Enantiospecific Synthesis of 4-Alkoxyazetidin-2-ones

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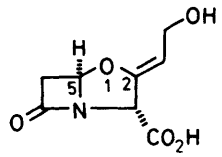
4-Alkoxyazetidin-2-ones were obtained by thermolysis of *N*-unsubstituted 4-alkylsulphinyl- and 4-benzothiazolylthio-azetidin-2-ones in the presence of a primary, secondary, or tertiary alcohol. The configuration of the incoming alkoxy group is controlled by the stereochemistry of the substituent at position-3 and a *trans* relationship between the two groups results. Thus, the thermally induced substitution at position-4 of (3*R*,4*R*,5*S*)-4-(2-methoxycarbonylethyl)sulphinyl-3-phthalimidoazetidin-2-one (6) and (3*R*,4*S*)-4-benzothiazol-2-ylthio-3-phthalimidoazetidin-2-one (7) by ethanol and pentan-3-ol afforded stereospecifically the corresponding (3*S*,4*S*)-4-alkoxy-3-phthalimidoazetidin-2-ones (14) and (15). Similarly (3*S*,4*R*)-3-chloro-4-methylsulphinylazetidin-2-one (17) was substituted by 2-methylbut-3-yn-2-ol to give (3*R*,4*R*)-3-chloro-4-(2-methylbut-3-yn-2-yloxy)azetidin-2-one (21) and by pentan-3-ol to give mainly (3*R*,4*R*)-3-chloro-4-(1-ethylpropoxy)azetidin-2-one (22). Nitrogen protection followed by chlorine reduction of (22) afforded the enantiomerically pure (4*R*)-(1-ethylpropoxy)azetidin-2-one (27).

The recent introduction of clavulanic acid (1) [1] and of the 1-oxacephem derivative (2) [2] into the medical practice suggests that compounds deriving from the general structure (3) may function as useful complementary agents to the classical penicillins and cephalosporins for the treatment of bacterial infections. Their synthesis is therefore of considerable interest and has been comprehensively reviewed.[2-4] In recent communications we have reported a new method for the synthesis of some racemic compounds of type (3).[5] This synthesis is based on the free-radical annelation of non-fused β-lactams (4), readily obtained from racemic β-lactams (5), in which R represents an alkenyl or alkynyl group. Extension of this method for the synthesis of compounds of potentially useful biological activity requires, *inter alia* the use of β-lactams (5)



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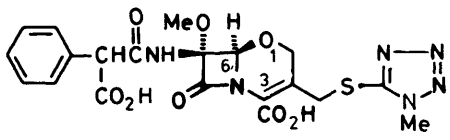

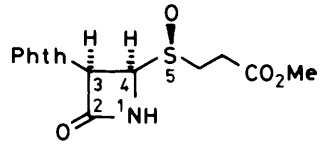
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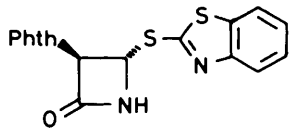
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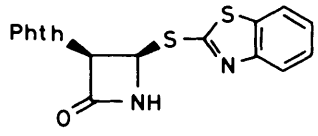
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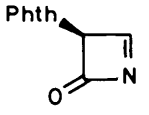
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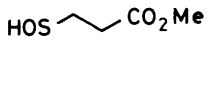
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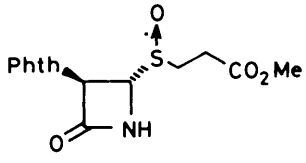
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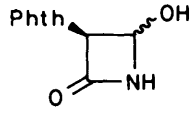
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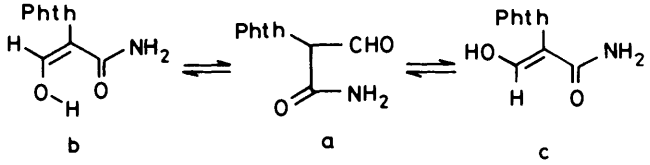
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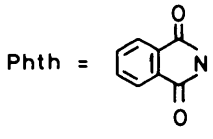
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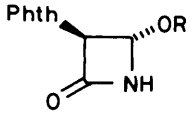
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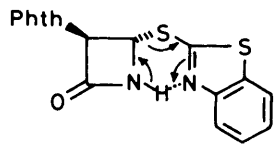
(15) R = $CHEt_2$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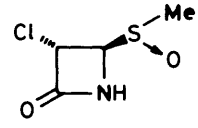
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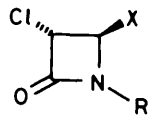
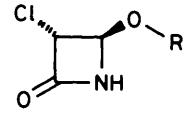
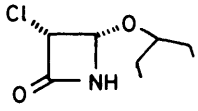

(18) X = SMe, R = $Me_2C{=}C(I)CO_2Me$
(19) X = S(O)Me, R = $Me_2C{=}C(I)CO_2Me$
(20) X = S(O)Me, R = $COCO_2Me$


(21) R = $Me_2C(I)-C{\equiv}CH$
(22) R = $CHEt_2$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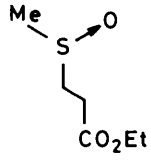
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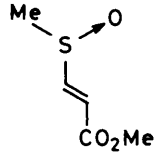
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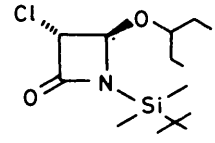
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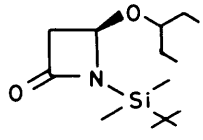
(27)

necessary to prepare a modified precursor bearing a steric control element in the opposite configuration to that occupied by the phthalimido group in the β-lactams (6) and (7) and which is can be readily removed or exchanged. (3*S*,4*R*)-3-Chloro-4-methylsulphinylazetidin-2-one (17) was found to fulfil these requirements. It can be readily obtained from the optically active methylthioazetidinone (18), which is prepared by the method of Thomas [13] from 6-aminopenicillanic acid. Thus, oxidation of the sulphide (18) with sodium metaperiodate in methanol-water afforded in a 1 : 1 ratio the two epimeric sulphoxides (19). The β-lactam nitrogen atom was unmasked to give the key compound (17) by a known procedure [14] involving ozonolysis of the double bond in methylene dichloride at −78 °C followed by methanolysis at −10 °C of the resulting methoxalyl derivative (20).

Heating the azetidinone sulphoxide (17) (two epimers) with an excess of 2-methylbut-3-yn-2-ol at 90 °C for 20 h afforded the (3*R*,4*R*)-3-chloro-4-alkoxyazetidin-2-one (21) (68%), $[\alpha]_D^{26}$ +31°. A similar alkoxylation of the azetidinones (17) with pentan-3-ol (100 °C; 9 h) gave (3*R*,4*R*)-3-chloro-4-(1-ethylpropoxy)azetidin-2-one (22) (59%), $[\alpha]_D^{20}$ +54°. Since the pyrolysis of the β-lactam sulphoxides (17) to (3*R*)-chloroazetin-2-one and methanesulphenic acid is a reversible process, the yield of the 4-(1-ethylpropoxy)azetidinone (22) was increased, and the reaction time decreased by adding a trapping agent for sulphenic acids. Thus, heating the β-lactam sulphoxides (17) with pentan-3-ol in ethyl acrylate (95 °C; 4 h) yielded the 4-(1-ethylpropoxy)azetidinone (22) (70%) and the sulphoxide (24) (79%), while heating them with pentan-3-ol (excess) and methyl propiolate (5 equiv.) in benzene (80 °C; 7 h) resulted in the formation of the (3*R*,4*R*)-3-chloro-4-(1-ethylpropoxy)azetidin-2-one (22) (86%) along with its epimer (3*R*,4*S*)-3-chloro-4-(1-ethylpropoxy)azetidin-2-one (23) (7%), $[\alpha]_D^{20}$ +16° and the adduct (25) (85%) of methanesulphenic acid and methyl propiolate.

The chlorine atom, which functioned as a steric control element, was removed from the 3-chloroazetidinone (22) by reduction with tri-n-butylstannane. For this purpose the β-

lactam nitrogen atom was first protected with a dimethyl-t-butylsilyl group by treatment with dimethyl-t-butylsilyl chloride and di-isopropylethylamine in *N,N*-dimethylformamide (DMF). Heating the protected β-lactam (26) with tri-n-butylstannane and a catalytic amount of azobis-isobutyronitrile in toluene afforded the enantiomerically pure (4*R*)-(1-ethylpropoxy)azetidin-2-one (27) (80%), $[\alpha]_D^{20}$ −125°.

Experimental

M.p.s were measured using a Büchi apparatus and are uncorrected. I.r. spectra were recorded with a Perkin-Elmer 237 spectrophotometer. ^{1}H N.m.r. data were determined at 80 MHz on a Varian FT-80A, at 90 MHz on a Bruker FT-HFX-10, and at 270 MHz on a Bruker WH-270 instrument. Low and high resolution mass spectra were recorded on a Varian MAT-731 (Double Focusing) spectrometer. Optical rotations were measured with a Perkin-Elmer 141 polarimeter. Unless otherwise stated, reactions were performed in dry solvents under argon. Column chromatography was carried out using Merck Silica Gel 60, 70–230 mesh. Preparative thin-layer chromatography was carried out on Merck Silica Gel Plates, 60, F254.

Isomerization of (3R,4R,5S)-4-[(2-*Methoxycarbonylethyl*)-*sulphinyl*]-3-*phthalimidoazetidin*-2-*one* (6).—A suspension of the *cis*-β-lactam (6) [7] (100 mg) in benzene (10 ml) was heated at 65 °C for 3 h. Upon cooling and concentration of the reaction mixture, the trans-β-*lactam* (11) crystallized out (100 mg, quantitative), m.p. 143—145 °C (decomp.), $\nu_{max.}$ ($CHCl_3$) 3 410, 1 800, 1775, 1 730, and 1 725 cm^{-1}; δ (90 MHz; $CDCl_3$) 3.0—2.8 [m, $S(O)CH_2CH_2CO_2$], 3.67 (s, OMe), 4.96 (d, *J* 2.5 Hz, azetidine H), 5.52 (d, *J* 2.5 Hz, azetidine H), 7.53br (s, NH), and 7.83 (m, ArH) (Found: C, 51.4; H, 4.1; N, 7.75. $C_{15}H_{14}N_2O_6S$ requires C, 51.43; H, 4.03; N, 8.00%).

Pyrolysis of the β-*Lactam Sulphoxide* (6) *in the Presence of Water*.—A solution of the β-lactam sulphoxide (6) [7] (100 mg) in tetrahydrofuran, (THF) (10 ml) with water (2 drops) was heated under reflux for 24 h. The solvent was evaporated to give an oily residue. Trituration with benzene and filtration gave *formyl*(*phthalimido*)*acetamide* (13) (40 mg, 60%) as a colourless solid; positive test with $FeCl_3$; $\nu_{max.}$ (Nujol) 3 430, 1 780, 1 710, and 1 640 cm^{-1}; δ (90 MHz; [$^2H_8$]dioxan) 6.6br (NH_2), 7.15 and 7.28 [both s, C=C*H*OH, enolamide forms (13b) and (13c), ratio 1 : 2], 7.86 (m, ArH), and 9.80 [s, CHO; aldehyde amide form (13a), *ca.* 10% of the enol amide forms]; δ[90 MHz; $(CD_3)_2SO$–D_2O] 7.48 and 7.81 [both s, C=C*H*OH, enol amide forms (13b) and (13c), ratio 1 : 6], and 7.90 (s, ArH) (Found: M^+ 232.0469. $C_{11}H_8N_2O_4$ requires M^+ 232.0484); *m/e* 215 ($M^+ - NH_3$), 214 ($M^+ - H_2O$), 204 ($M^+ - CO$), 189 ($M^+ - NH_2CO$), 187 (PhthCH=C=O$^+$), and 44 ($CONH_2^+$) (Found: C, 56.95; H, 3.4; N, 11.75. $C_{11}H_8N_2O_4$ requires C, 56.90; H, 3.45; N, 12.07%).

(3S,4S)-4-*Ethoxy*-3-*phthalimidoazetidin*-2-*one* (14).—(*a*) *From the sulphoxide* (6). A solution of the β-lactam sulphoxide (6) (250 mg) in chloroform (6 ml) and ethanol (2 ml) was heated at 65 °C for 18 h. The solvent was evaporated and the residue chromatographed on silica gel (toluene–ethyl acetate 3 : 1) to give the *ethoxyazetidinone* (14) (156 mg, 84%), m.p. 174—175 °C (from toluene); $[\alpha]_D^{26}$ −57° (*c* 0.9, $CHCl_3$); $\nu_{max.}$ ($CHCl_3$) 1 795, 1 775, and 1 725 cm^{-1}; δ (90 MHz; $CDCl_3$) 1.26 (t, *J* 7 Hz, OCH_2CH_3), 3.62 (q, *J* 7 Hz, OCH_2CH_3), 5.22 (d, *J* 1.5 Hz, azetidine H), 5.41 (d, *J* 1.5 Hz, azetidine H), 6.87br (s, NH), and 7.80 (m, ArH) (Found: M^+, 260.0774. $C_{13}H_{12}N_2O_4$ requires M^+, 260.0796); *m/e* 217 (M^+ − NHCO), 214 (M^+ − EtOH), and 187 (PhthCH=C=O$^+$) (Found: C, 59.9; H, 4.6; N, 10.6. $C_{13}H_{12}N_2O_4$ requires C, 59.99; H, 4.65; N, 10.77%).

(*b*) *From the sulphide* (7). A solution of the *trans*-azetidinone (7) [7] (50 mg) in chloroform (5 ml) containing ethanol, was heated at 60 °C for 3 days. The solvent was evaporated and the residue chromatographed on a preparative silica-gel plate (toluene–ethyl acetate) to give the 4-*ethoxyazetidin*-2-*one* (14) (30 mg, 88%); physical data identical with those described for the product in (*a*).

(3S,4S)-4-(1-*Ethylpropoxy*)-3-*phthalimidoazetidin*-2-*one* (15).—A suspension of the *trans*-azetidinone (7) [7] (100 mg) in pentan-3-ol (3 ml) was heated at 90 °C. After 7 h the solution became clear and the alcohol was evaporated off. The residue was chromatographed on preparative silica-gel plate (hexane–ethyl acetate 1 : 1) to give the *azetidin*-2-*one* (15) (60 mg, 76%) as a colourless foam; $[\alpha]_D^{20}$ −42° (*c* 1.0, CH_2Cl_2); $\nu_{max.}$ ($CHCl_3$) 3 420, 1 790br, and 1 725 cm^{-1}; δ (80 MHz; $CDCl_3$) 0.89 (t) and 0.91 (t) [*J* 6.5 Hz, $OCH(CH_2CH_3)_2$], 1.35—1.7 [m, $OCH(CH_2CH_3)_2$], 3.36 (quintet, *J* 5.8 Hz, $OCHEt_2$), 5.21 (d, *J* 1.5 Hz, azetidine H), 5.47 (d, *J* 1.5 Hz, azetidine H), 6.7br (NH), and 7.82 (m, ArH) (Found: M^+ 302.1244. $C_{16}H_{18}N_2O_4$ requires M^+ 302.1246); *m/e* 259 (M^+ − NH=C=O), 232 ($M^+ - C_5H_{10}$), 214 [$M^+ - (CH_3CH_2)_2CHOH$], and 187 (Phth−CH=C=O$^+$).

(3S,4R)-3-*Chloro*-1-(1-*methoxycarbonyl*-2-*methylprop*-1-*enyl*)-4-*methylsulphinylazetidin*-2-*one* (19).—To a solution of the sulphide (18) [13] (4.7 g) in methanol (80 ml) and water (60 ml), sodium metaperiodate (3.8 g, 17.8 mmol) was added in one portion. After the reaction mixture had been stirred at room temperature for 7 h, the iodate was filtered off and washed with chloroform. The aqueous phase was extracted with chloroform and the combined organic extracts were washed with water and brine. The oily residue, obtained after drying and evaporation of the solvent, contained almost pure sulphoxide (19) as a mixture of two isomers (ratio 1 : 1; 4.7 g, 94%). The two isomers were separated by chromatography on a silica-gel column (ethyl acetate) to give: (a) the less polar isomer of the sulphoxide (19), $\nu_{max.}$ ($CHCl_3$) 1 790, 17 25, and 1 030 cm^{-1}; δ (80 MHz; $CDCl_3$) 2.04 (s, C=CMe), 2.29 (s, C=CMe), 2.64 [s, S(O)Me], 3.80 (s, OMe), 4.89 (d, *J* 1.9 Hz, azetidine H), and 5.40 (d, *J* 1.9 Hz, azetidine H) (Found: M^+ 216.0412. $C_9H_{11}NO_3{}^{35}Cl$ requires M^+ 216.0428); *m/e* 216 and 218 ($M^+ - CH_3SO$), 188 and 190 ($M^+ - CH_3SO - CO$); (b) the more polar isomer of the sulphoxide (19), $\nu_{max.}$ ($CHCl_3$) 1 790, 1 725, and 1 060 cm^{-1}; δ (80 MHz; $CDCl_3$) 2.16 (s, C=CMe), 2.28 (s, C=CMe), 2.58 [s, S(O)Me], 3.83 (s, OMe), 4.90 and 4.93 (ABq, *J* 2.1 Hz, two azetidine H) (Found: M^+ 216.0415. $C_9H_{11}NO_3{}^{35}Cl$ requires M^+ 216.0428); *m/e* 216 and 218 ($M^+ - CH_3SO$), 188 and 190 ($M^+ - CH_3SO - CO$).

(3S,4R)-3-*Chloro*-4-*methylsulphinylazetidin*-2-*one* (17).—A stream of ozone was passed through a solution of the sulphoxide (19) (400 mg, mixture of the two isomers) in CH_2Cl_2 (50 ml) at −78 °C. Excess of ozone was removed by a stream of nitrogen, and the reaction mixture was washed with cold 3% aqueous $NaHSO_3$ and brine. The aqueous washings were re-extracted with a small amount of CH_2Cl_2. The combined organic extracts were dried and evaporated to afford the *N*-methoxalylazetidinone (20) (oil; mixture of two isomers); δ (80 MHz; $CDCl_3$) 2.72 (s) and 2.86 (s) (CH_3SO of the two isomers), 3.98 (s, OMe), 5.03 and 5.61 (ABq, *J* 3.0 Hz, two azetidine H of one isomer), and 5.11 and 5.21 (ABq, *J* 3 Hz, two azetidine H of the second isomer). The crude *N*-methoxalylazetidinone (20) was immediately dissolved in ethyl acetate (30 ml) and methanol (20 ml) and left at −10 °C for

16 h. The solvent was then evaporated and the oily residue was triturated with benzene. The crystalline material thus obtained was filtered and washed with small portions of benzene and CH_2Cl_2, to yield the *azetidinone* (17) [84 mg, 35% based on (19)], m.p. 141—142 °C (decomp.); $\nu_{max.}$ (KBr) 3 100br, 1 785, and 1 010 cm^{-1}; δ[80 MHz; $(CD_3)_2SO$] 2.61 (s, MeSO), 4.84 (d, *J* 1.6 Hz, 4-H), 5.35br (s, 3-H), and 9.37br (NH). Upon addition of D_2O, the signal at 9.37 disappeared and the broad singlet at 5.35 changed into a doublet, *J* 1.6 Hz, *m/e* 104 and 106 ($M^+ - CH_3SOH$), 76 and 78 ($ClCH{=}C{=}O^+$), and 64 (CH_3SOH^+) (Found: C, 28.75; H, 3.8; Cl, 21.25; N, 8.1. $C_4H_6ClNO_2S$ requires C, 28.66; H, 3.61; Cl, 21.15; N, 8.36%).

(3R,4R)-3-*Chloro*-4-(1-*ethylpropoxy*)*azetidin*-2-*one* (22).—(*a*) A solution of the β-lactam sulphoxide (17) (150 mg) in pentan-3-ol (4 ml) was heated at 100 °C for 9 h. After evaporation excess of alcohol, the reaction mixture was chromatographed on silica gel (hexane–ethyl acetate 3 : 1) to give the *azetidinone* (22) (100 mg, 59%), a colourless oil; $[\alpha]_D^{20}$ + 54° (*c* 1.4, CH_2Cl_2); $\nu_{max.}$ ($CHCl_3$) 3 410 and 1 790 cm^{-1}; δ (270 MHz; $CDCl_3$) 0.92 (t) and 0.93 (t) [*J* 7.3 Hz, $CH(CH_2CH_3)_2$], 1.55 [m, $CH(CH_2CH_3)_2$], 3.41 (quintet, *J* 5.9 Hz, $OCHEt_2$), 4.51 (dd, *J* 1.0 and 0.8 Hz, 3-H), 5.00 (d, *J* 0.8 Hz, 4-H), and 6.99br (NH); *m/e* 191vw (M^+), 148 and 150 ($M^+ - NHCO$), 121 and 123 ($M^+ - C_5H_{10}$), 104 and 106 ($M^+ - C_5H_{11}O$).

(*b*) A solution of the β-lactam sulphoxide (17) (100 mg) in ethyl acrylate (3 ml) and pentan-3-ol (0.5 ml), was heated at 95 °C for 4 h. Chromatography of the residue, obtained after evaporation of the solvent, afforded the *azetidinone* (22) (80 mg, 70%), physical data as in (*a*) and the sulphoxide (24) [15] (70 mg, 79%); δ (80 MHz; $CDCl_3$) 1.27 (t, *J* 7 Hz, $CO_2CH_2CH_3$), 2.61 (s, CH_3SO), 2.7—3.0 (m, $CH_2CH_2CO_2$), and 4.18 (q, *J* 7 Hz, $CO_2CH_2CH_3$).

(*c*) To a suspension of the β-lactam sulphoxide (17) (200 mg) in benzene (8 ml), methyl propiolate (500 mg) and pentan-3-ol (1 ml) were added. The reaction mixture was refluxed for 7 h. The solvent and excess of reagents were evaporated and the residue chromatographed on silica gel (hexane–ethyl acetate) to give: (i) the trans-*azetidinone* (22) (190 mg, 84%); physical data as in (*a*). (ii) The cis-*azetidinone* (23) (17 mg, 7.4%), m.p. 80—81 °C; $[\alpha]_D^{20}$ +16° (*c* 0.9, CH_2Cl_2); $\nu_{max.}$ ($CHCl_3$) 3 410 and 1 790 cm^{-1}; δ (80 MHz; $CDCl_3$) 0.93 (t) and 0.94 (t) [*J* 7 Hz, $CH(CH_2CH_3)_2$], 1.59 [m, $CH(CH_2CH_3)_2$], 3.43 (quintet, *J* 5.8 Hz, $OCHEt_2$), 4.91 (dd *J* 3.7 and 2.8 Hz, 3-H), 5.25 (d, *J* 2.8 Hz, 4-H), and 7.0br (NH) [Found: ($M^+ - NHCO$) 148.0645. $C_7H_{13}O^{35}Cl$ requires ($M^+ - NHCO$) 148.0655]; *m/e* 148 and 150 ($M^+ - NHCO$), 121 and 123 ($M^+ - C_5H_{10}$), 104 and 106 ($M^+ - C_5H_{11}O$). (iii) The most polar component was identified as the sulphoxide (25) (150 mg, 85%) by comparison of its n.m.r. and i.r. spectra with those reported in the literature.[15]

(3R,4R)-3-*Chloro*-4-(2-*methylbut*-3-*yn*-2-*yloxy*)*azetidin*-2-*one* (21).—A suspension of the sulphoxide (17) (250 mg) in 2-methylbut-3-yn-2-ol (3 ml) was heated at 90 °C for 20 h. Excess of alcohol was evaporated and the residue chromatographed on silica gel (hexane–ethyl acetate) to afford the title compound (21) (190 mg, 68%), m.p. 63—64 °C; $[\alpha]_D^{26}$ +31° (*c* 0.5, $CHCl_3$); $\nu_{max.}$ ($CHCl_3$) 3 420, 3 310, and 1 795 cm^{-1}; δ (80 MHz; $CDCl_3$) 1.54 (s, $OCMe_2$), 2.60 (s, HC≡C), 4.53 (dd, *J* 1.5 and 0.8 Hz, 3-H), 5.34 (d, *J* 0.8 Hz, 4-H), and 7.0br (NH) (Found: M^+ 187.0450. $C_8H_{10}NO_2{}^{35}Cl$ requires M^+ 187.0401). *m/e* 187 (M^+), 121 and 123 ($M^+ - C_5H_6$), 104 and 106 ($M^+ - C_5H_7O$), 76 and 78 ($ClCH{=}C{=}O^+$).

(3R,4R)-3-*Chloro*-4-(1-*ethylpropoxy*)-1-(*t-butyldimethylsilyl*)-*azetidin*-2-*one* (26).—To an ice-cold solution of the *N*-unsubstituted azetidinone (22) (190 mg) in DMF (4 ml), t-butyldimethylsilyl chloride (162 mg) and di-isopropylethylamine (0.1 ml) were added. After the reaction mixture had been stirred at 0 °C for 45 min, it was poured into a solution of benzene–ethyl acetate (1 : 1; 10 ml), washed with water and brine, dried and evaporated. Chromatography of the residue over silica gel (hexane–ethyl acetate 5 : 1) afforded the title compound (26) (260 mg, 87%); $\nu_{max.}$ (film) 1 775 cm^{-1}; δ (80 MHz; $CDCl_3$) 0.24 (s) and 0.29 (s) ($SiMe_2$), 0.90 [m, $CH(CH_2CH_3)_2$], 0.97 (s, CMe_3), 1.4—1.75 [m, $CH(CH_2CH_3)_2$], 3.42 (quintet, *J* 5.6 Hz, $OCHEt_2$), 4.40 (d, *J* 0.9 Hz, azetidine H), and 4.78 (d, *J* 0.9 Hz, azetidine H).

(4R)-4-(1-*Ethylpropoxy*)-1-(*t-butyldimethylsilyl*)*azetidin*-2-*one* (27).—To a stirred solution of the chloro β-lactam (26) (120 mg) in toluene (6 ml), tri-n-butylstannane [16] (174 mg) and azobisisobutyronitrile (6 mg, 0.04 mmol) were added. The solution was heated to 90 °C for 1 h. The solvent was evaporated off and the residue was chromatographed twice on silica gel (hexane–ethyl acetate) to afford the *azetidinone* (27) (85 mg, 80%) as an oil; $[\alpha]_D^{20}$ −125° (*c* 1.2, CH_2Cl_2); $\nu_{max.}$ (film) 1 760 cm^{-1}; δ (80 MHz; $CDCl_3$) 0.22 (s) and 0.25 (s) ($SiMe_2$), 0.88 (t) and 0.90 (t) [*J* 7.7 Hz, $CH(CH_2CH_3)_2$], 0.96 (s, CMe_3), 1.3—1.7 [m, $CH(CH_2CH_3)_2$], 2.78 (dd, AX part of ABX system, J_{AB} 15, J_{AX} 1.5 Hz; azetidine 3α-H), 3.09 (dd, BX part of ABX system, J_{AB} 15, J_{BX} 3.4 Hz; azetidine 3β-H), 3.26 (quintet, *J* 5.6 Hz, $OCHEt_2$), and 4.22 (dd, *J* 3.4 and 1.5 Hz, azetidine 4-H) [Found: (M^+ − Bu) 214.1283. $C_{10}H_{20}NO_2{}^{28}Si$ requires 214.1263 (M^+ − Bu)]; *m/e* 200 ($M^+ - C_5H_{11}$) and 184 ($M^+ - C_5H_{11}O$); the low resolution mass spectrum shows a weak peak, 271 (M^+).

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