Synthesis of 1,3-Selenazoles and Bis(selenazoles) from Primary Selenocarboxylic Amides and Selenourea

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Received 13 October 2003

Abstract: The reaction of nitriles with P_2Se_5 in the presence of EtOH–H_2O afforded primary selenocarboxylic amides. The cyclization of these compounds with α-halo ketones afforded a variety of functionalized 1,3-selenazoles. The use of P_2Se_5 also allowed the convenient synthesis of selenocarboxylic diamides which were transformed into bis(selenazol-2-yl)alkanes ('bis-selenazoles'). A practical method for the synthesis of selenourea was developed. This useful small building block was successfully applied to the synthesis of primary 2-amino-1,3-selenazoles.

Key words: cyclizations, heterocycles, nitriles, selenium, amides

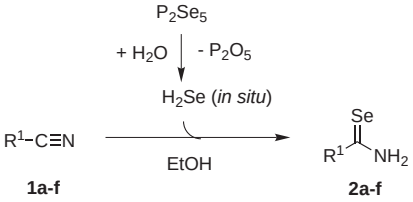
Selenium represents an essential element for higher organisms.[1] In this context, the selenium containing enzymes glutathioneperoxidase and 5′-deiodase type 1 play an important role. In fact, a number of diseases can result from selenium deficiency.[2,3] Therefore, selenium containing molecules are of considerable biochemical and pharmacological relevance. A prominent example is the antitumor and antiviral active *C*-glycosyl selenazole selenazofurin.[4] Unfortunately, selenium compounds are in most cases less stable than the corresponding sulfur analogues. In addition, the methods and conditions available for the synthesis of sulfur compounds can often not be applied to selenium. Therefore, the development of new methods for the synthesis of small selenium-containing building blocks is of considerable current interest.

In contrast to 1,3-thiazoles, there exist only limited methods for the synthesis of 1,3-selenazoles.[5] Many syntheses rely on the cyclization of primary selenoureas and selenocarboxylic amides. Selenocarboxylic amides have been prepared by the use of H_2Se, NaSeH[6] (generated from $NaBH_4$–Se),[6,7] tris(trimethylsilyl)monoselenophosphate[8] or Al_2Se_3.[9,10] However, there are a number of drawbacks associated with these methods.[11] Primary selenocarboxylic amides are not available to date by reaction of amides with Woollins reagent.[12]

We have recently reported a new and convenient method for the synthesis of primary selenocarboxylic amides by reaction of nitriles with P_2Se_5 in the presence of EtOH–H_2O.[11] From a preparative viewpoint, the use of P_2Se_5 is more convenient and reliable than the use of Al_2Se_3 and is less toxic than CO, NaSeH or H_2Se. In addition, P_2Se_5 is more readily available in pure form and less prone to hydrolysis than Al_2Se_3.[13] Herein, we report the application of our methodology to the synthesis of a variety of 1,3-selenazoles, bis(selenazol-2-yl)alkanes ('bis-selenazoles') and 2-amino-1,3-selenazoles.[14,15]

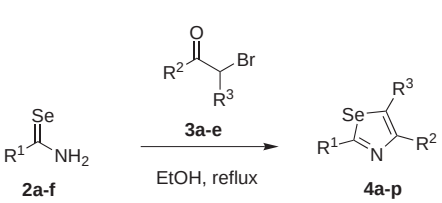
Selenocarboxylic Amides and 1,3-Selenazoles

In our preliminary communication, we showed that primary selenocarboxylic amides can be prepared in good yields by reaction of nitriles with P_2Se_5.[11] Slow addition of water to the reaction mixture resulted in formation of small amounts of hydrogen selenide in situ which subsequently added to the nitrile (Scheme 1). The reaction of benzonitrile, cyclohexylacetonitrile, 2-tolylnitrile, MeCN, diphenylacetonitrile, and 1-naphthylacetonitrile with P_2Se_5 afforded the selenocarboxylic amides **2a–f** (Scheme 1, Table 1) in good yields.



Scheme 1 Synthesis of selenocarboxylic amides by reaction of nitriles with P_2Se_5

The cyclization of selenobenzoic amides **2a–f** with phenacyl bromides **3a–e** afforded the 1,3-selenazoles **4a–p** in 34–98% yield (Scheme 2, Table 1). The regioselectivity of cyclization is supported by analysis of the ^2J (SeH) coupling constants for the hydrogen atoms 5-H and by comparison with known selenazole syntheses.[5,6] The yields are generally lower for cyclizations of aliphatic than for aromatic substrates.



Scheme 2 Synthesis of 1,3-selenazoles **4a–p**

SYNTHESIS 2004, No. 6, pp 0875–0884
Advanced online publication: 15.03.2004
DOI: 10.1055/s-2004-822312; Art ID: T10803SS.pdf

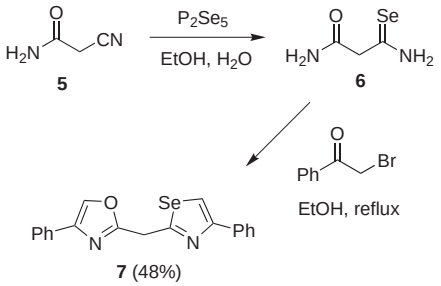
Table 1 Yields of 1,3-Selenazoles **4a**–**p**

2	4	R^1	R^2	R^3	Mp (°C)	Yield **4** (%)[a]
a	**a**	Ph	Ph	H	99–100	87[16]
	b	Ph	4-MeC_6H_4	H	122–123	86
	c	Ph	4-BrC_6H_4	H	134–135	98[16]
	d	Ph	4-$(O_2N)C_6H_4$	H	135–136	98[16]
b	**e**	*c*-Hex	Ph	H	36–37	44
	f	*c*-Hex	4-MeC_6H_4	H	53–54	49
	g	*c*-Hex	4-BrC_6H_4	H	77–78	54
	h	*c*-Hex	4-$(O_2N)C_6H_4$	H	86–88	45
c	**i**	Me	4-MeC_6H_4	H	92–95	42
	j	Me	4-$(O_2N)C_6H_4$	H	136–137	45
d	**k**	2-MeC_6H_4	4-BrC_6H_4	H	95–96	95
	l	2-MeC_6H_4	Et	H	125/0.02 Torr[b]	34
e	**m**	Ph_2CH	Ph	H	148–149	96
	n	Ph_2CH	4-$(O_2N)C_6H_4$	H	187–188	98
	o	Ph_2CH	Ph	Ph	106–107	72[17]
f	**p**	2-Naphthyl	4-BrC_6H_4	H	117–120	73

[a] Isolated yields.
[b] Boiling point.

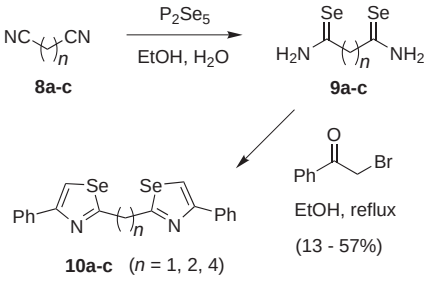
Bis-selenazoles

The reaction of α-cyanoacetic amide (**5**) with P_2Se_5 (1 equiv) afforded the novel monoselenomalonic diamide **6** (Scheme 3). The nitrile was chemoselectively attacked in the presence of the amide moiety. The reaction of **6** with phenacyl bromide (2 equiv) resulted in formation of product **7** containing an oxazole and a selenazole moiety.



Scheme 3 Synthesis of 1,3-selenazole **7**

The synthesis of non-annulated bis(selenazol-2-yl)alkanes ('bis-selenazoles') has, to the best of our knowledge, not yet been reported. The reaction of malonic dinitrile (**8a**) with P_2Se_5 (2 equiv) afforded the novel selenomalonic diamide (**9a**). The double cyclization of **9a** with phenacyl bromide gave the bis-selenazole **10a** (Scheme 4). The reaction of P_2Se_5 with 1,2-dicyanoethane (**8b**) and 1,4-dicyanobutane (**8c**) gave selenosuccinic diamide (**9b**) and selenoadipic diamide (**9c**), respectively. The cyclization of **9b** and **9c** with phenacyl bromide afforded the bis-selenazoles **10b** and **10c**, respectively.



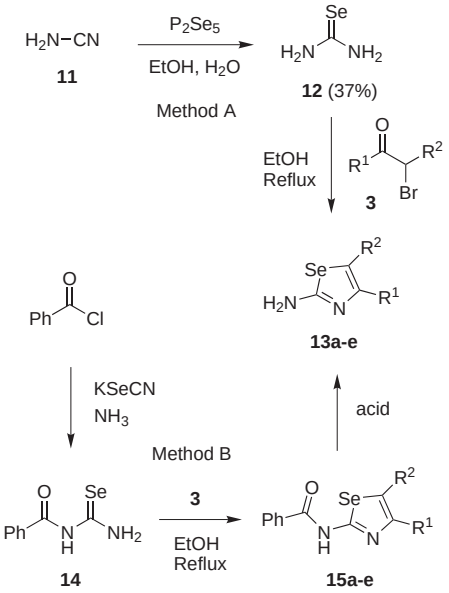
Scheme 4 Synthesis of bis(selenazol-2-yl)alkanes **10**

2-Aminoselenazoles

The synthesis of primary 2-aminoselenazoles from selenourea (**12**) was studied next (Scheme 5). Known methods for the synthesis of **12** require the generation and handling of the highly toxic gaseous hydrogen selenide (H_2Se).[18] Therefore, our first goal was the development of a more convenient approach to this useful small molecule. The reaction of P_2Se_5 with cyanamide afforded, after op-

timization of the conditions (see experimental section), the desired unstable product in acceptable yield. The cyclization of **12** with α-bromo ketones **3** afforded the desired primary 2-aminoselenazoles **13** in 68–94% yield (Method A, Table 2). A second strategy for the synthesis of 2-aminoselenazoles has been previously reported by Heimgartner and others.[19] We have adopted this approach, which does not require the use of **12**, to the synthesis of 2-aminoselenazoles **13** (Method B). The stable benzoylselenourea (**14**) was prepared according to Douglass[20] by reaction of an acetone solution of potassium selenocyanate with benzoyl chloride and subsequent addition of ammonia.[19] The cyclization of **14** with **3** afforded the protected 2-aminoselenazoles **15** which were subsequently deprotected by treatment with phosphoric or sulfuric acid. The two-step transformations of **14** into **13** were carried out in very good overall yields (except for the synthesis of **13b**).

The reaction of selenourea with chloroacetonitrile afforded the selenazolidine **16**. The latter was formed by attack of the selenium atom onto the chloride and subsequent cyclization by attack of the nitrogen atom onto the nitrile.



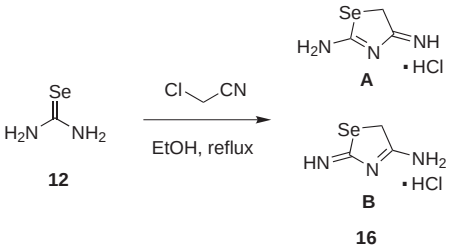
Scheme 5 Synthesis of 2-aminoselenazoles **13**

Table 2 Yields of 2-Aminoselenazoles **13**

13	R^1	R^2	Mp (°C)	Yield (%) (A)[a]	Yield (%) (B)[b]
a	Ph	H	131–132	87	99 + 84 (83)
b	4-MeC_6H_4	H	168	84	88 + 51 (45)
c	4-BrC_6H_4	H	175	94	96 + 91 (87)
d	4-$(O_2N)C_6H_4$	H	250	91	88 + 99 (87)
e	Ph	Ph	199–201	68	90 + 95 (86)

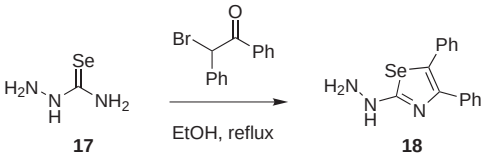
[a] Yields for method A.
[b] Yields for method B: yield of **15** + **13** (in brackets: yields over two steps, **14** → **13**).

Product **16** resides in the form of the iminoselenazolidine rather than the aminoselenazole tautomer (Scheme 6). However, both tautomers **A** and **B** are possible for the iminoselenazolidine. The tautomerism of the corresponding sulfur analog was studied in detail by Hartmann.[21]



Scheme 6 Cyclization of selenourea with chloroacetonitrile

The cyclization of selenosemicarbazide (**17**)[22] with desyl bromide afforded the novel 2-hydrazinoselenazole **18** (Scheme 7). This compound represents a useful building block for the synthesis of other selenazoles, such as pyrazole-substituted 1,3-selenazoles. The formation of a 1,2,4-selenadiazine isomer was excluded by comparison of **18** with an authentic sample of the latter.



Scheme 7 Cyclization of selenosemicarbazide with desyl bromide

CAUTION: Toxic hydrogen selenide is generated in small quantities during the reaction of P_2Se_5 with nitriles and water or during the hydrolysis of P_2Se_5 in air.

P_2Se_5
A mixture of red phosphorus (20 mmol) and grey selenium powder (50 mmol) was heated in a tube with a small Bunsen burner flame until the reaction was complete. The reaction mixture was ground and powdered to give P_2Se_5 as a grey solid. The reagent was stored under inert atmosphere and was prepared freshly for all applications. The product is slowly hydrolyzed, if exposed to the air.

Selenobenzoic Amide (2a)
To a refluxing EtOH solution (30 mL) of benzonitrile (5.15 g, 50.0 mmol) and freshly prepared P_2Se_5 (9.12 g, 20.0 mmol) was added dropwise H_2O (6 mL) over 2 h. After cooling, the solution was filtered and H_2O was added to the filtrate, which resulted in formation of a precipitate. The latter was filtered off and recrystallized (C_6H_6–petroleum ether) to give **2a**.

Yield: 7.73 g (84%); golden needles; mp 125.5–126 °C.

IR (KBr): 667 (m), 687 (m) 835 (m), 1260 (m), 1309 (m), 1320 (w), 1415 (m), 1628 (s) cm^{-1}.

Anal. Calcd for C_7H_7NSe (184.10): C, 45.67; H, 3.83; N, 7.60. Found: C, 45.80; H, 3.82; N, 7.50.

Cyclohexaneselenocarboxylic Amide (2b)
Cyclohexanecarbonitrile (5.45 g, 50.0 mmol) was dissolved in a mixture of EtOH (20 mL) and H_2O (3 mL). To the refluxing solu-

tion was added freshly prepared P_2Se_5 (9.12 g, 20.0 mmol) in small portions over 2 h. The solution was cooled and filtered. H_2O (20 mL) was added to the filtrate, which resulted in formation of a precipitate. The mixture was extracted with benzene. The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Addition of petroleum ether resulted in crystallization of the product. The crude product was dried (desiccator, P_2O_5) and recrystallized (C_6H_6–petroleum ether) to give **2b**.

Yield: 2.50 g (26%); colorless needles; mp 130–133 °C.

IR (KBr): 780 (m), 900 (w), 965 (s), 1150 (w), 1235 (w), 1291 (s), 1365 (m), 1415 (m), 1475 (s), 1650 (s), 2940 s) cm^{-1}.

Anal. Calcd for $C_7H_{13}NSe$ (190.15): C, 44.22; H, 6.89; N, 7.37. Found: C, 44.14; H, 6.74; N, 7.67.

2-Methylselenobenzoic Amide (2c)
This compound was obtained by reaction of 2-methylbenzonitrile (11.8 g, 100.0 mmol) with freshly prepared P_2Se_5 (9.12 g, 20.0 mmol) as described for **2a**.

Yield: 5.94 g (30%); yellow needles (C_6H_6–petroleum ether); mp 109–111 °C.

IR (KBr): 660 (m), 728 (m), 855 (m), 1045 (w), 1130 (w), 1155 (w), 1230 (w), 1265 (w), 1290 (m), 1420 (s), 1620 (s) cm^{-1}.

^1H NMR (C_6D_6, 300 MHz): δ = 2.15 (s, 3 H, CH_3), 5.90 (br, 1 H, NH), 6.78–7.22 (m, 4 H, Ar), 8.20 (br, 1 H, NH).

^{13}C NMR (C_6D_6, 75 MHz): δ = 19.67 (CH_3), 125.67, 125.68, 126.22, 126.24, 128.99, 130.70 (Ar), 210.46 (C=Se).

MS (EI, 70 eV): *m*/*z* (%) = 199 (100, M^+).

Anal. Calcd for C_8H_9NSe (198.13): C, 48.50; H, 4.58; N, 7.07, Se, 38.86. Found: C, 48.50; H, 4.30; N, 7.10; Se, 39.50.

Selenoacetic Amide (2d)
To freshly prepared P_2Se_5 (36.48 g, 80.0 mmol) was added dropwise MeCN (8.20 g, 200.0 mmol). Subsequently, H_2O (10 mL) was added dropwise over 5 h at 80 °C. After cooling, the solution was filtered and H_2O (20 mL) was added to the filtrate. The aq layer was extracted with benzene. The combined organic layers were dried (Na_2SO_4), filtered and concentrated. The product crystallized upon cooling (ice) to give **2d**.

Yield: 12.15 g (50%); colorless prisms (C_6H_6); mp 125–126 °C.

IR (KBr): 640 (s), 730 (w), 770 (m), 1040 (m), 1290 (s), 1365 (m), 1415 (s), 1485 (s), 1660 (s) cm^{-1}.

Anal. Calcd for C_2H_5NSe (122.03): C, 19.69; H, 4.13; N, 11.48. Found: C, 19.50; H, 4.20; N, 11.40.

Diphenylselenoacetamide (2e)
Diphenylacetonitrile (4.83 g, 25.0 mmol) was dissolved in EtOH (80 mL). To the refluxing solution was added freshly prepared P_2Se_5 (13.7 g, 30.0 mmol) and H_2O (4.5 mL) in small portions over 24 h. The solution was cooled, filtered and H_2O was added to the filtrate. The mixture was extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated. The product crystallized to give **2e**.

Yield: 5.50 g (81%); yellow prisms (C_6H_6–petroleum ether); mp 148.5–150 °C.

IR (KBr): 612 (m), 700 (s), 835 (m), 1180 (m), 1200 (m), 1295 (s), 1420 (m), 1450 (m), 1620 (s) cm^{-1}.

Anal. Calcd for $C_{14}H_{13}NSe$ (274.23): C, 61.32; H, 4.78; N, 5.11. Found: C, 61.30; H, 4.90; N, 5.05.

Naphth-1-yl-selenocarboxylic Amide (2f)
An EtOH solution (50 mL) of 1-naphthylacetonitrile (5.0 g, 13.0 mmol) and freshly prepared P_2Se_5 (5.96 g, 13.0 mmol) was refluxed. H_2O (3 mL) was added dropwise to the refluxing solution within 3.5 h. The solution was concentrated in vacuo. After cooling to 20 °C, a crystalline precipitate formed which was filtered off and recrystallized (EtOH) to give **2f**.

Yield: 2.66 g (35%); as yellow prisms; mp 130–132 °C.

IR (KBr): 791 (s), 891 (m), 1065 (w), 1265 (m) 1304 (m), 1355 (m), 1401 (m), 1445 (s), 1635 (s), 3116 (m) cm^{-1}.

Anal. Calcd for $C_{11}H_9NSe$ (234.16): C, 56.42; H, 3.87; N, 5.98. Found: C, 56.40; H, 3.90; N, 5.80.

2,5-Diphenyl-1,3-selenazole (4a)
An EtOH solution (20 mL) of selenobenzoic amide (1.84 g, 10.0 mmol) and phenacyl bromide (1.99 g, 10.0 mmol) was stirred for 10 min, which resulted in an increase of the temperature. After cooling, the mixture was poured into H_2O (20 mL), which resulted in the formation of a precipitate. This was filtered off and recrystallized (EtOH) to give **4a**.

Yield: 2.47 g (87%); colorless lamella; mp 99 °C.

IR (KBr): 686 (m) 730 (s), 758 (s), 835 (w), 868 (w), 919 (w), 952 (s), 999 (w), 1027 (m), 1043 (s), 1071 (m), 1152 (m), 1279 (m), 1442 (s), 1481 (s), 1509 (w), 1579 (w), 1598 (w), 3114 (m) cm^{-1}.

^1H NMR ($CDCl_3$, 300 MHz): δ = 7.38–8.01 (m, 10 H, ArH), 8.06 [s, 1 H, Hetar, ^2J (SeH) = 58.3 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 118.26 (C-5), 126.72 (Ar), 127.08 (Ar), 127.91 (Ar), 128.70 (Ar), 128.97 (Ar), 130.21 (Ar), 135.42 (Ar), 136.41 (Ar), 156.93 (C-4), 173.87 (C-2).

^{77}Se NMR ($CDCl_3$, Me_2Se): δ = 712.69.

MS (70 eV): *m*/*z* (%) = 285 (M^+, 59), 182 (100), 103 (16), 102 (86), 89 (8), 77 (13), 51 (8), 28 (16).

Anal. Calcd for $C_{15}H_{11}NSe$ (284.22): C, 63.39; H, 3.90; N, 4.93. Found: C, 63.45; H, 3.92; N, 4.91.

2-Phenyl-4-tolyl-1,3-selenazole (4b)
This compound was obtained by reaction of selenobenzoic amide (1.84 g, 10.0 mmol) with 4-methylphenacyl bromide (2.13 g, 10.0 mmol) in EtOH (20 mL) following the procedure as described for **4a**.

Yield: 2.56 g (86%); colorless needles (EtOH); mp 122–123 °C.

IR (KBr): 691 (s), 742 (s), 822 (s), 952 (s), 1040 (s), 1226 (m), 1272 (w), 1294 (w), 1441 (m), 1480 (s), 1511 (m), 3106 (m) cm^{-1}.

^1H NMR ($CDCl_3$, 300 MHz): δ = 2.38 (s, 3 H, Me), 7.22–7.99 (m, 9 H, ArH), 8.02 [s, 1 H, Hetar, ^2J (SeH) = 48.60 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 21.27 (Me), 117.42 (C-5), 126.59 (Ar), 127.05 (Ar), 128.93 (Ar), 129.36 (Ar), 130.11 (Ar), 132.73 (Ar), 136.46 (Ar), 137.66 (Ar), 156.97 (C-4), 173.67 {C-2, ^1J [(C-2)Se] = 130.3 Hz}.

^{77}Se NMR ($CDCl_3$, Me_2Se): δ = 709.64.

MS (70 eV): *m*/*z* (%) = 299 (M^+, 79), 297 (40), 196 (100), 194 (56), 116 (44), 115 (90), 89 (13), 78 (13), 77 (12), 51 (9), 28 (6).

Anal. Calcd for $C_{16}H_{13}NSe$ (298.25): C, 64.44; H, 4.39; N, 4.70. Found: C, 64.41; H, 4.31; N, 4.69.

2-Phenyl-4-(4-bromophenyl)-1,3-selenazole (4c)
This compound was obtained by reaction of selenobenzoic amide (1.84 g, 10.0 mmol) with 4-bromophenacyl bromide (2.76 g, 10.0 mmol) in EtOH (20 mL) following the procedure as described for **4a**.

Yield: 3.56 g (98%); colorless needles (EtOH); mp 134–135 °C.

IR (KBr): 667 (m), 765 (s), 833 (m), 1006 (m), 1037 (w), 1071 (w), 1224 (w), 1478 (s), 1506 (m), 1634 (m), 3050 (m), 3108 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 7.87–8.01 (m, 9 H, ArH), 8.05 [s, 1 H, Hetar, ^2J (SeH) = 48.5 Hz].

MS (EI, 70 eV): *m*/*z* (%) = 362/364 (M^+, 40), 314/316 (48), 301/303 (100), 260/262 (44), 207 (8), 180/182 (48), 101 (40), 89 (30), 55 (14), 41 (18).

Anal. Calcd for $C_{15}H_{10}NBrSe$ (363.12): C, 49.62; H, 2.78; N, 3.85. Found: C, 49.10; H, 2.90; N, 3.79.

2-Phenyl-4-(4-nitrophenyl)-1,3-selenazole (4d)
This compound was obtained by reaction of selenobenzoic amide (1.84 g, 10.0 mmol) with 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in EtOH (20 mL) following the procedure as described for **4a**.

Yield: 3.24 g (98%); yellow prisms (EtOH); mp 135.5–136.5 °C.

IR (KBr): 735 (m), 757 (s), 766 (m), 847 (s), 860 (m), 956 (m), 1046 (m), 1243 (m), 1284 (m), 1336 (s), 1445 (m), 1480 (s), 1519 (s), 1592 (s), 1502 (s), 3107 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 7.43–8.30 (m, 9 H, ArH), 8.32 [s, 1 H, 5-H, ^2J (SeH) = 43.1 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 122.06 (C-2), 124.18 (CH, Ar), 127.16 (CH, Ar), 127.21 (CH, Ar), 129.14 (CH, Ar), 130.74 (CH, Ar), 135.87 (Ar), 141.13 (Ar), 147.06 (Ar), 154.58 (C-4), 174.87 (C-2).

^{77}Se NMR ($CDCl_3$, Me_2Se): δ = 730.16.

MS (EI, 70 eV): *m*/*z* (%) = 329 (M^+, 100), 328 (48), 300 (2), 257 (2), 227 (80), 197 (30), 181 (32), 169 (17), 117 (16), 103 (12), 89 (95), 77 (26).

Anal. Calcd for $C_{15}H_{10}N_2O_2Se$ (329.15): C, 54.73; H, 3.06; N, 8.51. Found: C, 54.40; H, 3.20; N, 8.49.

2-Cyclohexyl-4-phenyl-1,3-selenazole (4e)
A mixture of cyclohexaneselenocarboxylic amide (1.90 g, 10.0 mmol) and phenacyl bromide (1.99 g, 10.0 mmol) in EtOH (28 mL) was stirred for 10 min and subsequently briefly refluxed. After cooling to 20 °C, selenium was filtered off. The mixture was poured into H_2O (50 mL). The precipitated product was filtered off and recrystallized from EtOH to give **4e**.

Yield: 1.28 g (44%); colorless prisms; mp 36–37 °C.

IR (KBr): 820 (s), 870 (w), 900 (m), 1030 (m), 1350 (m), 1515 (s), 2945 (m), 3030 (w), 3120 (w) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.31–3.07 (m, 10 H, cyclohexyl), 2.97 (s, 1 H, CH-cyclohexyl), 7.36–7.89 (m, 5 H, ArH), 7.96 [s, 1 H, 5-H, ^2J (SeH) = 51.70 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 25.85 (CH_2-cyclohexyl), 26.00 (CH_2-cyclohexyl), 34.49 (CH_2-cyclohexyl), 45.85 (CH-cyclohexyl), 116.85 (C-5), 126.63 (Ar), 127.58 (Ar), 128.62 (Ar), 135.71 (Ar), 155.15 (C-4), 184.21 (C-2).

^{77}Se NMR ($CDCl_3$, MeSe): δ = 713.5.

MS (70 eV): *m*/*z* (%) = 291 (M^+, 71), 290 (37), 262 (12), 237 (81), 223 (100), 221 (74), 102 (97), 90 (10), 77 (10), 55 (10), 51 (8), 41 (17), 28 (12).

Anal. Calcd for $C_{15}H_{18}NBrSe$ (290.27): C, 48.51; H, 4.82; N, 4.82. Found: C, 48.62; H, 4.71; N, 4.49.

2-Cyclohexyl-4-tolyl-1,3-selenazole (4f)
This compound was obtained by reaction of cyclohexaneselenocarboxylic amide (1.90 g, 10.0 mmol) with 4-methylphenacyl bromide (2.13 g, 10.0 mmol) in EtOH (50 mL) following the procedure as described for **4e**.

Yield: 1.49 g (49%); colorless needles (EtOH–H_2O); mp 53–54 °C.

IR (KBr): 820 (s), 870 (w), 895 (s), 990 (m), 1030 (w), 1120 (w), 1160 (m), 1180 (w), 1300 (m), 1370 (w), 1445 (m), 1515 (s), 2940 (m), 3030 (w), 3120 (w) cm^{-1}.

^{1}H NMR ($CDCl_3$, 200 MHz): δ = 1.23–2.28 (m, 8 H, CH_2-cyclohexyl), 2.34 (s, 3 H Me), 2.93 (m, 1 H, CH-cyclohexyl), 3.41–3.49 (m, 1 H, CH-cyclohexyl), 7.13–7.76 (m, 4 H, ArH), 7.89 (s, 1 H, 5-H-Hetar).

^{13}C NMR ($CDCl_3$, 50 MHz): δ = 21.24 (Me), 25.85 (CH_2-cyclohexyl), 115.99 (C-5), 126.50 (CH, Ar), 129.29 (CH, Ar), 133.0 (Ar), 137.32 (Ar), 155 (C-4), 184.04 (C-2).

MS (EI, 70 eV): *m*/*z* (%) = 305 (M^+, 60), 250 (54), 237 (94), 196 (64), 114 (100), 91 (15), 55 (20), 41 (23), 28 (15).

Anal. Calcd for $C_{16}H_{19}NSe$ (304.29): C, 63.15; H, 6.29; N, 4.60. Found: C, 63.20; H, 6.30; N, 4.34.

2-Cyclohexyl-4-(4′-bromophenyl)-1,3-selenazole (4g)
This compound was obtained by reaction of cyclohexaneselenocarboxylic amide (1.90 g, 10.0 mmol) and 4-bromophenacyl bromide (2.76 g, 10.0 mmol) in EtOH (150 mL) following the procedure as described for **4e**.

Yield: 1.99 g (54%); colorless needles (EtOH); mp 77–78 °C.

IR (KBr): 850 (m), 895 (w), 1010 (w), 1045 (w), 1080 (w), 1170 (w), 1190 (w), 1300 (w), 1401 (w), 1470 (m), 1515 (m), 2380 (m), 2960 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.22–1.55 (m, 4 H, CH_2-cyclohexyl), 1.84–2.20 (m, 4 H, CH_2-cyclohexyl), 2.97–3.05 (m, 1 H, CH-cyclohexyl), 3.68–3.75 (m, 1 H, CH-cyclohexyl), 7.48–7.79 (m, 4 H, ArH), 7.97 [s, 1 H, 5-H, ^2J (SeH) = 47.10 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 18.44 (CH_2), 25.84 (CH_2), 26.9 (CH_2), 34.48 (CH_2), 45.85 (CH), 117.37 (C-5), 121.58 (CH, Ar), 128.20 (CH, Ar), 131.72 (CH, Ar), 134.64 (Ar), 154.01 (C-4), 184.58 (C-2).

^{77}Se NMR ($CDCl_3$, Me_2Se): δ = 719.88.

MS (70 eV): *m*/*z* (%) = 369 (M^+, 46), 316 (39), 303 (80), 301 (100), 299 (43), 262 (35), 260 (44), 182 (41), 101 (32), 55 (31), 41 (39), 28 (13).

Anal. Calcd for $C_{15}H_{16}NBrSe$ (369.16): C, 48.80; H, 4.37; N, 3.79. Found: C, 48.62; H, 4.41; N, 3.74.

2-Cyclohexyl-4-(4′-nitrophenyl)-1,3-selenazole (4h)
This compound was obtained by reaction of cyclohexaneselenocarboxylic amide (1.90 g, 10.0 mmol) and 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in EtOH (125 mL) following the procedure as described for **4e**.

Yield: 1.58 g (45%); orange needles (EtOH); mp 86–88 °C.

IR (KBr): 870 (m), 897 (w), 1001 (w), 1030 (w), 1115 (m), 1160 (w), 1200 (w), 1345 (s), 1470 (s), 1515 (s), 1608 (s), 2870 (m), 2945 (m), 3120 (w) cm^{-1}.

^{1}H NMR (DMSO-d_6, 300 MHz): δ = 1.16–2.26 (m, 9 H, CH_2-cyclohexyl), 2.98 (m, 1 H, CH-cyclohexyl), 7.54–7.86 (m, 4 H, ArH), 8.54 (s, 1 H, 5-H).

MS (EI, 70 eV): *m*/*z* (%) = 336 (M^+, 50), 734 (16), 285 (76), 273 (100), 231 (23), 181 (20), 169 (8), 89 (43), 41 (20), 28 (5).

Anal. Calcd for $C_{15}H_{16}N_2O_2Se$ (335.25): C, 53.74; H, 4.81; N, 8.36. Found: C, 54.08; H, 4.81; N, 8.66.

2-Methyl-4-(4′-tolyl)-1,3-selenazole (4i)
A mixture of selenoacetic amide (1.22 g, 10.0 mmol) and 4-methylphenacyl bromide (2.13 g, 10.0 mmol) in EtOH (30 mL) and pyridine (0.79 g, 10.0 mmol) was stirred at 20 °C for 10 min. A colorless precipitate of pyridine hydrobromide was filtered off and

the filtrate was concentrated. After cooling (0 °C), a crystalline precipitate was formed. Recrystallization (EtOH) of which gave **4i**.

Yield: 0.99 g (42%); colorless prisms; mp 92–95 °C.

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 2.35 (s, 3 H, Me-Tol), 2.77 (s, 3 H, 2-Me), 7.08–7.80 (m, 5 H, Ar, 5-H).

MS (EI, 70 eV): *m*/*z* (%) = 236 (M^+, 100).

Anal. Calcd for $C_{11}H_{11}NSe$ (236.18): C, 55.94; N, 4.69; N, 5.93. Found: C, 55.98; H, 4.81; N, 5.86.

2-Methyl-4-(4′-nitrophenyl)-1,3-selenazole (4j)
This compound was obtained by reaction of selenoacetic amide (1.22 g, 10.0 mmol) with 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in EtOH (20 mL) following the procedure as described for **4a**.

Yield: 1.20 g (45%); yellow needles (EtOH); mp 136–137 °C.

IR (KBr): 741 (s), 851 (s), 1108 (s), 1319 (m), 1339 (s), 1503 (s), 1529 (m), 3115 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.83 (s, 3 H, Me), 8.03–8.28 (m, 4 H, ArH) 8.21 [s, 1 H, 5-H, ^2J (SeH) = 45.90 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 23.32 (Me), 122.32 (C-5), 124.19 (CH, Ar), 127.12 (CH, Ar), 141.16 (Ar), 146.96 (Ar), 153.21 (C-4), 172.82 (C-2).

^{77}Se NMR ($CDCl_3$, Me_2Se): δ = 767.07.

MS (EI, 70 eV): *m*/*z* (%) = 268 (M^+, 100), 266 (49), 227 (80), 197 (30), 181 (34), 169 (18), 101 (14), 89 (96), 76 (28), 64 (17), 51 (15), 28 (7).

Anal. Calcd for $C_{10}H_8N_2O_2Se$ (267.15): C, 44.96; H, 3.02; N, 10.49. Found: C, 44.79; H, 3.08; N, 10.51.

2-(2′-Methylpheny)-4-(4′-bromophenyl)-1,3-selenazole (4k)
This compound was obtained by reaction of 2-methylselenobenzoic amide (1.98 g, 10.0 mmol) and 4-bromophenacyl bromide (2.76 g, 10.0 mmol) in EtOH (50 mL) following the procedure as described for **4a**.

Yield: 3.60 g (95%); colorless prisms (EtOH–H_2O); mp 95–96 °C.

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 2.64 (s, 3 H, Me), 6.96–8.18 (m, 8 H, ArH), 8.19 (s, 1 H, 5-H, Hetar).

MS (EI, 70 eV): *m*/*z* (%) = 378 (M^+, 100).

Anal. Calcd for $C_{16}H_{12}NBrSe$ (377.15): C, 50.96; H, 3.21; N, 3.71. Found: C, 50.90; H, 3.40; N, 3.39.

2-(2′-Methylphenyl)-4-ethyl-1,3-selenazole (4l)
This compound was obtained by reaction of 2-methylselenobenzoic amide (2.97 g, 15.0 mmol) and 1-chlorobutan-2-one (1.60 g, 15.0 mmol) in EtOH (20 mL) following the procedure as described for **4a**. The product was dissolved in H_2O and filtered. Addition of NH_3 resulted in separation of a yellow oil which was distilled in vacuo (124–125 °C/0.02 torr).

Yield: 1.27 g (34%).

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 1.22 (t, 3 H, Me), 2.59 (s, 3 H, Me-Tol), 3.01–3.32 (q, 2 H, CH_2), 7.22–7.46 (m, 5 H, Ar, 5-H).

MS (EI, 70 eV): *m*/*z* (%) = 250 (M^+, 100).

Anal. Calcd for $C_{12}H_{13}NSe$ (250.21): C, 57.61; H, 5.24; N, 5.60. Found: C, 57.80; H, 5.30; N, 5.39.

2-Benzhydryl-4-phenyl-1,3-selenazole (4m)
This compound was obtained by reaction of diphenylselenoacetic amide (2.74 g, 10.0 mmol) and phenacyl bromide (1.99 g, 10.0 mmol) in EtOH (30 mL) following the procedure as described for **4a**.

Yield: 3.60 g (96%); yellow rods (EtOH); mp 148–149 °C.

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 4.57 (s, 1 H, CH), 7.08–7.99 (m, 15 H, Ar, 5-H).

MS (EI, 70 eV): *m*/*z* (%) = 374 (M^+, 100).

Anal. Calcd for $C_{22}H_{17}NSe$ (374.35): C, 70.58; H, 4.58; N, 3.74. Found: C, 70.0; H, 4.40; N, 3.67.

2-Benzhydryl-4-(4′-nitrophenyl)-1,3-selenazole (4n)
This compound was obtained by reaction of diphenylselenoacetic amide (2.74 g, 10.0 mmol) and 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in EtOH (30 mL) following the procedure as described for **4a**.

Yield: 4.10 g (98%); light yellow prisms (EtOH–DMF, 2:1); mp 187–188 °C.

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 5.82 (s, 1 H, CH), 7.10–8.38 (m, 14 H, ArH), 8.39 (s, 1 H, 5-H, Hetar).

MS (EI, 70 eV): *m*/*z* (%) = 420 (M^+, 100).

Anal. Calcd for $C_{22}H_{16}N_2Se$ (419.35): C, 63.02; H, 3.85; N, 6.68. Found: C, 63.04; H, 4.00; N, 6.64.

2-Benzhydryl-4,5-diphenyl-1,3-selenazole (4o)
This compound was obtained by reaction of diphenylselenoacetic amide (2.74 g, 10.0 mmol) with desyl bromide (2.75 g, 10.0 mmol) in EtOH (30 mL) following the procedure as described for **4a**.

Yield: 3.24 g (72%); colorless needles (EtOH–DMF, 2:1); mp 106.5–107 °C.

^{1}H NMR ($CDCl_3$, 100 MHz): δ = 5.77 (s, 1 H, CH), 7.12–7.54 (m, 20 H, ArH).

MS (EI, 70 eV): *m*/*z* (%) = 450 (M^+, 100).

Anal. Calcd for $C_{28}H_{21}NSe$ (450.45): C, 74.66; H, 4.70; N, 3.11. Found: C, 74.74; H, 4.80; N, 3.03.

2-(Naphth-1′-yl)-4-(4′-bromophenyl-1,3-selenazole (4p)
This compound was obtained by reaction of 1-naphthylselenocarboxylic amide (0.234 g, 1.0 mmol) and 4-bromophenacyl bromide (0.27 g, 1.0 mmol) in EtOH (20 mL) as described for **4a**.

Yield: 0.30 g (73%); colorless prisms (EtOH); mp 117–120 °C.

IR (KBr): 791 (s), 811 (m), 912 (s), 1005 (m), 1090 (s),1192 (m), 1235 (s) 1354 (w), 1415 (m), 1525 (s), 1615 (s), 3116 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 200 MHz): δ = 2.38 (s, 3 H, Me), 7.51–8.05 (m, 11 H, Ar) 8.22 [s, 1 H, Hetar, ^2J (SeH) = 48.0 Hz].

^{13}C NMR ($CDCl_3$, 50 MHz): δ = 120.03 (C-5), 121.85 (Ar), 125.08 (CH-Ar), 125.90 (CH-Ar), 126.46 (CH-Ar) 127.46 (CH-Ar), 128.28 (CH-Ar), 129.07 (CH-Ar), 129.74 (Ar), 130.59 CH-(Ar), 131.85 (CH-Ar), 133.28 (Ar), 134.09 (Ar), 134.35 (Ar), 155.63 (C-4, Hetar), 173.68 (C-2, Hetar).

Anal. Calcd for $C_{16}H_{13}NSe$ (413.18): C, 55.23; H, 2.93; N, 3.39. Found: C, 55.40; H, 3.09; N, 3.36.

Monoselenomalonic Amide (6)
To an EtOH solution (15 mL) of cyanoacetic amide (4.20 g, 50.0 mmol) was added NH_3 until pH 8 was attained. To the solution was added freshly prepared P_2Se_5 (9.12 g, 20.0 mmol). Subsequently, H_2O (3 mL) was added dropwise to the refluxing solution over 2 h. The solution was cooled and filtered. H_2O was added to the filtrate, which resulted in precipitation of **6**.

Yield: 3.88 g (47%); brown needles (EtOH); mp 119.5–121 °C.

IR (KBr): 705 (m), 852 (m), 920 (m), 1098 (m), 1301 (s), 1399 (m), 1652 (s), 1995 (s), 3121 (m).

MS (EI, 70 eV): *m*/*z* (%) = 165 (M^+, 100).

Anal. Calcd for $C_3H_6N_2OSe$ (165.05): C, 21.83; H, 3.66; N, 16.97. Found: C, 21.81; H, 3.52; N, 21.97.

(4′-Phenyloxazolyl-2′-yl)-4-phenylselenazolyl-2-methane (7)
A mixture of monoselenomalonic amide (0.33 g, 2.0 mmol) and phenacyl bromide (0.8 g, 4.0 mmol) in EtOH (15 mL) was stirred for 20 min with evolution of heat. After cooling with ice, a crystalline product formed, which was was filtered off and recrystallized (EtOH) to give **7**.

Yield: 0.35 g (48%); colorless lamella; mp 197 °C.

IR (KBr): 699 (m), 725 (m), 776 (m), 901 (w), 1027 (m), 1124 (m), 1310 (w), 1426 (m), 1506 (m), 3196 (m) cm^{-1}.

^1H NMR (DMSO-d_6, 200 MHz): δ = 4.34 (s, 2 H, CH_2), 7.27–7.70 (m, 12 H, Ar, 2 × 5-H, Hetar).

MS (EI, 70 eV): *m*/*z* (%) = 366 (M^+, 100).

Anal. Calcd for $C_{19}H_{14}N_2OSe$: (365.29): C, 62.47; H, 3.86; N, 7.67. Found: C, 62.41; H, 3.91; N, 7.71.

Diselenomalonic Amide (9a)
Malonic dinitrile (2.20 g, 33.0 mmol) was dissolved in pyridine (35 mL). To the solution was added freshly prepared P_2Se_5 (36.4 g, 80.0 mmol) and H_2O (12 mL) in a Soxhelet tube. The mixture was shaken for 3 h. H_2O was added to the solution which resulted in precipitation of a yellow solid. The crude product was dried (desiccator, P_2O_5) and was recrystallized from EtOH to give **9a**.

Yield: 3.93 g (52%); yellow prisms; mp 97 °C (decomp.).

IR (KBr): 630 (m), 890 (m), 965 (s), 995 (m), 291 (s) 1365 (m), 1456 (s), 1650 (s) cm^{-1}.

MS (CI): *m*/*z* (%) = 229 (M^+, 100).

Anal. Calcd for $C_3H_6N_2Se_2$ (228.01): C, 15.80; H, 2.65; N, 12.28. Found: C, 15.75; H, 2.60; N, 12.44.

Diselenosuccinic Amide (9b)
Succinic dinitrile (3.20 g, 40.0 mmol) was dissolved in EtOH (10 mL). To the solution was added freshly prepared P_2Se_5 (9.12 g, 20.0 mmol). H_2O (5 mL) was added dropwise to the refluxing solution over 2.5 h. The hot solution was filtered. After cooling, the solution was again filtered and H_2O was added to the filtrate, which resulted in precipitation of **9b**. The product was dried (desiccator, P_2O_5).

Yield: 1.20 g (12%); yellow prisms; the product decomposed during recrystallization from EtOH, so therefore the mp is not reported.

IR (KBr): 1165 (m), 1475 (s), 1620 (s) cm^{-1}.

MS (CI): *m*/*z* (%) = 243 (M^+, 100).

Anal. Calcd for $C_4H_8N_2Se_2$ (242.04): C, 19.85; H, 3.33; N, 11.57. Found: C, 19.90; H, 3.42; N, 11.65.

Diselenoadipic Amide (9c)
This compound was obtained by reaction of adipic dinitrile (4.30 g, 40.0 mmol) with freshly prepared P_2Se_5 (9.12 g, 20.0 mmol) as described for **9a**.

Yield: 1.60 g (16%); yellow prisms; the product decomposed during recrystallization from EtOH, so therefore the mp is not reported.

IR (KBr): 1135 (m), 1355 (m) 1475 (s), 1655 (s) cm^{-1}.

MS (CI): *m*/*z* (%) = 268 (M^+, 100).

Anal. Calcd for $C_6H_{12}N_2Se_2$ (270.09): C, 26.68; H, 4.48; N, 10.37. Found: C, 26.50; H, 4.50; N, 10.10.

Bis(4-phenylselenazol-2-yl)methane (10a)
This compound was obtained by reaction of diselenomalonic amide (0.45 g, 2.0 mmol) and phenacyl bromide (0.80 g, 4.0 mmol) in EtOH (20 mL) as described for **7**.

Yield: 0.488 g (57%); yellow needles (EtOH); mp 107 °C.

IR (KBr): 725 (s), 770 (s), 795 (m), 815 (s), 1021 (m), 1071 (m), 1121 (m), 1305 (w), 1401 (w), 1431 (m), 1511 (s) cm^{-1}.

^1H NMR ($CDCl_3$, 100 MHz): δ = 4.99 (s, 2 H, CH_2), 7.00–8.25 (m, 12 H, Ar, 5-H).

1,2-Bis(4-phenylselenazol-2-yl)ethane (10b)
This compound was obtained by reaction of diselenosuccinic amide (0.24 g, 1.0 mmol) and phenacyl bromide (0.40 g, 2.0 mmol) in EtOH (10 mL) as described for **7**.

Yield: 0.06 g (13%); colorless needles (EtOH); mp 130.5–132 °C.

IR (KBr): 935 (w), 1030 (m), 1191 (m), 1290 (m), 1445 (m), 3080 (w), 3120 (w) cm^{-1}.

^1H NMR ($CDCl_3$, 100 MHz): δ = 3.62–3.65 (m, 4 H, CH_2), 7.29–7.86 (m, 12 H, ArH and 5-H).

MS (EI, 70 eV): *m*/*z* (%) = 442 (M^+, 55).

Anal. Calcd for $C_{20}H_{16}N_2Se_2$ (442.28): C, 54.31; H, 3.64; N, 6.33. Found: C, 54.22; H, 3.74; N, 5.95.

1,4-Bis(4-phenylselenazol-2-yl)butane (10c)
This compound was obtained by reaction of diselenoadipic amide (0.27 g, 1.0 mmol) and phenacyl bromide (0.40 g, 2.0 mmol) in EtOH (20 mL) as described for **7**.

Yield: 0.10 g (21%); light brown needles (EtOH); mp 108–110 °C.

IR (KBr): 835 (s), 920 (w), 1036 (m), 1080 (w), 1101 (w), 1190 (w), 1285 (w), 1325 (w), 1445 (m), 1525 (s), 3030 (w), 3081 (w), 3118 (w) cm^{-1}.

^1H NMR (DMSO-d_6, 100 MHz): δ = 1.92 (m, 4 H, 2 CH_2), 3.13 (m, 4 H, 2 CH_2), 7.38–7.94 (m, 10 H, Ar), 8.50 (s, 2 H, 5-H).

MS (EI, 70 eV): *m*/*z* = 470 (M^+, 42), 392 (21), 250 (91), 236 (77), 234 (44), 224 (28), 182 (68), 102 (100), 77 (9), 28 (3).

Anal. Calcd for $C_{22}H_{20}N_2Se_2$ (470.33): C, 56.18; H, 4.29; N, 5.96. Found: C, 56.25; H, 4.31; N, 6.10.

Selenourea (12)[18]
Cyanamide (4.10 g, 100.0 mmol) was dissolved in H_2O (20 mL). To the refluxing solution was added freshly prepared P_2Se_5 (9.12 g, 20.0 mmol) in small portions over 3 h. The solution was subsequently refluxed for 1 h. The solution was cooled to give a precipitate. The precipitate was filtered off, recrystallized from H_2O and dried (desiccator, P_4O_{10}) to give **12**.

Yield: 4.50 g (37%); colorless needles; mp 204–206 °C.

IR (KBr): 1110 (w), 1415 (w), 1495 (s), 1630 (s) cm^{-1}.

Anal. Calcd for CH_4N_2Se (123.02): C, 9.76; H, 3.28; N, 22.77. Found: C, 9.81; H, 3.32; N, 22.67.

2-Amino-5-phenyl-1,3-selenazole (13a)
Method A
An EtOH solution (30 mL) of selenourea (1.23 g, 10.0 mmol) and phenacyl bromide (1.99 g, 10.0 mmol) was briefly refluxed and the hot solution was filtered. After cooling of the filtrate to 20 °C, aq NH_3 (2 mL, concd) and, subsequently, H_2O (20 mL) were added. A precipitate formed, which was recrystallized from EtOH–H_2O to give **13a**.

Yield: 1.94 g (87%); colorless needles; mp 131–132 °C.

IR (KBr): 825 (s), 900 (m), 1198 (m), 1325 (s), 1571 (s), 1608 (s), 1665 (s), 3130 (m), 3376 (m), 3478 (m) cm^{-1}.

^1H NMR (DMSO-d_6, 300 MHz): δ = 7.41–7.69 (m, 6 H, Ar, 1 H, 5-H), 9.00 (s, br, 2 H, NH_2).

^{13}C NMR (DMSO-d_6, 75 MHz): δ = 126.02, 129.13, 129.27, 130.12, 139.29, 174.22, 201.14.

^{77}Se NMR (DMSO-d_6, 60% Me_2Se in $CDCl_3$): δ = 556.40.

MS (70 eV): *m*/*z* (%) = 224 (M^+, 86), 182 (82), 102 (100), 80 (19), 77 (14), 51 (13), 28 (26).

UV (EtOH): λ_{max} (log ε) = 235 (4.36), 289 nm (3.82).

Anal. Calcd for $C_9H_8N_2Se$ (223.14): C, 48.45; H, 3.61; N, 12.55. Found: C, 48.51; H, 3.72; N, 12.62.

Method B

2-Benzoylamino-4-phenyl-1,3-selenazole **15a** (3.27 g, 10.0 mmol) was refluxed in aq H_2SO_4 (68%, 60 mL) for 30 min. The benzoic acid was removed by steam distillation. After cooling, the solution was poured into H_2O (200 mL) and was neutralized by addition of aq NaOH (10%). The precipitated product was filtered off and recrystallized from C_6H_6 to give **13a**.

Yield: 1.83 g (84%); colorless needles; mp 132 °C.

2-Amino-4-tolyl-1,3-selenazole (13b
Method A

A mixture of selenourea (1.23 g, 10.0 mmol) and 4-methylphenacyl bromide (2.13 g, 10.0 mmol) in EtOH (50 mL) was refluxed for 5 min. The hot solution was filtered. After cooling, a solution of NH_3 (5 mL, concd) was added to the filtrate to give a crystalline precipitate. The precipitate was filtered, washed with H_2O and recrystallized (EtOH) to give **13b**.

Yield: 1.99 g (84%); colorless needles (EtOH); mp 168 °C.

IR (KBr): 688 (m), 726 (s), 823 (s), 1028 (s), 1185 (m), 1285 (m), 1300 (s), 1321 (s), 1494 (m), 1521 (s), 1522 (s), 1556 (s), 1599 (s), 1646 (m), 3029 (m), 3108 (m) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.35 (s, 3 H, Me), 5.49 (br s, 2 H, NH_2), 7.15–7.67 (m, 4 H, Ar), 7.21 [s, 1 H, 5-H, ^2J (SeH) = 50.30 Hz].

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 20.71 (Me), 107.23 {C-5, ^1J [(C-5)Se] = 97.11 Hz}, 126.24 (Ar), 129.25 (Ar), 132.85 (Ar), 137.30 (Ar), 152.08 (C-4), 168.89 {C-2, ^1J [(C-2)Se] = 126.70 Hz}.

^{77}Se ($CDCl_3$, Me_2Se): δ = 591.28.

MS (EI, 70 eV): *m*/*z* (%) = 238 (M^+, 100), 236 (44), 196 (71), 194 (37), 116 (46), 114 (91), 91 (15), 77 (3), 64 (12), 51 (6), 28 (36).

UV (EtOH): λ_{max} (log ε) = 238 (4.38), 289 nm (3.90).

Anal. Calcd for $C_{10}H_{10}N_2Se$: (237.16): C, 50.64; H, 4.25; N, 11.81. Found: C, 50.68; H, 4.31; N, 11.76.

Method B

2-Benzoylamino-4-tolyl-1,3-selenazole **15b** (3.77 g, 10.0 mmol) was refluxed in aq H_3PO_4 (85%, 60 mL) for 2 h. The work up was carried out as described for **13a** (Method B).

Yield: 1.21 g (51%); colorless needles (EtOH); mp 168 °C.

2-Amino-4′-bromophenyl-1,3-selenazole (13c)
Method A

A mixture of selenourea (1.23 g, 10.0 mmol) and 4-bromophenacyl bromide (2.76 g, 10.0 mmol) in EtOH (60 mL) was refluxed for 10 min. After cooling, aq NH_3 (5 mL, concd) and H_2O (20 mL) were added. The precipitated product was filtered off and recrystallized from C_6H_5 to give **13c**.

Yield: 2.84 g (94%); colorless needles; mp 175 °C.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 5.40 (br s, 2 H, NH_2), 7.30–7.87 (m, 4 H, ArH), 7.21 [s, 1 H, 5-H, ^2J (SeH) 48.30 Hz].

MS (EI, 70 eV): *m*/*z* (%) = 302/304 (M^+, 100), 260/262 (40), 180/182 (24), 111 (9), 101 (20), 89 (12), 78/80 (12), 51 (6).

UV (EtOH): λ_{max} (log ε) = 300 (3.92), 345 nm (4.39).

Anal. Calcd for $C_9H_7N_2BrSe$ (302.03): C, 35.79; H, 2.34; N, 9.28. Found: C, 35.88; H, 2.31; N, 9.29.

Method B

A mixture of 2-benzoylamino-4-(4′-bromophenyl)-1,3-selenazole **15c** (4.06 g, 10.0 mmol) was refluxed in aq H_2SO_4 (68%, 60 mL) for 1.5 h. The work up was carried out as described for **13a** (Method B).

Yield: 2.77 g (91%); colorless needles; mp 175 °C.

2-Amino-4-(4-nitrophenyl)-1,3-selenazole (13d)
Method A

This compound was obtained by reaction of selenourea (1.23 g, 10.0 mmol) with 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in EtOH (60 mL) following the procedure as described for **13a**.

Yield: 2.44 g (91%); brown rods (HOAc); mp 250 °C.

IR (KBr): 729 (m), 1300 (s),1550 (s), 1650 (s) cm^{-1}.

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 5.31 (br s, 2 H, NH_2), 7.15–7.77 (m, 4 H, ArH), 7.21 [s, 1 H, 5-H, ^2J (SeH) = 48.60 Hz].

^{13}C NMR (DMSO-d_6, 75 MHz): δ = 111.37 (C-5), 124.09 (CH, Ar), 126.86 (CH, Ar), 136.08 (Ar), 139.02 (Ar), 146.82 (C-4), 173.00 (C-2).

MS (70 eV): *m*/*z* (%) = 269 (M^+, 100), 239 (7), 226 (26), 197 (14), 181 (12), 142 (5), 117 (4), 101 (6), 89 (54), 77 (6), 75 (10), 51 (6).

UV (EtOH): λ_{max} (log ε) = 266 (4.04), 361 nm (4.02).

Anal. Calcd for $C_9H_7N_3O_2Se$ (268.13): C, 40.32; H, 2.63; N, 15.67. Found: C, 40.38; H, 2.61; N, 15.74.

Method B

A mixture of 2-benzoylamino-4-(4′-nitrophenyl)-1,3-selenazole **15d** (3.72 g, 10.0 mmol) was refluxed in aq H_2SO_4 (70%, 75 mL) for 2 h. The work up was carried out as described for **13a** (Method B). The crude product was treated with hot EtOH and was recrystallized (HOAc) to give **13d**.

Yield: 2.66 g (99%); brown rods; mp 250 °C.

2-Amino-4,5-diphenyl-1,3-selenazole (13e)
Method A

A mixture of selenourea (1.23 g, 10.0 mmol) and desyl bromide (2.75 g, 10.0 mmol) in EtOH (50 mL) was refluxed for 30 min. After cooling with ice, a crystalline precipitate was formed. The precipitate was filtered off and washed with Et_2O. The free base of **13e** was obtained by addition of aq NH_3 (concd) to an ethanolic solution of the hydrobromide.

Yield: 2.02 g (68%); colorless needles (EtOH); mp 199–201 °C.

^{1}H NMR (DMSO-d_6, 200 MHz): δ = 7.12–7.38 (m, 10 H, Ar).

^{13}C NMR (DMSO-d_6, 50 MHz): δ = 124.28 (C-5), 126.65 (CH, Ar), 127.05 (CH, Ar), 127.90 (CH, Ar), 128.57 CH, Ar), 128.85 (CH, Ar), 129.22 (CH, Ar), 135.08 (Ar), 136.08 (Ar), 145.70 (C-4), 167.13 (C-2).

MS (EI, 70 eV): *m*/*z* (%) = 300 (M^+, 100), 258 (22), 220 (8), 193 (6), 178 (78), 152 (7), 128 (4), 110 (3), 89 (6), 51 (2).

UV (EtOH): λ_{max} (log ε) = 241 (4.29), 329 nm (3.91).

Anal. Calcd for $C_{15}H_{12}N_2Se$ (299.23): C, 60.21; H, 4.04; N, 9.36. Found: C, 60.21; H, 4.31; N, 9.46.

Method B

A mixture of 2-benzoylamino-4,5-diphenyl-1,3-selenazole **15e** (3.72 g, 10.0 mmol) was refluxed in aq H_2SO_4 (68%, 60 mL) for 2 h. The work up was carried out as described for **13a** (Method B).

Yield: 2.84 g (95%); colorless rods (EtOH); mp 199–201 °C.

2-Benzoylamino-4-phenyl-1,3-selenazole (15a)
A mixture of benzoylselenourea (2.30 g, 10.0 mmol) and phenacyl bromide (1.99 g, 10.0 mmol) in acetone (20 mL) was refluxed for 20 min. After cooling to 20 °C, aq NH_3 (4 mL, concd) was added to give a crystalline precipitate. The precipitate was recrystallized from EtOH to give **15a**.

Yield: 3.23 g (99%); colorless needles; mp 165.5 °C.

IR (KBr): 901 (w), 1030 (w), 1066 (w), 1089 (w), 1198 (w), 1305 (s), 1575 (s), 1685 (s), 3080 (w) cm^{-1}.

^1H NMR ($CDCl_3$, 200 MHz): δ = 2.17 (s, 1 H, NH), 7.31–7.78 (m, 10 H, Ar), 7.82 [s, 1 H, 5-H, ^2J(SeH) = 47 Hz].

^{13}C NMR ($CDCl_3$, 50 MHz): δ = 113.26 (5-C, Hetar), 126.22 (CH, Ar), 127.30 (CH, Ar), 127.71 (CH, Ar), 128.58 (CH, Ar), 128.73 (CH, Ar), 131.78, 132.72, 135.23, 150.61, 160.75 (C), 165.41 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 328 (M^+, 34), 326 (17), 182 (6), 105 (100), 77 (75), 51 (16), 28 (2).

UV (EtOH): λ_{max} (log ε) = 241 (4.43), 276 (4.23), 317 nm (3.92).

Anal. Calcd for $C_{16}H_{12}N_2OSe$ (327.23): C, 58.73; H, 3.70; N, 8.56. Found: C, 58.81; H, 3.82; N, 8.72.

2-Benzoylamino-4-tolyl-1,3-selenazole (15b)
A mixture of benzoylselenourea (2.30 g, 10.0 mmol) and 4-methylphenacyl bromide (2.13 g, 10.0 mmol) in acetone (20 mL) was refluxed for 20 min. The work-up was carried out following the procedure as given for **15a**.

Yield: 3.00 g (88%); colorless lamella (EtOH); mp 186–187 °C.

IR (KBr): 721 (s), 1300 (s), 1563 (s), 1617 (w) cm^{-1}.

MS (EI, 70 eV): *m*/*z* (%) = 342 (M^+, 100).

UV (EtOH, nm): λ_{max} (log ε) = 244 (4.39), 273 (4.25), 322 nm (3.85).

Anal. Calcd for $C_{17}H_{14}N_2OSe$ (341.27): C, 59.83; H, 4.13; N, 8.21. Found: C, 58.81; H, 4.22; N, 8.22.

2-Benzoylamino-4-(4′-bromophenyl)-1,3-selenazole (15c)
A mixture of benzoylselenourea (2.30 g, 10.0 mmol) and of 4-bromophenacyl bromide (2.78 g, 10.0 mmol) in acetone (20 mL) was refluxed for 20 min. The work-up was carried out following the procedure as described for **15a**.

Yield: 3.89 g (96%); colorless lamella (BuOH); mp 231 °C.

MS (EI, 70 eV): *m*/*z* (%) = 406 (M^+, 100).

UV (EtOH, nm): λ_{max} (log ε) = 246 (4.42), 283 (4.34), 320 nm (3.87).

Anal. Calcd for $C_{16}H_{11}N_2BrOSe$ (406.14): C, 47.32; H, 2.73; N, 6.90. Found: C, 47.31; H, 2.72; N, 6.92.

2-Benzoylamino-4-(4′-nitrophenyl)-1,3-selenazole (15d)
A mixture of benzoylselenourea (2.30 g, 10.0 mmol) and 4-nitrophenacyl bromide (2.44 g, 10.0 mmol) in acetone (20 mL) was refluxed for 20 min. The work-up was carried out following the procedure as described for **15a**.

Yield: 3.27 g (88%); colorless lamella (BuOH); mp 239 °C.

IR (KBr): 721 (s), 1313 (s), 1516 (s), 1605 (s), 1671 (s) cm^{-1}.

MS (EI, 70 eV): *m*/*z* (%) = 372 (M^+, 100).

UV (EtOH): λ_{max} (log ε) = 233 (4.39), 260 (4.14), 330 nm (3.62).

Anal. Calcd for $C_{16}H_{11}N_3O_3Se$ (372.24): C, 51.63; H, 2.98; N, 11.29. Found: C, 51.61; H, 2.92; N, 11.22.

2-Benzoylamino-4,5-diphenyl-1,3-selenazole (15e)
A mixture of benzoylselenourea (2.30 g, 10.0 mmol) and desyl bromide (2.75 g, 10.0 mmol) in acetone (20 mL) was refluxed for 20 min. The work-up was carried out as described for **15a**.

Yield: 3.63 g (90%); colorless prisms (EtOH); mp 170 °C.

Anal. Calcd for $C_{22}H_{16}N_2OSe$ (403.34): C, 65.51; H, 4.00; N, 6.95. Found: C, 65.61; H, 3.99; N, 6.92.

2-Amino-4-imino-4,5-dihydro-1,3-selenazole Hydrochloride (16)
Selenourea (0.98 g, 8.0 mmol) was dissolved in hot EtOH (30 mL). An EtOH solution of chloroacetonitrile (0.60 g, 8.0 mol) was neutralized with pyridine and the solution was added dropwise, and the mixture was refluxed for 5 min. After cooling, a colorless precipitate formed which was filtered off to give **16**.

Yield: 0.90 g (56%); colorless prisms (EtOH–Et_2O); mp 198.5 °C.

^1H NMR (DMSO-d_6, 200 MHz): δ = 4.57 (s, 2 H, 5-CH_2), 9.90 (s, 2 H, NH_2), 10.44 (br s, 2 H, =NH_2^+).

^{13}C NMR (DMSO-d_6, 50 MHz): δ = 35.13 (CH_2), 183.92 (C-4), 184.54 (C-2).

MS (EI, 70 eV): *m*/*z* (%) = 162 (M^+, 38).

Anal. Calcd for $C_3H_6N_3ClSe$ (198.51): C, 18.15; H, 3.04; N, 21.17. Found: C, 18.21; H, 3.01; N, 20.91.

2-Hydrazino-4,5-diphenyl-1,3-selenazole (18)
To a solution of selenosemicarbazide (1.38 g, 10.0 mmol) was added EtONa [prepared from sodium (0.46 g) and EtOH (20 mL). A solution of desyl bromide (2.75 g, 10.0 mmol) in anhyd EtOH (20 mL) was added dropwise within 30 min at 20 °C with stirring. The solution was subsequently allowed to stand at 20 °C for 1 h. The precipitated product was filtered off and recrystallized (EtOH) to give **18**.

Yield: 2.20 g (70%); colorless needles (EtOH); mp 199–200 °C.

^1H NMR ($CDCl_3$, 300 MHz): δ = 7.05–7.48 (m, 10 H, Ar).

MS (EI, 70 eV): *m*/*z* (%) = 315 (M^+, 25), 298 (8), 282 (4), 258 (8), 218 (14), 206 (8), 190 (4), 178 (100), 152 (10), 126 (3), 105 (6), 86 (24), 63 (9), 51 (19).

Anal. Calcd for $C_{15}H_{13}N_3Se$ (314.25): C, 57.33; H, 4.17; N, 13.37. Found: C, 57.21; H, 4.31; N, 13.36.

Acknowledgement

Financial support from the Deutsche Forschungsgemeinschaft (Heisenberg-scholarship for P. L.) is gratefully acknowledged.

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