Synthesis of Benzimidazolyl Selenophenes

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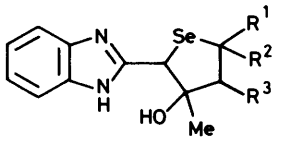
Benzimidazol-2-ylmethaneselenol (**5a**) and its sodium salt (**5b**) have been prepared and treated *in situ* with α,β-unsaturated ketones to give the β-seleno ketones (**3**). In the absence of a α,β-C=C double bond, the seleno ketones appeared highly prone to retro-Michael type decomposition. Thus, cyclisation to give the tetrahydro- and dihydro-selenophene derivatives (**1**) and (**2**) was found to be efficient only in the case of compound (**3c**) which has an α,β-C=C bond. Some peculiar but not unprecedented reactions such as selenium extrusion from the diselenide (**8**) and reductive cyclisation of the bis(benzimidazolylmethyl) selenides (**9**), (**10**), and (**11**) were encountered.

It is known that Michael adducts arising from 2-(α-mercaptoalkyl)benzimidazoles and α,β-unsaturated ketones cyclise under various conditions to give 2-(tetrahydro-2-thienyl)benzimidazoles,[1] whereas the same thiols, on reaction with epichlorhydrins or dihalogenopropanols, lead to tricyclic derivatives of the type 1,4-thiazepino[3,2-*a*]benzimidazole.[2] A number of these compounds are of current pharmaceutical interest[3] and our aim was to investigate viable synthetic routes to their selenium analogues. Little or no information exists in the literature[4] on heterocyclic selenols or diselenides such as (**5a**) and (**8**), and as will be detailed below, a number of unusual aspects of organoselenium chemistry were seen during this investigation.

Results and Discussion

According to previous reports[1,2] on their sulphur analogues, the target molecules (**1**) and (**2**) could be reached easily for example through Michael addition of selenol (**5a**) or its sodium salt (**5b**) to α,β-unsaturated ketones to give compounds (**3**), followed by cyclisation of the latter under mild conditions. This strategy appeared attractive to us since a potential precursor of compound (**5a**), 2-chloromethylbenzimidazole (**4**), is a commercially available product. Alternatively, γ-oxo selenols (**7**) should be available from α,β-unsaturated ketones and sodium hydrogen selenide and, on reaction with the chloride (**4**), should also lead to the key intermediates (**3**).

The three synthetic routes suggested by these ideas are out-

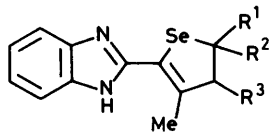


(**1**)

a; $R^1 = R^2 = R^3 = H$

b; $R^1 = Ph$, $R^2 = R^3 = H$

c; $R^1 = Ph$, $R^2 = R^3 =$ bond

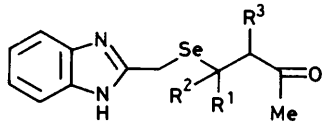


(**2**)

a; $R^1 = R^2 = R^3 = H$

b; $R^1 = Ph$, $R^2 = R^3 = H$

c; $R^1 = Ph$, $R^2 = R^3 =$ bond

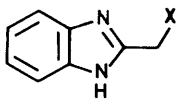


(**3**)

a; $R^1 = R^2 = R^3 = H$

b; $R^1 = Ph$, $R^2 = R^3 = H$

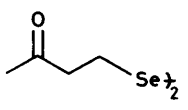
c; $R^1 = Ph$, $R^2 = R^3 =$ bond



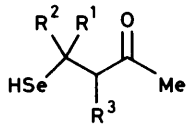
(**4**) X = Cl

(**5a**) X = SeH, (**5b**) X = SeNa

(**6**) X = H



(**12**)

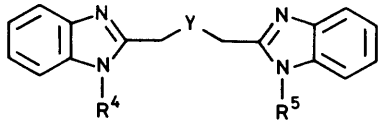


(**7**)

a; $R^1 = R^2 = R^3 = H$

b; $R^1 = Ph$, $R^2 = R^3 = H$

c; $R^1 = Ph$, $R^2 = R^3 =$ bond



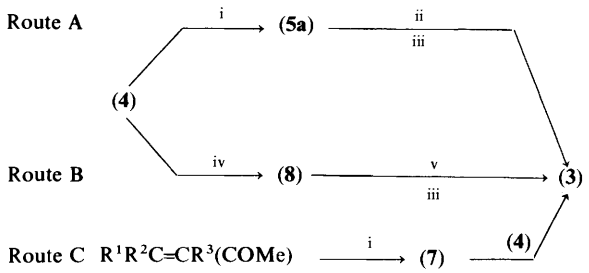
(**8**) Y = Se—Se; $R^4 = R^5 = H$

(**9**) Y = Se, $R^4 = R^5 = H$

(**10**) Y = Se, $R^4 = (CH_2)_2COMe$, $R^5 = H$

(**11**) Y = Se, $R^4 = R^5 = (CH_2)_2COMe$

lined in Scheme 1. Besides the order of mixing and the nature of the reagents, the three pathways differ in that routes A and C are one pot syntheses, whereas route B proceeds through the diselenide (**8**) which can be isolated and identified.



Scheme 1. *Reagents:* i, NaHSe; ii, Na_2CO_3; iii, $R^1R^2C = CR^3(COMe)$; iv, Na_2Se_2; v, $NaBH_4$

Sodium hydrogen selenide has been prepared by sodium borohydride reduction of grey metallic selenium in ethanol[5] and sodium diselenide has been obtained by reacting grey metallic selenium with sodium in liquid ammonia.[6]

Route A.—At temperatures above −25 °C sodium hydrogen selenide in ethanol produced 2-methylbenzimidazole (**6**) in nearly quantitative yield (90%) when treated with the chloride (**4**). This reaction is analogous with the reduction of benzyl halides by thiolate and selenolate anions observed earlier.[7] However, at or below −45 °C, the reduction was suppressed and selenol (**5a**) was formed predominantly but not quantitatively. *In situ* reactions in the presence of potassium carbonate, with methyl vinyl ketone gave several products. In addition to the β-seleno ketone (**3a**) which was isolated in only 37% yield, diselenide (**8**) and selenide (**9**) were produced in a combined yield of 39%, and diselenide (**12**) was formed in 23% yield. Thus reaction of compound (**4**) with NaHSe (Scheme 1, Route A) proceeded with 77% conversion when methyl vinyl ketone was added to the mixture, allowing the formation of 3-oxobutaneselenol (**7a**) from the residual NaHSe; oxidation of this selenol during work-up formed the diselenide (**12**). The presence of compounds (**8**) and (**9**) in the product mixture was puzzling since (**8**) can arise from oxidation of (**5a**) or (**5b**), which means either that Michael addition of (**5b**) to methyl vinyl ketone is an equilibrium reaction or that the addition itself is complete, but (**3a**) undergoes a retro-Michael reaction during work-up and purification. The fact that the latter event occurs indeed (*vide infra*) does not exclude the former one: both can be operative simultaneously (see route B).

Attempts to increase the yield of the seleno ketone (**3a**) by using other solvents such as dimethylformamide (DMF) or dimethoxyethane (DME) or other pH conditions for the Michael addition failed. It is also remarkable that NaHSe prepared by reaction of elemental selenium with $NaBH_4$ in DME completely reduced the chloride (**4**) into 2-methylbenzimidazole (**6**) at temperatures as low as −45 °C and even in the presence of small quantities of ethanol. Compound (**3a**) could be separated from the by-products by preparative t.l.c. but even the purified product contained about 10% of the diselenide (**8**) due to partial decomposition of (**3a**) on contact with silica (see below). Other methods of purification (precipitation, acid-base extraction and salt forming techniques) failed to give better results.

Route B.—The diselenide (**8**) was prepared first by treating the chloride (**4**) with Na_2Se_2 in liquid ammonia.[6] The purity of the product depended upon the method of isolation: evaporation of the solvent ammonia led to a 2:1 mixture of (**8**) and (**9**). When, in smaller batches, the reaction mixture was cautiously poured into water, the precipitated diselenide (**8**) was free of selenide (**9**) and contained only a trace amount of elemental red selenium. This observation indicated that in the polar ammonia solution diselenide (**8**) underwent partial decomposition by selenium extrusion. Similar phenomena have been reported on several occasions. For example, dibenzyl diselenide and bis(*p*-nitrobenzyl) diselenide deposited amorphous red selenium under the action of diffuse day light;[8] Loevenich and co-workers argued[9] for the formation of a branched diselenide from di(2-naphthyl) diselenide when heated pure or in ethanol, but later the compound was shown[10] to be a mixture of the starting diselenide and of di(β-naphthyl) selenide. In the case of diselenide (**8**) bearing two electron withdrawing benzyl type groups decomposition was also promoted by other polar solvents, *e.g.*, a dimethyl sulphoxide (DMSO) solution of pure (**8**) contained after 3 days at room temperature and in the dark a 1:4 mixture of compounds (**8**) and (**9**) together with red selenium. The crude diselenide (**8**) could be purified in moderate yield (40%) by rapid recrystallisation from tetrahydrofuran (THF). Carrying out the first step of Route B in other solvents (*i.e.*, evaporating ammonia and redissolving the Na_2Se_2 in aqueous ethanol or DMF) also led to mixtures of compounds (**8**) and (**9**) but in lower yields.

Conversion of the diselenide (**8**) into the seleno ketone (**3a**) was effected by a modified sodium borohydride reduction of the diselenide (**8**) into the sodium salt (**5b**) followed by *in situ* reaction of the latter with methyl vinyl ketone. Under the original conditions[11] (2 mol $NaBH_4$ for 1 mol of (**8**) in ethanol at 0 °C) the main product was again 2-methylbenzimidazole (**6**). Moreover, the addition product (**3a**) was partially reduced by the excess of borohydride into the γ-hydroxy selenide arising from reduction of the carbonyl group of (**3a**). In ethanol the yield of compound (**3a**) was not increased substantially by lowering the temperature to −45 °C or by decreasing the amount of $NaBH_4$ to 0.5 mol per mol of (**8**). In DME at −45 °C, however, the diselenide (**8**) was cleanly reduced to (**5b**) (0.5 mol of $NaBH_4$ used) and *in situ* reaction of the latter with methyl vinyl ketone afforded (**3a**) in 76% yield, with some unchanged (**8**) remaining.

Route C.—The presence of the diselenide (**12**) in the product mixture of route A suggested that route C might also be a valuable approach to intermediate β-oxo selenides (**3**). Indeed, ethanolic sodium hydrogen selenide[5] reacted with methyl vinyl ketone at 0 °C to give the selenol (**7a**) which, on addition of chloride (**4**) gave the seleno ketone (**3a**) in 48% yield. Owing to the fact that the first step in this sequence is presumably an equilibrium reaction, the product mixture also contained the diselenides (**8**) and (**12**) (16% and 12% yields respectively).

When applied to benzylidene acetone, route C produced compound (**3b**) in only 10—15% yield; the product (**3b**) underwent substantial decomposition during chromatographic purification on silica gel.

In contrast, 4-phenylbut-3-yn-2-one gave the doubly bonded (**3c**) in satisfactory yield (58%) as a 1:3 mixture of *E*- and *Z*-isomers which could be separated by fractional crystallisation followed by preparative t.l.c.

Cyclisation of β-Seleno Ketones (**3**).—While the sulphur analogues of (**3**) have been described[1] to cyclise efficiently under a variety of mild conditions, most of our attempts to induce similar transformations of β-seleno ketones (**3**) failed. As judged from the products formed in the reactions carried out in the presence of a base or an acid, the primary reason for failure is the very high propensity of compounds (**3**) to undergo retro-

Michael type decomposition which is particularly favoured under basic conditions. Thus, treatment of ketone (**3**) with piperidine in chloroform at room temperature led to the diselenide (**8**) (81%), and methyl vinyl ketone liberated in the retro-Michael reaction was trapped by piperidine to afford *N*-(3-oxobutyl)piperidine in 57% yield.

In acetic anhydride–pyridine at room temperature compound (**3a**) was transformed to its *N*-acetyl derivative, whereas at higher temperature or in acetic acid a variety of compounds (detailed in the next section) were formed.

As a result of the presence of the C=C double bond in compound (**3c**), cyclisation could occur but under somewhat more severe conditions than for the sulphur analogues. Heating compound *Z*-(**3c**) in DMSO at 70 °C for 4 h gave the 3-hydroxy-2,3-dihydroselenophene derivative (**1c**) (63%) as a single diastereoisomer, which on standing in the same solvent for 4 months deposited crystals of the unsaturated compound (**2c**). Solutions of compound *Z*-(**3c**) in polar solvents (DMSO, nitromethane) gave the selenophene (**1c**) also at room temperature, but the conversion was very low even after one month.

On the other hand, heating *Z*-(**3c**) in acetic acid at 100 °C for 3 h directly produced compound (**2c**) in 70% yield.

It thus appears that when retro-Michael decomposition of the key intermediates (**3**) is inhibited for structural reasons, cyclisation into (**1**) or (**2**) is a viable alternative.

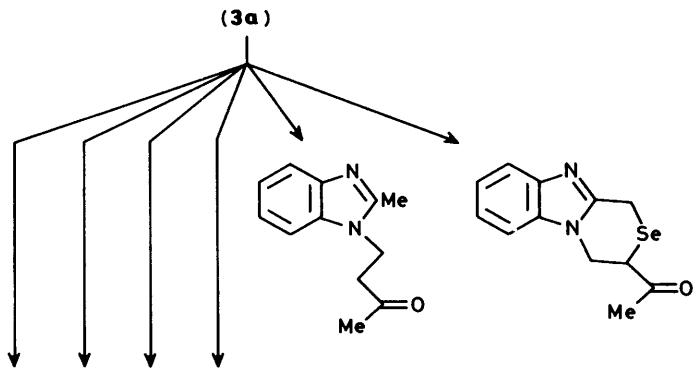
Retro-Michael Decomposition of β-Seleno Ketones (**3**).—Evidence was obtained of decomposition of the β-seleno ketones (**3a**) and (**3b**) during chromatographic purification over silica gel as well as on attempted cyclisation under various conditions. In order to obtain more detailed information about this decomposition a non-crystalline sample of compound (**3a**) [containing *ca.* 10% of (**8**)] was allowed to stand at room temperature. After a period of 70 days, t.l.c. and ^{1}H n.m.r. indicated that all the starting material (**3a**) had been consumed and that a mixture of six products was formed. The products were separated by preparative t.l.c. and their structures were elucidated by spectroscopic means as well as by independent syntheses when necessary. Scheme 2 lists the products together with their proportions (%) at various times during the spontaneous decomposition of (**3a**). The diselenide (**8**) is the first product to appear most likely by retro-Michael decomposition of (**3a**) into methyl vinyl ketone and the selenol (**5a**) followed by air-oxidation of the latter. That the other compounds, *i.e.* (**6**), (**10**), (**11**), (**13**), and (**14**), arise from the interaction of methyl vinyl ketone and diselenide (**8**) has been confirmed by separate experiments.

Thus, when one equivalent of the selenide (**8**) and 3 equivalents of methyl vinyl ketone were allowed to react in ethanol at room temperature for 72 h, 40% of unchanged (**8**) was recovered, and compounds (**13**) and (**14**) were isolated in 33% and 49% yield respectively [based on consumed (**8**)]. Under similar conditions, reaction of the selenide (**9**) with methyl vinyl ketone led to a mixture of products from which (**10**), (**11**), (**13**), and (**14**) were isolated in 13, 24, 13, and 30% yield respectively. It seems reasonable that the first step in both of these reaction sequences is mono-or bis-*N*-(3-oxo)butylation of the benzimidazole entities. Therefore we can envisage the formation of compounds (**6**), (**13**), and (**14**) as depicted in Scheme 3, which implies an electrophilic behaviour of the selenium atoms in both the *N*-(3-oxo)butylated diselenide and the selenides (**10**) or (**11**) so that formation of compound (**14**) may be viewed as an intramolecular selenenylation carried out on the enol form of the 3-oxobutyl side chain. Taking into account the relatively strong electron withdrawing nature of the *N*-alkylated benzimidazolyl entity (σ_p^- 0.58)[12] such electrophilic behaviour may appear acceptable.

The structures of (**13**) and (**14**) were further confirmed by the quantitative formation of compound (**13**) [based on consumed 2-methylbenzimidazole (**6**)] when equimolar amounts of (**6**) and methyl vinyl ketone were reacted in ethanol at room temperature. Also, the chloride (**4**) on reaction with methyl vinyl ketone gave 2-chloromethyl-1-(3-oxobutyl)benzimidazole (73%) which reacted further with NaHSe to give (**13**) (63% yield) and a compound identical to (**14**) in all respects (7%).

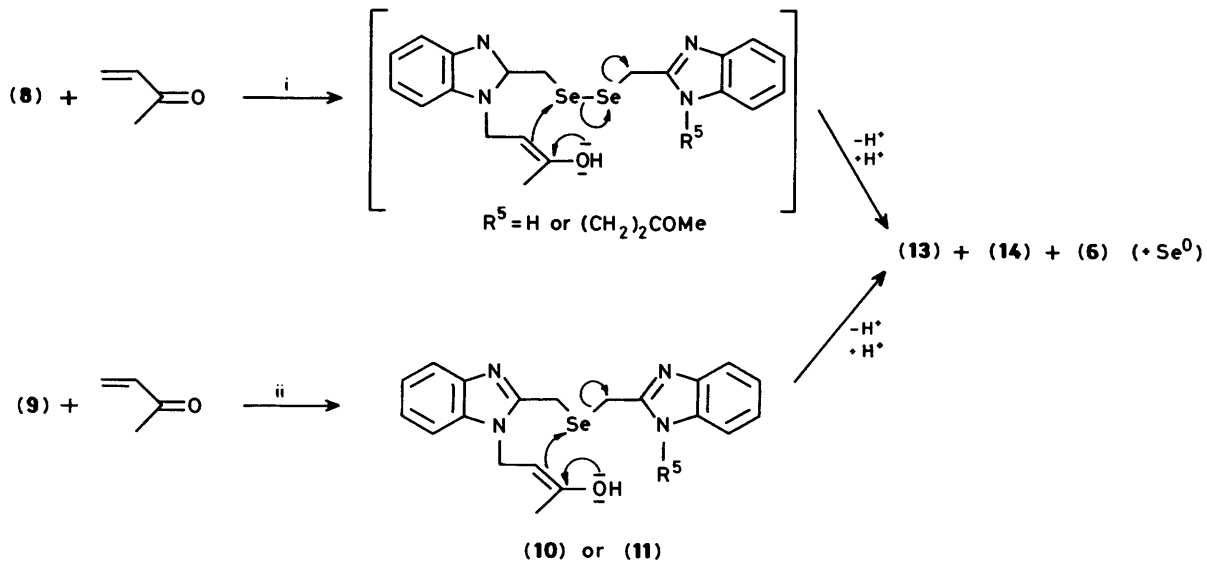
Experimental

M.p.s were determined on a Tottoli apparatus and are uncorrected. I.r. spectra were recorded on a Perkin-Elmer Type 370 instrument and ^{1}H n.m.r. spectra on a JEOL JNP PMX 60



Time (days)	(3a)	(8)	(10)	(11)	(6)	(13)	(14)
0	89	11	...	...	...	...	...
8	75	25	...	...	...	Trace	...
20	33	33	14	...	...	20	...
70	...	27	11	7	7	37	11

Scheme 2.



Scheme 3. *Reagents:* i, EtOH, 20 °C, 72 h; ii, EtOH, 20 °C, 40 h

SI spectrometer in $CDCl_3$ or [$^2H_6$]DMSO using TMS as internal standard. ^{13}C And ^{77}Se n.m.r. spectra were run on a JEOL JNM FX 90Q multinuclear spectrometer in the same solvents using TMS for ^{13}C and $Se(Me)_2$ for ^{77}Se as internal standards. Mass spectra were taken on a Hewlett-Packard Type 5995 A gas chromatograph/mass spectrometer; m.s. data are given for the most abundant ^{80}Se isotope. Analytical and preparative t.l.c. was performed on glass plates coated with silica gel, the spots were visualized under u.v. light and/or by spraying with phosphomolybdenic acid. R_F Values given below were obtained using the following eluant systems: (a) benzene–pyridine (6:1), (b) ethyl acetate, and (c) benzene–diethylamine (9:1). All preparations with air-sensitive selenium reagents were performed in solvents distilled under a stream of argon.

Bis(benzimidazol-2-ylmethyl) Diselenide (**8**).—Solid 2-chloromethylbenzimidazole (**4**) (1.67 g, 10 mmol) was added in small portions to a mixture of Na_2Se_2 (5.25 mmol) and liquid NH_3 (20 ml) at −78 °C under argon prepared as described by Brandsma *et al.*[6] After 5 min the mixture was poured cautiously with rapid stirring onto water (500 ml), whereupon a precipitate was formed. The mixture was stirred for a further 10 min, then the product, a light brown powder, was filtered off and dried (1.71 g, 81%). According to the ^1H n.m.r. spectrum the crude product contained no appreciable amounts of the selenide (**9**).

The crude product (**8**) was stirred for 10 min in THF (30 ml), the insoluble material was filtered off, and the filtrate was concentrated to about 5 ml and allowed to stand for 1 h. Pure compound (**8**) separated as a beige powder (0.41 g, 41%), m.p. 162—164 °C. Trituration with dichloromethane raised the melting point to 166—168 °C, R_F[eluant (a)] 0.30 (Found: C, 46.1; H, 3.6. $C_{16}H_{14}N_4Se_2$ requires C, 45.73; H, 3.36%); δ_H ([$^2H_6$]DMSO) 4.41 (br s, 4 H, CH_2) and 7.0—7.8 (m, 8 H, ArH).

Bis(benzimidazol-2-ylmethyl) Selenide (**9**).—A solution of 2-chloromethylbenzimidazole (333 mg, 2 mmol) dissolved in DMF (3 ml) was added to a suspension of Na_2Se (125 mg, 1 mmol) in oxygen-free DMF (3 ml) stirred under argon at 0 °C and the mixture was stirred for 10 min. Addition of water (10 ml) precipitated compound (**9**) (260 mg, 76%). Recrystallisation from acetonitrile gave white crystals of m.p. 176—177 °C, R_F[eluant (a)] 0.2 (Found: C, 56.35; H, 4.4. $C_{16}H_{14}N_4Se$ requires C, 56.49; H, 4.13%); δ_H([$^2H_6$]DMSO) 4.13 (s, 4 H, CH_2) and 7.0—7.8 (m, 8 H, ArH); *m/z* 342 (M^+).

Preparation of Seleno Ketones (**3**).—(*i*) *Route A.* A solution of 2-chloromethylbenzimidazole (333 mg, 2 mmol) in ethanol (6 ml) was added *via* a syringe to a solution of NaHSe (2 mmol) in ethanol, prepared under argon as described by Klayman and Griffin[5] and cooled to −45 °C. After being stirred for 5 min the mixture was treated with K_2CO_3 (0.30 g, 2.17 mmol) and a solution of methyl vinyl ketone (145 mg, 2.07 mmol) in ethanol (1 ml) was added. The reaction mixture was stirred for 30 min at −45 °C, and then for a further 30 min without cooling. After addition of water (30 ml) the precipitate formed was filtered off and washed with water and then with ether to give a 2:1 mixture of compounds (**8**) and (**9**) (39%). The aqueous filtrate was extracted with ether and the combined organic layers and washings were washed with brine, dried ($MgSO_4$), and evaporated to dryness. The residue (370 mg) contained the desired compound (**3a**) (37%), the aliphatic diselenide (**12**) (26%), and a small amount of the diselenide (**8**). Purification by preparative t.l.c. [SiO_2, eluant (a), R_F 0.4] gave compound (**3a**) (162 mg, 29%) containing *ca.* 8% of (**8**) as a light yellow oil which crystallised upon standing, m.p. 90—92 °C. Because of spontaneous decomposition it was not possible to obtain compound (**3a**) in sufficient purity for elemental analysis; $\nu_{max.}(CDCl_3)$ 3 400—2 400 (NH) and 1 700 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.03 (s, 3 H, Me), 2.78 (s, 4 H, CH_2CH_2), 4.0 (s, 2 H, CH_2Se), and 7.1—7.7 (m, 4 H, ArH); $\delta_C(CDCl_3)$ 30.06 (Me), 17.19 and 19.14 (CH_2SeCH_2), 44.31 (CH_2CO), 138.66, 122.77, 122.28, 114.95, 114.45 (ArC), 152.58 (benzimidazole C-2), and 207.90 (CO); $\delta_{Se}(CDCl_3)$ 267.43 p.p.m.

The aliphatic diselenide (**12**), a colourless oil, had the following analytical data (Found: C, 32.2; H, 4.8. $C_8H_{14}O_2Se_2$ requires C, 32.02; H, 4.70%); $\nu_{max.}$(liq. film) 1 705 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.14 (s, 6 H, Me) and 2.78 (br s, 8 H, CH_2CH_2); $\delta_C(CDCl_3)$ 16.78 (CH_2Se), 29.98 (Me), 44.48 (CH_2CO), and 207.00 (CO); $\delta_{Se}(CDCl_3)$ 204.6 p.p.m.; R_F[eluant (a)] 0.75.

(*ii*) *Route B.* A solution of $NaBH_4$ (6 mg, 0.16 mmol) in DME (1 ml) was added *via* a syringe to a suspension of the diselenide (**8**) (140 mg, 0.33 mmol) in DME (5 ml) stirred under argon at −45 °C and the mixture was stirred for 1 h at the same temperature. Methyl vinyl ketone (47 mg, 0.67 mmol) in DME

(1 ml) was added and stirring was continued for 30 min at −45 °C, then for 45 min at 0 °C. The yellow solution was diluted with water (50 ml) and extracted with ether; the organic layer was then washed with brine, dried ($MgSO_4$), and evaporated to dryness. Chromatographic purification [SiO_2, eluant (a)] of the residue (162 mg) gave compound (**3a**) (76%) [based on unrecovered (**8**)].

The same reaction carried out in ethanol at −45 °C led to compounds (**3a**) and (**6**) in 14% and 53% yields respectively.

(*iii*) *Route C.* Methyl vinyl ketone (150 mg, 2.1 mmol) in ethanol (1 ml) was added at 0 °C to a solution of NaHSe (2 mmol) in ethanol (5 ml).[5] After being stirred for 1 h 2-chloromethylbenzimidazole (333 mg, 2 mmol) in ethanol (6 ml) was added and stirring was continued for 1 h at the same temperature. The mixture was diluted with water (30 ml), a small amount of tarry impurity was filtered off, and the clear solution was extracted with ether. The organic extracts were washed with brine, dried ($MgSO_4$), and evaporated to dryness. According to the ^1H n.m.r. spectrum, the residue (390 mg) contained the desired (**3a**), the diselenide (**8**), the aliphatic diselenide (**12**), and unchanged (**4**) in 48, 16, 12, and 6% yields respectively.

The seleno ketone (**3b**) was prepared in the same way (Route C) from benzylidene acetone. Preparative t.l.c. purification [SiO_2, eluant (b), R_F 0.6] of the crude product gave a very low yield (5%) of (**3b**) still containing (**8**) and benzylidene acetone: $\delta_H(CDCl_3)$ 2.09 (s, 3 H, Me), 3.16 (d, *J* 7 Hz, 2 H, $CHCH_2$), 3.90 (s, 2 H, CH_2Se), 4.40 (t, *J* 7 Hz, 1 H, $CHCH_2$), and 7.1—7.7 (m, 4 H, ArH).

The seleno ketone (**3c**) was prepared as above from 4-phenylbut-3-yn-2-one. Preparative t.l.c. purification [SiO_2, eluant (a), R_F 0.7] of the crude product gave a 3:1 mixture of *Z*-(**3c**) and *E*-(**3c**) in combined 58% yield. Crystallisation from ethyl acetate gave yellow crystals (31%, m.p. 58—60 °C) which melted at 138—140 °C after drying at 80 °C under vacuum for 2 h (Found: C, 61.05; H, 4.7. $C_{18}H_{16}N_2OSe$ requires C, 60.85; H, 4.54%); $\nu_{max.}(CDCl_3)$ 1 640 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.20 (s, 3 H, Me), 3.66 (s, 2 H, CH_2), 6.60 (s, 1 H, CH), and 6.8—7.6 (m, 9 H, ArH); $\delta_C(CDCl_3)$ 22.65 (CH_2Se), 29.98 (Me), 114.87, 122.53, 125.78, 127.90, 128.72, 129.04, 139.06 (Ar + C=C), 150.79 (benzimidazole-C2), and 196.34 (CO). A small amount of the pure *E*-(**3c**) isomer was obtained by repeated preparative t.l.c. as a thick yellow oil, R_F[eluant (a)] 0.72; $\nu_{max.}(CDCl_3)$ 1 640 cm^{-1} (CO); $\delta_H(CDCl_3)$ 1.82 (s, 3 H, Me), 4.13 (s, 2 H, CH_2), 6.50 (s, 1 H, CH), and 7.0—7.7 (m, 9 H, ArH).

Cyclisation of the Seleno Ketone Z-(**3c**) *into the Selenophene* (**1c**).—Compound *Z*-(**3c**) (200 mg, 0.56 mmol) in DMSO (2 ml) was heated at 70 °C for 4 h. After being cooled the solution was poured onto water (20 ml). Filtration of the precipitate afforded the dihydroselenophene (**1c**) (126 mg, 63%) as a white powder which, after recrystallisation from acetonitrile, melted partially at about 200 °C, then resolidified and melted again at 320—322 °C [see m.p. of (**2c**)] (Found for (**1c**) C, 60.85; H, 4.65. $C_{18}H_{16}N_2OSe$ requires C, 60.85; H, 4.54%); $\nu_{max.}$(KBr pellet) 3 300 cm^{-1} (OH); $\delta_H([^2H_6]DMSO)$ 1.65 (s, 3 H, Me), 5.3 (s, 1 H, CHSe), 5.8—6.0 (br s, 1 H, OH), 6.6 (s, 1 H, =CH), 7.1—7.6 (m, 9 H, ArH), and 11.9—12.3 (br s, 1 H, NH); $\delta_C([^2H_6]DMSO)$ 26.9 (Me), 49.6, 85.7, 130.1, 138.4 (dihydroselenophene), 114.9, 121.7, 136.8 (benzimidazole-C_6H_4), 126.6, 128.7, 134.9 (Ph), and 151.7 (benzimidazole C-2); *m/z* 356 (M^+) and 338 $(M - H_2O)^+$; R_F 0.6 using eluant (b).

Synthesis of the Selenophene (**2c**).—Compound *Z*-(**3c**) (150 mg, 0.42 mmol) in glacial acetic acid (2 ml) was heated on a steam bath for 3 h. The solution was then poured on water, and the precipitate filtered off to give compound (**2c**) (100 mg, 70%), R_F[eluant (b)] 0.85. Recrystallisation from acetonitrile gave yellow needles, m.p. 322—323 °C (Found: C, 64.25; H, 4.4. $C_{18}H_{14}N_2Se$ requires C, 64.1; H, 4.18%); $\delta_H([^2H_6]DMSO)$ 2.6 (s, 3 H, Me), 7.0—7.7 (m, 10 H, Ar + =CH), and 12.3 (br s, 1 H, NH); $\delta_C([^2H_6]DMSO)$ 17.3 (Me), 115.6, 131.0, 131.3, 148.3 (selenophene), 115.0, 122.4, 140.2 (benzimidazole C_6H_4), 125.9, 128.5, 129.4, 135.3 (Ph), and 149.5 (benzimidazole C-2); *m/z* 338 (M^+).

Spontaneous decomposition of compound (**3a**) was effected as described in the text and Scheme 2. After each period of time the sample was dissolved in dichloromethane, the amorphous red selenium formed was filtered off, the solvent was evaporated, and the residue was subjected to t.l.c. [eluant (c)] and n.m.r. analysis. The volatile methyl vinyl ketone was not detected by n.m.r., but benzylidene acetone, arising from the decomposition of compound (**3b**) was clearly identified in the ^1H n.m.r. spectrum of the decompositionn product mixture.

Compounds (**10**), (**11**), (**13**), and (**14**) have been obtained in a pure state from the decomposition product mixture of (**3a**) as well as from independent syntheses carried out under conditions indicated in the text. These compounds had the following analytical data.

(**10**) (Found: C, 58.6; H, 5.1. $C_{20}H_{20}N_4OSe$ requires C, 58.40; H, 4.90%); R_F[eluant (c)] 0.3; $\nu_{max.}(CDCl_3)$ 1 710 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.13 (s, 3 H, Me), 3.02 (t, *J* 7 Hz, 2 H, CH_2CO), 4.46 (t, *J* 7 Hz, 2 H, NCH_2), 3.80 and 4.10 (2 × s, 2 × 2 H, CH_2SeCH_2), and 7.05—7.8 (m, 8 H, ArH).

(**11**) (Found: C, 60.0; H, 5.7. $C_{24}H_{26}N_4O_2Se$ requires C, 59.84; H, 5.44%); R_F[eluant (c)] 0.40; $\nu_{max.}(CDCl_3)$ 1 708 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.06 (s, 6 H, Me); 2.91 (t, *J* 7 Hz, 4 H, CH_2CO), 4.37 (t, *J* 7 Hz, 4 H, NCH_2), 4.21 (s, 4 H, CH_2SeCH_2), and 7.1—7.8 (m, 8 H, ArH); $\delta_C(CDCl_3)$ 18.25 ($SeCH_2$), 30.14 (Me), 38.29 (CH_2CO), 42.53 (NCH_2), 109.41, 119.67, 122.36, 122.85, 134.99, 142.73 (ArC), 151.37 (benzimidazole C-2), and 205.05 (CO).

(**13**) (Found: C, 71.1; H, 7.2. $C_{12}H_{14}N_2O$ requires 71.26; H, 6.98%); R_F[eluant (c)] 0.45; m.p. 39—43 °C; $\nu_{max.}(CDCl_3)$ 1 705 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.12 (s, 3 H, MeCO), 2.62 (s, 3 H, 2-Me), 2.92 (t, *J* 7 Hz, 2 H, CH_2CO), 4.36 (t, *J* 7 Hz, 2 H, NCH_2), and 7.02—7.7 (m, 4 H, ArH); $\delta_C(CDCl_3)$ 13.69 (2-Me), 30.14 ($MeCO$), 38.04 (CH_2CO), 42.44 (NCH_2), 108.84, 119.18, 121.87, 122.04, 134.66, 142.89 (ArC), 151.32 (benzimidazole C-2), and 204.89 (CO).

(**14**) (Found: C, 51.85; H, 4.5. $C_{12}H_{12}N_2OSe$ requires C, 51.47; H, 4.32%); $\nu_{max.}(CDCl_3)$ 1 700 cm^{-1} (CO); $\delta_H(CDCl_3)$ 2.40 (s, 3 H, Me), 4.1—4.5 (m, 3 H, $CHCH_2$), 4.01 (s, 2 H, CH_2Se), 7.0—7.8 (m, 4 H, ArH); $\delta_C(CDCl_3)$ 15.48 (CH_2Se), 27.78 (Me), 40.41 (CHSe), 43.91 (NCH_2), 108.84, 119.51, 122.53, 122.69, 135.23, 147.29 (ArC), 164.22 (benzimidazole C-2), and 201.79 (CO); $\delta_{Se}(CDCl_3, -60\ °C)$ 225.71; *m/z* 280 (M^+) and 237 (M − acetyl)$^+$; R_F[eluant (c)] 0.55.

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