Studies Related to Penicillins. Part XI.[1] Mechanism of Degradation of Benzylpenicillinic and Phenoxymethylpenicillinic Acid by Mercury(II) Acetate [2]

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Acetoxymercury(II) (2*S*)-3-acetoxymercurio(II)thio-2-{(1*R*,5*S*)-3-benzyl-6-oxo-2-oxa-4,7-diazabicyclo[3.2.0]-hept-3-en-7-yl}-3-methylbutanoate (16) is formed when potassium benzylpenicillinate (1) is added to mercury(II) acetate in acetic acid. The salt (16) is converted into (3*S*,4*S*)-4-acetoxy-1-(2-methylprop-1-enyl)-3-phenylacetamidoazetidin-2-one (6) by hot acetic acid, into (1*R*,5*S*)-3-benzyl-7-(2-methylprop-1-enyl)-2-oxa-4,7-diazabicyclo[3.2.0]hept-3-en-6-one (10) by dimethyl sulphoxide, and into methyl (2*S*)-2-{(1*R*,5*S*)-3-benzyl-6-oxo-2-oxa-4,7-diazabicyclo[3.2.0]hept-3-en-7-yl}-3-mercapto-3-methylbutanoate (15) by diazomethane. Pyridine removes the elements of mercury(II) acetate from the salt (16) to give the derivative (21).

Potassium phenoxymethylpenicillinate (2) undergoes an analogous reaction in the presence of mercury(II) acetate and acetic acid to give the salt (18). This derivative is also converted into the acetate (7) by hot acetic acid, into the methylpropenyl derivative (12) by dimethyl sulphoxide, into the ester (17) by diazomethane, and into the salt (22) by pyridine.

RECENTLY we reported the conversion of penicillanic acids, *e.g.* (1), into monocyclic azetidinones, *e.g.* (6), by mercury(II) acetate in hot acetic acid.[3] The timing of the 1,2- and 1,5-bond ruptures, which must occur during the reaction, was not established. We have now investigated the degradation in more detail in an attempt to delineate the course of the reaction and in the hope of exploiting it for the synthesis of β-lactam antibiotic analogues.

When potassium benzylpenicillinate (1) was added to a solution of mercury(II) acetate in acetic acid at room temperature, an amorphous salt was precipitated. This salt, $C_{20}H_{22}Hg_2N_2O_8S$, showed a medium-intensity i.r. peak at 1765 (β-lactam C=O) and a strong peak at 1575 (CO_2^-) cm^{-1}. The n.m.r. spectrum of a freshly prepared solution of the salt in [$^2H_6$]dimethyl sulphoxide possessed very broad signals; however, after 5 h a sharp spectrum, characteristic of the methylpropenyl derivative (10), was obtained. The sharpening of the n.m.r. spectrum was accompanied by a darkening of the solution and the deposition of a black precipitate [presumably mercury(II) sulphide].

The derivative (10) was isolated when the foregoing reaction was repeated on a preparative scale. Its yield depended upon the origin of the salt; thus, a sample which had been dried overnight in a vacuum desiccator afforded the oxazoline (10) in 13% yield, whereas a freshly prepared sample which had been air-dried for *ca.* 1 h gave the derivative in 30% yield.

When treated with diazomethane, the salt was converted into a mixture of products, which was fractionated by silica gel chromatography. The first-eluted material, although homogeneous on t.l.c., was identified as a mixture (*ca.* 1 : 1) of the methylpropenyl derivative (10) and the unsaturated ester (11),[4-6] on the basis of n.m.r. spectroscopy. The second-eluted substance, which was a single component on t.l.c., was the thiol (15). Its structure was established by spectroscopic evidence and by its conversion into the unsaturated ester (11) by mercury(II) acetate.

On the basis of the foregoing evidence, structure (16) is proposed for the salt.

When heated in acetic acid, the derivative (16) afforded the acetate (6),[3] which was also obtained from the reaction of compound (10) with acetic acid at room temperature. Consequently, the conversion of potassium benzylpenicillinate (1) into the acetate (6) involves the intermediacy of the salt (16) and possibly the oxazoline (10).

The salt (16) was soluble in pyridine but after a few minutes the solution deposited granular crystals, $C_{16}H_{16}HgN_2O_4S$. The i.r. spectrum of this substance, although similar to that of the starting material, was better defined; it showed strong absorptions at 1765 (β-lactam C=O) and 1585 (CO_2^-) and a medium-intensity peak at 1645 (C=N) cm^{-1}. The material, which again possessed broad signals in the n.m.r. spectrum, was converted into the methylpropenyl derivative (10) by dimethyl sulphoxide, into the thiol (15) by diazomethane, and into the salt (16) by mercury(II) acetate. Structure (21) is proposed for this compound.

When heated in acetic acid, the derivative (21) formed the acetate (6) in only low yield. Consequently, it is not an important intermediate in the conversion of potassium benzylpenicillinate (1) into the acetate (6).

Potassium phenoxymethylpenicillinate (2) was transformed into the salt (18) by mercury(II) acetate in acetic acid. The structure of the salt was indicated by elemental analysis, by i.r. spectroscopy, and by its

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

[2] Preliminary communication, R. J. Stoodley and N. R. Whitehouse, *J.C.S. Chem. Comm.*, 1973, 477.

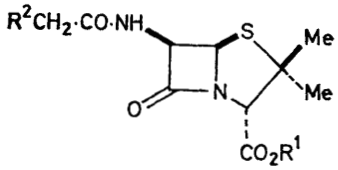
[3] R. J. Stoodley and N. R. Whitehouse, *J.C.S. Perkin I*, 1973, 32.

[4] J. C. Sheehan in 'Molecular Modification in Drug Design,' Advances in Chemistry Series No. 45, American Chemical Society, Washington D.C., 1964, p. 15.

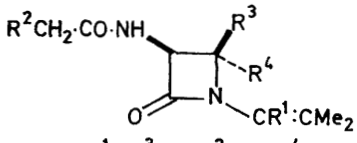
[5] D. H. R. Barton, F. Comer, and P. G. Sammes, *J. Amer. Chem. Soc.*, 1969, **91**, 1529; D. H. R. Barton, F. Comer, D. G. T. Greig, P. G. Sammes, C. M. Cooper, G. Hewitt, and W. G. E. Underwood, *J. Chem. Soc.* (*C*), 1971, 3540.

[6] S. Wolfe, J.-B. Ducep, G. Kannengiesser, and W. S. Lee, *Canad. J. Chem.*, 1972, **50**, 2902.

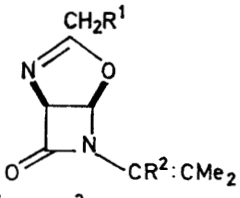
conversion into the methylpropenyl derivative (12) in the presence of dimethyl sulphoxide.



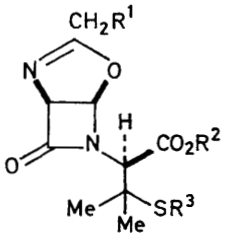
(1) R^1 = K, R^2 = Ph
(2) R^1 = K, R^2 = OPh
(3) R^1 = $CH_2 \cdot CCl_3$, R^2 = Ph
(4) R^1 = Me, R^2 = Ph
(5) R^1 = $CH_2 \cdot C_6H_4 \cdot OMe$-*p*, R^2 = OPh



(6) R^1 = R^3 = H, R^2 = Ph, R^4 = OAc
(7) R^1 = R^3 = H, R^2 = OPh, R^4 = OAc
(8) R^1 = $CH_2 \cdot C_6H_4 \cdot OMe$-*p*, R^2 = OPh, R^3 = SMe, R^4 = H
(9) R^1 = CO_2Me, R^2 = Ph, R^3 = H, R^4 = Cl

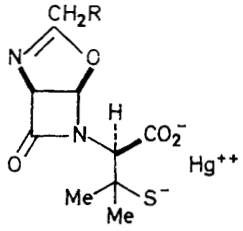


(10) R^1 = Ph, R^2 = H
(11) R^1 = Ph, R^2 = CO_2Me
(12) R^1 = OPh, R^2 = H
(13) R^1 = OPh, R^2 = CO_2Me
(14) R^1 = OPh, R^2 = $CH_2 \cdot C_6H_4 \cdot OMe$-*p*



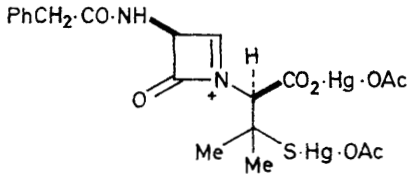
(15) R^1 = Ph, R^2 = Me, R^3 = H
(16) R^1 = Ph, R^2 = R^3 = Hg·OAc
(17) R^1 = OPh, R^2 = Me, R^3 = H
(18) R^1 = OPh, R^2 = R^3 = Hg·OAc
(19) R^1 = OPh, R^2 = Me, R^3 = $Hg \cdot CH_2 \cdot OAc$
(20) R^1 = OPh, R^2 = Me, R^3 = $Hg \cdot CH_2 \cdot \overset{+}{N} : N \quad \bar{O}Ac$

Diazomethane reacted with the salt to give a mixture of products, which was fractionated by silica gel chromatography. The first-eluted material, although homogeneous on t.l.c., was shown to be a mixture (*ca.* 1 : 1) of the methylpropenyl derivative (12) and the unsaturated ester (13) by n.m.r. spectroscopy. The second-eluted fraction also appeared to be a single component on t.l.c. Its n.m.r. spectrum was similar to that of the thiol (17) but it contained additional signals at τ 7·92 (3H) and 5·67 (2H). Mass spectroscopy established that two mercury-containing components were present; the peak at *m/e* 638 corresponded to the molecular formula, $C_{20}H_{24}HgN_2O_7S$, and that at *m/e* 582 to the formula, $C_6H_{10}Hg_2O_4S$. On this evidence, the material is considered to contain the mercury derivative (19) as the major constituent and the bis(mercury) derivative (23) as the minor constituent. The third-eluted substance, which was a single entity on t.l.c., was identified as the thiol (17), on the basis of spectroscopic evidence.



$(AcO \cdot CH_2 \cdot Hg)_2S$

(21) R = Ph (23)
(22) R = OPh



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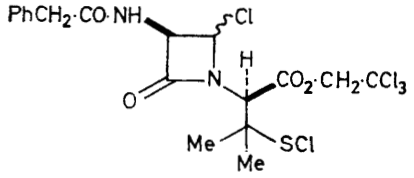

(25)

The foregoing results show that the degradation of penicillanic acid derivatives by mercury(II) acetate involves an initial 1,5-bond cleavage. A likely intermediate in the reaction is the cation, *e.g.* (24), which then affords the oxazoline, *e.g.* (16).

Only one other procedure is available for the selective cleavage of the 1,5-bond of a penicillanic acid derivative without the loss of the sulphur atom. Thus, the chlorine-induced conversion of 2,2,2-trichloroethyl benzylpenicillinate (3) into the sulphenyl chlorides (25) has been described by Kukolja.[7] The last-mentioned compounds have been shown to be versatile intermediates in the synthesis of novel β-lactam derivatives.[8]

[7] S. Kukolja, *J. Amer. Chem. Soc.*, 1971, **93**, 6267; S. Kukolja and S. R. Lammert, *Croat. Chem. Acta*, 1972, **44**, 423.
[8] S. Kukolja, *J. Amer. Chem. Soc.*, 1972, **94**, 6270, 7590.

The formation of oxazolines from penicillins has been reported previously. Thus, Sheehan [4] first described the formation of the oxazoline (11) from methyl benzylpenicillinate (4) and t-butyl hypochlorite. The same compound was subsequently obtained from the ester (4) and iodobenzene dichloride [5] and by cyclisation of the chloride (9).[6] Nayler and his co-workers [9] isolated the oxazoline (14) when the azetidinone (8) was treated with either lead tetra-acetate or *N*-bromosuccinimide and when *p*-methoxybenzyl phenoxymethylpenicillinate (5) was treated with t-butyl hypochlorite.

The formation of the mercury derivative (19) from the reaction of the salt (18) with diazomethane presumably involves species (2) as an intermediate. It is not clear, however, why the salt (16) does not behave in a similar manner. An analogy for the reaction involves the formation of (benzoyloxymethyl)phenylmercury(II) from phenylmercury(II) benzoate and diazomethane.[10]

EXPERIMENTAL

For general experimental details see Part I.[11] Mercury was determined gravimetrically as mercury(II) sulphide.[12]

Reaction of Potassium Benzylpenicillinate (1) *with Mercury*-(II) *Acetate*.—The salt (1) (3·73 g, 10 mmol) was added to a stirred solution of mercury(II) acetate (6·37 g, 20 mmol) in acetic acid (100 ml) at room temperature. Acetone (100 ml) was mixed with the resultant gel and the insoluble material was filtered off and washed with acetone followed by ether to give *acetoxymercury*(II) (2S)-3-*acetoxymercurio*-(II)*thio*-2-{(1R,5S)-3-*benzyl*-6-*oxo*-2-*oxa*-4,7-*diazabicyclo*-[3.2.0]*hept*-3-*en*-7-*yl*}-3-*methylbutanoate* (16) (6·4 g, 75%), $\nu_{max.}$ (KBr) 1765 (β-lactam C=O) and 1575br cm^{-1} (CO_2^-) (Found: C, 27·9; H, 2·5; Hg, 48·1; N, 3·4. $C_{20}H_{22}Hg_2N_2O_8S$ requires C, 28·2; H, 2·6; Hg, 47·1; N, 3·3%).

The filtrate was diluted with water, filtered, adjusted to *ca.* pH 5 with solid sodium hydrogen carbonate, and extracted with chloroform (3 times). The organic layer was washed with sodium hydrogen carbonate solution followed by water, dried ($MgSO_4$), and evaporated to leave the acetate (6) [3] (0·115 g, 3·5%), m.p. 68—70° (from benzene–light petroleum).

Reaction of the Salt (16) *with Acetic Acid*.—A suspension of the salt (16) (1·0 g, 1·18 mmol) was gently heated (oil-bath) in acetic acid (25 ml). When the bath temperature reached 85°, the mixture was cooled and filtered. Work-up of the filtrate as before yielded a syrup (0·265 g), which was fractionated by silica gel chromatography (benzene–ether as eluant) to give the acetate (6) [3] (0·154 g, 40%), m.p. 68—70° (from benzene–light petroleum).

Reaction of the Salt (16) *with Dimethyl Sulphoxide*.—(*a*) The salt (16) (3·0 g, 3·5 mmol), which had been dried ($CaCl_2$) overnight in a vacuum desiccator, was stirred in dimethyl sulphoxide (15 ml). After 20 h the mixture was diluted with methanol (50 ml) and filtered. Ether was added to the filtrate, which was washed (twice) with water, dried ($MgSO_4$), and concentrated. Addition of ether to the residue and filtration afforded (1R,5S)-3-*benzyl*-7-(2-*methyl*-*prop*-1-*enyl*)-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-6-*one* (10) (0·12 g, 13%), m.p. 108—110° (from ether–light petroleum), $[\alpha]_D$ −49° (0·5% in $CHCl_3$), $\nu_{max.}$ (KBr) 1760 (β-lactam C=O) and 1640 cm^{-1} (C=N), τ ($CDCl_3$) 8·33br (6H, m, *gem*-Me_2), 6·25 (2H, s, CH_2·CO), 4·83 (1H, d, *J* 4 Hz, 5-H), 4·15 (2H, m, 1-H and vinylic proton), and 2·65 (5H, s, aromatic protons) [Found: C, 70·3; H, 6·1; N, 10·9%; *M* (mass spectrum), 256. $C_{15}H_{16}N_2O_2$ requires C, 70·3; H, 6·2; N, 10·9%; *M*, 256].

(*b*) Freshly prepared salt (16) (6·4 g, 7·5 mmol) was treated with dimethyl sulphoxide as described in procedure (*a*). Work-up after 18 h afforded the oxazoline (10) (0·579 g, 30%), m.p. 108—110° (from ether–light petroleum).

Reaction of the Oxazoline (10) *with Acetic Acid*.—A solution of the oxazoline (10) (0·05 g, 0·4 mmol) in acetic acid (1 ml) was left at room temperature for 0·5 h. The mixture was diluted with chloroform and sodium hydrogen carbonate solution and the organic layer was washed with water and dried ($MgSO_4$). Evaporation left the acetate (6) [3] (0·06 g, 95%), m.p. 68—70° (from benzene–light petroleum).

Reaction of the Salt (16) *with Diazomethane*.—An excess of diazomethane in ether was added to a stirred suspension of the salt (16) (3·0 g, 3·5 mmol) in dimethyl sulphoxide (15 ml). After 2 h the mixture was diluted with ether, filtered, and washed (3 times) with water. The dried ($MgSO_4$) organic layer was concentrated to leave a syrup (1·435 g), which was fractionated by silica gel chromatography (benzene–ether as eluant). The first-eluted material (0·14 g) was identified as a mixture (*ca.* 1 : 1) of the methylpropenyl derivative (10) and the unsaturated ester (11) [4-6] on the basis of n.m.r. spectroscopy. The second-eluted substance (0·588 g, 48%), was *methyl* (2S)-2-{(1R,5S)-3-*benzyl*-6-*oxo*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*mercapto*-3-*methylbutanoate* (15), $[\alpha]_D$ +38° (1·02% in $CHCl_3$), $\nu_{max.}$ (film) 1775 (β-lactam C=O), 1735 (ester C=O), and 1650 cm^{-1} (C=N), τ ($CDCl_3$) 8·62 and 8·50 (each 3H, s, *gem*-Me_2), 6·30 (5H, s, MeO and CH_2·CO), 5·38 (1H, s, 2-H), 4·87 (1H, d, *J* 4 Hz, 5-H), 3·80 (1H, d, *J* 4 Hz, 1-H), and 2·72 (5H, s, aromatic protons) [Found: *M* (mass spectrum), 348·1143. $C_{17}H_{20}N_2O_4S$ requires 348·1144].

Reaction of the Thiol (15) *with Mercury*(II) *Acetate*.—A solution of the thiol (15) (0·12 g, 0·35 mmol) and mercury(II) acetate (0·055 g, 0·17 mmol) in dimethyl sulphoxide (4 ml) was stirred for 18 h. The mixture was diluted with ether, filtered, and washed (twice) with water. Evaporation of the dried ($MgSO_4$) organic layer afforded a syrup (0·109 g), which was purified by silica gel chromatography (benzene–ether as eluant) to give the oxazoline (11) [4-6] (0·071 g, 65%), m.p. 120—122° (from ether), $[\alpha]_D$ +46° (1·0% in $CHCl_3$) [Found: *M* (mass spectrum), 314·1261. Calc. for $C_{17}H_{18}N_2O_4$: *M*, 314·1267]. I.r. and n.m.r. spectroscopic data were in agreement with those published.[5]

Reaction of the Salt (16) *with Pyridine*.—The salt (16) (20 g, 23·5 mmol) was dissolved in dry pyridine (40 ml). After *ca.* 2 min the solution deposited granular crystals, which were filtered off and washed well with methanol to give *mercury*(II) (2S)-2-{(1R,5S)-3-*benzyl*-6-*oxo*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*methyl*-3-*sulphidobutanoate* (21) (10·5 g, 84%), $\nu_{max.}$ (KBr) 1765 (β-lactam C=O), 1645

[9] E. G. Brain, A. J. Eglington, J. H. C. Nayler, M. J. Pearson, and R. Southgate, *J.C.S. Chem. Comm.*, 1972, 229.

[10] P. Pfeiffer and H. Jäger, *Chem. Ber.*, 1947, **80**, 1; P. Pfeiffer, R. Schulze-Bentrop, K. H. La Roche, and E. Schmitz, *ibid.*, 1952, **85**, 232.

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

[12] A. I. Vogel, 'A Textbook of Quantitative Inorganic Analysis Including Elementary Instrumental Analysis,' Longmans, London, 1962, p. 486.

(C=N), and 1585 cm^{-1} (CO_2^-) (Found: C, 35·7; H, 3·3; Hg, 36·2; N, 5·2. $C_{16}H_{16}HgN_2O_4S$ requires C, 36·1; H, 3·0; Hg, 37·6; N, 5·3%).

Reaction of the Salt (21) *with Mercury*(II) *Acetate*.—The salt (21) (1·0 g, 1·88 mmol) was added to a stirred solution of mercury(II) acetate (0·6 g, 1·88 mmol) in acetic acid (25 ml). After 5 min the resultant gel was mixed with acetone (50 ml) and the insoluble material was filtered off and washed with acetone followed by ether. The product (1·06 g, 66%) was identical with the salt (16) by i.r. spectroscopy.

Reaction of the Salt (21) *with Acetic Acid*.—The salt (21) (1·0 g, 1·88 mmol) was heated in acetic acid, as described for derivative (16). Work-up yielded a syrup (0·166 g), which was fractionated by silica gel chromatography (benzene–ether as eluant) to give the acetate (6) [3] (0·02 g, 4%), m.p. 68—70° (from benzene–light petroleum).

Reaction of the Salt (21) *with Diazomethane*.—An excess of diazomethane in ether was added to a stirred suspension of the salt (21) (1·0 g, 1·88 mmol) in dimethyl sulphoxide (10 ml). Work-up after 2 h yielded a syrup (0·42 g), which was fractionated by silica gel chromatography (benzene–ether as eluant) to give the thiol (15) (0·23 g, 22%), identified on the basis of t.l.c. and i.r. and n.m.r. spectroscopy.

Reaction of Potassium Phenoxymethylpenicillinate (2) *with Mercury*(II) *Acetate*.—The salt (2) (3·88 g, 10 mmol) was treated with mercury(II) acetate in acetic acid, as described for derivative (1), to give *acetoxymercury*(II) (2S)-3-*acetoxymercurio*(II)*thio*-2-{(1R,5S)-6-*oxo*-3-*phenoxymethyl*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*methylbutanoate* (18) (6·61 g, 76%), $\nu_{max.}$ (KBr) 1765 (β-lactam C=O) and 1575br cm^{-1} (CO_2^-) (Found: C, 27·8; H, 2·6; Hg, 46·9; N, 3·3. $C_{20}H_{22}Hg_2N_2O_9S$ requires C, 27·7; H, 2·5; Hg, 46·2; N, 3·2%).

Reaction of the Salt (18) *with Acetic Acid*.—The salt (18) (1·0 g, 1·16 mmol) was heated in acetic acid, as described for the derivative (16). Work-up yielded a syrup (0·265 g), which was fractionated by silica gel chromatography (benzene–ether as eluant) to give the acetate (7) [3] (0·098 g, 25%), $[\alpha]_D$ −12° (1·4% in $CHCl_3$).

Reaction of the Salt (18) *with Dimethyl Sulphoxide*.—The freshly prepared salt (18) (6·83 g, 7·9 mmol) was treated with dimethyl sulphoxide, as described for the derivative (16). Work-up afforded a syrup (2·00 g), which was fractionated by silica gel chromatography (benzene–ether as eluant) to give (1R,5S)-7-(2-*methylprop*-1-*enyl*)-3-*phenoxymethyl*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-6-*one* (12) (0·60 g, 28%), m.p. 86—88° (from ether–light petroleum), $[\alpha]_D$ −61° (0·56% in $CHCl_3$), $\nu_{max.}$ (KBr) 1755 (β-lactam C=O) and 1645 cm^{-1} (C=N), τ ($CDCl_3$) 8·32 and 8·30 (each 3H, s, *gem*-Me_2), 5·18 (2H, s, CH_2·CO), 4·77 (1H, d, *J* 4 Hz, 5-H), 4·17 (1H, s, vinylic proton), 4·02 (1H, d, *J* 4 Hz, 1-H), and 3·15—2·65 (5H, m, aromatic protons) [Found: C, 65·9; H, 6·0; N, 10·2%; *M* (mass spectrum), 272. $C_{15}H_{16}N_2O_3$ requires C, 66·2; H, 5·9; N, 10·3%; *M* 272].

Reaction of the Salt (18) *with Diazomethane*.—The salt (18) (3·0 g, 3·5 mmol) was treated with diazomethane, as described for the derivative (16). Work-up gave a syrup (1·53 g), which was fractionated by silica gel chromatography (benzene–ether as eluant). The first-eluted material (0·13 g) was identified as a mixture (*ca.* 1 : 1) of the methylpropenyl derivative (12) and the unsaturated ester (13) on the basis of n.m.r. spectroscopy: τ ($CDCl_3$) [for (13)] 8·24 and 7·82 (each 3H, s, *gem*-Me_2), 6·28 (3H, s, MeO), 5·24 (2H, s, CH_2·O), 4·80 (1H, d, *J* 4 Hz, 5-H), 3·95 (1H, d, *J* 4 Hz, 1-H), and 3·24—2·58 (5H, m, aromatic protons). The second-eluted substance (0·195 g, 8%) was predominantly *methyl* (2S)-3-*acetoxymethylmercurio*(II)*thio*-2-{(1R,5S)-3-*benzyl*-6-*oxo*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*methylbutanoate* (19), $[\alpha]_D$ +12° (0·9% in $CHCl_3$), $\nu_{max.}$ (film) 1775 (β-lactam C=O), 1730 (ester C=O), and 1655 cm^{-1} (C=N), τ ($CDCl_3$) 8·48 and 8·35 (each 3H, s, *gem*-Me_2), 7·92 (3H, s, MeCO), 6·20 (3H, s, MeO), 5·67 (2H, s, CH_2·Hg), 5·50 (1H, s, 2-H), 5·15 (2H, s, CH_2·CO), 4·72 (1H, d, *J* 4 Hz, 5-H), 3·56 (1H, d, *J* 4 Hz, 1-H), and 3·14—2·45 (5H, m, aromatic protons) [Found: *M* (mass spectrum), 638·1046. $C_{20}H_{24}HgN_2O_7S$ requires 638·1010]. Mass spectroscopy indicated that the sample also contained bis[acetoxymethylmercury(II)] sulphide (23) [Found: *M* (mass spectrum), 581·9726. $C_6H_{10}Hg_2O_4S$ requires 581·9712]. The third-eluted material (0·41 g, 32%), was *methyl* (2S)-2-{(1R,5S)-6-*oxo*-3-*phenoxymethyl*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*mercapto*-3-*methylbutanoate* (17), $[\alpha]_D$ +5° (0·6% in $CHCl_3$), $\nu_{max.}$ (film) 1775 (β-lactam C=O), 1735 (ester C=O), and 1660 cm^{-1} (C=N), τ ($CDCl_3$) 8·55 and 8·38 (each 3H, s, *gem*-Me_2), 6·30 (3H, s, MeO), 5·33 (1H, s, 2-H), 5·25 (2H, s, CH_2·CO), 4·83 (1H, d, *J* 4 Hz, 5-H), 3·70 (1H, d, *J* 4 Hz, 1-H), and 3·30—2·60 (5H, m, aromatic protons) [Found: *M* (mass spectrum), 364·1061. $C_{17}H_{26}N_2O_5S$ requires 364·1093].

Reaction of the Salt (18) *with Pyridine*.—The salt (18) (5·0 g, 5·8 mmol) was treated with pyridine, as described for the derivative (16), to give *mercury*(II) (2S)-2-{(1R,5S)-6-*oxo*-3-*phenoxymethyl*-2-*oxa*-4,7-*diazabicyclo*[3.2.0]*hept*-3-*en*-7-*yl*}-3-*methyl*-3-*sulphidobutanoate* (22) (3·1 g, 98%), $\nu_{max.}$ 1775 (β-lactam C=O), 1660 (C=N), and 1600 cm^{-1} (CO_2^-) (Found: C, 37·0; H, 3·2; Hg, 35·1; N, 5·9. $C_{16}H_{16}N_2O_5S$,0·33-C_5H_5N requires C, 36·9; H, 3·1; Hg, 34·8; N, 5·7%). The presence of pyridine in the sample was indicated by mass spectroscopy.

Reaction of the Salt (22) *with Mercury*(II) *Acetate*.—The salt (22) (1·0 g, 1·16 mmol) was treated with mercury(II) acetate, as described for the derivative (21), to give a material (1·16 g, 73%) which was identical by i.r. spectroscopy with the salt (18).

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