Studies Related to Penicillins. Part XIII.[1] Transformations of Methyl α-[(2*R*,3*R*)-1-(2-Hydroxy-2-methylpropionyl)-4-oxo-3-phenoxyacetamidoazetidin-2-ylthio]acetate

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Methyl α-[(2*R*,3*R*)-1-(2-hydroxy-2-methylpropionyl)-4-oxo-3-phenoxyacetamidoazetidin-2-ylthio]acetate (3) is converted into a mixture of dimethyl 2,2'-dithiodiacetate (8) and methyl 3-(2-hydroxy-2-methylpropionamido)-2-phenoxyacetamidoacrylates (12) and (15) by sodium methoxide. Methyl (2*R*,3*R*)-3-(2-hydroxy-2-methylpropionamido)-3-methoxycarbonylmethylthio-2-phenoxyacetamidopropionate (17) is an intermediate in the reaction. Ammonia cleaves the β-lactam bond of the azetidinone (3) to give the amide (18); corresponding reactions occur with hydrazine, with methylamine, and with ethylamine to yield derivatives (19)—(21), respectively. In addition to the amide (22), the (*E*)-acryloylthioacetate (16) is formed when the azetidinone (3) is treated with t-butylamine; the derivative (16) rearranges to the *Z*-isomer (13) under the reaction conditions. Diethylamine and triethylamine convert the azetidinone (3) into the (*Z*)-acryloylthioacetate (13).

Methyl α-[(2*R*,3*R*)-1-(2-acetoxy-2-methylpropionyl)-4-oxo-3-phenoxyacetamidoazetidin-2-ylthio]acetate (4), formed from the reaction of the alcohol (3) with isopropenyl acetate and toluene-*p*-sulphonic acid, is transformed into the (*Z*)-acryloylthioacetate (14) by sodium methoxide, by t-butylamine, and by triethylamine and into the amides (23) and (24) by methylamine and by ethylamine, respectively.

The sulphoxides (27), prepared by oxidation with *m*-chloroperbenzoic acid of the sulphide (3), are converted into the disulphide (8) and into 2,2-dimethyl-6-phenoxyacetamido-1,4-oxazepine-3(2*H*),7(4*H*)-dione (28) by triethylamine.

RECENTLY we reported [2] that oxidation of the cepham (1) by potassium permanganate yielded the acid (2). The derivative (2) is of potential value in the synthesis of β-lactam antibiotic analogues if the acyl group at position 1 can be replaced by hydrogen. We now describe the results of some attempts to achieve this reaction.

The acid (2) was readily converted into the ester (3) by acidic methanol. Diazomethane also effected this transformation although a less-pure product was obtained since the ester (3) reacted further to give non-β-lactam-containing materials.

Cooper and Jose have shown that the thiazoline (6) yields compound (7) in the presence of methanol containing a small amount of sodium methoxide.[3] However, under similar conditions, the azetidinone (3) was transformed within 2 h into a mixture of mainly three components, which were separated by silica gel chromatography. The first-eluted material was considered to be the disulphide (8), on the basis of its spectroscopic properties; moreover, it was also obtained from the reaction of methyl 2-mercaptoacetate with methanolic sodium methoxide. Spectroscopic evidence left little doubt that the second- and the third-eluted substances were the (*Z*)-acrylate (12) and the (*E*)-acrylate (15), respectively; in particular, the u.v. absorption maxima at 275 nm (ε *ca.* 15,000) were suggestive of the diacylaminoacrylate chromophore.[4] The evidence for the configuration of the diastereoisomers is discussed later.

In principle, the formation of the acrylates (12) and (15) from the azetidinone (3) and methanolic sodium methoxide may involve the intermediacy of either the ester (17) or the azetinone (25). When the reaction was quenched after 5 s, the ester (17) was the predominant product (n.m.r. spectroscopy). It was converted into a mixture of the disulphide (8) and the acrylates (12) and (15) by methanolic sodium methoxide. Since the acrylates (12) and (15) were not interconverted under the reaction conditions, their formation from the ester (3) must be kinetically controlled. Evidently the β-lactam carbonyl group of the azetidinone (3) is attacked in preference to the exocyclic carbonyl group by sodium methoxide.

[1] Part XII, D. F. Corbett and R. J. Stoodley, *J.C.S. Perkin I*, 1974, 185.

[2] N. S. Watson and R. J. Stoodley, *J.C.S. Perkin I*, 1973, 2105.

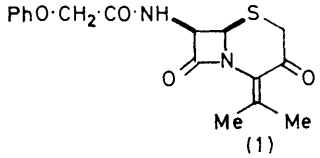
[3] R. D. G. Cooper and F. L. José, *J. Amer. Chem. Soc.*, 1972, **94**, 1021.

[4] D. L. Ostercamp, *J. Org. Chem.*, 1970, **35**, 1632.

Heusler has shown that the formyl group of the derivative (5) can be hydrolysed by ammonium hydroxide.[5] Under similar conditions, the azetidinone (3) afforded a complex mixture of products. Although a clean reaction ensued when the azetidinone (3) was treated with gaseous ammonia, the amide (18) was the sole product. Hydrazine reacted in an analogous manner to give the hydrazide (19).

In the hope of directing some attack to the exocyclic carbonyl group, the behaviour of the azetidinone (3) towards organic amines with various steric requirements was examined. Methylamine and ethylamine again cleaved the β-lactam bond to give the derivatives (20) and (21), respectively. Although the amide (22) was also formed when t-butylamine was employed, the two major products (*ca.* 2 : 1) were isomers of the starting material. The isomers, which could be separated by silica gel chromatography, possessed identical mass spectra; they are considered to be the acryloylthioacetates (13) and (16), on the basis of spectroscopic evidence.*

When treated further with t-butylamine, the amide (22) was recovered unchanged. In consequence, the foregoing rearrangement probably involves a base-induced β-elimination to give the azetinone (25) and methyl 2-mercaptoacetate, which then react to give the (*E*)-acryloylthioacetate (16). The isomerisation of penicillanic acid derivatives to 1,4-thiazepines is a mechanistically similar reaction.[6] An essential feature of this proposal is that the derivative (16) is converted into the *Z*-isomer (13) under the reaction conditions. In the presence of t-butylamine, the major acryloylthioacetate was recovered unchanged whereas the minor acryloylthioacetate was transformed into the major isomer. Consequently, the minor isomer was the (*E*)-acryloylthioacetate (16).



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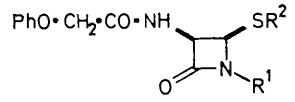
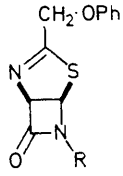
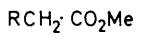


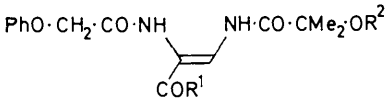
(2) R^1 = CO·CMe_2·OH, R^2 = CH_2·CO_2H
(3) R^1 = CO·CMe_2·OH, R^2 = CH_2·CO_2Me
(4) R^1 = CO·CMe_2·OAc, R^2 = CH_2·CO_2Me
(5) R^1 = CHO, R^2 = CMe:CH_2



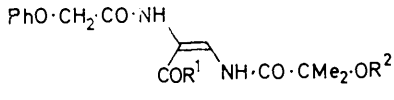
(6) R = CO·CO_2Me
(7) R = H



(8) R = S·S·CH_2·CO_2Me
(9) R = S·OH
(10) R = S·SO·CH_2·CO_2Me
(11) R = SO·OH



(12) R^1 = OMe, R^2 = H
(13) R^1 = S·CH_2·CO_2Me, R^2 = H
(14) R^1 = S·CH_2·CO_2Me, R^2 = Ac



(15) R^1 = OMe, R^2 = H
(16) R^1 = S·CH_2·CO_2Me, R^2 = H

The azetidinone (3) was isomerised to the (*Z*)-acryloylthioacetate (13) by diethylamine and by triethylamine; there was no evidence for the presence of the *E*-isomer (16) in these cases.

The foregoing results indicate that attack at the β-lactam carbonyl group of the derivative (3) is sensitive to the nature of the amine. With a hindered amine, removal of the hydrogen atom at position 3 can become the preferred mode of reaction.

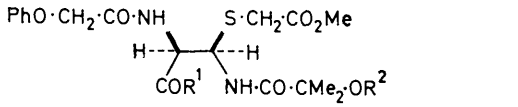
In an attempt to substantiate the acryloylthioacetate structure and to provide evidence for the configuration of the acrylate, the (*Z*)-acryloylthioacetate (13) was treated with methanolic sodium methoxide. It was hoped that the disulphide (8) and the (*Z*)-acrylate (12)

* A thiol ester, analogous to the acryloylthio-acetate, has recently been isolated from the reaction of 2,2,2-trichloroethyl α-[(2*R*,3*R*)-2-butyldithio-4-oxo-3-phenylacetamidoazetidin-1-yl]-α-isopropylideneacetate with triethyl phosphite (R. D. Allan, D. H. R. Barton, M. Girijavallabhan, P. G. Sammes, and M. V. Taylor, *J.C.S. Perkin I*, 1973, 1182).

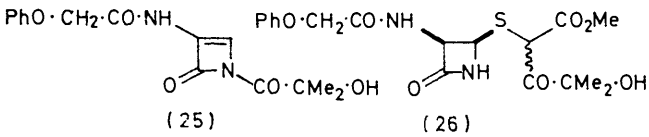
[5] K. Heusler, *Helv. Chim. Acta*, 1972, **55**, 388.
[6] O. K. J. Kovacs, B. Ekstrom, and B. Sjöberg, *Tetrahedron Letters*, 1969, 1863; *Acta Chem. Scand.*, 1973, **27**, 677; J. R. Jackson and R. J. Stoodley, *Chem. Comm.*, 1970, 14; *J.C.S. Perkin I*, 1972, 1062; J. P. Clayton, R. Southgate, B. G. Ramsay, and R. J. Stoodley, *J. Chem. Soc.* (*C*), 1970, 2089; S. Wolfe, W. S. Lee, and R. Misra, *Chem. Comm.*, 1970, 1067; B. G. Ramsay and R. J. Stoodley, *Chem. Comm.*, 1971, 450; R. J. Stoodley, *Progr. Org. Chem.*, 1973, **8**, 102.

would be formed in this reaction. However, in addition to these products, the (*E*)-acrylate (15) was also produced. This isomerisation must have occurred prior to the methanolysis since the acrylates were not interconverted by methanolic sodium methoxide.

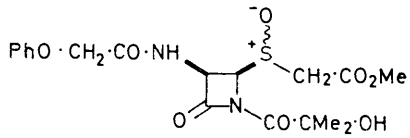
In principle, the hydroxy-function of the derivative (3) may influence the relative ease of nucleophilic attack at the exocyclic and the endocyclic carbonyl groups. For example, it may promote scission of the β-lactam bond by intramolecular participation or by intramolecular catalysis. In order to assess the importance of these effects, attempts were made to prepare the acetate (4). Although acetic anhydride in pyridine failed to acetylate the hydroxy-group of the azetidinone (3), the reaction was accomplished by isopropenyl acetate and toluene-*p*-sulphonic acid.



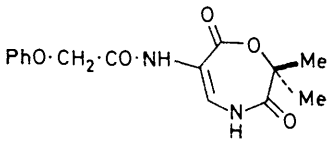
(17) R^1 = OMe, R^2 = H (21) R^1 = NHEt, R^2 = H
(18) R^1 = NH_2, R^2 = H (22) R^1 = $NHBu^t$, R^2 = H
(19) R^1 = NH·NH_2, R^2 = H (23) R^1 = NHMe, R^2 = Ac
(20) R^1 = NHMe, R^2 = H (24) R^1 = NHEt, R^2 = Ac



(25) (26)



(27)



(28)

When treated with methanolic sodium methoxide, the acetate (4) was converted into the (*Z*)-acryloylthioacetate (14). The structure of the derivative (14) was indicated by its spectroscopic properties; the similarity of its n.m.r. spectrum to that of compound (13) suggested that it possessed the *Z*-configuration.

There is thus a marked difference between the behaviour of the alcohol (3) and that of the acetate (4) towards sodium methoxide. In the former instance, the reagent initially attacks the β-lactam carbonyl group whereas in the latter case it removes the hydrogen atom at position 3.

The reactions of the acetate (4) with organic amines paralleled those of the alcohol (3). Thus, the amides (23) and (24) were produced with methylamine and with ethylamine, respectively, and the (*Z*)-acryloylthioacetate (14) was obtained with t-butylamine and with triethylamine.

In principle, the azetidinone (3) may undergo a base-induced intramolecular acyl transfer to give the derivative (26). Such a reaction is likely to be facilitated in the case of the sulphoxides (27), because of the increased acidity of the methylene hydrogen atoms. A mixture (*ca.* 1·3 : 1) of sulphoxides (27) was produced by oxidation of the sulphide (3) with *m*-chloroperbenzoic acid; the major isomer was isolated by fractional crystallisation.

When treated with triethylamine, the mixture of sulphoxides (27) was converted into the disulphide (8) and the oxazepine (28). The structure of the derivative (28) was assigned on the basis of analytical and spectroscopic evidence. Moreover, compound (28) was converted into a mixture of two products by methanolic sodium methoxide, one of which was identical (t.l.c. and n.m.r. spectroscopy) with the minor acrylate isolated from the reaction of the ester (3) with sodium methoxide. The structure of the second product was not established but it was not the major acrylate. Consequently, the minor acrylate was the *E*-isomer (15).

The reaction of the sulphoxides (27) with triethylamine is probably initiated by a β-elimination to yield the azetinone (25) and methyl 2-sulphenoacetate (9). The oxazepine (28) almost certainly arises from the azetinone (25). However, the formation of the disulphide (8) is surprising. It is known that sulphenic acids readily dimerise to thiosulphinates [7] but usually these products are isolable. Possibly in the above case the thiosulphinate (10) reacts further with the sulphenic acid (9) to give the disulphide (8) and the sulphinic acid (11). Benzenesulphenic acid and *S*-phenyl benzenethiosulphinate are believed to undergo a similar reaction to give benzenesulphinic acid and diphenyl disulphide.[8]

EXPERIMENTAL

For general experimental details see Part I.[9]

Methyl α-[(2R,3R)-1-(2-*Hydroxy*-2-*methylpropionyl*)-4-*oxo*-3-*phenoxyacetamidoazetidin*-2-*ylthio*]*acetate* (3).—(*a*) A solution of the acid (2) [2] (0·158 g, 0·4 mmol) in methanol (5 ml) containing conc. hydrochloric acid (1 drop) was left at room temperature for 4 h. The solution was diluted with chloroform, washed with sodium hydrogen carbonate solution followed by water, and dried ($MgSO_4$). Evaporation left the *ester* (3) (0·155 g, 95%), m.p. 129—131° (from chloroform–ether), $[\alpha]_D$ −36° (0·2% in $CHCl_3$), $\nu_{max.}$ (KBr) 3400 (NH and OH), 1785 (β-lactam C=O), 1735 (ester C=O), and 1705 and 1660 cm^{-1} (each amide C=O), $\lambda_{max.}$ (EtOH) 222 (ε 15,700), 264 (2150), 270 (2800), and 277 nm (1350), τ ($CDCl_3$) 8·53 and 8·48 (each 3H, s, *gem*-Me_2), 6·36 (2H, ABq,

[7] J. R. Shelton and K. E. Davis, *J. Amer. Chem. Soc.*, 1967, **89**, 718.

[8] J. L. Kice, C. G. Venier, and L. Heasley, *J. Amer. Chem. Soc.*, 1967, **89**, 3557.

[9] I. McMillan and R. J. Stoodley, *J. Chem. Soc.* (*C*), 1968, 2533.

J 16 Hz, CH_2·S), 6·25 (3H, s, MeO), 5·37 (2H, s, CH_2·O), 5·22 (1H, s, OH), 4·55 (1H, dd, *J* 7·5, *J'* 6 Hz, 3-H), 4·33 (1H, d, *J* 6 Hz, 2-H), 3·08—2·46 (5H, m, aromatic protons), and 2·34br (1H, d, *J* 7·5 Hz, NH) [addition of deuterium oxide caused the signals at τ 5·22 and 2·34 to disappear and that at 4·55 to collapse to a doublet (*J* 6 Hz)] [Found: C, 52·7; 5·3; N, 6·9%; *M* (mass spectrum), 410. $C_{18}H_{22}N_2O_7S$ requires C, 52·7; H, 5·4; N, 6·8%; *M*, 410].

(*b*) The acid (2) [2] (0·059 g, 0·15 mmol) was treated with an excess of diazomethane in ether for 10 min. Evaporation gave a syrup (0·060 g), which contained the ester (3) and minor amounts of other products, on the basis of t.l.c. and n.m.r. spectroscopy. Crystallisation of the syrup from chloroform–ether gave the ester (3) (0·010 g, 16%), m.p. 129—131°.

(*c*) The ester (3) (0·041 g, 0·1 mmol) was treated with an excess of diazomethane in ether for 5 h. Evaporation left a syrup (0·040 g), which contained a complex mixture of products, on the basis of t.l.c. and n.m.r. spectroscopy. The i.r. spectrum of the mixture did not contain any β-lactam carbonyl absorption; the product was not further investigated.

Reaction of the Azetidinone (3) *with Sodium Methoxide.*—(*a*) A solution of the azetidinone (3) (0·185 g, 0·45 mmol) in methanol (9 ml) was treated with 0·1M-sodium methoxide (0·9 ml, 0·09 mmol). Work-up after 2 h gave a syrup which contained three components (t.l.c.). The product was fractionated by silica gel chromatography (chloroform as eluant). The first-eluted material (0·033 g, 70%) was dimethyl 2,2'-dithiodiacetate (8), $\nu_{max.}$ (film) 1735 cm^{-1} (ester C=O), τ ($CDCl_3$) 6·38 (4H, s, 2 CH_2·S) and 6·20 (6H, s, 2MeO) [Found: *M* (mass spectrum), 210·0015. Calc. for $C_6H_{10}O_4S_2$: *M*, 210·0020]. The second-eluted constituent (0·054 g, 36%) was *methyl* (Z)-3-(*2-hydroxy-2-methylpropionamido*)-2-*phenoxyacetamidoacrylate* (12), $\nu_{max.}$ (film) 3340 (NH and OH), 1695sh (unsat. ester C=O), and 1665 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 216 (ε 14,500), 263sh (12,800), 270 (14,900), 276 (15,600), and 281sh nm (14,400), τ ($CDCl_3$) 8·49 (6H, s, *gem*-Me_2), 7·1br (1H, s, OH), 6·14 (3H, s, MeO), 5·37 (2H, s, CH_2·O), 3·05—2·48 (5H, m, aromatic protons), 2·11 (1H, d, *J* 11 Hz, vinylic proton), 1·1br (1H, s, NH), and —0·95br (1H, d, *J* 11 Hz, NH) (addition of deuterium oxide initially caused the signals at τ 7·1 and 1·1 to disappear; subsequently, the signal at 2·11 collapsed to a singlet and that at —0·95 disappeared) [Found: *M* (mass spectrum), 336·1331. $C_{16}H_{20}N_2O_6$ requires *M*, 336·1321]. The third-eluted component (0·027 g, 18%) was *methyl* (E)-3-(*2-hydroxy-2-methylpropionamido*)-2-*phenoxyacetamidoacrylate* (15), $\nu_{max.}$ (film) 3380 (NH and OH), 1695br (ester and amide C=O), and 1635 cm^{-1} (C=C), $\lambda_{max.}$ (EtOH) 219 (ε 11,200), 265sh (11,800), 271 (13,900), 276 (14,500), and 281sh nm (13,700), τ ($CDCl_3$) 8·49 (6H, s, *gem*-Me_2), 6·21 (3H, s, MeO), 5·46 (2H, s, CH_2·O), 3·20—2·45 (5H, m, aromatic protons), 2·0br (1H, s, NH), 1·73 (1H, d, *J* 12 Hz, vinylic proton), and —1·03br (1H, d, *J* 12 Hz, NH) (addition of deuterium oxide initially caused the signal at τ 2·00 to disappear; subsequently, the signal at 1·73 collapsed to a singlet and that at —1·03 disappeared) [Found: *M* (mass spectrum), 336·1331. $C_{16}H_{20}N_2O_6$ requires *M*, 336·1321].

(*b*) A stirred solution of the azetidinone (3) (0·061 g, 0·15 mmol) in methanol (2 ml) was treated with 0·1M-sodium methoxide (0·02 ml, 0·002 mmol). Work-up after 5 s yielded a syrup (0·060 g, 91%), which was predominantly methyl (2*R*,3*R*)-3-(2-hydroxy-2-methylpropionamido)-3-methoxycarbonylmethylthio-2-phenoxyacetamidopropionate (17), $\nu_{max.}$ (film) 3380 (NH and OH), 1740 (ester C=O), and 1675 cm^{-1} (amide C=O), τ ($CDCl_3$) 8·62 and 8·59 (each 3H, s, *gem*-Me_2), 6·57 (2H, ABq, *J* 16 Hz, CH_2·S), 6·31 and 6·24 (each 3H, s, MeO), 5·47 (2H, s, CH_2·O), 5·01 (1H, dd, *J* 8·5, *J'* 5 Hz, 3-H or 2-H), 4·46 (1H, dd, *J* 9·5, *J'* 5 Hz, 2-H or 3-H), 3·15—2·59 (5H, m, aromatic protons), 2·25br (1H, d, *J* 8·5 Hz, NH), and 2·10br (1H, d, *J* 9·5 Hz, NH) [addition of deuterium oxide caused the signals at τ 5·01 and 4·46 to collapse to doublets (*J* 5 Hz) and those at 2·25 and 2·10 to disappear].

0·1M-Sodium methoxide (0·3 ml, 0·03 mmol) was added to a stirred solution of the crude diester (17) (0·066 g, 0·15 mmol). Work-up after 2 h gave a syrup (0·060 g), which contained the disulphide (8), the (*Z*)-acrylate (12), and the (*E*)-acrylate (15), on the basis of t.l.c. and n.m.r. spectroscopy.

Reaction of the Acrylates (12) *and* (15) *with Sodium Methoxide.*—(*a*) A solution of the (*Z*)-acrylate (12) (0·050 g, 0·15 mmol) in methanol (3 ml) was treated with 0·1M-sodium methoxide (0·3 ml, 0·03 mmol). Work-up after 2 h yielded a syrup (0·046 g), which contained (n.m.r. spectroscopy) the starting material and an unidentified component; there was no evidence for the presence of the (*E*)-acrylate (15).

(*b*) The (*E*)-acrylate (15) (0·014 g, 0·04 mmol) was treated with sodium methoxide, as described in procedure (*a*). Work-up after 2 h afforded a syrup (0·014 g, 100%), which was identical with the starting material (t.l.c. and n.m.r. spectroscopy).

Reaction of Methyl 2-Mercaptoacetate with Sodium Methoxide.—A solution of methyl 2-mercaptoacetate (0·021 g, 0·2 mmol) in methanol (5 ml) was treated with 0·1M-sodium methoxide (0·4 ml, 0·04 mmol). Work-up after 2 h gave a syrup (0·020 g, 96%), which was identical (t.l.c. and i.r., n.m.r., and mass spectroscopy) with the disulphide (8).

Reaction of the Azetidinone (3) *with Ammonia.*—(*a*) The procedure of Heusler [5] was followed. A solution of the azetidinone (3) (0·061 g, 0·15 mmol) in dichloromethane (4 ml) was stirred vigorously with 0·13M-ammonium hydroxide (4 ml). Work-up after 18 h gave a mixture of products (t.l.c.), the i.r. spectrum of which did not possess a β-lactam carbonyl absorption.

(*b*) Gaseous ammonia was passed for 5 s through a solution of the azetidinone (3) (0·123 g, 0·3 mmol) in dichloromethane (10 ml). After 20 min the precipitated *methyl* α-[(1R,2R)-2-*carbamoyl*-1-(*2-hydroxy-2-methylpropionamido*)-2-*phenoxyacetamidoethylthio*]*acetate* (18) (0·110 g, 86%) was filtered off, m.p. 168—170° (from ethanol), $[\alpha]_D$ +26° (0·2% in MeOH), $\nu_{max.}$ (KBr) 3380, 3300, and 3200sh (NH and OH), 1730 (ester C=O), and 1705 and 1660 cm^{-1} (each amide C=O), $\lambda_{max.}$ (EtOH) 213 and 218 (each ε 7200), 263 (700), 269 (1100), and 276 nm (900), τ [$(CD_3)_2SO$] 8·80br and 8·75br (each 3H, s, *gem*-Me_2), 6·59br (2H, s, CH_2·S), 6·41br (3H, s, MeO), 5·45—5·23br (3H, m, CH_2·O and 2-H or 1-H), 4·65—4·40br (2H, m, OH and 1-H or 2-H), 3·12—2·49br (7H, m, aromatic protons and NH_2), 1·85br (1H, d, *J* 10 Hz, NH), and 1·41br (1H, d, *J* 10 Hz, NH) [addition of deuterium oxide caused the signals at τ 4·65—4·40 to collapse to a doublet (*J* 5 Hz) and those at 1·85 and 1·41 to disappear] (Found: C, 50·3; H, 5·9; N, 9·8. $C_{18}H_{25}N_3O_7S$ requires C, 50·6; H, 5·9; N, 9·8%).

Reaction of the Azetidinone (3) *with Hydrazine.*—Hydrazine hydrate (0·010 g, 0·2 mmol) in dichloromethane (1 ml) was added to a solution of the azetidinone (3) (0·082 g, 0·2 mmol) in dichloromethane (5 ml). After 20 min the precipitated

methyl α-[(1R,2R)-2-*carbazoyl*-1-(2-*hydroxy*-2-*methylpropionamido*)-2-*phenoxyacetamidoethylthio*]*acetate* (19) (0·073 g, 83%) was filtered off, m.p. 169—171° (from methanol), $[\alpha]_D$ −136° (0·1% in $CHCl_3$), $\nu_{max.}$ (KBr) 3360 and 3320 (NH and OH), 1740 (ester C=O), and 1685 and 1655 cm^{-1} (each amide C=O), $\lambda_{max.}$ (EtOH) 212 (ε 12,600), 216 (12,500), 262 (1400), 268 (1900), and 274 nm (1600), τ [$(CD_3)_2SO$] 8·80br and 8·74br (each 3H, s, *gem*-Me_2), 6·58br (2H, s, CH_2·S), 6·40br (3H, s, MeO), 5·80br (2H, s, NH_2), 5·47br (2H, s, CH_2·O), 5·35br (1H, dd, *J* 9·5, *J′* 6 Hz, 2-H or 1-H), 4·74—4·43br (2H, m, OH and 1-H or 2-H), 3·17—2·60br (5H, m, aromatic protons), 1·88br (1H, d, *J* 9·5 Hz, NH), 1·44br (1H, d, *J* 9·5 Hz, NH), and 0·63br (1H, s, NH) [addition of deuterium oxide caused the signals at τ 5·80, 1·88, 1·44, and 0·63 to disappear and those at 5·35 and 4·61 to collapse to doublets (each *J* 6 Hz)] (Found: C, 48·7; H, 6·0; N, 13·0. $C_{18}H_{26}N_4O_7S$ requires C, 48·9; H, 5·9; N, 12·7%).

Reaction of the Azetidinone (3) *with Methylamine.*—A solution of the azetidinone (3) (0·123 g, 0·3 mmol) in benzene (10 ml) was treated with 25% aqueous methylamine (0·04 ml, 0·32 mmol) in benzene (1 ml). After 1·5 h the solution was diluted with chloroform and washed with dilute hydrochloric acid followed by water. Evaporation of the dried ($MgSO_4$) organic layer afforded *methyl* α-[(1R,2R)-1-(2-*hydroxy*-2-*methylpropionamido*)-2-*methylcarbamoyl*-2-*phenoxyacetamidoethylthio*]*acetate* (20) (0·075 g, 68%), m.p. 181—182° (from ethanol), $[\alpha]_D$ +12° (0·6% in MeOH), $\nu_{max.}$ (KBr) 3300 (NH and OH), 1735 and 1715 (each ester C=O), and 1655 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 211 (ε 11,100), 215 (10,800), 262 (1200), 268 (1600), and 274 nm (1400), τ ($CDCl_3$) 8·56 (6H, s, *gem*-Me_2), 7·18 (3H, d, *J* 5 Hz, MeN), 6·42 (2H, ABq, *J* 16 Hz, CH_2·S), 6·22 (3H, s, MeO), 5·32 (2H, s, CH_2·O), 5·02 (1H, dd, *J* 9, *J′* 6 Hz, 2-H or 1-H), 4·54 (1H, dd, *J* 10, *J′* 6 Hz, 1-H or 2-H), 3·3—2·39 (6H, m, aromatic protons and NH), and 1·64br (2H, d, separation 10 Hz, 2NH) [addition of deuterium oxide caused the signals at τ 5·02 and 4·54 to collapse to doublets (each *J* 6 Hz) and that at 1·64 to disappear] (Found: C, 51·7; H, 6·0; N, 9·8. $C_{19}H_{27}N_3O_7S$ requires C, 51·7; H, 6·1; N, 9·5%).

Reaction of the Azetidinone (3) *with Ethylamine.*—The azetidinone (3) (0·223 g, 0·54 mmol) was treated with 70% aqueous ethylamine (method as described for methylamine). Work-up after 30 min yielded *methyl* α-[(1R,2R)-2-*ethylcarbamoyl*-1-(2-*hydroxy*-2-*methylpropionamido*)-2-*phenoxyacetamidoethylthio*]*acetate* (21) (0·202 g, 82%), m.p. 175—177° (from ethanol), $[\alpha]_D$ +15° (0·7% in MeOH), $\nu_{max.}$ (KBr) 3380sh and 3280 (NH and OH), 1735 and 1715 (each ester C=O), and 1645 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 211 (ε 11,400), 215 (11,000), 262 (1100), 268 (1600), and 274 nm (1400), τ ($CDCl_3$) 8·92br (3H, t, *J* 7 Hz, *Me*CH_2), 8·60br (6H, s, *gem*-Me_2), 7·01—6·2br (5H, m, OH, CH_2·S, and C*H*$_2$Me), 6·28br (3H, s, MeO), 5·44br (2H, s, CH_2·O), 5·15br (1H, dd, *J* 7·5 *J′* 5·5 Hz, 2-H or 1-H), 4·70br (1H, dd, *J* 9, *J′* 5·5 Hz, 1-H or 2-H), 3·37br (1H, s, NH), 3·14—2·58br (5H, m, aromatic protons), and 1·94—1·65br (2H, m, 2NH) [addition of deuterium oxide caused the signals at τ 5·15 and 4·70 to collapse to doublets (each *J* 5·5 Hz) and those at 3·37 and 1·94—1·65 to disappear] (Found: C, 52·6; H, 6·4; N, 9·2. $C_{20}H_{29}N_3O_7S$ requires C, 52·8; H, 6·4; N, 9·2%).

Reaction of the Azetidinone (3) *with t-Butylamine.*—A solution of the azetidinone (3) (0·164 g, 0·4 mmol) in dry benzene (10 ml) was treated with t-butylamine (0·028 g, 0·4 mmol) in dry benzene (1 ml). Work-up after 30 min gave a syrup (0·130 g), which contained three components (t.l.c.). The mixture was fractionated by silica gel chromatography [benzene–ether (4 : 1) as eluant]. The first-eluted constituent (0·070 g, 43%), obtained as a chromatographically homogeneous syrup, was *methyl* α-[(Z)-3-(2-*hydroxy*-2-*methylpropionamido*)-2-*phenoxyacetamidoacryloylthio*]*acetate* (13), $\nu_{max.}$ (film) 3360 (NH and OH), 1740 and 1720 (each ester C=O), 1680 (amide and thiol ester C=O), and 1640 cm^{-1} (C=C), $\lambda_{max.}$ (EtOH) 218 (ε 11,700), 264sh (9700), 271sh (11,100), 277sh (12,700), and 294 nm (15,300), τ ($CDCl_3$) 8·50 (6H, s, *gem*-Me_2), 6·27 (3H, s, MeO), 6·23 (2H, s, CH_2·S), 5·43 (2H, s, CH_2·O), 3·17—2·79 (5H, m, aromatic protons), 2·11 (1H, d, *J* 11 Hz, vinylic proton), 1·10br (1H, s, NH), and −0·84br (1H, d, *J* 11 Hz, NH) (addition of deuterium oxide initially caused the signal at τ 1·10 to disappear; subsequently, the signal at 2·11 collapsed to a singlet and that at −0·84 disappeared) [Found: *M* (mass spectrum), 410. $C_{18}H_{22}N_2O_7S$ requires *M*, 410]. The second-eluted constituent (0·035 g, 21%), obtained as a chromatographically homogeneous syrup, was *methyl* α-[(E)-3-(2-*hydroxy*-2-*methylpropionamido*)-2-*phenoxyacetamidoacryloylthio*]*acetate* (16), $\nu_{max.}$ (film) 3340 (NH and OH), 1735 and 1710sh (ester C=O), 1680 (amide and thiol ester C=O), and 1655 cm^{-1} (C=C), $\lambda_{max.}$ (EtOH) 217 (ε 9400), 263sh (4900), 270sh (6900), 277sh (9000), and 301 nm (15,000), τ ($CDCl_3$) 8·50 (6H, s, *gem*-Me_2), 6·30 (5H, s, CH_2·S and MeO), 5·38 (2H, s, CH_2·O), 3·15—2·68 (5H, m, aromatic protons), 2·63 (1H, d, *J* 12·5 Hz, 3-H), 2·05br (1H, s, NH), and −1·37br (1H, d, *J* 12·5 Hz, NH) (addition of deuterium oxide initially caused the signal at τ 2·05 to disappear; subsequently, the signal at 2·63 collapsed to a singlet and that at −1·37 disappeared) [Found: *M* (mass spectrum), 410. $C_{18}H_{22}N_2O_7S$ requires *M*, 410]. The third-eluted constituent (0·015 g, 8%), was methyl α-[(1*R*,2*R*)-2-t-butylcarbamoyl-1-(2-hydroxy-2-methylpropionamido)-2-phenoxyacetamidoethylthio]acetate (22), $[\alpha]_D$ −14° (0·8% in $CHCl_3$), $\nu_{max.}$ (film) 3340 (NH and OH), 1740 (ester C=O), and 1665 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 219 (ε 8100), 263 (1500), 269 (2000), and 276 nm (1900), τ ($CDCl_3$) 8·68 (9H, s, Me_3C), 8·59 and 8·58 (each 3H, s, *gem*-Me_2), 6·50 (2H, ABq, *J* 16 Hz, CH_2·S), 6·30 (3H, s, MeO), 5·47 (2H, s, CH_2·O), 5·20 (1H, dd, *J* 8, *J′* 5·5 Hz, 2-H or 1-H), 4·67 (1H, dd, *J* 9·5, *J′* 5·5 Hz, 1-H or 2-H), 3·16br (1H, s, NH), 3·10—2·56 (6H, m, aromatic protons and NH), and 1·93br (1H, d, *J* 8 Hz, NH) [addition of deuterium oxide caused the signals at τ 5·20 and 4·67 to collapse to doublets (each *J* 5·5 Hz) and those at 3·16 and 1·93 to disappear].

Reaction of the Amide (22) *with t-Butylamine.*—The amide (22) (0·029 g, 0·06 mmol) was treated with t-butylamine, as described for the ester (3). Work-up after 3 h gave a syrup (0·027 g, 93%), identical with the starting material (t.l.c. and n.m.r. spectroscopy).

Reaction of the Acryloylthioacetates (13) *and* (16) *with t-Butylamine.*—(*a*) The (*Z*)-acryloylthioacetate (13) (0·052 g, 0·13 mmol) was treated with t-butylamine, as described for the ester (3). Work-up after 30 min gave a syrup (0·049 g, 94%), which was identical with the starting material (t.l.c. and n.m.r. spectroscopy)

(*b*) The (*E*)-acryloylthioacetate (16) (0·025 g, 0·06 mmol) was treated with t-butylamine, as described for the ester (3). Work-up after 40 min yielded a syrup (0·024 g, 96%), which was identical with the (*Z*)-acryloylthioacetate (13) (t.l.c. and n.m.r. spectroscopy).

Reaction of the Azetidinone (3) *with Diethylamine.*—The azetidinone (3) (0·052 g, 0·13 mmol) was treated with diethylamine, as described for t-butylamine. Work-up

after 45 min gave a syrup (0·047 g), which was fractionated by silica gel chromatography (chloroform as eluant). The derived material (0·035 g, 67%) was identical with the (*Z*)-acryloylthioacetate (13) (t.l.c. and n.m.r. spectroscopy).

Reaction of the Azetidinone (3) *with Triethylamine.*—Triethylamine was added dropwise to a solution of the ester (3) (0·041 g, 0·1 mmol) in deuteriochloroform (0·6 ml) and the reaction was monitored by n.m.r. spectroscopy. Work-up after 90 min yielded a syrup (0·038 g), which was purified by silica gel chromatography (chloroform as eluant). The derived material (0·015 g, 37%), was identical with the (*Z*)-acryloylthioacetate (13) (t.l.c. and n.m.r. spectroscopy).

Reaction of the (Z)-*Acryloylthioacetate* (13) *with Sodium Methoxide.*—A solution of the (*Z*)-acryloylthioacetate (13) (0·053 g, 0·13 mmol) in methanol (3 ml) was treated with 0·1M-sodium methoxide (0·26 ml, 0·026 mmol). Work-up after 2 h yielded a syrup (0·051 g), which was fractionated by silica gel chromatography [benzene–ether (4 : 1) as eluant]. The first-eluted material (0·010 g, 73%) was the disulphide (8) (t.l.c. and i.r., n.m.r., and mass spectroscopy). The second-eluted substance (0·017 g, 39%) corresponded to the (*Z*)-acrylate (12) (t.l.c. and n.m.r. spectroscopy). The third-eluted material (0·009 g, 21%) was the (*E*)-acrylate (15) (t.l.c. and n.m.r. spectroscopy).

Reaction of the Azetidinone (3) *with Isopropenyl Acetate.*—Toluene-*p*-sulphonic acid hydrate (0·294 g, 1·55 mmol) was added to a stirred solution of the azetidinone (3) (0·635 g, 1·55 mmol) in isopropenyl acetate (5 ml). After 18 h the mixture was diluted with chloroform, washed with water (5 times), and dried ($MgSO_4$). Evaporation left a syrup (0·61 g), which was fractionated by silica gel chromatography [benzene–ether (1 : 1) as eluant] to give *methyl* α-[(2R,3R)-1-(2-*acetoxy*-2-*methylpropionyl*)-4-*oxo*-3-*phenoxyacetamidoazetidin*-2-*ylthio*]*acetate* (4) (0·411 g, 59%), m.p. 164—166° (from chloroform–ether), $[\alpha]_D$ −52° (0·7% in $CHCl_3$), $\nu_{max.}$ (KBr) 3340 (NH), 1820 (β-lactam C=O), 1725 (ester C=O), and 1690 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 219 (ε 8700), 263 (900), 270 (1000), and 276 nm (800), τ ($CDCl_3$) 8·43 and 8·37 (each 3H, s, *gem*-Me_2), 7·94 (3H, s, MeCO), 6·40 (2H, ABq, *J* 16 Hz, CH_2·S), 6·33 (3H, s, MeO), 5·43 (2H, s, CH_2·O), 4·72 (1H, dd, *J*, *J′* 6·5 Hz, 3-H), 4·48 (1H, d, *J* 6·5 Hz, 2-H), and 3·20—2·40 (6H, m, aromatic protons and NH) [addition of deuterium oxide caused the signal at τ 4·72 to collapse to a doublet (*J* 6·5 Hz)] [Found: C, 52·9; H, 5·2; N, 6·2%; *M* (mass spectrum), 452. $C_{20}H_{24}N_2O_8S$ requires C, 53·1; H, 5·3; N, 6·2%; *M*, 452].

Reaction of the Acetate (4) *with Sodium Methoxide.*—A stirred solution of the acetate (4) (0·045 g, 0·1 mmol) in methanol (3 ml) was treated with 0·1M-sodium methoxide (0·05 ml, 0·005 mmol). Work-up after 30 min yielded a residue (0·042 g), which was fractionated by silica gel chromatography [benzene–ether (4 : 1) as eluant] to afford *methyl* α-[(Z)-3-(2-*acetoxy*-2-*methylpropionamido*)-2-*phenoxyacetamidoacryloylthio*]*acetate* (14) (0·020 g, 44%) as a chromatographically homogeneous syrup, $\nu_{max.}$ (film) 3340 (NH), 1745 and 1720sh (each ester C=O), 1680 (amide and thiol ester C=O), and 1640 cm^{-1} (C=C), $\lambda_{max.}$ (EtOH) 220 (ε 11,700), 264sh (7800), 271sh (8700), 277sh (10,100), and 303 nm (16,100), τ ($CDCl_3$) 8·36 (6H, s, *gem*-Me_2) 7·86 (3H, s, MeCO), 6·27 (3H, s, MeO), 6·23 (2H, s, CH_2·S), 5·44 (2H, s, CH_2·O), 3·18—2·57 (5H, m, aromatic protons), 2·10 (1H, d, *J* 10·5 Hz, 3-H), 0·91br (1H, s, NH), and −1·24br (1H, d, *J* 10·5 Hz, NH) (addition of deuterium oxide initially caused the signal at τ 0·91 to disappear; subsequently, the signal at 2·10 collapsed to a singlet and that at −1·24 disappeared) [Found: *M* (mass spectrum), 452·1249. $C_{20}H_{24}N_2O_8S$ requires 452·1253].

Reaction of the Acetate (4) *with Methylamine.*—The acetate (4) (0·045 g, 0·1 mmol) was treated with methylamine as described for the alcohol (3). Work-up after 20 min yielded *methyl* α-[(1R,2R)-1-(2-*acetoxy*-2-*methylpropionamido*)-2-*methylcarbamoyl*-2-*phenoxyacetamidoethylthio*]*acetate* (23), m.p. 172—174° (from benzene–light petroleum), $[\alpha]_D$ −20° (0·15% in $CHCl_3$), $\nu_{max.}$ (KBr) 3310 (NH), 1735 (ester C=O), and 1650 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 218 (ε 9800), 264 (1300), 270 (1700), and 276 nm (1500), τ ($CDCl_3$) 8·42 (6H, s, *gem*-Me_2), 7·93 (3H, s, MeCO), 7·26 (3H, d, *J* 5 Hz, MeN), 6·40 (2H, ABq, *J* 17 Hz, CH_2·S), 6·31 (3H, s, MeO), 5·41 (2H, s, CH_2·O), 5·21 (1H, dd, *J* 8, *J′* 5·5 Hz, 2-H or 1-H), 4·72 (1H, dd, *J* 9, *J′* 5·5 Hz, 1-H or 2-H), 3·33br (1H, NH), 3·10—2·57 (5H, m, aromatic protons), 2·06br (1H, d, *J* 9 Hz, NH), and 1·92br (1H, d, *J* 8 Hz, NH) [addition of deuterium oxide caused the signal at τ 7·26 to collapse to a singlet, those at 5·21 and 4·72 to collapse to doublets (*J* 5·5 Hz), and those at 3·33, 2·06, and 1·92 to disappear] (Found: C, 51·9; H, 6·2; N, 8·8. $C_{21}H_{29}N_3O_8S$ requires C, 52·1; H, 6·0; N, 8·7%).

Reaction of the Acetate (4) *with Ethylamine.*—The acetate (4) (0·090 g, 0·2 mmol) was treated with ethylamine, as described for the alcohol (3). Work-up after 30 min yielded *methyl* α-[(1R,2R)-1-(2-*acetoxy*-2-*methylpropionamido*)-2-*ethylcarbamoyl*-2-*phenoxyacetamidoethylthio*]*acetate* (24) (0·080 g, 81%), m.p. 154—156° (from benzene–light petroleum), $[\alpha]_D$ −34° (0·4% in $CHCl_3$), $\nu_{max.}$ (KBr) 3300 (NH), 1740 (ester C=O), and 1665 and 1650 cm^{-1} (each amide C=O), $\lambda_{max.}$ (EtOH) 214 and 218 (each ε 11,900), 263sh (1900), 270 (2400), and 277 nm (2200), τ ($CDCl_3$) 8·91 (3H, t, *J* 7 Hz, *Me*CH_2), 8·40 (6H, s, *gem*-Me_2), 7·90 (3H, s, MeCO), 6·77 (2H, ABq, *J* 7 Hz, *CH*$_2$Me), 6·36 (2H, ABq, *J* 16 Hz, CH_2·S), 6·26 (3H, s, MeO), 5·35 (2H, s, CH_2·O), 5·18 (1H, dd, *J* 8, *J′* 5·5 Hz, 2-H or 1-H), 4·64 (1H, dd, *J* 8·5, *J′* 5·5 Hz, 1-H or 2-H), 3·4br (1H, NH), 3·06—2·45 (5H, m, aromatic protons), and 2·12—1·88 (2 H, m, 2NH) [addition of deuterium oxide caused the signals at τ 5·18 and 4·64 to collapse to doublets (each *J* 5·5 Hz) and those at 3·4 and 2·12—1·88 to disappear] [Found: *M* (mass spectrum), 497. $C_{22}H_{31}N_3O_8S$ requires *M*, 497].

Reaction of the Acetate (4) *with t-Butylamine.*—The acetate (4) (0·065 g, 0·14 mmol) was treated with t-butylamine, as described for the alcohol (3). Work-up after 1 h yielded a syrup (0·060 g), which was purified by silica gel chromatography (chloroform as eluant). The derived material (0·042 g, 65%) was identical with the (*Z*)-acryloylthioacetate (14) (t.l.c. and n.m.r. spectroscopy).

Reaction of the Acetate (4) *with Triethylamine.*—The acetate (4) (0·045 g, 0·01 mmol) was treated with triethylamine, as described for the alcohol (3). Work-up after 2 h yielded a syrup (0·040 g), which contained the (*Z*)-acryloylthioacetate (14) as the predominant product (t.l.c. and n.m.r. spectroscopy).

Reaction of the Azetidinone (3) *with* m-*Chloroperbenzoic Acid.*—A solution of the ester (3) (0·320 g, 0·78 mmol) in dichloromethane (10 ml) was treated with *m*-chloroperbenzoic acid (0·135 g, 0·78 mmol) dissolved in dichloromethane (1 ml). After 1 h the mixture was diluted with chloroform, washed with sodium hydrogen carbonate solution followed by water, and dried ($MgSO_4$). Evaporation left *methyl* α-[(2R,3R)-1-(2-*hydroxy*-2-*methylpropionyl*)-4-*oxo*-2-*phenoxyacetamidoazetidin*-2-*ylsulphinyl*]*acetate* (27) (0·240 g, 72%) as a mixture (*ca.* 4 : 3 by n.m.r. spectro-

scopy) of isomers. Crystallisation from boiling methanol afforded the major sulphoxide (0·080 g, 24%), m.p. 160—162°, $[\alpha]_D$ −167° (0·2% in Me_2CO), $\nu_{max.}$ (KBr) 3420 (NH and OH), 1780 (β-lactam C=O), 1730 and 1715 (each ester C=O), and 1690 cm^{-1} (amide C=O), $\lambda_{max.}$ (EtOH) 217 (ε 10,200), 264 (2300), 270 (2400), 277 (2300), and 315 nm (4700), τ[$(CD_3)_2SO$] 8·56br (6H, s, *gem*-Me_2), 6·33br (3H, s, MeO), 5·90br (2H, ABq, *J* 14·5 Hz, CH_2·S), 5·28br (2H, s, CH_2·O), 4·68—4·58br (2H, m, 2-H and OH), 3·96br (1H, dd, *J* 10, *J'* 6 Hz, 3-H), 3·15—2·60br (5H, m, aromatic protons), and 1·51br (1H, d, *J* 10 Hz, NH) [addition of deuterium oxide caused the signals at τ 4·68—4·58 and 3·96 to collapse to doublets (each *J* 6 Hz) and that at 1·15 to disappear] (Found: C, 50·9; H, 5·3; N, 6·5. $C_{18}H_{22}N_2O_6S$ requires C, 50·7; H, 5·2; N, 6·6%).

Reaction of the Sulphoxides (27) *with Triethylamine.*—The mixture of sulphoxides (27) (0·170 g, 0·4 mmol) was treated with triethylamine, as described for the sulphide (3). Work-up after 20 min gave a partially crystalline residue (0·110 g), which was recrystallised from chloroform to give 2,2-*dimethyl*-6-*phenoxyacetamido*-1,4-*oxazepine*-3(2H),7-(4H)-*dione* (28), m.p. 236—238°, $\nu_{max.}$ (KBr) 3340 (NH and OH), 1715 (lactone C=O), 1690 and 1670 (each amide C=O), and 1655 cm^{-1} (C=C), $\lambda_{max.}$ (EtOH) 218 (ε 10,800), 264sh (4600), 271sh (6300), 277 (7400), and 293 nm (7900), τ [$(CD_3)_2SO$] 8·60 (6H, s, *gem*-Me_2), 5·55 (2H, s, CH_2·O), 3·28—2·70 (6H, m, aromatic protons and 5-H), 0·84br (1H, s, NH), and −0·45br (1H, s, NH) (addition of deuterium oxide caused the signals at τ 0·84 and −0·45 to disappear) [Found: C, 59·1; H, 5·4; N, 9·0%; *M* (mass spectrum), 304. $C_{15}H_{16}N_2O_5$ requires C, 59·2; H, 5·3; N, 9·2%; *M*, 304]. The filtrate, obtained after removal of the oxazepine (28), was concentrated and the residue was purified by silica gel chromatography [benzene–ether (4 : 1) as eluant] to give the disulphide (8) (0·017 g, 63%) (t.l.c. and n.m.r. and mass spectroscopy).

Reaction of the Oxazepine (28) *with Sodium Methoxide.*—The oxazepine (28) (0·025 g, 0·08 mmol) in methanol (5 ml) was treated with 0·1M-sodium methoxide (0·15 ml, 0·015 mmol). Work-up after 1 h gave a syrup (0·025 g), which was a mixture (*ca.* 1 : 1) of two substances (n.m.r. spectroscopy). The mixture was partially separated by silica gel chromatography [benzene–ether (4 : 1) as eluant]. The first eluted constituent (0·011 g, 40%) was the (*E*)-acrylate (15) (t.l.c. and n.m.r. spectroscopy). The second-eluted material (0·010 g) was not identified; however, its spectroscopic properties differed from those of the (*Z*)-acrylate (12).

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