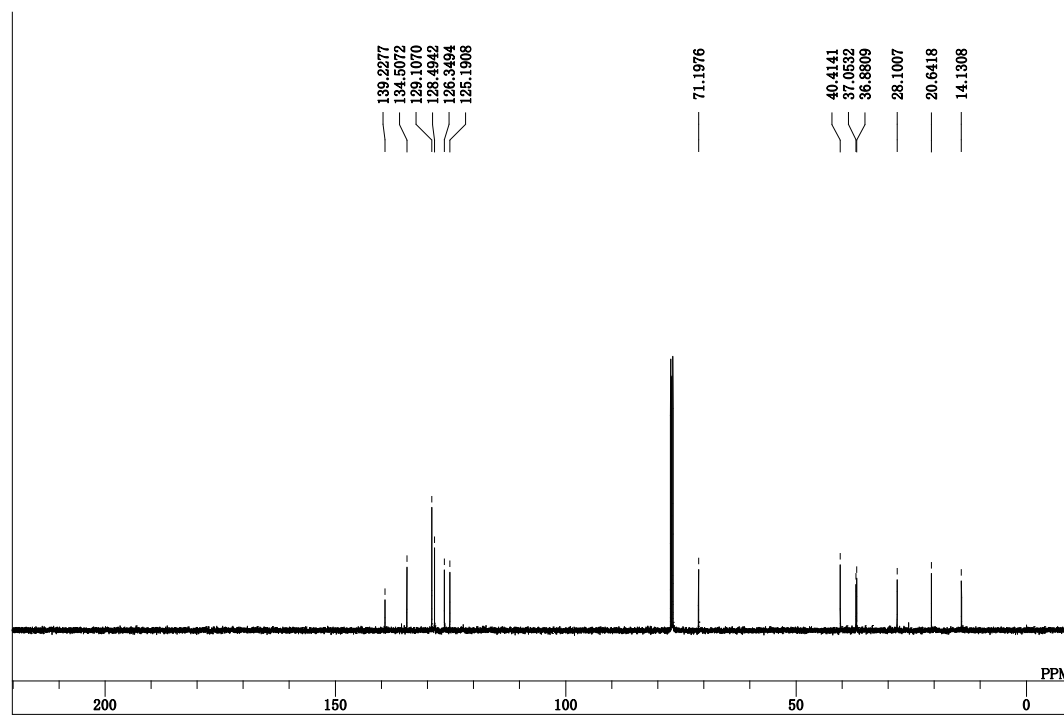
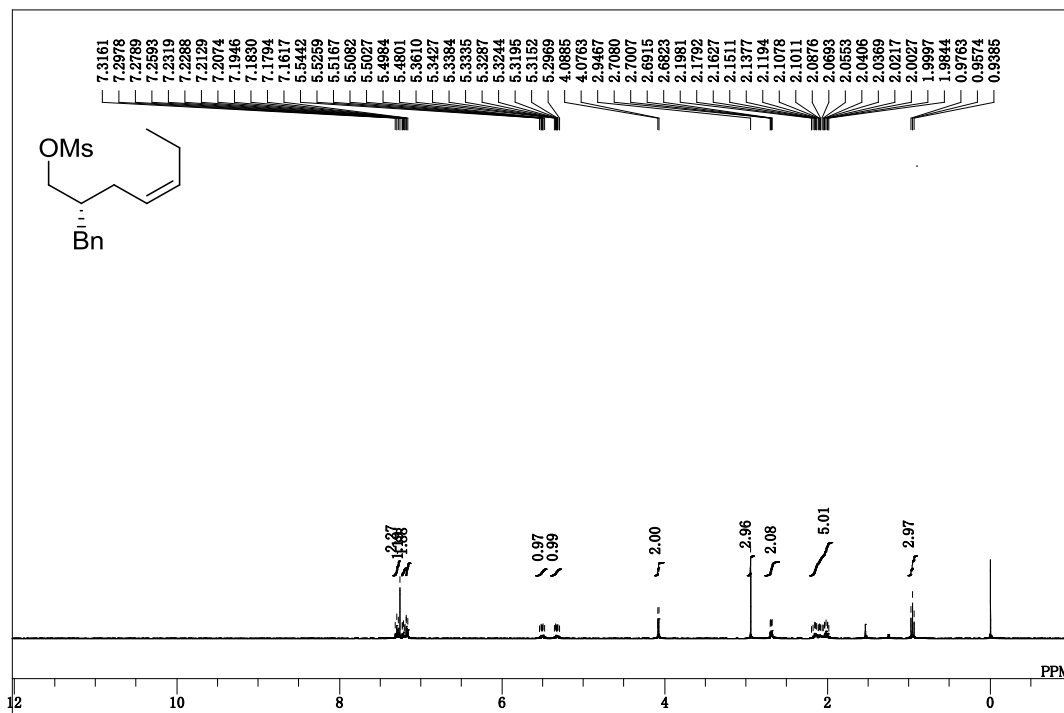
(Z)-2-Benzyl-5-(4-bromophenyl)pent-4-en-1-yl methanesulfonate (Table 3, entry 3)



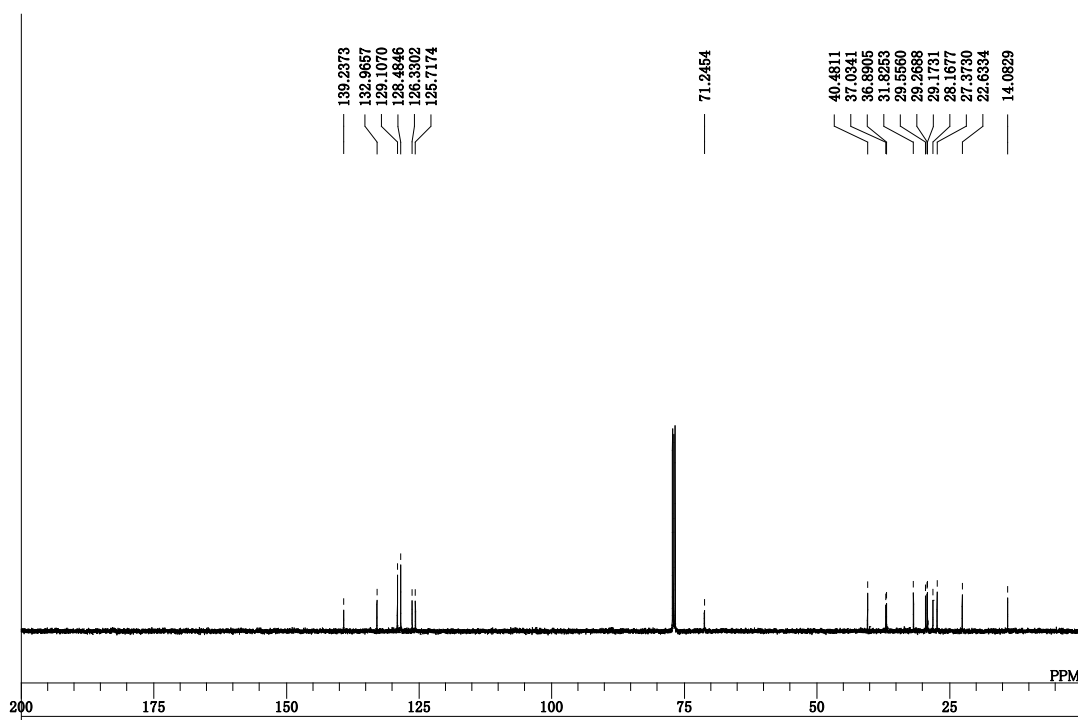
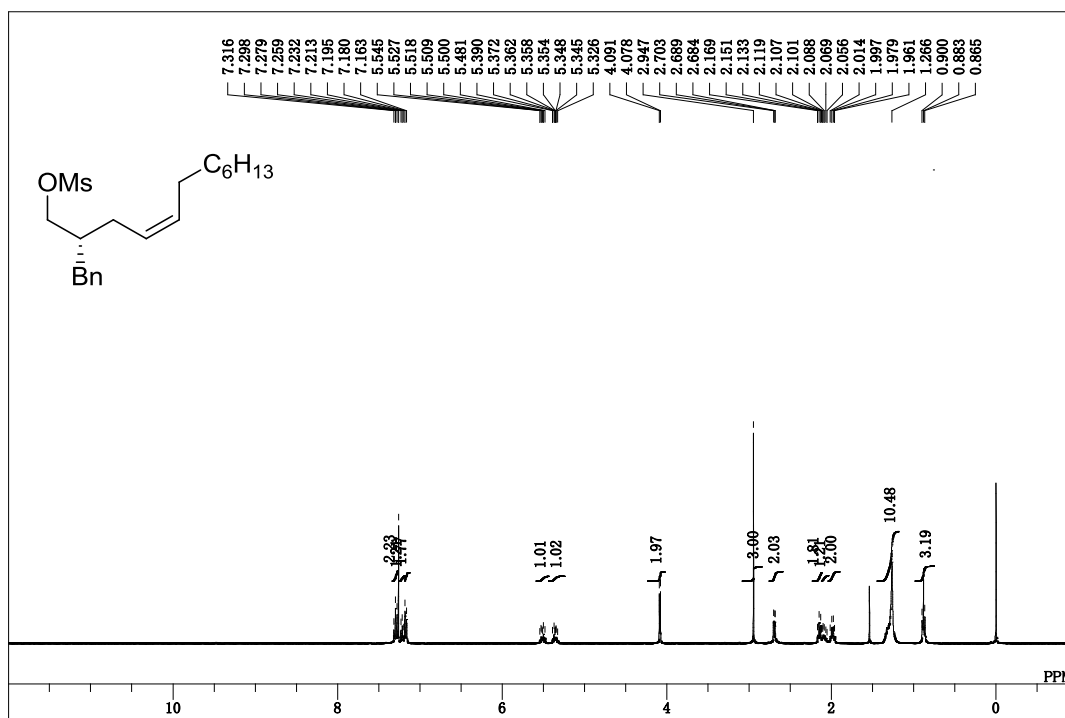
(Z)-2-Benzylhex-4-en-1-yl methanesulfonate (Table 3, entry 4)



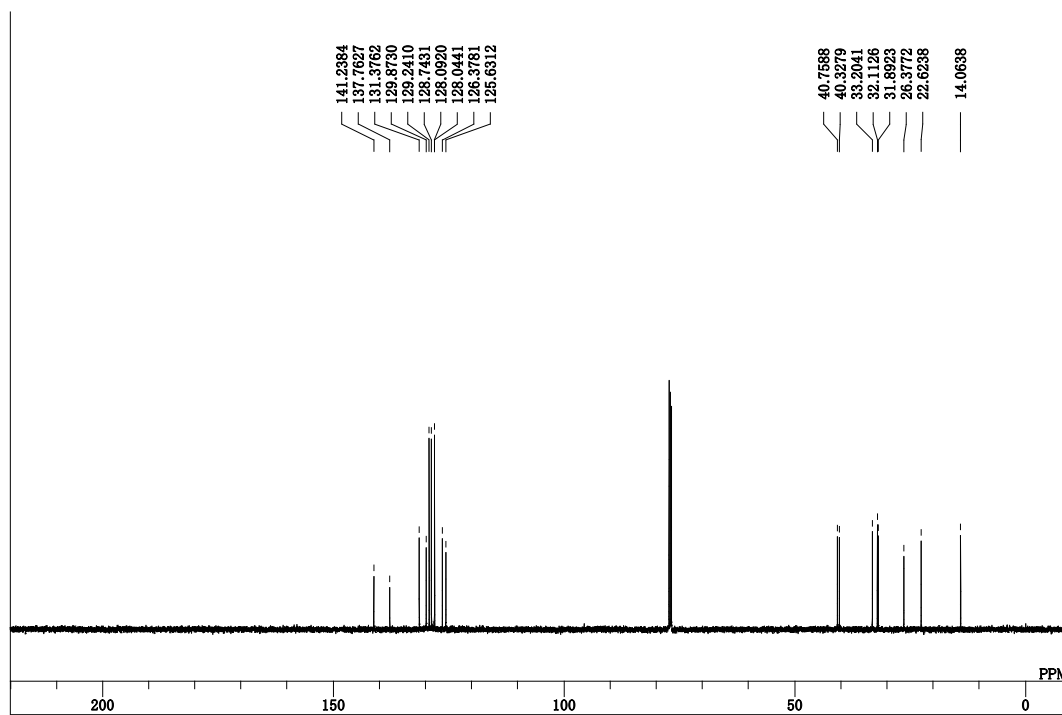
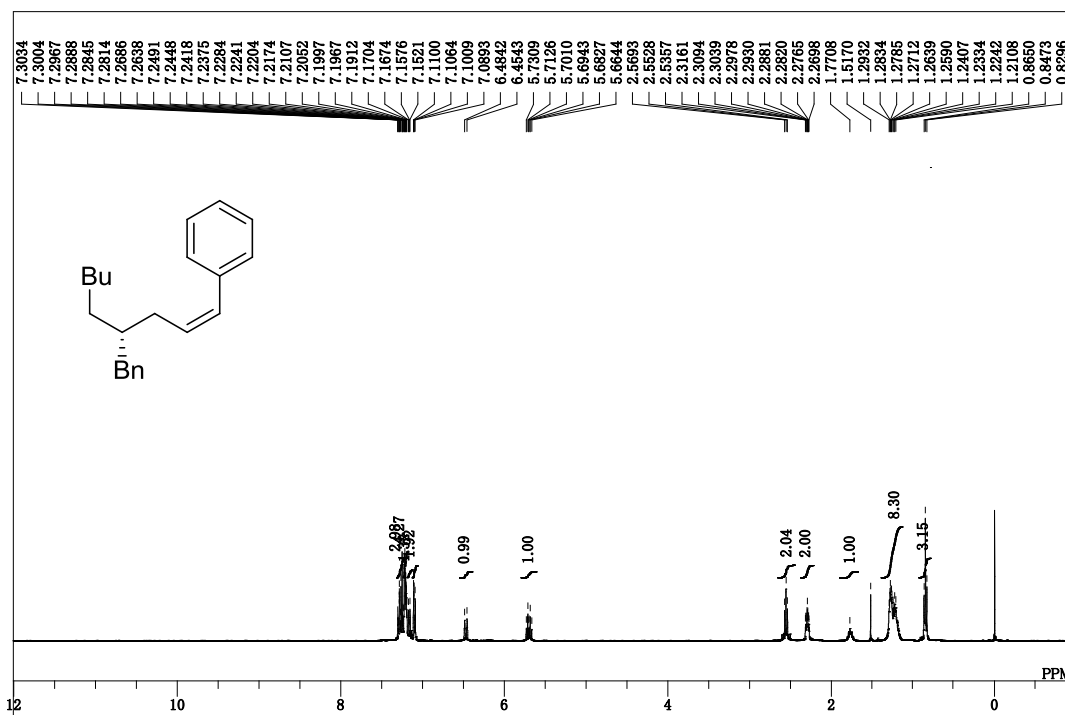
(Z)-2-Benzylhept-4-en-1-yl methanesulfonate (Table 3, entry 5)



(Z)-2-Benzyldec-4-en-1-yl methanesulfonate (Table 3, entry 6)

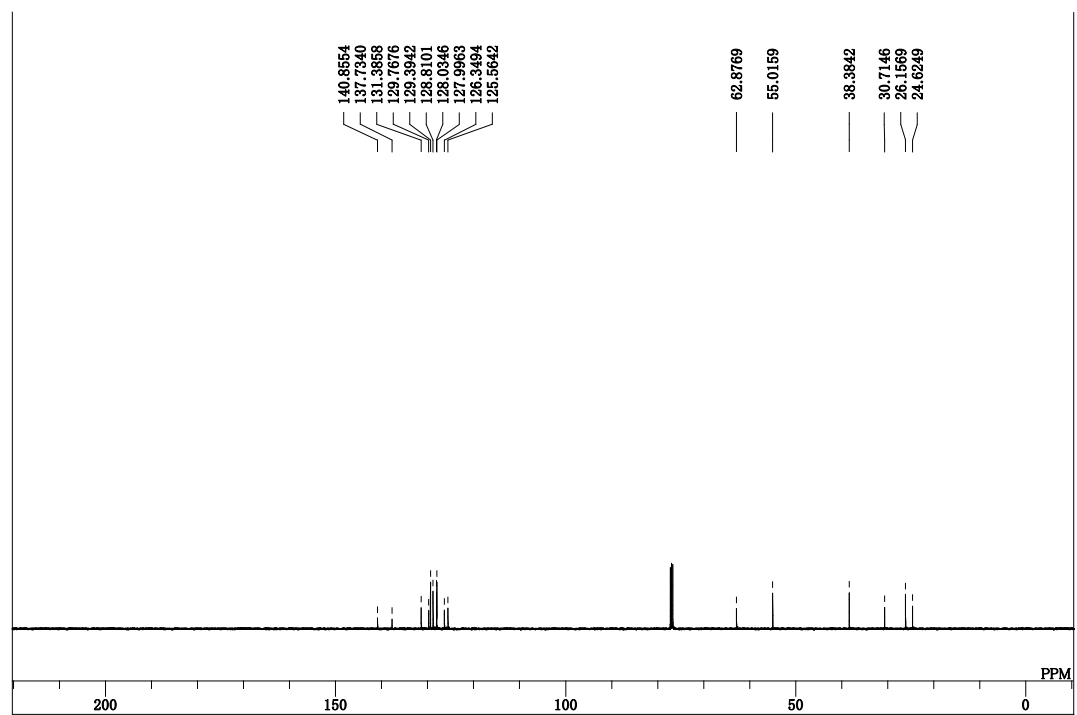
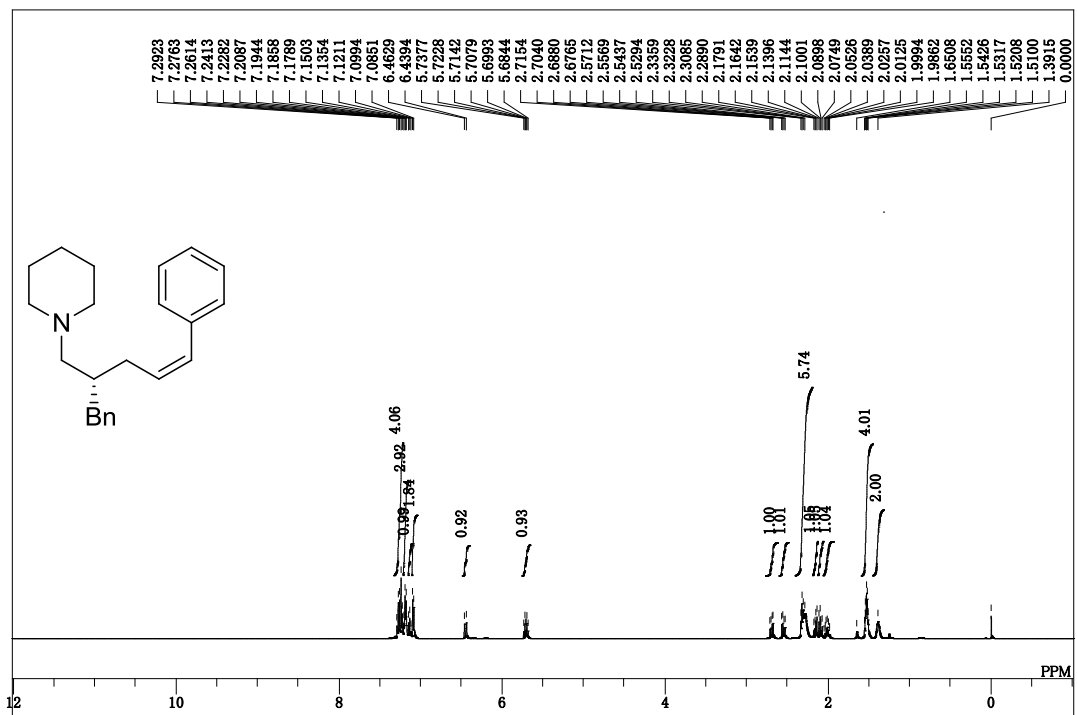


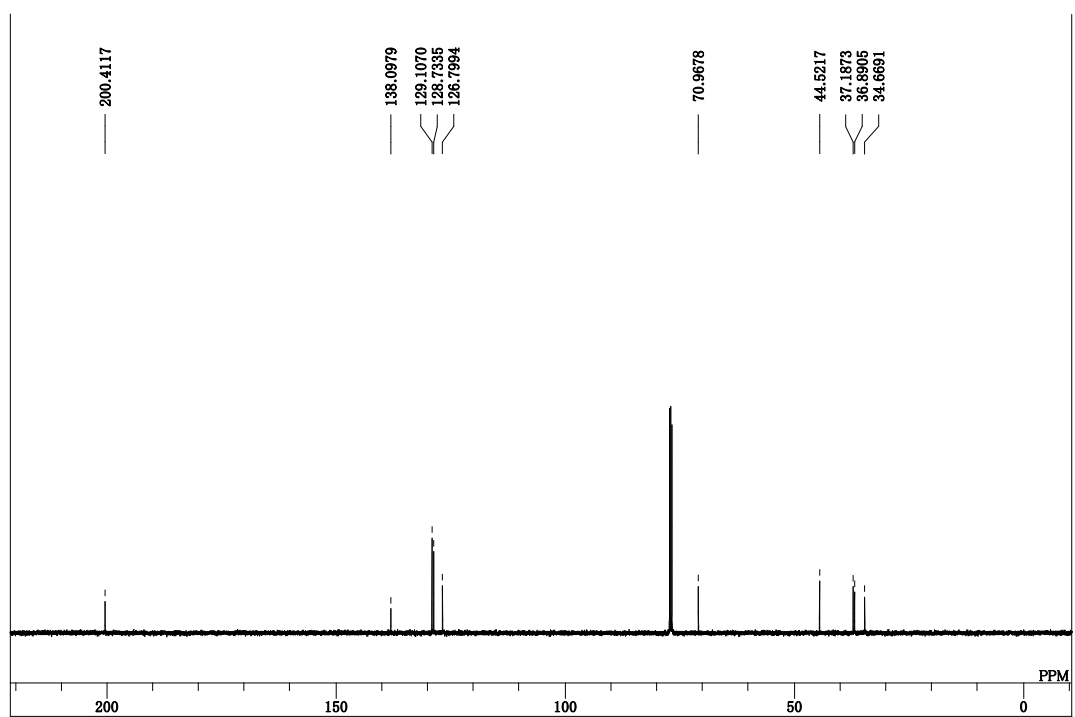
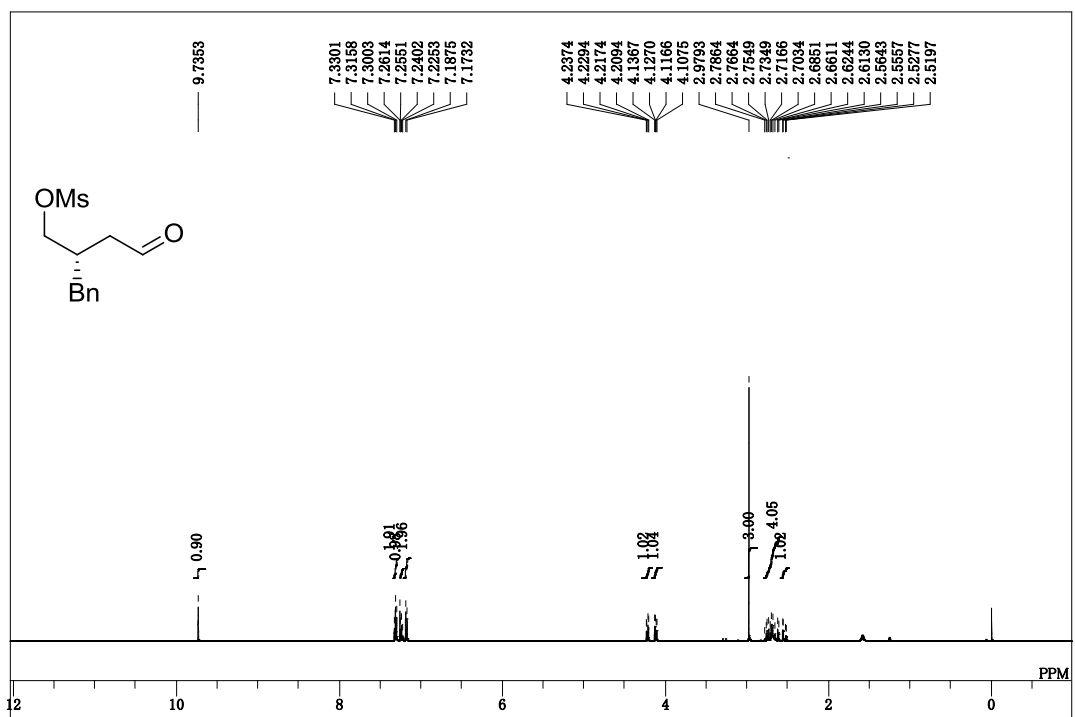
**(Z)-(4-Pentylpent-1-ene-1,5-diyl)dibenzene**



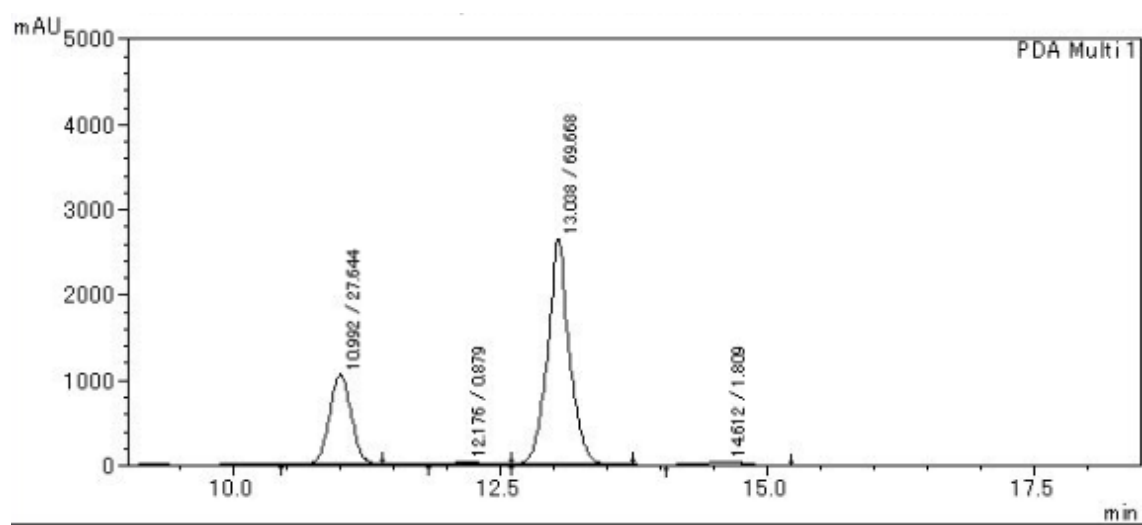
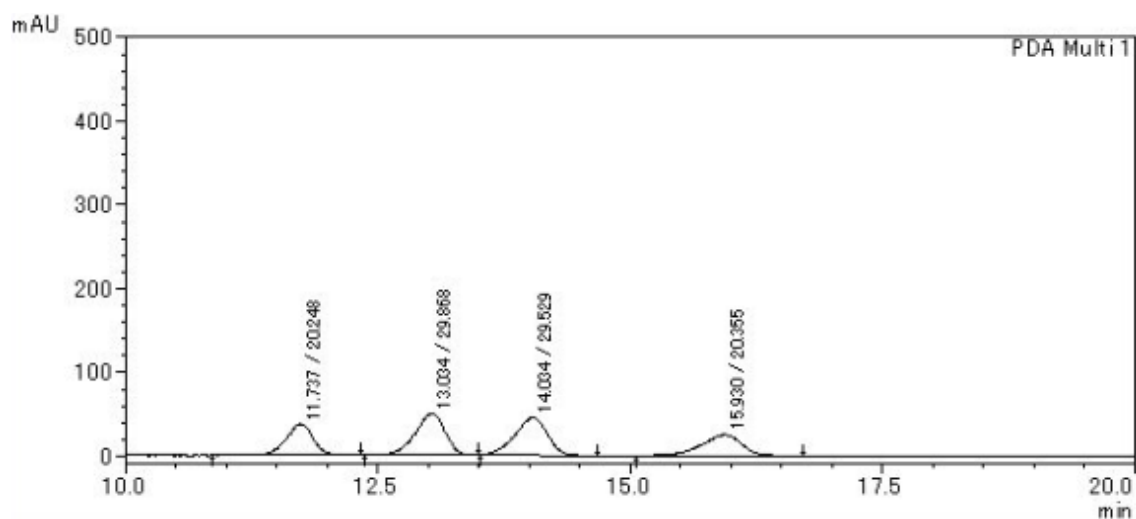
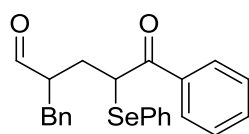


**(Z)-1-(2-Benzyl-5-phenylpent-4-en-1-yl)piperidine**

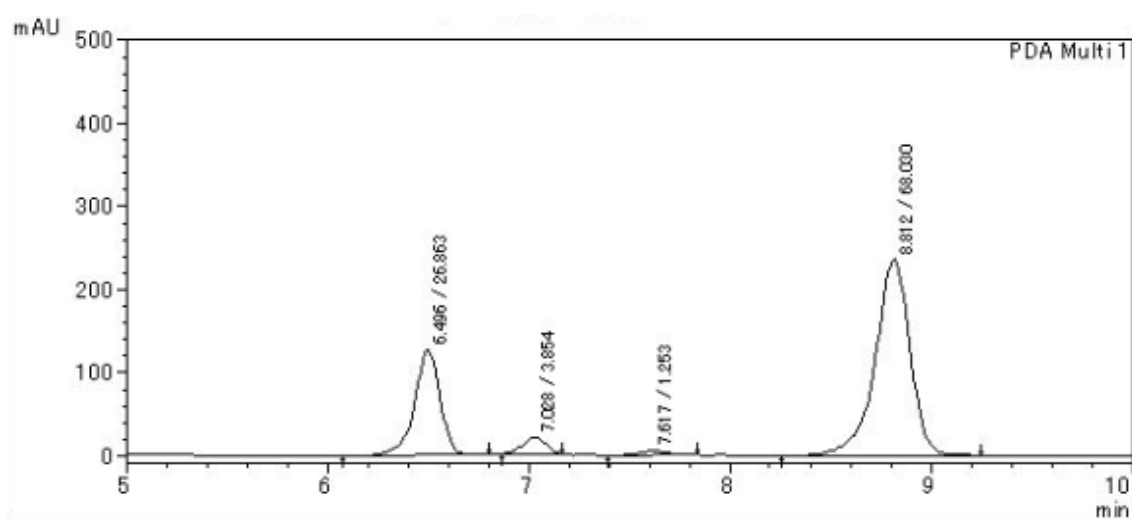
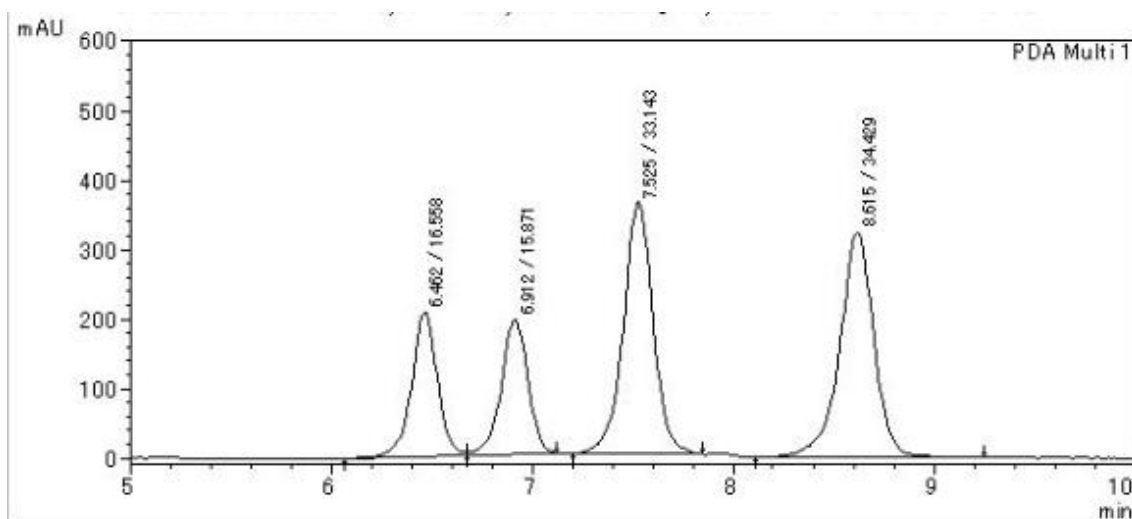
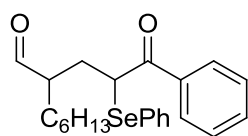




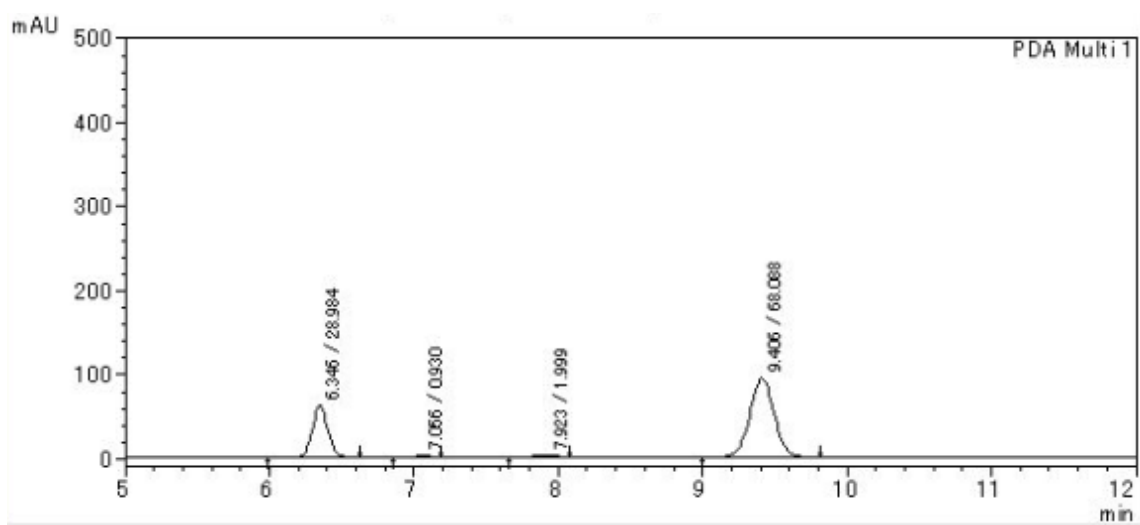
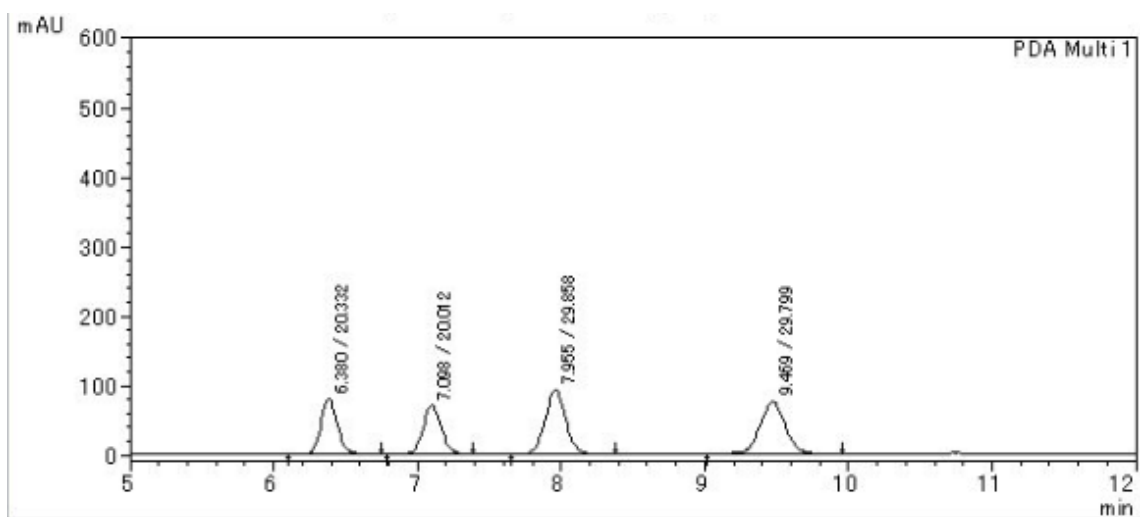
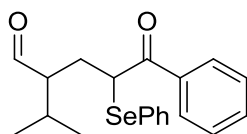
## 2-Benzyl-5-oxo-5-phenyl-4-(phenylselenanyl)pentanal



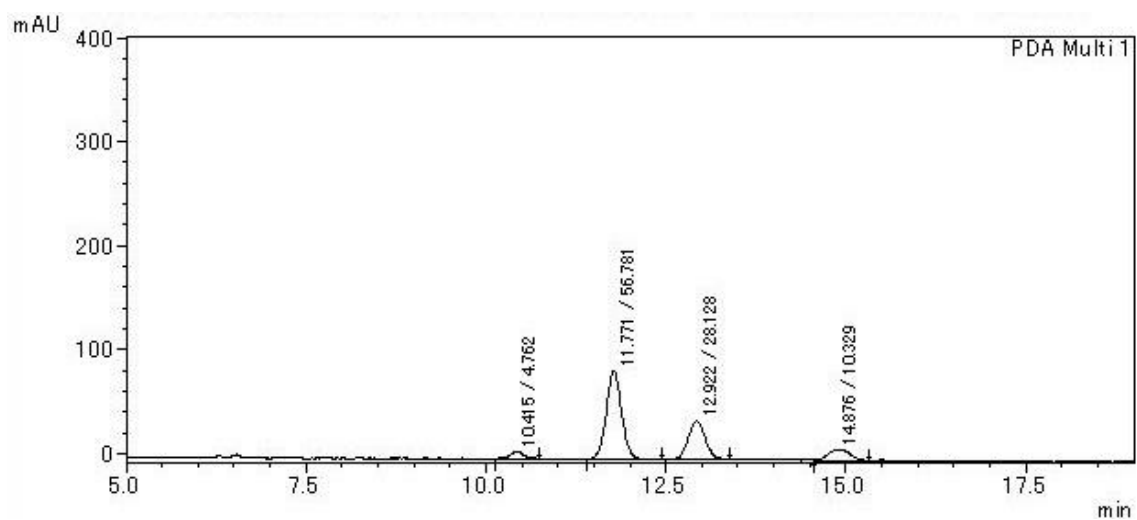
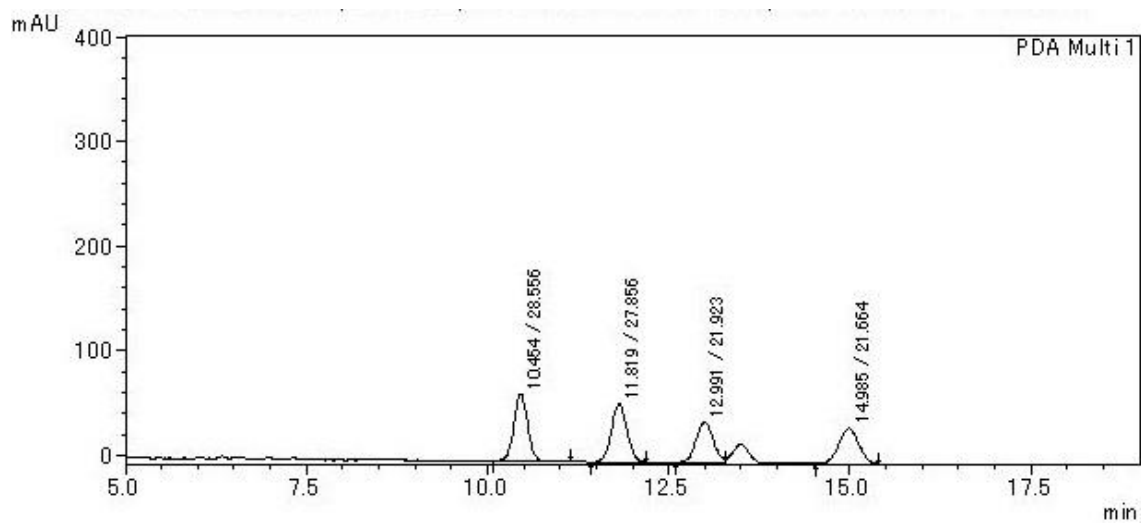
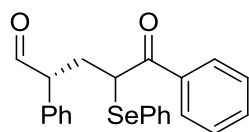
## 2-(3-Oxo-3-phenyl-2-(phenylselanyl)propyl)octanal



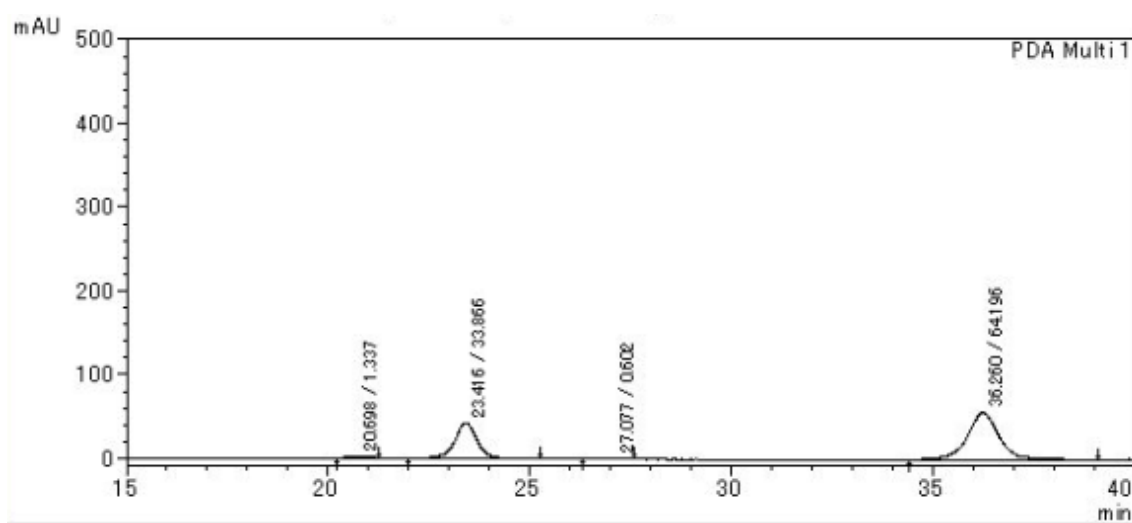
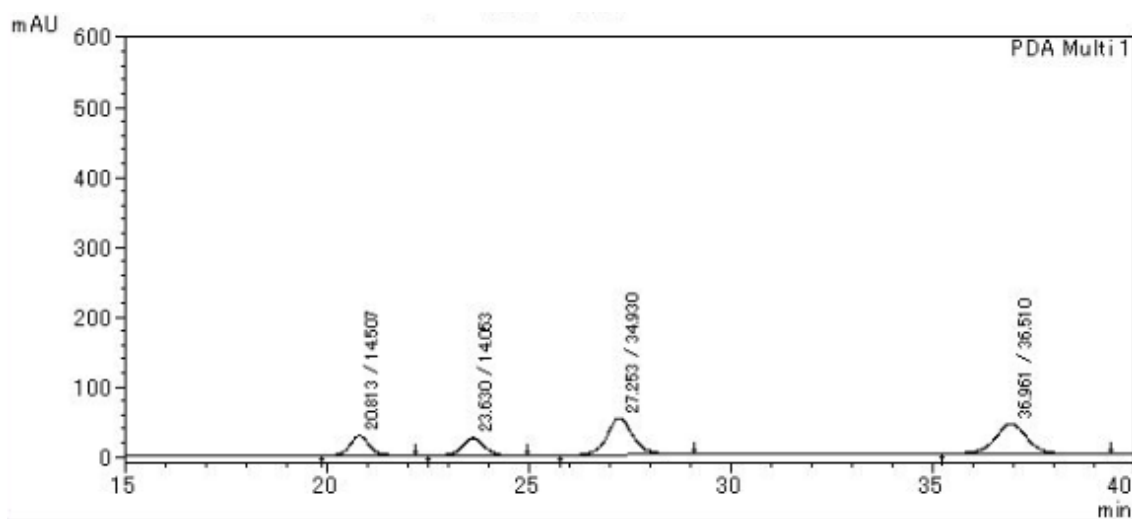
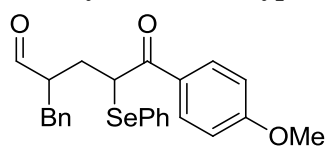
## 2-Isopropyl-5-oxo-5-phenyl-4-(phenylselanyl)pentanal



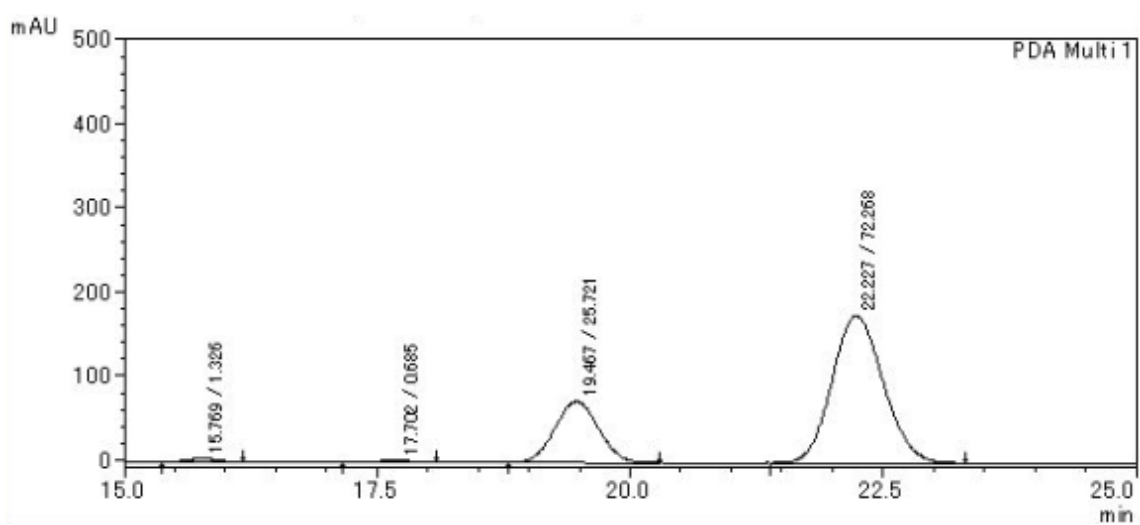
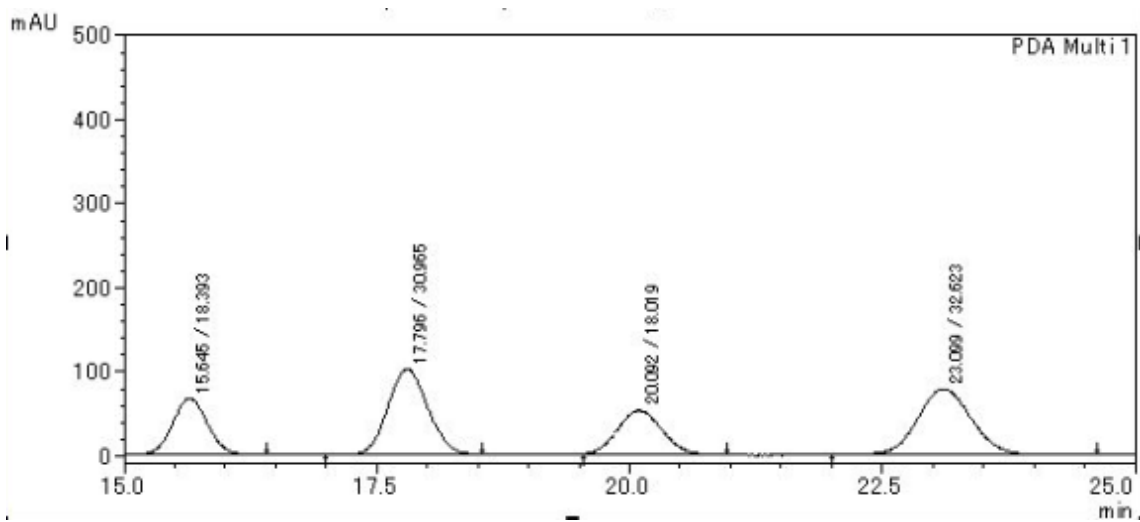
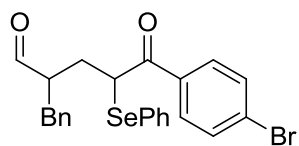
### 5-Oxo-2,5-diphenyl-4-(phenylselanyl)pentanal



## 2-Benzyl-5-(4-methoxyphenyl)-5-oxo-4-(phenylselanyl)pentana

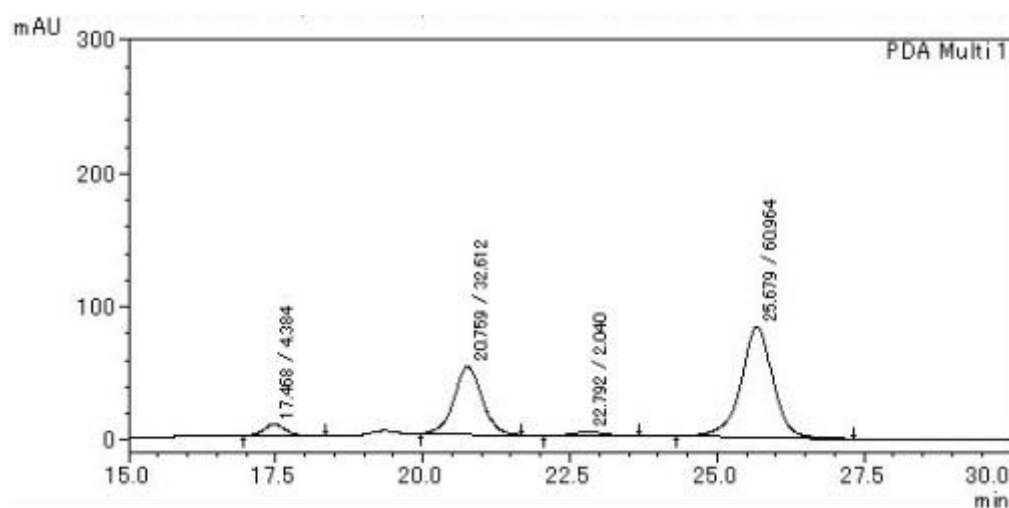
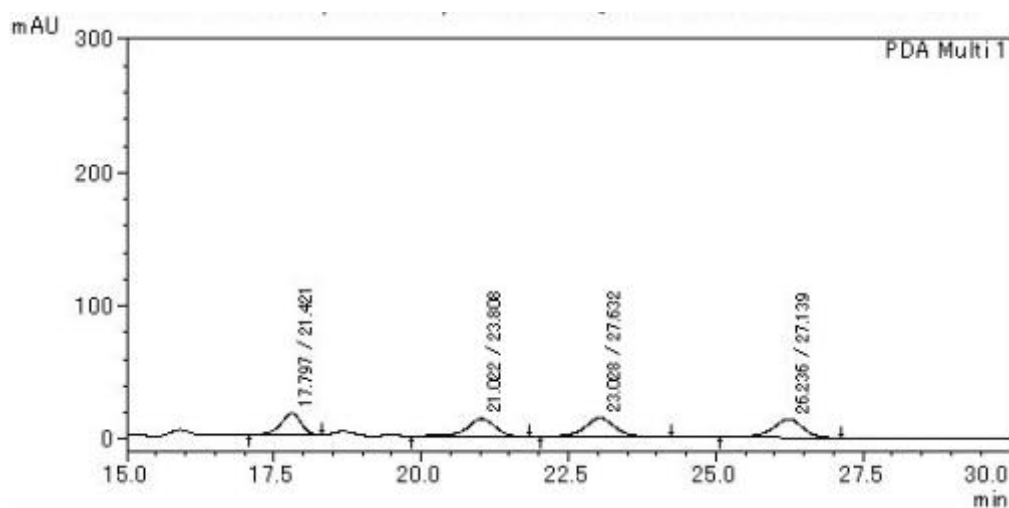
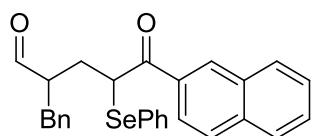


## 2-Benzyl-5-(4-bromophenyl)-5-oxo-4-(phenylselanyl)pentanal

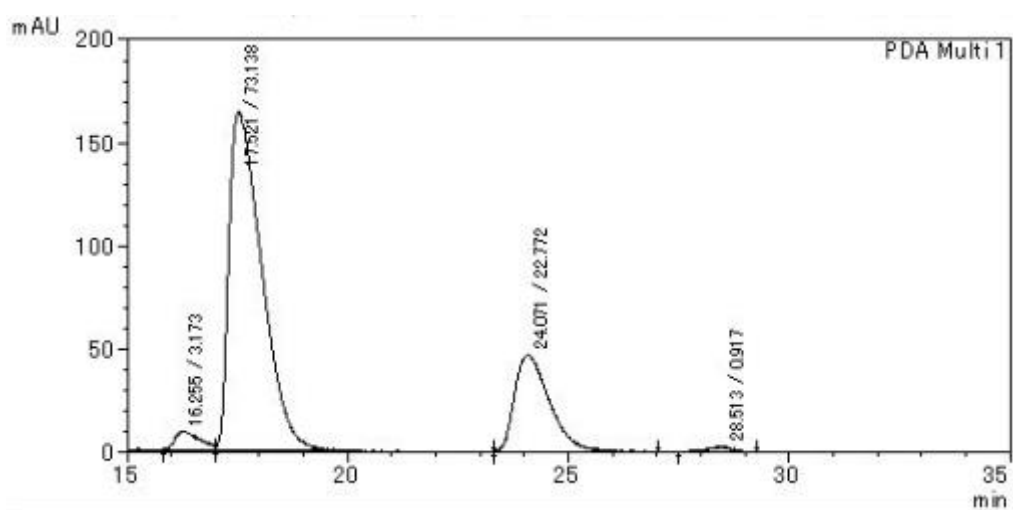
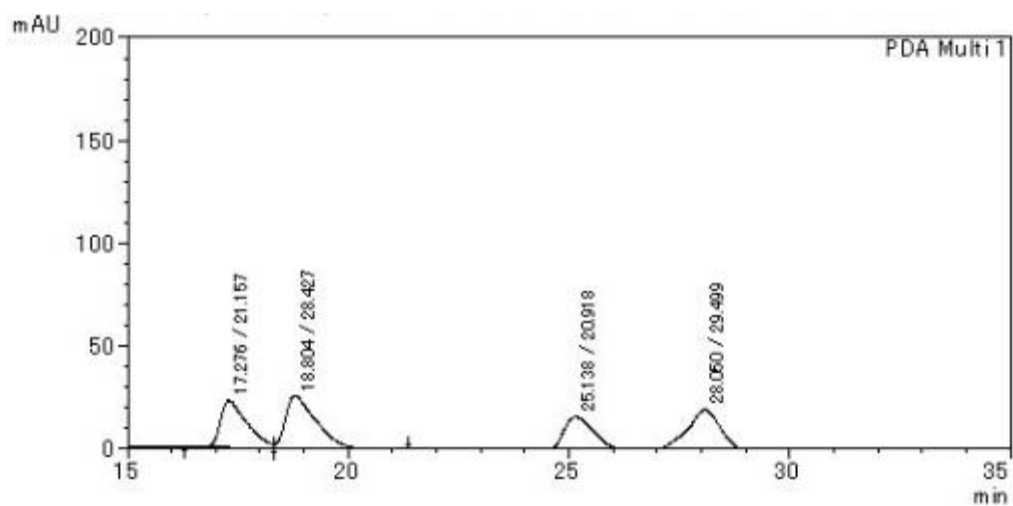
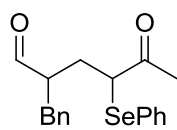




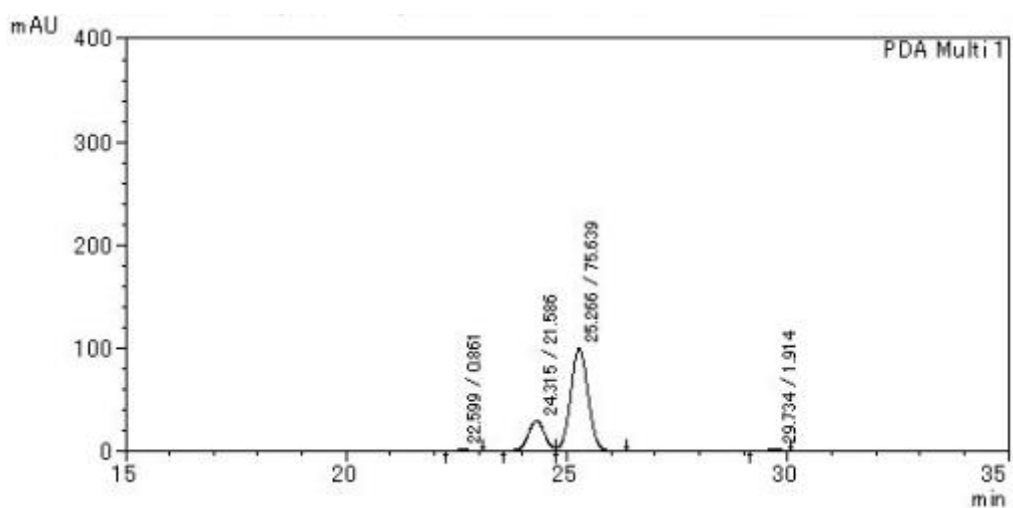
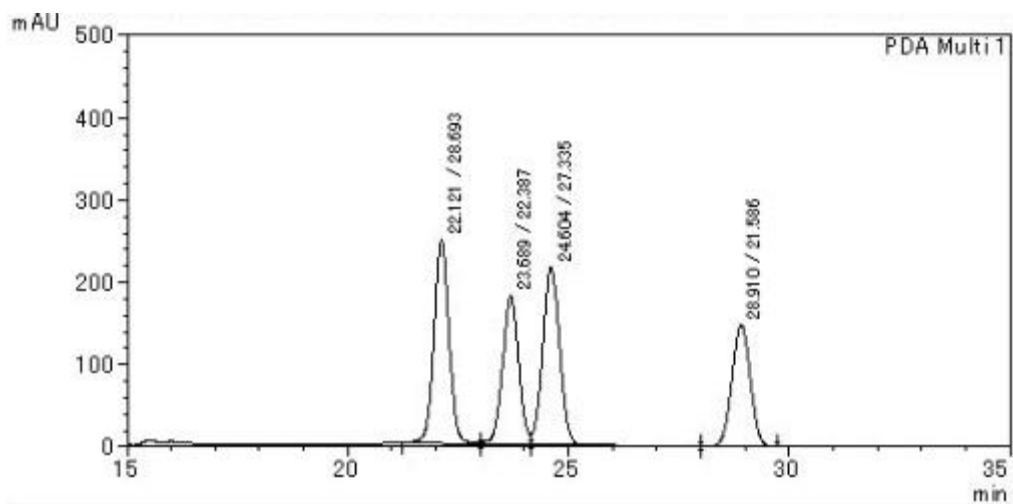
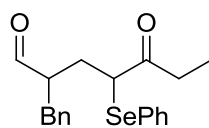
**2-Benzyl-5-(naphthalen-2-yl)-5-oxo-4-(phenylselanyl)pentanal**



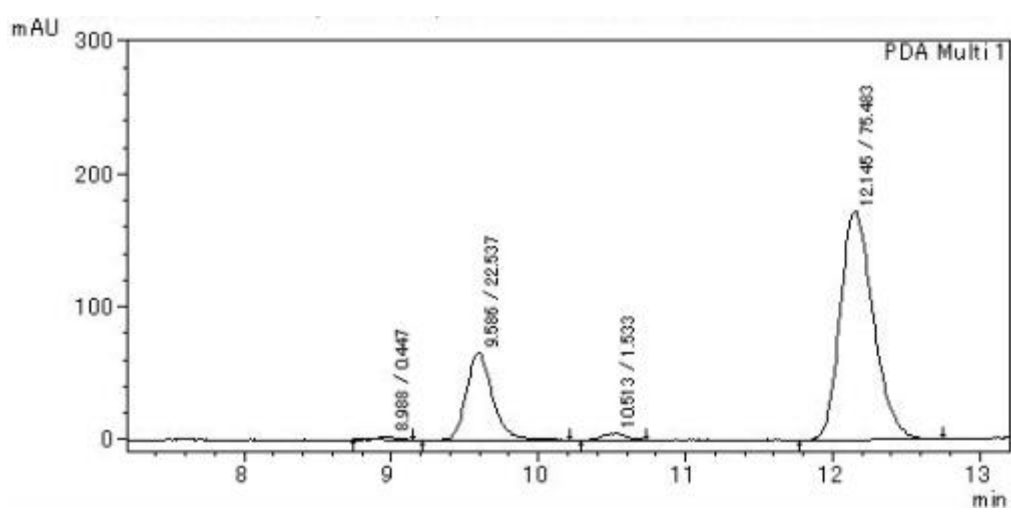
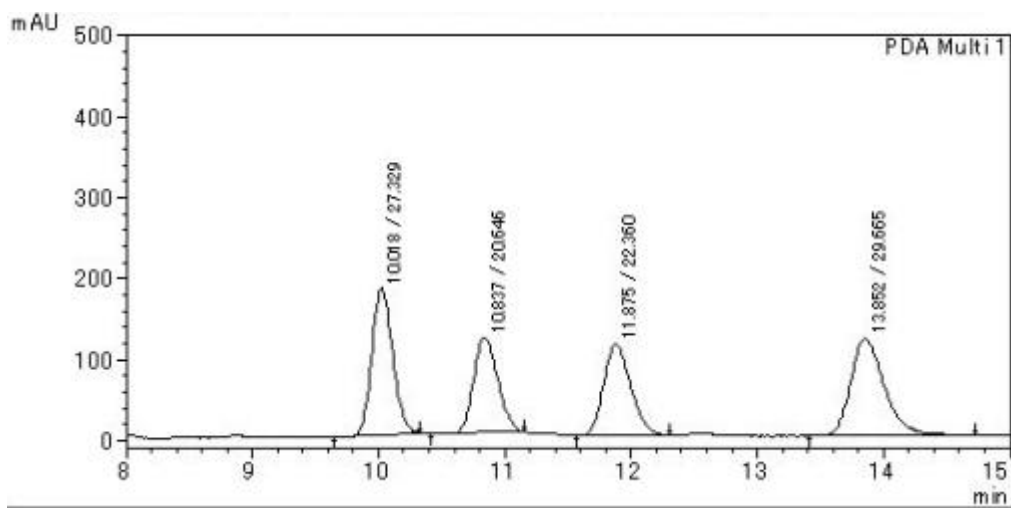
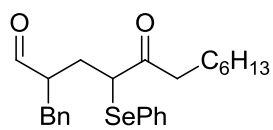
## 2-Benzyl-5-oxo-4-(phenylselanyl)hexanal



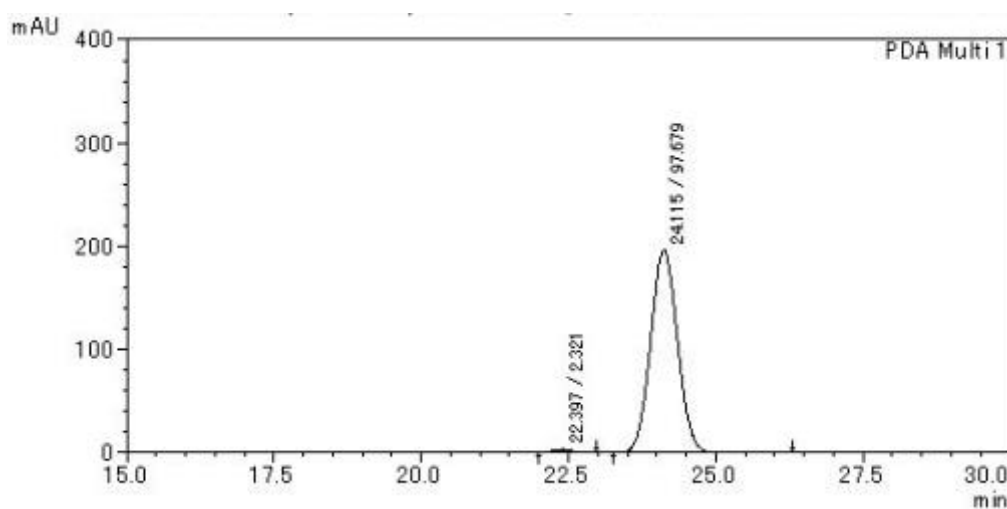
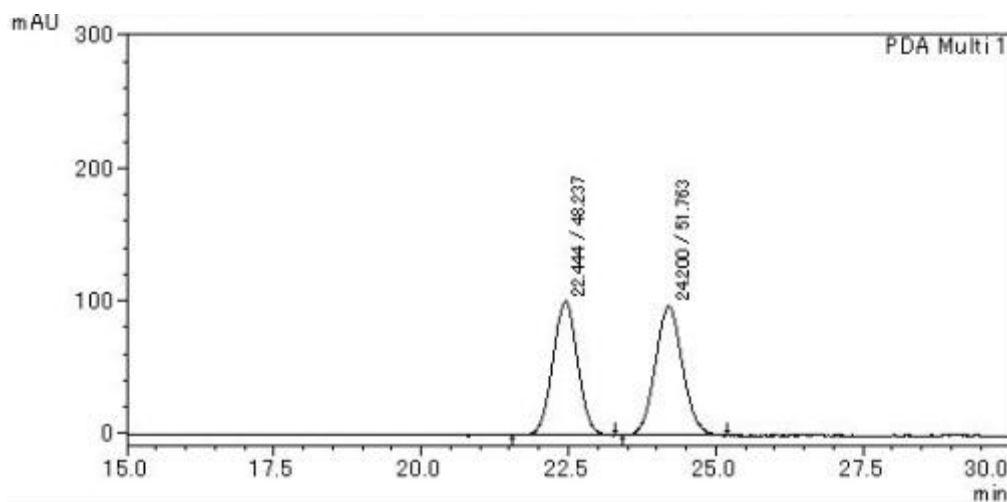
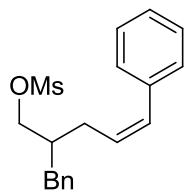
## 2-Benzyl-5-oxo-4-(phenylselanyl)heptanal



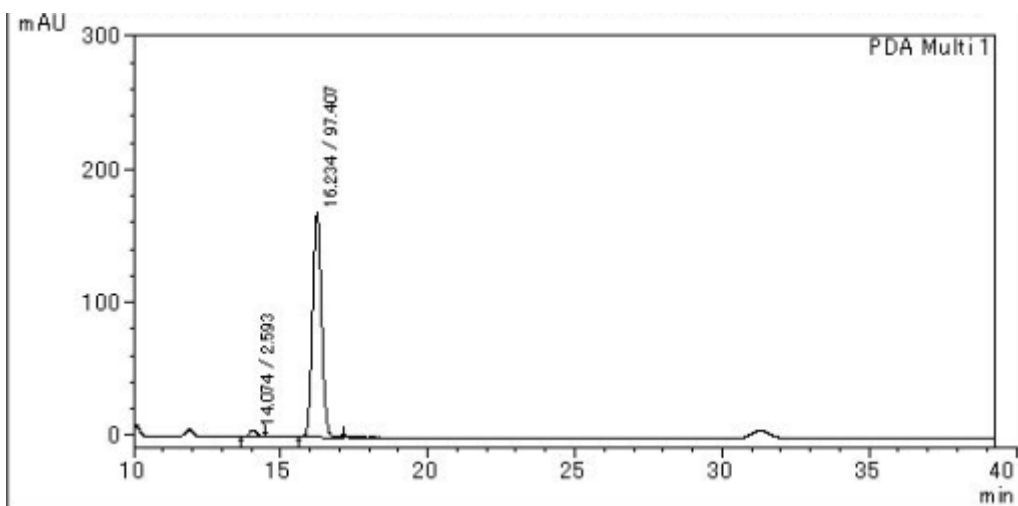
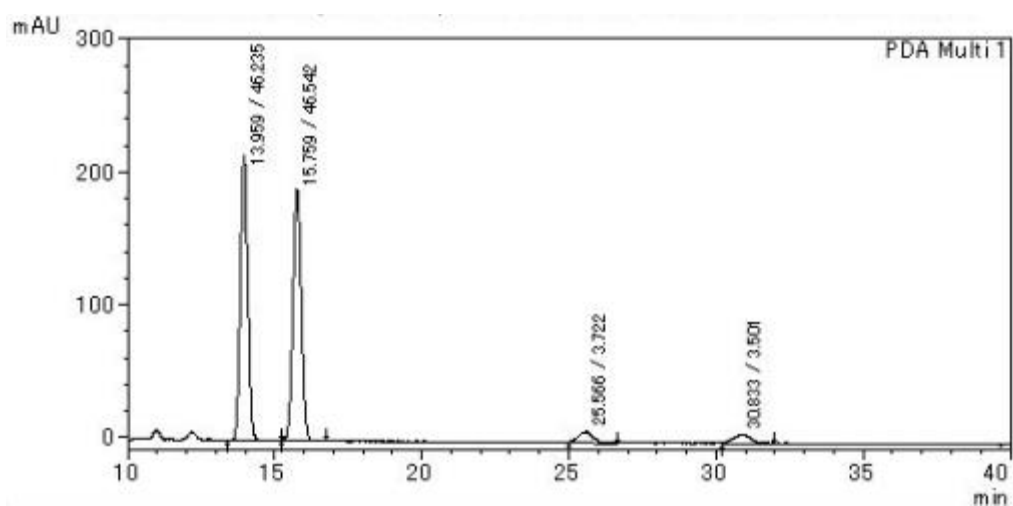
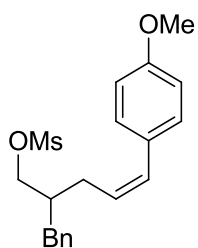
## 2-Benzyl-5-oxo-4-(phenylselanyl)dodecanal



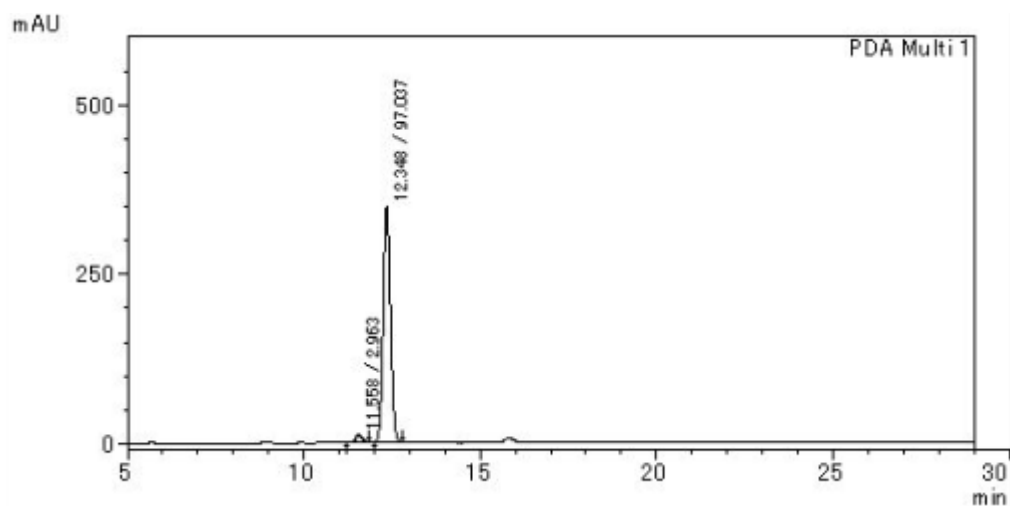
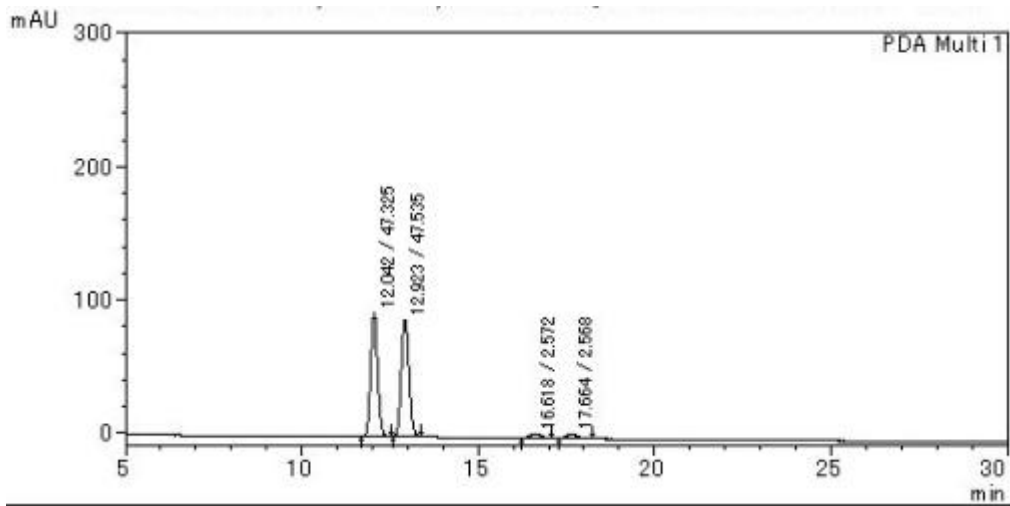
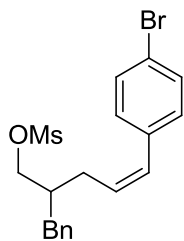
**(Z)-2-Benzyl-5-phenylpent-4-en-1-yl methanesulfonate**



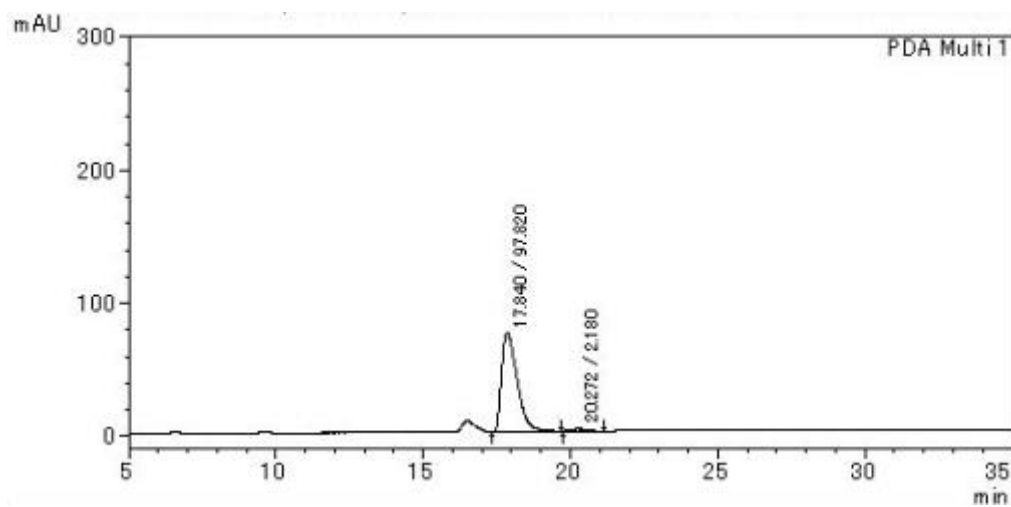
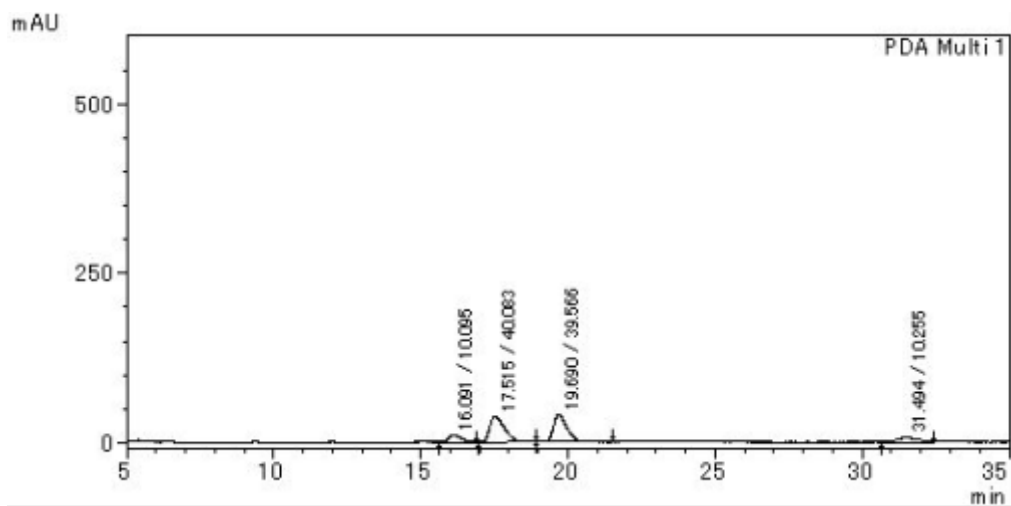
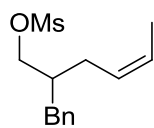
**(Z)-2-Benzyl-5-(4-methoxyphenyl)pent-4-en-1-yl methanesulfonate**



**(Z)-2-Benzyl-5-(4-bromophenyl)pent-4-en-1-yl methanesulfonate**

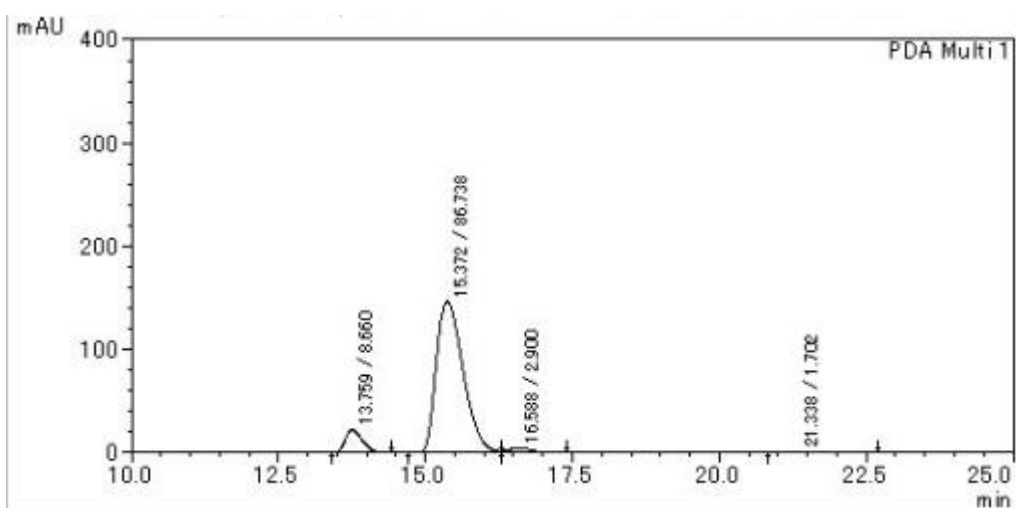
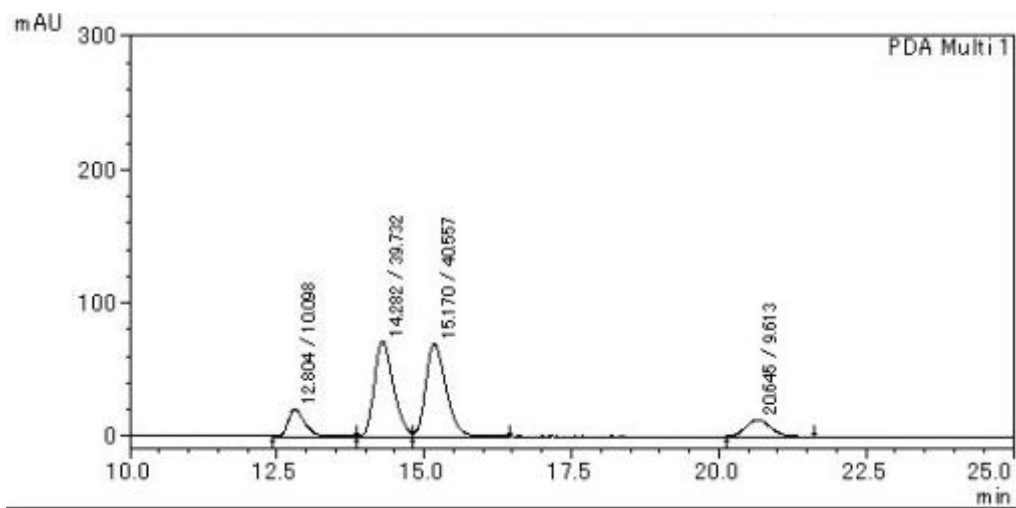
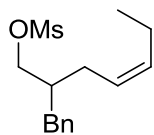


**(Z)-2-Benzylhex-4-en-1-yl methanesulfonate**

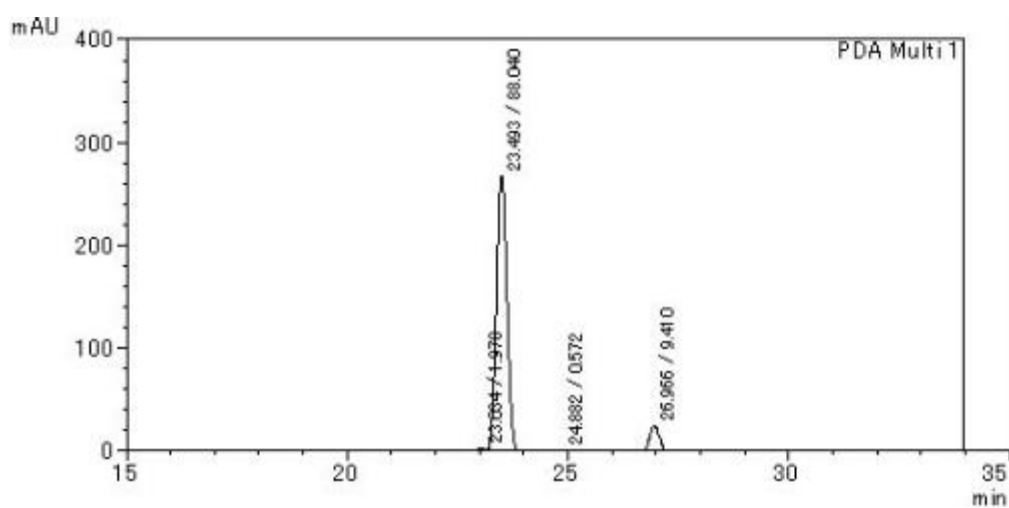
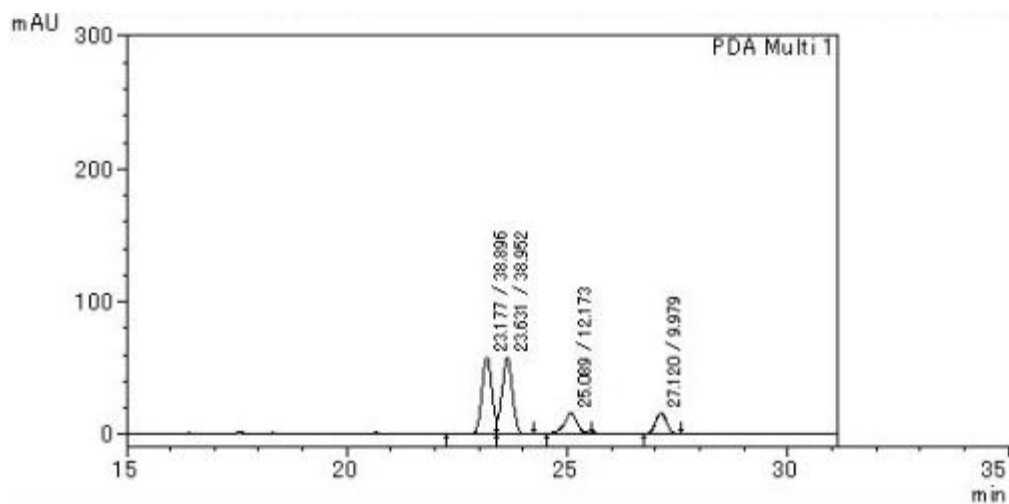
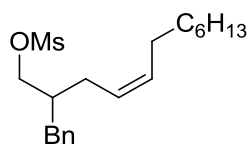




**(Z)-2-Benzylhept-4-en-1-yl methanesulfonate**



**(Z)-2-Benzyldec-4-en-1-yl methanesulfonate**



## 2-Benzyl-4-oxobutyl methanesulfonate

