Reaction of Dicyano Epoxides with Thiocyanate Ion: Route to α-Thiocyanato Derivatives or to 2-Acetylimino-1,3-oxathioles and X-Ray Crystal Structure of 2-Acetylimino-4-(4-tolyl)-1,3-oxathiole-5-carbonitrile

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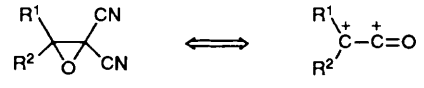
β-Aryl dicyano epoxides reacted as synthetic equivalents of ketene dications with KSCN in aq. dimethyl sulfoxide or EtOH, or with NH_4SCN in acetonitrile, to give α-thiocyanato derivatives. When Ac_2O was used as a solvent, the 1,3-oxathiolane intermediates were trapped as 2-acylimino-1,3-oxathioles. This new synthetic route to 1,3-oxathioles was extended to 1,3-oxaselenoles by using KSeCN as the reactant in Ac_2O. The crystal structure of an important intermediate compound, 2-acetylimino-4-(4-tolyl)-1,3-oxathiole-5-carbonitrile, was determined by means of X-ray diffraction.

The usual method for the preparation of simple thiiranes is the thiocyanate procedure using epoxides as starting materials.[1] The reaction is a nucleophilic ring opening of the epoxide. It proceeds through an oxathiolane intermediate which usually cannot be isolated. The isolation of thiiranes is not difficult unless they are substituted with electron-withdrawing groups which promote the decomposition of thiiranes into alkenes.[1a,b] In this context it seemed important to us to find out how the presence of two electron-withdrawing cyano groups, which are also good leaving groups, affected the course of reaction of dicyano epoxides **1** with a thiocyanate ion. We have already shown that epoxides **1** are interesting starting materials in organic synthesis because they can be considered as synthetic equivalents[2] of ketene dications **A**.[3] This is the reason why



1 **A**

we assumed that the reaction of epoxide **1** with thiocyanate ion would not give the corresponding thiiranes (or alkenes), but would lead to α-thiocyano acids or their derivatives. In this paper we shall demonstrate the correctness of our assumptions and also describe a new way of synthesizing 2-acetylimino-1,3-oxathioles and 2-acetylimino-1,3-oxaselenoles.

Results and Discussion

When epoxides **1** (R^1 = Ar; R^2 = H) reacted at room temperature with KSCN, the products obtained depended on the solvent used for the reaction. If the solvent was aq. dimethyl sulfoxide (DMSO), a mixture of acids **2** and **3** was obtained, both of which were characterized by means of IR, NMR and mass spectra (Experimental section). If ethanol was used as the solvent, a mixture of α-thiocyanato ester **4** and the thiazole **5** was obtained, and both products were characterized. However, the only product isolated, in moderate yield (51%), by reaction of compound **1** (R^1 = *p*-$NO_2C_6H_4$; R^2 = H) with KSCN in ethanol was the oxathiole **6**. In addition to its spectral data, compound **6** was characterized by its reaction with Ac_2O giving **7**, and by its hydrolysis to the thiazolone **8**. Of more synthetic interest was the opening of epoxides **1** (R^2 = Ar; R^1 = H) with ammonium thiocyanate in dry acetonitrile. Under these conditions, α-thiocyanato amides **9** were easily purified with reasonable yield (55–65%) except when the reaction was carried out with the epoxide **1** (R^1 = *p*-$NO_2C_6H_4$; R^2 = H). In that case, the only product isolated was the oxathiole **6** (Ar = *p*-$NO_2C_6H_4$). Having assumed that compound **6** resulted from the acylation of an oxathiole intermediate **D**, we decided to trap this intermediate by Ac_2O. We succeeded in preparing the 2-acetylimino-1,3-oxathioles **7** by reaction of epoxides **1** (R^1 = Ar; R^2 = H) with KSCN in Ac_2O (Scheme 1).

The previously presented experimental results call for the following remarks: as with the protic nucleophilic reagents used until now for the ring opening[3] of epoxides **1** (R^1 = Ar, R^2 = H), we observe that the reaction is highly regioselective. The nucleophile always attacks the carbon β from the two cyano groups. In order to confirm this fact, the structure of compound **7** (Ar = *p*-MeC_6H_4) was clearly established by X-ray analysis. The view of the molecule (Table 1) is shown in Fig. 1. Selected

Table 1 Fractional atomic co-ordinates for the non-hydrogen atoms for 2-acetylimino-3-(4-tolyl)-1,3-oxathiole-5-carbonitrile **7** (Ar = *p*-MeC_6H_4)

	x	*y*	*z*
S(1)	0.089 59(20)	0.080 3(4)	0.132 24(12)
C(2)	0.257 4(7)	0.045 4(12)	0.147 6(5)
O(3)	0.303 9(5)	−0.021 2(9)	0.225 5(3)
C(4)	0.206 0(8)	−0.038 1(13)	0.273 0(5)
C(5)	0.087 7(8)	0.008 7(13)	0.235 7(5)
C(8)	0.247 1(9)	−0.113 5(14)	0.353 6(5)
N(9)	0.278 7(8)	−0.176 0(13)	0.419 1(5)
N(1)	0.340 3(6)	0.072 5(11)	0.099 8(4)
C(6)	0.288 3(9)	0.143 8(13)	0.021 4(5)
O(1)	0.171 9(6)	0.166 5(10)	−0.003 1(4)
C(7)	0.387 5(9)	0.187 4(15)	−0.031 2(5)
C(10)	−0.033 3(7)	0.014 5(12)	0.269 8(5)
C(11)	−0.152 3(8)	−0.026 4(12)	0.218 6(5)
C(12)	−0.267 3(9)	−0.018 1(14)	0.249 6(5)
C(13)	−0.266 9(8)	0.040 9(12)	0.331 2(5)
C(14)	−0.149 5(8)	0.082 7(13)	0.381 5(5)
C(15)	−0.032 3(8)	0.071 1(13)	0.351 8(5)
C(16)	−0.394 7(8)	0.058 0(17)	0.363 0(6)

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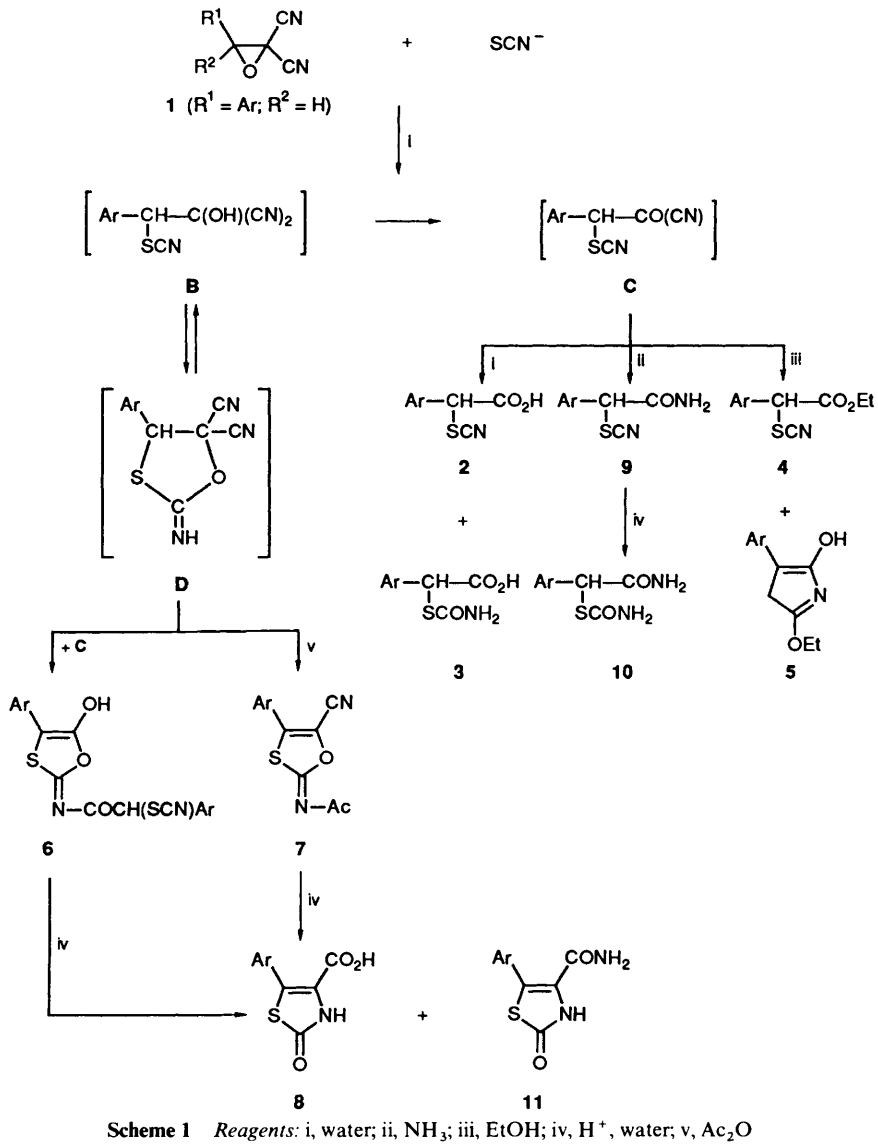


Scheme 1 *Reagents:* i, water; ii, NH_3; iii, EtOH; iv, H^+, water; v, Ac_2O

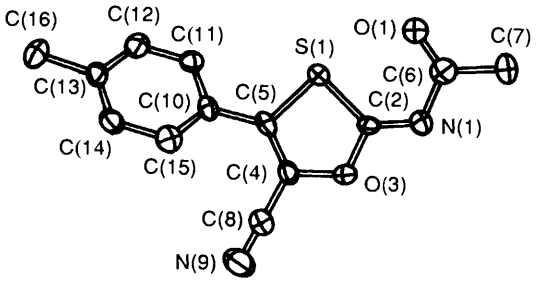


Fig. 1

bond distances and angles are in Table 2. The bond lengths are normal and in agreement with expectation. The bonds N^1–C^2 [1.279(11) Å] and C^4–C^5 [1.318(11) Å] clearly have some double-bond character. The separate acetylimino group, 1,3-oxathiole ring and phenyl ring are planar to within 0.006(9), 0.012(9) and 0.015(10) Å, respectively. The phenyl ring is twisted by 38.3° out of the nearly planar 2-acetylamino-1,3-oxathiole moiety. The dihedral angle between the acetylimino group and the 1,3-oxathiole ring is 6.1°. It seems that this planar arrangement is achieved through a weak single-bond–no-bond interaction[4] $S^1 \cdots O$ of 2.579(7) Å. It should be noted that the reaction of the studied epoxides with KSCN in

Table 2 Bond lengths (Å) and angles (°) with standard deviations in parentheses for 2-acetylimino-3-(4-tolyl)-1,3-oxathiole-5-carbonitrile **7** (Ar = *p*-MeC_6H_4)

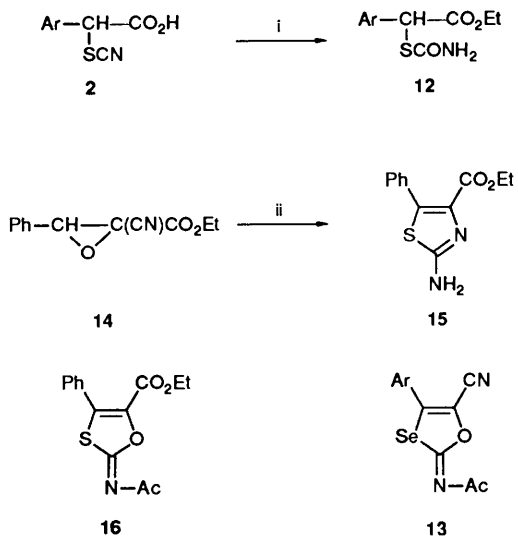
S(1)–C(2)	1.743(8)	C(6)–O(1)	1.219(11)
S(1)–C(5)	1.763(9)	C(6)–C(7)	1.492(14)
C(2)–O(3)	1.361(9)	C(10)–C(11)	1.395(10)
C(2)–N(1)	1.279(11)	C(10)–C(15)	1.393(12)
O(3)–C(4)	1.394(11)	C(11)–C(12)	1.386(13)
C(4)–C(5)	1.318(11)	C(12)–C(13)	1.394(12)
C(4)–C(8)	1.414(12)	C(13)–C(14)	1.378(11)
C(5)–C(10)	1.470(12)	C(13)–C(16)	1.521(13)
C(8)–N(9)	1.149(12)	C(14)–C(15)	1.397(13)
N(1)–C(6)	1.392(10)		
C(2)–S(1)–C(5)	90.3(4)	N(1)–C(6)–O(1)	123.3(7)
S(1)–C(2)–O(3)	111.3(5)	N(1)–C(6)–C(7)	114.1(7)
S(1)–C(2)–N(1)	131.6(5)	O(1)–C(6)–C(7)	122.6(7)
O(3)–C(2)–N(1)	117.0(6)	C(5)–C(10)–C(11)	120.2(7)
C(2)–O(3)–C(4)	112.0(6)	C(5)–C(10)–C(15)	120.8(7)
O(3)–C(4)–C(5)	116.2(7)	C(11)–C(10)–C(15)	118.9(7)
O(3)–C(4)–C(8)	114.7(7)	C(10)–C(11)–C(12)	120.8(7)
C(5)–C(4)–C(8)	129.0(7)	C(11)–C(12)–C(13)	120.4(7)
S(1)–C(5)–C(4)	110.1(6)	C(12)–C(13)–C(14)	118.8(7)
S(1)–C(5)–C(10)	120.7(6)	C(12)–C(13)–C(16)	119.8(7)
C(4)–C(5)–C(10)	129.2(6)	C(14)–C(13)–C(16)	121.4(7)
C(4)–C(8)–N(9)	179.0(11)	C(13)–C(14)–C(15)	121.5(7)
C(2)–N(1)–C(6)	114.8(7)	C(10)–C(15)–C(14)	119.6(7)

Ac_2O results in only one product, which was confirmed by ^1H NMR spectroscopy. However, no signal was observed which could be attributed to the presence of a possible isomer (sulfur on the carbon α from the cyano groups).

This regioselectivity is accounted for by assuming that the epoxide is first protonated (by the protic solvent or by NH_4^+) so that the reaction proceeds through a carbocationic-like transition stage. The consequence is that the practical positive charge will develop mainly on the carbon β from the two cyano groups of the epoxide **1**.

As previously mentioned, the initially formed cyanohydrins **B** and cyanoformyl intermediates **C** were too reactive to be isolated.[3] Intermediates **C** were trapped either with the solvent or with NH_3 (conjugate base of the ammonium ion of NH_4SCN) to give thiocyanates **2**, **4** and **9**. The formation of the oxathiole **7**, observed when the reaction is performed in Ac_2O, leads us to postulate possible reversible formation of the oxathiole **D**. As has been said before, similar oxathioles, formed during the reaction of 'normal' epoxides with ^-SCN, evolve into thiiranes. The specific reaction observed in our case is linked to the possible elimination of cyanohydric acid, either from the cyanohydrin **B** to give **C** or from the 2-iminooxathiolane **D** to give oxathioles **7** in the presence of Ac_2O. The reaction is highly chemoselective as it is always the ^-SCN nucleophile that opens the epoxide, while the second nucleophile (solvent or NH_3) reacts with the cyanoformyl intermediate **C**. It appears that the thiocyanato group in compounds **2** and **4** is reactive toward the nucleophile present in the medium (water or EtOH), and as a consequence they are obtained together with compounds **3** and **5**. The formation of the 4-hydroxythiazole is likely to be explained by the reaction of EtOH with the ^-SCN group, subsequently followed by an intramolecular heterocyclization. We have been able to show that the α-thiocyanato acid **2** (Ar = Ph) reacts with ethanol to give the ester **12** (Scheme 2), while the amide **9** is quantitatively hydrolysed to give thiocarbamate **10** (Scheme 1). The rate of the reaction **9** ⟶ **10** is accelerated by the presence of an acid, so that this reaction can be observed during the recording of the NMR spectrum of compound **9** in [$CDCl_3$ + CF_3CO_2H (TFA)] as solvent.

Although quite stable, the oxathioles **6** and **7** can be hydrolysed to give, according to experimental conditions, either the 2-oxo-1,3-thiazole-4-carboxamide **11**, or the 2-oxo-1,3-thiazole-4-carboxylic acid **8**, or a mixture of compounds **11** + **8**. The observed conversion of an oxathiole into a thiazole ring during the hydrolysis of the imino group of the oxathiole is not unexpected since a closely related reaction has already been described.[5] In our case, the concurrent hydrolysis of a cyano group into a carboxylic group is worth noting as the obtained 1,3-thiazole-4-carboxylic acids **8** can be considered as dehydroamino acids which are compounds of special interest.[6] In order to extend the scope of the afore described reaction of KSCN with the epoxides **1** (R^1 = Ar; R^2 = H), we have studied the reaction of this same epoxide with potassium selenocyanate in Ac_2O. As described in a short communication, we succeeded in the synthesis of 2-acetylimino-1,3-oxaselenoles **13** which are the first compounds so far described in the oxaselenole series.[7] We tried also to use the ester epoxides **14** instead of epoxide **1** (R^1 = Ar; R^2 = H). These ester epoxides **14** were less reactive toward NH_4SCN than is epoxide **1** (R^1 = Ar; R^2 = H), and the reaction needed to be performed in boiling ethanol. Under these experimental conditions NH_4SCN rearranged into thiourea,[8] which subsequently reacted with epoxide **14** to give the 2-amino-1,3-thiazole **15** as reported.[9] This last reaction is of no synthetic value because the thiazole **15** is more easily prepared from the reaction of thiourea with epoxide **14**.[9] On the other hand, the reaction of epoxide **14** with KSCN in Ac_2O gave the new 2-acetylimino-1,3-oxathiole **16**, which is of similar structure to the nitrile **7** (Scheme 2).



Scheme 2 *Reagents:* i, EtOH; ii, NH_4SCN

Conclusions.—The *gem*-disubstitution in the epoxides **1** by two cyano groups acting as leaving groups explains the synthetic equivalence of these epoxides with ketene dications **A**. The thiocyanate ion reacts chemoselectively and regioselectively with epoxides **1** (R^1 = Ar; R^2 = H) to give the α-thiocyanato derivatives **2**, **4** and **9** depending on the nature of the second nucleophile present in the medium (respectively water, EtOH, NH_3). However, owing to the reactivity of the thiocyanato group, the reaction is of synthetic utility for the preparation of thiocyanato amides **9** only.

When the reaction is performed in Ac_2O, the oxathiolane intermediate **D** is trapped by Ac_2O and the reaction is an interesting way of preparing 2-acetylimino-1,3-oxathioles **7**. We have shown that the scope of this reaction can be extended to α-cyano epoxy ester **14** and that selenocyanate can be used instead of thiocyanate. This reaction allowed us to prepare the first compounds of the oxaselenole series.

Experimental

Dicyano epoxides **1** and **14** were prepared according to the method developed in our laboratory.[10] NMR spectra were recorded on Bruker WP80 and AM300 spectrometers using Me_4Si as internal standard. IR spectra were obtained on a Perkin-Elmer 1420 IR spectrometer. Mass spectra were recorded on Varian Mat 311. Microanalyses were carried out in the microanalytical laboratory of CNRS (Lyon). M.p.s were measured by using a Kofler bank.

Preparation of α-Thiocyanato Acids **2** (*Ar* = *Ph*, p-ClC_6H_4) *and the Thiocarbamoyl Acid* **3** (*Ar* = p-ClC_6H_4).—An aqueous solution (2 cm^3) of KSCN (15 mmol) was added to a solution of epoxide **1** (R^1 = Ph or *p*-ClC_6H_4; R^2 = H) (6 mmol) in DMSO (10 cm^3). After 4 h (Ar = Ph) or 1 h (Ar = *p*-ClC_6H_4) the reaction mixture was diluted in cold water (80 cm^3). The pH was adjusted with HCl (30%) to 6 using a pH test paper, and the mixture was extracted with diethyl ether. The ethereal phase was washed with water and then extracted with aq. $NaHCO_3$ (10%). The water phase was acidified (pH 5), and the obtained oil was extracted with diethyl ether. After evaporation of the ether, the acid **2** was obtained. When Ar = *p*-ClC_6H_4, a mixture of products **2** and **3** was isolated. The two products were separated by recrystallization from benzene. A mixture was also obtained in the case of Ar = Ph, but only the thiocyanate **2** was properly purified.

Compound **2** (*Ar* = *Ph*) (40%), m.p. 125 °C (from benzene); $\nu_{max}(CCl_4)/cm^{-1}$ 3505br (OH), 3100br (OH), 2161s (SCN), 1757s (CO) and 1050br (OH); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 9.71 (1 H, s, OH), 7.40 (5 H, s, Ph) and 5.59 (1 H, s, CH) (Found: $M^{\bullet+}$, 193.020. $C_9H_7NO_2S$ requires *M*, 193.019).

Compound **2** (Ar = *p*-ClC_6H_4) (20%), m.p. 120 °C (from benzene); $\nu_{max}(CCl_4)/cm^{-1}$ 3500s (OH), 3100br (OH), 2161s (SCN), 1755s (CO), 1718s (CO) and 1050br (OH); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 8.72 (1 H, s, OH), 7.60 (4 H, m, Ar) and 5.70 (1 H, s, CH).

Compound **3** (*Ar* = p-*ClC*$_6H_4$) (35%), m.p. 170 °C (from benzene) (Found: C, 44.4; H, 3.7; N, 5.6%; $M^{\bullet+}$, 244.992. $C_9H_8ClNO_3S$ requires C, 44.20; H, 3.27; N, 5.72%; *M*, 244.991); ν_{max}(Nujol)/cm^{-1} 3417s (NH), 3187br (OH), 1706s (CO), 1644s (CO) and 878br (OH); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 7.65 (4 H, m, Ar), 6.87 (2 H, s, NH_2) and 5.20 (1 H, s, CH).

Preparation of α-Thiocyanato Ester **4** (*Ar* = *Ph*) *and the Thiazoles* **5** (*Ar* = *Ph*, p-*ClC*$_6H_4$).—Epoxides **1** (R^1 = Ph, *p*-ClC_6H_4; R^2 = H) (15 mmol) and KSCN (15 mmol) were dissolved in absolute ethanol (120 cm^3). The reaction mixture was left at room temperature for 24 h. The ethanol (100 cm^3) was then evaporated off and the residue was diluted with water (300 cm^3). The mixture was extracted with diethyl ether, and the extract was washed with water and dried (Na_2SO_4). After evaporation of the ether the obtained oil slowly crystallized to deposit the thiazole **5**. In the case of Ar = Ph, the obtained oil was distilled (*P* 0.5 mmHg; *T* 150 °C). A more volatile fraction was captured in the form of an oil which slowly crystallized to give the thiazole **5**, while the remaining oil corresponded to the thiocyanato ester **4**.

Compound **4** (*Ar* = *Ph*) (20%), $\nu_{max}(CCl_4)/cm^{-1}$ 2159s (SCN), 1748vs (CO) and 1735s (CO); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 7.40 (5 H, s, Ph), 5.34 (1 H, s, CH), 4.26 (2 H, q, CH_2) and 1.26 (3 H, t, Me); *m/z* 221 ($M^{\bullet+}$); 163 (M − SCN)$^{\bullet+}$ and 148 (M − $CO_2Et)^{\bullet+}$ (Found: $M^{\bullet+}$, 221.051. $C_{11}H_{11}NO_2S$ requires *M*, 221.051).

Compound **5** (Ar = *p*-ClC_6H_4) (14%), m.p. 167 °C (from EtOH); $\nu_{max}(CCl_4)/cm^{-1}$ 3550br (OH); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 7.70 (4 H, m, Ph), 4.66 (2 H, q, CH_2) and 1.54 (3 H, t, Me).

Compound **5** (Ar = Ph) (14%), m.p. 169 °C (from EtOH); $\nu_{max}(CCl_4)/cm^{-1}$ 3559br (OH); δ_H(80 MHz; CD_3COCD_3; Me_4Si) 8.58 (1 H, s, Ph), 4.42 (2 H, q, CH_2) and 1.36 (3 H, t, Me).

Preparation of the 2-(Thiocyanatoacetylimino)-1,3-oxathiole **6** (*Ar* = p-*NO*$_2C_6H_4$).—After 2 h at room temperature a solution of epoxide **1** (R^1 = *p*-$NO_2C_6H_4$; R^2 = H) (1 g, 4.6 mmol) and KSCN (1 g, 10 mmol) in ethanol (100 cm^3) was diluted with water. The obtained precipitate was washed successively with HCl (30%), water, ethanol and diethyl ether to give the title product (2.38 g, 51%), m.p. 292 °C (from EtOH); ν_{max}(Nujol)/cm^{-1} 2211s (CN) and 2151s (SCN); δ_H(80 MHz; $CDCl_3$ + TFA; Me_4Si) 8.0 (8 H, m, Ar) and 3.35 (1 H, s, CH); *m/z* 467 ($M^{\bullet+}$ not observed), 274 [M − CH(SCN)$C_6H_4NO_2$]$^{\bullet+}$, 228 (274 − $NO_2)^{\bullet+}$, 193 (M − $C_{11}H_4N_3O_4S)^{\bullet+}$, 192 (193 − H) and 146 (192 − $NO_2)^{\bullet+}$.

Preparation of 2-Acetylimino-1,3-oxathioles **7** (*Ar* = *Ph*, p-*ClC*$_6H_4$, p-*MeOC*$_6H_4$, p-*NO*$_2C_6H_4$, p-*MeC*$_6H_4$).—The epoxide **1** (R^1 = Ph, *p*-ClC_6H_4, *p*-$MeOC_6H_4$, *p*-$NO_2C_6H_4$, *p*-MeC_6H_4; R^2 = H) (1 g) was added to a solution of KSCN (0.7 g, 7.1 mmol) in Ac_2O (10 cm^3, but 6 cm^3 for R^1 = *p*-MeC_6H_4 and R^1 = Ph). After 3 h (15 h for R^1 = *p*-$NO_2C_6H_4$) the reaction mixture was put into a refrigerator for 30 min. The precipitate was filtered off and washed with water (to eliminate AcOH).

Another way of preparing compound **7** (R^1 = *p*-$NO_2C_6H_4$) consists of dissolution of the thiocyanate **6** (Ar = *p*-$NO_2C_6H_4$) (0.5 g, 1 mmol) in Ac_2O (100 cm^3) and, after 8 h, water is added and the required product **7** (0.2 g, 69%) is obtained.

Compound **7** (*Ar* = *Ph*) (0.42 g, 42%), m.p. 100 °C (from EtOH) (Found: C, 58.6; H, 3.3; N, 11.5. $C_{12}H_8N_2O_2S$ requires C, 59.00; H, 3.30; N, 11.47%); $\nu_{max}(CCl_4)/cm^{-1}$ 2229s (CN) and 1668s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 2.41 (3 H, s, Me) and 7.50 (5 H, m, Ph).

Compound **7** (*Ar* = p-*ClC*$_6H_4$) (0.57 g, 42%), m.p. 131 °C (from EtOH) (Found: C, 51.3; H, 2.6; N, 9.65. $C_{12}H_7ClN_2O_2S$ requires C, 51.80; H, 2.52; N, 10.07%); $\nu_{max}(CCl_4)/cm^{-1}$ 2225s (CN) and 1667s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 7.55 (4 H, m, Ar) and 2.42 (3 H, s, Me).

Compound **7** (*Ar* = p-*MeOC*$_6H_4$) (0.54 g, 48%), m.p. 143 °C (from EtOH) (Found: C, 57.2; H, 3.6; N, 9.8. $C_{13}H_{10}N_2O_3S$ requires C, 56.90; H, 3.60; N, 10.02%); $\nu_{max}(CCl_4)/cm^{-1}$ 2227s (CN) and 1667s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 7.58 (2 H, d, Ar), 6.95 (2 H, d, Ar), 3.83 (3 H, s, Me) and 2.37 (s, 3 H).

Compound **7** (*Ar* = p-*NO*$_2C_6H_4$) (0.56 g, 45%), m.p. 131 °C (from EtOH) (Found: C, 49.7; H, 2.3; N, 14.2. $C_{12}H_7N_3O_4S$ requires C, 49.90; H, 2.42; N, 14.54%); $\nu_{max}(CCl_4)/cm^{-1}$ 2228s (CN) and 1671s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 8.0 (2 H, d, Ar), 8.45 (2 H, d, Ar) and 2.48 (3 H, s, Me).

Compound **7** (*Ar* = p-*MeC*$_6H_4$) (0.86 g, 61%), m.p. 132 °C (from EtOH) (Found: C, 60.3; H, 3.9; N, 10.7. $C_{13}H_{10}N_2O_2S$ requires C, 60.46; H, 3.88; N, 10.85%); $\nu_{max}(CCl_4)/cm^{-1}$ 2227s (CN) and 1658s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 7.40 (4 H, m, Ar) and 2.48 (6 H, s, Me and COMe); δ_C(80 MHz; $CDCl_3$) 182.7 (*C*OMe), 173.6 (*C*NCOMe), 122.8 (s, *p*-MeC_6H_4-*C*), 114.3 (s, C-*C*N), 110.1 (s, *C*-CN), 27.28 (CO*Me*) and 22 (*Me*C_6H_4).

Preparation of the 2-Oxo-1,3-thiazole-4-calboxylic Acid **8** (*Ar* = p-*NO*$_2C_6H_4$) *and the 2-Oxo-1,3-thiazole-4-carboxamide* **11** (*Ar* = p-*ClC*$_6H_4$).—A suspension of compound **6** (Ar = *p*-$NO_2C_6H_4$) (0.467 g, 1 mmol) in conc. HCl (20 cm^3) was heated under reflux for 2 h. After dilution with water, a precipitate of compound **8** (0.2 g, 69%) was obtained. The same compound **8** (R^1 = *p*-$NO_2C_6H_4$; R^2 = H) was obtained if compound **7** (R^1 = *p*-$NO_2C_6H_4$; R^2 = H) (0.2 g, 1 mmol) was heated for 2.5 h under reflux in conc. HCl (20 cm^3). Compound **7** (R^1 = *p*-ClC_6H_4; R^2 = H) gave a mixture of products **8** and **11** after reflux for 2 h in conc. HCl (20 cm^3). Co-product **8** was eliminated by rinsing of the precipitate with aq. $NaHCO_3$ (0.5 mol dm^{-3}) and the remaining product **11** was recrystallized from EtOH.

Compound **8** (Ar = *p*-$NO_2C_6H_4$) (0.16 g, 80%), m.p. 227 °C (from EtOH); ν_{max}(Nujol)/cm^{-1} 3400–3200br (NH, OH), 1729s (CO), 1694vs (CO), 1680br (CO) and 900br (OH); δ_H(80 MHz; $CDCl_3$ + TFA; Me_4Si) 8.30 (4 H, m, Ar); *m/z* 226 ($M^{\bullet+}$), 248 (M − $H_2O)^{\bullet+}$, 238 (M − CO)$^{\bullet+}$, 222 (M − HNCO)$^{\bullet+}$, 166 (M − $C_7H_4NO_2S)^{\bullet+}$ and 120 (M − $C_6H_4CS)^{\bullet+}$.

Compound **11** (*Ar* = p-*ClC*$_6H_4$) (0.15 g, 60%), m.p. 232 °C (from EtOH); ν_{max}(Nujol)/cm^{-1} 3390–3166br (NH), 1739w (CO) and 1682s (CO); δ_H(80 MHz; $CDCl_3$ + TFA; Me_4Si) 8.35 (4 H, m, C_6H_4); *m/z* 254 ($M^{\bullet+}$), 237 (M + $NH_3)^{\bullet+}$, 209 (237 − CO)$^{\bullet+}$, 181 (209 − CO)$^{\bullet+}$ and 155 (M − $ClC_6H_4CS)^{\bullet+}$ (Found: M^+, 253.9918. $C_{10}H_7ClN_2O_2S$ requires *M*, 253.9917).

Preparation of α-Thiocyanato Amide **9** (*Ar* = *Ph*, p-*ClC*$_6H_4$).—An epoxide **1** (R^1 = Ph, *p*-ClC_6H_4; R^2 = H) (0.5 mmol) was added to a solution of NH_4SCN (0.76 g, 10 mmol) in MeCN (60 cm^3) (distilled over P_2O_5) and the reaction mixture was put in a refrigerator for 18 h. MeCN (40 cm^3) was evaporated off and the residue was diluted with water (200 cm^3). If the product **9** precipitated out it was filtered off, otherwise it was extracted with diethyl ether. Work-up gave *compound* **9** (*Ar* = *Ph*) (0.62 g, 55%), m.p. 144 °C (from benzene) (Found: C, 56.25; H, 4.1; N, 14.8. $C_9H_8N_2OS$ requires C, 56.30; H, 4.16; N, 14.57%); ν_{max}(Nujol)/cm^{-1} 3381s (NH), 3250br (NH), 2159s

(SCN) and 1668s (CO); δ_H(80 MHz; pyridine; Me_4Si) 8.72 (5 H, m, Ph) and 5.82 (1 H, s, CH).

Compound **9** (*Ar* = p-ClC_6H_4) (0.72 g, 65%), m.p. 157 °C (from benzene) (Found: C, 47.7; H, 3.2; N, 12.2. $C_9H_7ClN_2OS$ requires C, 47.78; H, 3.09; N, 12.38%); ν_{max}(Nujol)/cm^{-1} 3383s (NH), 3250br (NH), 2158s (SCN) and 1668s (CO); δ_H(80 MHz; pyridine; Me_4Si) 8.77 (4 H, m, Ar) and 5.83 (1 H, s, CH).

Preparation of Amide Thiocarbamate **10** (*Ar* = *Ph*).—Thiocyanate amide **9** (Ar = Ph) (0.3 g, 1.6 mmol) was dissolved in TFA (5 cm^3). After 18 h a precipitate of compound **10** was filtered off (0.191 g, 91%), m.p. 193 °C (from EtOH) (Found: C, 50.9; H, 4.9; N, 13.4. $C_9H_{10}N_2O_2S$ requires C, 51.14; H, 4.76; N, 13.33%); ν_{max}(Nujol)/cm^{-1} 3400s (NH), 3200w (NH), 1645vs (CO) and 1605s (CO); δ_H(80 MHz; $CDCl_3$ + TFA; Me_4Si) 7.44 (5 H, s, Ph) and 5.39 (1 H, s, CH).

Preparation of Ester **12** (*Ar* = *Ph*).—To a solution of acid **2** (Ar = Ph) in absolute ethanol (30 cm^3) were added two drops of conc. H_2SO_4 and then the reaction mixture was heated under reflux for 68 h. After dilution with water, extraction with diethyl ether and evaporation of the extract were carried out to give *compound* **12** (*Ar* = *Ph*) (0.5 g, 81%), m.p. 137 °C (from EtOH) (Found: C, 54.8; H, 5.3; N, 6.05. $C_{11}H_{13}NO_3S$ requires C, 55.24; H, 5.43; N, 5.85%); ν_{max}(CCl_4)/cm^{-1} 3524w (NH), 1740s (CO) and 1702s (CO); δ_H(80 MHz; $CDCl_3$ + TFA; Me_4Si) 7.60 (5 H, m, Ph), 5.28 (1 H, s, CH), 4.24 (2 H, q, CH_2) and 1.22 (3 H, t, Me).

Preparation of 2-Acetylimino-1,3-oxaselenoles **13** (*Ar* = p-ClC_6H_4, p-$MeOC_6H_4$, p-$NO_2C_6H_4$, p-MeC_6H_4).—Epoxide **1** (R^1 = *p*-ClC_6H_4, *p*-$MeOC_6H_4$, *p*-$NO_2C_6H_4$, *p*-MeC_6H_4; R^2 = H) was added to a solution of KSeCN (1 g, 10 mmol) in Ac_2O (10 cm^3). After 30 min at room temperature, the reaction mixture was put into a refrigerator for 1 h. The precipitate of AcOK was filtered off and Ac_2O was evaporated off under reduced pressure to give compound **13** (Ar = *p*-ClC_6H_4); yield, m.p., and spectral data were as published [7a] (Found: C, 44.15; H, 2.2; N, 8.25. Calc. for $C_{12}H_7ClN_2O_2Se$: C, 44.26; H, 2.16; N, 8.60%); δ_C(75 MHz; $CDCl_3$) 182.8 (*C*OMeCO), 176 (*C*NAc), 126.2 (*p*-ClC_6H_4-*C*), 115.93 (CN), 110 (*C*-CN) and 27.43 (CO*Me*).

Compound **13** (Ar = *p*-$MeOC_6H_4$); yield, m.p., and spectral data were published [7a] (Found: C, 48.75; H, 3.2; N, 8.65. Calc. for $C_{13}H_{10}N_2O_3Se$: C, 48.61; H, 3.14; N, 8.72%); *m/z* 322 ($M^{\bullet+}$), 280 (M − CH_2CO)$^{\bullet+}$, 253 (M − CH_3COCN)$^{\bullet+}$, 174 (280 − SeCN)$^+$, 199 ($CH_3OC_6H_4CSe$) and 43 (CH_3CO)$^+$.

Compound **13** (Ar = *p*-$NO_2C_6H_4$); yield, m.p., and spectral data were as published [7a] (Found: C, 43.1; H, 2.1; N, 12.4. Calc. for $C_{12}H_7N_3O_4Se$: C, 42.88; H, 2.10; N, 12.50%).

Compound **13** (*Ar* = p-MeC_6H_4) (0.69 g, 45%), m.p. 149 °C (EtOH) (Found: C, 51.5; H, 3.4; N, 9.1; $C_{13}H_{10}N_2O_2Se$ requires C, 51.18; H, 3.30; N, 9.18%); ν_{max}(CCl_4)/cm^{-1} 2223s (CN) and 1655s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 7.40 (4 H, m, Ar), 2.46 (3 H, s, Me) and 2.44 (3 H, s, Me).

Preparation of the 2-Amino-1,3-thiazole **15**.—An ethanolic (40 cm^3) solution of epoxide **14** (1 g, 4.3 mmol) and thiourea (0.33 g, 4.3 mmol) was heated under reflux for 16 h. After cooling, the precipitate of compound **15** was isolated (9%), m.p. 180 °C (from EtOH); spectral data were identical with those in the literature.[8]

Preparation of the 2-Acetylimino-1,3-oxathiole **16**.—A solution of KSCN (0.417 g, 4.3 mmol) and epoxide **14** (1 g, 4.3 mmol) in Ac_2O (10 cm^3) was heated to the boiling point and then left to cool to room temperature for 5 h. The obtained precipitate of *compound* **16** was filtered off, and washed with water (0.36 g, 30%), m.p. 104 °C (from EtOH) (Found: C, 57.35; H, 4.4; N, 4.5. $C_{14}H_{13}NO_3S$ requires C, 57.79; H, 4.46; N, 4.80%); ν_{max}(CCl_4)/cm^{-1} 1733s (CO) and 1659s (CO); δ_H(80 MHz; $CDCl_3$; Me_4Si) 7.50 (5 H, m, Ph), 4.33 (2 H, q, CH_2), 2.43 (3 H, s, Me) and 1.25 (3 H, t, Me).

Table 3 Selected torsion angles (°) with e.s.d.s in parentheses for 2-acetylimino-3-(4-tolyl)-1,3-oxathiole-5-carbonitrile **7** (Ar = *p*-MeC_6H_4)[a]

C(5)–S(1)–C(2)–O(3)	1.8(6)
C(2)–S(1)–C(5)–C(4)	−1.2(7)
C(5)–S(1)–C(2)–N(1)	−177.6(9)
C(2)–S(1)–C(5)–C(10)	176.2(8)
S(1)–C(2)–O(3)–C(4)	−2.0(6)
S(1)–C(2)–N(1)–C(6)	0.5(7)
N(1)–C(2)–O(3)–C(4)	177.5(10)
O(3)–C(2)–N(1)–C(6)	−178.8(11)
C(2)–O(3)–C(4)–C(5)	1.1(8)
C(2)–O(3)–C(4)–C(8)	177.6(10)
O(3)–C(4)–C(5)–S(1)	0.3(6)
O(3)–C(4)–C(5)–C(10)	−176.8(14)
O(3)–C(4)–C(8)–N(9)	−147(3)
C(8)–C(4)–C(5)–S(1)	−175.6(13)
C(5)–C(4)–C(8)–N(9)	29(3)
C(8)–C(4)–C(5)–C(10)	7.3(9)
S(1)–C(5)–C(10)–C(11)	36.9(8)
S(1)–C(5)–C(10)–C(15)	−139.3(11)
C(4)–C(5)–C(10)–C(11)	−146.3(14)
C(4)–C(5)–C(10)–C(15)	37.5(10)
C(2)–N(1)–C(6)–O(1)	−5.4(9)
C(2)–N(1)–C(6)–C(7)	175.7(11)
C(5)–C(10)–C(11)–C(12)	−178.8(13)
C(5)–C(10)–C(15)–C(14)	177.3(13)
C(15)–C(10)–C(11)–C(12)	−2.6(9)
C(11)–C(10)–C(15)–C(14)	1.1(8)
C(10)–C(11)–C(12)–C(13)	3.5(9)
C(11)–C(12)–C(13)–C(14)	−2.9(9)
C(11)–C(12)–C(13)–C(16)	177.0(14)
C(12)–C(13)–C(14)–C(15)	1.5(9)
C(16)–C(13)–C(14)–C(15)	−178.5(14)
C(13)–C(14)–C(15)–C(10)	−0.6(9)

[a] Sign convention from ref. 12.

X-Ray Structural Determination.—Thin crystals of compound **7** (Ar = *p*-MeC_6H_4) were grown from ethanolic solution. They exhibited poor scattering properties. Several crystals were tested.

Crystal data. $C_{13}H_{10}N_2O_2S$, M_r = 258.3. Monoclinic, *a* = 10.441(5), *b* = 7.354(3), *c* = 16.235(8) Å, β = 100.50(6)°, *V* = 1226(2) Å^3 (by least-squares refinement on diffractometer angles for 25 automatically centred reflections; 8 < θ < 12° range, λ = 0.710 69 Å), space group $P2_1/c$ (N° 14), *Z* = 4, D_x = 1.399 g cm^{-3}, *F*(000) = 536. Fragile, transparent, thin plate-like crystal 0.16 × 0.40 × 0.04 mm, μ(Mo-Kα) = 2.46 cm^{-1}.

Data collection and processing.[11] CAD-4-diffractometer, ω/2θ mode with ω scan width 0.9 + 0.3 tan θ, variable ω scan rate 1.8–6.7° min^{-1}, graphite-monochromated MO-Kα radiation, 5397 reflections measured up to $(\sin\theta/\lambda)_{max}$ = 0.64 Å^{-1}, ±*h*, ±*k*, +*l*; 2670 unique reflections (R_{int} = 0.056) and 1014 considered as observed [$I > 3\sigma(I)$]. Control-intensity decline of 12% was corrected during processing.

Structure analysis and refinement. Automatic direct methods. Full-matrix least-squares refinement with all non-hydrogen atoms unisotropic and hydrogens in calculated positions with an overall isotropic temperature factor U_{iso} = 0.10(1) Å^2. The weighting scheme, $w = [\sigma^2(F_o) + 0.0056\ F_o^2]^{-1}$, with $\sigma(F_o)$ from counting statistics, was used during anisotropic refinement. Final conventional *R*- and R_w-values are 0.071 and 0.077 and the corresponding *S*-value was 1.26 for 1014 reflections and 164 parameters. The maximum and minimum residual electron density in the final Δσ map were +0.397 and −0.389 e Å^{-3}. Programs, computer used, and sources of scattering factor data are given in ref. 11. The derived structure

is given in Fig. 1. Final atomic co-ordinates are given in Table 1, bond lengths and angles in Table 2, and selected torsion angles in Table 3.*

* *Supplementary data* (see section 5.6.3 of Instructions for Authors, *J. Chem. Soc., Perkin Trans 1*, 1993, issue 1). Tables of torsion angles, bond-lengths and angles and hydrogen coordinates have been deposited at the Cambridge Crystallographic Data Centre.

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