

Trifluoroacetoxysulphenylation of Unsaturated Nitriles and Transformation of the Adducts into Lactones

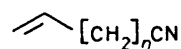
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Reactions of metal acetates with organic disulphides in dichloromethane-trifluoroacetic acid in the presence of unsaturated nitriles give trifluoroacetoxy sulphides, which on hydrolysis readily afford mixtures of the regioisomeric hydroxy sulphides. Optimum yields were obtained with manganese(III) acetate. The mixtures of regioisomeric trifluoroacetoxy sulphides react with acetonitrile under Ritter conditions to give further mixtures of regioisomeric vicinal acetamido sulphides. The regiochemistry of these reactions is discussed. Hydrolysis of the mixtures of trifluoroacetoxy sulphides in aqueous cobalt chloride gives substituted lactones. This high-yield transformation depends upon lactonisation proceeding *via* an episulphonium ion intermediate; hence conversion of unsaturated nitriles into sulphenyl lactones is characterised by good regiocontrol.

In the first studies¹ of trifluoroacetoxysulphenylation of alkenes, leading to vicinal hydroxy sulphides, and also in our later extension^{2,3} of this synthesis, sulphur electrophiles were generated by reactions of organic disulphides with lead(IV) salts. In the two preceding papers^{4,5} we have described our interest in extending such reactions to a variety of unsaturated substrates. At an early stage of our study with allylic derivatives we found that the use of lead(IV) salts afforded adducts in rather poor yields. In this paper we describe the use of other metal salts, which permit adducts to be obtained in substantially higher yields. In particular, our earlier observations that manganese(III) salts could be used with advantage has enabled us to use manganese(III) acetate successfully in the functionalisation of unsaturated esters, amides, acids, and as described earlier⁶ and in the present paper, nitriles.

A major interest in the trifluoroacetoxysulphenylation of allylic, homoallylic, and other unsaturated derivatives is the control of regiochemistry. With allylic esters⁴ and amides⁵ we have achieved substantial regiocontrol. However, in view of the poor regiocontrol (see later) in the trifluoroacetoxysulphenylation of unsaturated nitriles, we have examined further the chemistry of the adducts. We have found that under Ritter conditions leading to vicinal acetamido sulphides regiocontrol is again poor. However, under conditions of transformation of the nitrile functionality, mixtures of adducts can be converted into sulphenyl lactones with a very high degree of regiocontrol.

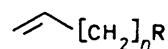
Following the strategy of the two preceding papers^{4,5} concerned with unsaturated esters, amides, and carboxylic acids, we chose to examine additions to the readily available allyl cyanide (1), pent-4-enitrile (2), and hex-5-enitrile (3). In initial experiments we examined the addition of diphenyl disulphide (4) and dipropyl disulphide (5) to these alkenes in dichloromethane-trifluoroacetic acid in the presence of lead(IV) acetate. With non-functionalised alkenes such additions¹⁻³ proceed normally in good yield. However, although on work-up the desired adducts could be obtained, yields were very poor. Thus allyl cyanide (1) with diphenyl disulphide (4) afforded after hydrolysis the pair of adducts (14) and (15), and with dipropyl disulphide (5) the adducts (16) and (17). Similarly pent-4-enitrile gave the adducts (20) and (21) with diphenyl disulphide (4), and the adducts (22) and (23) with dipropyl disulphide (5) (see Table 1). The poor yields can be attributed to interference by the nitrile group with the normal role of lead(IV) in these additions, *i.e.* generation of the electrophile from the disulphide. As we had previously⁷ used copper(II) salts to generate such electrophiles, we briefly investigated additions promoted by iron(III) or copper(II) salts. As shown in Table 1



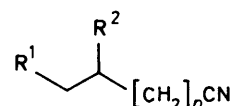
- (1) $n = 1$
 (2) $n = 2$
 (3) $n = 3$

RSSR

- (4) R = Ph
 (5) R = Pr
 (6) R = 4-MeC₆H₄



- (7) R = OAc, $n = 1$
 (8) R = NHAc, $n = 1$
 (9) R = OCOCF₃, $n = 1$
 (10) R = NHCOCF₃, $n = 1$
 (11) R = OAc, $n = 2$
 (12) R = OCOCF₃, $n = 2$
 (13) R = OCOCF₃, $n = 3$



- (14) R¹ = PhS, R² = OH, $n = 1$
 (15) R¹ = OH, R² = PhS, $n = 1$
 (16) R¹ = PrS, R² = OH, $n = 1$
 (17) R¹ = OH, R² = PrS, $n = 1$
 (18) R¹ = 4-MeC₆H₄S, R² = OH, $n = 1$
 (19) R¹ = OH, R² = 4-MeC₆H₄S, $n = 1$
 (20) R¹ = PhS, R² = OH, $n = 2$
 (21) R¹ = OH, R² = PhS, $n = 2$
 (22) R¹ = PrS, R² = OH, $n = 2$
 (23) R¹ = OH, R² = PrS, $n = 2$
 (24) R¹ = 4-MeC₆H₄S, R² = OH, $n = 2$
 (25) R¹ = OH, R² = 4-MeC₆H₄S, $n = 2$
 (26) R¹ = PhS, R² = OH, $n = 3$
 (27) R¹ = OH, R² = PhS, $n = 3$
 (28) R¹ = PrS, R² = OH, $n = 3$
 (29) R¹ = OH, R² = PrS, $n = 3$
 (30) R¹ = 4-MeC₆H₄S, R² = OH, $n = 3$
 (31) R¹ = OH, R² = 4-MeC₆H₄S, $n = 3$

these attempted additions failed. However manganese(III) acetate, which as an oxidant may be considered less reactive than lead(IV) acetate, but more reactive than either iron(III) acetate or copper(II) acetate, proved a satisfactory alternative. A

Table 1. Hydroxy sulphides from trifluoroacetoxy sulphenylation of unsaturated nitriles

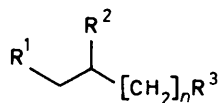
Alkene	Oxidant	Disulphide	Markovnikov		Anti-Markovnikov	
			Product	Yield%	Product	Yield%
(1)	Mn(OAc) ₃	(4)	(14)	20	(15)	66
(1)	Mn(OAc) ₃	(6)	(18)	15	(19)	73
(1)	Mn(OAc) ₃	(5)	(16)	11	(17)	46
(2)	Mn(OAc) ₃	(4)	(20)	28	(21)	47
(2)	Mn(OAc) ₃	(6)	(24)	36	(25)	47
(2)	Mn(OAc) ₃	(5)	(22)	24	(23)	49
(3)	Mn(OAc) ₃	(4)	(26)	42	(27)	14
(3)	Mn(OAc) ₃	(6)	(30)	50	(31)	14
(3)	Mn(OAc) ₃	(5)	(28)	72	(29)	5
(1)	Pb(OAc) ₄	(4)	(14)	3	(15)	18
(2)	Pb(OAc) ₄	(5)	(22)	9	(23)	12
(1)	Pb(OAc) ₄	(4)	(14)	3	(15)	15
(2)	Pb(OAc) ₄	(5)	(22)	7	(23)	24
(1)	Fe(OAc) ₃	(4)		No addition		
(1)	Cu(OAc) ₂	(4)		No addition		

Table 2. Regioselectivity in additions to unsaturated compounds

Alkene	Disulphide	Markovnikov		Anti-Markovnikov	
		Product	Yield (%)	Product	Yield (%)
(7)	(4)	(32)	82	(33)	
(7)	(5)	(34)	77	(35)	
(8)	(4)	(36)	87	(37)	
(9)	(4)	(38)		(39)	98
(9)	(5)	(40)		(41)	84
(19)	(4)	(42)	19	(43)	68
(11)	(4)	(44)	69	(45)	
(12)	(4)	(46)	40	(47)	45
(13)	(4)	(48)	77	(49)	

Table 3. Acetamidisulphenylation *via* trifluoroacetoxy sulphenylation of unsaturated nitriles and subsequent Ritter reaction

Nitrile	Disulphide	Markovnikov		Anti-Markovnikov	
		Product	Yield (%)	Product	Yield (%)
(1)	(6)	(50)	9	(51)	46
(1)	(6)	(52)	11	(53)	45
(2)	(4)	(54)	12	(55)	21
(2)	(6)	(56)	12	(57)	19
(3)	(4)	(58)	43	(59)	14
(3)	(6)	(60)	21	(61)	6



- (32) R¹ = PhS, R² = OH, R³ = OAc, n = 1
 (33) R¹ = OH, R² = PhS, R³ = OAc, n = 1
 (34) R¹ = PrS, R² = OH, R³ = OAc, n = 1
 (35) R¹ = OH, R² = PrS, R³ = OAc, n = 1
 (36) R¹ = PhS, R² = OH, R³ = NHAc, n = 1
 (37) R¹ = HO, R² = PhS, R³ = NHAc, n = 1
 (38) R¹ = PhS, R² = OH, R³ = OH, n = 1
 (39) R¹ = OH, R² = PhS, R³ = OH, n = 1
 (40) R¹ = PrS, R² = OH, R³ = OH, n = 1
 (41) R¹ = OH, R² = PrS, R³ = OH, n = 1
 (42) R¹ = PhS, R² = OH, R³ = NHCOCF₃, n = 1
 (43) R¹ = OH, R² = PhS, R³ = NHCOCF₃, n = 1
 (44) R¹ = PhS, R² = OH, R³ = OAc, n = 2
 (45) R¹ = OH, R² = PhS, R³ = OAc, n = 2
 (46) R¹ = PhS, R² = OH, R³ = OH, n = 2
 (47) R¹ = OH, R² = PhS, R³ = OH, n = 2
 (48) R¹ = PhS, R² = OH, R³ = OH, n = 3
 (49) R¹ = OH, R² = PhS, R³ = OH, n = 3

large number of experiments described in this and other papers^{4,5} show that manganese(III) acetate efficiently promotes additions by organic disulphides yet is tolerant of a wide range of functionality in the substituted alkene participating in the addition.

With manganese(III) acetate, the addition reactions of the unsaturated nitriles (1)–(3) and the disulphides (4) and (5) and di-*p*-tolyl disulphide (6) were studied. In each case the initial trifluoroacetate adducts were isolated and hydrolysed, to give

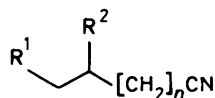
the hydroxy sulphides (14)–(31) (Table 1). The pairs of adducts were readily separated by chromatography, and structures were assigned by analysis of ¹H and ¹³C n.m.r. spectra.

The additions to allyl cyanide (1) to give the adducts (14)–(19) are characterised by a preference for formation of the anti-Markovnikov adduct. A summary of the observed regioselectivity in a number of additions, based on this and previous papers,^{4,5} is given in Tables 1 and 2. From these results it can be seen that the regiocontrol exercised by the nitrile functionality is less than that of the trifluoroacetoxy group. In each case the control is attributed to an inductive effect of the substituent.

In the case of additions to pent-4-enonitrile, affording the adducts (20)–(25), there is still a slight preference for the anti-Markovnikov adduct. This selectivity is similar to that observed on addition to the trifluoroacetate (12). Hence there is an apparent conflict in the magnitudes of substituent effects exerted in allylic and homoallylic derivatives. In additions to allylic derivatives the trifluoroacetoxy group exerts a greater regiocontrol than the nitrile group, yet in additions to homoallylic derivatives they appear to exert similar effects. We explain this anomaly in terms of some neighbouring group participation by the nitrile group in additions to the homoallylic nitriles. Hence regioselectivity to allylic nitriles is controlled by inductive effects, but with homoallylic nitriles, where the nitrile group might participate at an incipient carbocationic centre through a five- or a six-membered transition state, steric constraints may favour the six-membered transition state and hence anti-Markovnikov addition. In additions to hex-5-enonitrile (3) where a nitrile group might participate in a six- or a seven-membered ring in formation of the adducts (26)–(31), the yields of the anti-Markovnikov products are surprisingly high. Possibly again neighbouring group participation by the nitrile group is involved; we note the greater selectivity in the addition

Table 4. Cobalt(II) chloride-promoted lactonisation of hydroxy nitriles

Hydroxy nitrile	Product	Yield (%)
(14)	(62)	70
(15)	(62)	93
(18)	(63)	85
(19)	(63)	87
(20)	(65)	90
(21)	(65)	86
(26)	(68)	89
(27)	(68)	87



- (50) R¹ = PhS, R² = NHAc, n = 1
 (51) R¹ = NHAc, R² = PhS, n = 1
 (52) R¹ = 4-MeC₆H₄S, R² = NHAc, n = 1
 (53) R¹ = NHAc, R² = 4-MeC₆H₄S, n = 1
 (54) R¹ = PhS, R² = NHAc, n = 2
 (55) R¹ = NHAc, R² = PhS, n = 2
 (56) R¹ = 4-MeC₆H₄S, R² = NHAc, n = 2
 (57) R¹ = NHAc, R² = 4-MeC₆H₄S, n = 2
 (58) R¹ = PhS, R² = NHAc, n = 3
 (59) R¹ = NHAc, R² = PhS, n = 3
 (60) R¹ = 4-MeC₆H₄S, R² = NHAc, n = 3
 (61) R¹ = NHAc, R² = 4-MeC₆H₄S, n = 3

of dipropyl disulphide (5) in the preferential formation of the Markovnikov product.

The results in Table 1 establish that mixtures of adducts can be efficiently generated by manganese(III)-promoted additions of disulphides to unsaturated nitriles. However the relative lack of regiocontrol puts in question the synthetic value of these additions. We have examined further transformations of the mixtures of adducts with a view to establishing whether common products might be obtained from pairs of adducts, and hence whether in a multi-step process the required regiocontrol might be achieved. Two examples of such subsequent transformations have been chosen, one to give acyclic and one to give cyclic products.

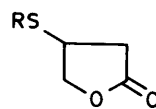
We have previously established² that vicinal trifluoroacetoxy sulphides can be converted under Ritter conditions into acetamido sulphides. Such reactions are likely to pass through the same ionic intermediate, which is also an intermediate in the initial formation of the trifluoroacetoxy sulphide. Accordingly it is likely that similar regioselectivities will be observed in the two processes of formation of the trifluoroacetoxy sulphides and the acetamido sulphides. In Table 3 are the yields of the adducts (50)–(61) obtained by reaction of the appropriate unsaturated nitrile and disulphide, followed by direct reaction of the mixture of trifluoroacetoxy sulphides under Ritter conditions to give the final acetamido sulphides. In each case the pair of adducts was separated by chromatography and the components were characterised by their ¹H and ¹³C n.m.r. spectra.

The overall yields based on the two-step transformation are moderate but it can be seen from Table 3 that the observed regioselectivity is in each case very similar to that observed (see Table 1) in the formation of the related trifluoroacetoxy sulphides. Hence in the Ritter transformation, although episulphonium ion intermediates may be involved, thus offering the possibility of the formation of products in a highly regioselective manner, in fact poor regioselectivity is observed under Ritter conditions giving acyclic products.

However the results in Tables 4 and 5 show a very different

Table 5. Preparation of lactones *via* trifluoroacetoxylation of unsaturated nitriles and subsequent hydrolysis

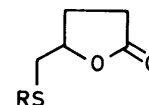
Nitrile	Disulphide	Intermediate alcohols	Lactone	Yield (%)
(1)	(4)	(14) and (15)	(62)	65
(1)	(6)	(18) and (19)	(63)	65
(1)	(5)	(16) and (17)	(64)	61
(2)	(4)	(20) and (21)	(65)	75
(2)	(6)	(24) and (25)	(66)	75
(2)	(5)	(22) and (23)	(67)	69
(3)	(4)	(26) and (27)	(68)	85
(3)	(6)	(30) and (31)	(69)	73
(3)	(5)	(28) and (29)	(70)	80



(62) R = Ph

(63) R = 4-MeC₆H₄

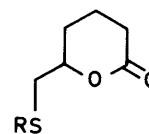
(64) R = Pr



(65) R = Ph

(66) R = 4-MeC₆H₄

(67) R = Pr



(68) R = Ph

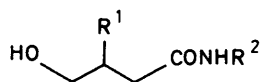
(69) R = 4-MeC₆H₄

(70) R = Pr

situation in the formation of cyclic compounds. In Table 4 the yields are given for the transformation of individual hydroxy sulphides into lactones. In Table 5 the yields are given for the two-step transformation of unsaturated nitriles *via* the trifluoroacetate adducts into the same lactones (62)–(70). In experiments described in Table 5 the crude mixture of trifluoroacetates from a given unsaturated nitrile was treated directly to give the appropriate lactone. In each case a single lactone was obtained; hence the overall two-step process constitutes a regioselective cyclofunctionalisation. Most of these conversions of either individual hydroxy sulphides or crude trifluoroacetates were carried out with cobalt(II) chloride in hot water to effect lactonisation. In a case detailed in the Experimental section more sulphuric acid was added.

The choice of reaction conditions for the transformations into the lactones was based on two areas of previous study. The hydrolysis of nitriles is promoted⁸ by a number of different metals or metal ions. Cobalt salts⁹ facilitate this hydrolysis particularly efficiently. In the case of our lactonisations it is probable that initial hydrolysis of the crude trifluoroacetates affords hydroxy sulphides. Subsequent hydrolysis of the nitrile group can be helped by intramolecular assistance by the hydroxy group. Such intramolecular participation has already been recognised;¹⁰ even cobalt(II) chloride promotes¹¹ the conversion of hydroxy nitriles into cyclic lactams.

The second area of recent study which assists the understanding of our results is the demonstration by Warren's group¹² that under acidic conditions phenylthio migration readily occurs *via* episulphonium ion intermediates. The lactones (62)–(70) are formed from some hydroxy nitriles, *e.g.*

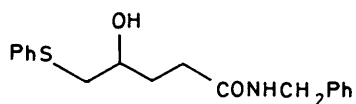


(71) $R^1 = \text{PhS}$, $R^2 = \text{Bu}^t$

(72) $R^1 = \text{PhS}$, $R^2 = \text{Ph}$

(73) $R^1 = \text{PhS}$, $R^2 = \text{PhCH}_2$

(74) $R^1 = \text{PrS}$, $R^2 = \text{C}_6\text{H}_{11}$



(75)

(15), without phenylthio or alkylthio migration, but in the case of other hydroxy nitriles, e.g. (14), lactones are formed *via* 1,2-migration involving the appropriate episulphonium ion (see Table 4). Thus the lactones (62)—(70) shown in Table 5 are obtained in part *via* 1,2-migration from the appropriate hydroxy nitriles. In each case there are two possible lactone products. Formation of the lactones (62)—(64) is to be expected rather than formation of the alternatives having a four-membered ring. Similarly the lactones (65)—(67) and (68)—(70) are to be expected rather than those having respectively a six- or a seven-membered ring, on the basis of many recent studies¹³ of lactonisation. The two-step transformation permits unsaturated nitriles to be efficiently converted into single sulphenylated lactones.

Finally the hydroxy amides (71)—(75) were obtained by reactions of the appropriate lactones and amines. These reactions served two functions. First, they permitted the further characterisation of liquid lactones as their solid amide derivatives. Secondly, they permitted the establishment of a regioselective route to the hydroxy sulphide adducts of unsaturated amides. We have shown elsewhere⁵ that direct attempted trifluoroacetoxysulphenylation of unsaturated amides leads to lactones. The route *via* trifluoroacetoxysulphenylation of unsaturated nitriles followed by the reactions described here offers a satisfactory alternative.

Experimental

General experimental details are described in an earlier paper.⁴

Preparation of Nitriles.—With the exception of the following compounds all nitriles were obtained from commercial sources.

Pent-4-enonitrile (2). Reaction of ethyl cyanoacetate with sodium hydride in dimethylformamide followed by addition of allyl bromide afforded, after reaction at 100 °C for 18 h and work-up, ethyl 2-cyanobut-4-enoate (93% with respect to allyl bromide) as a colourless liquid, b.p. 108 °C at 17 mmHg. Hydrolysis and decarboxylation by the method of Krapcho,¹⁴ with sodium chloride in dimethyl sulphoxide at 160 °C for 4 h, and subsequent work-up afforded pent-4-enonitrile (2) (65%) as a colourless liquid, b.p. 140 °C.

Hex-5-enonitrile (3). Reaction of 5-bromopent-1-ene at 100 °C for 2 h with potassium cyanide in ethane-1,2-diol afforded after work-up hex-5-enonitrile (3) (88% yield) as a colourless liquid, b.p. 160—162 °C.

General Procedure for Trifluoroacetoxysulphenylation with Manganese(III) Acetate Dihydrate.—Trifluoroacetic acid (5 ml) was added to a stirred solution of manganese(III) acetate dihydrate (1.48 g, 5.5 mmol) in dichloromethane (50 ml) at 0 °C.

After 5 min the disulphide (3.7 mmol) was added and immediately the alkene (7.5 mmol) was added to the solution at 0 °C. The solution was stirred for 8 h, while the initial orange colour faded to give a colourless solution. The mixture was poured into water (50 ml) and extracted with ether (3 × 50 ml). The organic phase was washed with aqueous potassium hydrogen carbonate (3 × 50 ml) and then water (3 × 50 ml), dried (MgSO₄), filtered, and evaporated under reduced pressure. Typically, the crude trifluoroacetoxy sulphide was either hydrolysed to afford hydroxy sulphides, or treated with acetonitrile to afford acetamido sulphides.

General Procedure for Trifluoroacetoxysulphenylation with Lead Tetra-acetate.—Trifluoroacetic acid (5 ml) was added to lead tetra-acetate (1.58 g, 3.7 mmol) in dichloromethane (50 ml) at 0 °C. The disulphide (3.7 mmol) and alkene (7.5 mmol) were added and the solution was stirred at 0 °C for 30 min. An initial turquoise colour faded to yellow, which continued to fade. Work-up as before afforded crude trifluoroacetoxy sulphides.

Preparation of Hydroxy Sulphides.—The crude trifluoroacetoxy sulphide (1.2 g) dissolved in the minimum quantity of ether (10 ml) was added to aqueous sodium carbonate (30 ml; 15% solution). The mixture was stirred at room temperature for 18 h. Addition of a little water (10 ml) was followed by extraction with more ether (3 × 50 ml). The combined extracts were washed with more water (3 × 50 ml), dried (MgSO₄), and evaporated under reduced pressure to give the crude hydroxy sulphides. Products were purified by chromatography over silica gel. Details of yields are given in the Tables.

Allyl cyanide (1) (0.6 g) and diphenyl disulphide (4) (0.81 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant ethyl acetate–light petroleum (1:1)], as the less polar fraction, 3-hydroxy-4-phenylthiobutanonitrile (14) (95 mg) (Found: M^+ , 193.0501. $\text{C}_{10}\text{H}_{11}\text{NOS}$ requires M , 193.0561); m/z 194 ($M^+ + 1$, 7%), 193 (50), 135 (14), and 122 (100); ν_{max} (CHCl₃) 3 460, 2 260, and 1 600 cm^{-1} ; δ_{H} 2.57 (1 H, dd, J 17 and 5 Hz) and 2.64 (1 H, dd, J 17 and 5 Hz) (CH₂CN), 3.05 (2 H, m, CH₂S), 3.55 (1 H, s, OH), 3.95 (1 H, m, CHOH), and 7.2—7.5 (5 H, m, aromatic); δ_{C} 24.46 (CH₂CN), 40.20 (CH₂S), 66.08 (CHOH), 117.26 (CN), and 127.00, 129.18, 130.19, and 134.32 (aromatic carbon); and as the more polar fraction 4-hydroxy-3-phenylthiobutanonitrile (15) (471 mg) (Found: M^+ , 193.0528. $\text{C}_{10}\text{H}_{11}\text{NOS}$ requires M , 193.0561); m/z 194 ($M^+ + 1$, 11%), 193 (95), 162 (89), 136 (100), and 109 (99); ν_{max} (CHCl₃) 3 490, 2 260, and 1 600 cm^{-1} ; δ_{H} 2.63 (1 H, dd, J 17 and 7 Hz) and 2.74 (1 H, dd, J 17 and 6 Hz) (CH₂CN), 3.13 (1 H, s, OH), 3.3—3.4 (1 H, m, CHS), 3.67 (1 H, dd, J 11 and 7 Hz) and 3.81 (1 H, dd, J 11 and 5 Hz) (CH₂O), and 7.2—7.5 (5 H, m, aromatic); δ_{C} 20.53 (CH₂CN), 47.07 (CHS), 63.16 (CH₂OH), 117.50 (CN), and 128.50, 129.37, 131.66, and 133.54 (aromatic carbon).

Allyl cyanide (1) (0.6 g) and di-*p*-tolyl disulphide (6) (0.91 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant ethyl acetate–light petroleum (1:1)], as the less polar fraction, 3-hydroxy-4-*p*-tolylthiobutanonitrile (18) (115 mg) (Found: M^+ , 207.0717. $\text{C}_{11}\text{H}_{13}\text{NOS}$ requires M , 207.0718); m/z 208 ($M^+ + 1$, 6%), 207 (M^+ , 37), 149 (7), and 137 (100); ν_{max} (CHCl₃) 3 500, 2 260, and 1 600 cm^{-1} ; δ_{H} 2.30 (3 H, s, Me), 2.56 (1 H, dd, J 17 and 6 Hz) and 2.65 (1 H, dd, J 17 and 5 Hz) (CH₂CN), 3.01 (2 H, m, CH₂S), 3.41 (1 H, s, OH), 3.93 (1 H, quint, CHOH), and 7.05—7.3 (4 H, m, aromatic); δ_{C} 20.85 (Me), 24.42 (CH₂CN), 40.95 (CH₂S), 66.07 (CHOH), 117.23 (CN), and 130.02, 130.30, 131.02, and 137.39 (aromatic carbon); and as the more polar fraction 4-hydroxy-3-*p*-tolylthiobutanonitrile (19) (560 mg) (Found: M^+ , 207.0701. $\text{C}_{11}\text{H}_{13}\text{NOS}$ requires M , 207.0718); m/z 207 (M^+ , 100%), 176 (72), 149 (64), 123 (49), and 91 (49); ν_{max} (CHCl₃) 3 480, 2 260, and 1 600 cm^{-1} ; δ_{H} 2.31 (3 H,

s, Me), 2.59 (1 H, dd, J 17 and 7 Hz) and 2.73 (1 H, dd, J 17 and 6 Hz) (CH_2CN), 3.27 (1 H, m, CHS), 3.43 (1 H, br s, OH), 3.64 (1 H, m) and 3.78 (1 H, m) (CH_2OH), and 7.1–7.4 (4 H, m, aromatic); δ_{C} 20.24 (CH_2CN), 20.86 (Me), 46.93 (CHS), 62.92 (CH_2OH), 117.58 (CN), and 127.57, 129.94, 133.88, and 138.64 (aromatic carbon).

Allyl cyanide (1) (0.6 g) and dipropyl disulphide (5) (0.55 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant light petroleum–acetone (3:1)], as the less polar fraction, 3-hydroxy-2-propylthiobutanonitrile (16) (62 mg) (Found: M^+ , 159.0725. $\text{C}_7\text{H}_{13}\text{NOS}$ requires M , 159.0718); m/z 159 (M^+ , 24%), 131 (3), 119 (11), 99 (7), and 89 (100); $\nu_{\text{max.}}$ (CCl_4) 3 460 and 2 260 cm^{-1} ; δ_{H} 1.00 (3 H, t, J 7 Hz, Me), 1.62 (2 H, sext, J 7 Hz, CH_2), 2.5–2.8 (6 H, complex, CH_2CN , CH_2S , and CH_2S), 3.32 (1 H, br s, OH), and 4.02 (1 H, m, CHOH); δ_{C} 13.19 (Me), 22.96 (CH_2), 24.61 (CH_2CN), 34.73 and 38.42 (CH_2S), 66.35 (CHOH), and 117.27 (CN); and as the more polar fraction 2-hydroxy-3-propylthiobutanonitrile (17) (267 mg) (Found: M^+ , 159.0709. $\text{C}_7\text{H}_{13}\text{NOS}$ requires M , 159.0718); m/z 159 (M^+ , 17%), 128 (16), 119 (20), 102 (45), and 43 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 500 and 2 260 cm^{-1} ; δ_{H} 1.00 (3 H, t, J 7 Hz, Me), 1.64 (2 H, sext, J 7 Hz, CH_2), 2.55–2.65 (2 H, m, CH_2), 2.69 (1 H, dd, J 17 and 7 Hz), and 2.81 (1 H, dd, J 17 and 6 Hz) (CH_2), 2.91 (1 H, br s, OH), 3.00 (1 H, quint, J 7 Hz, CHS), 3.65 (1 H, dd, J 11 and 7 Hz), and 3.77 (1 H, dd, J 11 and 5 Hz); δ_{C} 13.25 (Me), 21.44 (CH_2), 23.20 (CH_2CN), 33.76 (CH_2S), 44.16 (CHS), 63.76 (CH_2OH), and 117.70 (CN).

Pent-4-enitrile (2) (600 mg) and diphenyl disulphide (4) (0.81 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant benzene–acetone (9:1)], as the less polar fraction, 4-hydroxy-5-phenylthiopentanitrile (20) (220 mg) (Found: M^+ , 207.0724. $\text{C}_{11}\text{H}_{13}\text{NOS}$ requires M , 207.0718); m/z 207 (M^+ , 29%), 123 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 520, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.75 (1 H, m) and 1.90 (1 H, m) (CH_2), 2.4–2.55 (2 H, m, CH_2CN), 2.86 (1 H, br s, OH), 2.88 (1 H, dd, J 14 and 8 Hz) and 3.08 (1 H, dd, J 14 and 4 Hz) (CH_2S), 3.75 (1 H, m, CHO), and 7.15–7.4 (5 H, m, aromatic); δ_{C} 13.72 (CH_2), 31.57 (CH_2CN), 41.98 (CH_2S), 68.01 (CHO), 119.49 (CN), 127.07, 129.27, 130.45, and 134.89 (aromatic carbon); and as the more polar fraction 5-hydroxy-4-phenylthiopentanitrile (21) (362 mg) (Found: M^+ , 207.0727. $\text{C}_{11}\text{H}_{13}\text{NOS}$ requires M , 207.0718); m/z 207 (M^+ , 82%), 176 (83), 149 (32), 136 (87), and 110 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 500, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.79 (1 H, m) and 2.10 (1 H, m) (CH_2), 2.65 (2 H, m, CH_2CN), 2.77 (1 H, br s, OH), 3.21 (1 H, m, CHS), 3.55–3.7 (2 H, m, CH_2OH), and 7.25–7.5 (5 H, m, aromatic); δ_{C} 15.05 (CH_2), 27.28 (CH_2CN), 50.74 (CHS), 64.01 (CH_2OH), 119.22 (CN), and 127.98, 129.27, 132.65, and 132.97 (aromatic carbon).

Pent-4-enitrile (2) (0.6 g) and di-*p*-tolyl disulphide (6) (0.91 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant benzene–acetone (9:1)], as the less polar fraction, 4-hydroxy-5-*p*-tolylthiopentanitrile (24) (296 mg, 36% w.r.t. di-*p*-tolyl disulphide) (Found: M^+ , 221.0878. $\text{C}_{12}\text{H}_{15}\text{NOS}$ requires M , 221.0874); m/z 221 (M^+ , 42%) and 137 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 530, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.70 (1 H, m) and 1.86 (1 H, m) ($\text{CH}_2\text{CH}_2\text{CN}$), 2.32 (3 H, s, Me), 2.50 (2 H, m, CH_2CN), 2.75 (1 H, br s, OH), 2.82 (1 H, dd, J 14 and 9 Hz) and 3.06 (1 H, dd, J 14 and 4 Hz) (CH_2S), 3.70 (1 H, m, CHOH), and 7.1–7.3 (4 H, m, aromatic); and as the more polar fraction 5-hydroxy-4-*p*-tolylthiopentanitrile (25) (388 mg; 47% w.r.t. di-*p*-tolyl disulphide) (Found: M^+ , 221.0875. $\text{C}_{12}\text{H}_{15}\text{NOS}$ requires M , 221.0874); m/z 221 (M^+ , 100%), 190 (64), 163 (20), 150 (48), and 137 (57); $\nu_{\text{max.}}$ (CHCl_3) 3 500, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.78 (1 H, m) and 2.04 (1 H, m) ($\text{CH}_2\text{CH}_2\text{CN}$), 2.34 (3 H, s, Me), 2.37 (1 H, br s, OH), 2.65 (2 H, m, CH_2CN), 3.14 (1 H, m, CHS), 3.61 (2 H, m, CH_2OH), and 7.1–7.4 (4 H, m, aromatic).

Pent-4-enitrile (2) (0.6 g) and dipropyl disulphide (5) (0.55

g) with manganese(III) acetate (1.59 g) afforded after chromatography [eluant light petroleum–ethyl acetate (3:2)], as the less polar fraction, 4-hydroxy-5-propylthiopentanitrile (22) (150 mg) (Found: M^+ , 173.0812. $\text{C}_8\text{H}_{15}\text{NOS}$ requires M , 173.0874); m/z 173 (M^+ , 37%), 119 (27), 100 (17), and 89 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 510 and 2 260 cm^{-1} ; δ_{H} 1.00 (3 H, t, J 7 Hz, Me), 1.65 (2 H, m, CH_2), 1.76 (1 H, m), and 1.89 (1 H, m) (CH_2), 2.45–2.75 (6 H, complex, CH_2S and CH_2CN), 2.90 (1 H, br, OH), and 3.75 (1 H, m, CHO); δ_{C} 13.14 (Me), 13.59 (CH_2), 22.92 (CH_2), 31.52 (CH_2CN), 34.49 (CH_2S), 39.54 (CH_2S), 67.80 (CHOH), and 119.50 (CN); and as the more polar fraction 5-hydroxy-4-propylthiopentanitrile (23) (310 mg) (Found: M^+ , 173.0868. $\text{C}_8\text{H}_{15}\text{NOS}$ requires M , 173.0874); m/z 173 (M^+ , 32%), 142 (100), and 100 (92); $\nu_{\text{max.}}$ (CHCl_3) 3 500 and 2 260 cm^{-1} ; δ_{H} 1.00 (3 H, t, J 7 Hz, Me), 1.63 (2 H, m, CH_2), 1.75 (1 H, m), and 2.08 (1 H, m) ($\text{CH}_2\text{CH}_2\text{CN}$), 2.45–2.65 (4 H, complex, CH_2CN and CH_2S), 2.77 (1 H, br, OH), 2.80 (1 H, m, CHS), 3.63 (1 H, dd, J 12 and 6 Hz), and 3.67 (1 H, dd, J 12 and 6 Hz); δ_{C} 13.39 (Me), 15.10 (CH_2), 23.42 (CH_2), 27.81 (CH_2CN), 33.18 (CH_2S), 47.66 (CHS), 64.50 (CH_2OH), and 119.41 (CN).

Hex-5-enitrile (3) (0.7 g) and diphenyl disulphide (4) (0.81 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant benzene–acetone (9:1)], as the less polar fraction, 5-hydroxy-6-phenylthiohexanonitrile (26) (350 mg) (Found: M^+ , 221.0888. $\text{C}_{12}\text{H}_{15}\text{NOS}$ requires M , 221.0874); m/z 221 (M^+ , 37%) and 124 (100); $\nu_{\text{max.}}$ (CCl_4) 3 510, 2 260, and 1 590 cm^{-1} ; δ_{H} 1.5–1.85 (4 H, complex, $\text{CH}_2\text{CH}_2\text{CN}$ and CH_2CHOH), 2.30 (2 H, m, CH_2CN), 2.86 (1 H, dd, J 14 and 8 Hz) and 3.04 (1 H, dd, J 14 and 4 Hz) (CH_2S), 2.92 (1 H, br s, OH), 3.63 (1 H, m, CHOH), and 7.15–7.4 (5 H, m, aromatic); δ_{C} 15.84 ($\text{CH}_2\text{CH}_2\text{CN}$), 21.70 (CH_2CHOH), 34.53 (CH_2CN), 41.78 (CH_2S), 68.66 (CHOH), 119.49 (CN), and 126.49, 128.96, 129.82, and 135.16 (aromatic carbon); and as the more polar fraction 6-hydroxy-5-phenylthiohexanonitrile (27) (115 mg) (Found: M^+ , 221.0869. $\text{C}_{12}\text{H}_{15}\text{NOS}$ requires M , 221.0874); m/z 221 (M^+ , 58%), 190 (91), 149 (50), and 110 (100); $\nu_{\text{max.}}$ (CHCl_3) 3 480, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.55–2.05 (4 H, complex, $\text{CH}_2\text{CH}_2\text{CN}$ and CH_2CHS), 2.35 (2 H, t, CH_2CN), 2.63 (1 H, br s, OH), 3.12 (1 H, m, CHS), 3.58 (2 H, m, CH_2OH), and 7.25–7.5 (5 H, m, aromatic); δ_{C} 17.05 ($\text{CH}_2\text{CH}_2\text{CN}$), 23.06 (CH_2CHS), 30.46 (CH_2CN), 51.51 (CHS), 64.15 (CH_2OH), 119.33 (CN), and 127.74, 129.19, 132.83, and 133.31 (aromatic carbon).

Hex-5-enitrile (3) (0.7 g) and di-*p*-tolyl disulphide (6) (0.91 g) with manganese(III) acetate (1.48 g) afforded after chromatography [eluant benzene–acetone (9:1)], as the less polar fraction, 5-hydroxy-6-*p*-tolylthiohexanonitrile (30) (435 mg) (Found: M^+ , 235.1053. $\text{C}_{13}\text{H}_{17}\text{NOS}$ requires M , 235.1026); m/z 235 (M^+ , 48%) and 137 (100); $\nu_{\text{max.}}$ (neat) 3 460, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.48–1.87 (4 H, complex, $\text{CH}_2\text{CH}_2\text{CN}$ and CH_2CHOH), 2.25–2.35 (5 H, complex, CH_3 and CH_2CN), 2.83 (1 H, dd, J 14 and 8 Hz) and 3.02 (1 H, dd, J 14 and 4 Hz) (CH_2S), 2.84 (1 H, br s, OH), 3.63 (1 H, m, CHOH), and 7.07–7.3 (4 H, aromatic); δ_{C} 16.88 (CH_2), 20.83 (CH_3), 21.79 (CH_2), 34.55 (CH_2CN), 42.61 (CH_2S), 68.64 (CH), 119.49 (CN), and 129.80, 130.71, 131.32 and 136.83 (aromatic carbon); and as the more polar fraction 6-hydroxy-5-*p*-tolylthiohexanonitrile (31) (120 mg) (Found: M^+ , 235.1071. $\text{C}_{13}\text{H}_{17}\text{NOS}$ requires M , 235.1026); m/z 235 (M^+ , 42%), 204 (48), and 123 (100); $\nu_{\text{max.}}$ (neat) 3 480, 2 260, and 1 600 cm^{-1} ; δ_{H} 1.5–2.0 (4 H, complex, $\text{CH}_2\text{CH}_2\text{CN}$ and CH_2CHS), 2.28–2.35 (5 H, complex, CH_3 and CH_2CN), 2.58 (1 H, s, OH), 3.02 (1 H, m, CHS), 3.55 (2 H, m, CH_2OH), and 7.1–7.35 (4 H, aromatic); δ_{C} 16.91 (CH_2), 20.93 (CH_3), 22.95 (CH_2), 30.26 (CH_2CN), 51.62 (CHS), 63.96 (CH_2OH), 119.30 (CN), and 129.22, 129.84, 132.07, and 137.92 (aromatic carbon).

Hex-5-enitrile (3) (0.7 g) and dipropyl disulphide (5) (0.55 g) with manganese(III) acetate (1.48 g) afforded after chromato-

graphy [eluant ethyl acetate–light petroleum (2:3)] as the less polar fraction, 5-hydroxy-6-propylthiohexanonitrile (**28**) (494 mg) (Found: M^+ , 187.1052. $C_9H_{17}NOS$ requires M , 187.1030); m/z 187 (M^+ , 72%), v_{max} (neat) 3 480 and 2 260 cm^{-1} ; δ_H 0.87 (3 H, t, J 7 Hz, CH_3), 1.38–1.82 (6 H, complex, CH_3CH_2 , CH_2CH_2CN , and CH_2CHOH), 2.25–2.60 (6 H, complex, CH_2CN and CH_2S), 2.92 (1 H, s, OH), and 3.55 (1 H, m, $CHOH$); δ_C 13.03 (CH_3), 16.78 (CH_2), 21.72 (CH_2), 22.80 (CH_2), 34.29 (CH_2), 34.60 (CH_2S), 39.80 (CH_2S), 68.62 ($CHOH$), and 119.37 (CN); and as the more polar fraction 6-hydroxy-5-propylthiohexanonitrile (**29**) (34 mg) (Found: M^+ , 187.1069. $C_9H_{17}NOS$ requires M , 187.1030); m/z 187 (M^+ , 26%) and 156 (100); v_{max} (neat) 3 460 and 2 260 cm^{-1} ; δ_H 0.97 (3 H, t, J 7 Hz, CH_3), 1.5–2.0 (6 H, complex CH_3CH_2 , CH_2CH_2CN and CH_2CHS), 2.35–2.55 (5 H, complex, CH_2CN , CH_2S , and OH), 2.67 (1 H, m, CHS), and 3.56 (2 H, m, CH_2OH); δ_C 13.43 (CH_3), 17.12 (CH_2), 23.14 (CH_2), 23.41 (CH_2), 30.82 (CH_2CN), 32.85 (CH_2S), 48.39 (CHS), 64.29 (CH_2OH), and 119.64 (CN).

Preparation of Acetamido Sulphides.—The crude trifluoroacetoxy sulphide (1.2 g) dissolved in acetonitrile (50 ml) containing added concentrated sulphuric acid (0.5 ml) was heated under reflux for 2 days. The cold solution was poured into water (150 ml), basified with concentrated aqueous sodium carbonate, and extracted with chloroform (3 \times 50 ml). The combined organic phase was washed with water (3 \times 50 ml), dried ($MgSO_4$), and evaporated under reduced pressure to give the crude acetamido sulphides. Products were purified by chromatography over silica gel. Details of yields are given in the Tables.

Allyl cyanide (**1**) (0.6 g) and diphenyl disulphide (**4**) (0.8 g) after oxidation with $Mn(OAc)_3 \cdot 2H_2O$ (1.5 g) (Ritter reaction) as already described and chromatography [eluant acetone–light petroleum (1:1)] afforded, as the less polar fraction, 3-acetamido-4-phenylthiobutanonitrile (**50**) (80 mg) (Found: M^+ , 234.0825. $C_{12}H_{14}N_2OS$ requires M , 234.0827); m/z 234 (M^+ , 9%) and 175 (100); v_{max} ($CHCl_3$) 3 435, 3 350, 2 260, and 1 675 cm^{-1} ; δ_H 1.84 (3 H, s, COMe), 2.69 (2 H, m, CH_2CN), 2.93 (1 H, dd, J 14 and 7 Hz) and 3.09 (1 H, dd, J 14 and 6 Hz) (CH_2S), 4.10 (1 H, m, CHN), 6.9 (1 H, br, NH), and 7.1–7.3 (5 H, m, aromatic); δ_C 21.83 (CH_2CN), 22.74 (Me), 36.89 (CH_2S), 40.67 (CHN), 117.00 (CN), 127.07, 129.40, 130.20, and 134.22 (aromatic carbon), and 170.36 (CO); and as the more polar fraction 4-acetamido-3-phenylthiobutanonitrile (**51**) (0.39 g), m.p. 78–80 °C (from ethyl acetate–pentane) (Found: C, 61.8; H, 6.2; N, 11.6. $C_{12}H_{14}N_2OS$ requires C, 61.5; H, 6.0; N, 12.0%); m/z 234 (M^+ , 19%) and 175 (100); v_{max} ($CHCl_3$) 3 460, 3 350, 2 260, and 1 675 cm^{-1} ; δ_H 1.98 (3 H, s, COMe), 2.62 (2 H, m, CH_2CN), 3.4–3.6 (3 H, complex, CHS and CH_2N), 7.06 (1 H, br, NH), and 7.3–7.5 (5 H, m, aromatic); δ_C 21.73 (CH_2CN), 22.82 (Me), 42.62 (CH_2N), 44.55 (CHS), 117.18 (CN), 128.37, 129.31, 131.67, and 133.23 (aromatic carbon), and 170.90 (CO).

Allyl cyanide (**1**) (0.6 g) and di-*p*-tolyl disulphide (**6**) (0.91 g) after oxidation with manganese(III) acetate (1.5 g) (Ritter reaction as already described and chromatography [eluant light petroleum–acetone (1:1)] afforded, as the less polar fraction, 3-acetamido-4-*p*-tolylthiobutanonitrile (**52**) (101 mg) (Found: M^+ , 248.0960. $C_{13}H_{16}N_2OS$ requires M , 248.0983); m/z 248 (M^+ , 8%) and 189 (100); v_{max} ($CHCl_3$) 3 440, 3 360, 2 260, 1 680, and 1 600 cm^{-1} ; δ_H 1.95 (3 H, s, $COCH_3$), 2.32 (3 H, s, CH_3), 2.80 (2 H, m, CH_2CN), 3.03 (1 H, dd, J 14 and 7 Hz) and 3.17 (1 H, dd, J 14 and 7 Hz) (CH_2S), 4.18 (1 H, m, CHN), 6.40 (1 H, d, J 7 Hz, NH), and 7.1–7.3 (4 H, aromatic); δ_C 21.02 (CH_3), 22.02 (CH_2), 22.46 (CH_3), 37.76 (CH_2S), 46.26 (CHN), 117.03 (CN), 124.12, 130.44, 131.31, and 137.80 (aromatic carbon), and 170.24 (CO); and as the more polar fraction 4-acetamido-3-*p*-tolylthiobutanonitrile (**53**) (408 mg), m.p. 128–130 °C (from ethyl acetate–pentane) (Found: C, 62.6; H, 6.5; N, 11.1.

$C_{13}H_{16}N_2OS$ requires C, 62.9; H, 6.45; N, 11.3%); m/z 248 (M^+ , 14%), 189 (76), 176 (11), and 43 (100); v_{max} ($CHCl_3$) 3 460, 3 360, 2 260, 1 680, and 1 600 cm^{-1} ; δ_H 1.95 (3 H, s, $COCH_3$), 2.30 (3 H, s, CH_3), 2.80 (2 H, m, CH_2CN), 3.02 (1 H, dd, J 14 and 7 Hz) and 3.16 (1 H, dd, J 14 and 6 Hz) (CH_2N), 4.19 (1 H, m, CHS), 6.43 (1 H, d, J 7 Hz, NH), and 7.1–7.3 (4 H, aromatic); δ_C 21.00 (CH_3), 21.98 (CH_2CN), 22.97 (CH_3), 37.70 (CH_2N), 46.22 (CHS), 117.05 (CN), 130.21, 131.25, and 137.74 (aromatic carbon), and 170.28 (CO).

Pent-4-enonitrile (**2**) (600 mg) and diphenyl disulphide (**4**) (0.81 g) after oxidation with manganese(III) acetate (1.5 g) (Ritter reaction) as already described and chromatography [eluant acetonitrile–benzene–ethyl acetate (3:4:3)] afforded as an oil, as the less polar fraction, 4-acetamido-5-phenylthiopentanonitrile (**54**) (112 mg) (Found: M^+ , 248.1021. $C_{13}H_{16}N_2OS$ requires M , 248.0983); v_{max} ($CHCl_3$) 3 460, 3 360, 2 260, and 1 675 cm^{-1} ; δ_H 1.7–2.1 (2 H, m, CH_2CH_2CN), 1.89 (3 H, s, CH_3), 2.35 (2 H, m, CH_2CN), 3.01 (1 H, dd, J 14 and 6 Hz) and 3.11 (1 H, dd, J 14 and 6 Hz) (CH_2S), 4.11 (1 H, m, CHN), 6.84 (1 H, s, NH), and 7.15–7.5 (5 H, complex, aromatic); δ_C 14.05 (CH_2CH_2CN), 22.86 (CH_3), 27.81 (CH_2CN), 38.26 (CH_2S), 48.61 (CHN), 119.28 (CN), 126.51, 127.78, 129.63, and 135.42 (aromatic carbon), and 170.44 (CO); and as the more polar fraction 5-acetamido-4-phenylthiopentanonitrile (**55**) (196 mg) (Found: M^+ , 248.0884. $C_{13}H_{16}N_2OS$ requires M , 248.0983); m/z 248 (10%) and 189 (100); v_{max} ($CHCl_3$) 3 455, 3 355, 2 260, and 1 680 cm^{-1} ; δ_H 1.67–2.04 (2 H, m, CH_2CH_2CN), 1.93 (3 H, s, CH_3), 2.63 (2 H, m, CH_2CN), 3.27 (1 H, m, CHS), 3.34 (1 H, dd, J 14 and 6 Hz) and 3.42 (1 H, dd, J 14 and 6 Hz) (CH_2N), 6.84 (1 H, s, NH), and 7.25–7.45 (5 H, complex, aromatic); δ_C 14.68 (CH_2CH_2CN), 22.76 (CH_3), 29.25 (CH_2CN), 42.65 (CH_2N), 47.89 (CHS), 119.04 (CN), 127.70, 128.95, 129.11, and 132.43 (aromatic carbon), and 170.49 (CO).

Pent-4-enonitrile (**2**) (0.6 g) and di-*p*-tolyl disulphide (**6**) (0.9 g) after oxidation with manganese(III) acetate (1.5 g) (Ritter reaction) and chromatography [eluant benzene–acetonitrile–ethyl acetate (4:3:3)] afforded, as the less polar fraction, 4-acetamido-5-*p*-tolylthiopentanonitrile (**56**) (120 mg) (Found: M^+ , 262.1123. $C_{14}H_{18}N_2OS$ requires M , 262.1140); m/z 262 (M^+ , 11%) and 203 (100); v_{max} ($CHCl_3$) 3 420, 3 320, 2 260, 1 675, and 1 600 cm^{-1} ; δ_H 1.8–2.2 (2 H, m, CH_2CH_2CN), 1.91 (3 H, s, COMe), 2.25–2.40 (5 H, complex, Me and CH_2CN), 3.05 (2 H, m, CHS), 4.15 (1 H, m, CHN), 6.24 (1 H, br, NH), and 7.1–7.4 (4 H, m, aromatic); δ_C 14.27 (CH_2), 21.02 (COMe), 23.09 (Me), 29.63 (CH_2CN), 39.32 (CH_2S), 48.92 (CHN), 119.42 (CN), 130.05, 130.75, and 137.17 (aromatic carbon), and 170.47 (CO); and as the more polar fraction 5-acetamido-4-*p*-tolylthiopentanonitrile (**57**) (185 mg) (Found: M^+ , 262.1121. $C_{14}H_{18}N_2OS$ requires M , 262.1140); m/z 262 (M^+ , 11%) and 203 (100); v_{max} ($CHCl_3$) 3 320, 2 260, 1 675, and 1 600 cm^{-1} ; δ_H 1.73 (1 H, m) and 1.94 (1 H, m) (CH_2CH_2CN), 1.96 (3 H, s, COMe), 2.30 (2 H, m, CH_2CN), 2.33 (3 H, s, Me), 2.64 (2 H, m, CH_2CN), 3.16 (1 H, m, CHS), 3.37 (2 H, m, CH_2N), 6.36 (1 H, s, NH), and 7.1–7.4 (4 H, m, aromatic); δ_C 14.95 (CH_2), 21.02 (COMe), 23.03 (Me), 28.07 (CH_2CN), 42.63 (CH_2NH), 48.97 (CHS), 119.08 (CN), 130.04, 130.17, 133.45, and 138.48 (aromatic carbon), and 170.37 (CO).

Hex-5-enonitrile (**3**) (0.7 g) and diphenyl disulphide (**4**) (0.81 g) after oxidation with manganese(III) acetate (1.5 g) (Ritter reaction) and chromatography [eluant benzene–acetonitrile (1:1)] afforded, as the less polar fraction, 5-acetamido-6-phenylthiohexanonitrile (**58**) (203 mg), m.p. 83 °C (from ethyl acetate–light petroleum) (Found: C, 63.85; H, 7.0; N, 10.5; S, 12.3. $C_{14}H_{18}N_2OS$ requires C, 64.1; H, 6.9; N, 10.7; S, 12.2%); v_{max} ($CHCl_3$) 3 440, 2 260, 1 675, and 1 590 cm^{-1} ; δ_H 1.5–1.8 (4 H, complex, CH_2CH_2CN and CH_2CH), 1.84 (3 H, s, CH_3), 2.27 (2 H, m, CH_2CN), 2.96 (1 H, dd, J 14 and 6 Hz) and 3.03 (1 H, dd, J 14 and 6 Hz) (CH_2S), 4.07 (1 H, m, $CHNH$), 6.46 (1 H, d,

NH), and 7.1—7.35 (5 H, complex, aromatic); δ_c 16.60 (CH₂), 21.93 (CH₂), 22.86 (CH₃), 32.50 (CH₂), 38.71 (CH₂S), 48.21 (CH), 119.22 (CN), 126.34, 128.95, 129.53, and 135.83 (aromatic carbon), and 170.01 (CO); and as the more polar fraction 6-acetamido-5-phenylthiohexanonitrile (**59**) (60 mg) (Found: M^+ , 262.1144. C₁₄H₁₈N₂OS requires M , 262.1140); m/z 262 (M^+ , 7%), 203 (87), 190 (24), 175 (45), and 43 (100); ν_{\max} (CHCl₃), 3 460, 2 260, 1 675, and 1 590 cm⁻¹; δ_H 1.6—2.05 (4 H, complex, CH₂CH₂CN and CH₂CH), 1.97 (3 H, s, CH₃), 2.38 (2 H, t, J 7 Hz, CH₂CN), 3.22 (1 H, m, CHS), 3.32 (1 H, m) and 3.47 (1 H, m) (CH₂NH), 6.17 (1 H, br s, NH), and 7.25—7.5 (5 H, complex, aromatic); δ_c 17.03 (CH₂), 22.93 (CH₂), 23.14 (CH₃), 31.38 (CH₂CN), 43.16 (CH₂NH), 48.49 (CHS), 119.25 (CN), 127.72, 129.31, 132.43, and 134.5 (aromatic carbon), and 170.41 (CO).

Hex-5-enonitrile (**3**) (0.7 g) and di-*p*-tolyl disulphide (**6**) (0.91 g) after oxidation with manganese(III) acetate (1.5 g) (Ritter reaction) and chromatography [eluant benzene-acetonitrile (1:1)] afforded, as the less polar fraction, 5-acetamido-6-*p*-tolylthiohexanonitrile (**60**) (220 mg) (Found: M^+ , 276.1310. C₁₅H₂₀N₂OS requires M , 276.1290); m/z 276 (M^+ , 10%), 217 (94), and 97 (100); ν_{\max} (CHCl₃) 3 445, 3 360, 2 260, 1 675, and 1 605 cm⁻¹; δ_H 1.55—1.8 (4 H, complex, CH₂CH₂CN and CH₂CHNH), 1.88 (3 H, s, COCH₃), 2.30 (3 H, s, CH₃), 2.31 (2 H, m, CH₂CN), 2.96 (1 H, dd, J 13 and 6 Hz) and 3.03 (1 H, dd, J 13 and 6 Hz) (CH₂S), 4.08 (1 H, m, CHN), 6.45 (1 H, br s, NH), and 7.05—7.3 (4 H, aromatic); δ_c 16.46 (CH₂), 20.61 (CH₃), 21.82 (CH₂), 22.72 (COCH₃), 32.38 (CH₂CN), 39.22 (CH₂S), 48.14 (CHN), 119.17 (CN), 129.59, 130.12, 131.93, and 136.36 (aromatic carbon), and 169.95 (CO); and as the more polar fraction 6-acetamido-5-*p*-tolylthiohexanonitrile (**61**) (80 mg) (Found: M^+ , 276.1273. C₁₅H₂₀N₂OS requires M , 276.1290); m/z 276 (81%) and 217 (100); ν_{\max} (CHCl₃) 3 445, 3 365, 2 260, 1 675, and 1 600 cm⁻¹; δ_H 1.5—2.05 (4 H, complex, CH₂CH₂CN and CH₂CHS), 1.97 (3 H, s, COCH₃), 2.34 (5 H, complex, CH₃ and CH₂CN), 3.10 (1 H, m, CHS), 3.28 (1 H, dd, J 14 and 7 Hz) and 3.42 (1 H, dd, J 14 and 5 Hz) (CH₂N), 6.25 (1 H, br s, NH), and 7.1—7.4 (4 H, aromatic); δ_c 16.98 (CH₂), 21.03 (CH₃), 22.93 (CH₂), 23.11 (COCH₃), 31.35 (CH₂CN), 42.99 (CH₂NH), 48.86 (CHS), 119.24 (CN), 129.42, 130.64, 133.21, and 138.11 (aromatic carbon), and 170.31 (CO).

General Lactonisation Procedure.—The appropriate mixture of crude trifluoroacetoxy nitriles was stirred at 170 °C (external bath temp.) for 5 h in aqueous cobalt(II) chloride hexahydrate. The cold mixture was extracted with diethyl ether (2 × 50 ml) and the combined organic extracts were washed with water (3 × 20 ml), dried (MgSO₄), filtered, and evaporated under reduced pressure to leave the crude lactone. Pure lactones were obtained by chromatography over silica gel.

The trifluoroacetoxy nitriles obtained by reaction of diphenyl disulphide (**4**) and allyl cyanide (**1**) afforded after hydrolysis and subsequent chromatography [eluant light petroleum-ethyl acetate (7:3)] 4-phenyl-4,5-dihydrofuran-2(3*H*)-one (**62**) (467 mg, 65% w.r.t. diphenyl disulphide) (Found: M^+ , 194.0393. C₁₀H₁₀O₂S requires M , 194.0401); m/z 194 (M^+ , 96%), 136 (59), and 110 (100); ν_{\max} (neat) 1 780 cm⁻¹; δ_H 2.48 (1 H, dd, J 18 and 6 Hz) and 2.88 (1 H, dd, J 18 and 8 Hz) (CH₂CO), 4.01 (1 H, m, CHS), 4.17 (1 H, dd, J 10 and 5 Hz) and 4.51 (1 H, dd, J 10 and 7 Hz) (CH₂O), and 7.25—7.45 (5 H, aromatic); δ_c 34.98 (CH₂CO), 41.47 (CHS), 72.48 (CH₂O), 128.13, 129.33, and 132.40 (aromatic carbon), and 174.60 (CO). Further elution afforded, as a colourless oil, 3-hydroxy-4-phenylthiobutanonitrile (**14**) (94 mg, 14% w.r.t. diphenyl sulphide).

Similarly, after hydrolysis and work-up 4-hydroxy-3-phenylthiobutanonitrile (**15**) (0.4 g) afforded 4-phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) [0.37 g, 92.5% w.r.t. the hydroxynitrile (**15**)].

3-Hydroxy-4-phenylthiobutanonitrile (**14**) (0.2 g) was hydro-

lysed under the same conditions, modified only by the addition of concentrated sulphuric acid (2 drops) to the mixture. After reaction was complete (5 h) the cold solution was extracted with ether. The organic phase was washed with dilute aqueous sodium carbonate (3 × 20 ml) and then water (2 × 20 ml), dried (MgSO₄), and evaporated under reduced pressure. Chromatography [eluant light petroleum-ethyl acetate (7:3)] afforded 4-phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) [0.14 g, 70% w.r.t. the hydroxy nitrile (**14**)] and a little unchanged starting material (45 mg). In the absence of added sulphuric acid under similar conditions the butanonitrile (**14**) was unchanged.

The trifluoroacetoxy nitriles obtained by reaction of diphenyl disulphide and allyl cyanide, hydrolysed by this modified procedure with added acid, afforded 4-phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) (555 mg, 77% w.r.t. diphenyl disulphide).

The trifluoroacetoxy nitriles obtained by reaction of di-*p*-tolyl disulphide (**6**) and allyl cyanide (**1**) afforded, after hydrolysis and subsequent chromatography [eluant light petroleum-ethyl acetate (7:3)], 4-*p*-tolylthio-4,5-dihydrofuran-2(3*H*)-one (**63**) (500 mg, 65% w.r.t. di-*p*-tolyl disulphide) (Found: M^+ , 208.0550. C₁₁H₁₂O₂S requires M , 208.0558); m/z 208 (M^+ , 100%), 150 (33), 135 (29), 124 (69), and 91 (70); ν_{\max} (CHCl₃) 1 785 cm⁻¹; δ_H 2.35 (3 H, s, CH₃), 2.48 (1 H, dd, J 18 and 6 Hz) and 2.84 (1 H, dd, J 18 and 8 Hz) (CH₂CO), 3.93 (1 H, m, CHS), 4.17 (1 H, dd, J 10 and 5 Hz) and 4.48 (1 H, dd, J 10 and 7 Hz) (CH₂O), and 7.1—7.4 (4 H, aromatic); δ_c 21.05 (CH₃), 35.01 (CH₂CO), 41.94 (CHS), 72.59 (CH₂O), 128.49, 130.21, 133.38, and 138.78 (aromatic carbon), and 174.78 (CO). Further elution afforded, as a colourless oil, 3-hydroxy-4-*p*-tolylthiobutanonitrile (**18**) (95 mg, 12% w.r.t. di-*p*-tolyl disulphide).

Similarly, after hydrolysis and work-up, 4-hydroxy-3-*p*-tolylthiobutanonitrile (**19**) (0.4 g) afforded 4-*p*-tolylthio-4,5-dihydrofuran-2(3*H*)-one (**63**) [0.35 g, 87% w.r.t. the hydroxy nitrile (**19**)].

2-Hydroxy-1-*p*-tolylthiobutanonitrile (**18**) (0.2 g) was hydrolysed under the same conditions modified only by the addition of concentrated sulphuric acid (2 drops) to the mixture. Work-up as before afforded 4-*p*-tolylthio-4,5-dihydrofuran-2(3*H*)-one (**63**) [0.17 g, 85% w.r.t. the hydroxy nitrile (**18**)]. In the absence of added sulphuric acid under similar conditions the nitrile (**18**) was unchanged.

The trifluoroacetoxy nitriles obtained by reaction of dipropyl disulphide (**5**), and allyl cyanide (**1**) afforded, after hydrolysis and subsequent chromatography [eluant light petroleum-ethyl acetate (3:1)], 4-*propylthio*-4,5-dihydrofuran-2(3*H*)-one (**64**) (355 mg, 61% w.r.t. dipropyl disulphide) (Found: M^+ , 160.0554. C₇H₁₂O₂S requires M , 160.0558); m/z (M^+ , 52%), 142 (15), 102 (52), 85 (36), and 60 (100); ν_{\max} 1 790 cm⁻¹; δ_H 1.02 (3 H, t, J 7 Hz, CH₃), 1.63 (2 H, m, CH₂), 2.44 (1 H, dd, J 18 and 6 Hz) and 2.90 (1 H, dd, J 18 and 8 Hz) (CH₂CO), 2.56 (2 H, t, J 7 Hz, CH₂S), 3.67 (1 H, m, CHS), 4.12 (1 H, dd, J 10 and 6 Hz) and 4.57 (1 H, dd, J 10 and 7 Hz) (CH₂O); δ_c 12.89 (CH₃), 22.60 (CH₂), 32.91 (CH₂CO), 35.33 (CH₂S), 38.28 (CHS), 72.97 (CH₂O), and 174.79 (CO).

The trifluoroacetoxy nitriles obtained by reaction of diphenyl disulphide (**4**) and pent-4-enonitrile (**2**) afforded after hydrolysis and subsequent chromatography [eluant benzene-acetone (9:1)] 5-phenylthiomethyl-4,5-dihydrofuran-2(3*H*)-one (**65**) (574 mg, 75% w.r.t. diphenyl disulphide) (Found: M^+ , 208.0542. C₁₁H₁₂O₂S requires M , 208.0558); m/z 208 (M^+ , 54%), 181 (3), 123 (88), and 85 (100); ν_{\max} (neat) 1 780 cm⁻¹; δ_H 1.98 (1 H, m) and 2.36 (1 H, m) (CH₂), 2.4—2.6 (2 H, m, CH₂CO), 3.04 (1 H, dd, J 14 and 7 Hz) and 3.32 (1 H, dd, J 14 and 5 Hz) (CH₂S), 4.59 (1 H, m, CHO), and 7.2—7.45 (5 H, aromatic); δ_c 26.83 (CH₂), 28.32 (CH₂), 38.67 (CH₂S), 78.51 (CHO), 126.89, 129.12, 130.18, and 134.90 (aromatic carbon), and 176.42 (CO).

Similarly, after hydrolysis and work-up 5-hydroxy-4-phenyl-

thiopentanitrile (**21**) afforded 5-phenylthiomethyl-4,5-dihydrofuran-2(3*H*)-one (**65**) in 90% yield. Likewise 4-hydroxy-5-phenylthiopentanitrile (**20**) gave 5-phenylthiomethyl-4,5-dihydrofuran-2(3*H*)-one (**65**) in 86% yield.

The trifluoroacetoxy nitriles obtained by reaction of di-*p*-tolyl disulphide (**6**) and pent-4-enonitrile (**2**) afforded after hydrolysis and subsequent chromatography [eluant ethyl acetate–light petroleum (2:3)] 5-*p*-tolylthiomethyl-4,5-dihydrofuran-2(3*H*)-one (**66**) (610 mg, 75% w.r.t. di-*p*-tolyl disulphide) (Found: M^+ , 222.0709. $C_{12}H_{14}O_2S$ requires M , 222.0710); m/z 222 (M^+ , 43%) and 137 (100); $\nu_{\max.}(\text{CHCl}_3)$ 1 780 cm^{-1} ; δ_{H} 1.91 (1H, m) and 2.27 (1H, m) (CH_2), 2.25 (3H, s, CH_3), 2.44 (2H, m, CH_2), 2.98 (1H, dd, J 14 and 7 Hz) and 3.19 (1H, dd, J 14 and 5 Hz) (CH_2S), 4.52 (1H, m, CHO), and 7.1–7.3 (4H, aromatic); δ_{C} 20.43 (CH_3), 26.33 (CH_2), 27.85 (CH_2), 38.71 (CH_2), 78.15 (CH), 129.46, 130.21, 131.02, and 136.43 (aromatic carbon), and 175.85 (CO).

The trifluoroacetoxy nitriles obtained by reaction of dipropyl disulphide (**5**) and pent-4-enonitrile (**2**) afforded after hydrolysis and subsequent chromatography [eluant light petroleum–ethyl acetate (3:2)] 5-propylthiomethyl-4,5-dihydrofuran-3(2*H*)-one (**67**) (442 mg, 69% w.r.t. dipropyl disulphide) (Found: M^+ , 174.0723 $C_8H_{14}O_2S$ requires M , 174.0714); m/z 174 (M^+ , 17%), 156 (17), 141 (21), 123 (27), 115 (30), 102 (15), 85 (58), and 43 (100); $\nu_{\max.}(\text{CHCl}_3)$ 1 790 cm^{-1} ; δ_{H} 1.1 (3H, t, J 7 Hz, CH_3), 1.62 (2H, m, CH_2), 2.0–2.5 (2H, m, CH_2), 2.45–2.65 (4H, m, CH_2CO and CH_2S), 2.77 (1H, dd, J 14 and 6 Hz) and 2.87 (1H, dd, J 14 and 5 Hz) (CH_2CHO), and 4.68 (1H, m, CHO); δ_{C} 13.12 (CH_3), 22.88 (CH_2), 26.74 (CH_2), 28.37 (CH_2), 35.14 (CH_2), 36.58 (CH_2), 79.67 (CHO), and 176.44 (CO).

The trifluoroacetates obtained by reaction of diphenyl disulphide (**4**) and hex-5-enonitrile (**3**) afforded after hydrolysis and subsequent chromatography [eluant ethyl acetate–light petroleum (2:3)] 6-phenylthiomethyltetrahydro-2-pyrone (**68**) (435 mg, 53% w.r.t. diphenyl disulphide) as a white solid, m.p. 50–52 °C (from ether–light petroleum) (Found: C, 65.1; H, 6.4; S, 14.4. $C_{12}H_{14}O_2S$ requires C, 64.8; H, 6.35; S, 14.4%); $\nu_{\max.}(\text{CHCl}_3)$ 1 740 cm^{-1} ; δ_{H} 1.5–2.1 (4H, complex), 2.38 (1H, m) and 2.53 (1H, m) (CH_2), 3.02 (1H, dd, J 14 and 8 Hz) and 3.28 (1H, dd, J 14 and 5 Hz) (CH_2S), 4.38 (1H, m, CHO), and 7.15–7.14 (5H, aromatic); δ_{C} 18.05 (CH_2), 26.65 (CH_2), 29.25 (CH_2), 38.67 (CH_2), 78.70 (CH), 126.45, 128.94, 129.59, and 135.33 (aromatic carbon), and 170.93 (CO).

Similarly after hydrolysis and work-up 6-hydroxy-5-phenylthiohexanitrile (**27**) afforded the pyrone (**68**) in 87% yield. Likewise 5-hydroxy-6-phenylthiohexanitrile (**26**) gave the 2-pyrone (**68**) in 89% yield.

The trifluoroacetoxy nitriles obtained by reaction of di-*p*-tolyl disulphide (**6**) and hex-5-enonitrile (**4**) afforded after hydrolysis and subsequent chromatography [eluant ethyl acetate–light petroleum (2:3)] 6-*p*-tolylthiomethyltetrahydro-2-pyrone (**69**) (507 mg, 58% w.r.t. di-*p*-tolyl disulphide) as a white solid, m.p. 61–62 °C (from ether–light petroleum) (Found: C, 66.2; H, 6.9; S, 13.4. $C_{13}H_{16}O_2S$ requires C, 66.1; H, 6.8; S, 13.6%); $\nu_{\max.}(\text{CHCl}_3)$ 1 735 cm^{-1} ; δ_{H} 1.45–2.1 (4H, complex), 2.28 (3H, s, CH_3), 2.38 (1H, m) and 2.51 (1H, m) (CH_2), 2.97 (1H, m) and 3.21 (1H, m) (CH_2S), 4.34 (1H, m, CHO), and 7.1–7.3 (4H, aromatic); δ_{C} 17.32 (CH_2), 20.48 (CH_3), 26.83 (CH_2), 29.46 (CH_2), 39.08 (CH_2), 78.16 (CH), 129.47, 130.23, 131.03, and 136.52 (aromatic carbon), and 170.91 (CO).

After hydrolysis and work-up, 5-hydroxy-6-propylthiohexanitrile (**28**) afforded in 80% yield 6-propylthiomethyltetrahydro-2-pyrone (**70**) (Found: M^+ , 188.0876. $C_9H_{16}O_2S$ requires M , 188.0866); m/z 188 (M^+ , 24%) and 71 (100); $\nu_{\max.}(\text{CHCl}_3)$ 1 735 cm^{-1} ; δ_{H} 0.99 (3H, t, J 7 Hz, CH_3), 1.57–2.15 (6H, complex, CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CO}$, and CH_2CHO), 2.42–2.67 (4H, complex, CH_2CO and CH_2S), 2.72 (1H, dd, J 14 and 7 Hz) and 2.84 (1H, dd, J 14 and 5 Hz) (CH_2CHO), and

4.40 (1H, m, CHO); δ_{C} 13.22 (CH_3), 18.28 (CH_2), 22.95 (CH_2), 26.82 (CH_2), 29.43 (CH_2), 35.37 (CH_2), 37.00 (CH_2), 80.09 (CHO), and 170.84 (CO).

Reactions of Lactones with Amides.—The appropriate lactone (2.1 mmol) was heated under reflux in tetrahydrofuran (30 ml) with the appropriate amine (4.2 mmol). The solvent was removed under reduced pressure and the pure amide was isolated by chromatography and subsequent crystallisation.

4-Phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) with *t*-butylamine in tetrahydrofuran gave in 90% yield 4-hydroxy-3-phenylthio-*N*-*t*-butylbutanamide (**71**), m.p. 85–87 °C (from ethyl acetate–light petroleum) (Found: C, 62.95; H, 7.9; N, 5.2. $C_{14}H_{21}NO_2S$ requires C, 62.9; H, 7.9; N, 5.2%); $\nu_{\max.}(\text{CHCl}_3)$ 3 440, 3 345, and 1 665 cm^{-1} ; δ_{H} 1.37 (9H, s, Bu^t), 2.43 (1H, dd, J 14 and 6 Hz) and 2.52 (1H, dd, J 14 and 7 Hz) (CH_2), 3.6–3.8 (4H, complex, CHS, OH, and CH_2O), 5.85 (1H, s, NH), and 7.2–7.5 (5H, aromatic); δ_{C} 28.80 (CH_3), 40.30 (CH_2), 47.72 (CHS), 51.65 [$C(\text{CH}_3)_3$], 64.40 (CH_2OH), 127.55, 129.18, 132.38, and 134.00 (aromatic carbon), and 170.05 (CO).

4-Phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) with aniline in tetrahydrofuran similarly gave in 60% yield 4-hydroxy-4-phenylthio-*N*-phenylbutanamide (**72**), m.p. 98–99 °C (from ethyl acetate–light petroleum) (Found: C, 66.7; H, 6.0; N, 4.8; S, 11.2. $C_{16}H_{17}NO_2S$ requires C, 66.9; H, 5.9; N, 4.9; S, 11.15%); $\nu_{\max.}(\text{CHCl}_3)$ 3 440, 3 330, and 1 680 cm^{-1} ; δ_{H} 2.64 (1H, dd, J 15 and 6 Hz) and 2.75 (1H, dd, J 15 and 7 Hz) (CH_2CO), 3.23 (1H, br s, OH), 3.65–3.8 (3H, complex, CHS and CH_2O), and 7.05–7.55 (10H, aromatic); δ_{C} 40.14 (CH_2), 47.87 (CHS), 64.25 (CH_2O), 120.41, 124.76, 127.92, 129.13, 129.35, 132.74, and 137.75 (aromatic carbon), and 169.24 (CO).

4-Phenylthio-4,5-dihydrofuran-2(3*H*)-one (**62**) with benzylamine in tetrahydrofuran similarly gave in 93% yield as a white solid 4-hydroxy-4-phenylthio-*N*-benzylbutanamide (**73**), m.p. 81 °C (from ethyl acetate–light petroleum) (Found: C, 67.5; H, 6.3; N, 4.4; S, 10.8. $C_{17}H_{19}NO_2S$ requires C, 67.8; H, 6.6; N, 4.65; S, 10.6%); $\nu_{\max.}(\text{CHCl}_3)$ 3 440, 3 330, and 1 665 cm^{-1} ; δ_{H} 2.44 (1H, dd, J 15 and 7 Hz) and 2.58 (1H, dd, J 15 and 6 Hz) (CH_2CO), 3.53–3.7 (3H, complex, CHS and CH_2O), 3.89 (1H, s, OH), 4.31 (2H, m, CH_2N), 6.84 (1H, t, NH), and 7.15–7.4 (10H, aromatic); δ_{C} 39.05 (CH_2), 43.72 (CH_2), 47.47 (CHS), 64.30 (CH_2O), 127.43, 127.49, 127.70, 128.64, 129.09, 132.32, 133.60, and 138.04 (aromatic carbon), and 170.97 (CO).

4-Propylthio-4,5-dihydrofuran-2(3*H*)-one (**64**) (0.4 g) was heated under reflux under nitrogen in tetrahydrofuran (30 ml) containing cyclohexylamine (0.4 g) for 72 h. Evaporation under reduced pressure and chromatography of the residue [eluant light petroleum–acetone (1:1)] afforded as white crystals 4-hydroxy-3-propylthio-*N*-cyclohexylbutanamide (**74**) (0.52 g, 81%), m.p. 70–72 °C (from pentane–dichloromethane) (Found: C, 60.1; H, 9.4; N, 5.6. $C_{13}H_{25}NO_2S$ requires C, 60.2; H, 9.6; N, 5.4%); $\nu_{\max.}(\text{CHCl}_3)$ 3 440, 3 330, and 1 665 cm^{-1} ; δ_{H} 1.00 (3H, t, J 7 Hz, CH_3), 1.1–2.0 (12H, complex), 2.4–2.65 (4H, complex, CH_2S and CH_2CO), 3.18 (1H, m, CHS), 3.75–3.81 (3H, complex, CH_2OH and CHN), 3.93 (1H, br s, OH), and 6.42 (1H, s, NH); δ_{C} 13.32 (CH_3), 23.21 (CH_2), 24.75 (CH_2), 25.50 (CH_2), 32.88 (CH_2), 33.50 (CH_2CO), 40.18 (CH_2S), 44.71 (CHS), 48.42 (CHN), 64.68 (CH_2OH), and 170.18 (CO).

5-Phenylthiomethyl-4,5-dihydrofuran-2(3*H*)-one (**65**) with benzylamine in tetrahydrofuran similarly gave in 77% yield as a white solid, 4-hydroxy-5-phenylthio-*N*-benzylpentanamide (**75**), m.p. 89–90 °C (from ethyl acetate–light petroleum) (Found: C, 68.25; H, 6.6; N, 4.5; S, 10.3. $C_{18}H_{21}NO_2S$ requires C, 68.5; H, 6.7; N, 4.4; S, 10.2%); $\nu_{\max.}(\text{CHCl}_3)$ 3 460, 3 340, and 1 665 cm^{-1} ; δ_{H} 1.72 (1H, m) and 1.95 (1H, m) ($\text{CH}_2\text{CH}_2\text{CO}$), 2.34 (2H, t, J 7 Hz, CH_2CO), 2.96 (2H, m, CH_2S), 2.98 (1H, br s, OH), 3.70 (1H, m, CHO), 4.30 (2H, m, CH_2N), 4.64 (1H, s, NH), and 7.1–7.35 (10H, aromatic); δ_{C} 31.58 (CH_2), 32.50 (CH_2), 41.01 (CH_2S),

43.25 (CH₂N), 69.32 (CHO), 27.04, 127.46, 128.34, 128.75, 129.14, 136.10, and 138.35 (aromatic carbon), and 173.32 (CO).

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