The Pyridylseleno Group in Organic Synthesis. Part 5.[1] Amidoseleniation of Alkenes

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The reaction of β-methoxyalkyl 2-pyridyl selenides with acetonitrile in the presence of trifluoromethanesulphonic acid and water affords β-acetamidoalkyl 2-pyridyl selenides in good to excellent yields. This reaction has been used in the two-step amidoseleniation of electron-rich alkenes such as styrene and buta-1,3-dienes, and of tri- or tetra-substituted alkenes, previously reported as being resistant to amidoseleniation.

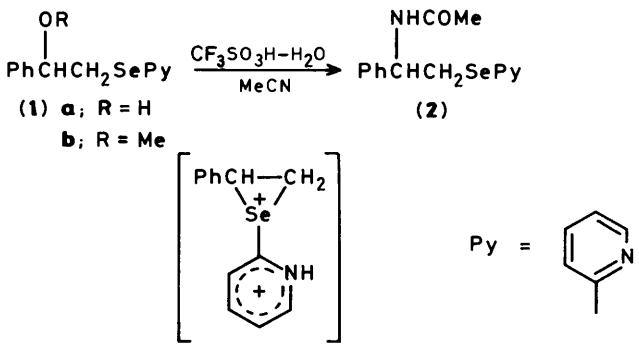
We have already reported a Ritter-type amide synthesis which affords β-amidoalkyl phenyl selenides by the reaction of alkenes with benzeneselenenyl chloride in acetonitrile in the presence of trifluoromethanesulphonic acid and water.[2,3] Subsequently, we reported the improved procedure[4] which used β-hydroxyalkyl phenyl selenides as starting materials and which overcame some of the limitations of the previously reported procedure. In spite of this, the amidoseleniation of electron-rich alkenes such as butadienes and tri- or tetra-substituted alkenes was not successful. We attributed this failure to the very effective stabilization of the episelenonium ion intermediate† by the electron-donating substituents and argued that the use of the 2-pyridylseleno group instead of the previously used phenylseleno group should increase the reactivity of the episelenonium ion.

When β-hydroxy- or β-methoxy-alkyl 2-pyridyl selenides were prepared from electron-rich alkenes and were treated with acetonitrile in the presence of trifluoromethanesulphonic acid (and water), β-acetamidoalkyl 2-pyridyl selenides were produced in good to excellent yields. In addition to the expected 1,2-addition (amidoseleniation) products, 1,4-addition products were obtained from 3-methoxy-4-(2-pyridylseleno)but-1-ene derivatives. The allylic selenide structure in these 1,4-addition products were capable of undergoing further 2,3-sigmatropic rearrangements[6] in order to introduce other nitrogen or oxygen functional groups.

The results obtained here clearly show another example of the usefulness of the 2-pyridylseleno group in organic synthesis.

Results and Discussion

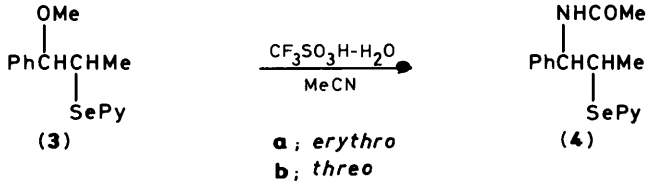
1-Phenyl-2-(2-pyridylseleno)ethanol (**1a**) was prepared in moderate yield from styrene oxide, 2,2′-dipyridyl diselenide, and sodium borohydride by a reported procedure.[7] Reaction of (**1a**) with acetonitrile (also the solvent) in the presence of trifluoromethanesulphonic acid and water (2 equiv. each) at reflux temperature for 1 h afforded *N*-[1-phenyl-2-(2-pyridylseleno)-ethyl]acetamide (**2**) in 91% isolated yield (Scheme 1). However, when the amount of the acid and water was reduced to 1 equiv., the yield of (**2**) was unsatisfactory (Table 1). These results suggest the protonation of both oxygen (in alcohol) and nitrogen (in pyridine) atoms to produce a highly electrophilic episelenonium ion intermediate as depicted in Scheme 1. We tried the use of methoxy substituted (**1b**) as the starting material instead of (**1a**), as (**1b**) can be prepared quantitatively from styrene and pyridine-2-selenenyl bromide in methanol.[1] Although a longer reaction time was required, (**2**) was produced from (**1b**) in comparable yields to



Scheme 1.

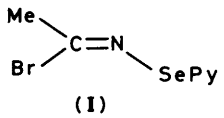
those from (**1a**). Typical results are summarized in Table 1; *cf.* the yields of the phenylseleno analogue of (**2**) [*N*-(1-phenyl-2-phenylselenoethyl)acetamide] (36—45%) using the initially reported[2,3] and subsequently improved[4,8] procedures. This difference indicates that the 2-pyridylseleno group is superior to the phenylseleno group for the introduction of the acetamide group to a carbon framework bearing electron-donating substituents.

The direct reaction of pyridine-2-selenenyl bromide with styrene in acetonitrile for the preparation of (**2**) was unsuccessful owing to the formation of an addition product between pyridine-2-selenenyl bromide and acetonitrile.‡



Scheme 2.

‡ Several attempted reactions of (**I**) with alkenes resulted in failure.



(**I**)

Spectral data of (**I**) are as follows; m.p. 164.5—165 °C (decomp.) (Found: C, 30.75; H, 2.5; N, 10.35. $C_7H_7BrN_2Se$ requires C, 30.25; H, 2.55; N, 10.1%); $\nu_{max.}$(KBr disc) 3 100, 3 020, 1 626, 1 599, 1 448, 1 370, 776, 721, and 711 cm^{-1}; δ_H(100 MHz; D_2O) 3.25 (3 H, s), 7.67 (1 H, dt, *J* 1.5 and 6 Hz), 8.01 (1 H, dt, *J* 1.5 and 7 Hz), 8.38 (1 H, br d, *J ca.* 8 Hz), and 8.85 (1 H, br d, *J ca.* 7 Hz).

† It has been reported that an excessive stabilization of a carbonium ion can inhibit the alkylation of nitriles.[5]

Table 1. Reaction conditions for conversion of (**1**) into (**2**)[a]

Starting material	CF_3SO_3H (mmol)	H_2O (mmol)	Temp. (°C)	Time (h)	Yield (**2**) (%)[b]
(**1a**)	2	2	Reflux	1	91
(**1a**)	1	1	Reflux	1	29
(**1a**)	2	10	Reflux	44	46
(**1a**)	2	2	25	100	86
(**1b**)	2	2	Reflux	8	83
(**1b**)	3	3	Reflux	10	87

[a] Carried out using (**1**) (1 mmol) in acetonitrile (3 ml). [b] Isolated yield by column chromatography.

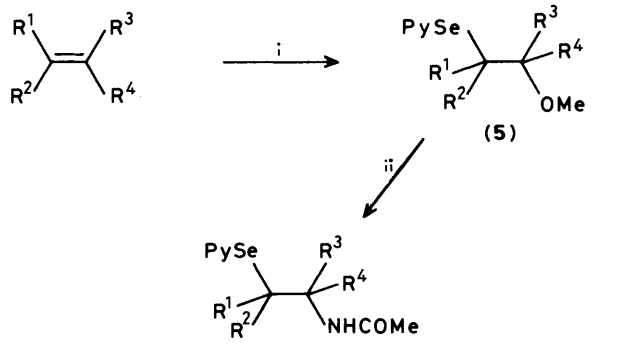
Table 2. Yield and stereochemistry of the conversion of (**3**) into (**4**)[a]

Starting material	CF_3SO_3H (mmol)	H_2O (mmol)	Temp. (°C)	Time (h)	Product(s)	Yield (ratio)[b] %
(**3a**)	3	3	25	24	(**4a**)	69
(**3b**)	3	3	25	24	(**4b**)	33
(**3b**)	3	3	Reflux	3	(**4a**) + (**4b**)	77 (78:22)
(**3b**)	10	10	25	36	(**4b**)	74

[a] Carried out using (**3**) (1 mmol) in acetonitrile (3 ml). [b] Isolated by column chromatography.

We prepared *erythro*- and *threo*-1-methoxy-1-phenyl-2-(2-pyridylseleno)propane (**3a**) and (**3b**)* and tried the substitution of the methoxy group by the acetamide group. While (**4a**) was obtained in a good yield by the reaction of (**3a**) (*erythro* isomer) with acetonitrile in the presence of 3 equiv. of the acid and water at 25 °C, the yield of (**4b**) from (**3b**) (*threo* isomer) was not satisfactory under the same conditions. When this reaction was carried out at reflux temperature, (**3b**) afforded a mixture of stereoisomers (**4a**) and (**4b**). By the addition of 10 equiv. of the acid and water at room temperature, (**4b**) was produced selectively from (**3b**) in good yield (Scheme 2, Table 2).

The two-step amidoseleniation of alkenes described thus far was applied to tri- and tetra-substituted alkenes. Markovnikov-type oxyseleniation products (**5a**) and (**5b**) were regioselectively

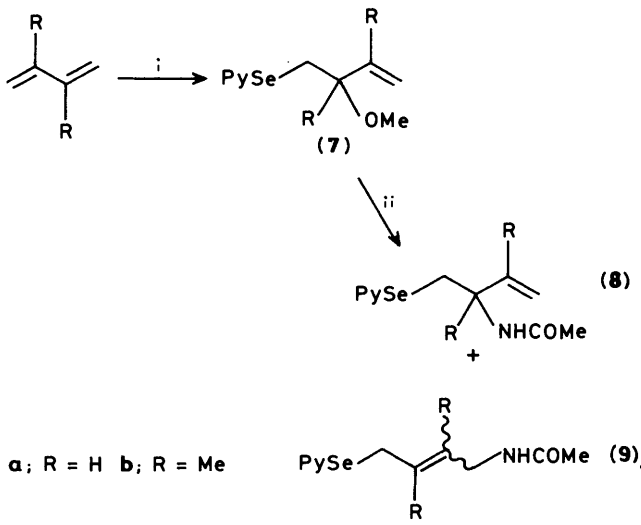


a; R^1 = H, R^2 = R^3 = R^4 = Me; 48 h, 60%
b; R^1, R^3 = $-(CH_2)_4-$, R^2 = H, R^4 = Me; 1 h, 44%
c; R^1 = R^2 = R^3 = R^4 = Me; 48 h, 54%

Scheme 3. *Reagents:* i, PySeBr–MeOH;[1] ii, CF_3SO_3H–water (3 equiv.)–MeCN, 25 °C

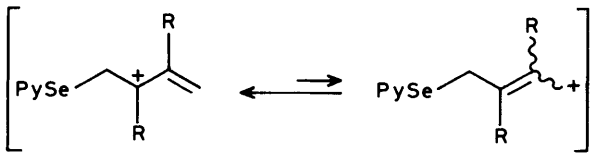
* Compound (**3a**) was prepared selectively from (*E*)-β-methylstyrene by oxyseleniation using pyridine-2-selenenyl bromide in methanol. Compound (**3b**) was isolated by column chromatography from a mixture of (**3b**) and (**3a**) which was obtained from a mixture of (*Z*)- and (*E*)-β-methylstyrene.

converted into the corresponding amidoseleniation products (**6a**) and (**6b**) in 44—60% yield (Scheme 3). Regioisomers of (**6a**) and (**6b**) were not detected by t.l.c. and n.m.r. spectroscopy. 2,3-Dimethylbut-2-ene was also converted to (**6c**) in 54% yield. Amidoseleniation of 1,3-dienes was also realized by this methodology. The initial step, oxyseleniation of buta-1,3-diene and 2,3-dimethylbuta-1,3-diene, afforded 1,2-addition products (**7a**) and (**7b**) in good to quantitative yields. Reaction of (**7a**) with acetonitrile in the presence of the acid and water (3 equiv.) at reflux for 1 h produced a mixture of (**8a**) and (**9a**) in a yield of 78% (67:33). The coupling constants in the n.m.r. signals of the vinylic protons confirmed that (**9a**) was present only as the trans isomer. As the ratio (**8a**):(**9a**) was largely unaffected by increased reaction time (24 h: 63:37), we supposed the allylic cation shown in Scheme 4 to be the intermediate in this reaction.



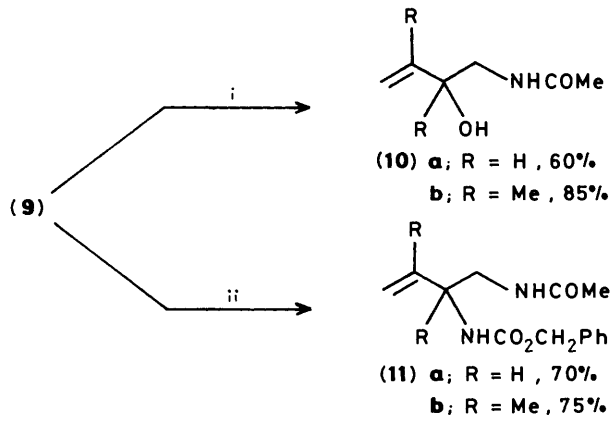
Scheme 4. *Reagents:* i, PySeBr–MeOH, 25 °C; ii, CF_3SO_3H–water (3 equiv.)–MeCN

When the dimethyl substituted selenide (**7b**) was used as the starting material, the reaction proceeded at 25 °C to afford only the rearranged product (**9b**). In contrast with (**9a**), (**9b**) consisted of *trans*- and *cis*-isomers, the ratio being *ca.* 1. These isomer distributions seem to reflect the thermodynamic stability. The



two-step amidoseleniation reactions using the 2-pyridylseleno group should complement the previously reported phenylseleno procedures,[2–4] as the latter were not suitable for the preparation of phenylseleno analogues of (**6**), (**8**), and (**9**).

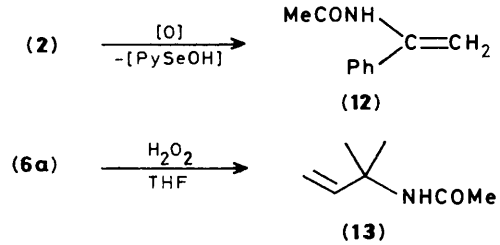
It has been reported that [2,3]-sigmatropic rearrangements of allylic selenoxides or *N*-substituted selenoimides proceed spontaneously to afford, ultimately, allylic alcohols[6a–d] or *N*-substituted allylic amines.[6e] The allylic selenide (**9**) was subjected to these reactions in order to introduce other oxygen or nitrogen functional groups. Reaction of (**9**) with hydrogen peroxide under reported conditions afforded the amino alcohol derivatives (**10a**) and (**10b**) in good to excellent yields (Scheme 5). Thus, selective introduction of nitrogen and oxygen functional groups into 1- and 2-positions of 1,3-dienes was realized



Scheme 5. *Reagents:* i, (**9**) (1 mmol)–H_2O_2(3 mmol)–pyridine (3 mmol)–CH_2Cl_2(5 ml); at 0 °C, 0.5 h; 25 °C, 1 h; ii, (**9**) (1 mmol)–$NH_2CO_2CH_2Ph$ (3 mmol)–Et_3N (6 mmol)–NCS (3 mmol)–MeOH(1.2 ml); at 0 °C, 0.5 h; 25 °C, 1 h

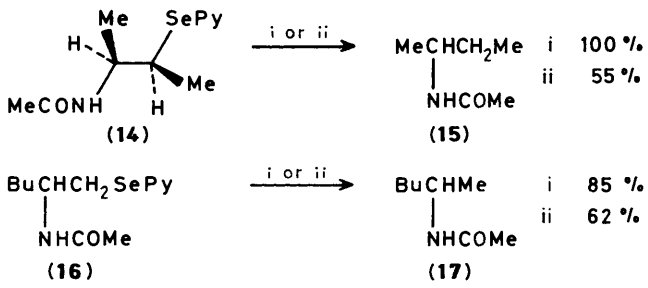
by the use of the amidoseleniation reaction. Similar oxidation of (**9**) using *N*-chlorosuccinimide in the presence of benzyl carbamate produced the 1,2-diamine derivatives (**11a**) and (**11b**) *via* the rearrangement of allylic selenoimide intermediates. It should be noted that two amino groups in (**11**) were protected by different groups, potentially allowing the differentiation of the amino groups. It may be concluded that allyl 2-pyridyl selenides are at least as efficient as phenyl allyl selenides in undergoing 2,3-sigmatropic rearrangement reactions.

Another procedure which utilizes the amidoseleniation reaction in organic synthesis is the oxidative and reductive removal of 2-pyridylseleno groups to produce unsaturated and saturated amides. We selected (**2**) as the substrate for selenoxide elimination. The elimination of methine hydrogen is required for the formation of *N*-(α-styryl)acetamide (**12**) from (**2**), and this seems to be more difficult than the selenoxide elimination * to afford *N*-(β-styryl)acetamide reported in the literature.[9] When *m*-chloroperbenzoic acid or hydrogen peroxide was used as the oxidizing reagent, the yield of (**12**) was unsatisfactory. However, the use of ozone as the oxidizing reagent and the addition of triethylamine in the elimination step,[10] produced (**12**) in an acceptable yield (76%). The characteristic feature of this amidoseleniation reaction was utilized in the preparation of the tertiary allylic amide (**13**) as shown in Scheme 6. Selenoxide



Scheme 6.

elimination from (**6a**) proceeded smoothly using a convenient oxidation reagent (H_2O_2) to give (**13**) in a yield of 91%. Reductive removal of the 2-pyridylseleno group from (**14**) and (**16**)† was carried out using triphenyltin hydride[3,11] or nickel boride[12] as the reducing agent. As shown in Scheme 7, *N*-(butan-2-yl)- and *N*-(hexan-2-yl)acetamide, (**15**) and (**17**), were obtained in good to quantitative yields. These yields were similar to or better than those obtained from phenylseleno analogues of (**14**) and (**16**).[3]



Scheme 7. *Reagents:* i, Ph_3SnH (4 equiv.)–toluene, reflux, 4 h; ii, $NiCl_2·6H_2O$ (2 equiv.)–$NaBH_4$ (6 equiv.)–THF–MeOH(4:1), 0 °C, 15 min

Experimental

I.r. spectra were recorded with a JASCO IR-810 spectrophotometer. ^1H N.m.r. spectra were obtained with JEOLCO JNM-FX-100 (100 MHz) and JEOLCO-GX-400 (400 MHz) instruments for solutions in $CDCl_3$ with Me_4Si as the internal standard. M.p.s were determined with a Shimadzu MM-2 micro melting-point determination apparatus and are uncorrected. G.l.c. analyses were carried out with a Shimadzu 4CMPF apparatus with PEG-6000 (25%)–Shimalite (1 m) column.

2,2′-Dipyridyl diselenide and pyridine-2-selenenyl bromide were prepared by the reported methods.[10b] β-Hydroxy- and β-methoxy-alkyl 2-pyridyl selenides were prepared using modified reported procedures.[1,7] Spectral and combustion analytical data of as yet unreported compounds are as follows.

1-*Phenyl*-2-(2-*pyridylseleno*)*ethanol* (**1a**). Colourless liquid (Found: C, 55.85; H, 4.75; N, 5.05. $C_{13}H_{13}NOSe$ requires C, 56.1; H, 4.7; N, 5.05%); $\nu_{max.}$(liquid film) 3 350, 1 570, 1 447, 1 410, 752, and 697 cm^{-1}; δ_H(100 MHz) 3.33 (1 H, dd, *J* 13.9 and 6.8 Hz), 3.55 (1 H, dd, *J* 13.9 and 3.9 Hz), 5.16 (1 H, dd, *J* 6.8 and 3.9 Hz), 5.78 (1 H, br s), 6.8—7.6 (8 H, m), and 8.2—8.5 (1 H, m).

1-(2-*Pyridylseleno*)*hexan*-2-*ol*. Yellow liquid (Found: C, 51.2; H, 6.75; N, 5.65. $C_{11}H_{17}NOSe$ requires C, 51.15; H, 6.65; N, 5.4%); $\nu_{max.}$(liquid film) 3 370, 2 955, 2 930, 2 860, 1 572, 1 450, 1 412, 753, and 697 cm^{-1}; δ_H(100 MHz) 0.5—1.9 (9 H, m), 3.35 (1 H, dd, *J* 13.7 and 3.4 Hz), 3.18 (1 H, dd, *J* 13.7 and 6.4 Hz), 3.7—4.3 (1 H, m), 5.0—6.0 (1 H, m), 6.8—7.2 (1 H, m), 7.2—7.6 (2 H, m), and 8.0—8.5 (1 H, m).

erythro-1-*Methoxy*-1-*phenylpropan*-2-*yl* 2-*pyridyl selenide* (**3a**). White plates, m.p. 145—146 °C [from hexane–ethyl acetate (1:1)] (Found: C, 58.9; H, 5.6; N, 4.6. $C_{15}H_{17}NOSe$ requires C, 58.85; H, 5.6; N, 4.55%); $\nu_{max.}$(KBr disc) 2 925, 1 570, 1 553, 1 447, 1 412, 755, 708, and 508 cm^{-1}; δ_H(100 MHz) 1.41 (3 H, d, *J* 6.8 Hz), 3.34 (3 H, s), 4.42 (1 H, dq, J 3.4 and 6.8 Hz), 4.64 (1 H, d, J 3.4 Hz), 6.8—7.6 (8 H, m), and 8.3—8.5 (1 H, m).

threo-1-*Methoxy*-1-*phenylpropan*-2-*yl* 2-*pyridyl selenide* (**3b**).

* The 4-nitrophenylseleno group was used as the leaving group presumably because the rate was expected to be enhanced by the electron-withdrawing nitro substituent.

† Compound (**14**) was prepared from (*Z*)-but-2-ene *via* methoxyseleniation as described in the text [the second step was carried out at reflux for 24 h; in contrast to the case of (**4b**), the *threo* isomer was found to be the sole product under these reaction conditions]. However, (**16**) was not obtained from 2-methoxyhexyl 2-pyridyl selenide even under the more forcing conditions. When 1-(2-pyridylseleno)hexan-2-ol was used as the starting material (**16**) was produced in 57% yield (reflux, 3 h). This seems to reflect the leaving ability of methoxy and hydroxy groups in a substrate which bears a poor electron-donating substituent.

Colourless liquid (Found: C, 58.7; H, 5.6; N, 4.6. $C_{15}H_{17}NOSe$ requires C, 58.85; H, 5.6; N, 4.55%); $\nu_{max.}$(liquid film) 2 130, 1 572, 1 448, 1 410, 752, and 700 cm^{-1}; δ_H(400 MHz) 1.47 (3 H, d, *J* 7.3 Hz), 3.28 (3 H, s), 4.22 (1 H, dq, *J* 5.9 and 7.3 Hz), 4.37 (1 H, d, *J* 5.9 Hz), 6.99 (1 H, ddd, *J* 7.3, 4.9, and 1.5 Hz), 7.25—7.4 (7 H, m), and 8.40 (1 H, ddd, *J* 4.9, 2.0, and 1.0 Hz).

3-*Methoxy*-3-*methylbutan*-2-*yl* 2-*pyridyl selenide* (**5a**). Pale yellow liquid (Found: C, 51.3; H, 6.55; N, 5.2. $C_{11}H_{17}NOSe$ requires C, 51.15; H, 6.65; N, 5.4%); $\nu_{max.}$(liquid film) 2 975, 1 575, 1 450, 1 412, 1 108, 1 082, 753, and 700 cm^{-1}; δ_H(100 MHz) 1.32 (6 H, s), 1.58 (3 H, d, *J* 6.8 Hz), 3.25 (3 H, s), 4.22 (1 H, q, *J* 6.8 Hz), 6.8—7.1 (1 H, m), 7.2—7.5 (2 H, m), and 8.2—8.5 (1 H, m).

3-*Methoxy*-4-(2-*pyridylseleno*)*but*-1-*ene* (**7a**). Pale yellow liquid (Found: C, 49.55; H, 5.3; N, 5.9. $C_{10}H_{13}NOSe$ requires C, 49.6; H, 5.4; N, 5.8%); $\nu_{max.}$(liquid film) 2 940, 1 575, 1 415, 1 110, 757, and 702 cm^{-1}; δ_H(100 MHz) 3.33 (3 H, s), 3.39 (2 H, d, *J* 5.9 Hz), 3.95 (1 H, dt, *J* 7.3 and 5.9 Hz), 5.24 (1 H, dd, *J* 9.8 and 2.0 Hz), 5.30 (1 H, dd, *J* 17.6 and 2.0 Hz), 5.79 (1 H, ddd, *J* 17.6, 9.8, and 7.3 Hz), 6.9—7.1 (1 H, m), 7.1—7.6 (2 H, m), and 8.3—8.5 (1 H, m).

2,3-*Dimethyl*-3-*methoxy*-4-(2-*pyridylseleno*)*but*-1-*ene* (**7b**). Pale yellow liquid (Found: C, 53.35; H, 6.3; N, 5.25. $C_{12}H_{17}NOSe$ requires C, 53.35; H, 6.35; N, 5.2%); $\nu_{max.}$(liquid film) 2 980, 2 940, 1 572, 1 449, 1 410, 753, and 697 cm^{-1}; δ_H(100 MHz) 1.42 (3 H, s), 1.76 (3 H, s), 3.12 (3 H, s), 3.57 (2 H, s), 5.03 (2 H, br s), 6.8—7.1 (1 H, m), 7.1—7.5 (2 H, m), and 8.2—8.5 (1 H, m).

All other organic materials were commercial products and were purified before use by distillation. Inorganic materials were all commercial products and were used without further purification.

Preparation of N-[1-*Phenyl*-2-(2-*pyridylseleno*)*ethyl*]*acetamide* (**2**) *from* (**1a**).—*General procedure.* To a solution of (**1a**) (0.28 g, 1 mmol) in acetonitrile (3 ml) was added a 1:1 (molar ratio) mixture of trifluoromethanesulphonic acid and water (0.34 g, 2 mmol) and the resulting mixture was heated at reflux temperature for 1 h. The solution was poured into saturated aqueous sodium hydrogen carbonate (50 ml) and was extracted with dichloromethane (20 ml × 5). The extract was washed with brine, dried, and evaporated under reduced pressure to leave a pale yellow oil. Column chromatography of this on silica gel with hexane–ethyl acetate (1:1) as the eluant yielded (**2**) (0.29 g, 0.91 mmol, 91%); white needles, m.p. 126—127 °C [from hexane–ethyl acetate (1:1)] (Found: C, 56.5; H, 5.05; N, 8.75. $C_{15}H_{16}N_2OSe$ requires C, 56.45; H, 5.05; N, 8.75%); $\nu_{max.}$(KBr disc) 3 290, 1 652, 1 557, 753, and 707 cm^{-1}; δ_H(100 MHz) 1.89 (3 H, s), 3.38 (1 H, dd, *J* 13.4 and 4.4 Hz), 3.53 (1 H, dd, *J* 13.4 and 8.8 Hz), 5.19 (1 H, ddd, *J* 10.7, 8.8, and 4.4 Hz), 7.0—7.5 (8 H, m), and 8.2—8.5 (2 H, m).

Spectral and combustion analytical data of other amidoalkyl 2-pyridyl selenides are as follows.

erythro-N-[1-*Phenyl*-2-(2-*pyridylseleno*)*propyl*]*acetamide* (**4a**). White semisolid (Found: C, 57.45; H, 5.55; N, 8.4. $C_{16}H_{18}N_2OSe$ requires C, 57.65; H, 5.45; N, 8.4%); $\nu_{max.}$(KBr disc) 3 300, 1 647, 1 570, 1 548, 757, and 702 cm^{-1}; δ_H(100 MHz) 1.46 (3 H, d, *J* 7.3 Hz), 2.00 (3 H, s), 4.20 (1 H, dq, *J* 3.4 and 7.3 Hz), 5.20 (1 H, dd, *J* 6.4 and 3.4 Hz), 7.11 (1 H, ddd, *J* 6.4, 4.9, and 2.4 Hz), 7.2—7.6 (7 H, m), and 8.1—8.6 (2 H, m).

threo-N-[1-*Phenyl*-2-(2-*pyridylseleno*)*propyl*]*acetamide* (**4b**). Yellow liquid (Found: C, 57.8; H, 5.55; N, 8.15. $C_{16}H_{18}N_2OSe$ requires C, 57.65; H, 5.45; H, 8.4%); $\nu_{max.}$(liquid. film) 3 280, 1 650, 1 572, 1 555, 1 450, 1 412, 755, 730, and 700 cm^{-1}; δ_H(100 MHz) 1.40 (3 H, d, *J* 7.3 Hz), 1.84 (3 H, s), 3.97 (1 H, dq, *J* 9.3 and 7.3 Hz), 4.97 (1 H, dd, *J* 9.3 and 7.3 Hz), 7.15 (1 H, ddd, *J* 8.7, 5.2, and 2.6 Hz), 8.2—8.6 (7 H, m), 8.3—8.6 (1 H, m), and 8.7—9.1 (1 H, br d, *J ca.* 7 Hz).

N-[2-*Methyl*-3-(2-*pyridylseleno*)*butan*-2-*yl*]*acetamide* (**6a**). White needles, m.p. 82.5—83.5 °C (from hexane) (Found: C, 50.35; H, 6.15; N, 9.75. $C_{12}H_{18}N_2OSe$ requires C, 50.55; H, 6.35; N, 9.8%); $\nu_{max.}$(KBr disc) 3 294, 1 646, 1 577, 1 558, 749, and 699 cm^{-1}; δ_H(100 MHz) 1.56 (6 H, s), 1.57 (3 H, d, *J* 7.3 Hz), 1.85 (3 H, s), 3.81 (1 H, q, *J* 7.3 Hz), 7.10 (1 H, ddd, *J* 5.9, 4.9, and 2.9 Hz), 7.3—7.5 (2 H, m), 8.27 (1 H, br s), and 8.42 (1 H, ddd, *J* 4.9, 2.0, and 1.0 Hz).

N-[1-*Methyl*-2-(2-*pyridylseleno*)*cyclohexyl*]*acetamide* (**6b**). Pale yellow liquid (Found: C, 53.85; H, 6.85; N, 8.75. $C_{14}H_{20}N_2OSe$ requires C, 54.0; H, 6.5; N, 9.0%); $\nu_{max.}$(liquid film) 2 938, 1 769, 1 580, 760, 735, and 700 cm^{-1}; δ_H(100 MHz) 1.0—2.0 (6 H, m), 1.58 (3 H, s), 1.86 (3 H, s), 2.0—2.4 (1 H, m), 2.8—3.2 (1 H, m), 3.70 (1 H, dd, *J* 12.9 and 4.2 Hz), 7.0—7.2 (1 H, m), 7.3—7.6 (2 H, m), 8.3—8.5 (1 H, m), and 8.62 (1 H, br s).

N-[2,3-*Dimethyl*-3-(2-*pyridylseleno*)*butan*-2-*yl*]*acetamide* (**6c**). Yellow needles, m.p. 44—45 °C (from hexane) (Found: C, 52.1; H, 6.9; N, 9.3. $C_{13}H_{20}N_2OSe$ requires C, 52.15; H, 6.75; N, 9.35%); $\nu_{max.}$(KBr disc) 1 662, 1 562, and 757 cm^{-1}; δ_H(100 MHz) 1.57 (12 H, s), 2.04 (3 H, s), 7.0—7.3 (1 H, m), 7.4—7.6 (2 H, m), 8.3—8.5 (1 H, m), and 9.4 (1 H, br s).

N-[1-(2-*Pyridylseleno*)*but*-3-*en*-2-*yl*]*acetamide* (**8a**). White needles, m.p. 49—49.5 °C (from hexane) (Found: C, 48.85; H, 5.2; N, 10.45. $C_{11}H_{14}N_2OSe$ requires C, 49.1; H, 5.25; N, 10.4%); $\nu_{max.}$(KBr disc) 3 276, 3 070, 3 052, 1 654, 1 575, 1 558, 1 415, 757, and 702 cm^{-1}; δ_H(100 MHz) 1.90 (3 H, s), 3.33 (2 H, d, *J* 6.4 Hz), 4.69 (1 H, dtq, *J* 5.4, 1.5 and 6.4 Hz), 5.15 (1 H, dt, *J* 9.8 and 1.5 Hz), 5.28 (1 H, dt, *J* 17.1 and 1.5 Hz), 5.88 (1 H, ddd, *J* 17.1, 9.8, and 5.4 Hz), 6.9—7.6 (3 H, m), 7.22 (1 H, br s), and 8.3—8.5 (1 H, m).

(2E)-N-[4-(2-*Pyridylseleno*)*but*-2-*enyl*]*acetamide* (**9a**). Colourless liquid (Found: C, 48.6; H, 5.1; N, 10.25. $C_{11}H_{14}N_2OSe$ requires C, 49.1; H, 5.25; N, 10.4%); $\nu_{max.}$(liquid film) 3 284, 1 657, 1 650, 1 573, 1 553, 1 413, 757, and 700 cm^{-1}; δ_H(400 MHz) 1 97 (3 H, s), 3.81—3.83 (4 H, m), 5.54 (1 H, br s), 5.64 (1 H, dt, *J* 15.1 and 6.4 Hz), 5.85 (1 H, dtt, *J* 15.1, 7.6, and 1.5 Hz), 7.05 (1 H, ddd, *J* 7.3, 4.9, and 1.0 Hz), 7.31 (1 H, dt, *J* 8.3 and 1.0 Hz), 7.46 (1 H, ddd, *J* 8.3, 7.3, and 2.0 Hz), and 8.46 (1 H, ddd, *J* 4.9, 2.0, and 1.0 Hz).

N-[2,3-*Dimethyl*-4-(2-*pyridylseleno*)*but*-2-*enyl*]*acetamide* (**9b**). Mixture of two isomers, *ca.* 54:46; yellow liquid (Found: C, 52.2; H, 6.0; N, 9.4. $C_{13}H_{18}N_2OSe$ requires C, 52.55; H, 6.1; N, 9.4%); $\nu_{max.}$(liquid film) 3 290, 1 652, 1 575, 1 558, 1 453, 1 415, 757, and 702 cm^{-1}; δ_H(400 MHz) (major isomer) 1.70 (3 H, q, *J* 1.0 Hz), 1.79 (3 H, q, *J* 1.0 Hz), 1.94 (3 H, s), 3.93 (2 H, s), 3.95 (2 H, d, 5.4 Hz), 6.25 (1 H, br s), 7.02—7.06 (1 H, m), 7.32—7.34 (1 H, m), 7.42—7.45 (1 H, m), and 8.42—8.45 (1 H, m); δ_H (minor isomer) 1.74 (3 H, q, *J* 1.5 Hz), 1.85 (3 H, q, *J* 1.5 Hz), 1.98 (3 H, s), 3.86 (2 H, d, *J* 5.4 Hz), 4.01 (2 H, s), 6.10 (1 H, br s), 7.02—7.06 (1 H, m), 7.32—7.34 (1 H, m), 7.42—7.45 (1 H, m), and 8.42—8.45 (1 H, m).

threo-N-[3-(2-*Pyridylseleno*)*butan*-2-*yl*]*acetamide* (**14**). Pale yellow liquid (Found: C, 48.65; H, 6.1; N, 10.15. $C_{11}H_{16}N_2OSe$ requires C, 48.7; H, 5.95; N, 10.35%); $\nu_{max.}$(liquid film) 3 270, 2 970, 1 647, 1 570, 1 553, 1 447, 1 410, 763, and 697 cm^{-1}; δ_H(100 MHz) 1.28 (3 H, d, *J* 6.4 Hz), 1.54 (3 H, d, *J* 7.3 Hz), 1.91 (3 H, s), 3.74 (1 H, dq, *J* 6.8 and 7.3 Hz), 4.13 (1 H, ddq, *J* 7.3, 6.8, and 6.4 Hz), 7.0—7.2 (1 H, m), 7.4—7.55 (2 H, m), 7.7—8.1 (1 H, m), and 8.35—8.5 (1 H, m).

N-[1-(2-*Pyridylseleno*)*hexan*-2-*yl*]*acetamide* (**16**). Colourless liquid (Found: C, 52.05; H, 6.65; N, 9.4. $C_{13}H_{20}N_2OSe$ requires C, 52.15; H, 6.75; N, 9.35%); $\nu_{max.}$(liquid film) 3 280, 2 964, 2 937, 1 650, 1 573, 1 559, 1 453, 1 415, 757, and 701 cm^{-1}; δ_H(100 MHz) 0.8—1.0 (3 H, m), 1.2—1.8 (6 H, m), 1.83 (3 H, s), 3.32 (2 H, d, *J* 5.9 Hz), 4.08 (1 H, br sextet, *J ca.* 6.5 Hz), 7.0—7.15 (2 H, m), 7.4—7.5 (2 H, m), and 8.35—8.45 (1 H, m).

Conversion of (**9a**) *into* 1-*Acetamidobut*-3-*en*-2-*ol* (**10a**).—To a solution of (**9a**) (0.27 g, 1 mmol) and pyridine (0.16 g, 2 mmol) in dichloromethane (5 ml) was added 30% aqueous hydrogen peroxide (0.34 g, 3 mmol) dropwise under ice-bath cooling. After having been stirred at 0 °C for 0.5 h and then at 25 °C for 1 h, the mixture was added to 1M aqueous sodium thiosulphate (25 ml). The phases were separated and the aqueous layer was extracted with dichloromethane (25 ml × 35). The dried extract was evaporated under reduced pressure to leave a yellow oil. Column chromatography of this on silica gel with hexane–acetone (2:5) as the eluant yielded (**10a**) (0.077 g, 0.6 mmol, 60%) (Found: M^+, 129.0772. $C_6H_{11}NO_2$ requires M, 129.0790); $\nu_{max.}$(liquid film) 3 305, 1 650, and 1 558 cm^{-1}; δ_H(100 MHz) 1.99 (3 H, s), 3.15 (1 H, ddd, J 13.7, 7.3, and 5.4 Hz), 3.48 (1 H, ddd, J 13.7, 6.4, and 3.9 Hz), 4.1—4.3 (1 H, m), 4.3—4.7 (1 H, br s), 5.16 (1 H, ddd, J 10.3, 2.0, and 1.5 Hz), 5.31 (1 H, ddd, J 17.1, 2.0, and 1.5 Hz), 5.86 (1 H, ddd, J 17.1, 10.3, and 5.4 Hz), and 6.7—7.2 (1 H, br s).

1-*Acetamido*-2,3-*dimethylbut*-3-*en*-2-*ol* (**10b**). This was obtained similarly as a pale yellow liquid (Found: C, 60.85; H, 9.6; N, 8.7. $C_8H_{15}NO_2$ requires C, 61.1; H, 9.6; N, 8.9%); $\nu_{max.}$(liquid film) 3 350, 2 985, 1 660, 1 550, 1 377, 1 146, and 905 cm^{-1}; δ_H(100 MHz) 1.30 (3 H, s), 1.77 (3 H, br s), 1.99 (3 H, s), 3.37 (2 H, d, J 5.9 Hz), 3.49 (1 H, br s), 4.90 (1 H, quintet, J 1.4 Hz), 5.06—5.14 (1 H, m), and 6.1—6.5 (1 H, br s).

Conversion of (**9a**) *into* N-(2-*Benzyloxycarbonylaminobut*-3-*enyl*)*acetamide* (**11a**). A solution of (**9a**) (0.27 g, 1 mmol), benzyl carbamate (0.45 g, 3 mmol), and triethylamine (0.61 g, 6 mmol) in methanol (1 ml) was cooled to 0 °C and *N*-chlorosuccinimide (0.40 g, 3 mmol) was added in several portions. The resulting mixture was stirred at 0 °C for 0.25 h, and then at 25 °C for 1 h. The solution was poured into water (25 ml) and extracted with dichloromethane (25 ml × 40). The extract was dried and evaporated under reduced pressure to leave a yellow oil. Column chromatography of this on silica gel with hexane–acetone (2:5) as the eluant yielded (**11a**) (0.21 g, 0.7 mmol, 70%); white semi-solid (Found: M^+, 262.1267. $C_{14}H_{18}N_2O_3$ requires M, 262.1317); $\nu_{max.}$(KBr disc) 3 300, 1 682, 1 652, 1 537, 752, and 693 cm^{-1}; δ_H(100 MHz) 1.88 (3 H, s), 3.33 (2 H, br t, J *ca.* 6.1 Hz), 4.27 (1 H, br quintet, J *ca.* 6.6 Hz), 5.07 (2 H, s), 5.09 (1 H, dt, J 10.3 and 1.5 Hz), 5.13 (1 H, dt, J 17.1 and 1.5 Hz), 5.74 (1 H, ddd, J 17.1, 10.3, and 5.4 Hz), 6.00 (1 H, d, J 7.8 Hz), 6.86 (1 H, br t, J 5.9 Hz), and 7.30 (5 H, s).

N-(2-*Benzyloxycarbonylamino*-2,3-*dimethylbut*-3-*enyl*)-*acetamide* (**11b**). This was obtained similarly as a yellow liquid (Found: M^+, 290.1616. $C_{16}H_{22}N_2O_3$ requires M, 290.1630); $\nu_{max.}$(liquid film) 3 340, 1 710, 1 645, 1 530, 1 445, 1 375, 740, and 697 cm^{-1}; δ_H(100 MHz) 1.40 (3 H, s), 1.75 (3 H, s), 1.94 (3 H, s), 3.31 (1 H, dd, J 13.7 and 6.4 Hz), 3.55 (1 H, dd, J 13.7 and 5.9 Hz), 4.90 (1 H, br s), 4.95 (1 H, br s), 5.03 (2 H, s), 6.00 (1 H, s), 6.7—6.95 (1 H, br s), and 7.31 (5 H, s).

Oxidative or reductive removal of the pyridylseleno group from (**2**), (**6a**), (**14**), and (**16**) was carried out using reported procedures.[3,10–12]

N-(α-Styryl)acetamide (**12**) was isolated by column chromatography, m.p. 89.5—90 °C (from hexane) (lit.,[13] 92 °C). *N*-(1,1-dimethylprop-2-enyl)acetamide (**13**) was also isolated by column chromatography on silica gel using hexane–ethyl acetate (1:5) as the eluant; colourless liquid (Found: M^+, 127.1033. $C_7H_{13}NO$ requires M, 127.0997); $\nu_{max.}$(liquid film) 3 300, 3 090, 2 980, 2 930, 1 657, and 1 552 cm^{-1}; δ_H(100 MHz) 1.42 (6 H, s), 1.93 (3 H, s), 5.03 (1 H, dd, J 10.6 and 0.8 Hz), 5.09 (1 H, dd, J 17.4 and 0.8 Hz), 5.35 (1 H, br s), and 6.02 (1 H, dd, J 17.4 and 10.6 Hz). Authentic samples of (**15**) and (**17**) were prepared by the acetylation of the corresponding amines.

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