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SYNTHESES OF 4-SELENAZOLONES. HETERO DIELS-ALDER REACTION OF THE SELENAZADIENES WITH DMAD

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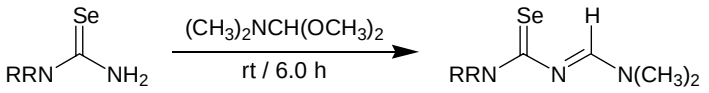
Abstract – Hetero Diels-Alder reaction of selenazadiene with dimethyl acetylenedicarboxylate yielded 4-selenazolone instead of the expected Diels-Alder adduct.

INTRODUCTION

Many syntheses of selenium-containing heterocyclic compounds have been reported because of their interesting reactivities[1] and pharmaceutical alications.[2] Recently, the synthesis of selenium heterocycles has been extensively studied using the carbon-selenium double bond as 2π dienophile intermediates for [4+2] cycloadditions. For example, α,β-unsaturated selenoaldehydes and selenoketones selectively undergo 'head-to-head' [4+2] dimerization to give six-membered cyclic diselenides.[3] Furthermore, the reaction of *N*-selenoacylamidine with dimethyl acetylenedicarboxylate (DMAD) affords a 4*H*-selenazine six-membered ring compound that converts to a 4*H*-selenopyran by cycloreversion and recycloaddtion with excess DMAD.[4] Here, we secure an interesting pathway to 1,3-selenazol-4-one (**4**)**,** from a cycloaddition and intramolecular substitution between selenoazadiene (**2**) and DMAD.[5]

RESULTS AND DISCUSSION



	R	R	Yield (%)
1a / **2a**	CH_3	CH_3	76
1b / **2b**	C_2H_5	C_2H_5	75
1c / **2c**	$-(CH_2)_4-$		81
1d / **2d**	$-(CH_2)_5-$		98
1e / **2e**	$-(CH_2)_2O(CH_2)_2-$		97

Scheme 1

Selenoazadienes (**2**) were prepared by a modified route based on reported experimental conditions described for synthesis of *N*-thioacylamidine from thiobenzamide.[6]

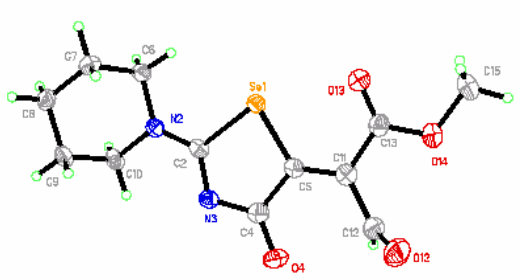
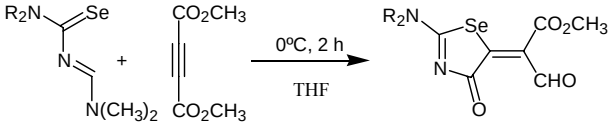
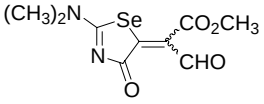
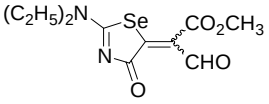
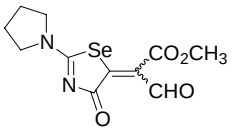
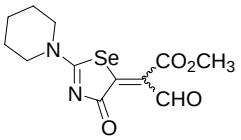
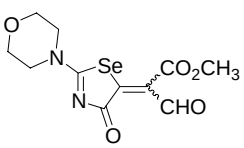


Figure 1. X-Ray crystal structure of **4d-*Z***.

Table 1. Synthesis of 1,3-selenazol-4-one.



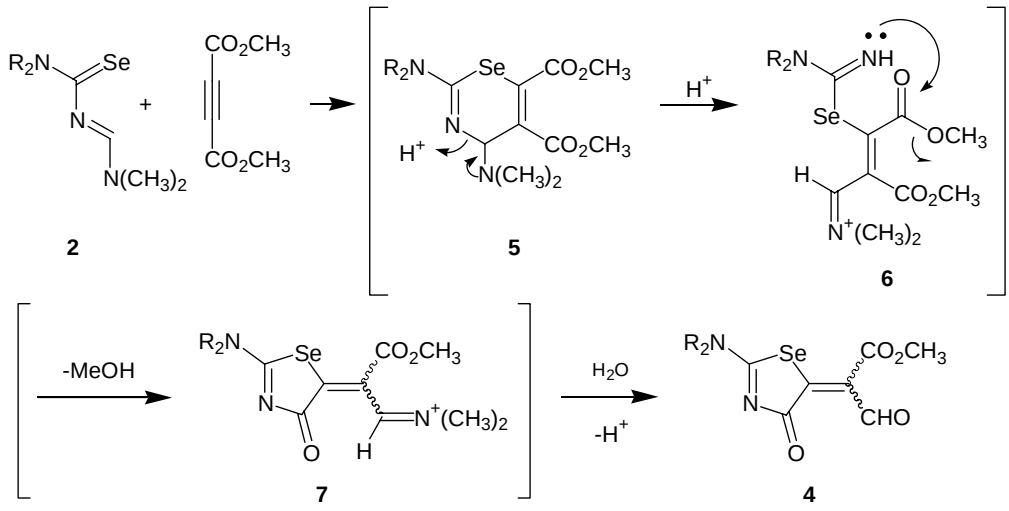
2 **4**

Product		Yield (%)[a] (*E*/*Z*)[b]
	**4a**	70 (70/30)
	**4b**	80 (56/44)
	**4c**	81 (55/45)
	**4d**	84 (58/42)
	**4e**	86 (73/27)

a: Isolated yield. b: Calculated by ^{1}H NMR.

Condensation of *N*,*N*-unsubstituted selenourea (**1**) with *N*,*N*-dimethylformamide dimethylacetal (1.5 equiv.), at room temperature for 6 h led to high yields of five different selenoazadienes (**2**) (Scheme 1).

There is only one example of the synthesis of a *N*,*N*-dimethyl-*N*'-(dimethylaminomethylidene)selenourea (**2a**) in the literature,[7] products (**2b-2e**) are novel compounds. We next attempted a hetero Diels-Alder reaction using selenoazadienes (**2**) as diene with DMAD as a dienophile (Scheme 2).



Scheme 2.

Interestingly, the reaction did not give the expected Diels-Alder adduct but instead a separable mixture of *E*/*Z* isomers of **4** was obtained. After their separation, the structure of **4** was confirmed by studies of IR, MS, ^{1}H, ^{13}C and ^{77}Se NMR spectra and elemental analysis. Single crystals were prepared and subjected to X-Ray diffraction analysis to determine absolute structure. The X-Ray diffraction study of the product confirmed that the crystals were not the Diels-Alder adduct but 4-selenazolone (**4**) (Figure 1).[8] The bond angle of the selenium atom (C5-Se1-C2) was 83.6(2)°, consistent with the previous reported value.[9] The sum of the three angles around each of the C2, C4 and C5 atoms was exactly 360.0°, showing that the arrangement of Se1, C2, N3, C4, C5, N2, O4 and C11 atoms was planar. The three C-N bond lengths of C2-N2 (1.305(6) Å) N3-C4 (1.353(7) Å) and C2-N3 (1.318(6) Å) in **4d-*Z*** are shorter than the typical value of 1.47 Å.[10] These results can be attributed to the delocalization of two π electrons and lone pair electrons on N2. The N2 nitrogen has sp^2 rather than sp^3 character. In ^{1}H NMR spectrum of **4d**, a formyl proton signal of *E*-form of **4d** was observed in δ 9.81. In contrast, the signal of the *Z*- form was observed in down field (δ 10.40). This suggests that there would be steric interaction between formyl group and two oxygen atoms (O4 and O14 shown in Figure 1). Five kinds of 4-selenazolones (**4a-4e**) were prepared by reactions of the corresponding selenoazadienes (**2**) with DMAD in 70-86% yields (Table1). Both reactions of primary selenoamides with α,β-unsaturated ketone[11] and of *N*-selenoacylamidine with methyl acrylate[4] gave the corresponding 5,6-dihydro-4*H*-1,3-selenazines. In order to trap an intermediate in the present reaction, various trials were carried out. When the reaction mixture was washed by anhydrous *n*-hexane without a purification using silica gel column chromatography, we could obtain a Diels-Alder adduct (**5**).[12] It was confirmed the compound (**5**) was converted into **4** while the process of purification

using silica gel. Protonation of cycloaddition adduct (**5**) afforded selenoamidine (**6**). Compound (**6**) was converted into an intermediate (**7**) by a nucleophilic recyclization. Thus, the formation of **4** could be explained by the mechanism described in Scheme 2. In conclusion, a hetero Diels-Alder reaction of selenoazadienes (**2**) with DMAD gives 1,3-selenazol-4-one (**4**) in good yields. Compound (**4**) was formed by conversion of Diels-Alder adduct (**5**).

ACKNOWLEDGMENT

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EXPERIMENTAL

General Procedure for synthesis of *N*,*N*-Dimethyl-*N*'-(dimethylaminomethylidene)selenourea (2a)

N,*N*-Dimethylformamide acetals (1.56 mL, 12.0 mmol) was added to the tetrahydrofuran solution (25 mL) of *N*,*N*-dimethylselenourea (**1**)(1.52 g, 10.0 mmol). The reaction mixture was stirred at rt for 6 h. The mixture was evaporated to dryness. The residue was purified by flash chromatography on silica gel with dichloromethane:ether (30:1) to give **2a** 1.58 g (76%) as a orange solid. mp: 109.0 – 111.0°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.09 (3H, s, CH_3), 3.18 (3H, s, CH_3), 3.31 (3H, s, CH_3), 3.61 (3H, s, CH_3), 8.76 (1H, s, N=CH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 35.7, 39.1, 41.1, 45.4, 163.9, 190.3; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 205.3; IR (KBr): 1619 cm^{-1}; MS (CI): m/z = 208 [M^+ + 1]; Anal. Calcd for $C_6H_{13}N_3Se$: C, 34.96; H, 6.36; N, 20.38. Found: C, 35.03; H, 6.41; N, 20.57.

N,*N*-Diethyl-*N*'-(dimethylaminomethylidene)selenourea (2b)

mp: 36.2 – 38.6°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.19 (3H, t, *J* = 6.8 Hz, CH_3), 1.31 (3H, t, *J* = 6.8 Hz, CH_3), 3.08 (3H, s, CH_3), 3.17 (3H, s, CH_3), 3.76 (2H, q, *J* = 6.8 Hz, CH_2), 4.11 (2H, q, *J* = 6.8 Hz, CH_2), 8.81 (1H, s, N=CH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 12.4, 12.8, 35.7, 41.1, 44.2, 49.8, 164.2, 188.8; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 186.1; IR (KBr): 1623 cm^{-1}; MS (CI): m/z = 236 [M^+ + 1]; Anal. Calcd for $C_8H_{17}N_3Se$: C, 41.03; H, 7.32; N, 17.94. Found: C, 41.14; H, 7.36; N, 17.88.

N^1,*N*^{1}-Dimethyl-*N*^{2}-(pyrrolidinoselenocarbonyl)formamidine (2c)

mp: 90.6 – 92.2°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.97 (4H, m, CH_2), 3.07 (3H, s, CH_3), 3.17 (3H, s, CH_3), 3.70 (2H, t, *J* = 7.3 Hz, CH_2), 3.94 (2H, t, *J* = 6.8 Hz, CH_3), 8.79 (1H, s, N=CH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 24.3, 25.2, 35.7, 41.1, 49.5, 54.4, 163.1, 185.9; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 219.3; IR (KBr): 1615 cm^{-1}; MS (CI): m/z = 234 [M^+ + 1]; Anal. Calcd for $C_8H_{15}N_3Se$: C, 41.38; H, 6.51; N, 18.10. Found: C, 41.22; H, 6.68; N, 18.21.

N^1,*N*^{1}-Dimethyl-*N*^{2}-(piperidinoselenocarbonyl)formamidine (2d)

mp: 83.4 – 85.0°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.57 (2H, m, CH_2), 1.71 (4H, m, CH_2), 3.07 (3H, s, CH_3), 3.17 (3H, s, CH_3), 4.03 (2H, m, CH_2), 4.37 (2H, m, CH_2), 8.84 (1H, s, N=CH); ^{13}C NMR (100

MHz, $CDCl_3$): δ 24.6, 25.7, 26.0, 35.7, 41.2, 47.8, 54.4, 165.0, 188.7; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 185.4; IR (KBr): 1619 cm^{-1}; MS (CI): m/z = 248 [M^+ + 1]; Anal. Calcd for $C_9H_{17}N_3Se$: C, 43.90; H, 6.96; N, 17.07. Found: C, 44.18; H, 6.99; N, 17.01.

***N*^{1},*N*^{1}-Dimethyl-*N*^{2}-(morpholinoselenocarbonyl)formamidine (2e)**

mp: 68.0 – 69.0°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.09 (3H, s, CH_3), 3.20 (3H, s, CH_3), 3.66 (2H, t, *J* = 4.4 Hz, CH_2), 3.78 (2H, t, *J* = 4.4 Hz, CH_2), 4.10 (2H, t, *J* = 4.4 Hz, CH_2), 4.47 (2H, t, *J* = 4.9 Hz, CH_2), 8.86 (1H, s, N=CH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 35.9, 41.3, 47.3, 53.0, 66.2, 66.6, 165.2, 190.7; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 199.1; IR (KBr): 1624 cm^{-1}; MS (CI): m/z = 250 [M^+ + 1]; Anal. Calcd for $C_8H_{15}N_3OSe$: C, 38.72; H, 6.09; N, 16.93. Found: C, 38.62; H, 6.16; N, 17.06.

***N*^{1},*N*^{1}-Dimethyl-*N*^{2}-(piperidinoselenocarbonyl)acetoamidine (3)**

mp: 73.8 – 75.0°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.54 (2H, s, CH_2), 1.69 (4H, s, CH_2), 2.27 (3H, s, CH_3), 3.04 (6H, s, CH_3), 3.65 (2H, m, CH_2), 4.26 (2H, s, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 17.6, 23.8, 25.3, 25.6, 37.4, 38.0, 47.6, 53.2, 157.5, 184.3; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 336.1; IR (KBr): 1603 cm^{-1}; MS (CI): m/z = 262 [M^+ + 1]; Anal. Calcd for $C_{10}H_{19}N_3Se$: C, 46.15; H, 7.36, N, 16.15. Found: C, 46.33; H, 7.52, N, 16.29.

***Z*- and *E*-Methyl 2-(2-dimethylamino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4a)**

DMAD (0.21 g, 1.0 mmol) was added to the tetrahydrofuran solution (10 mL) of *N*,*N*-dimethyl-*N*'-(dimethylaminomethylidene)selenourea **2a** (0.21 g, 1.0 mmol). The reaction mixture was stirred at 0°C for 2 h. The mixture was extracted with diethyl ether and washed with saturated NaCl solution. The organic layer was dried over sodium sulfate and evaporated to dryness. The residue was purified by preparative thin layer chromatography with dichloromethane: diethyl ether (1:1) to give 0.22 g of **4a-*E*** and **4a-*Z*** mixture (77%, *E*:*Z*=70:30) as yellow solids. They were separated into **4a-*E*** (yellow solids) and **4a-*Z*** (pale yellow solids) by flash chromatography on silica gel with dichloromethane:diethyl ether (10:1). **4a-*E*** (yellow solids) mp: 207.0 – 209.2°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.28 (3H, s, CH_3), 3.45 (3H, s, CH_3), 3.90 (3H, s, CH_3), 10.40 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 40.8, 41.0, 53.8, 132.1, 155.0, 165.7, 176.2, 180.5, 189.7; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 521.1; IR (KBr): 1697, 1563 cm^{-1}; MS (CI): m/z = 291 [M^+ + 1]; Anal. Calcd for $C_9H_{10}N_2O_4Se$: C, 37.38; H, 3.49, N, 9.69. Found: C, 37.52; H, 3.57, N, 9.71. **4a-*Z*** (pale yellow solids) mp: 140.2 – 141.6°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.30 (3H, s, CH_3), 3.45 (3H, s, CH_3), 3.98 (3H, s, CH_3), 9.80 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 40.9, 41.0, 53.4, 129.8, 151.0, 166.7, 176.5, 179.8, 186.7; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 554.8; IR (KBr): 1725, 1592 cm^{-1}; MS (CI): m/z = 291 [M^+ + 1]; Anal. Calcd for $C_9H_{10}N_2O_4Se$: C, 37.38; H, 3.49, N, 9.69. Found: C, 37.57; H, 3.53, N, 9.83.

***Z*-Methyl 2-(2-diethylamino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4b-*Z*)**

mp: 123.2 – 125.4°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.32 (3H, t, *J* = 6.8 Hz, CH_3), 1.41 (3H, t, *J* = 6.8 Hz, CH_3), 3.55 (2H, q, *J* = 6.8 Hz, CH_2), 3.86 (2H, q, *J* = 6.8 Hz, CH_2), 3.90 (3H, s, CH_3), 10.39 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 12.8, 13.9, 46.3, 47.3, 53.5, 131.6, 154.6, 165.4, 174.3, 180.5, 189.6; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 522.7; IR (KBr): 1706, 1563 cm^{-1}; MS (CI): m/z = 319 [M^+ + 1]; Anal. Calcd for $C_{11}H_{14}N_2O_4Se$: C, 41.65; H, 4.45, N, 8.83. Found: C, 41.68; H, 4.64, N, 8.80.

***E*-Methyl 2-(2-dimethylamino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4b-*E*)**

mp: 92.0 – 95.8°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.31 (3H, t, *J* = 6.8 Hz, CH_3), 1.39 (3H, t, *J* = 6.8 Hz, CH_3), 3.54 (2H, q, *J* = 6.8 Hz, CH_2), 3.86 (2H, q, *J* = 6.8 Hz, CH_2), 3.99 (3H, s, CH_3), 9.81 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 12.9, 14.2, 46.6, 47.4, 53.3, 129.7, 150.7, 166.7, 174.8, 180.0, 186.8; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 556.0; IR (KBr): 1730, 1571 cm^{-1}; MS (CI): m/z = 319 [M^+ + 1]; Anal. Calcd for $C_{11}H_{14}N_2O_4Se$: C, 41.65; H, 4.45, N, 8.83. Found: C, 41.74; H, 4.57, N, 8.91.

***Z*-Methyl 2-(2-pyrrolidino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4c-*Z*)**

mp: 176.2 – 177.6°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.14 (4H, m, CH_2), 3.66 (2H, t, *J* = 6.8 Hz, CH_2), 3.89 (2H, t, *J* = 6.8 Hz, CH_2), 3.89 (3H, s, CH_3), 10.39 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 24.8, 25.0, 50.0, 51.3, 53.6, 131.9, 154.6, 165.5, 172.1, 180.1, 189.7; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 522.6; IR (KBr): 1697, 1566 cm^{-1}; MS (CI): m/z = 317 [M^+ + 1]; Anal. Calcd for $C_{11}H_{12}N_2O_4Se$: C, 41.92; H, 3.84, N, 8.89. Found: C, 41.77; H, 3.82, N, 8.74.

***E*-Methyl 2-(2-pyrrolidino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4c-*E*)**

mp: 144.6 – 151.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.13 (4H, m, CH_2), 3.68 (2H, t, *J* = 6.8 Hz, CH_2), 3.89 (2H, t, *J* = 6.8 Hz, CH_2), 3.97 (3H, s, CH_3), 9.79 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 24.7, 24.9, 50.0, 51.4, 53.2, 129.7, 150.6, 166.7, 172.3, 179.3, 186.5; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 555.8; IR (KBr): 1726, 1588 cm^{-1}; MS (CI): m/z = 317 [M^+ + 1]; Anal. Calcd for $C_{11}H_{12}N_2O_4Se$: C, 41.92; H, 3.84, N, 8.89. Found: C, 41.86; H, 3.90, N, 8.96.

***Z*-Methyl 2-(2-piperidino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4d-*Z*)**

mp: 171.0 – 174.6°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.66 – 1.90 (6H, m, CH_2), 3.53 (2H, m, CH_2), 3.89 (3H, s, CH_3), 4.05 (2H, m, CH_2), 10.41 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.8, 25.5, 26.5, 50.4, 52.2, 53.6, 131.7, 154.7, 165.7, 173.7, 180.9, 189.6; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 520.3; IR (KBr): 1697, 1560 cm^{-1}; MS (CI): m/z = 331 [M^+ + 1]; Anal. Calcd for $C_{12}H_{14}N_2O_4Se$: C, 43.78; H, 4.29, N, 8.51. Found: C, 43.76; H, 4.28, N, 8.63; X-Ray Crystallographic Data: Single crystals were grown from dichloromethane:ether (1:5). Crystal system Orthorhombic; Space group *Pbca*; T = 190(2) K; a = 9.588(3) Å, b = 7.446(3) Å, c = 37.229(16) Å, α = 90°, β = 90°, γ = 90°, Z = 4; D_c = 1.645 g cm^{-3}; Crystal size 0.72 x 0.08 x 0.08 mm; θ range for data collection 3.1 to 26.8 °, Limiting indices $-11 \le h \le 12$, $-8 \le k \le 9$, $-46 \le l \le 45$; Reflections collected: 8823, Independent reflections: 2559 [R_{int} = 0.0672]; Refinement method:

Full-matrix least-squares on F^2, Goodness of fit on F^2: 1.130, Final R indices [$I>2\sigma(I)$] $R1$ = 0.0484, $wR2$ = 0.1001 R indices (all data) $R1$ = 0.0796, $wR2$ = 0.1100, Largest diff. peak and hole 0.441 and -0.555 eÅ^{-3}; Selected bond lengths (Å) and angles (°), Se(1)-C(5): 1.863(5), Se(1)-C(2): 1.945(5), C(2)-N(2): 1.305(6), C(2)-N(3): 1.318(6), N(2)-C(6): 1.458(6), N(3)-C(4): 1.353(7), C(4)-O(4): 1.238(6), C(4)-C(5): 1.510(7), C(5)-C(11): 1.338(7), C(5)-Se(1)-C(2): 83.8(2), N(2)-C(2)-N(3): 123.4(4), N(2)-C(2)-Se(1): 120.1(4), N(3)-C(2)-Se(1): 116.6(4), C(2)-N(2)-C(6): 124.4(4), C(2)-N(3)-C(4): 113.6(4), O(4)-C(4)-N(3): 124.7(5), O(4)-C(4)-C(5): 119.5(5), N(3)-C(4)-C(5): 115.8(5), C(11)-C(5)-C(4): 123.2(5), C(11)-C(5)-Se(1): 126.5(4), C(4)-C(5)-Se(1): 110.3(3), C(5)-C(11)-C(13): 117.5(5), C(5)-C(11)-C(12): 123.0(5), C(13)-C(11)-C(12): 119.5(5) for all data.[8]

***E*-Methyl 2-(2-piperidino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4d-*E*)**

^{1}H NMR (400 MHz, $CDCl_3$): δ 1.66 – 1.90 (6H, m, CH_2), 3.56 (2H, m, CH_2), 3.97 (3H, s, CH_3), 4.06 (2H, m, CH_2), 9.81 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.7, 25.4, 26.4, 50.5, 52.1, 53.1, 129.4, 150.6, 166.6, 174.0, 180.1, 186.6; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 553.8; MS (CI): m/z = 331 [M^+ + 1]; Anal. Calcd for $C_{12}H_{14}N_2O_4Se$: C, 43.78; H, 4.29, N, 8.51. Found: C, 43.82; H, 4.33, N, 8.52.

***Z*-Methyl 2-(2-morpholino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4e-*Z*)**

mp: 245.2°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.58 (2H, t, J = 4.8 Hz, CH_2), 3.82 (2H, t, J = 4.8 Hz, CH_2), 3.87 (2H, t, J = 4.8 Hz, CH_2), 3.90 (3H, s, CH_3), 4.13 (2H, t, J = 4.8 Hz, CH_2), 10.40 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 49.4, 50.5, 53.8, (66.3), (66.4), (130.0), (149.6), (166.5), 175.2, 180.7, 189.5; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 519.6; IR (KBr): 1697, 1551 cm^{-1}; MS (CI): m/z = 333 [M^+ + 1]; Anal. Calcd for $C_{11}H_{12}N_2O_5Se$: C, 39.89; H, 3.65, N, 8.46. Found: C, 39.97; H, 3.78, N, 8.50.

***E*-Methyl 2-(2-morpholino-4-oxo-1,3-selenazoliden)-3-oxopropionate (4e-*E*)**

mp: 230.0°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.61 (2H, t, J = 4.8 Hz, CH_2), 3.81 (2H, t, J = 4.8 Hz, CH_2), 3.86 (2H, t, J = 4.8 Hz, CH_2), 3.99 (3H, s, CH_3), 4.14 (2H, t, J = 4.8 Hz, CH_2), 9.82 (1H, s, CHO); ^{13}C NMR (100 MHz, $CDCl_3$): δ 49.7, 50.6, 53.4, 66.3, 66.4, 130.0, 149.6, 166.5, 175.6, 180.0, 186.8; ^{77}Se NMR (76 MHz, $CDCl_3$): δ 553.7; IR (KBr): 1730, 1568 cm^{-1}; MS (CI): m/z = 333 [M^+ + 1]; Anal. Calcd for $C_{11}H_{12}N_2O_5Se$: C, 39.89; H, 3.65, N, 8.46. Found: C, 39.80; H, 3.67, N, 8.44.

Spectral data of **5**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.57-1.67 (6H, m, CH_2), 2.29 (6H, s, CH_3), 3.43-3.52 (4H, m, CH_2), 3.804 (3H, s, CH_3), 3.814 (3H, s, CH_3), 5.24 (1H, s, CH), ^{13}C NMR (100 MHz, $CDCl_3$) δ 24.8, 25.3, 40.6, 48.1, 52.4, 52.9, 84.2, 126.5, 134.2, 147.6, 164.0, 167.0 ^{77}Se NMR (76 MHz, $CDCl_3$) δ 321.4, MS (CI) *m/z* = 390 [M^++1], HRMS Calcd for $C_{15}H_{23}O_3N_4Se$: 387.09354. found: 387.09343.

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8 Crystallographic data for the structural analysis have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication, CCDC No. 191471 for **4d-*Z***. Copies of this information can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge, CB2 1EZ, UK (fax: + 44 1233 336033 or e-mail: deposit@ccdc.cam.ac.uk).

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12 Intermediate (**5c**) was isolated. **5c**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.56 – 1.60 (m, 4H, 2 x CH_2), 1.62 - 1.68 (m, 2H, CH_2), 2.29 (s, 6H, 2 x CH_3), 3.43 - 3.52 (m, 4H, 2 x CH_2), 3.806 (s, 3H, CH_3), 3.814 (s, 3H, CH_3), 5.24 (s, 1H, CH), ^{13}C NMR (100 MHz, $CDCl_3$) δ 24.8, 25.3, 40.6, 48.1, 52.4, 52.9, 80.8, 126.5, 134.2, 147.6, 164.0, 167.4, ^{77}Se NMR (76 MHz, $CDCl_3$) δ 321.4, MS (CI): *m/z* = 390 [M^++1].