# Synthesis and characterization of novel 1,3-selenazine derivatives. $BF_3 \cdot Et_2O$ -assisted reaction of primary selenoamides with $\alpha,\beta$ -unsaturated ketones

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Reaction of primary selenoamides with  $\alpha$ , $\beta$ -unsaturated ketones in the presence of BF<sub>3</sub>·Et<sub>2</sub>O provided 5,6-dihydro-4*H*-1,3-selenazine derivatives in high yields. Among the 1,3-selenazine diastereomers bearing two asymmetric carbons at the C4 and C6 positions, the *cis* form is predominant.

### Introduction

Many syntheses of heterocyclic compounds containing sulfur or selenium<sup>1</sup> have been reported because of their various interesting biological activities. For example, 1,3-thiazine or thiazole derivatives possess antitumor activity,<sup>2</sup> antibacterial activity,<sup>3</sup> human immunodefiency virus (HIV) inhibition,<sup>4</sup> and other notable activities. On the other hand, only a few reports have been published on both selenium- and nitrogen-containing heterocyclic compounds.<sup>5</sup> This is mainly due to the fact that the essential selenium-containing starting materials are less readily available than the sulfur analogue intermediates. Only a few practical applications of primary selenoamides<sup>6</sup> to the synthesis of heterocycles have been made owing to the difficulty in preparing the primary selenoamides.

We have previously investigated the synthesis and characterization of selenocarbonyl compounds<sup>7</sup> and developed a convenient method for the synthesis of potassium selenocarboxylates.<sup>8</sup> It was found that the selenobenzoates function for a reagent of introducing selenium to nitriles to give primary selenoamides under mild conditions.<sup>9</sup> Here, we describe a convenient preparation and the spectroscopic characteristics of novel 5,6-dihydro-4*H*-1,3-selenazine derivatives from primary selenoamides.

#### **Results and discussion**

Because the selenoamide is considered to contain a selenoamide–selenoimidate tautomerism and bear two reactive sites, its reactivity is of interest. The reaction of primary selenoamides with 2 equiv. of aldehydes is initiated by nucleophilic addition of the nitrogen of the selenoamide to the carbonyl carbon to give 1,3,5-oxaselenazines.<sup>5g</sup> On the other hand, the reaction of the selenoamide with halomethyl ketone afforded 1,3-selenazole with attack of selenium on the ketone.<sup>5a,6d</sup> The reaction of primary selenoamide 1 with  $\alpha,\beta$ -unsaturated ketone 2 gives 1,3-selenazine derivative 3 in good yields under mild conditions (Scheme 1). The results are summarized in Table 1. The structure of 3 was confirmed by studies of IR, UV, <sup>1</sup>H, <sup>13</sup>C, and <sup>77</sup>Se NMR, HRMS, and/or elemental analysis. Because

 $R = R^{1} + R^{1} + R^{2} + R^{4} + R^{4} + R^{4} + R^{4} + R^{2} +$ 

<sup>1</sup>*J*(<sup>77</sup>Se<sup>-13</sup>C) values were observed at the C6 carbon of **3a**, it was confirmed that **3a** was formed by the nucleophilic addition of the selenium atom of selenoamide not to the carbonyl carbon of **2a** but to the β-position of the carbonyl carbon of **2a**. Similarly, the one step reaction of other  $\alpha$ ,β-unsaturated ketones with primary selenoamides gave 5,6-dihydro-4*H*-1,3-selenazine derivatives in good to high yields (entries 1–13). There was no difference in yield of 5,6-dihydro-4*H*-1,3-selenazine derivatives from the corresponding aromatic (entries 1–8) and aliphatic (entries 9–13) selenoamides. Even cyclohexenone (entries 8 and 13) afforded the 5,6-dihydro-4*H*-1,3-selenazine derivatives in good yield without steric hindrance. However, the reaction of selenoamide with 1,5-diphenylpenta-1,4-dien-3-one gave 6*H*-1,3-selenazine **3n**, and its yield was low (31.5%). 4-Methylselenobenzamide was recovered in 60% yield (entry 14).

As for spectroscopic data for the obtained 1,3-selenazine derivatives, in the IR spectra of 5,6-dihydro-4H-1,3-selenazine derivatives, the absorption of the C=N bond of 3a-3h was observed at 1594.1  $\pm$  3.2 cm<sup>-1</sup> and that of 3i–3m was 1643.2  $\pm$ 39.4 cm<sup>-1</sup>. In the mass spectra of 5,6-dihydro-4H-1,3-selenazine derivatives, the corresponding nitrile is observed as the most stable fragment ion peak together with molecular peak. For example, the CIMS spectrum of **3c** showed peaks at m/z (%, fragment) 118 (100.0, [p-toluonitrile + 1]<sup>+</sup>), 180 (34.7, [M - ptoluonitrile]<sup>+</sup>), 280 (12.1, [M + 1 - H<sub>2</sub>O]<sup>+</sup>), 296 (7.9, [M + 1 <sup>78</sup>Se isotope]<sup>+</sup>), and 298 (16.0,  $[M + 1]^+$ ). In the <sup>77</sup>Se NMR spectra of 1,3-selenazine derivatives, <sup>77</sup>Se signals were observed in the range of  $\delta$  334.6 ± 60.0, which are at a higher field compared with <sup>77</sup>Se signals of dihydroselenophenes ( $\delta$  480.0 ± 96.4)<sup>10</sup> and selenocarbonyl compounds ( $\delta$  1420–2131).<sup>11</sup> The <sup>77</sup>Se signals of 3d, 3g, 3h, 3l, and 3m are deshielded by approximately 50-100 ppm by the effect of the substituent at C6 compared with other 1,3-selenazines. <sup>1</sup>J(<sup>77</sup>Se-<sup>13</sup>C) values of 3, which were observed for the C6 carbon, were  $54.2 \pm 1.7$ Hz. These values are typical for a C-Se single bond with an sp<sup>3</sup> carbon but not for a C-Se double bond with an sp<sup>2</sup> carbon.12

Selenazines **3c**, **3e–3g**, and **3j–3l** consist of diastereomers containing two or three asymmetric centers at the C4, C6 and/ or C5 positions of the selenazine ring. NOE irradiation techniques confirmed that the major diastereomer has a *cis* relationship between the OH group at C4 and the substituent at C6. The NOE spectra indicated the presence of diastereomers in a ratio of approximately 74–90% (*cis*): 26–10% (*trans*). Irradiation of the methyl group of C4 produced a positive NOE effect on the hydrogen atoms at C6 and C5. The NOE effect between CH<sub>3</sub> at C4 and the hydrogen at C6 of **3f** was 9.8%, and that for **3g** was 14.2%, respectively.

 Table 1
 Preparation of 1,3-selenazines

Entry	Selenoamide 1	$\alpha,\beta$ -Unsaturated ketone <b>2</b>	Yield, % ( <i>cis/trans</i> ) <sup><i>a</i></sup>
1	$R = 4-CH_3C_6H_4$ 1a	0 — 2a	R Se N HO 3a
2	1a	2b	73.4 R Se HO HO 3b 87.9
3	1a	2c	$\begin{array}{c} R \\ N \\ HO \\ \mathbf{3c} \\ 93.3 \end{array}$
4	1a	2d	R Se / N / HO <b>3d</b> 85.0
5	1a	2e	$\begin{array}{c} \overset{R}{\underset{H}{\overset{Se}{}{\overset{N}{\overset{N}{\overset{N}{}{\overset{N}{\overset{N}{$
6	1a	21	$\mathbb{R} \xrightarrow{Se}_{HO} \mathbb{R}$
7	1a	2g	92.1 (83.9:16.1) R Se HO 3g 00.0 (74.2:25.8)
8	1a	o=∕⊂⊃∕ 2h	(74.2.25.8)
9	$R = n - C_5 H_{11}$ <b>1b</b>	2b	81.1 R Se N HO 3i 99.9
10	1b	2c	R Se II HO 3j 90.7
11	1b	2i	$\begin{array}{c} R \\ \parallel \\ N \\ HO \\ 3k \\ 91.3 (83.5:16.5) \end{array}$
12	1b	2g	$\begin{array}{c} R \\ N \\ HO \\ 31 \\ 86.2 (89.6 \cdot 10.4) \end{array}$
13	1b	2h	R Se N HO
14	1a	2j	99.9 R'Se 3n
<sup>a</sup> Calcu	lated from <sup>1</sup> H NMI	Spectra	31.5

Though the detailed mechanism of the above reaction has not been clarified yet, the 5,6-dihydro-4H-1,3-selenazine formation could be explained by the possible mechanism presented



in Scheme 2. The Michael adduct was detected by <sup>13</sup>C NMR spectroscopy.<sup>13</sup>

### **Experimental**

#### **General methods**

Primary selenoamides were synthesized in accordance with a previously described procedure.<sup>9</sup> The <sup>77</sup>Se NMR (76 MHz) spectra were obtained from a JEOL  $\alpha$ -400 spectrometer, and <sup>77</sup>Se chemical shifts are expressed in ppm deshielded with respect to neat Me<sub>2</sub>Se in CDCl<sub>3</sub>. <sup>1</sup>*J*(<sup>77</sup>Se<sup>-13</sup>C) values are the <sup>77</sup>Se satellites of the proton-decoupled <sup>13</sup>C NMR spectra.

### 4-Hydroxy-4-methyl-2-(4-methylphenyl)-5,6-dihydro-4*H*-1,3-selenazine (3a)

4-Hydroxy-4-methyl-2-(4-methylphenyl)-5,6-dihydro-4H-1,3selenazine 3a was synthesized as follows: to a solution of 4-methylselenobenzamide (0.20 g, 1 mmol) in dry dichloromethane (10 mL) was added methyl vinyl ketone (0.070 g, 1 mmol) at 0 °C under an argon atmosphere. To this solution was added BF<sub>3</sub>·Et<sub>2</sub>O (1.2 mmol). The reaction mixture was stirred for 3 h, quenched with saturated sodium carbonate solution (40 mL), and extracted with dichloromethane (40 mL  $\times$  3). The extracts were dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporated to dryness. The residue was purified by column chromatography on silica gel using dichloromethane as the eluent to give 0.203 g (73.4%) of 3a as a yellow powder. When the temperature of the reaction was raised to 25 °C or lowered to -25 °C, the yields of **3a** were 46.8% and 49.0%, respectively. Further, when CHCl<sub>3</sub>, ether or THF was used as a solvent instead of CH<sub>2</sub>Cl<sub>2</sub>, the yield of 3a was low. Mp 89.0-89.6 °C; IR (KBr) 3160, 1594 cm<sup>-1</sup>; UV/Vis  $(CH_2Cl_2) \lambda_{max} (\log (\epsilon/dm^3 mol^{-1} cm^{-1})) 341 (2.42), 255 (3.98);$ <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 1.28 (3H, s), 1.46–1.62 (1H, m), 1.88 (1H, dt, J = 4.2, 9.6 Hz), 2.25 (3H, s), 2.99–3.07 (2H, m), 3.81 (1H, br s), 7.07 (2H, d, *J* = 8.2 Hz), 7.54 (2H, d, *J* = 8.2 Hz); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 18.3, 21.4, 24.9, 30.0, 85.1, 126.5, 129.1, 137.5, 141.0, 156.8; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  245.0; Anal. Calc. for C<sub>12</sub>H<sub>15</sub>NOSe: C, 53.53; H, 5.62; N, 5.20. Found: C, 53.49; H, 5.61; N, 5.03%).

# 4-Ethyl-4-hydroxy-2-(4-methylphenyl)-5,6-dihydro-4*H*-1,3-selenazine (3b)

**3b–n** were prepared following the same procedure as **3a**. Mp 60.6–61.3 °C; IR (KBr) 3150, 1593 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\epsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 345 (3.17), 260 (3.94); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.02 (3H, t, J = 5.86 Hz, CH<sub>3</sub>), 1.62–1.74 (3H, m), 2.01–2.05 (1H, m), 2.36 (3H, s, CH<sub>3</sub>Ph), 2.86 (1H, br s, OH), 3.08–3.19 (1H, m), 7.17 (2H, d, J = 8.4 Hz, Ar), 7.64 (2H, d, J = 8.4 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  7.1, 17.7, 21.3, 27.6, 30.3,

86.6, 126.5, 129.0, 137.6, 140.9, 156.4; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  250.4; HRMS: m/z = 283.04748, calc. for C<sub>13</sub>H<sub>17</sub>NOSe, found 283.04745.

# 4-Hydroxy-4,5,6-trimethyl-2-(4-methylphenyl)-5,6-dihydro-4*H*-1,3-selenazine (3c)

Mp 110.0–111.8 °C; IR (KBr) 3288, 1594 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 343 (2.25), 260 (3.96); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.86 (3H, d, J = 6.6 Hz, CH<sub>3</sub>), 1.37 (3H, s, CH<sub>3</sub>), 1.46 (3H, d, J = 7.0 Hz, CH<sub>3</sub>), 1.64–1.77 (1H, m, CH), 2.36 (3H, s, PhCH<sub>3</sub>), 3.05 (1H, br s, OH), 3.88–4.01 (1H, m, CH), 7.17 (2H, d, J = 8.2 Hz, Ar), 7.65 (2H, d, J = 8.2 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  7.4,19.1, 21.3, 25.8, 36.8, 38.3, 90.3, 126.4, 129.0, 137.1, 140.9, 158.4; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  299.3; HRMS: m/z = 297.06312, calc. for C<sub>14</sub>H<sub>19</sub>NOSe, found 297.06309.

# 4-Hydroxy-4,6,6-trimethyl-2-(4-methylphenyl)-5,6-dihydro-4*H*-1,3-selenazine (3d)

Mp 92.0–93.3 °C; IR (KBr) 3316, 1590 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 340 (2.07), 260 (3.96); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.51 (3H, s, CH<sub>3</sub>), 1.63 (3H, s, CH<sub>3</sub>), 1.64 (3H, s, CH<sub>3</sub>), 1.79 (1H, d, J = 14.0 Hz), 1.84 (1H, d, J = 14.0 Hz), 2.36 (3H, s, CH<sub>3</sub>Ph), 2.88 (1H, br s, OH), 7.18 (2H, d, J = 7.8 Hz, Ar), 7.68 (2H, d, J = 7.8 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  21.3, 28.9, 33.0, 34.7, 41.7, 46.9, 88.7, 127.0, 129.0, 137.6, 141.0, 158.6; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  439.4; Anal. Calc. for C<sub>14</sub>H<sub>19</sub>NOSe: C, 56.56; H, 6.44; N, 4.71. Found: C, 56.27; H, 6.47; N, 4.63%.

#### *cis*-4-Hydroxy-6-isopropyl-4-methyl-2-(4-methylphenyl)-5,6dihydro-4*H*-1,3-selenazine (3e)

Mp 79.5–80.6 °C; IR (KBr) 3261, 1599 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 349 (1.68), 257 (4.02); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.01 (6H, d, J = 6.8 Hz, C6-C(CH<sub>3</sub>)<sub>2</sub>), 1.34 (3H, s, CH<sub>3</sub>), 1.35 (1H, t, J = 13.4 Hz), 1.85 (1H, q, J = 6.4 Hz), 1.97 (1H, dd, J = 6.4, 13.4 Hz), 2.34 (3H, s, CH<sub>3</sub>Ph), 3.37–3.49 (1H, m, C6), 4.01 (1H, br s, OH), 7.15 (2H, d, J = 8.1 Hz, Ar), 7.65 (2H, d, J = 8.1 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  19.8, 20.4, 21.2, 24.0, 33.7, 36.4, 45.3, 88.4, 126.5, 128.9, 137.2, 140.6, 157.6; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  306.5; Anal. Calc. for C<sub>15</sub>H<sub>21</sub>NOSe: C, 57.87; H, 6.80; N, 4.50. Found: C, 57.92; H, 6.78; N, 4.30%).

# *cis*-4-Hydroxy-4-methyl-2-(4-methylphenyl)-6-pentyl-5,6-dihydro-4*H*-1,3-selenazine (3f)

Mp 66.9–67.7 °C; IR (KBr) 3178, 1590 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\epsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 342 (2.37), 258 (4.01); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.90 (3H, t, J = 6.8 Hz), 1.30–1.33 (6H, m, (CH<sub>2</sub>)<sub>3</sub>), 1.33 (3H, s, CH<sub>3</sub>), 1.34–1.42 (2H, m), 1.62–1.68 (1H, m), 1.77–1.84 (1H, m), 1.98 (1H, dd, J = 4.4, 13.6 Hz), 2.33 (3H, s, CH<sub>3</sub>Ph), 3.48–3.53 (1H, m, C6), 4.02 (1H, br s, OH), 7.13 (2H, d, J = 8.1 Hz, Ar), 7.63 (2H, d, J = 8.1 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  13.8, 21.2, 22.3, 24.2, 26.7, 31.4, 37.4, 37.4, 39.1, 87.8, 126.5, 128.8, 137.1, 140.5, 157.1; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  339.4; HRMS: m/z = 339.11007, calc. for C<sub>17</sub>H<sub>25</sub>NOSe, found 339.11003.

### *cis*-4-Hydroxy-4-methyl-2-(4-methylphenyl)-6-phenyl-5,6dihydro-4*H*-1,3-selenazine (3g)

Mp; 105.3–106.3 °C; IR (KBr) 3260, 1597 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>-Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\epsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 342 (2.59), 259 (4.08); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.49 (3H, s, CH<sub>3</sub>), 1.96 (1H, t, J = 13.6 Hz), 2.19 (1H, dd, J = 4.4, 13.6 Hz), 2.36 (3H, s, CH<sub>3</sub>Ph), 3.13 (1H, br s, OH), 4.69 (1H, dd, J = 4.4, 13.6 Hz, C6), 7.18 (2H, d, J = 7.8 Hz, Ar), 7.24–7.29 (1H, m, Ar), 7.33–7.38 (4H, m, Ar), 7.66 (2H, d, J = 7.8 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  21.4, 24.9, 38.6, 40.2, 88.4 (C4), 126.6, 127.7, 127.9, 128.9, 129.1, 136.9, 140.9, 141.1, 157.6; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  387.4; Anal. Calc. for C<sub>18</sub>H<sub>19</sub>NOSe: C, 62.60; H, 5.55; N, 4.06. Found: C, 62.32; H, 5.47; N, 3.99%).

#### 5-Hydroxy-3-(4-methylphenyl)-4-aza-2-selenabicyclo[3.3.1]non-3-ene (3h)

Mp 115.1–117.0 °C; IR (KBr) 3264, 1596 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>-Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\epsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 300 (2.82), 263 (3.93); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  1.60–1.65 (2H, m), 1.77–1.811 (2H, m), 1.93 (1H, d, J = 10.6 Hz), 1.99 (2H, s), 2.07 (1H, d, J = 12.5 Hz), 2.34 (3H, s, CH<sub>3</sub>Ph), 3.49–3.53 (1H, m), 3.90 (1H, br s, OH), 7.16 (2H, d, J = 7.9 Hz, Ar), 7.64 (2H, d, J = 7.9 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  18.9, 21.2, 33.3, 34.1, 36.2, 39.4, 82.9, 126.4, 128.9, 137.3, 140.6, 158.0; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  380.2; HRMS: m/z = 295.04555, calc. for C<sub>14</sub>H<sub>17</sub>NOSe, found 295.04745.

#### 4-Ethyl-4-hydroxy-2-pentyl-5,6-dihydro-4H-1,3-selenazine (3i)

IR (Neat) 3408, 1713 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 305 (3.34), 245 (3.34); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.89 (3H, t, J = 6.6 Hz, CH<sub>3</sub>), 0.97 (3H, t, J = 7.5 Hz, CH<sub>3</sub>), 1.32 (4H, t, J = 3.6 Hz), 1.47–1.57 (1H, m), 1.58–1.65 (4H, m), 1.98 (1H, dt, J = 4.2, 13.9 Hz), 2.34–2.42 (2H, m), 2.99–3.03 (2H, m), 3.95 (1H, br s, OH); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  7.09, 13.9, 17.2, 22.3, 27.5, 27.7, 29.8, 31.0, 43.5, 86.2, 160.7; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  252.9; HRMS: m/z = 263.07877, calc. for C<sub>11</sub>H<sub>21</sub>NOSe, found 263.07871.

# 4-Hydroxy-4,5,6-trimethyl-2-pentyl-5,6-dihydro-4*H*-1,3-selenazine (3j)

IR (Neat) 3246, 1624 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon/dm^3 mol^{-1} cm^{-1}$ )) 302 (2.31), 242 (3.42); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.81 (3H, d, J = 6.8 Hz, CH<sub>3</sub>), 0.89 (3H, t, J = 7.1 Hz, CH<sub>3</sub>), 1.29 (3H, s, C4-CH<sub>3</sub>), 1.22–1.37 (4H, m, (CH<sub>2</sub>)<sub>2</sub>), 1.40 (3H, d, J = 7.0 Hz, CH<sub>3</sub>), 1.54–1.67 (3H, m), 2.42 (2H, t, J = 7.5 Hz), 3.78–3.91 (1H, m), 3.88 (br, 1H, OH); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  7.2, 13.9, 19.1, 22.3, 26.1, 27.7, 31.0, 36.3, 38.3, 43.0, 89.6, 162.9; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  303.6; HRMS: m/z = 277.09442, calc. for C<sub>12</sub>H<sub>23</sub>-NOSe, found 277.09437.

# *cis*-4-Hydroxy-4-methyl-2-pentyl-6-propyl-5,6-dihydro-4*H*-1,3-selenazine (3k)

IR (Neat) 3242, 1626 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 301 (2.46), 244 (3.45); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.89 (3H, t, J = 6.4 Hz, CH<sub>3</sub>), 0.94 (3H, t, J = 7.1 Hz, CH<sub>3</sub>), 1.29 (3H, s, C4-CH<sub>3</sub>), 1.29–1.48 (6H, m), 1.51–1.69 (4H, m), 1.73–1.86 (1H, m), 1.96 (1H, dt, J = 4.1, 13.5 Hz), 2.41 (2H, t, J = 7.0 Hz), 3.41–3.56 (1H, m, C6), 4.30 (1H, br s, OH); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  13.8, 13.9, 20.3, 22.3, 24.8, 27.7, 31.0, 36.6, 39.3, 39.7, 43.0, 87.3, 161.4; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  345.1; HRMS: m/z = 291.11007, calc. for C<sub>13</sub>H<sub>25</sub>NOSe, found 291.11001.

### *cis*-4-Hydroxy-4-methyl-2-pentyl-6-phenyl-5,6-dihydro-4*H*-1,3-selenazine (3l)

IR (Neat) 3198, 1634 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 292 (3.41), 241 (3.95); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.89 (3H, t, J = 6.8 Hz, CH<sub>3</sub>), 1.32–1.34 (4H, m, (CH<sub>2</sub>)<sub>2</sub>), 1.43 (3H, s, CH<sub>3</sub>), 1.61–1.66 (2H, m, CH<sub>2</sub>), 1.92 (1H, t, J = 13.7 Hz), 2.12 (1H, dd, J = 4.0, 13.7 Hz), 2.46 (2H, t, J = 7.1 Hz), 4.61 (1H, dd, J = 4.0, 13.7 Hz, C6), 4.63 (br, 1H, OH), 7.24–7.34 (5H, m, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  13.9, 22.3, 25.2, 27.6, 31.0, 38.7, 39.4, 42.7, 87.7, 127.5, 127.7, 128.8, 140.9, 162.1; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  395.6; HRMS: m/z = 325.09442, calc. for C<sub>16</sub>H<sub>23</sub>NOSe, found 325.09437.

#### 5-Hydroxy-3-pentyl-4-aza-2-selenabicyclo[3.3.1]non-3-ene (3m)

IR (Neat) 3214, 1619 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$  (log ( $\varepsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 304 (3.14), 236 (3.43); 1 H NMR (CDCl<sub>3</sub>)  $\delta$  0.90 (3H, t, *J* = 7.1 Hz), 1.33–1.37 (5H, m), 1.54–1.67 (3H, m), 1.73–1.80 (2H, m), 1.88–2.02 (4H, m), 2.45 (2H, q, *J* = 7.6 Hz), 3.80–3.83 (1H, m), 4.58 (1H, br s, OH); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  13.8, 18.9, 22.3, 27.9, 31.0, 33.2, 34.4, 35.9, 39.5, 43.5, 82.4, 163.3;

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<sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  385.7; HRMS: m/z = 275.07877, calc. for C<sub>12</sub>H<sub>21</sub>NOSe, found 275.07873.

#### 2-(4-Methylphenyl)-4-(2-phenylvinyl)-6-phenyl-6*H*-1,3-selenazine (3n)

Mp 54.5–56.0 °C; IR (KBr) 1599 cm<sup>-1</sup>; UV/Vis (CH<sub>2</sub>Cl<sub>2</sub>)  $\lambda_{max}$ (log ( $\epsilon$ /dm<sup>3</sup> mol<sup>-1</sup> cm<sup>-1</sup>)) 292 (4.33), 243 (4.13); <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  2.39 (3H, s, CH<sub>3</sub>Ph), 4.97 (1H, d, J = 6.0 Hz), 5.23 (1H, d, J = 1.1 Hz), 5.34 (1H, d, J = 6.0 Hz), 6.93 (1H, d, J = 15.8 Hz), 7.20–7.45 (6H, m, Ar), 7.54 (2H, dd, J = 1.3, 7.0Hz, Ar), 7.93 (2H, dd, J = 1.3, 7.0 Hz, Ar); <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  21.4, 38.0, 108.8, 126.8, 127.6, 127.7, 128.2, 128.6, 128.8, 129.0, 129.3, 129.5, 136.9, 137.3, 141.8, 142.3, 148.4, 161.5; <sup>77</sup>Se NMR (CDCl<sub>3</sub>)  $\delta$  350.1; HRMS: m/z = 415.08386, calc. for C<sub>25</sub>H<sub>21</sub>NOSe, found 415.08381.

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- 13 In <sup>13</sup>C NMR (CDCl<sub>3</sub>), the Michael adduct, *Se*-3-oxobutyl 4-methylbenzenecarboselenoimidate, as intermediate was observed. Two peaks were observed at  $\delta = 193.7$  and 207.0, which were assigned to the <sup>13</sup>C=NH<sub>2</sub> and the carbonyl carbon resonance of the Michael adduct, respectively. <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  18.4, 21.7, 29.8, 44.1, 128.3, 129.8, 140.0, 143.6, 193.7 (SeC=NH) and 207.0 (C=O).

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