Supplementary Information

Direct synthesis of dehydroselenocysteine-containing peptides from cysteine derivatives

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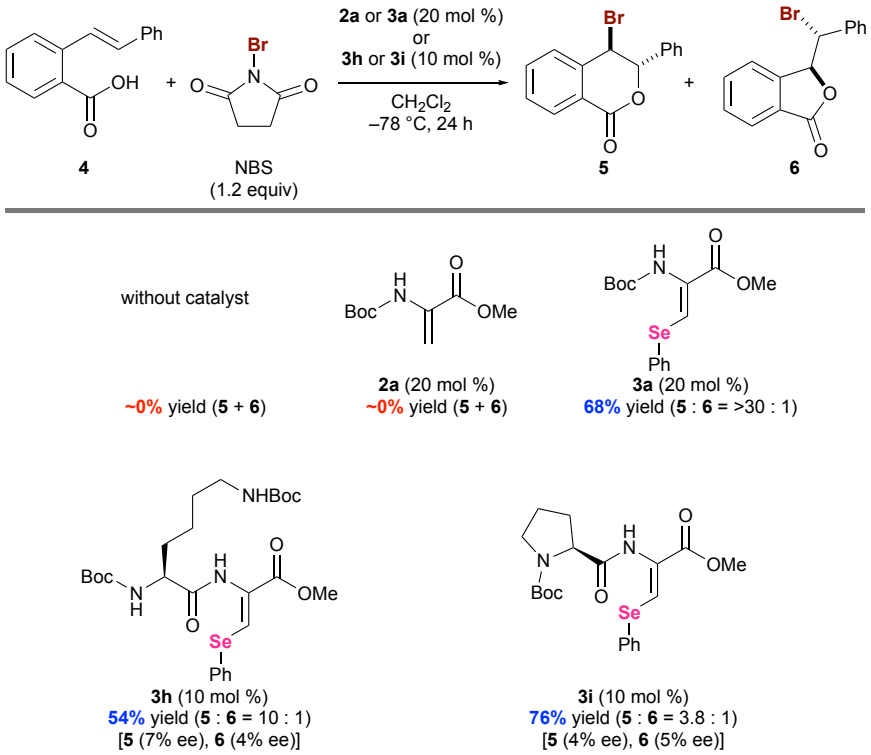
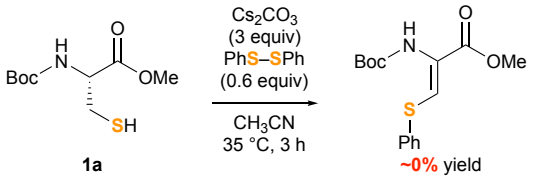
General Information

^{1}H, ^{13}C, and ^{77}Se NMR spectra were measured on a JEOL JNM-ECZ 400R NMR instrument (400 MHz for ^{1}H NMR, 100 MHz for ^{13}C NMR, and 76 MHz for ^{77}Se NMR). Tetramethylsilane (TMS) served as the internal standard (0 ppm) for ^{1}H NMR, solvent peaks served as the internal standard (77.0 ppm for $CDCl_3$; 39.5 ppm for DMSO-d_6) for ^{13}C NMR, and dimethylselenide (0 ppm) served as the internal standard for ^{77}Se NMR. The following abbreviations were used to express the multiplicities: s = singlet; d = doublet; t = triplet; q = quartet; m = multiplet; br = broad. High-resolution mass spectra (HRMS) were measured on a JEOL JMS-700N. Infrared spectra (IR) were measured on a JASCO FT/IR-4200 spectrometer. Optical rotations were measured on a JASCO P-2100 polarimeter. High performance liquid chromatography (HPLC) was performed on Shimadzu LC-20AT and SPD-20A instruments using Daicel Chiralpak IE-3 or IF-3 columns (4.6 mm × 250 mm). All reactions were monitored by thin-layer chromatography using Merck precoated TLC plates (silica gel 60GF-254, 0.25 mm), with visualization by the use of UV lamp (254 nm) or dyes. The products were purified by flash column chromatography on silica gel.



Scheme S1 Application of dehydroselenocysteines **3** as organoselenium catalysts in bromolactonization.[S1,S2]



Scheme S2 Reaction with diphenyl disulfide.

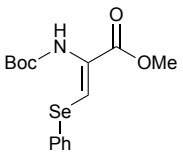
Experimental Section

1. Preparation of substrates

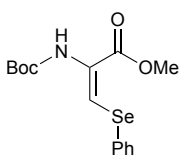
Amnio acid-derived substrates (**1a**–**k** and **2a**) are known and commercially available compounds.[S3]

2. Synthesis of dehydroselenocysteine derivative 3a (Scheme 2)

A mixture of cysteine derivative **1a** (24 mg, 0.10 mmol), diphenyl diselenide (19 mg, 0.060 mmol), cesium carbonate (98 mg, 0.30 mmol), and acetonitrile (1.0 mL) was warmed to 35 °C and stirred for 3 hours under open air conditions. After 3 hours, H_2O (5 mL) was added to the reaction mixture. The reaction products were extracted three times with ethyl acetate (5 mL × 3). The combined ethyl acetate extracts were dried over Na_2SO_4. Following filtration to remove Na_2SO_4, the filtrate was concentrated [The ^1H NMR analysis of the crude reaction mixture was conducted at this stage to confirm the *Z*/*E* stereoselectivity of product **3a**]. The residue was purified by flash column chromatography on silica gel (hexane/ethyl acetate = 100:1 − 50:1 − 20:1 − 10:1 − 5:1 − 2:1 as the eluent) to afford dehydroselenocysteine derivative **3a** in 69% yield (25 mg, 0.069 mmol, white solid). [The (*Z*)-**3a** and (*E*)-**3a** isomers were separated by careful silica gel column chromatography.]



(*Z*)-**3a**: ^1H NMR (400 MHz, $CDCl_3$) δ 7.71 (s, 1H), 7.61–7.56 (m, 2H), 7.36–7.31 (m, 3H), 6.55 (br, 1H), 3.78 (s, 3H), 1.51 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.2, 152.6, 133.3, 131.0, 130.6, 129.4, 128.1, 125.1, 81.2, 52.6, 28.1; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 401; IR (neat): 3329, 2978, 2952, 1703, 1495, 1477, 1437, 1367, 1321, 1241, 1156, 1045, 1023, 740, 691 cm^{-1}; HRMS (FAB) calcd for $C_{15}H_{19}NO_4Se$: 357.0479 ($[M]^+$), found 357.0479.

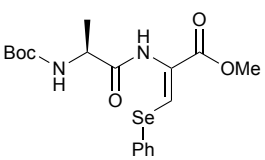


(*E*)-**3a**: ^1H NMR (400 MHz, $CDCl_3$) δ 8.16 (br, 1H), 7.66–7.61 (m, 2H), 7.39–7.31 (m, 3H), 6.79 (br, 1H), 3.91 (s, 3H), 1.46 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.5, 152.7, 132.9, 132.6, 129.3, 127.9, 121.1, 80.6, 52.5, 28.2; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 441; IR (neat): 3422, 2978, 1704, 1503, 1437, 1319, 1241, 1202, 1046, 1021, 740, 692 cm^{-1}; HRMS (FAB)

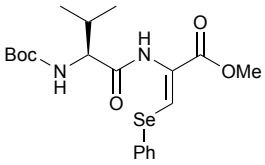
calcd for $C_{15}H_{19}NO_4Se$: 357.0479 ([M]$^+$), found 357.0479.

3. General methods for the preparation of dehydroselenocysteine-containing dipeptides (Schemes 3 and 4)

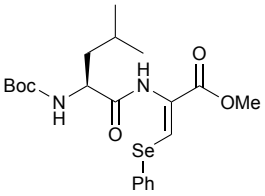
A mixture of cysteine-containing dipeptide **1** (0.10 mmol), diphenyl diselenide (19 mg, 0.060 mmol), cesium carbonate (98 mg, 0.30 mmol), and acetonitrile (1.0 mL) was warmed to 35 °C and stirred for 5 hours under open air conditions. After 5 hours, H_2O (5 mL) was added to the reaction mixture. The reaction products were extracted three times with ethyl acetate (5 mL × 3). The combined ethyl acetate extracts were dried over Na_2SO_4. Following filtration to remove Na_2SO_4, the filtrate was concentrated [The ^{1}H NMR analysis of the crude reaction mixture was conducted at this stage to confirm the *Z*/*E* stereoselectivity of product **3**]. The residue was purified by flash column chromatography on silica gel (hexane/ethyl acetate as the eluent) to afford dehydroselenocysteine-containing dipeptide **3**.



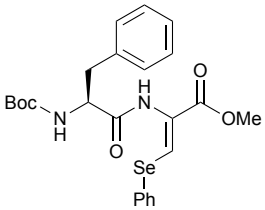
Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 10:1 − 5:1 − 2:1 − 1:1 as the eluent) to afford **3b**. (*Z*)-**3b**: $[\alpha]^{18}_D$ –45.0 (*c* = 1.0, $CHCl_3$, 99% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 33.4 min (major) and 45.5 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (br, 1H), 7.88 (s, 1H), 7.61–7.52 (m, 2H), 7.38–7.30 (m, 3H), 5.07 (br, 1H), 4.37 (br, 1H), 3.77 (s, 3H), 1.48–1.44 (m, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 162.8, 155.5, 133.9, 133.3, 130.9, 129.4, 128.2, 124.1, 80.4, 52.6, 50.3, 28.3, 18.2; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 413; IR (neat): 3315, 2978, 1714, 1676, 1506, 1317, 1233, 1165, 736 cm^{-1}; HRMS (FAB) calcd for $C_{18}H_{25}N_2O_5Se$: 429.0929 ([M+H]$^+$), found 429.0929. [(*E*)-**3b**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.75 (s, 1H), 8.41 (br, 1H), 7.65–7.59 (m, 2H), 7.36–7.32 (m, 3H), 4.91 (br, 1H), 4.23 (br, 1H), 3.92 (s, 3H), 1.46 (s, 9H), 1.38 (d, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 163.4, 155.6, 132.7, 132.6, 132.3, 129.4, 128.0, 120.9, 80.6, 52.7, 50.7, 28.2, 17.6; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 445; IR (neat): 3320, 2979, 1705, 1518, 1322, 1241, 1161, 738 cm^{-1}; HRMS (FAB) calcd for $C_{18}H_{25}N_2O_5Se$: 429.0929 ([M+H]$^+$), found 429.0929.]



Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 40:1 − 20:1 − 10:1 − 5:1 − 2:1 as the eluent) to afford **3c**. (*Z*)-**3c**: $[\alpha]^{21}_{D}$ –44.2 (*c* = 1.3, $CHCl_3$, >99.5% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 36.0 min (major) and ~41 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (s, 1H), 7.79 (br, 1H), 7.61–7.55 (m, 2H), 7.38–7.31 (m, 3H), 5.08 (br, 1H), 4.13 (br, 1H), 3.78 (s, 3H), 2.33–2.24 (m, 1H), 1.48 (s, 9H), 1.06 (d, *J* = 6.9 Hz, 3H), 1.01 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.7, 162.8, 155.8, 133.8, 133.3, 131.0, 129.4, 128.2, 124.0, 80.1, 60.0, 52.6, 30.8, 28.3, 19.3, 17.6; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 414; IR (neat): 3286, 2975, 1714, 1669, 1500, 1366, 1314, 1231, 1161, 730, 690 cm^{-1}; HRMS (FAB) calcd for $C_{20}H_{29}N_2O_5Se$: 457.1242 ($[M+H]^+$), found 457.1241.

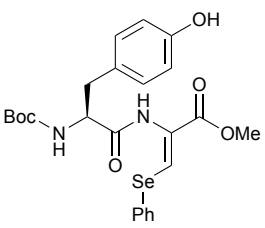


Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 10:1 − 5:1 − 3:1 − 2:1 as the eluent) to afford **3d**. (*Z*)-**3d**: $[\alpha]^{26}_{D}$ –93.6 (*c* = 0.51, $CHCl_3$, >99.5% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 24.5 min (major) and ~29 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (br, 1H), 7.87 (s, 1H), 7.61–7.52 (m, 2H), 7.38–7.30 (m, 3H), 4.91 (br, 1H), 4.28 (br, 1H), 3.77 (s, 3H), 1.85–1.72 (m, 2H), 1.61–1.51 (m, 1H), 1.48 (s, 9H), 1.01–0.96 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 162.9, 155.7, 133.6, 133.3, 131.0, 129.4, 128.2, 124.1, 80.4, 53.3, 52.6, 41.1, 28.3, 24.8, 22.9, 22.0; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 413; IR (neat): 3294, 2956, 1715, 1508, 1366, 1317, 1233, 1167, 740 cm^{-1}; HRMS (FAB) calcd for $C_{21}H_{31}N_2O_5Se$: 471.1398 ($[M+H]^+$), found 471.1398.

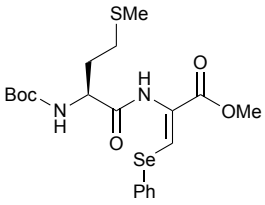


Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 20:1 − 10:1 − 5:1 − 3:1 − 2:1 as the eluent) to afford **3e**. (*Z*)-**3e**: $[\alpha]^{21}_{D}$ –32.2 (*c* = 0.82, $CHCl_3$, 94% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 300 nm; retention time: 38.1 min (minor) and 53.5 min (major). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (br, 1H), 7.86 (s, 1H), 7.60–7.52 (m, 2H), 7.37–7.22 (m, 8H), 5.01 (br, 1H), 4.55 (br, 1H), 3.74 (s, 3H), 3.26–

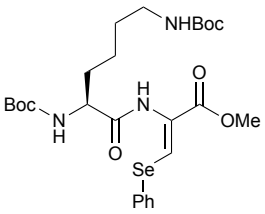
3.08 (m, 2H), 1.42 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 162.7, 155.4, 136.2, 133.7, 133.3, 131.0, 129.5, 129.2, 128.7, 128.3, 127.0, 123.9, 80.5, 55.9, 52.6, 38.0, 28.2; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 415; IR (neat): 3300, 2978, 1712, 1672, 1512, 1497, 1315, 1239, 1167, 735, 699 cm^{-1}; HRMS (FAB) calcd for $C_{24}H_{29}N_2O_5Se$: 505.1242 ([M+H]$^+$), found 505.1241.



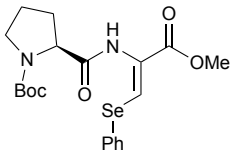
Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 5:1 − 2:1 − 1:1 − 1:2 as the eluent) to afford **3f**. (*Z*)-**3f**: $[\alpha]^{26}_D$ –29.8 (*c* = 0.10, Acetone, 94% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 254 nm; retention time: 17.8 min (minor) and 21.2 min (major). ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.65 (s, 1H), 9.18 (s, 1H), 7.71 (s, 1H), 7.62–7.55 (m, 2H), 7.44–7.37 (m, 3H), 7.13 (d, *J* = 8.2 Hz, 2H), 6.97 (d, *J* = 8.7 Hz, 1H), 6.66 (d, *J* = 8.5 Hz, 2H), 4.31–4.24 (m, 1H), 3.69 (s, 3H), 2.94 (dd, *J* = 13.8, 3.8 Hz, 1H), 2.69 (dd, *J* = 13.7, 11.0 Hz, 1H), 1.32 (s, 9H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 171.1, 162.5, 155.8, 155.3, 133.3, 132.4, 132.0, 130.2, 129.8, 128.2, 128.1, 126.1, 114.8, 78.0, 56.2, 52.3, 36.8, 28.2; ^{77}Se NMR (76 MHz, DMSO-d_6) δ 403; IR (neat): 3308, 2929, 1712, 1695, 1516, 1232, 1166, 736 cm^{-1}; HRMS (FAB) calcd for $C_{24}H_{29}N_2O_6Se$: 521.1191 ([M+H]$^+$), found 521.1191.



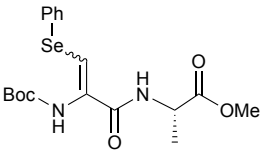
Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 7:1 − 5:1 − 3:1 − 2:1 as the eluent) to afford **3g**. (*Z*)-**3g**: $[\alpha]^{21}_D$ –33.7 (*c* = 0.59, $CHCl_3$, 94% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 40.4 min (major) and 57.5 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (br, 1H), 7.90 (s, 1H), 7.61–7.54 (m, 2H), 7.38–7.31 (m, 3H), 5.26 (br, 1H), 4.48 (br, 1H), 3.77 (s, 3H), 2.67 (t, *J* = 7.2 Hz, 2H), 2.25–2.15 (m, 1H), 2.15 (s, 3H), 2.10–1.95 (m, 1H), 1.48 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 162.7, 155.5, 134.4, 133.4, 130.7, 129.5, 128.3, 124.0, 80.5, 53.6, 52.7, 31.5, 30.1, 28.3, 15.3; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 413; IR (neat): 3299, 2978, 1712, 1671, 1502, 1313, 1230, 1164, 909, 728, 690 cm^{-1}; HRMS (FAB) calcd for $C_{20}H_{29}N_2O_5SSe$: 489.0962 ([M+H]$^+$), found 489.0961.



Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 10:1 − 5:1 − 3:1 − 2:1 − 1:1 as the eluent) to afford **3h**. (*Z*)-**3h**: $[\alpha]^{25}_{D}$ –38.2 (*c* = 1.1, $CHCl_3$, >99.5% ee); HPLC analysis: Daicel Chiralpak IF-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 17.1 min (major) and 23.7 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (br, 1H), 7.88 (s, 1H), 7.60–7.55 (m, 2H), 7.37–7.30 (m, 3H), 5.22 (br, 1H), 4.64 (br, 1H), 4.25 (br, 1H), 3.77 (s, 3H), 2.18–3.09 (m, 2H), 2.00–1.90 (m, 1H), 1.79–1.70 (m, 1H), 1.57–1.42 (m, 4H), 1.48 (s, 9H), 1.44 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1, 162.8, 156.2, 155.8, 133.9, 133.4, 130.9, 129.4, 128.3, 124.0, 80.4, 79.2, 54.7, 52.7, 39.8, 31.7, 29.7, 28.4, 28.3, 22.5; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 413; IR (neat): 3341, 2977, 2931, 1684, 1507, 1365, 1237, 1164, 735, 690 cm^{-1}; HRMS (FAB) calcd for $C_{26}H_{40}N_3O_7Se$: 586.2031 ($[M+H]^+$), found 586.2028.



Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 10:1 − 5:1 − 3:1 − 2:1 − 1:1 as the eluent) to afford **3i**. (*Z*)-**3i**: $[\alpha]^{20}_{D}$ –86.3 (*c* = 1.5, $CHCl_3$, >99.5% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 28.3 min (minor) and 34.3 min (major). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87–7.77 (m, 2H), 7.60–7.56 (m, 2H), 7.36–7.31 (m, 3H), 4.55–4.27 (m, 1H), 3.77 (s, 3H), 3.64–3.32 (m, 2H), 2.53–1.87 (m, 4H), 1.51 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.0 & 170.2, 162.8, 154.5, 133.8 & 132.8, 133.3, 131.0, 129.4, 128.2, 124.8 & 123.9, 81.1, 61.5 & 60.1, 52.6, 47.1, 31.5 & 29.7, 28.3, 24.6 & 23.7; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 412 & 410; IR (neat): 3279, 2975, 1697, 1398, 1315, 1232, 1163, 737 cm^{-1}; HRMS (FAB) calcd for $C_{20}H_{27}N_2O_5Se$: 455.1085 ($[M+H]^+$), found 455.1085.



Purified by flash column chromatography on silica gel (hexane/ethyl acetate = 10:1 − 5:1 − 3:1 − 2:1 − 1:1 as the eluent) to afford **3j**. **3j** (major): $[\alpha]^{23}_{D}$ –10.0 (*c* = 0.57, $CHCl_3$, 91% ee); HPLC analysis: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm; retention time: 23.1 min (major) and 27.6 min (minor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66–7.53 (m, 2H), 7.42 (s, 1H), 7.37–7.29 (m,

3H), 6.61 (d, J = 7.1 Hz, 1H), 6.26 (br, 1H), 4.66–4.58 (m, 1H), 3.75 (s, 3H), 1.50 (s, 9H), 1.44 (d, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 162.6, 152.9, 133.3, 129.5, 128.7, 128.2, 81.5, 52.6, 48.4, 28.1, 18.4 (The *C*=*C* peaks are not clearly observed due to signal broadening.); ^{77}Se NMR (The *Se* peak is not clearly observed due to signal broadening.); IR (neat): 3310, 2976, 1718, 1478, 1369, 1248, 1159, 741 cm^{-1}; HRMS (FAB) calcd for $C_{18}H_{25}N_2O_5Se$: 429.0929 ($[M+H]^+$), found 429.0920.

4. Experimental procedures for control experiments (Scheme 5)

A mixture of dehydroalanine derivative **2a** (20 mg, 0.10 mmol), diphenyl diselenide (19 mg, 0.060 mmol), cesium carbonate (33 mg, 0.10 mmol), and acetonitrile (1.0 mL) was warmed to 35 °C and stirred for 3 hours under open air conditions. After 3 hours, H_2O (5 mL) was added to the reaction mixture. The reaction products were extracted three times with ethyl acetate (5 mL × 3). The combined ethyl acetate extracts were dried over Na_2SO_4. Following filtration to remove Na_2SO_4, the filtrate was concentrated [The ^{1}H NMR analysis of the crude reaction mixture was conducted at this stage to confirm the *Z*/*E* stereoselectivity of product **3a**]. The residue was purified by flash column chromatography on silica gel (hexane/ethyl acetate = 100:1 − 50:1 − 20:1 − 10:1 − 5:1 − 2:1 as the eluent) to afford dehydroselenocysteine derivative **3a** in 76% yield (27 mg, 0.076 mmol, white solid).

A mixture of cysteine derivative **1a** (24 mg, 0.10 mmol), benzeneselenol (19 mg, 0.12 mmol), cesium carbonate (98 mg, 0.30 mmol), and acetonitrile (1.0 mL) was warmed to 35 °C and stirred for 3 hours under open air conditions. After 3 hours, H_2O (5 mL) was added to the reaction mixture. The reaction products were extracted three times with ethyl acetate (5 mL × 3). The combined ethyl acetate extracts were dried over Na_2SO_4. Following filtration to remove Na_2SO_4, the filtrate was concentrated [The ^{1}H NMR analysis of the crude reaction mixture was conducted at this stage to confirm the *Z*/*E* stereoselectivity of product **3a**]. The residue was purified by flash column chromatography on silica gel (hexane/ethyl acetate = 100:1 − 50:1 − 20:1 − 10:1 − 5:1 − 2:1 as the eluent) to afford dehydroselenocysteine derivative **3a** in 58% yield (21 mg, 0.058 mmol, white solid).

A mixture of benzeneselenol (19 mg, 0.12 mmol), cesium carbonate (98 mg, 0.30 mmol), and acetonitrile (1.0 mL) was warmed to 35 °C and stirred for 3 hours under open air conditions. After 3 hours, H_2O (5 mL) was added to the reaction mixture. The reaction products were extracted three times with ethyl acetate (5 mL × 3). The combined ethyl acetate extracts were dried over Na_2SO_4. Following filtration to remove Na_2SO_4, the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (hexane as the eluent) to afford diphenyl diselenide in 92% yield (17 mg, 0.055 mmol).

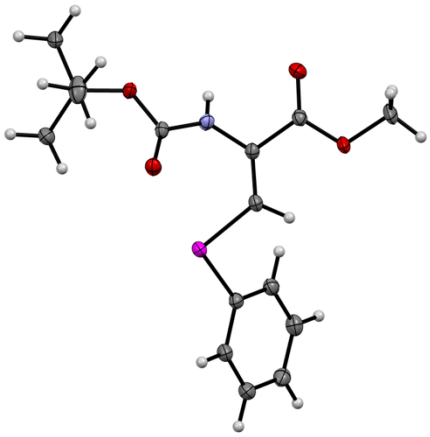
5. X-ray diffraction analysis of dehydroselenocysteine (*Z*)-3a

Dehydroselenocysteine product (*Z*)-**3a** was recrystallized from dichloromethane-hexane. Data of X-ray diffraction was collected by a Rigaku XtaLAB diffractometer with Cu-Kα (Wavelength = 1.54184 Å) radiation at Kyushu University.

The crystallographic data of (*Z*)-**3a** were summarized in the following table.

Formula	$C_{15}H_{19}NO_4Se$
Formula weight	356.27
Temperature/K	100.00(10)
Crystal system	orthorhombic
Space group	*Pbcn* (No. 60)
a/Å	15.3316(4)
b/Å	7.9185(2)
c/Å	26.4152(7)
Volume/Å^3	3206.89(14)
Z	8
D_{calc}/cm^{-3}	1.476
μ/mm^{-1}	3.305
Measured reflections	13615
Independent reflections	3263 [R(int) = 0.0327]
Goodness-of-fit	1.052
Final R indexes [I >=2σ (I)]	R_1 = 0.0308, wR_2 = 0.0803
Final R indexes [all data]	R_1 = 0.0356, wR_2 = 0.0835

The crystal structure has been deposited at the Cambridge Crystallographic Data Centre (CCDC 2505524).



References

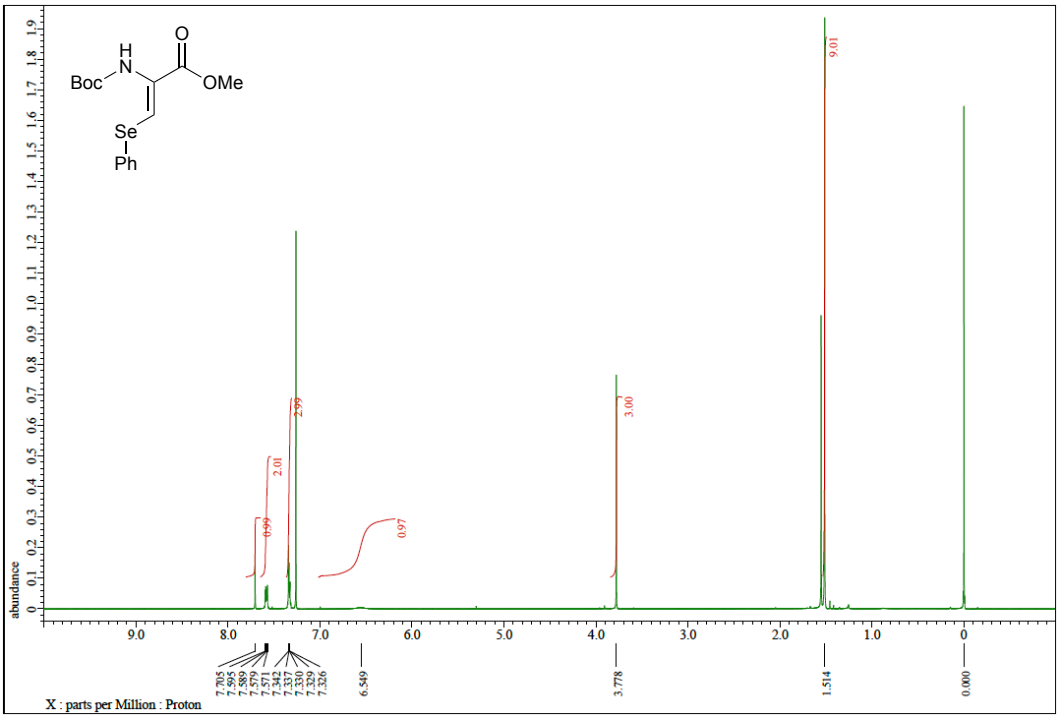
S1. K. Okuno, T. Nakamura and S. Shirakawa, *Asian J. Org. Chem.*, 2021, **10**, 655–659.

S2. A. Tsuchihashi and S. Shirakawa, *Synlett*, 2019, **30**, 1662–1666.

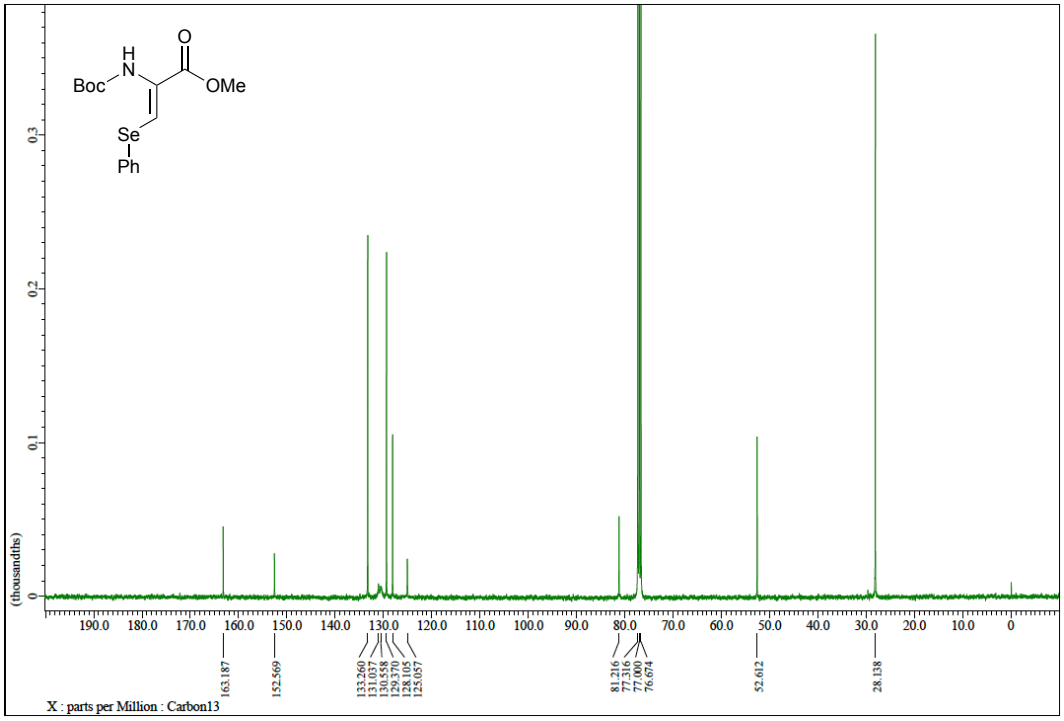
S3. T. Mori, K. Sakata and S. Shirakawa, *Chem. Commun.*, 2025, **61**, 4800–4803.

NMR Charts

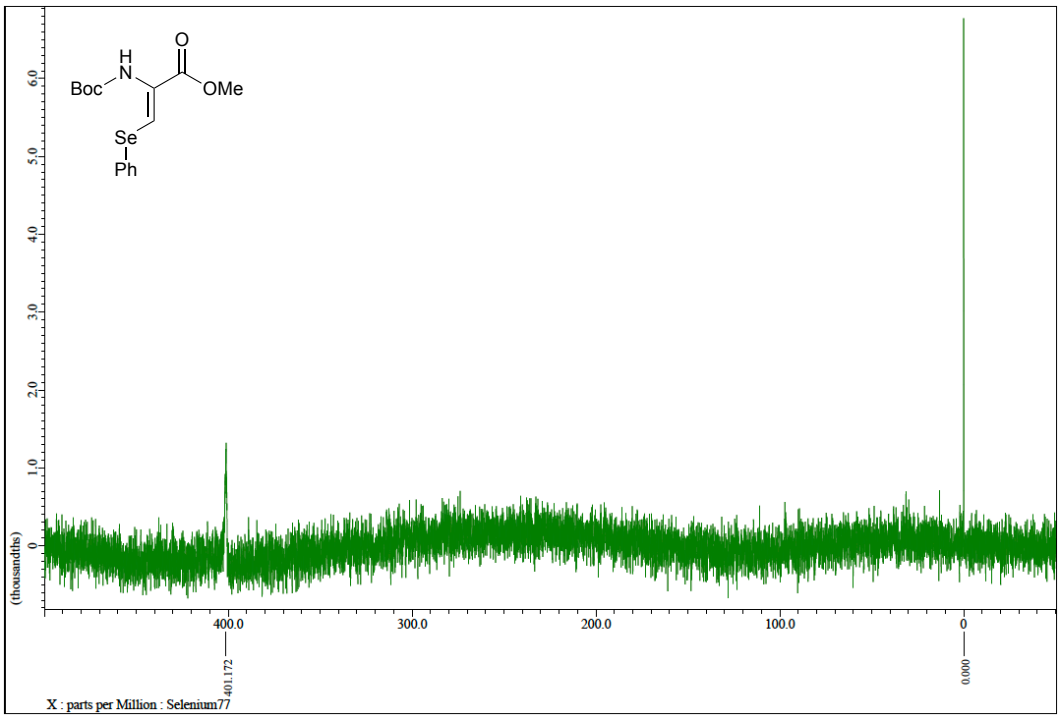
(*Z*)-**3a**: ^{1}H NMR ($CDCl_3$)



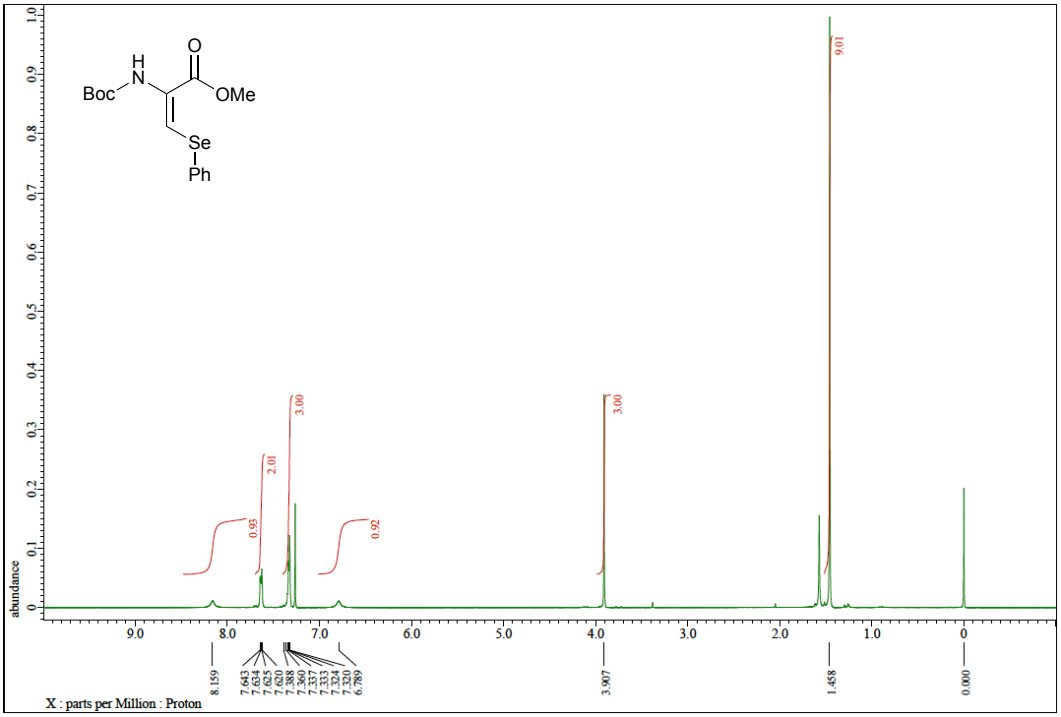
(*Z*)-**3a**: ^{13}C NMR ($CDCl_3$)



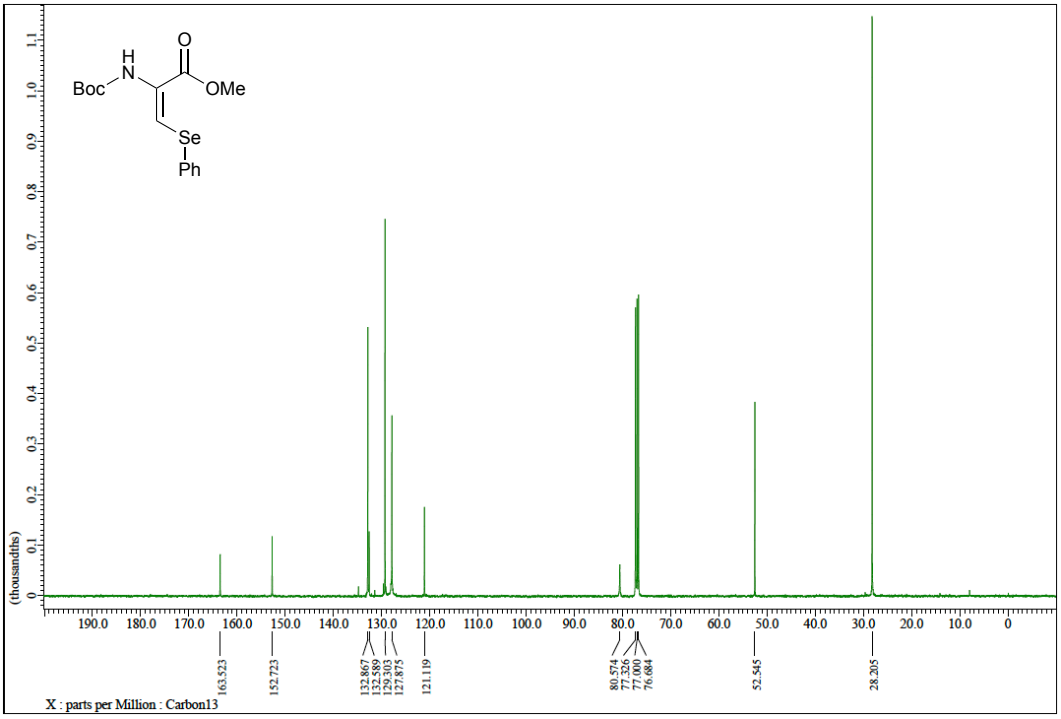
(*Z*)-**3a**: ^{77}Se NMR ($CDCl_3$)



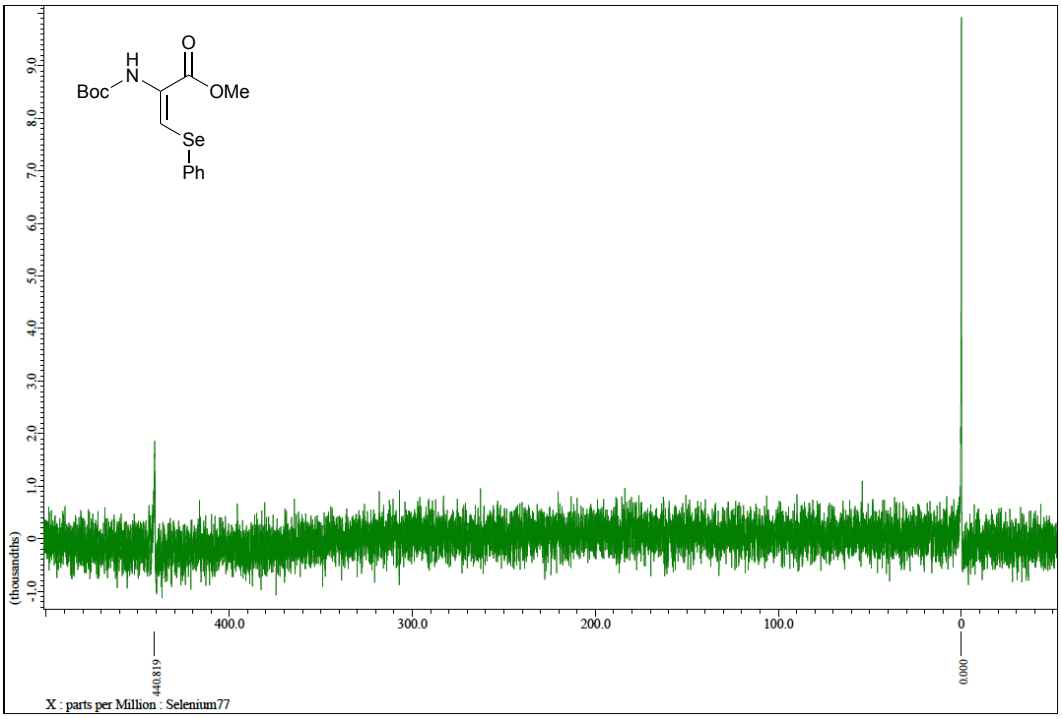
(*E*)-**3a**: ^{1}H NMR ($CDCl_3$)



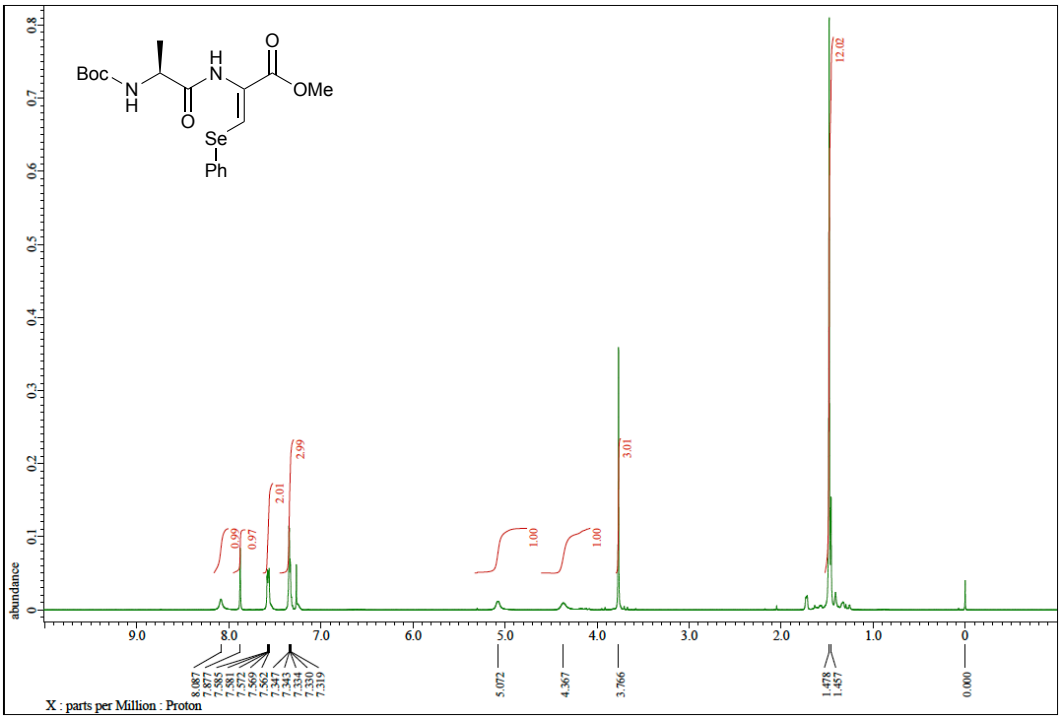
(*E*)-**3a**: ^{13}C NMR ($CDCl_3$)



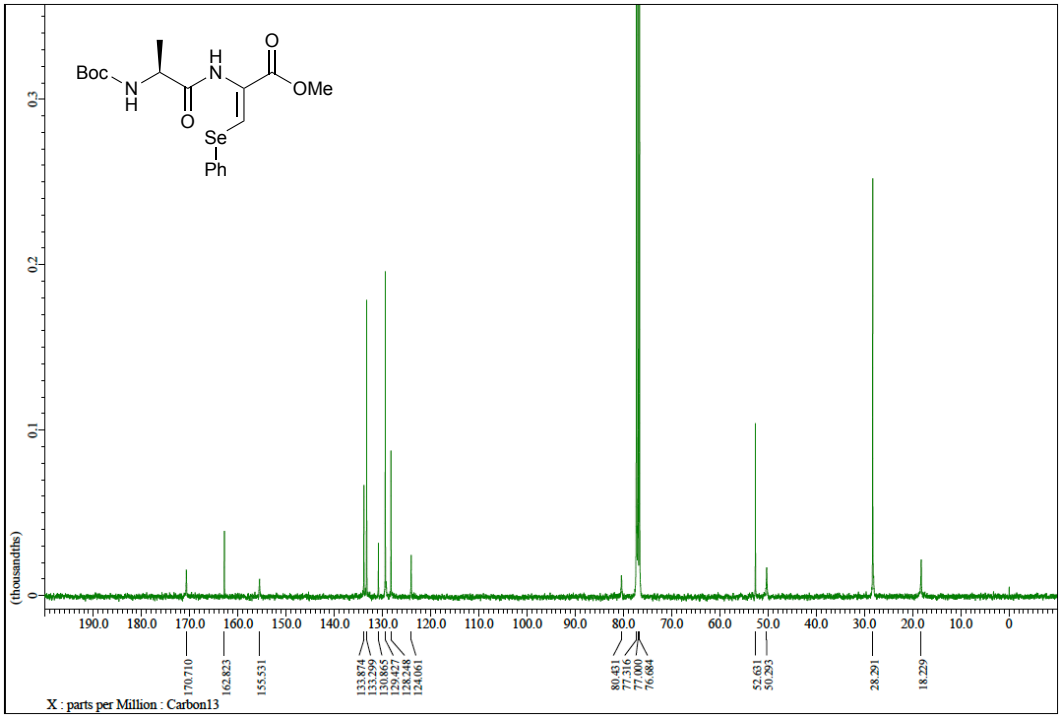
(*E*)-**3a**: ^{77}Se NMR ($CDCl_3$)



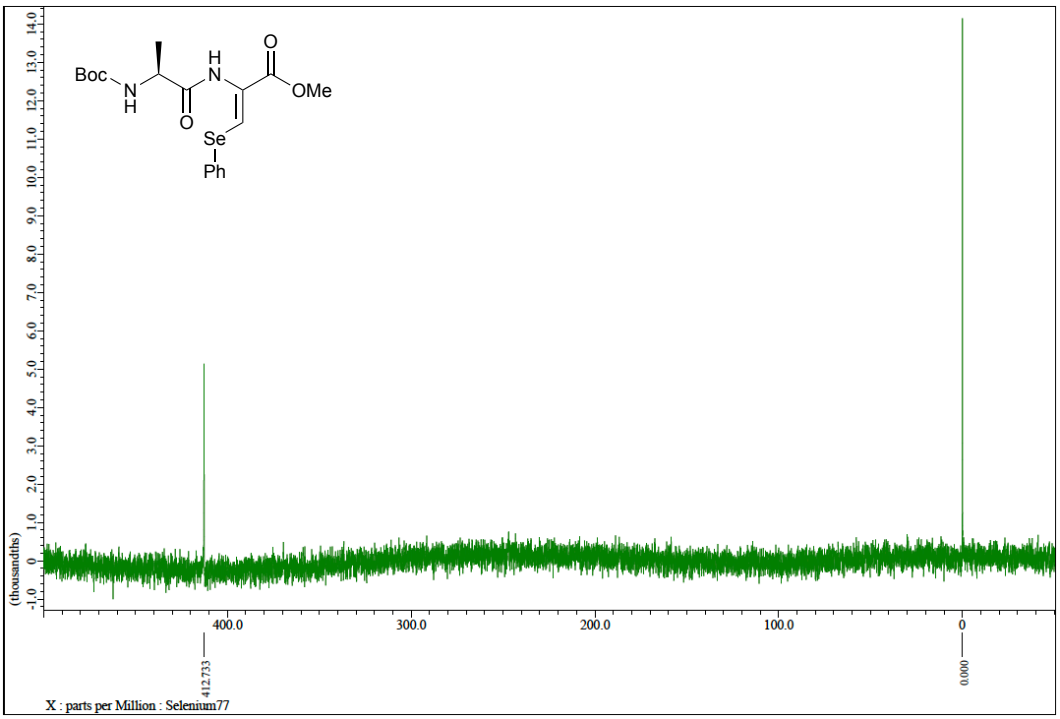
(*Z*)-**3b**: ^{1}H NMR ($CDCl_3$)



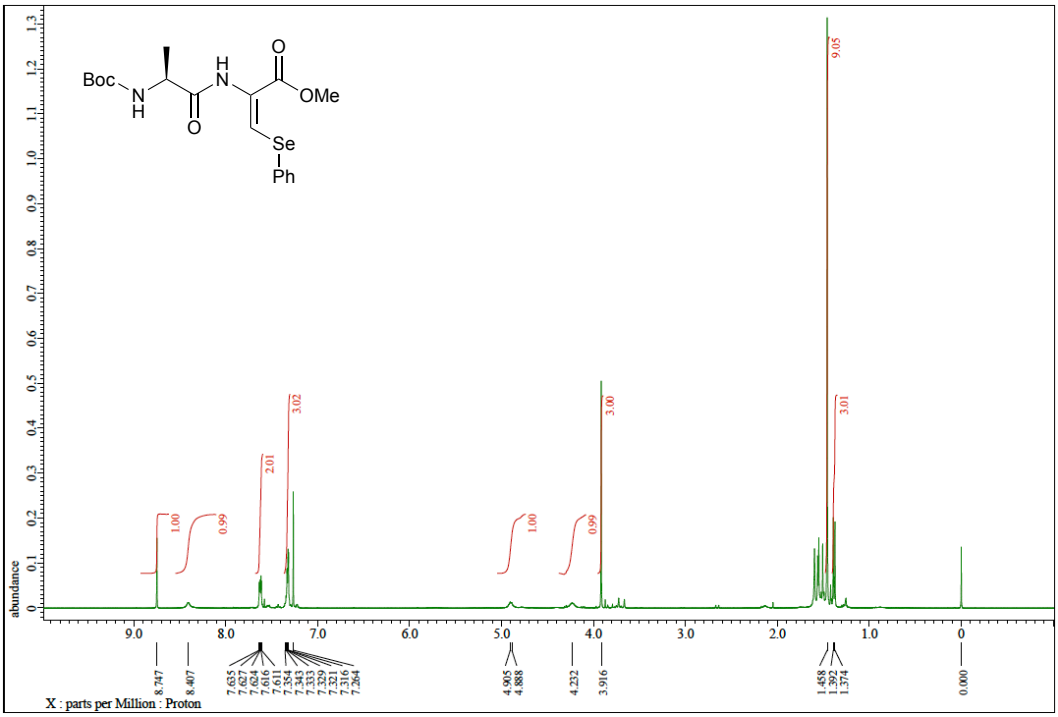
(*Z*)-**3b**: ^{13}C NMR ($CDCl_3$)



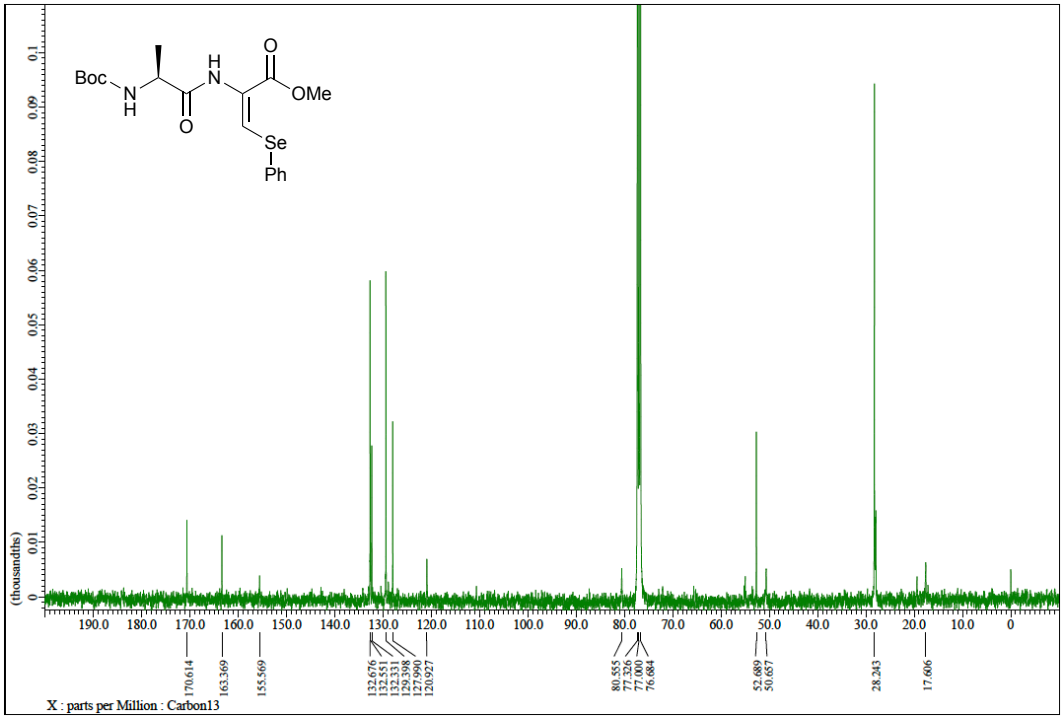
(*Z*)-**3b**: ^{77}Se NMR ($CDCl_3$)



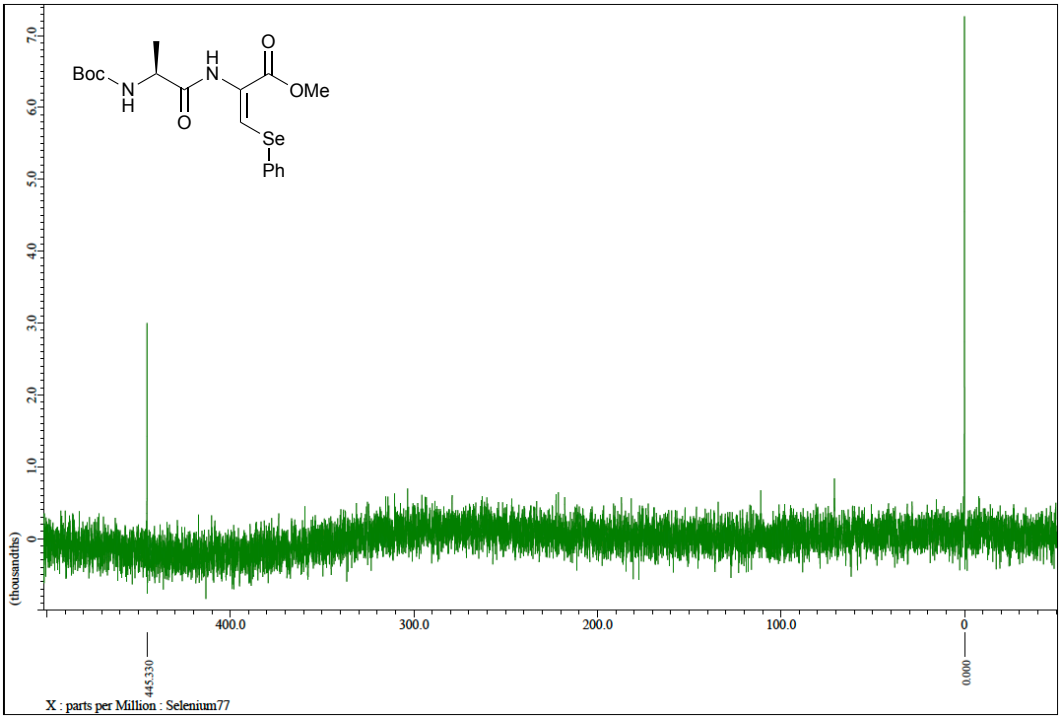
(*E*)-**3b**: ^{1}H NMR ($CDCl_3$)



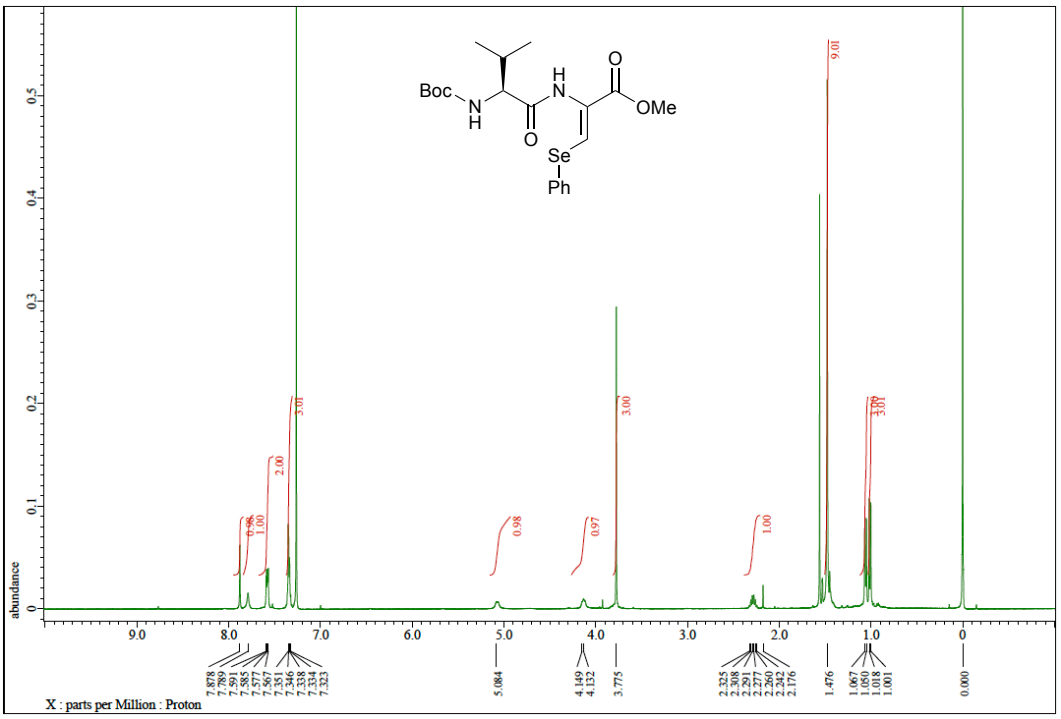
(*E*)-**3b**: ^{13}C NMR ($CDCl_3$)



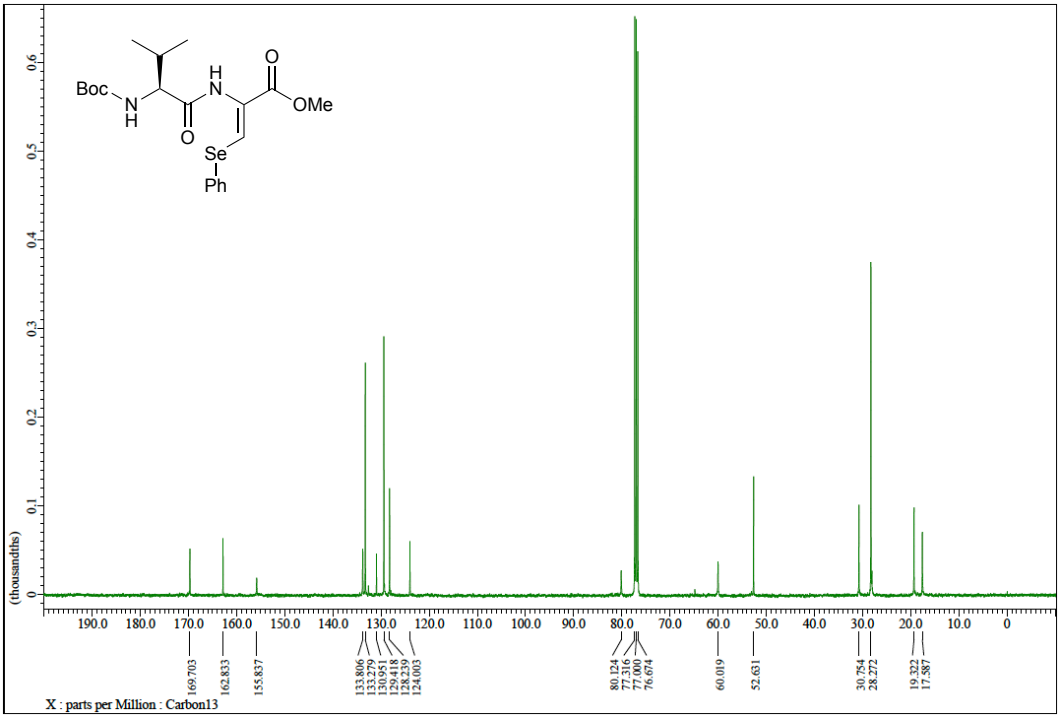
(*E*)-**3b**: ^{77}Se NMR ($CDCl_3$)



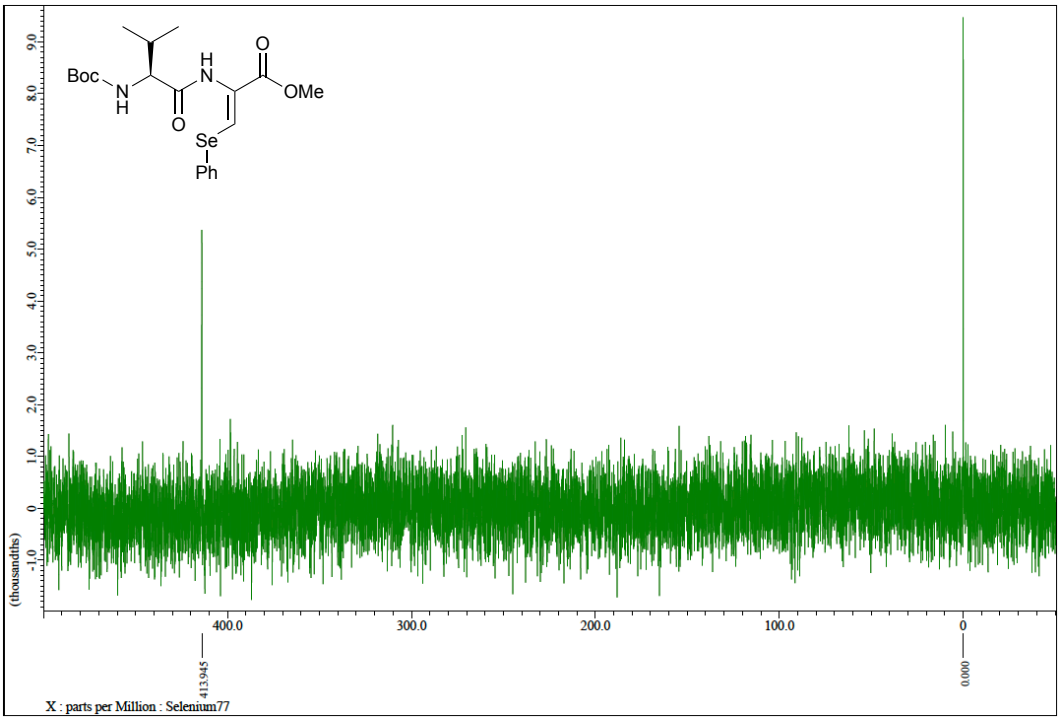
(*Z*)-**3c**: ^{1}H NMR ($CDCl_3$)



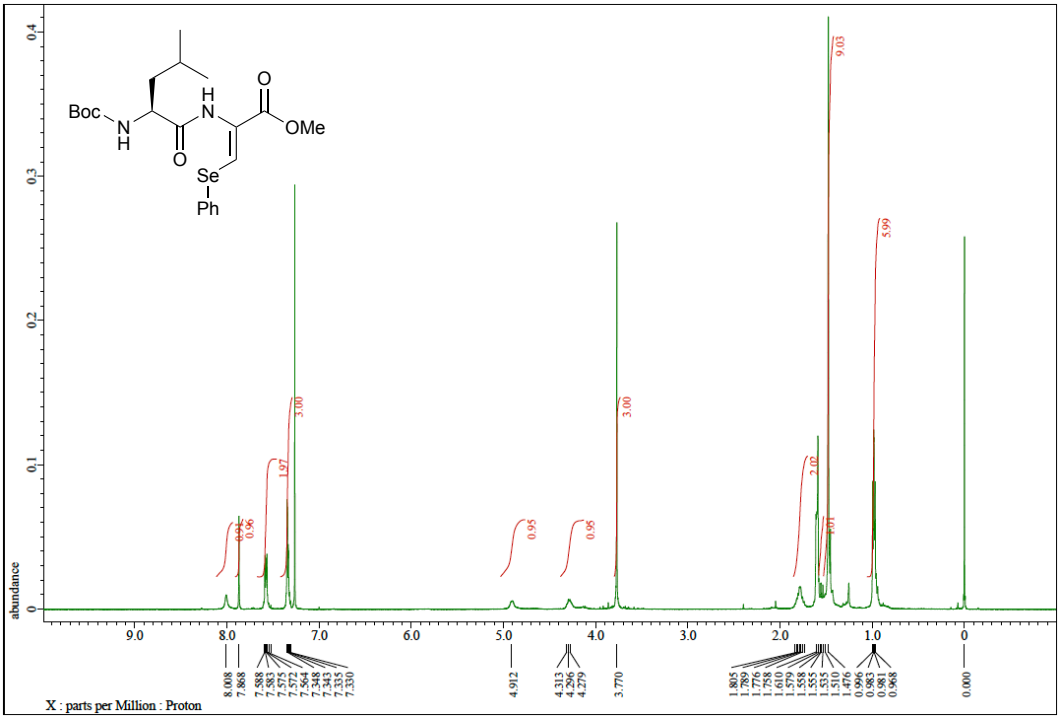
(*Z*)-**3c**: ^{13}C NMR ($CDCl_3$)



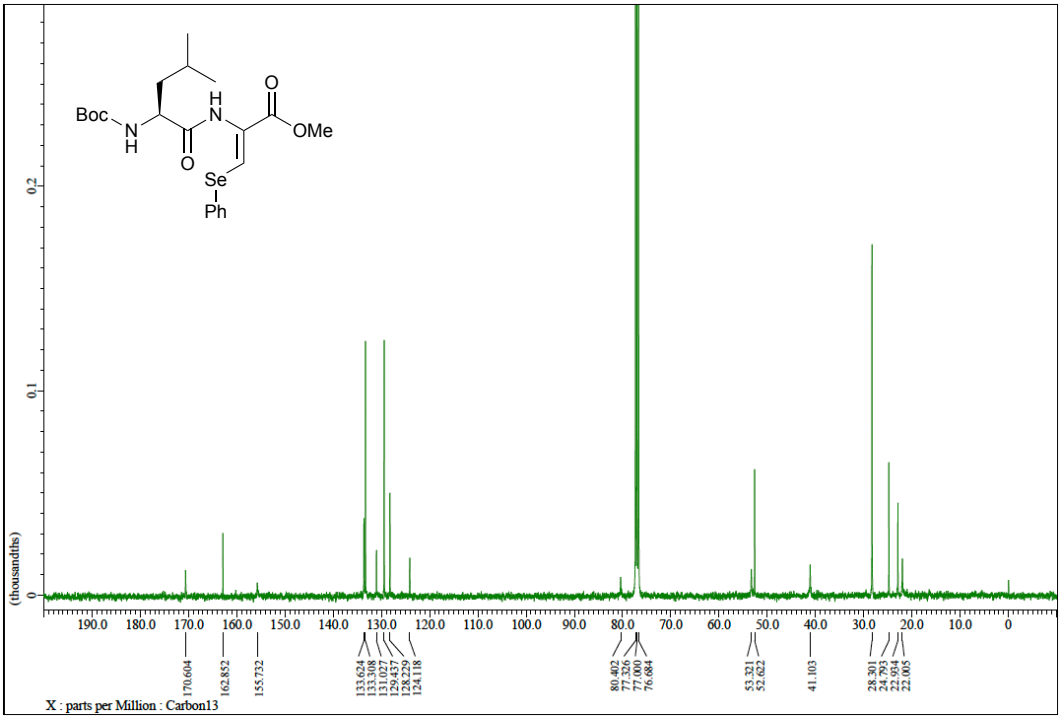
(*Z*)-**3c**: ^{77}Se NMR ($CDCl_3$)



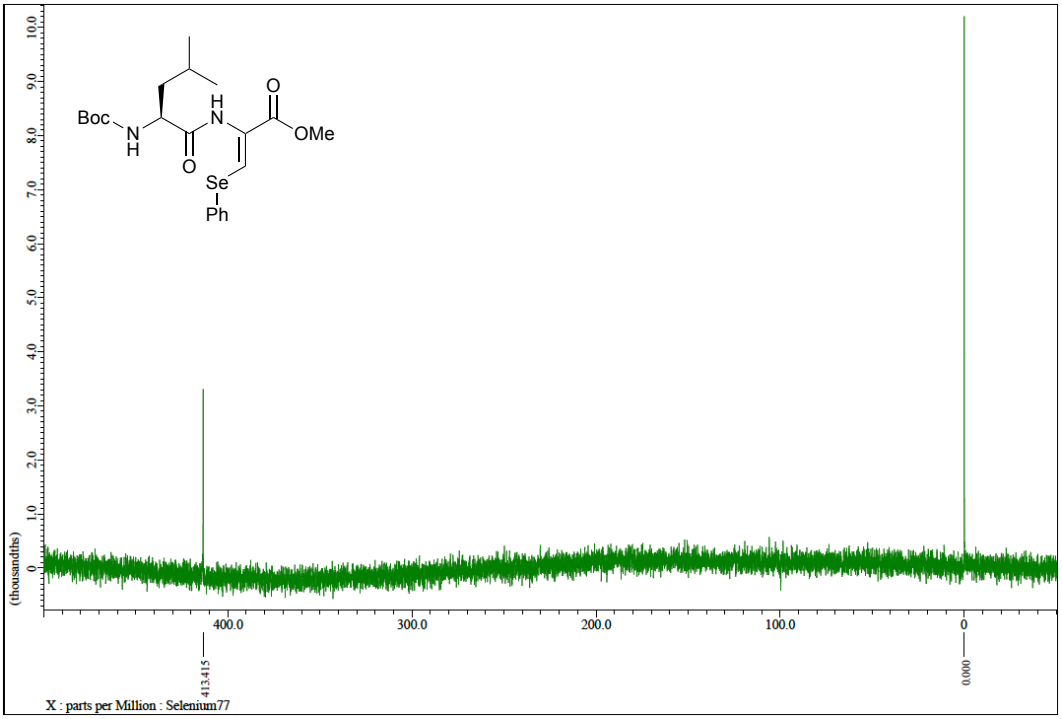
(*Z*)-**3d**: ^{1}H NMR ($CDCl_3$)



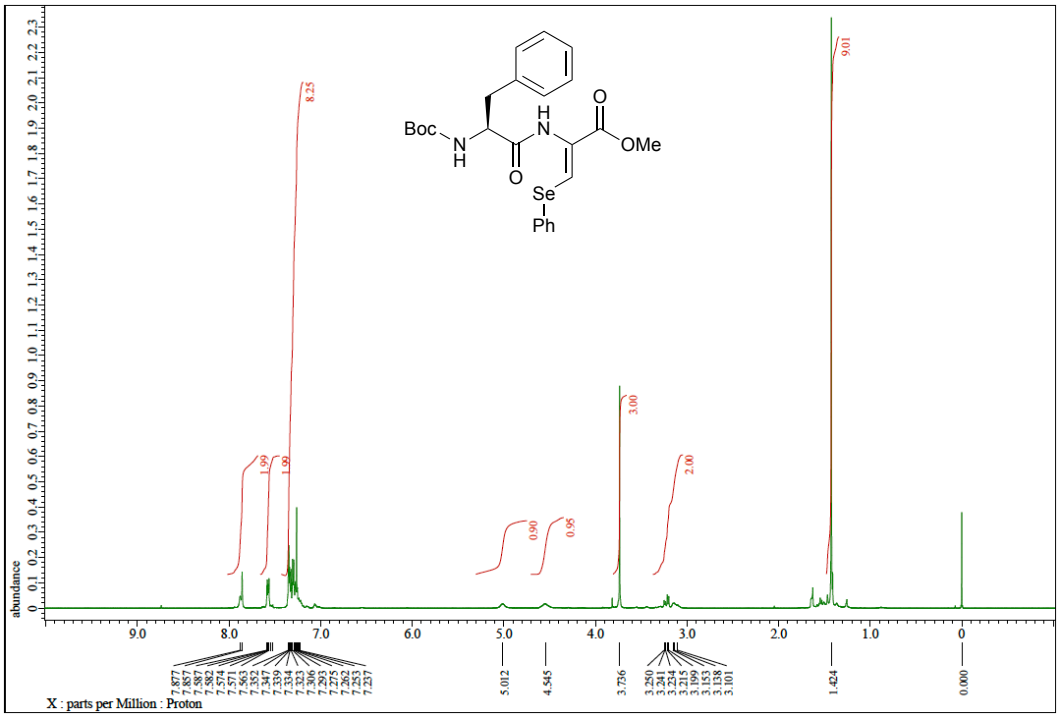
(*Z*)-**3d**: ^{13}C NMR ($CDCl_3$)



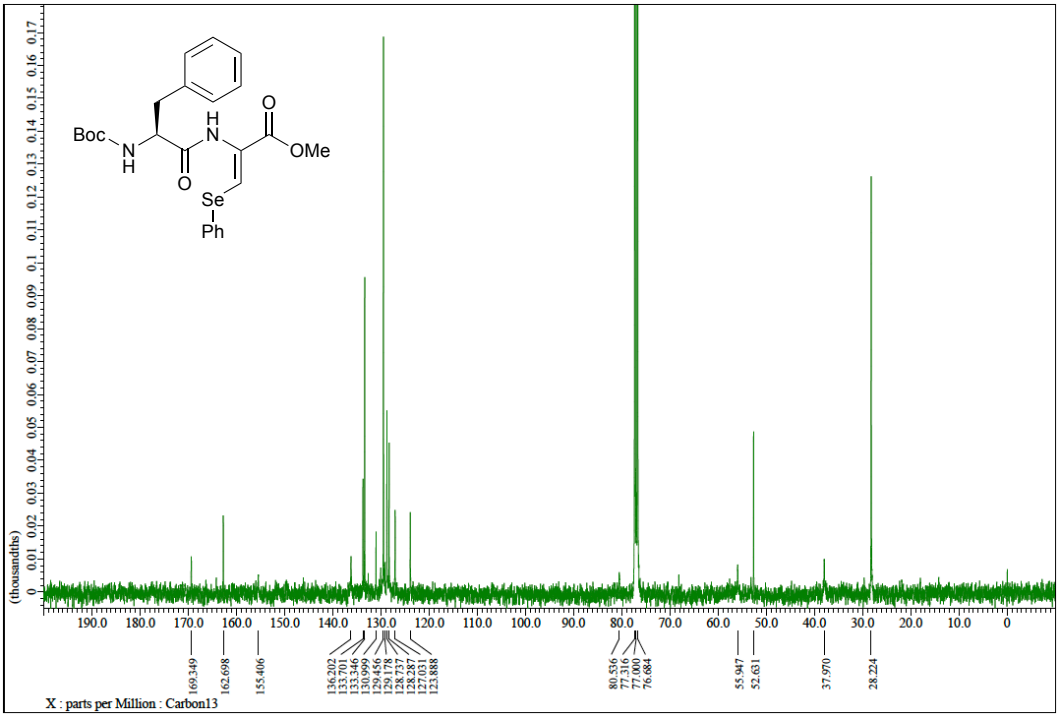
(*Z*)-**3d**: ^{77}Se NMR ($CDCl_3$)



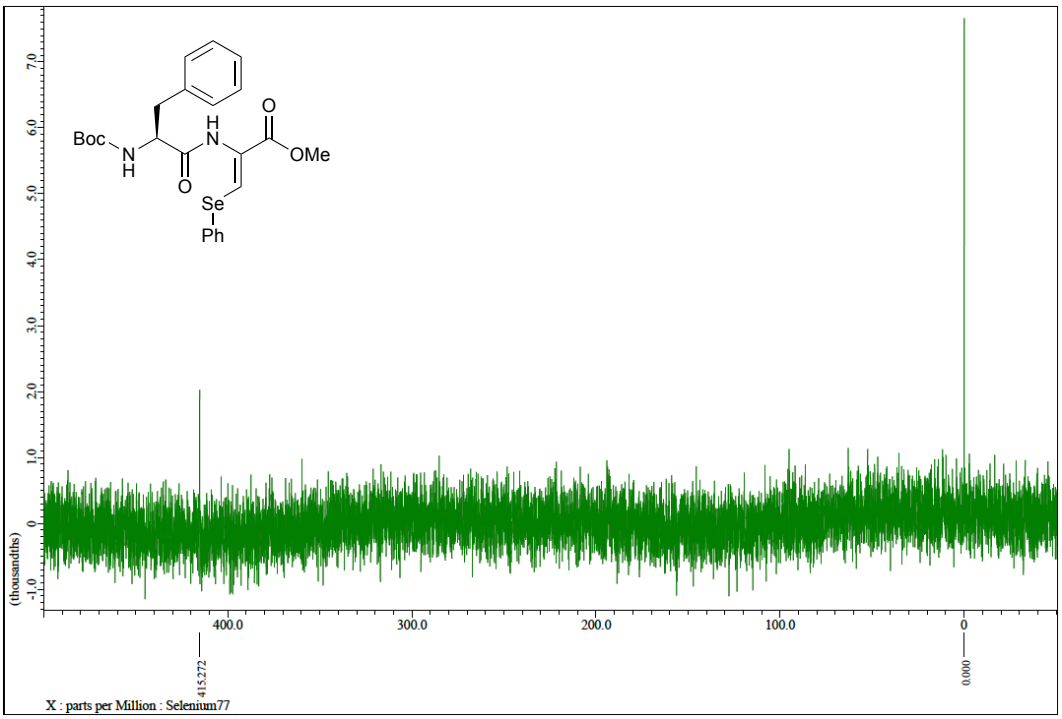
(*Z*)-**3e**: ^{1}H NMR ($CDCl_3$)



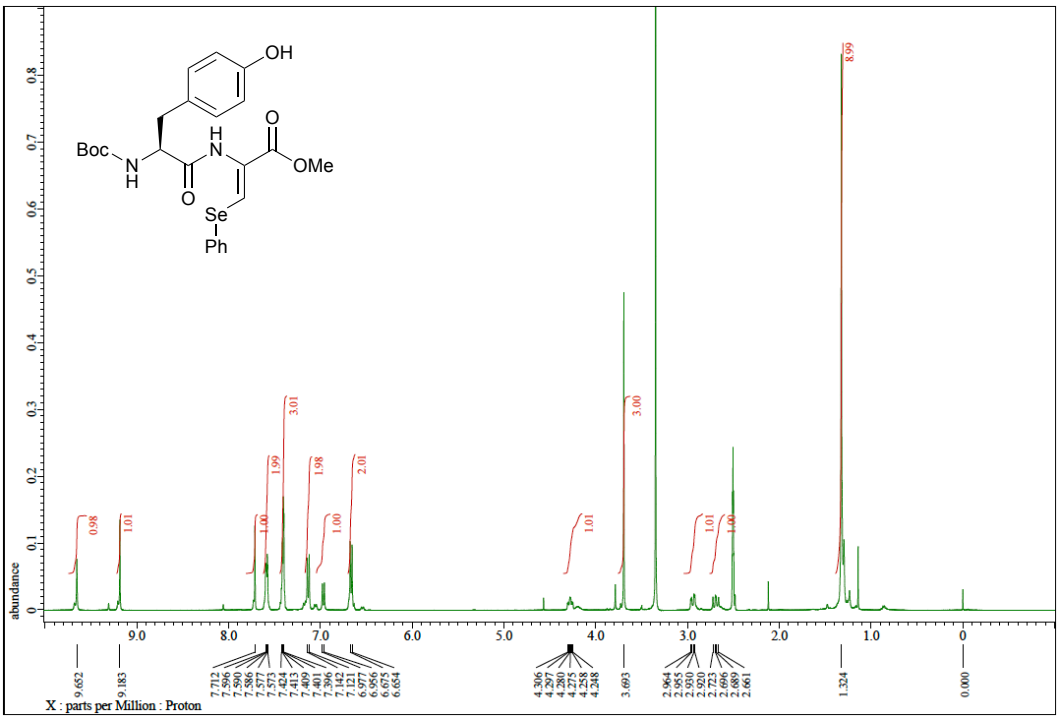
(*Z*)-**3e**: ^{13}C NMR ($CDCl_3$)



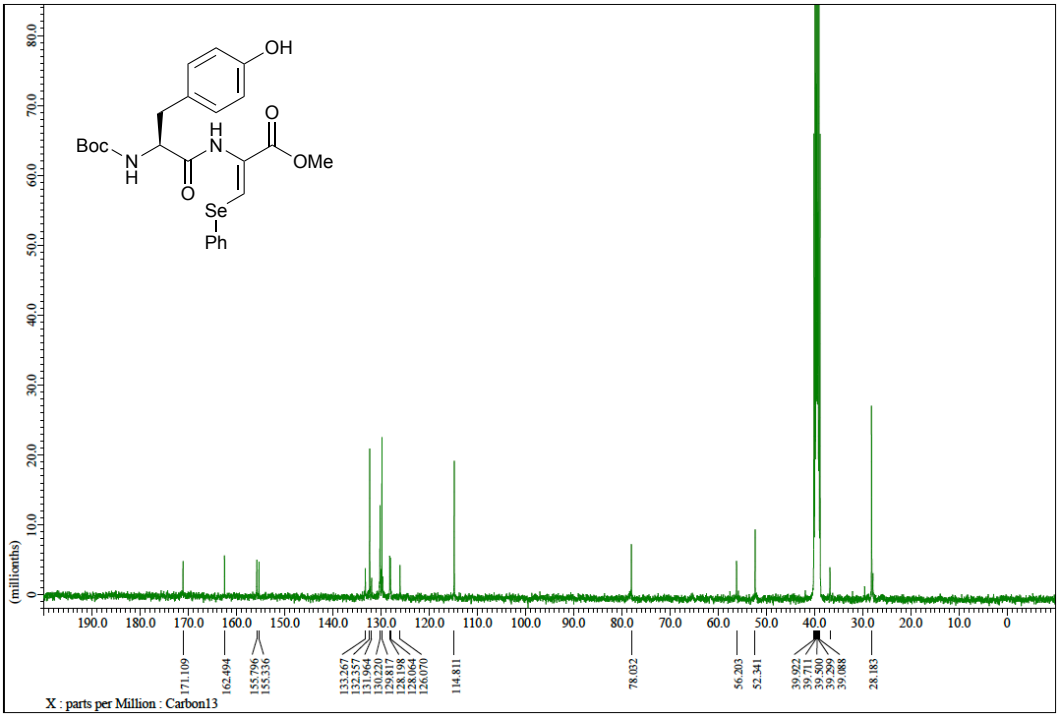
(*Z*)-**3e**: ^{77}Se NMR ($CDCl_3$)



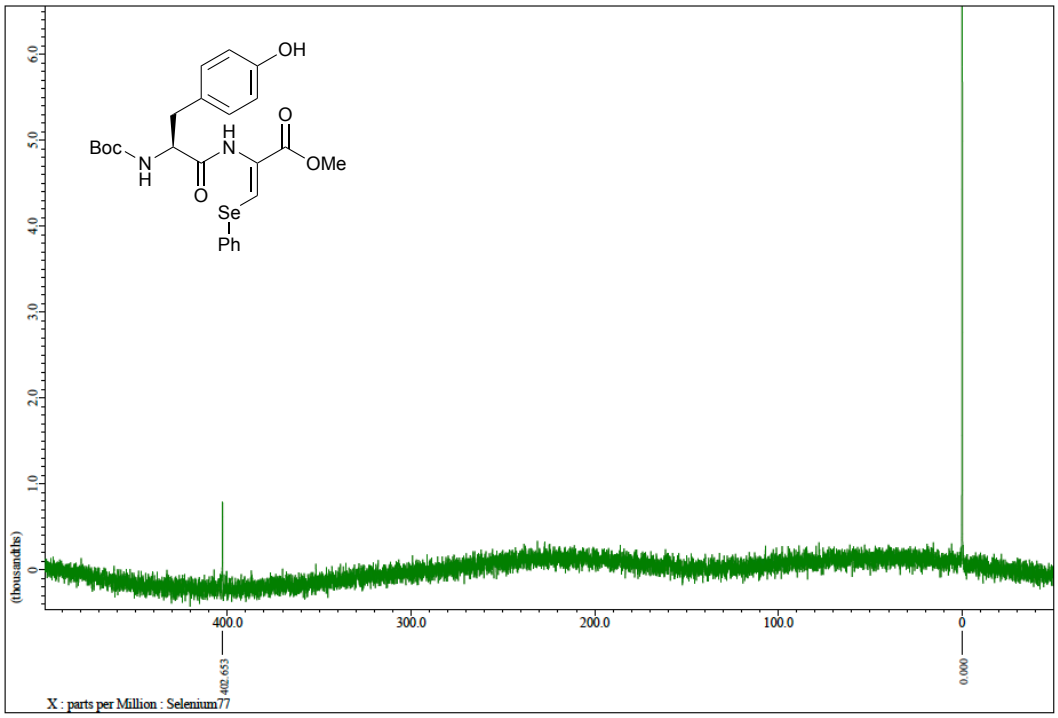
(*Z*)-**3f**: ^{1}H NMR (DMSO-d$_6$)



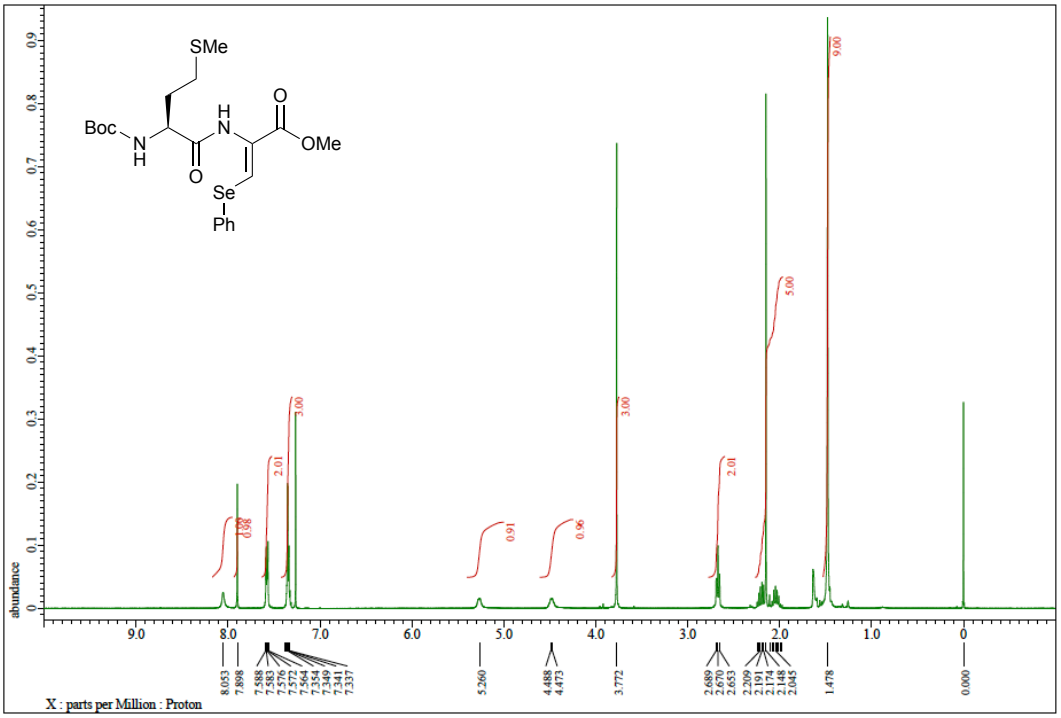
(*Z*)-**3f**: ^{13}C NMR (DMSO-d$_6$)



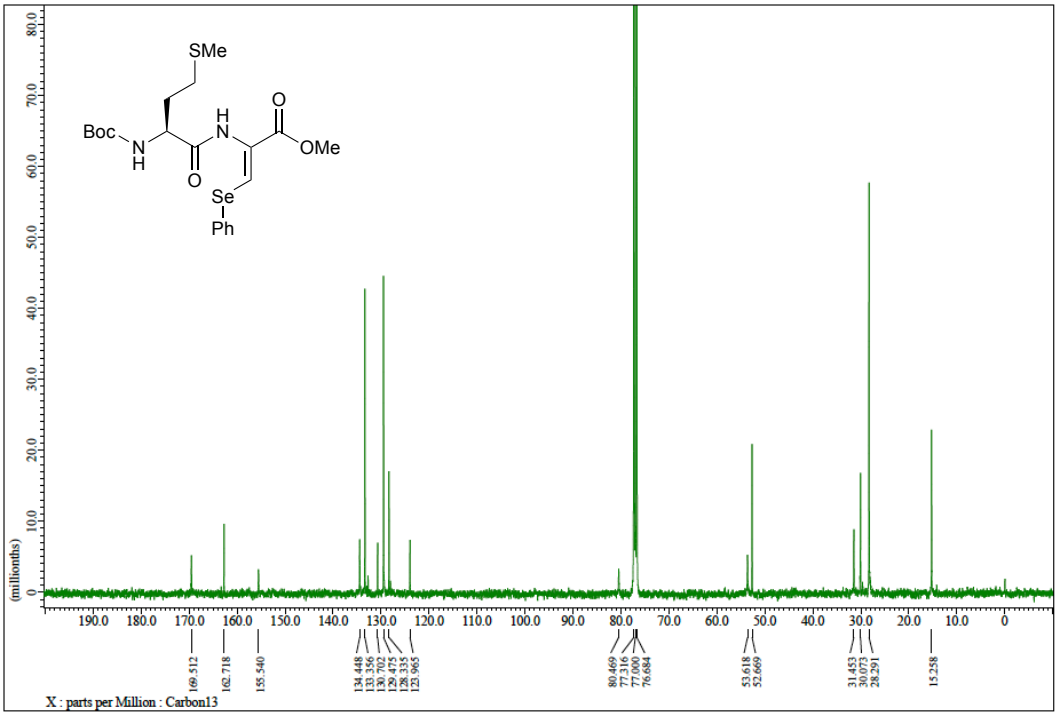
(*Z*)-**3f**: ^{77}Se NMR (DMSO-d_6)



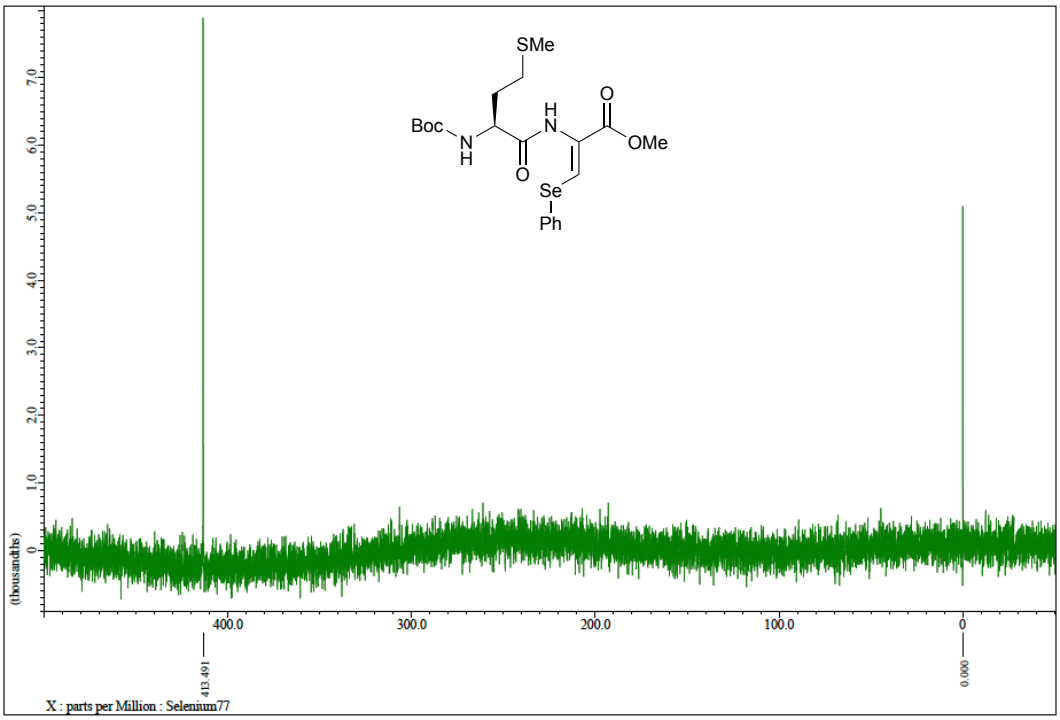
(*Z*)-**3g**: ^{1}H NMR ($CDCl_3$)



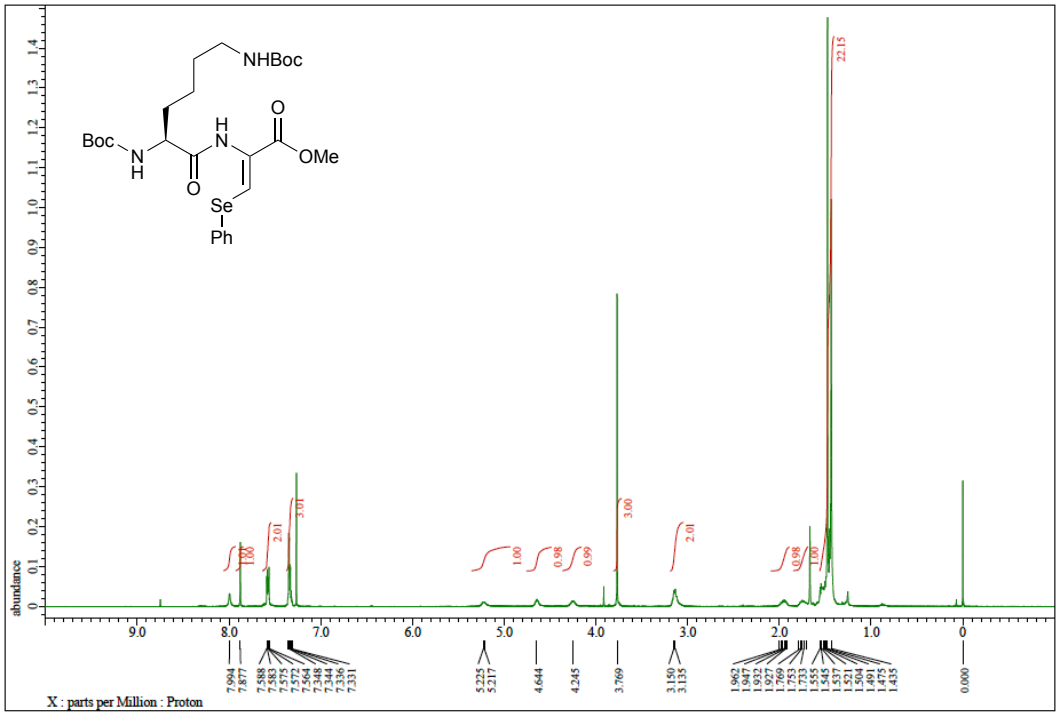
(*Z*)-**3g**: ^{13}C NMR ($CDCl_3$)



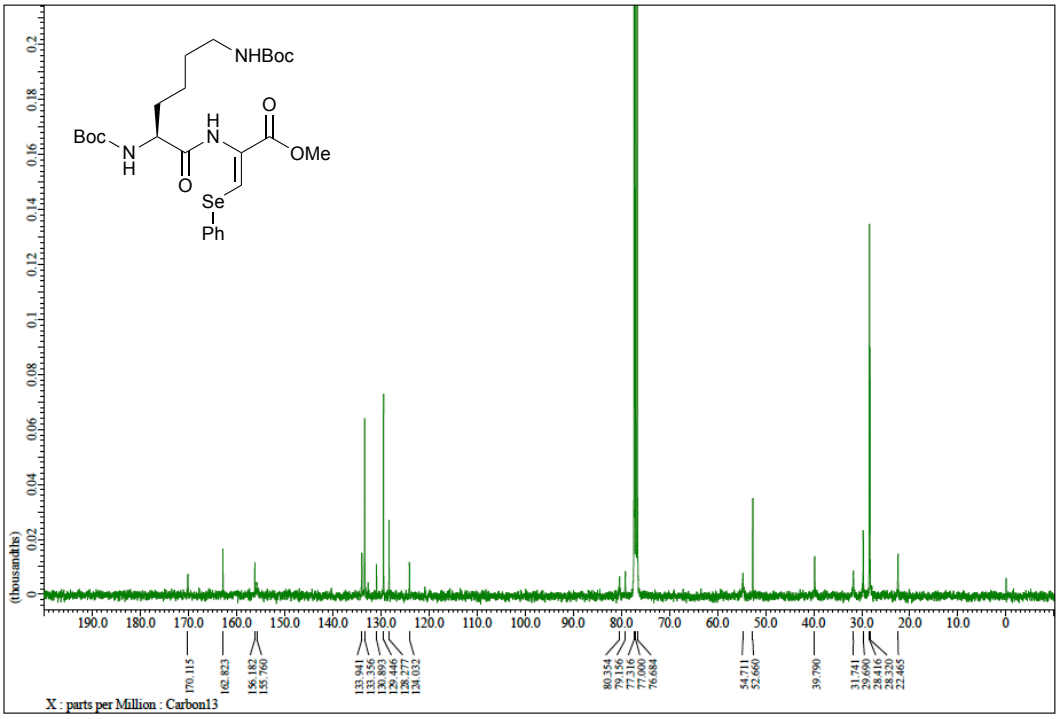
(*Z*)-**3g**: ^{77}Se NMR ($CDCl_3$)



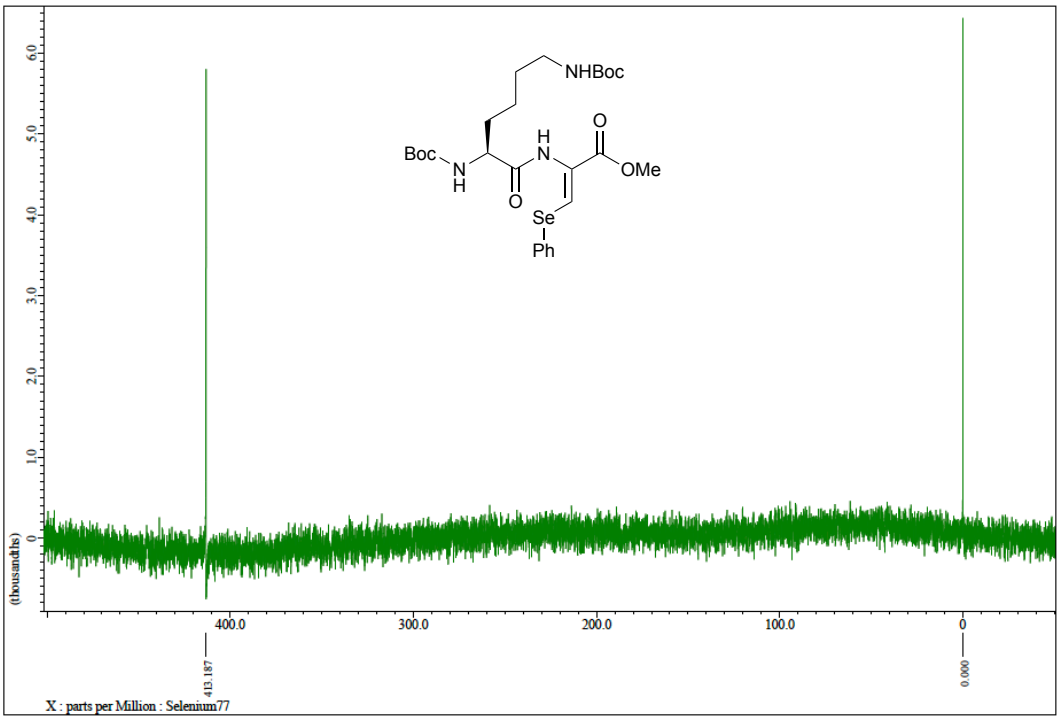
(*Z*)-**3h**: ^{1}H NMR ($CDCl_3$)



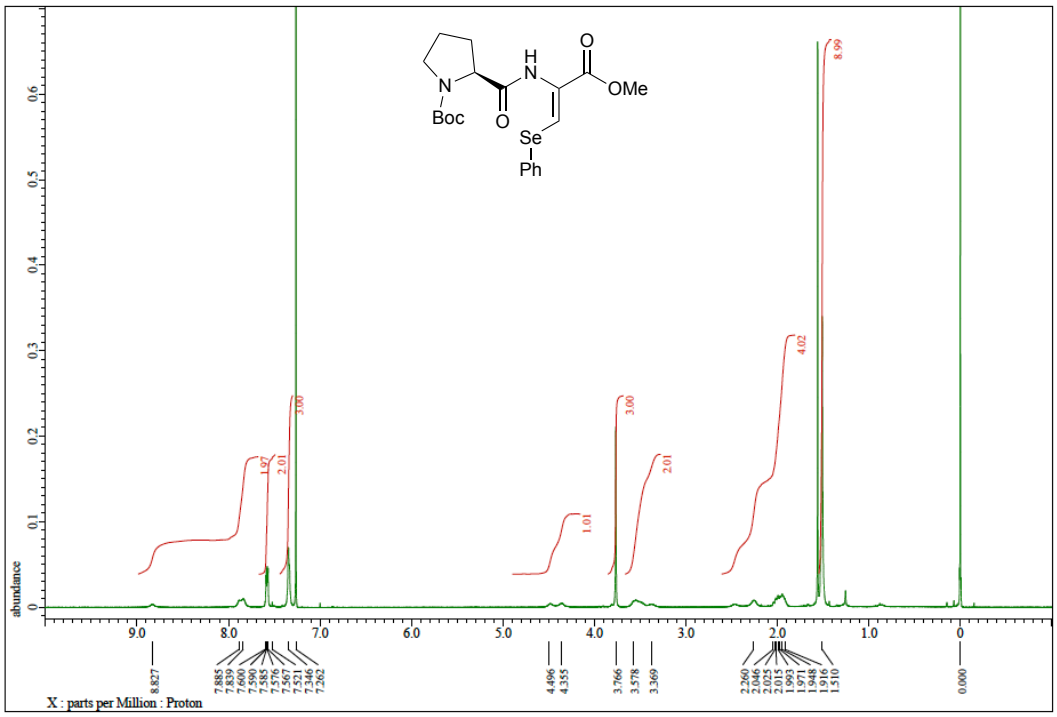
(*Z*)-**3h**: ^{13}C NMR ($CDCl_3$)



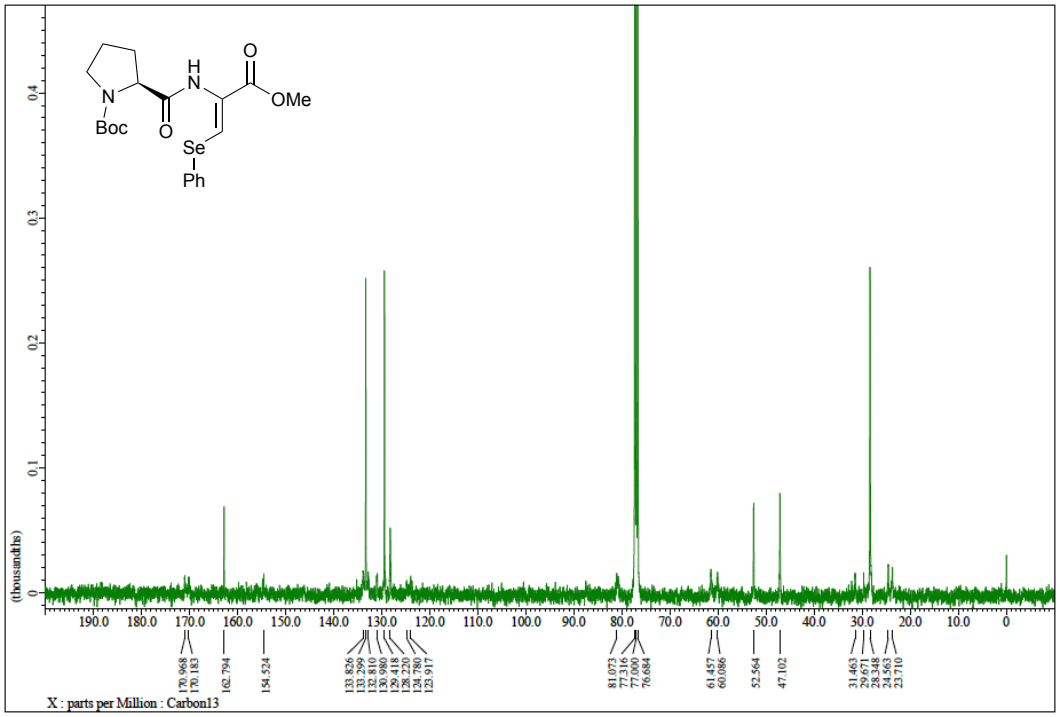
(*Z*)-**3h**: ^{77}Se NMR ($CDCl_3$)



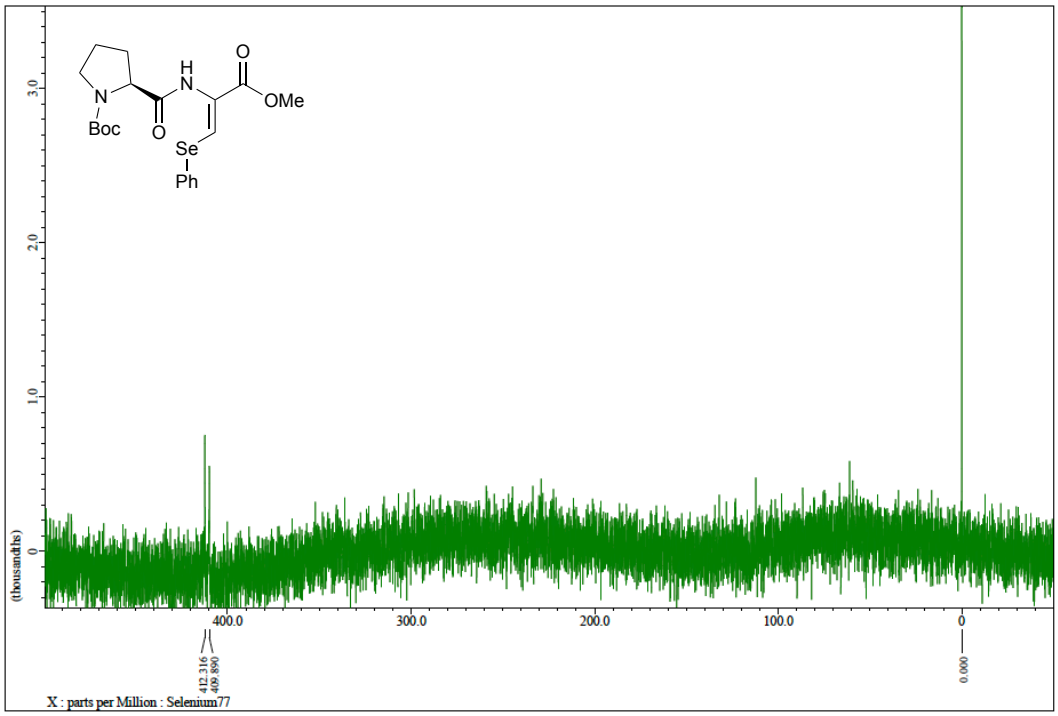
(*Z*)-**3i**: ^{1}H NMR ($CDCl_3$)



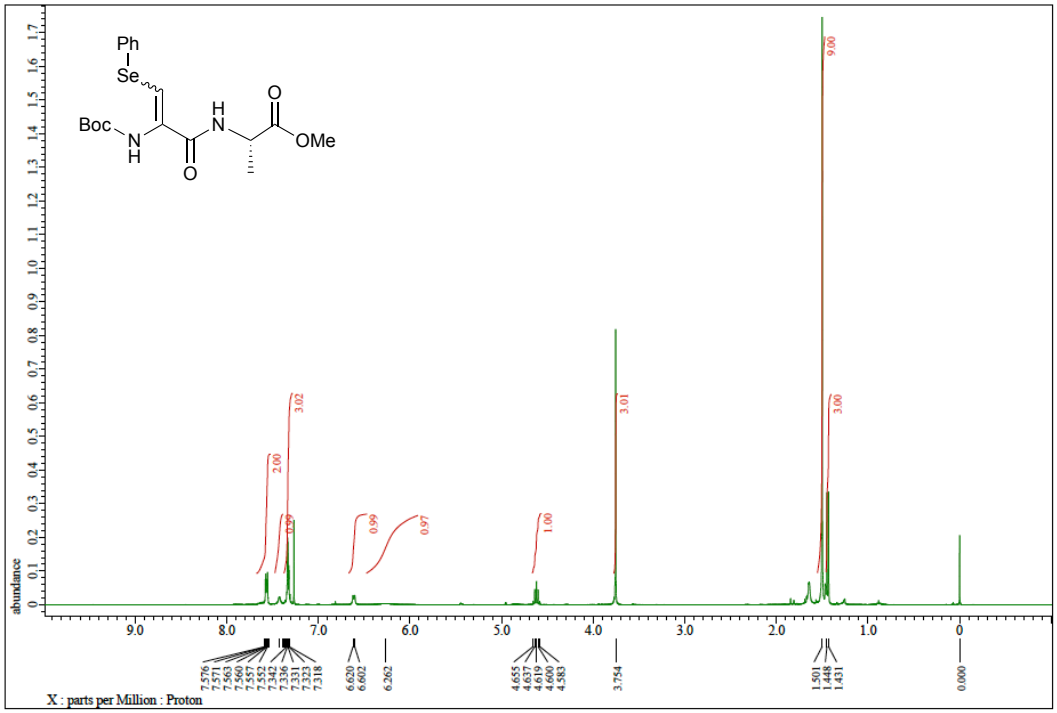
(*Z*)-**3i**: ^{13}C NMR ($CDCl_3$)



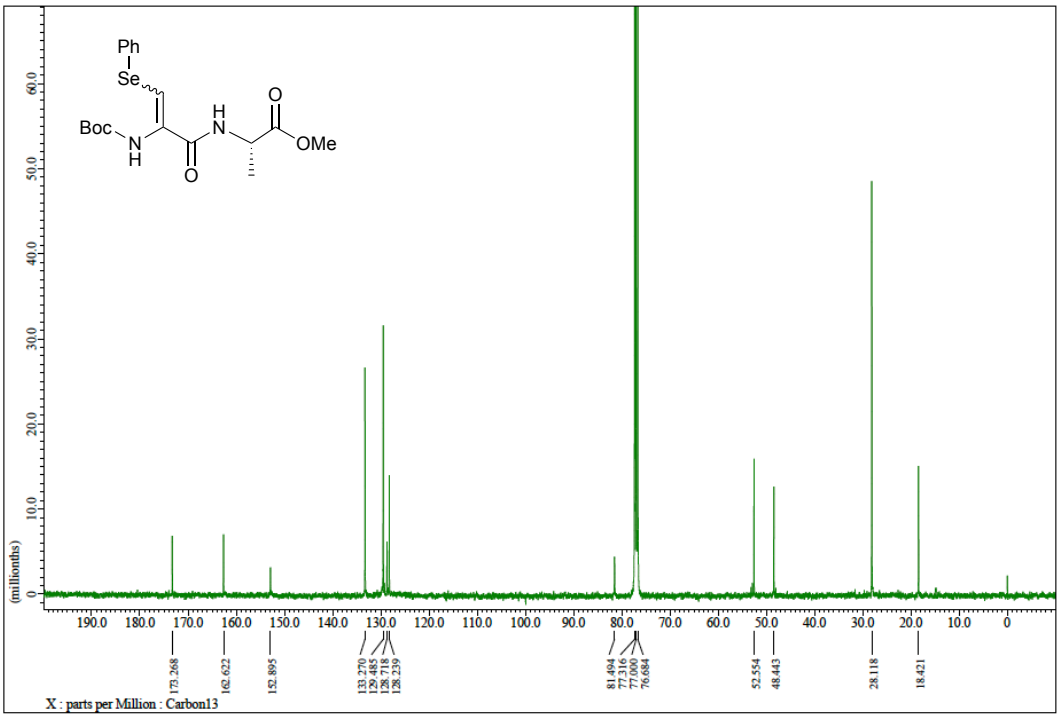
(*Z*)-**3i**: ^{77}Se NMR ($CDCl_3$)



3j (major): ^{1}H NMR ($CDCl_3$)

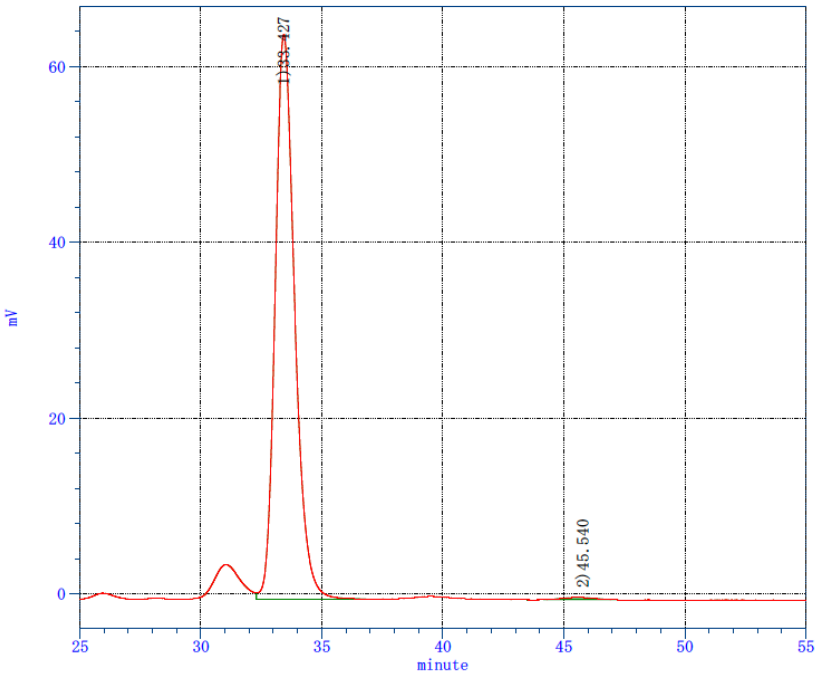


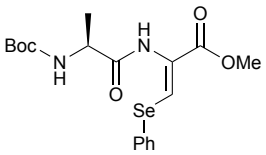
3j (major): ^{13}C NMR ($CDCl_3$)



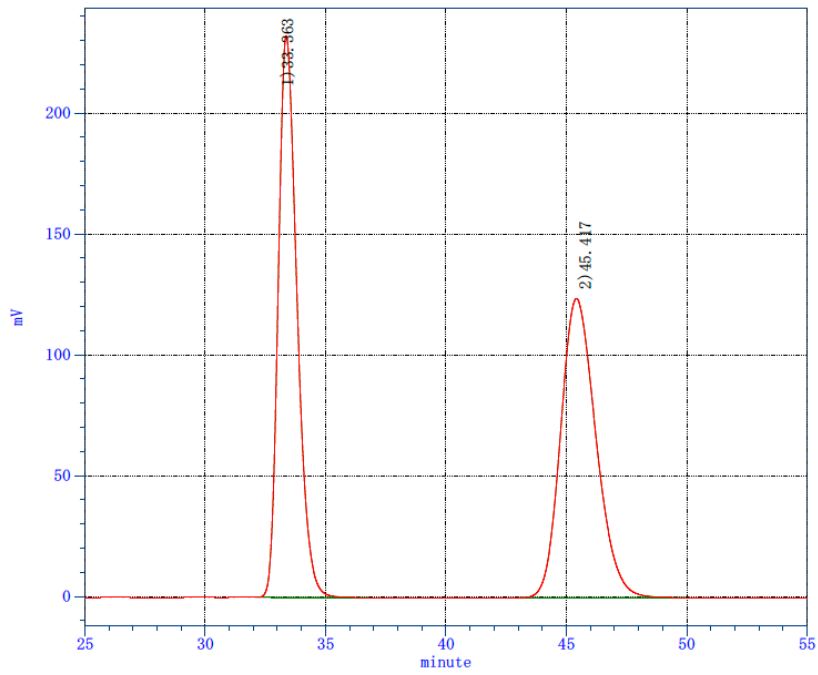
HPLC Charts

(*Z*)-**3b**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

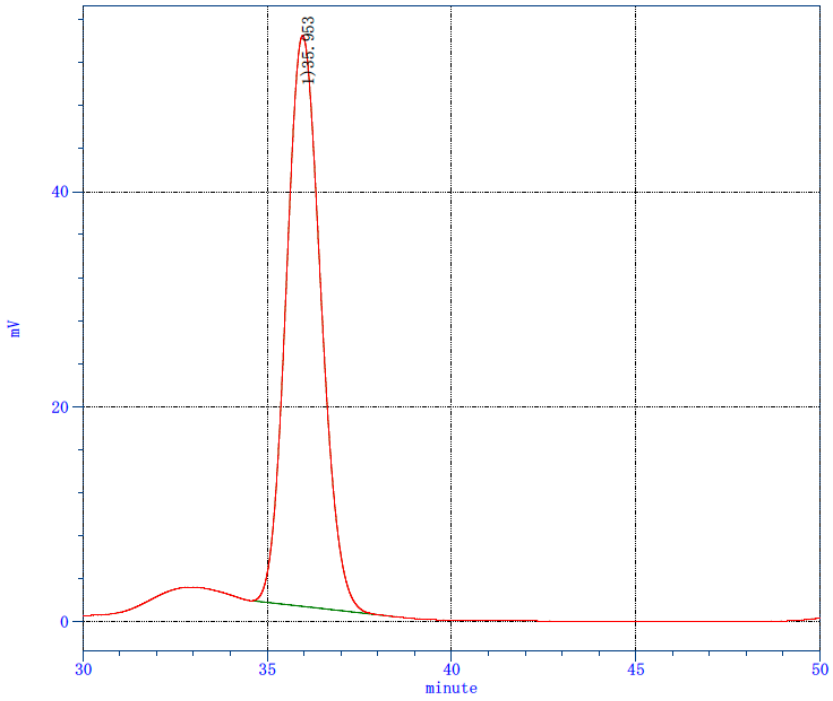


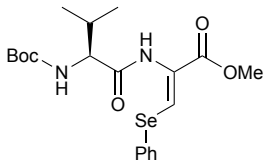


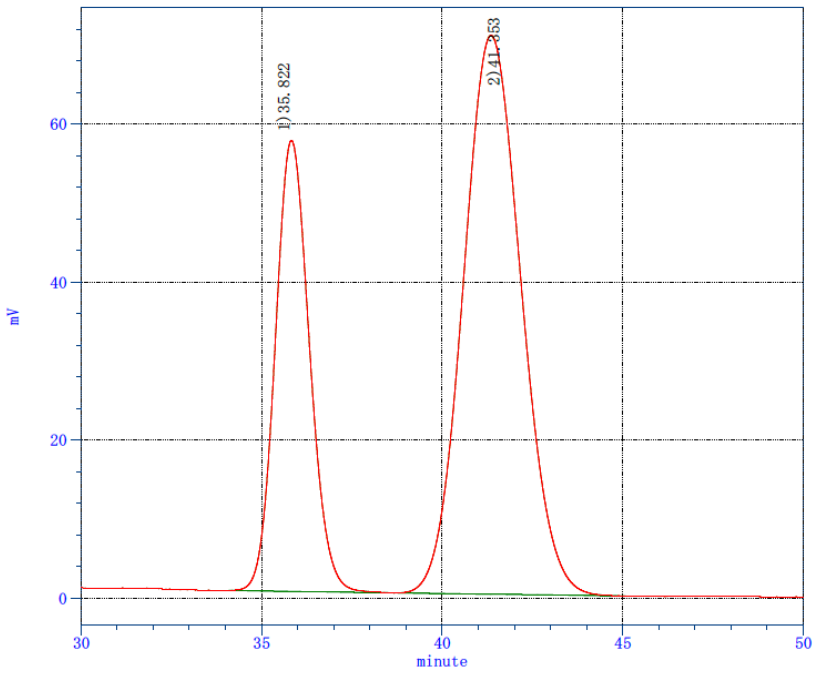
1	33.427	3604311	99.3770
2	45.540	22595	0.6230



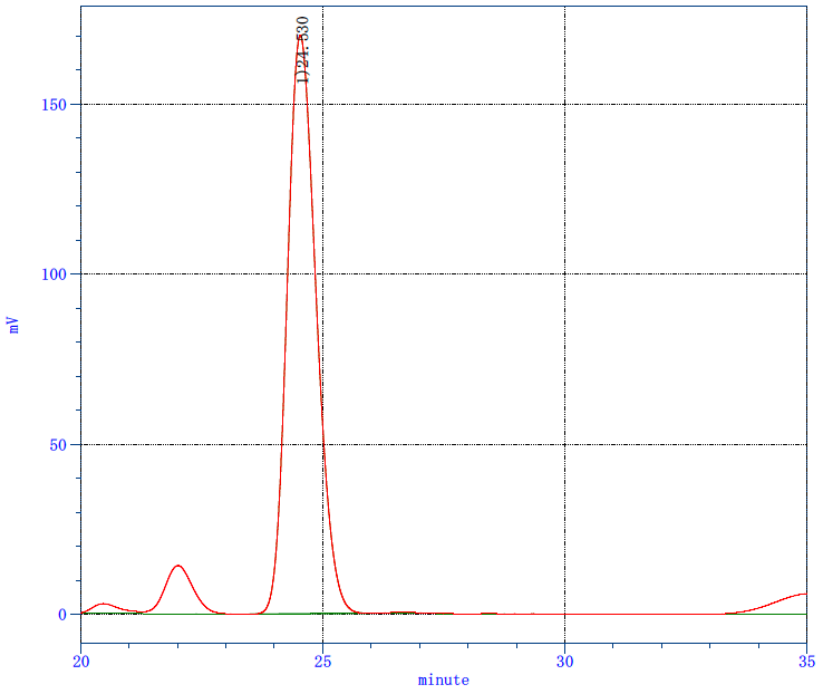
(*Z*)-**3c**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

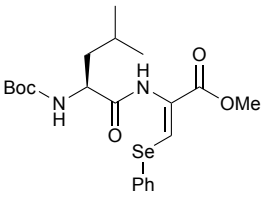


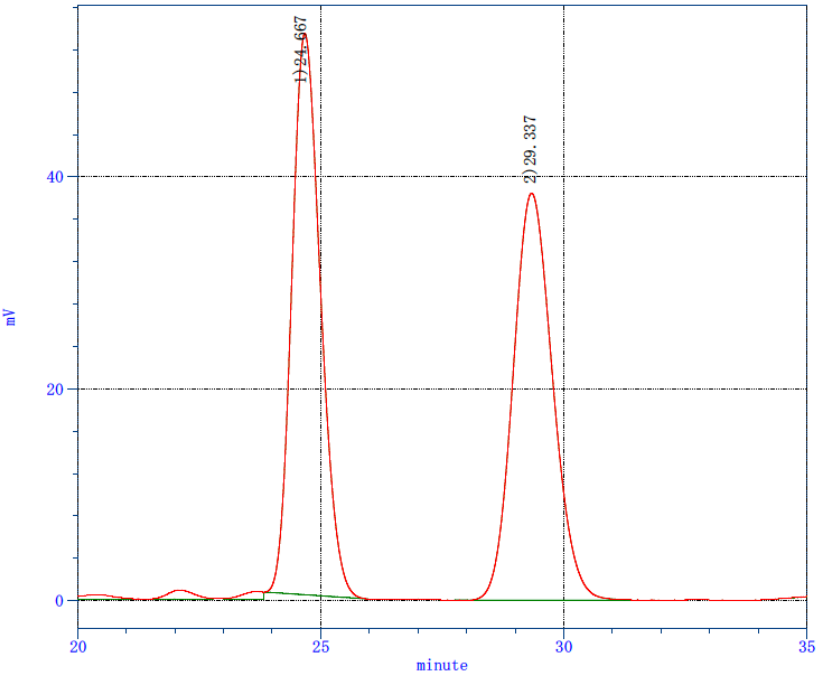




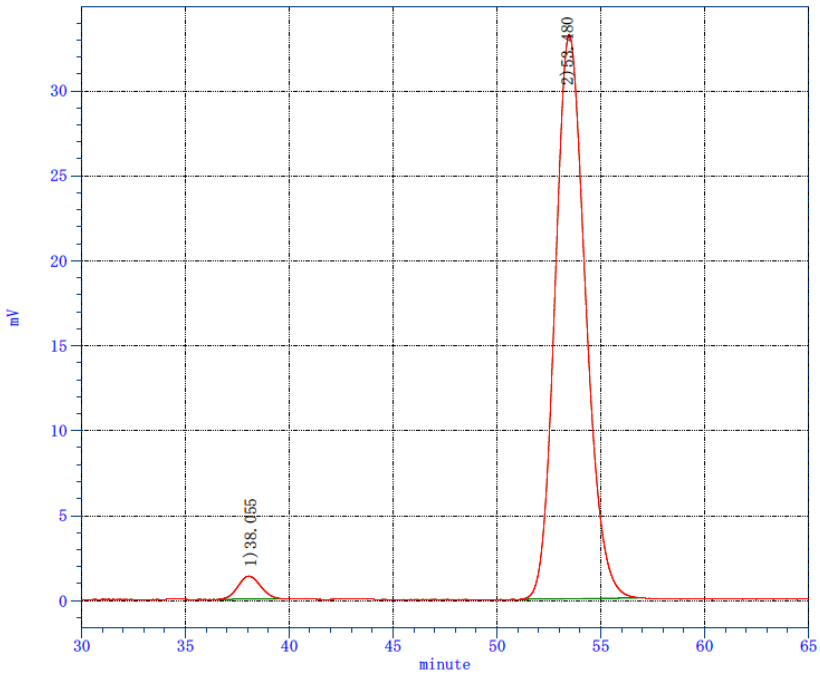
(*Z*)-**3d**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

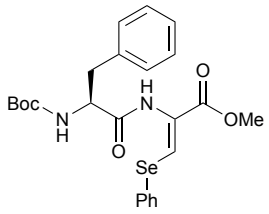




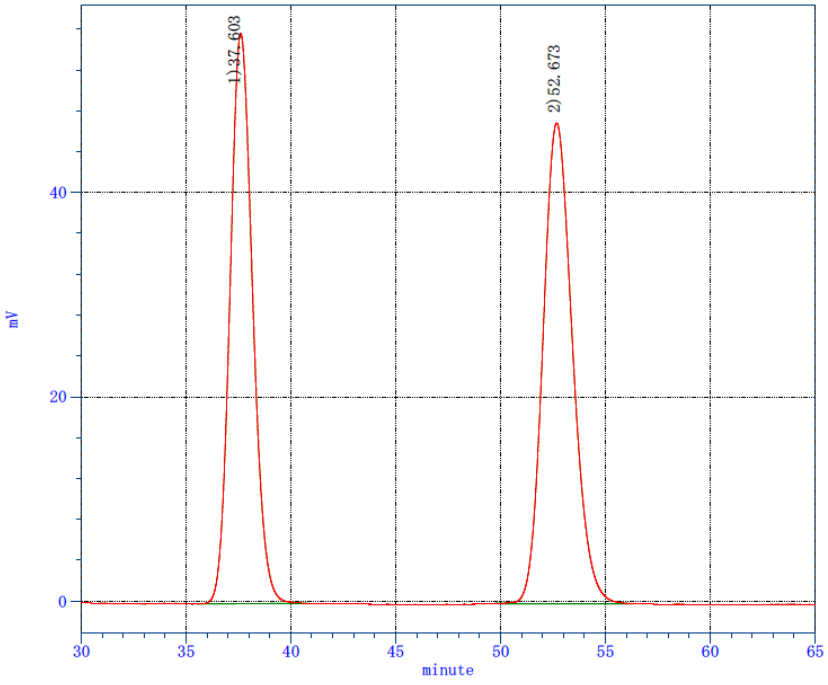


(*Z*)-**3e**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 300 nm

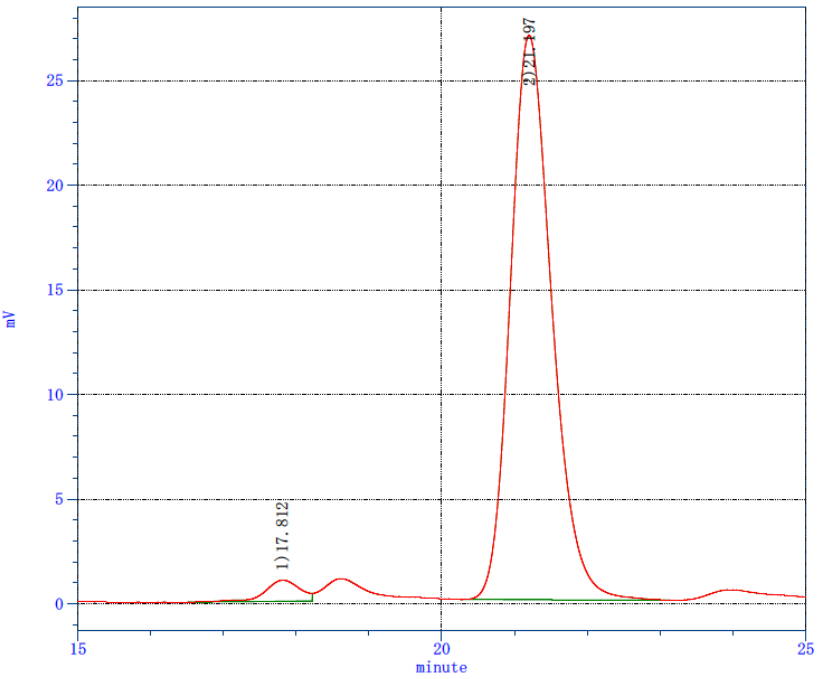


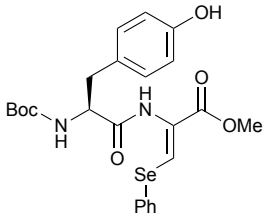


1	38.055	101899	2.9290
2	53.480	3377028	97.0710

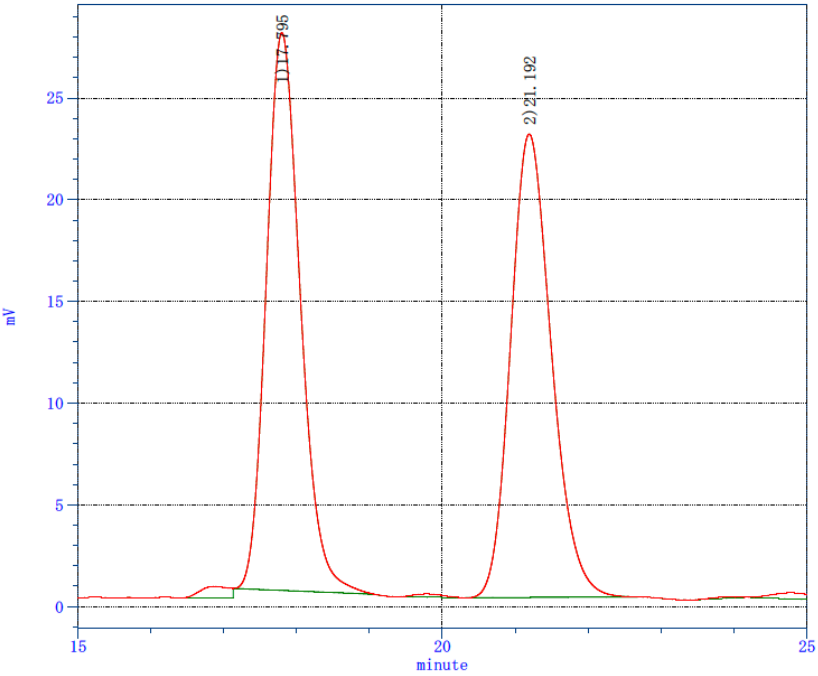


(*Z*)-**3f**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 254 nm

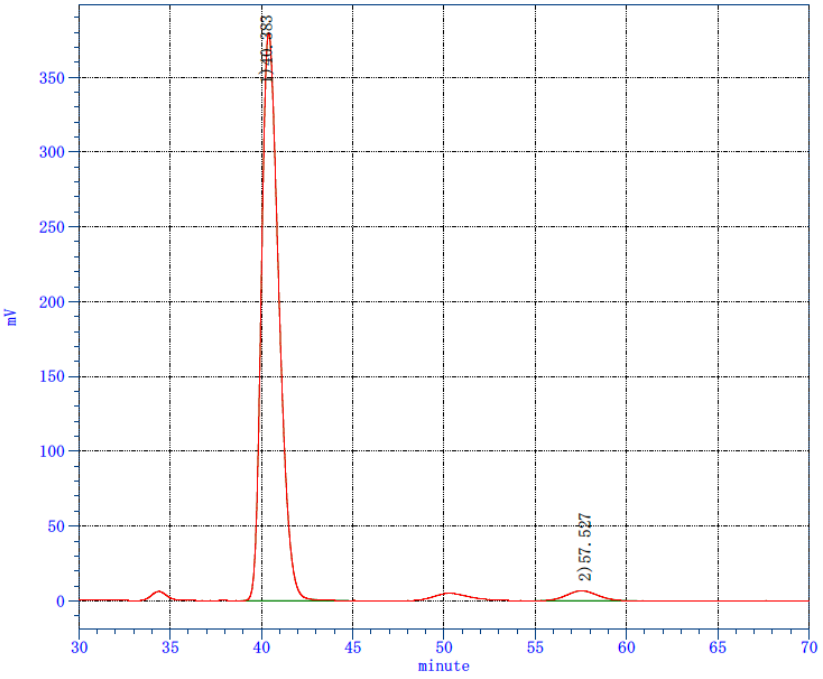


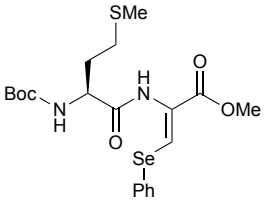


1	17.812	33353	3.0330
2	21.197	1066319	96.9670

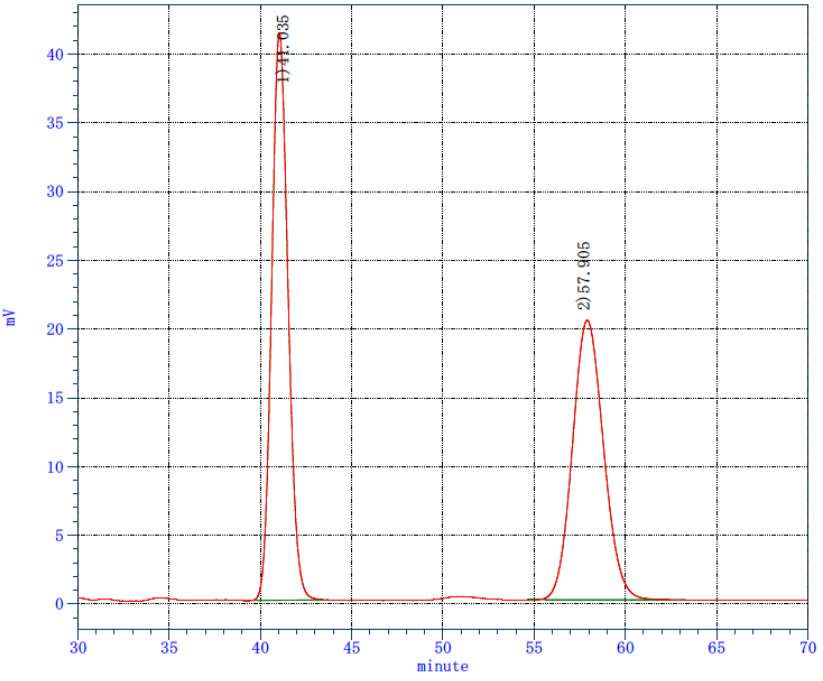


(*Z*)-**3g**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

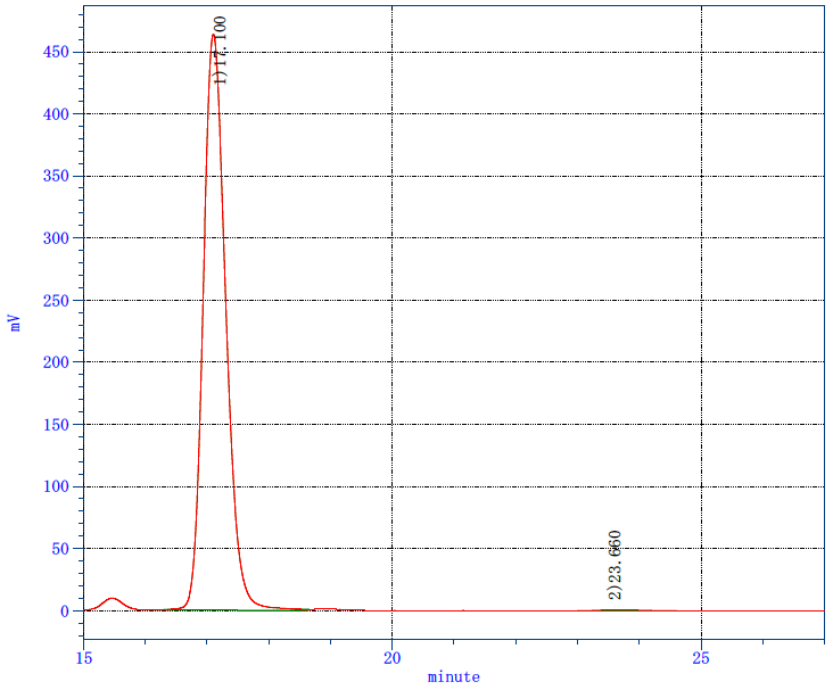


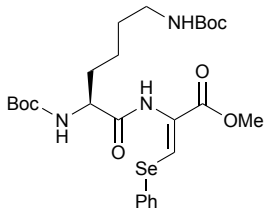


1	40.383	25263710	97.0291
2	57.527	773534	2.9709

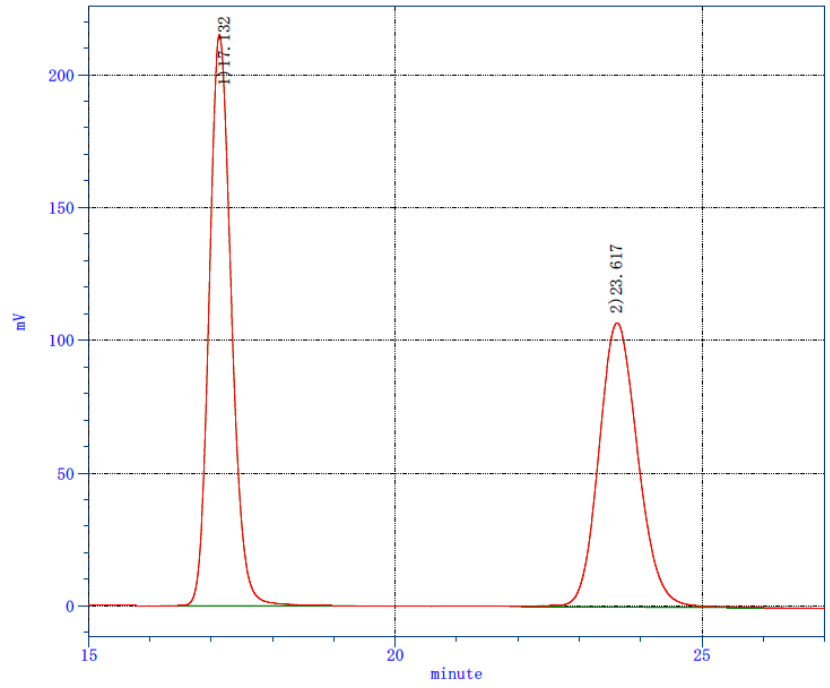


(*Z*)-**3h**: Daicel Chiralpak IF-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

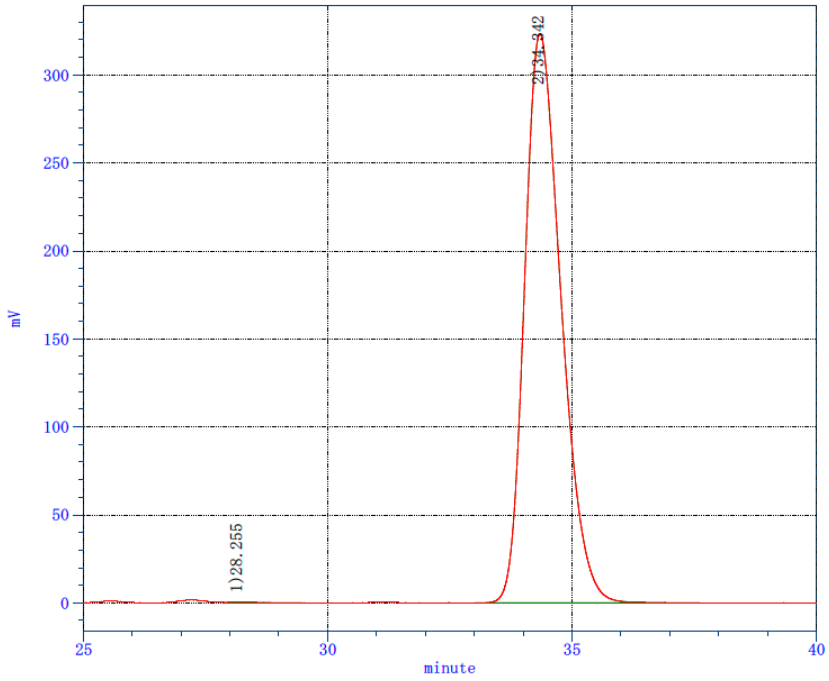


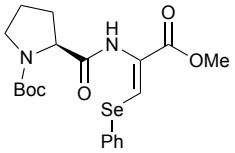


1	17.100	11811970	99.7956
2	23.660	24197	0.2044

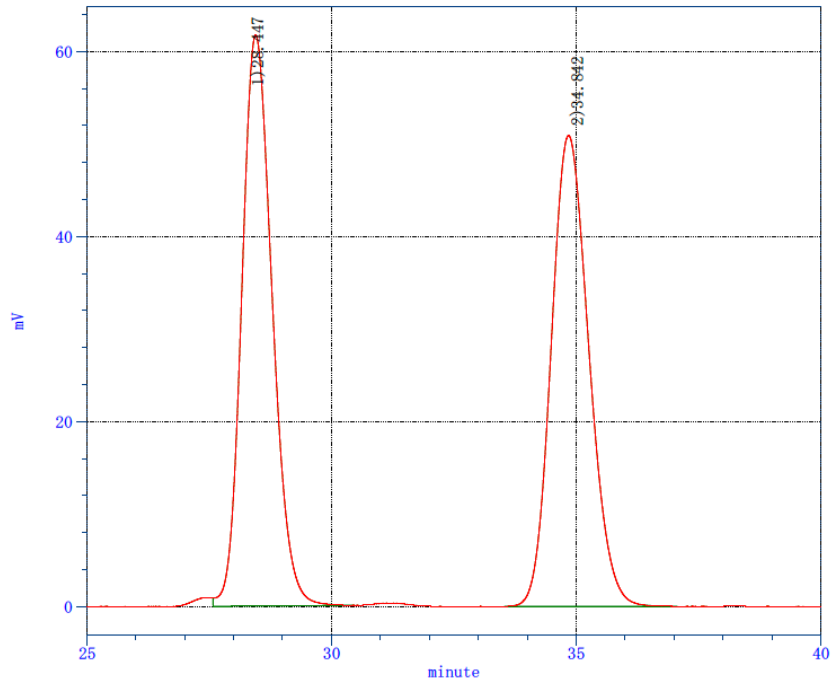


(*Z*)-**3i**: Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm

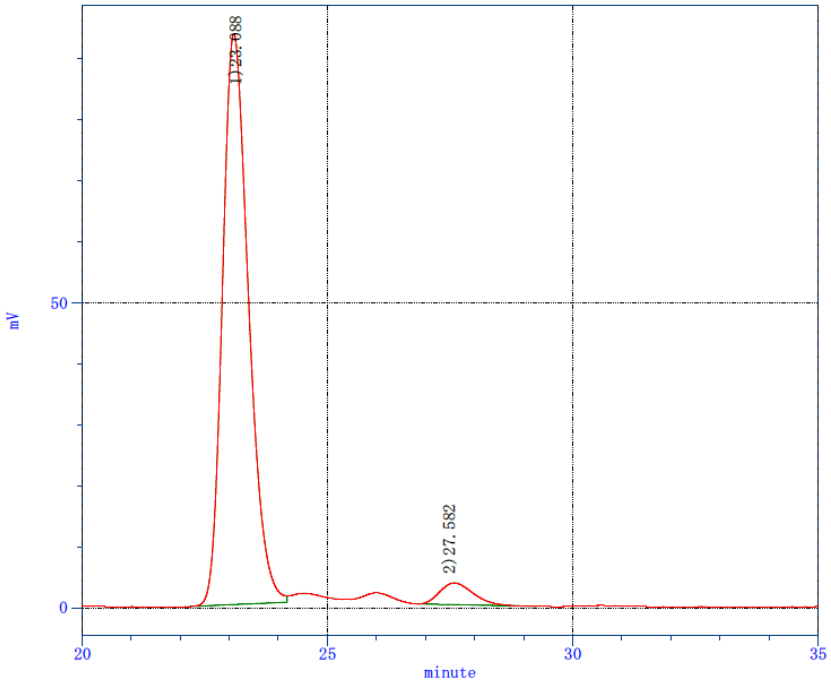


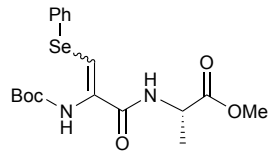


1	28.255	5846	0.0349
2	34.342	16730620	99.9651



3j (major): Daicel Chiralpak IE-3, hexane/2-propanol = 1:1, flow rate = 0.5 mL/min, 270 nm





1	23.088	3450190	95.3368
2	27.582	168760	4.6632