

SUPPORTING INFORMATION

Synthesis of selenium-containing bicyclic β -lactams via alkene metathesis

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Experimental Section:

General

All reactions were performed in round-bottom flask fitted with balloon filled with argon, otherwise specified. Transfer of air- and moisture-sensitive liquids was performed *via* cannula under a positive pressure of argon. TLC analysis was performed on Merck TLC (silica gel 60F₂₅₄ on glass plate). Evaporation and condensation were carried out *in vacuo*. The compound **1**¹ and **5**² were prepared according to the literature. Silica gel 60N (spherical, neutral) manufactured by Kanto Chemical Co. Inc. was used for flash column chromatography. DMF and toluene were deoxygenated prior to use. Tetramethylammonium fluoride and methyl hydrazine were purchased from Tokyo Chemical Industry Ltd. Grubbs 1st gen. catalyst, Grubbs 2nd gen. catalyst, LHMDS (1.0 M THF solution) and 3-bromo-2-methyl-propene were purchased from Aldrich Chemical Company. Schrock's catalyst was purchased from Strem Chemicals. 4-Bromo-1-butene was purchased from Alfa Aesar Company. (3*R*,4*R*)-4-Acetoxy-3-[(*R*)-(tert-butyldimethylsilyloxy)ethyl]-2-azetidinone, allyl bromide and cesium carbonate were purchased from Wako Pure Chemical Industries Ltd. NaH was purchased from Nacalai Tesque Inc.

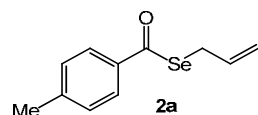
Melting points were measured by a Yanagimoto micromelting point apparatus (uncorrected). Optical rotation was recorded by Union PM-201 Automatic Digital Polarimeter (Horiba) at 28°C. IR spectra were measured on JASCO FT/IR-410 Fourier Transform Infrared Spectrometer. The ¹H NMR, ¹³C NMR spectra or ⁷⁷Se NMR spectra were measured on JEOL:JNM ECX-400P, JEOL:JNM ECA-500, JEOL:JNM ECA-600 spectrometers in CDCl₃. Chemical shifts of protons are reported in δ values referred to TMS as an internal standard, and the following abbreviations were used as follows: s: singlet, d: doublet, t: triplet, m: multiplet. The ⁷⁷Se chemical shifts were expressed in δ values deshielded with respect to neat Me₂Se. ¹J(⁷⁷Se-¹H) values are observed as ⁷⁷Se satellites of the ¹H NMR spectra. MS and HRMS were measured on a JEOL JMS-700.

References:

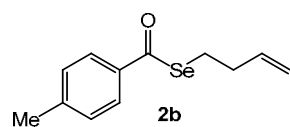
1. Y. Kawai, H. Ando, H. Ozeki, M. Koketsu and H. Ishihara, *Org. Lett.*, 2005, **7**, 4653.
2. D. R. Garud, H. Ando, Y. Kawai, H. Ishihara and M. Koketsu, *Org. Lett.*, 2007, **9**, 4455.

General Preparation of *Se*-alkene *p*-methylselenobenzoate (2): To a solution of potassium *p*-methylselenobenzoate **1** (12.65 mmol) in degassed DMF (50 mL) was added alkyl bromide (18.97 mmol) under an argon atmosphere, and the mixture was stirred for 1 h (TLC; CHCl₃:*n*-hexane = 1:5). The reaction mixture was filtered through celite and washed with CHCl₃. The combined filtrate and washing were extracted with CHCl₃ and washed with water and brine. The organic layer was dried over Na₂SO₄ and concentrated. The resulted residue was purified with column chromatography on silica gel (CHCl₃:*n*-hexane = 1:15 → 1:10 → 1:5) to give **2**.

The isolated yield and the spectral data for **2a** and **2b** are as follows:



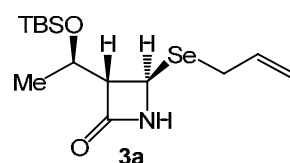
***Se*-3-Allyl 4-methylbenzoselenoate (2a).** Yield: 87%; IR (neat): 2921, 1682, 1661, 1604, 1203, 1172, 887 cm⁻¹; ¹H NMR (CDCl₃): δ 2.39 (s, 3H), 3.71 (d, *J* = 8.0 Hz, ²*J*(⁷⁷Se-¹H) = 14.0 Hz, 2H), 5.05 (d, *J* = 9.2 Hz, 1H), 5.26 (dd, *J* = 1.1, 17.2 Hz, 1H), 5.92-6.02 (m, 1H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.78 (d, *J* = 8.0 Hz, 2H); ¹³C NMR (CDCl₃): δ 21.7, 27.7, 117.3, 127.3, 129.4, 134.6, 136.4, 144.6, 193.7; ⁷⁷Se NMR (CDCl₃): δ 553.3; HRMS (EI): *m/z* = 240.0053 calcd. for C₁₁H₁₂OSe, found 240.0042.



***Se*-3-Butenyl 4-methylbenzoselenoate (2b).** Yield: 83%; IR (neat): 2924, 1681, 1661, 1604, 1406, 1202, 1172, 886 cm⁻¹; ¹H NMR (CDCl₃): δ 2.38 (s, 3H), 2.48-2.54 (m, 2H), 3.13 (t, *J* = 6.9 Hz, ²*J*(⁷⁷Se-¹H) = 26.3 Hz, 2H), 5.05 (dd, *J* = 1.7, 10.3 Hz, 1H), 5.10 (dd, *J* = 1.7, 17.2 Hz, 1H), 5.80-5.90 (m, 1H), 7.22 (d, *J* = 8.0 Hz, 2H), 7.79 (d, *J* = 8.0 Hz, 2H); ¹³C NMR (CDCl₃): δ 21.6, 24.4, 34.5, 116.0, 127.2, 129.3, 136.5, 137.2, 144.4, 194.0; ⁷⁷Se NMR (CDCl₃): δ 521.1; HRMS (EI): *m/z* = 254.0210 calcd. for C₁₂H₁₄OSe, found 254.0197.

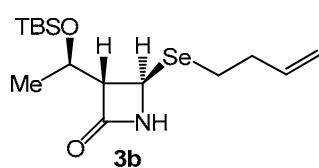
Typical procedure for the preparation of 4-alkylseleno-2-azetidinone (3): To stirred solution of selenium catalyst **2** (3.83 mmol), Cs₂CO₃ (3.83 mmol) in dry DMF (5 mL) at r.t. was added methyl hydrazine (3.83 mmol) under argon atmosphere. After stirring at this temperature for 10 minutes, (3*R*,4*R*)-4-acetoxy-3-[(*R*)-(*tert*-butyldimethylsilyloxy)ethyl]-2-azetidinone (3.48 mmol) was added and stirring continued for additional 30 min. The reaction mixture was extracted with dichloromethane and washed with water. The combined organic extracts were dried (Na₂SO₄) and concentrated *in vacuo* to afford a residue that was further subjected to flash chromatography (SiO₂: hexane / diethyl ether = 5/1) to afford compound **3**.

The isolated yield and the spectral data for **3a-3b** are as follows:



(3*S*,4*R*)-4-Allylseleno-3-[(*R*)-*tert*-butyldimethylsilyloxyethyl]-2-azetidinone (3a). Yield: 26%; Mp. 58–59 °C; IR (neat): 2955, 1766, 1723, 1654, 1637, 1374, 1250, 958, 835 cm⁻¹; ¹H NMR (CDCl₃): δ 0.07 (s, 3H), 0.08 (s, 3H), 0.87 (s, 9H), 1.23 (d, *J* = 6.3 Hz, 3H), 3.24 (s, 1H), 3.28-3.40 (m, 2H), 4.22-4.28 (m, 1H), 4.97 (d, *J* = 2.3 Hz, ²*J*(⁷⁷Se-¹H) = 18.9 Hz, 1H), 5.04 (d, *J* = 9.7 Hz, 1H), 5.14 (dd, *J* = 1.1, 17.2 Hz, 1H), 5.92-6.00 (m, 1H), 6.18 (brs, 1H); ¹³C NMR (CDCl₃): δ -5.12, -4.33, 17.9,

22.2, 25.7, 26.4, 46.8, 64.7, 67.0, 116.9, 135.4, 167.2; ^{77}Se NMR (CDCl_3): δ 310.5; HRMS: m/z = 292.0272 calcd. for $\text{C}_{10}\text{H}_{18}\text{NO}_2\text{SeSi}$, found 292.0231.



(3S,4R)-4-(3-Buteneseleno)-3-[(R)-tert-butyl dimethylsilyloxyethyl]-2-azetidinone (3b). Yield 92%; Mp. 70–71 °C; IR (neat): 2952, 1761,

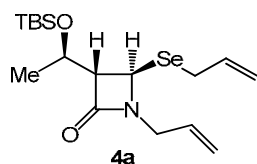
1672, 1567, 1386, 1257, 1095, 832 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.07 (s, 3H), 0.08 (s, 3H), 0.88 (s, 9H), 1.24 (d, J = 6.3 Hz, 3H), 2.41–2.53 (m, 2H), 2.75 (t, J = 7.4 Hz, 2H), 3.21 (s, 1H), 4.23–4.28 (m, 1H), 4.99 (d, J = 1.7 Hz, $^2J(^{77}\text{Se}-^1\text{H})$ = 26.9 Hz, 1H), 5.05–5.13 (m, 2H), 5.77–5.87 (m, 1H), 5.92 (brs, 1H); ^{13}C NMR (CDCl_3): δ -5.07, -4.31, 17.9, 22.1, 22.2, 25.7, 34.8, 46.4, 64.8, 67.4, 116.4, 136.9, 167.0; ^{77}Se NMR (CDCl_3): δ 277.3; HRMS: m/z = 306.0429 calcd. for $\text{C}_{11}\text{H}_{20}\text{NO}_2\text{SeSi}$, found 306.0420.

General procedure for the *N*-alkylation reaction of 3:

Method A: To a suspension of NaH (60% in mineral oil, 2.07 mmol) in 5 mL of THF at 0 °C was added compound 3 (1.38 mmol) in 15 mL THF over 15 minutes. The mixture was stirred at 0 °C for an additional 15 min, alkyl bromide (2.07 mmol) was added dropwise. The reaction mixture was stirred at r.t. for 1 hour to 3 days and then taken in 10 mL of ammonium chloride solution. The organic layer was washed with 10 mL of a saturated solution of sodium bicarbonate. The aqueous layer was extracted 3 times with 20 mL of diethyl ether each. The combined organic layers were dried (Na_2SO_4) and concentrated. The residue was purified by column chromatography (SiO_2 : hexane / diethyl ether = 15/1) to afford compound 4.

Method B: Lithium bis(trimethylsilyl)amide (0.66 mmol, 1.0 M solution in THF) was added dropwise to a stirred solution of compound 3 (0.55 mmol) in THF (10 mL) at -78 °C under argon atmosphere. The resultant solution was stirred at -78 °C for 10 minutes. Alkyl bromide (2.76 mmol) was added over 5 minutes and the resulting mixture allowed to warm to ambient temperature overnight. The resulting mixture was quenched with 10% HCl and extracted with diethyl ether. The combined organic extracts were dried (Na_2SO_4) and concentrated *in vacuo* to afford a residue that was further subjected to flash chromatography (SiO_2 : hexane / diethyl ether = 15/1) to afford the title compound 4 as clear oil

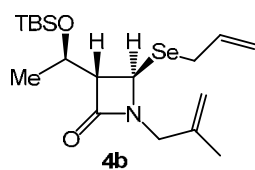
The isolated yield and the spectral data for 4a-e are as follows:



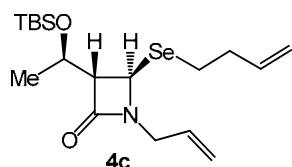
(3S,4R)-1-Allyl-4-(allylseleno)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-2-

-azetidinone (4a). Method A; Yield: 24%; IR (neat): 2928, 1763, 1633, 1388, 1251, 1065, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.08 (s, 3H), 0.87 (s, 9H), 1.22 (d, J = 6.2 Hz, 3H), 3.20–3.30 (m, 3H), 3.50 (dd, J = 7.5, 15.8 Hz, 1H), 4.08 (dd, J = 4.8, 15.8 Hz, 1H), 4.24–4.30 (m, 1H), 4.92 (d, J = 2.1 Hz, $^2J(^{77}\text{Se}-^1\text{H})$ = 19.9 Hz, 1H), 5.04 (d, J = 9.7 Hz, 1H), 5.10 (dd, J = 1.4, 17.2 Hz, 1H), 5.21 (dd, J = 1.4, 10.3 Hz, 1H), 5.29 (dd, J = 1.4, 17.2 Hz, 1H), 5.74–5.82 (m, 1H), 5.86–5.93 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.80, -4.61,

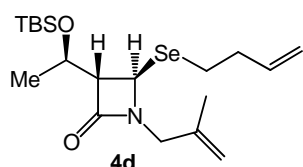
17.9, 22.3, 25.8, 42.7, 51.8, 64.7, 65.7, 117.2, 118.6, 131.8, 134.6, 166.2; ^{77}Se NMR (CDCl_3): δ 235.6; HRMS: $m/z = 332.0585$ calcd. for $\text{C}_{13}\text{H}_{22}\text{NO}_2\text{SeSi}$, found 332.0587.



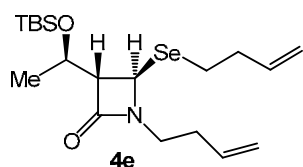
(3S,4R)-4-(Allylseleno)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-1-(2-methylallyl)-2-azetidinone (4b). Method A; Yield: 47%; IR (CHCl_3): 2955, 1758, 1633, 1462, 1387, 1254, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.09 (s, 3H), 0.88 (s, 9H), 1.24 (d, $J = 6.3$ Hz, 3H), 1.76 (s, 3H), 3.19-3.30 (m, 3H), 3.45 (d, $J = 16.0$ Hz, 1H), 3.97 (d, $J = 15.5$ Hz, 1H), 4.22-4.31 (m, 1H), 4.88 (d, $J = 1.7$ Hz, 1H), 4.92 (s, 1H), 4.96 (s, 1H), 5.03 (d, $J = 9.7$ Hz, 1H), 5.08 (d, $J = 16.7$ Hz, 1H), 5.84-5.93 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.81, -4.49, 18.0, 20.6, 22.3, 25.8, 26.0, 46.0, 52.4, 65.0, 65.8, 113.4, 117.2, 134.6, 139.6, 166.5; ^{77}Se NMR (CDCl_3): δ 233.7; HRMS: $m/z = 346.0742$ calcd. for $\text{C}_{14}\text{H}_{24}\text{NO}_2\text{SeSi}$, found 346.0760.



(3S,4R)-1-Allyl-4-(3-butenylseleno)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-2-azetidinone (4c). Method A; Yield: 51%; IR (neat): 2955, 1762, 1643, 1387, 1252, 1063, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.07 (s, 3H), 0.09 (s, 3H), 0.88 (s, 9H), 1.24 (d, $J = 6.4$ Hz, 3H), 2.38-2.50 (m, 2H), 2.58-2.71 (m, 2H), 3.19 (s, 1H), 3.49 (dd, $J = 7.3, 15.6$ Hz, 1H), 4.09 (dd, $J = 4.6, 15.6$ Hz, 1H), 4.23-4.31 (m, 1H), 4.91 (d, $J = 2.3$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 27.0$ Hz, 1H), 5.02-5.12 (m, 2H), 5.20 (d, $J = 10.1$ Hz, 1H), 5.28 (d, $J = 17.0$ Hz, 1H), 5.71-5.86 (m, 2H); ^{13}C NMR (CDCl_3): δ -4.81, -4.60, 18.0, 21.6, 22.3, 25.8, 34.7, 42.7, 51.5, 64.7, 65.9, 116.2, 118.6, 131.6, 136.8, 166.2; ^{77}Se NMR (CDCl_3): δ 213.0; HRMS: $m/z = 346.0742$ calcd. for $\text{C}_{14}\text{H}_{24}\text{NO}_2\text{SeSi}$, found 346.0724.



(3S,4R)-4-(3-Butenylseleno)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-1-(2-methylallyl)-2-azetidinone (4d). Method A; Yield: 82%; IR (neat): 2955, 1762, 1657, 1641, 1471, 1387, 1254, 1054, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.09 (s, 3H), 0.88 (s, 9H), 1.25 (d, $J = 6.3$ Hz, 3H), 1.75 (s, 3H), 2.40-2.47 (m, 2H), 2.59-2.69 (m, 2H), 3.21 (t, $J = 2.3$ Hz, 1H), 3.41 (d, $J = 16.0$ Hz, 1H), 3.99 (d, $J = 16.0$ Hz, 1H), 4.25-4.31 (m, 1H), 4.87 (d, $J = 2.3$ Hz, 1H), 4.91 (s, 1H), 4.95 (s, 1H), 5.03-5.12 (m, 2H), 5.75-5.85 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.82, -4.54, 18.0, 20.5, 21.9, 22.3, 25.8, 34.6, 45.9, 52.2, 65.1, 66.0, 113.3, 116.2, 136.8, 139.3, 166.3; ^{77}Se NMR (CDCl_3): δ 211.8; HRMS: $m/z = 360.0898$ calcd. for $\text{C}_{15}\text{H}_{26}\text{NO}_2\text{SeSi}$, found 360.0887.



(3S,4R)-1-(3-Butenyl)-4-(3-butenylseleno)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-2-azetidinone (4e). Method B; Yield: 38%; IR (neat): 2954, 1759, 1641, 1393, 1253, 1059, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.07 (s, 3H), 0.08 (s, 3H), 0.88 (s, 9H), 1.24 (d, $J = 6.3$ Hz, 3H), 2.30-2.49 (m, 4H), 2.59-2.70 (m, 2H), 2.97-3.04 (m, 1H), 3.17 (t, $J = 1.8$ Hz, 1H), 3.41-3.48 (m, 1H), 4.19-4.25 (m, 1H), 4.86 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 30.9$ Hz, 1H), 5.03-5.15 (m, 4H), 5.76-5.85 (m, 2H); ^{13}C NMR

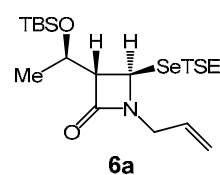
(CDCl₃): δ -4.82, -4.52, 17.9, 21.0, 22.4, 25.7, 32.2, 34.6, 39.7, 52.0, 65.1, 65.9, 116.3, 117.0, 134.9, 136.8, 166.3; ⁷⁷Se NMR (CDCl₃): δ 212.1; HRMS: m/z = 360.0898 calcd. for C₁₅H₂₆NO₂SeSi, found 360.0890

General procedure for the *N*-alkylation reaction of **5**:

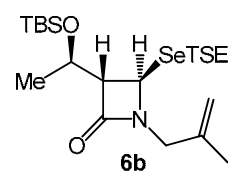
Method A: To a suspension of NaH (60% in mineral oil, 1.84 mmol) in 5 mL of THF at 0 °C was added (3*S*,4*R*)-3-[(*R*)-*tert*-butyldimethylsilyloxyethyl]-4-[2-(trimethylsilyl)ethylseleno]-2-azetidinone **5** (1.22 mmol) in 15 mL THF over 15 minutes. The mixture was stirred at 0 °C for an additional 15 min, alkyl bromide (1.84 mmol) was added dropwise. The reaction mixture was stirred at r.t. for 1 hour to 3 days and then taken in 10 mL of ammonium chloride solution. The organic layer was washed with 10 mL of a saturated solution of sodium bicarbonate. The aqueous layer was extracted 3 times with 20 mL of diethyl ether each. The combined organic layers were dried (Na₂SO₄) and concentrated. The residue was purified by column chromatography (SiO₂: hexane / diethyl ether = 15/1) to afford compound **6**.

Method B: Lithium bis(trimethylsilyl)amide (1.46 mmol, 1.0 M solution in THF) was added dropwise to a stirred solution of (3*S*,4*R*)-3-[(*R*)-*tert*-butyldimethylsilyloxyethyl]-4-[2-(trimethylsilyl)ethylseleno]-2-azetidinone **5** (1.22 mmol) in THF (10 mL) at -78 °C under argon atmosphere. The resultant solution was stirred at -78 °C for 10 minutes. Alkyl bromide (12.2 mmol) was added over 5 minutes and the resulting mixture allowed to warm to ambient temperature overnight. The resulting mixture was quenched with 10% HCl and extracted with diethyl ether. The combined organic extracts were dried (Na₂SO₄) and concentrated *in vacuo* to afford a residue that was further subjected to flash chromatography (SiO₂: hexane / diethyl ether = 15/1) to afford the title compound **6** as clear oil

The isolated yield and the spectral data for **6a-c** are as follows:

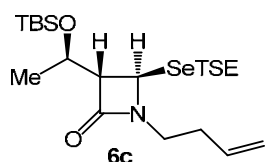


(3*S*,4*R*)-1-Allyl-3-[(*R*)-*tert*-butyldimethylsilyloxyethyl]-4-[2-(trimethylsilyl)ethylseleno]-2-azetidinone (6a**).** Method A; Yield: 64%; IR (neat): 2953, 2360, 1763, 1644, 1539, 1387, 1249, 837 cm⁻¹; ¹H NMR (CDCl₃): δ 0.00 (s, 9H), 0.04 (s, 3H), 0.06 (s, 3H), 0.86 (s, 9H), 0.90-1.00 (m, 2H), 1.22 (d, J = 6.3 Hz, 3H), 2.56-2.67 (m, 2H), 3.17 (t, J = 2.2 Hz, 1H), 3.48 (dd, J = 6.3, 14.8 Hz, 1H), 4.06 (dd, J = 5.2, 16.1 Hz, 1H), 4.22-4.27 (m, 1H), 4.88 (d, J = 2.3 Hz, ² J (⁷⁷Se-¹H) = 21.8 Hz, 1H), 5.17 (dd, J = 1.1, 10.4 Hz, 1H), 5.24 (dd, J = 1.1, 17.1 Hz, 1H), 5.71-5.80 (m, 1H); ¹³C NMR (CDCl₃): δ -4.82, -4.58, -1.91, 18.0, 18.2, 18.7, 22.3, 25.8, 42.7, 51.6, 64.8, 65.8, 118.5, 131.8, 166.3; ⁷⁷Se NMR (CDCl₃): δ 262.9; HRMS: m/z = 392.0980 calcd. for C₁₅H₃₀NO₂SeSi₂, found 392.0976.



(3*S*,4*R*)-3-[(*R*)-*tert*-Butyldimethylsilyloxyethyl]-4-[2-(trimethylsilyl)ethylseleno]-1-(2-methylallyl)-2-azetidinone (6b**).** Method A; Yield: 84%; IR (neat): 2954, 1764, 1658, 1472, 1386, 1249, 838 cm⁻¹; ¹H NMR (CDCl₃): δ 0.00 (s, 9H), 0.04 (s, 3H), 0.08 (s, 3H), 0.86 (s, 9H), 0.90-1.03 (m, 2H), 1.24 (d, J = 6.0

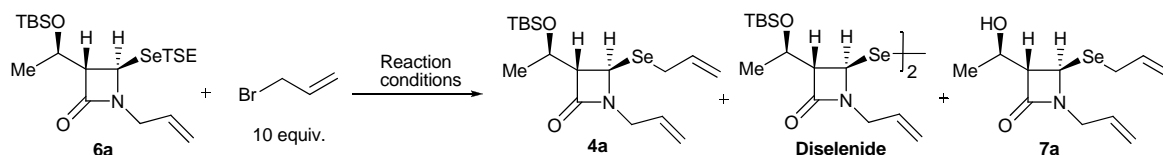
Hz, 3H), 1.73 (s, 3H), 2.53-2.68 (m, 2H), 3.16-3.22 (m, 1H), 3.43 (d, $J = 15.5$ Hz, 1H), 3.98 (d, $J = 15.5$ Hz, 1H), 4.22-4.30 (m, 1H), 4.85 (d, $J = 1.8$ Hz, 1H), 4.88 (s, 1H), 4.92 (s, 1H); ^{13}C NMR (CDCl_3): δ -4.82, -4.59, -2.00, 18.0, 18.5, 18.7, 20.5, 22.3, 25.8, 45.9, 52.3, 65.1, 65.7, 113.1, 139.4, 166.4; ^{77}Se NMR (CDCl_3): δ 262.9; HRMS: $m/z = 406.1137$ calcd. for $\text{C}_{16}\text{H}_{32}\text{NO}_2\text{SeSi}_2$, found 406.1127.



(3*S*,4*R*)-1-(3-Butenyl)-3-[(*R*)-*tert*-butyldimethylsilyloxyethyl]-4-[2-(trimethylsilyl)ethylseleno]-2-azetidinone (6c). Method A; Yield:14%; Method B; Yield: 45%; IR (neat): 2953, 1758, 1643, 1472, 1393, 1249, 838 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.02 (s, 9H), 0.06 (s, 3H), 0.08 (s, 3H), 0.88 (s, 9H),

0.92-1.01 (m, 2H), 1.24 (d, $J = 6.3$ Hz, 3H), 2.28-2.41 (m, 2H), 2.55-2.70 (m, 2H), 2.96-3.05 (m, 1H), 3.18 (s, 1H), 3.40-3.48 (m, 1H), 4.17-4.26 (m, 1H), 4.85 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 28.1$ Hz, 1H), 5.06 (dd, $J = 1.1, 10.3$ Hz, 1H), 5.12 (dd, $J = 1.1, 17.2$ Hz, 1H), 5.72-5.83 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.83, -4.50, -1.90, 17.5, 18.0, 18.6, 22.4, 25.8, 32.2, 39.7, 52.2, 65.2, 65.8, 117.0, 135.0, 166.4; ^{77}Se NMR (CDCl_3): δ 262.1; HRMS: $m/z = 406.1137$ calcd. for $\text{C}_{16}\text{H}_{32}\text{NO}_2\text{SeSi}_2$, found 406.1134.

Table 1: Optimization conditions for the synthesis of key intermediate **4a**.

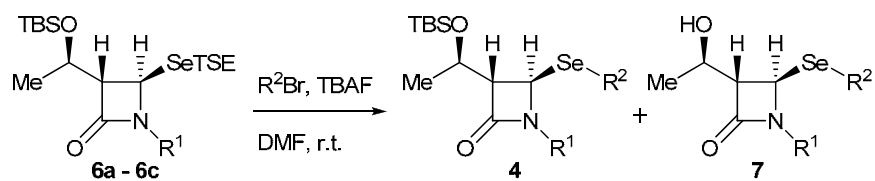


Entry	TBAF	Solvent	Temp.	Time	Yield (%) ^a		
					4a	Diselenide	7a
1.	1.1 equiv.	THF	-20 oC to r.t	3 days	12 ^b	5%	traces
2.	2.5 equiv.	DMF	r.t.	1 h	65%	18%	traces

^aAll reactions were carried out on 0.22 mmol scale on **6a**.

^bStarting material was isolated in 35% yield.

Table 2 Synthesis of key intermediates **4** and **7**



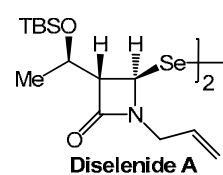
Entry	Starting	R ¹	R ²	Time	Yield (%) ^a	
					4	7
1	6a	CH ₂ CH=CH ₂	CH ₂ CH=CH ₂	15 min	71 (4a) ^b	trace (7a)
2	6b	CH ₂ (CH ₃)C=CH ₂	CH ₂ CH=CH ₂	15 min	66 (4b)	17 (7b)
3	6b	CH ₂ (CH ₃)C=CH ₂	CH ₂ CH=CH ₂	45 min	3 (4b)	87 (7b)
4	6a	CH ₂ CH=CH ₂	CH ₂ CH ₂ CH=CH ₂	18 h	10 (4c) ^b	- (7c)
5	6b	CH ₂ (CH ₃)C=CH ₂	CH ₂ CH ₂ CH=CH ₂	18 h	trace (4d) ^b	trace (7d)
6	6a	CH ₂ CH=CH ₂	CH ₂ (CH ₃)C=CH ₂	15 min	78 (4f)	14 (7f)
7	6a	CH ₂ CH=CH ₂	CH ₂ (CH ₃)C=CH ₂	45 min	27 (4f)	66 (7f)
8	6b	CH ₂ (CH ₃)C=CH ₂	CH ₂ (CH ₃)C=CH ₂	1 h	58 (4g)	35 (7g)
9	6c	CH ₂ CH ₂ CH=CH ₂	CH ₂ CH=CH ₂	1 h	76 (4h)	16 (7h)

^a Isolated yields. ^b Corresponding diselenide was obtained as a byproduct.

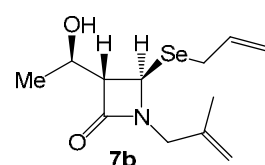
Typical procedure for the synthesis of **4** and **7**:

To a stirred solution of **6** (0.22 mmol) and alkyl bromide (2.23 mmol) in degassed dry DMF (2 mL) was added TBAF (1 M solution in THF, 0.56 mmol) at r.t. with argon bubbling to reaction mixture. The stirring was continued for above mentioned time and then reaction mixture extracted with chloroform and washed with water. The combined organic layers were dried (Na₂SO₄) and concentrated. The residue was purified by column chromatography (SiO₂: hexane / diethyl ether = 15/1) to afford compounds **4**, **7** or corresponding diselenide.

The isolated yield and the spectral data for **4**, **7** and diselenide are as follows:

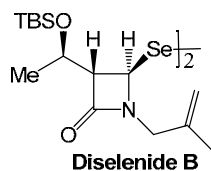


Diselenide a. Table 2, Entry 1; Yield: 9%; IR (neat): 2954, 1767, 1644, 1539, 1384, 1255, 837 cm⁻¹; ¹H NMR (CDCl₃): δ 0.06 (s, 3H), 0.08 (s, 3H), 0.87 (s, 9H), 1.22 (d, *J* = 6.4 Hz, 3H), 3.29 (s, 1H), 3.45 (dd, *J* = 7.3, 15.5 Hz, 1H), 4.10 (dd, *J* = 5.0, 15.5 Hz, 1H), 4.26-4.32 (m, 1H), 5.02 (d, *J* = 1.9 Hz, ²*J*(⁷⁷Se-¹H) = 40.8 Hz, 1H), 5.22 (d, *J* = 10.0 Hz, 1H), 5.30 (d, *J* = 16.9 Hz, 1H), 5.70-5.80 (m, 1H); ¹³C NMR (CDCl₃): δ -4.83, -4.64, 18.0, 22.4, 25.8, 43.0, 53.5, 64.4, 66.8, 119.4, 131.1, 165.7; ⁷⁷Se NMR (CDCl₃): δ 320.4; HRMS: *m/z* = 637.1100 calcd. for C₂₄H₄₃N₂O₄⁷⁸Se⁸⁰SeSi₂, found 637.1107.



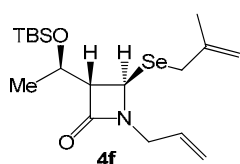
(3*S*,4*R*)-4-(Allylseleno)-3-[(*R*)-1-hydroxyethyl]-1-(2-methylallyl)-2-azetidinone (7b**).** Table 2, Entry 2; Yield: 17%; Entry 3; Yield: 87%; IR (neat): 3419, 2928, 1740, 1656, 1633, 1542, 1377, 1240, 815 cm⁻¹; ¹H NMR (CDCl₃): δ 1.31 (d, *J* = 7.5 Hz, 3H), 1.75 (s, 3H), 2.04 (brs, 1H), 3.21-3.34 (m, 3H), 3.40 (d, *J* = 15.5 Hz, 1H), 4.03 (d, *J* = 15.5 Hz, 1H), 4.23-4.32 (m, 1H), 4.84 (d, *J* = 1.7 Hz, ²*J*(⁷⁷Se-¹H) = 22.4 Hz, 1H), 4.93 (s, 1H), 4.96 (s, 1H), 5.04 (d, *J* = 9.7 Hz, 1H), 5.12 (d, *J* = 17.2 Hz,

1H), 5.84-5.95 (m, 1H); ^{13}C NMR (CDCl_3): δ 20.2, 21.1, 26.0, 46.1, 52.1, 64.5, 65.5, 113.7, 117.3, 134.6, 139.3, 166.5; ^{77}Se NMR (CDCl_3): δ 238.7; HRMS: $m/z = 289.0581$ calcd. for $\text{C}_{12}\text{H}_{19}\text{NO}_2\text{Se}$, found 289.0596.



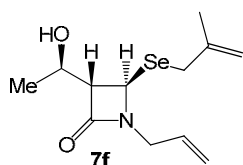
Diselenide B

Diselenide b. Entry 5; Yield: 12%; IR (neat): 2954, 1766, 1658, 1471, 1377, 1256, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.09 (s, 3H), 0.87 (s, 9H), 1.24 (d, $J = 6.4$ Hz, 3H), 1.76 (s, 3H), 3.32 (s, 1H), 3.39 (d, $J = 16.0$ Hz, 1H), 3.99 (d, $J = 16.0$ Hz, 1H), 4.27-4.33 (m, 1H), 4.92 (s, 1H), 4.95-5.00 (m, 2H); ^{13}C NMR (CDCl_3): δ -4.82, -4.47, 18.1, 20.7, 22.5, 25.8, 46.2, 54.3, 64.8, 66.9, 114.0, 138.8, 165.8; MS (EI): $m/z = 667$ [$\text{M}^+ - \text{tBu}$].



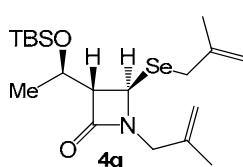
4f

(3S,4R)-1-Allyl-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-4-(2-methylallyl seleno)-2-azetidinone (4f). Entry 6; Yield: 78%; Entry 7; Yield: 27%; IR (CHCl_3): 2955, 2360, 1755, 1644, 1471, 1389, 1253, 1064, 756 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.08 (s, 3H), 0.87 (s, 9H), 1.21 (d, $J = 6.3$ Hz, 3H), 1.86 (s, 3H), 3.19-3.30 (m, 3H), 3.50 (dd, $J = 6.8, 16.1$ Hz, 1H), 4.05 (dd, $J = 5.1, 16.1$ Hz, 1H), 4.24-4.31 (m, 1H), 4.84 (s, 1H), 4.89 (s, 1H), 4.93 (d, $J = 2.3$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 22.9$ Hz, 1H), 5.20 (d, $J = 10.3$ Hz, 1H), 5.27 (d, $J = 17.2$ Hz, 1H), 5.73-5.82 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.80, -4.62, 17.9, 21.1, 22.2, 25.8, 30.9, 42.8, 52.0, 64.6, 65.8, 113.9, 118.5, 131.9, 141.7, 166.3; ^{77}Se NMR (CDCl_3): δ 221.0; HRMS: $m/z = 346.0742$ calcd. for $\text{C}_{14}\text{H}_{24}\text{NO}_2\text{SeSi}$, found 346.0727.



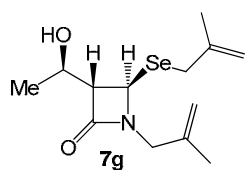
7f

(3S,4R)-1-Allyl-3-[(R)-1-hydroxyethyl]-4-(2-methylallyl seleno)-2-azetidinone (7f). Entry 6; Yield: 14%; Entry 7; Yield: 66%; IR (neat): 3419, 2969, 1740, 1644, 1589, 1427, 1375, 1244, 865 cm^{-1} ; ^1H NMR (CDCl_3): δ 1.26 (d, $J = 6.3$ Hz, 3H), 1.84 (s, 3H), 2.64 (brs, 1H), 3.19-3.35 (m, 3H), 3.47 (dd, $J = 6.3, 16.0$ Hz, 1H), 4.05 (d, $J = 4.6, 16.0$ Hz, 1H), 4.19-4.26 (m, 1H), 4.82 (s, 1H), 4.85 (d, $J = 2.3$ Hz, 1H), 4.88 (s, 1H), 5.19 (d, $J = 10.3$ Hz, 1H), 5.28 (d, $J = 17.2$ Hz, 1H), 5.70-5.80 (m, 1H); ^{13}C NMR (CDCl_3): δ 20.9, 21.1, 31.0, 42.6, 52.2, 64.2, 65.6, 114.0, 118.1, 131.4, 141.7, 166.5; ^{77}Se NMR (CDCl_3): δ 228.5. HRMS: $m/z = 289.0581$ calcd. for $\text{C}_{12}\text{H}_{19}\text{NO}_2\text{Se}$, found 289.0591.

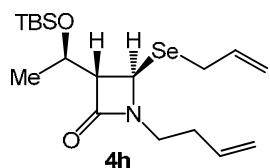


4g

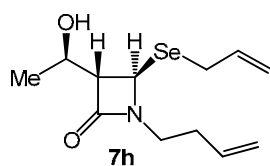
(3S,4R)-3-[(R)-1-tert-butyl dimethylsilyloxyethyl]-1-(2-methylallyl)-4-(2-methylallyl seleno)-2-azetidinone (4g). Entry 8; Yield: 58%; IR (neat): 2955, 1763, 1657, 1471, 1375, 1253, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.04 (s, 3H), 0.08 (s, 3H), 0.87 (s, 9H), 1.21 (d, $J = 6.3$ Hz, 3H), 1.75 (s, 3H), 1.85 (s, 3H), 3.17 (d, $J = 12.0$ Hz, 1H), 3.21-3.30 (m, 2H), 3.42 (d, $J = 16.0$ Hz, 1H), 3.96 (d, $J = 16.0$ Hz, 1H), 4.23-4.31 (m, 1H), 4.82 (s, 1H), 4.86 (s, 1H), 4.88 (d, $J = 2.3$ Hz, 1H), 4.90 (s, 1H), 4.95 (s, 1H); ^{13}C NMR (CDCl_3): δ -4.86, -4.49, 18.0, 20.6, 21.1, 22.2, 25.8, 31.1, 46.0, 52.6, 64.9, 65.7, 113.3, 113.9, 139.6, 141.6, 166.5; ^{77}Se NMR (CDCl_3): δ 219.1; HRMS: $m/z = 360.0898$ calcd. for $\text{C}_{15}\text{H}_{26}\text{NO}_2\text{SeSi}$, found 360.0893.



(3S,4R)-3-[(R)-1-Hydroxyethyl]-1-(2-methylallyl)-4-(2-methylallylseleno)-2-azetidinone (7g). Entry 8; Yield: 35%; IR (neat): 3419, 2969, 1746, 1657, 1538, 1375, 1247, 861 cm^{-1} ; ^1H NMR (CDCl_3): δ 1.27 (d, $J = 6.3$ Hz, 3H), 1.72 (s, 3H), 1.84 (s, 3H), 2.14 (brs, 1H), 3.20 (d, $J = 12.0$ Hz, 1H), 3.27 (d, $J = 12.0$ Hz, 1H), 3.30-3.33 (m, 1H), 3.36 (d, $J = 16.1$ Hz, 1H), 4.02 (d, $J = 16.1$ Hz, 1H), 4.20-4.29 (m, 1H), 4.78-4.84 (m, 2H), 4.87 (s, 1H), 4.91 (s, 1H), 4.94 (s, 1H); ^{13}C NMR (CDCl_3): δ 20.2, 21.0, 21.1, 31.1, 46.1, 52.3, 64.4, 65.5, 113.7, 114.0, 139.3, 141.7, 166.5; ^{77}Se NMR (CDCl_3): δ 222.7; HRMS: $m/z = 303.0738$ calcd. for $\text{C}_{13}\text{H}_{21}\text{NO}_2\text{Se}$, found 303.0732.

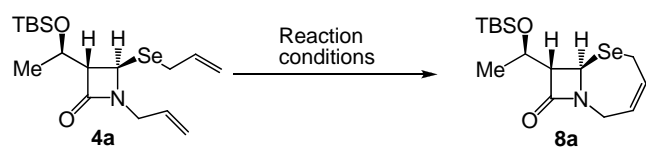


(3S,4R)-4-Allylseleno-1-(3-butenyl)-3-[(R)-1-tert-butyldimethylsilyloxyethyl]-2-azetidinone (4h). Entry 9; Yield: 76%; IR (neat): 2954, 1760, 1633, 1393, 1253, 1060, 836 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.08 (s, 3H), 0.88 (s, 9H), 1.24 (d, $J = 6.3$ Hz, 3H), 2.31-2.37 (m, 2H), 2.95-3.04 (m, 1H), 3.21-3.29 (m, 3H), 3.37-3.46 (m, 1H), 4.19-4.27 (m, 1H), 4.87 (d, $J = 2.3$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 30.8$ Hz, 1H), 5.02-5.18 (m, 4H), 5.75-5.84 (m, 1H), 5.88-5.98 (m, 1H); ^{13}C NMR (CDCl_3): δ -4.84, -4.53, 17.9, 22.3, 25.3, 25.7, 32.2, 39.8, 52.4, 65.0, 65.8, 117.0, 117.1, 134.8, 136.9, 166.4; ^{77}Se NMR (CDCl_3): δ 238.5; HRMS: $m/z = 346.0742$ calcd. for $\text{C}_{14}\text{H}_{24}\text{NO}_2\text{SeSi}$, found 346.0733.



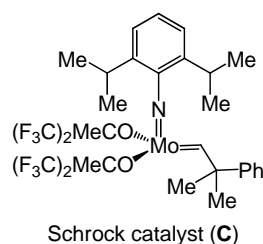
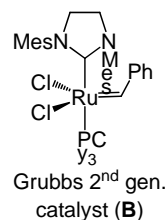
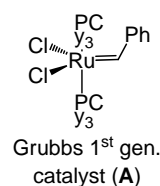
(3S,4R)-4-Allylseleno-1-(3-butenyl)-3-[(R)-1-hydroxyethyl]-2-azetidinone (7h). Entry 9; Yield: 16%; IR (neat): 3419, 2968, 1737, 1634, 1402, 1241, 1043, 862 cm^{-1} ; ^1H NMR (CDCl_3): δ 1.32 (d, $J = 6.3$ Hz, 3H), 2.27-2.41 (m, 2H), 2.96-3.04 (m, 1H), 3.25-3.34 (m, 3H), 3.45-3.53 (m, 1H), 4.17-4.24 (m, 1H), 4.83 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 20.6$ Hz, 1H), 5.03-5.19 (m, 4H), 5.72-5.84 (m, 1H), 5.89-5.99 (m, 1H); ^{13}C NMR (CDCl_3): δ 21.1, 25.5, 32.0, 39.7, 52.3, 64.9, 65.8, 117.3, 117.4, 134.8, 134.9, 166.2; ^{77}Se NMR (CDCl_3): δ 238.5; HRMS: $m/z = 289.0581$ calcd. for $\text{C}_{12}\text{H}_{19}\text{NO}_2\text{Se}$, found 289.0583.

Table 3 : Optimization conditions for ring-closing metathesis of **4a**



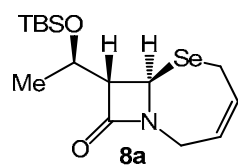
Entry	Catalyst	Solvent	Temp.	Time	Yield (%) ^a
					8a
1.	C (10 mol%)	DCM	r.t.	3 days	- ^b
2.	C (10 mol%)	DCM	reflux	2 days	- ^b
3.	C (10 mol%)	Toulene	reflux	1 day	- ^b
4.	C (10 mol%)	Toulene	80 °C	4 days	- ^b
5.	A (10 mol%)	DCM	reflux	2 days	trace ^c
6.	B (10 mol%)	DCM	reflux	3 days	38 ^d
7.	B (5 mol%)	Toluene	reflux	2 day	36 ^e
8.	B (10 mol%)	Toluene	reflux	2 h	78
9.	B (1 mol%)	Toluene	80 °C	4 days	trace ^c
10.	B (5 mol%)	Toluene	80 °C	4 days	26 ^f
11.	B (10 mol%)	Toluene	80 °C	4 days	45 ^g

^a Isolated yields. ^b Only starting material was recovered. ^c Starting material was recovered in quantitative. ^d 52% of starting material was recovered. ^e 56% of starting material was recovered. ^f 65% of starting material was recovered. ^g 47% of starting material was recovered.



Typical procedure for the RCM reaction: 10 mol% of catalyst **B** was added to the compound **4** or **7** (0.05 mmol) in toluene (2 mL). The mixture was allowed to stir for 2-4 days under reflux prior to destruction of the catalyst by exposure to air. The mixture was evaporated and chromatographed to afford compound **8**.

The isolated yield and the spectral data for **8a-j** are as follows:



(7R,8S)-8-[(R)-1-tert-Butyldimethylsilyloxyethyl]-1-aza-6-selenabicyclo[5.2

.0]non-3-en-9-one (8a). Yield: 78%; IR (neat): 2954, 1762, 1652, 1471, 1396,

1252, 836 cm⁻¹; ¹H NMR (CDCl₃): δ 0.06 (s, 3H), 0.08 (s, 3H), 0.86 (s, 9H),

1.22 (d, *J* = 6.3 Hz, 3H), 3.10 (dd, *J* = 8.6, 14.3 Hz, 1H), 3.26 (dd, *J* = 1.7, 3.4

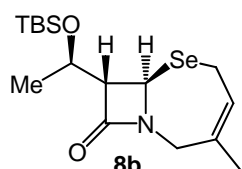
Hz, 1H), 3.56 (dd, *J* = 6.3, 14.3 Hz, 1H), 3.68 (dt, *J* = 1.7, 17.2 Hz, 1H), 4.21-4.26 (m, 1H), 4.37 (dd,

J = 5.8, 17.2 Hz, 1H), 5.10 (d, *J* = 1.7 Hz, ²*J*(⁷⁷Se-¹H) = 30.9 Hz, 1H), 5.44-5.49 (m, 1H), 6.09-6.19

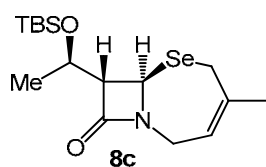
(m, 1H); ¹³C NMR (CDCl₃): δ -5.14, -4.22, 16.3, 17.9, 22.5, 25.7, 40.5, 49.5, 64.8, 68.5, 125.3, 132.0,

166.2; ⁷⁷Se NMR (CDCl₃): δ 359.4; HRMS: *m/z* = 304.0272 calcd. for C₁₁H₁₈NO₂SeSi, found

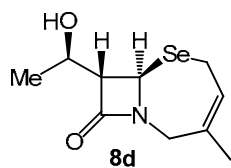
304.0258.



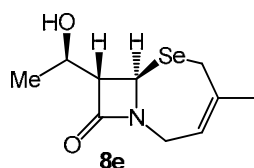
(7R,8S)-8-[(R)-1-tert-Butyldimethylsilyloxyethyl]-3-methyl-1-aza-6-selenabicyclo[5.2.0]non-3-en-9-one (8b). Yield: 92%; IR (KBr): 2955, 1760, 1661, 1471, 1400, 1256, 1135, 838 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.06 (s, 3H), 0.07 (s, 3H), 0.86 (s, 9H), 1.20 (d, $J = 6.3$ Hz, 3H), 1.73 (s, 3H), 3.02 (dd, $J = 9.2, 14.3$ Hz, 1H), 3.23-3.26 (m, 1H), 3.54 (dd, $J = 6.9, 14.3$ Hz, 1H), 3.60 (d, $J = 17.2$ Hz, 1H), 4.20-4.29 (m, 2H), 5.08 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 29.3$ Hz, 1H), 5.84 (t, $J = 7.4$ Hz, 1H); ^{13}C NMR (CDCl_3): δ -5.15, -4.25, 16.4, 17.9, 22.4, 23.1, 25.7, 44.9, 48.9, 64.7, 68.5, 126.3, 133.8, 166.3; ^{77}Se NMR (CDCl_3): δ 361.6; HRMS: $m/z = 318.0429$ calcd. for $\text{C}_{12}\text{H}_{20}\text{NO}_2\text{SeSi}$, found 318.0412.



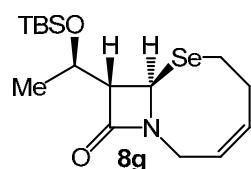
(7R,8S)-8-[(R)-1-tert-Butyldimethylsilyloxyethyl]-4-methyl-1-aza-6-selenabicyclo[5.2.0]non-3-en-9-one (8c). Yield: 75%; Mp. 48–49 °C; IR (KBr): 2958, 1754, 1733, 1655, 1542, 1400, 1256, 1136, 839 cm^{-1} ; ^1H NMR (CDCl_3): δ 0.05 (s, 3H), 0.06 (s, 3H), 0.86 (s, 9H), 1.20 (d, $J = 6.3$ Hz, 3H), 1.86 (s, 3H), 3.15-3.21 (m, 2H), 3.40 (d, $J = 13.2$ Hz, 1H), 3.68 (dd, $J = 5.8, 16.0$ Hz, 1H), 4.17-4.25 (m, 2H), 5.04 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 20.0$ Hz, 1H), 5.29 (t, $J = 5.8$ Hz, 1H); ^{13}C NMR (CDCl_3): δ -5.16, -4.24, 17.8, 22.6, 22.9, 24.2, 25.6, 39.5, 49.1, 64.7, 68.2, 117.4, 142.9, 165.5; ^{77}Se NMR (CDCl_3): δ 335.9; HRMS: $m/z = 318.0429$ calcd. for $\text{C}_{12}\text{H}_{20}\text{NO}_2\text{SeSi}$, found 318.0389.



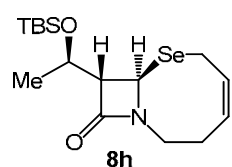
(7R,8S)-8-[(R)-1-Hydroxyethyl]-3-methyl-1-aza-6-selenabicyclo[5.2.0]non-3-en-9-one (8d). Yield: 82%; Mp. 97–98 °C; IR (KBr): 3365, 2969, 1747, 1715, 1663, 1445, 1376, 1121, 835 cm^{-1} ; ^1H NMR (CDCl_3): δ 1.31 (d, $J = 6.3$ Hz, 3H), 1.74 (s, 3H), 1.94 (brs, 1H), 3.04 (dd, $J = 8.6, 14.4$ Hz, 1H), 3.33 (dd, $J = 1.7, 5.1$ Hz, 1H), 3.54 (dd, $J = 5.1, 13.7$ Hz, 1H), 3.67 (d, $J = 17.2$ Hz, 1H), 4.20-4.31 (m, 2H), 5.10 (d, $J = 1.8$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 30.9$ Hz, 1H), 5.84 (t, $J = 7.9$ Hz, 1H); ^{13}C NMR (CDCl_3): δ 16.2, 21.4, 23.0, 45.1, 49.2, 64.6, 68.0, 126.1, 134.0, 166.2; ^{77}Se NMR (CDCl_3): δ 367.4; HRMS: $m/z = 261.0268$ calcd. for $\text{C}_{10}\text{H}_{15}\text{NO}_2\text{Se}$, found 261.0225.



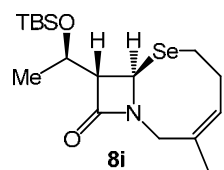
(7R,8S)-8-[(R)-1-Hydroxyethyl]-4-methyl-1-aza-6-selenabicyclo[5.2.0]non-3-en-9-one (8e). Yield: 74%; Mp. 110–111 °C; IR (KBr): 3365, 2927, 1737, 1676, 1655, 1399, 1289, 1152, 840 cm^{-1} ; ^1H NMR (CDCl_3): δ 1.30 (d, $J = 6.3$ Hz, 3H), 1.70 (brs, 1H), 1.86 (s, 3H), 3.19-3.26 (m, 2H), 3.40 (d, $J = 13.2$ Hz, 1H), 3.75 (dd, $J = 5.2, 16.0$ Hz, 1H), 4.19-4.26 (m, 2H), 5.06 (d, $J = 1.7$ Hz, $^2J(^{77}\text{Se}-^1\text{H}) = 18.3$ Hz, 1H), 5.31 (t, $J = 5.2$ Hz, 1H); ^{13}C NMR (CDCl_3): δ 21.5, 22.8, 24.2, 39.7, 49.1, 64.6, 67.7, 117.5, 142.9, 165.4; ^{77}Se NMR (CDCl_3): δ 341.0; HRMS: $m/z = 261.0268$ calcd. for $\text{C}_{10}\text{H}_{15}\text{NO}_2\text{Se}$, found 261.0223.



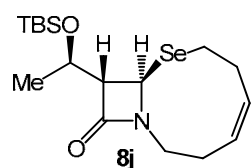
(8R,9S)-9-[(R)-1-tert-Butyldimethylsilyloxyethyl]-1-aza-7-selenabicyclo[6.2.0]dec-3-en-10-one (8g). Yield: 68%; IR (CHCl₃): 2953, 1758, 1692, 1566, 1486, 1255, 836 cm⁻¹; ¹H NMR (CDCl₃): δ 0.06 (s, 6H), 0.86 (s, 9H), 1.21 (d, *J* = 6.4 Hz, 3H), 2.66-2.78 (m, 3H), 2.82-2.97 (m, 2H), 3.67 (dd, *J* = 10.0, 13.2 Hz, 1H), 3.94 (dd, *J* = 6.9, 13.2 Hz, 1H), 4.21-4.28 (m, 1H), 5.00 (d, *J* = 2.3 Hz, ²*J*(⁷⁷Se-¹H) = 23.0 Hz, 1H), 5.53-5.61 (m, 1H), 5.90-5.99 (m, 1H); ¹³C NMR (CDCl₃): δ -5.19, -4.30, 17.9, 22.1, 23.6, 25.7, 30.7, 35.7, 50.3, 62.6, 64.5, 122.6, 135.0, 164.8; HRMS: *m/z* = 318.0429 calcd. for C₁₂H₂₀NO₂SeSi, found 318.0405.



(8R,9S)-9-[(R)-1-tert-Butyldimethylsilyloxyethyl]-1-aza-7-selenabicyclo[6.2.0]dec-4-en-10-one (8h). Yield: 74%; IR (CHCl₃): 2952, 1760, 1690, 1598, 1461, 1375, 1256, 1057, 836 cm⁻¹; ¹H NMR (CDCl₃): δ 0.05 (s, 3H), 0.07 (s, 3H), 0.87 (s, 9H), 1.19 (d, *J* = 6.3 Hz, 3H), 2.26-2.34 (m, 1H), 2.45-2.54 (m, 1H), 3.01 (t, *J* = 12.0 Hz, 1H), 3.13-3.18 (m, 1H), 3.25 (dd, *J* = 8.1, 12.0 Hz, 1H), 3.64 (dd, *J* = 9.7, 12.0 Hz, 1H), 3.82-3.88 (m, 1H), 4.21-4.27 (m, 1H), 5.10 (d, *J* = 2.3 Hz, 1H), 5.66-5.74 (m, 1H), 5.92-5.99 (m, 1H); ¹³C NMR (CDCl₃): δ -4.94, -4.36, 17.8, 18.7, 22.4, 25.2, 25.7, 42.9, 49.4, 64.7, 64.8, 128.6, 130.2, 168.2; HRMS: *m/z* = 318.0429 calcd. for C₁₂H₂₀NO₂SeSi, found 318.0403.



(8R,9S)-9-[(R)-1-tert-Butyldimethylsilyloxyethyl]-3-methyl-1-aza-7-selenabicyclo[6.2.0]dec-3-en-10-one (8i). Yield: 91%; IR (CHCl₃): 2954, 1758, 1670, 1461, 1377, 1255, 1064, 836 cm⁻¹; ¹H NMR (CDCl₃): δ 0.07 (s, 3H), 0.08 (s, 3H), 0.88 (s, 9H), 1.21 (d, *J* = 6.3 Hz, 3H), 1.77 (s, 3H), 2.58-2.86 (m, 4H), 2.94-2.97 (m, 1H), 3.75-3.82 (m, 2H), 4.23-4.29 (m, 1H), 4.93 (d, *J* = 2.3 Hz, 1H), 5.60 (t, *J* = 9.2 Hz, 1H); ¹³C NMR (CDCl₃): δ -4.77, -4.67, 18.0, 22.1, 22.8, 24.6, 25.8, 31.6, 40.6, 50.4, 62.9, 64.7, 128.9, 130.8, 165.2; ⁷⁷Se NMR (CDCl₃): δ 299.4; HRMS: *m/z* = 332.0585 calcd. for C₁₃H₂₂NO₂SeSi, found 332.0543.



(9R,10S)-10-[(R)-1-tert-Butyldimethylsilyloxyethyl]-1-aza-8-selenabicyclo[7.2.0]undec-4-en-11-one (8j). Yield: 74% yield; Mp: 77–78 °C; IR (CHCl₃): 2952, 1749, 1652, 1564, 1463, 1393, 1249, 1059, 833 cm⁻¹; ¹H NMR (CDCl₃): δ 0.05 (s, 3H), 0.06 (s, 3H), 0.86 (s, 9H), 1.22 (d, *J* = 6.3 Hz, 3H), 2.46-2.56 (m, 3H), 2.60-2.73 (m, 2H), 2.76-2.82 (m, 1H), 3.03 (dt, *J* = 5.7, 14.3 Hz, 1H), 3.19 (t, *J* = 2.3 Hz, 1H), 3.62-3.69 (m, 1H), 4.22-4.29 (m, 1H), 4.99 (d, *J* = 1.7 Hz, 1H), 5.58-5.69 (m, 2H); ¹³C NMR (CDCl₃): δ -5.13, -4.26, 17.9, 21.9, 22.2, 25.0, 25.7, 29.1, 40.6, 51.1, 64.6, 64.7, 129.4, 130.4, 167.3; HRMS: *m/z* = 332.0585 calcd. for C₁₃H₂₂NO₂SeSi, found 332.0551.