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Approaches to the Synthesis of Lincosamine, a Derived Portion of the Antibiotic Lincomycin

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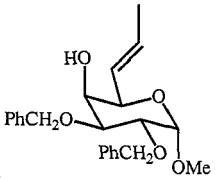
Abstract

A variety of approaches towards the synthesis of lincosamine, a derived portion of the antibiotic lincomycin, are reported. Initial approaches involved the intramolecular delivery of a nitrogen atom (trichloroacetimidate, trichloroacetylcarbamate, carbamate, 2-amino-2-phenylacetate) attached to O4 onto C6 of a 6,7-anhydrooctoside. Later approaches, albeit more direct but again largely unsuccessful, involved the Sharpless titanium(IV)-mediated nucleophilic opening of a suitable 6,7-anhydrooctose, and the Sharpless oxyamination and the aziridination of suitable octenoses.

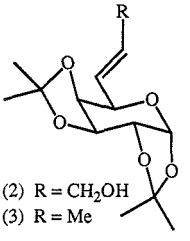
As an aid to the structure elucidation of several compounds encountered in this work, single-crystal X-ray structure determinations are reported for methyl 6,7-anhydro-2,3-di-*O*-benzyl-8-deoxy-α-D-*threo*-D-*galacto*-octopyranoside, methyl 6,7-anhydro-2,3-di-*O*-benzyl-8-deoxy-α-D-*threo*-D-*gluco*-octopyranoside and 7-azido-7-deoxy-1,2:3,4-di-*O*-isopropylidene-β-L-*erythro*-D-*galacto*-octose.

In the preceding paper we outlined the syntheses of various octenoses (1)–(4) as potential substrates for the synthesis of lincosamine (5), a derived portion of the antibiotic lincomycin.[1] This paper describes firstly our attempts to convert the alcohol (1), via an intermediate such as (6), into lincosamine (5), and concludes with approaches from the alkenes (2)–(4) to the same target molecule.

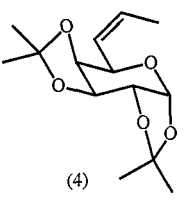
For the synthesis of an intermediate such as (6) we needed to prepare initially the epoxide (7), and two routes were available. Epoxidation of the alkene (8) followed by removal of the protecting group at O4 could formally lead to



(1)



(2) R = CH_2OH
(3) R = Me



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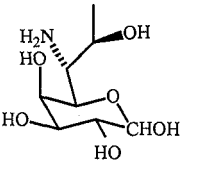

(5)

[1] Stick, R. V., and Tilbrook, D. M. G., *Aust. J. Chem.*, 1990, **43**, 1643.

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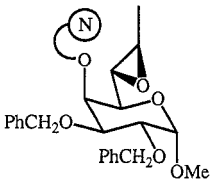
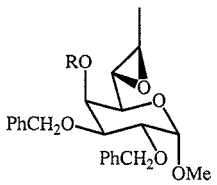
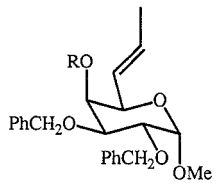
(7), whereas epoxidation of the alkene (1), taking advantage of the possible directing effect of the hydroxy group at C4,[2] could lead directly to the same epoxide (7). Thus, treatment of the alkene (8) with *m*-chloroperbenzoic acid gave a mixture of two epoxides which were separable by flash chromatography. The major product, formed in 57% yield, was the unwanted *β*-L-*threo* epoxide (9); the required *α*-D-*threo* epoxide (10) was obtained in only 17% yield. The assignment of structure to (9) and (10) was based on ^{13}C n.m.r. spectroscopy and comparison with related epoxides (see below): for (9), C6 resonated at *δ* 54·39 and C7 at 57·28, whereas the corresponding resonances in (10) were at 51·18 and 58·70.[3] The same oxidation (*m*-chloroperbenzoic acid) of the alkene (1) yielded an inseparable mixture of the two possible epoxides (11) and (7), in 58% yield and a ratio of 7 : 3. The ^{13}C n.m.r. spectrum was consistent with the structures for (11) (*δ* 54·0, C6; 57·2, C7) and (7) (*δ* 51·3, C6; 58·6, C7).



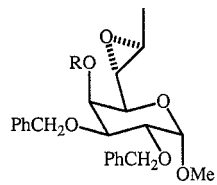
(6)



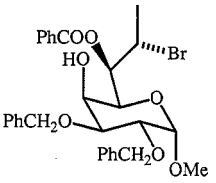
(7) R = H
(10) R = *p*-MeOC$_6$H$_4$CH$_2$



(8) R = *p*-MeOC$_6$H$_4$CH$_2$
(12) R = PhCO



(9) R = *p*-MeOC$_6$H$_4$CH$_2$
(11) R = H



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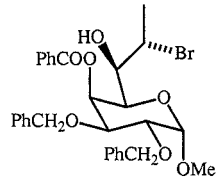

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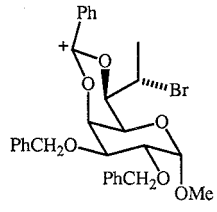

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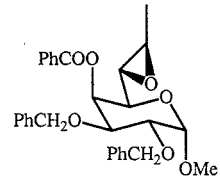


(16)

From the above two experiments it was apparent that a ready synthesis of (7) was not available by direct oxidation of an alkene. Therefore, in line with some of Danishefsky's work in his synthesis of lincosamine,[4] we converted the alcohol (1) into the benzoate (12). Treatment of (12) with *N*-bromosuccinimide in wet acetic acid gave a bromohydrin, but with the structure (13) rather than the expected (14). Apparently, and as observed and delineated by Danishefsky,[5] the benzoyl group at O4 of (12) participates in the delivery of Br^+ to the 6,7-alkene, forming the carbocation (15); hydrolysis then gives (13). Treatment of (13) with either sodium methoxide or potassium hydroxide then gave the desired epoxide (7) in moderate yield. Apparently, the oxide anion derived from deprotonation at O4 attacks the benzoyl group to generate the epoxy ester (16), and the benzoyl group is subsequently lost

[2] Chautemps, P., and Pierre, J.-L., *Tetrahedron*, 1976, **32**, 549.
[3] Schneider, H.-J., and Agrawal, P. K., *Mag. Reson. Chem.*, 1986, **24**, 718.
[4] Danishefsky, S. J., Larson, E., and Springer, J. P., *J. Am. Chem. Soc.*, 1985, **107**, 1274.
[5] Danishefsky, S., DeNinno, M. P., and Schulte, G., *J. Org. Chem.*, 1987, **52**, 3171.

under the reaction conditions to generate (7). The complete stereochemistry of (7) was obtained from a single-crystal X-ray structure determination (Fig. 1), and the ^{13}C n.m.r. spectrum showed C6 resonating at δ 51·19 and C7 at 58·49. This allows the structural assignment of the other epoxides (9)–(11) from the *m*-chloroperbenzoic acid oxidation of the alkenes (1) and (8).

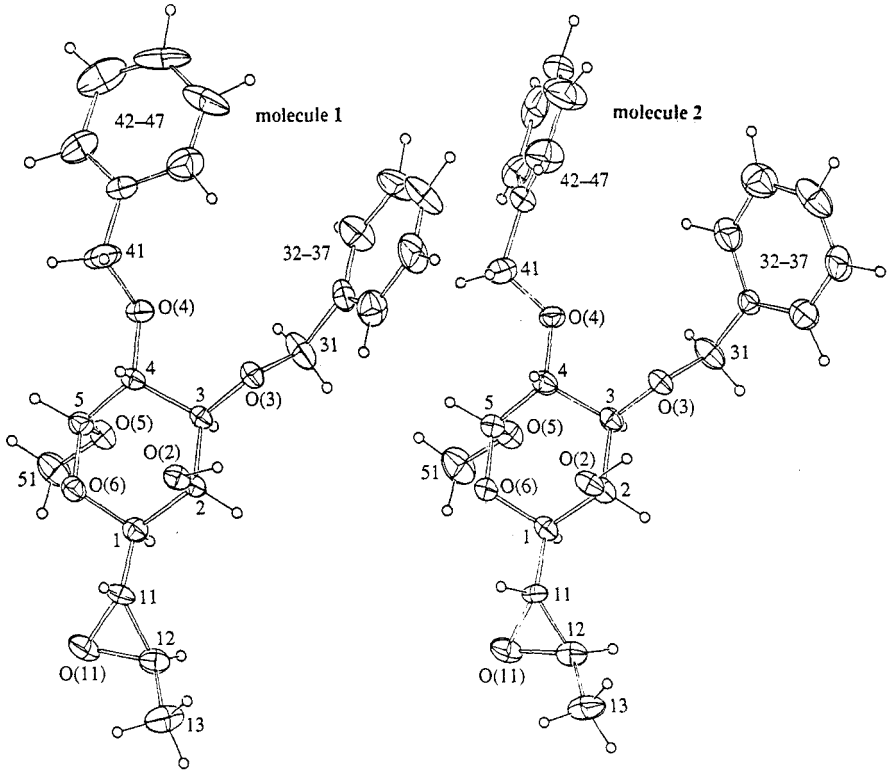
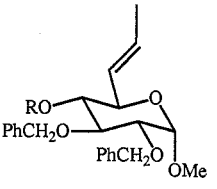


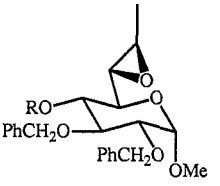
Fig. 1. The two molecules of (7).

With the alkenes (17) and (18) in hand from our previous synthetic work[1] it seemed, at this stage, worthwhile to mimic the above oxidations in the D-*gluco* series. Thus, treatment of the alkene (17) with *m*-chloroperbenzoic acid gave an almost quantitative yield of an inseparable mixture of the epoxides (19) and (20), in the ratio of 7 : 3. In the ^{13}C n.m.r. spectrum, (19) had C6 resonating at δ 52·0 and C7 58·6, while the minor isomer (20) had 51·2 and 59·1 for the same two carbons. Oxidation of the alkene (18) again gave a high yield of the two possible epoxides (21) and (22), in the ratio of 13 : 7 (^{13}C n.m.r.). This time, however, recrystallization of the mixture gave some of the major isomer (21) in pure form, and a single-crystal X-ray structure determination (Fig. 2) again established the stereochemistry of the molecule. In the ^{13}C n.m.r. spectrum the epoxide (21) (δ 51·76, C6; 58·47, C7) was clearly distinguishable from (22) (δ 51·83, C6; 59·11, C7), and these values for C7 were used in the assignment of epoxides (19) and (20) above. For the *N*-bromosuccinimide procedure to convert alkenes into epoxides, the alcohol (17) was converted into the benzoate (23). Treatment of (23), again with *N*-bromosuccinimide in

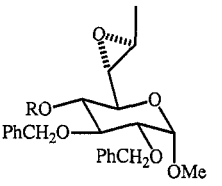
wet acetic acid, gave this time a *mixture* of bromohydrins which were not purified but converted directly into a mixture of epoxides, (21) and (22), in a ratio of 1 : 4 (37% yield).



(17) R = *p*-$MeOC_6H_4CH_2$
(18) R = H
(23) R = PhCO



(19) R = *p*-$MeOC_6H_4CH_2$
(21) R = H



(20) R = *p*-$MeOC_6H_4CH_2$
(22) R = H

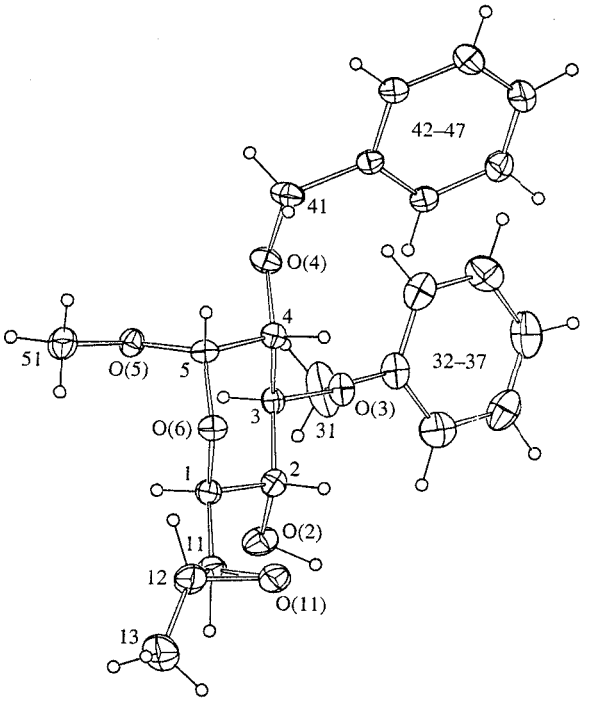


Fig. 2. The molecule of (21).

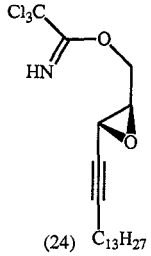
It seems worthwhile at this stage to make some comment about the product distribution of the epoxides from the D-*galacto versus* the D-*gluco* alkenes. In each case, the presence of a hydroxy group or a benzyl ether at C4 in the alkene made little difference to the ratio of the epoxides obtained, but the stereoselectivity for the D-*galacto* alkenes was opposite to that for the D-*gluco* alkenes, be it *m*-chloroperbenzoic acid- or *N*-bromosuccinimide-induced oxidations. Although it is possible to use rather sophisticated arguments[6,7] to

[6] Chamberlin, A. R., Mulholland, R. L., Jr, Kahn, S. D., and Hehre, W. J., *J. Am. Chem. Soc.*, 1987, **109**, 672.
[7] Kahn, S. D., Pau, C. F., Chamberlin, A. R., and Hehre, W. J., *J. Am. Chem. Soc.*, 1987, **109**, 650.

account for this difference in stereoselectivity, a rather simple, but perhaps naive, explanation is that the axial group at C4 in the D-*galacto* series blocks the top face (*re,re*) of the alkene, whereas the opposite holds true for the D-*gluco* alkenes. We make no effort to rationalize the *complete* stereoselectivity in the conversion of the D-*galacto* alkene (12) into the epoxide (7); the energy differences involved, when compared with a ratio of 7 : 3, are too small to allow precise interpretation.[8,9]†

With the alcohol (7) in hand it was now appropriate to investigate our intramolecular delivery of nitrogen from O4 onto C6 in a molecule such as (6). With the success of trichloroacetimidates for the delivery of a nitrogen atom onto an activated alkene,[10–12] and the limited extension of this work into epoxides, for example (24) → (25),[13] we chose first to prepare the trichloroacetimidate (26). Thus, treatment of the alcohol (7) with trichloroacetonitrile in the presence of potassium carbonate[14] gave none of the desired (26). In an effort to generate an anion at O4, the potassium carbonate was replaced by sodium hydride,[15] and the product of the reaction (an oil) appeared to be a mixture, showing absorptions in the infrared for possibly C=N (1655 cm^{-1}, trichloroacetimidate) and C=O [1760 cm^{-1}, trichloroacetate (27)].[16]

With the apparent instability of the imidate (26) we decided to try to form the derivative (28). Thus, treatment of the alcohol (7) with butyllithium presumably



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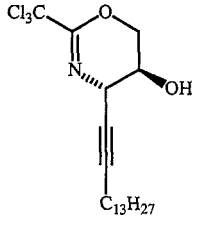

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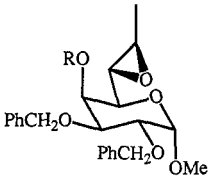
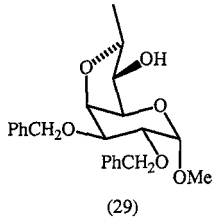


(26) R = $Cl_3CC{=}NH$
(27) R = Cl_3CCO
(28) R = $Cl_3CC{=}NSiMe_3$
(31) R = Me
(32) R = N≡C
(33) R = $Me_2NC{=}NH$
(36) R = $Cl_3CCONHCO$
(37) R = H_2NCO



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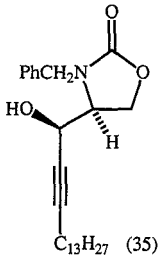
(34)



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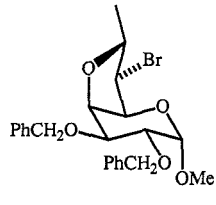


(30)

† We thank Dr Ray Carman for drawing our attention to this point, and the quoted references.

[8] Swain, C. G., *J. Org. Chem.*, 1984, **49**, 2005.
[9] Stirling, C. J. M., *Tetrahedron*, 1985, **41**, 1613.
[10] Bongini, A., Cardillo, G., Orena, M., Sandri, S., and Tomasini, C., *Tetrahedron*, 1983, **39**, 3801.
[11] Pauls, H. W., and Fraser-Reid, B., *J. Org. Chem.*, 1983, **48**, 1392.
[12] Giuliano, R. M., Deisenroth, T. W., and Frank, W. C., *J. Org. Chem.*, 1986, **51**, 2304.
[13] Bernet, B., and Vasella, A., *Tetrahedron Lett.*, 1983, **24**, 5491.
[14] Grundler, G., and Schmidt, R. R., *Liebigs Ann. Chem.*, 1984, 1826.
[15] Overman, L. E., *J. Am. Chem. Soc.*, 1976, **98**, 2901.
[16] Bellamy, L. J., 'The Infrared Spectra of Complex Molecules' (Chapman & Hall: London 1975).

gave the lithium alkoxide, and trichloroacetonitrile and chlorotrimethylsilane were added. Workup and chromatography gave only an isomer of (7), devoid of the epoxide moiety (^{1}H n.m.r.) and assigned the structure (29). Apparently the preformed lithium alkoxide was unreactive to trichloroacetonitrile and preferred to participate in an intramolecular opening of the epoxide ring, itself activated by the chlorotrimethylsilane. In a somewhat related process, the hydroxy alkene (1) was treated with *N*-bromosuccinimide in wet acetic acid to generate the bromide (30). The stereochemistry at C6 and C7 of (30) was assigned on the basis of our previous observations with the alkene (12), and decoupling experiments (^{1}H n.m.r.) located H7 (δ 4·27, dq, $J_{7,Me}$ 6·3, $J_{6,7}$ 9·6 Hz), H6 (δ 3·76, dd) and H4 (δ 4·29). As well, the carbon bearing the bromine atom resonated at δ 52·14 in the ^{13}C n.m.r. spectrum and, by using an XH correlation spectrum,[17] it was found that the bromine was attached to C6. For (29), the data (^{1}H n.m.r.) for H7 (δ 4·13, dq, $J_{7,Me}$ 6·7, $J_{6,7}$ 9·0 Hz) and H4 (δ 4·05) correlated nicely with those in (30). As well, the values for $J_{5,6}$ in (29) (0·0 Hz) and (30) (3·3 Hz) reflect the different configurations at C6 in both compounds. As expected on the basis of the above formation of (29), treatment of the epoxy alcohol (7) with chlorotrimethylsilane alone gave the rearranged alcohol (29).

To test the apparent lack of reactivity of the above lithium alkoxides, methyl iodide was added to a mixture of the alcohol (7) and butyllithium in tetrahydrofuran—none of the methyl ether (31) was formed. When the reaction was repeated with potassium t-butoxide as the base, the methyl ether (31) was isolated in high yield. However, treatment of the alcohol (7) with the same base in the presence of trichloroacetonitrile gave, after workup, only the ester (27). A similar lack of success was observed with potassium hydride and caesium carbonate as the base.

From the above log of reactions and frustrating results it appeared that the imidate (26) was difficult to form and even harder to obtain pure. Even with the apparently reactive potassium alkoxide derived from (7), any imidate (26) so formed (as the potassium salt) had the choice of reversion to the alkoxide ion, decomposition to the cyanate (32), hydrolysis to the ester (27) during workup or participation in the desired ring-opening of the adjacent epoxide moiety. Unfortunately, only the hydrolysis and reversion processes seemed to be at all favoured, and these observations seemed consistent with Giuliano's work on imidates from hindered carbohydrate alcohols,[12] and Jacobsen's general study on the intramolecular opening of carbohydrate epoxides with imidates.[18] In fact, treatment of the alcohol (7) with sodium hydride/dimethylcyanamide (Me_2NCN), a combination used by Giuliano[12] to solve problems of low alcohol reactivity, gave none of the desired (33).†

At this stage of our work we abandoned all attempts to form imidates and related molecules, and turned to carbamates, mainly on the basis of a report by Vasella[13] for the conversion of (34) into (35). Treatment of

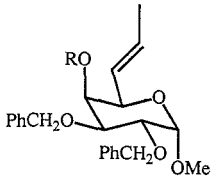
† *Note added in proof.*—A recent paper (Knapp, S., and Kukkola, P. J., *J. Org. Chem.*, 1990, **55**, 1632) reported a successful transformation (95%) of (7) into an oxazoline, and thence lincosamine.

[17] Bax, A., and Morris, G. A., *J. Magn. Reson.*, 1981, **42**, 501.
[18] Jacobsen, S., *Acta Chem. Scand., Ser. B*, 1988, **42**, 605.

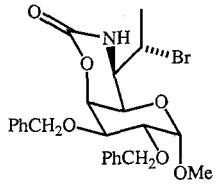
the alcohol (7) with trichloroacetyl isocyanate in dry tetrahydrofuran gave the trichloroacetylcarbamate (36) [1790, 1720 cm^{-1} (C=O)] in high yield, but attempted purification resulted only in decomposition. Therefore, the reaction was repeated and potassium t-butoxide added to the reaction mixture: only the trichloroacetylcarbamate (36) appeared to be present (t.l.c.). Heating the mixture with added 18-crown-6 ether resulted only in the formation of the carbamate (37), apparently from base-induced decomposition of (36). In fact, the carbamate (37) was formed in excellent yield by treatment of (36) [generated from (7) in tetrahydrofuran] with methanol/potassium carbonate, and this method appears to be potentially superior to the normal methods for the conversion of alcohols directly into unsubstituted carbamates.

In all of the above experiments the presence of the trichloroacetylcarbamate (36) was assured, but the subsequently generated nitrogen anion, flanked by two carbonyl groups, was probably too stable to open the adjacent epoxide. Therefore, the carbamate (37) itself was treated with a variety of bases in various solvents, but only the epoxy alcohol (7) was formed to any extent. Apparently, any anion formed from (37) prefers to extrude cyanic acid (HNCO) rather than interact with the epoxide.

Before abandonment of a carbamate approach completely, the alcohol (1) was converted into the trichloroacetylcarbamate (38) and thence the carbamate (39) by our newly established methodology. Treatment of (39) with *N*-bromosuccinimide in wet acetic acid, in an attempt to prepare (40), gave a mixture of two compounds, the major component of which appeared to be the carbonimidate (41). This assignment was made partly on the basis of the upfield chemical shift of H4 (δ 4·61) in the ^1H n.m.r. spectrum as compared with that for (39) (δ 5·34), and on a strong absorbance (1725 cm^{-1}) in the infrared spectrum.[16]



(38) R = $Cl_3CCONHCO$
(39) R = H_2NCO



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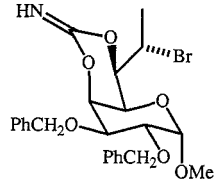
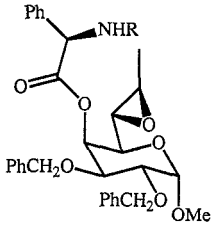
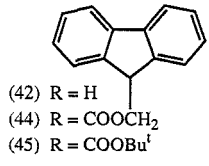
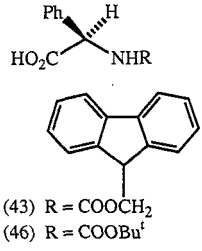


(41)





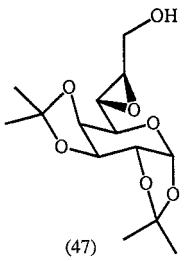
(42) R = H
(44) R = $COOCH_2$
(45) R = $COOBu^t$



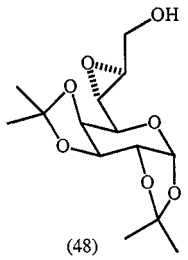
(43) R = $COOCH_2$
(46) R = $COOBu^t$

Our last attempt towards a molecule such as (6) involved preparation of the amino ester (42), where now a seven-membered-ring would be involved in the delivery of nitrogen onto C6. Thus, arbitrarily, (*R*)-(−)-2-

amino-2-phenylacetic acid was converted into the fluorenylmethyl[19] carbamate (43) by using Chang's procedure,[20] and attempts were made to couple (43) and the alcohol (7) to form the ester (44). However, with *N,N'*-dicyclohexylcarbodiimide/4-dimethylaminopyridine as the coupling agent, no conditions could be found for the synthesis of (44). A ready synthesis of the ester (45) was available from the alcohol (7) and the protected amino acid (46) by using the *N,N'*-dicyclohexylcarbodiimide/4-dimethylaminopyridine combination, but subsequent preparation of the amino ester (42) was not considered owing to the strongly acidic conditions required to remove the t-butoxycarbonyl protecting group from (45). Apparently the increased size of the fluorenylmethoxycarbonyl protecting group and its base sensitivity preclude formation of the ester (44) from the rather unreactive alcohol (7).



(47)

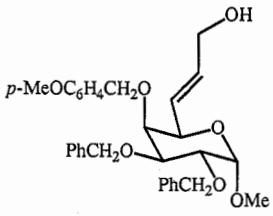


(48)

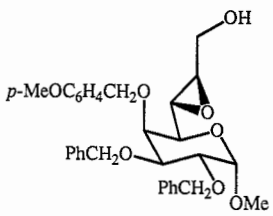
The final part of this paper deals with some attempts at the synthesis of lincosamine directly from the alkenes (2)–(4). Sharpless[21] has reported the titanium(IV)-mediated ring-opening of some 2,3-epoxy alcohols with nucleophiles to give 3-substituted 1,2-diols, and so we required the epoxy alcohol (47). Brimacombe[22] has studied the epoxidation of the allylic alcohol (2) utilizing the Sharpless asymmetric epoxidation.[23] With (+)-diisopropyl tartrate as the chiral auxiliary, only the *β*-L-*threo* epoxide (48) was formed from (2), whereas a change to the (–)-tartrate gave an equimolar mixture of the two possible epoxides (47) and (48). In a much simpler procedure, treatment of (2) with *m*-chloroperbenzoic acid gave a mixture of (47) and (48) in a ratio of 3 : 1; flash chromatography of this mixture then provided pure (47), far superior to the tedious fractional crystallization utilized by Brimacombe to isolate impure (47).[22] Somewhat incidentally, a similar oxidation (*m*-chloroperbenzoic acid) of the alkene (49) appeared to give a mixture of the two possible epoxides (50) and (51), in a ratio of 1 : 1 (^{13}C n.m.r.).

The epoxy alcohol (47) was now treated with trimethylsilyl azide/titanium(IV) isopropoxide in benzene at reflux to give a low yield of an azido diol. The presence of an azide group was obvious from the infrared spectrum (2090 cm^{-1}), but the regiochemistry of the product could not be determined from the ^{1}H n.m.r. spectrum (δ 3·89, H6; 3·72, H7). The same azido diol was prepared

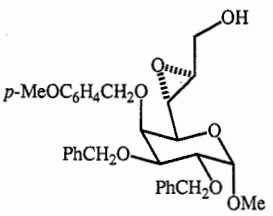
[19] Carpino, L. A., and Han, G. Y., *J. Org. Chem.*, 1972, **37**, 3404.
[20] Chang, C.-D., Waki, M., Ahmad, M., Meienhofer, J., Lundell, E. O., and Haug, J. D., *Int. J. Pept. Protein Res.*, 1980, **15**, 59.
[21] Caron, M., and Sharpless, K. B., *J. Org. Chem.*, 1985, **50**, 1557.
[22] Brimacombe, J. S., Kabir, A. K. M. S., and Bennett, F., *J. Chem. Soc., Perkin Trans. 1*, 1986, 1677.
[23] Pfenninger, A., *Synthesis*, 1986, 89.



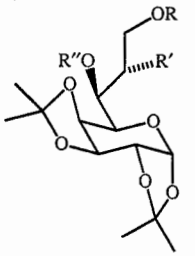
(49)

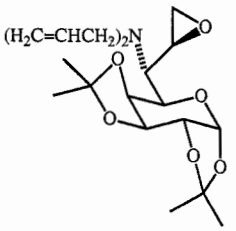


(50)



(51)





(57)

	R	R'	R"
(52)	H	N_3	H
(53)	H	$N(CH_2CH{=}CH_2)_2$	H
(54)	Ac	$N(CH_2CH{=}CH_2)_2$	Ac
(55)	$SiPh_2Bu^t$	$N(CH_2CH{=}CH_2)_2$	H
(56)	$SiPh_2Bu^t$	$N(CH_2CH{=}CH_2)_2$	SO_2Me

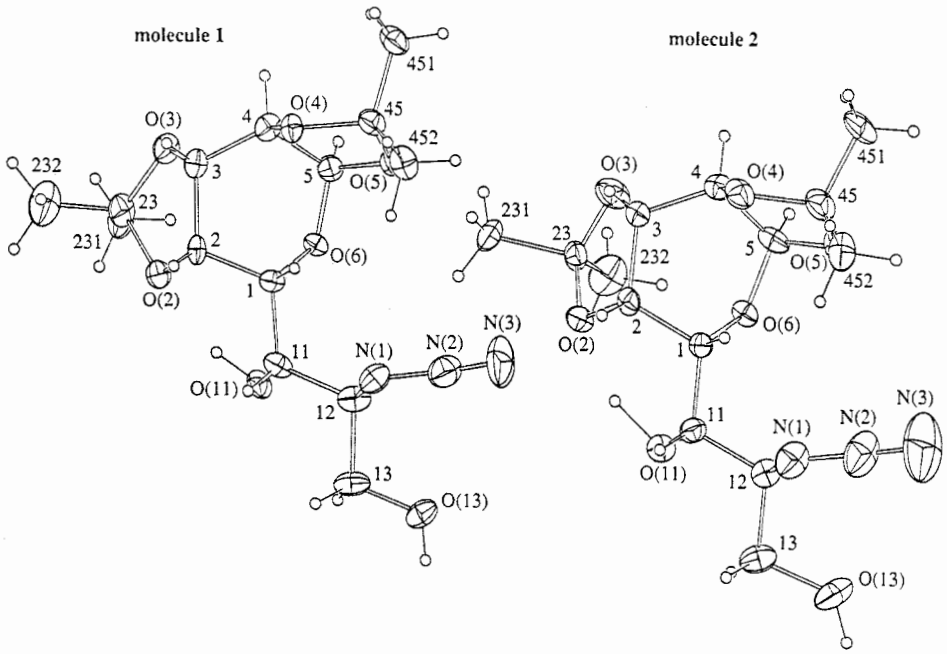
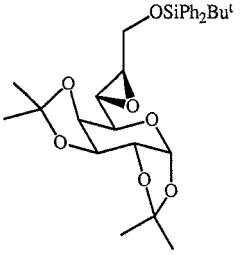


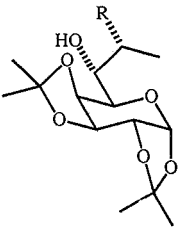
Fig. 3. The two molecules of (52). Note the alternative conformations of the fused ring at C(2,3).

in better yield (49%) by treatment of (47) with preformed titanium(IV) diazide diisopropoxide [$Ti(N_3)_2(OPr^i)_2$], the species that is supposedly responsible for the epoxide ring-opening.[21] The structure of the azido diol was finally assigned as (52) from a single-crystal X-ray structure determination (Fig. 3). The desired epoxide ring-opening had indeed occurred, but unfortunately with the introduction of azide at C7 rather than at C6. A similar result was observed when the epoxide (47) was treated with diallylamine/titanium(IV) isopropoxide, except that the amino diol (53) was obtained in a higher yield. The structure of (53) was predictable in light of the formation of (52), and the ^1H n.m.r. spectrum showed H7 (δ 3·05, m) expectedly upfield from H6 (δ 4·17, dd). As well, the derived diacetate (54) showed a marked deshielding of H6 (δ 5·53) compared to H7 (δ 3·45).

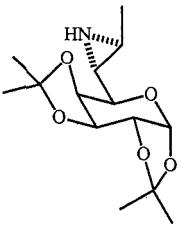
In an attempt to rectify the regiochemistry obtained in the above diols, the amino diol (53) was converted into the silyl ether (55). Subsequent treatment with methanesulfonyl chloride was expected to give the mesylate (56) which, under heating and subsequent fluoride ion treatment, we hoped would rearrange to the desired amino epoxide (57). Such was not the case! Although the hydroxy group of the silyl ether (55) could be acetylated with ease, our expectations for the mesylate (56) were too great.† Finally, we prepared the epoxy silyl ether (58) in the hope that the bulky protecting group at O8 would somehow compensate for the pyranose ring in the Sharpless epoxide ring-opening process. However, treatment of (58) with diallylamine in the usual way gave no change, which confirmed the fact that titanium(IV) isopropoxide, being a weak Lewis acid, required the hydroxy group (at O8) to ensure coordination with, and hence activation of, the epoxide oxygen.



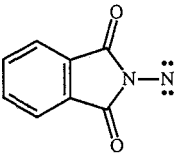
(58)



(59) R = OH
(60) R = NHTs



(61)



(62)

The Sharpless oxyamination reaction[24] is a direct means of transforming an alkene into a vicinal amino alcohol. Therefore the alkene (4), chosen because of its known propensity to form only the diol (59) with potassium permanganate,[25] was treated with *N*-chloro-4-toluenesulfonamide, sodium salt/osmium tetraoxide, but only the unwanted amido alcohol (60) was formed in excellent yield. The structure of (60) was again assigned from an analysis of the ^1H n.m.r. spectrum (δ 3·64, m, H7; 3·84, dd, H6; 5·39, d, NH). Irradiation of H6 did not affect the signal for NH, but irradiation of H7 caused the doublet at δ 5·39 to collapse to a singlet.

† We thank Dr Tony Barrett for suggesting this novel sequence to us.

[24] Herranz, E., and Sharpless, K. B., *J. Org. Chem.*, 1978, **43**, 2544.
[25] Lance, D. G., Szarek, W. A., Jones, J. K. N., and Howarth, G. B., *Can. J. Chem.*, 1969, **47**, 2871.

Although there are many methods for the direct insertion of a nitrene into an alkene to generate an aziridine, we tried only one on the alkene (3) in the hope of generating (61), a potential precursor to lincosamine. Oxidation of *N*-aminophthalimide with lead(IV) acetate in the presence of the alkene (3) presumably generated the nitrene (62),[26] but only starting material was recovered from the reaction mixture. The alkene (3) is not nucleophilic enough to react with the nitrene (62), which decomposes by other routes.

Experimental

Experimental details have been given previously.[27]

Peracid Epoxidation of Methyl (E)-*2,3-Di-O-benzyl-6,7,8-trideoxy-4-O-(4-methoxybenzyl)-α-*D-galacto-*oct-6-enoside (8)*

m-Chloroperbenzoic acid (145 mg of 80%, 0·7 mmol) was added to a solution of the alkene (8)[1] (170 mg, 0·34 mmol) in dry CH_2Cl_2 (10 ml, 0°), and the mixture stirred (24 h). Normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave a colourless oil (153 mg). Flash chromatography (EtOAc/petrol, 2 : 8) eluted firstly the *β*-L-threo *epoxide* (9) as a colourless oil (100 mg, 57%), $[\alpha]_D$ +97°, R_F 0·25 (EtOAc/petrol, 4 : 6) (Found: C, 71·5; H, 6·9. $C_{31}H_{36}O_7$ requires C, 71·6; H, 7·0%). ^{1}H n.m.r. (300 MHz) *δ* 1·30, d, $J_{7,Me}$ 5·2 Hz, Me; 2·83, dd, $J_{5,6}$ 6·2, $J_{6,7}$ 2·1 Hz, H6; 2·97, dq, H7; 3·32, s, OMe; 3·34–3·37, m, H5; 3·78, s, ArO**Me**; 3·89, dd, B part of ABMX, $J_{2,3}$ 10·2, $J_{3,4}$ 2·9 Hz, H3; 3·98–4·00, m, H4; 4·02, dd, A part of ABMX, $J_{1,2}$ 3·6 Hz, H2; 4·66, d, H1; 4·63–4·94, 3×ABq, 6H, ArC**H**$_2$; 6·81–6·86, BB′ arm of AA′BB′ system, 2H, Ar; 7·23–7·40, m, 12H, Ar. ^{13}C n.m.r. (75·4 MHz) *δ* 17·44, C8; 54·39, C6; 55·24, 55·38, 2C, OMe; 57·28, C7; 70·96, 75·43, 76·19, 78·52, C2,3,4,5; 73·15, 73·60, 74·52, 3C, ArC**H**$_2$; 98·93, C1; 113·65, 2C, Ar; 127·48, 127·52, 127·70, 128·08, 128·33, 128·37, 129·86, 12C, Ar; 130·63, 138·45, 138·70, 3C, Ar; 159·22, Ar. Further elution then gave the *α*-D-threo *epoxide* (10) as a colourless oil (30 mg, 17%), $[\alpha]_D$ 0°, $[\alpha]_{436}$ −52·6°, R_F 0·23 (EtOAc/petrol, 4 : 6) (Found: C, 71·7; H, 6·9). ^{1}H n.m.r. (300 MHz) *δ* 1·14, d, $J_{7,Me}$ 5·2 Hz, Me; 2·74, dq, $J_{6,7}$ 2·2 Hz, H7; 2·88, dd, $J_{5,6}$ 6·7 Hz, H6; 3·22–3·25, m, H5; 3·35, s, OMe; 3·79, s, ArO**Me**; 3·79–3·90, m, H3,4; 4·07, dd, A part of ABMX, $J_{1,2}$ 3·6, $J_{2,3}$ 9·6 Hz, H2; 4·63–4·90, 3×ABq, 6H, ArC**H**$_2$; 4·72, d, H1; 6·83–6·86, BB′ arm of AA′BB′ system, 2H, Ar; 7·21–7·42, m, 12H, Ar. ^{13}C n.m.r. (75·4 MHz) *δ* 17·12, C8; 51·18, C6; 55·24, 55·32, 2C, OMe; 58·70, C7; 72·29, 75·59, 76·37, 78·94, C2,3,4,5; 73·51, 73·61, 3C, ArC**H**$_2$; 98·65, C1; 113·71, 2C, Ar; 127·45, 127·54, 127·70, 128·05, 128·32, 128·37, 130·00, 12C, Ar; 130·35, 138·36, 138·68, 3C, Ar; 159·25, Ar.

Peracid Epoxidation of Methyl (E)-*2,3-Di-O-benzyl-6,7,8-trideoxy-α-*D-galacto-*oct-6-enopyranoside (1)*

To a solution of the alcohol (1)[1] (200 mg, 0·52 mmol) in dry CH_2Cl_2 (10 ml) was added powdered sodium carbonate (200 mg) and *m*-chloroperbenzoic acid (100 mg of 80%, 0·5 mmol), and the mixture heated at reflux (12h). Filtration followed by normal workup (CH_2Cl_2), with an initial $NaHSO_3$ wash, gave an oil (175 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of this oil gave a colourless oil (120 mg, 58%) homogeneous by t.l.c. The ^{13}C n.m.r. spectrum showed the oil to be a mixture of two hydroxy epoxides, (11) and (7) in the ratio of 7 : 3. ^{13}C n.m.r. (20·1 MHz) *δ* 51·3, C6; 58·6, C7 for the minor isomer (7); 54·0, C6; 57·2, C7 for the major isomer (11).

Methyl (E)-*4-O-Benzoyl-2,3-di-O-benzyl-6,7,8-trideoxy-α-*D-galacto-*oct-6-enoside (12)*

The secondary alcohol (1) (1·98 g, 5·2 mmol) was dissolved in pyridine/CH_2Cl_2 (50 ml, 1 : 1), and benzoyl chloride (815 *μ*l, 7·0 mmol) added. After standing (3 days) the mixture was concentrated and subjected to normal workup (EtOAc) to give a yellow oil (2·78 g).

[26] Anderson, D. J., Gilchrist, T. L., Horwell, D. C., and Rees, C. W., *J. Chem. Soc. C*, 1970, 576.
[27] Rodriguez, E. B., and Stick, R. V., *Aust. J. Chem.*, 1990, **43**, 665.

Flash chromatography (EtOAc/petrol, 1 : 9) gave *methyl* (E)-*4-O-benzoyl-2,3-di*-O-*benzyl-6,7,8-trideoxy-α*-D-galacto-*oct-6-enoside* (12) as a colourless oil (2·38 g, 95%), $[\alpha]_D$ +49·5°. $\bar{\nu}_{max}$ (thin film) 1710 cm^{-1} (CO); R_F 0·25 (EtOAc/petrol, 2 : 8) (Found: C, 73·5; H, 6·7. $C_{30}H_{32}O_6$ requires C, 73·8; H, 6·6%). ^1H n.m.r. (80 MHz) δ 1·61, d, $J_{7,Me}$ 6·1 Hz, Me; 3·42, s, OMe; 3·35–4·91, m, 8H, PhC**H**$_2$, H1,2,3,5; 5·22–6·13, m, 3H, H4,6,7; 7·03–7·67, m, 13H, Ph; 7·88–8·23, m, 2H, Ph. ^{13}C n.m.r. (20·1 MHz) δ 17·9, C8; 55·6, OMe; 69·9, 71·4, 75·0, 76·4, C2,3,4,5; 72·0, 73·8, 2C, Ph**C**H$_2$; 99·4, C1; 128·0, 128·4, 128·5, 128·7, 130·1, 18C, Ph, C6,7; 138·4, 138·6, 2C, Ph; 166·2, CO.

Methyl 6,7-Anhydro-2,3-di-O-*benzyl-8-deoxy-α*-D-threo-D-galacto-*octopyranoside (7)*

(i) To a solution of the alkene (12) (510 mg, 1·05 mmol) in a mixture of CH_2Cl_2 (5 ml), acetic acid (5 ml) and water (300 μl) was added *N*-bromosuccinimide (200 mg, 1·1 mmol), and the mixture stirred (25 h) in the absence of light. Normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave a colourless oil (605 mg). This oil was dissolved in dry Et_2O (10 ml), and sodium methoxide (2·4 ml of 0·92 M in MeOH, 2·2 mmol) added. After 15 h the mixture was diluted with Et_2O (30 ml), washed with water (×3) and brine, dried and concentrated to give a yellow oil (370 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of this oil gave only *methyl 6,7-anhydro-2,3-di*-O-*benzyl-8-deoxy-α*-D-threo-D-galacto-*octopyranoside* (7) (215 mg, 51%) as a colourless crystalline solid, m.p. 124–126° (diisopropyl ether), $[\alpha]_D$ +44·4°, R_F 0·25 (EtOAc/petrol, 2 : 8) (Found: C, 68·9; H, 7·1. $C_{23}H_{28}O_6$ requires C, 69·0; H, 7·0%). ^1H n.m.r. (300 MHz) δ 1·34 d, $J_{7,Me}$ 5·2 Hz, Me; 2·60, d, $J_{4,OH}$ 1·3 Hz, OH; 2·95, dq, $J_{6,7}$ 2·1 Hz, H7; 3·02, dd, $J_{5,6}$ 6·1 Hz, H6; 3·37, s, OMe; 3·39–3·45, m, H5; 3·84, dd, B part of ABMX, $J_{2,3}$ 9·9, $J_{3,4}$ 2·8 Hz, H3; 3·86, dd, A part of ABMX, $J_{1,2}$ 3·1 Hz, H2; 4·02–4·03, m, H4; 4·67–4·80, 2×ABq, 4H, PhC**H**$_2$; 4·69, d, H1; 7·26–7·45, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 17·29, Me; 51·19, C6; 55·34, OMe; 58·49, C7; 69·17, 70·54, 75·64, 77·34, C2,3,4,5; 72·84, 73·44, 2C, Ph**C**H$_2$; 98·55, C1; 127·77, 127·88, 127·97, 128·37, 128·47, 10C, Ph; 138·05, 138·29, 2C, Ph.

(ii) To a cooled (0°) solution of the alkene (12) (490 mg, 1·0 mmol) in a mixture of CH_2Cl_2 (5 ml), acetic acid (5 ml) and water (300 μl) was added *N*-bromosuccinimide (180 mg, 1·0 mmol), and the mixture stirred (2 h) in the absence of light. Workup as above gave a colourless oil (545 mg). Flash chromatography (EtOAc/petrol, 2 : 8) then gave the *bromohydrin* (13) as a colourless glass (375 mg, 64%), $[\alpha]_D$ +43·5°. $\bar{\nu}_{max}$ (thin film) 1720 cm^{-1} (CO); R_F 0·20 (EtOAc/petrol, 2 : 8) (Found: C, 61·3; H, 5·8. $C_{30}H_{33}BrO_7$ requires C, 61·5; H, 5·7%). ^1H n.m.r. (300 MHz) δ 1·74, d, $J_{7,Me}$ 6·9 Hz, Me; 2·6, br s, OH; 3·29, s, OMe; 3·80–3·88, m, H2,3; 3·94–3·99, m, H4; 4·07, d, $J_{5,6}$ 6·2 Hz, H5; 4·47, dd, $J_{6,7}$ 4·8 Hz, H7; 4·59–4·81, 2×ABq, 4H, PhC**H**$_2$; 4·66, s, H1; 5·79, dd, H6; 7·20–7·55, m, 13H, Ph; 7·98–8·12, m, 2H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 21·09, C8; 49·09, C7; 55·52, OMe; 62·88, 66·55, 75·23, 75·62, 77·44, C2,3,4,5,6; 72·92, 73·41, 2C, Ph**C**H$_2$; 98·51, C1; 127·79, 127·82, 127·94, 128·34, 128·47, 129·75, 129·82, 132·98, 16C, Ph; 137·85, 138·20, 2C, Ph; 165·61, CO. The bromohydrin (13) (375 mg, 0·64 mmol) was dissolved in methanol (20 ml), aqueous potassium hydroxide solution (3 ml of 2 M, 6 mmol) added and the mixture allowed to stand (overnight). T.l.c. then showed complete disappearance of the starting material. The methanol was removed by evaporation, Et_2O added, the mixture washed with water and brine, dried and concentrated to give a white crystalline solid (195 mg). Recrystallization gave the epoxide (7) (140 mg, 55%), m.p. 122·5–124°.

(iii) To a cooled (0°) solution of the alkene (12) (2·38 g, 4·9 mmol) in a mixture of CH_2Cl_2 (25 ml), acetic acid (25 ml) and water (1·3 ml) was added *N*-bromosuccinimide (870 mg, 4·9 mmol) in portions (0·5 h) in the absence of light, and the mixture stirred (5 min). T.l.c. showed no starting material remaining, and workup as above gave a colourless oil (2·64 g). This oil was dissolved in methanol (150 ml), and powdered potassium hydroxide (1·1 g, 20 mmol) added. After stirring (1 day) the mixture was concentrated to give a yellow oil (3·7 g). Crystallization (diisopropyl ether) gave the epoxy alcohol (7) (820 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of the mother liquors gave a further amount of the epoxide (7) (310 mg), total yield 1·13 g (58%), m.p. 124–126°.

Peracid Epoxidation of Methyl (E)-*2,3-Di-O-benzyl-6,7,8-trideoxy-4-O-(4-methoxybenzyl)-α-D-gluco-oct-6-enoside (17)*

Treatment of the D-*gluco* alkene (17) (160 mg) with *m*-chloroperbenzoic acid as for the D-*galacto* alkene (8) gave a material (155 mg), homogeneous by t.l.c., which crystallized slowly, and which the ^{13}C n.m.r. spectrum showed to be a 7 : 3 mixture of epoxides (19) and (20) [δ 52·0, C6; 58·6, C7 for (19); 51·2, C6; 59·1, C7 for (20)].

Peracid Epoxidation of Methyl (E)-*2,3-Di-O-benzyl-6,7,8-trideoxy-α-D-gluco-oct-6-enopyranoside (18)*

Treatment of the alcohol (18) (605 mg) with *m*-chloroperbenzoic acid gave an oil (590 mg), homogeneous by t.l.c., which crystallized on standing. ^{13}C n.m.r. spectroscopy showed a mixture of two epoxides in the ratio of 13 : 7. Recrystallization (×3) gave the major isomer, *methyl 6,7-anhydro-2,3-di-O-benzyl-8-deoxy-α-D-threo-D-gluco-octopyranoside* (21) (150 mg, 24%), m.p. 130–131·5° (diisopropyl ether), $[\alpha]_D$ +25·8°, R_F 0·20 (EtOAc/petrol, 4 : 6) (Found: C, 69·0; H, 7·2. $C_{23}H_{28}O_6$ requires C, 69·0; H, 7·0%). ^1H n.m.r. (300 MHz) δ 1·31, d, $J_{7,Me}$ 5·2 Hz, Me; 2·47, d, $J_{4,OH}$ 1·3 Hz, OH; 2·91, dd, $J_{5,6}$ 3·7, $J_{6,7}$ 2·2 Hz, H6; 3·10, dq, H7; 3·36, s, OMe; 3·44–3·53, m, H2,3,5; 3·71–3·79, m, H4; 4·59, d, $J_{1,2}$ 3·5 Hz, H1; 4·62–5·03, 2×ABq, 4H, PhC**H**$_2$; 7·25–7·45, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 17·33, C8; 51·76, C6; 55·32, OMe; 58·47, C7; 69·75, 71·11, 77·46, 81·30, C2,3,4,5; 73·14, 75·41, 2C, Ph**C**H$_2$; 98·08, C1; 127·90, 127·96, 128·00, 128·11, 128·49, 128·61, 10C, Ph; 137·91, 138·66, 2C, Ph. From the mother liquors the following data on methyl 6,7-anhydro-2,3-di-*O*-benzyl-8-deoxy-β-L-*threo*-D-*gluco*-octopyranoside (22) could be obtained: ^{13}C n.m.r. (75·4 MHz) δ 17·34, C8; 51·83, C6; 55·29, OMe; 59·11, C7; 69·00, 72·33, 79·29, 81·07, C2,3,4,5; 73·17, 75·40, 2C, Ph**C**H$_2$; 98·04, C1; 126·66, 127·96, 128·46, 128·57, 128·96, 129·31, 10C, Ph; 137·92, 138·61, 2C, Ph.

Methyl (E)-*4-O-Benzoyl-2,3-di-O-benzyl-6,7,8-trideoxy-α-D-gluco-oct-6-enopyranoside (23)*

Treatment of the crude alcohol (18) (910 mg) with benzoyl chloride gave the *benzoate* (23) (750 mg) as an oil, $[\alpha]_D$ −11·9°. $\bar{\nu}_{max}$ (thin film) 1720 cm^{-1} (CO); R_F 0·50 (EtOAc/petrol, 4 : 6) (Found: C, 74·0; H, 6·6. $C_{30}H_{32}O_6$ requires C, 73·8; H, 6·6%). ^1H n.m.r. (80 MHz) δ 1·55, d, $J_{7,Me}$ 5·5 Hz, Me; 3·42, s, OMe; 3·35–4·40, m, H2,3,5; 4·54–4·77, m, 5H, PhC**H**$_2$, H1; 4·91–6·05, m, H4,6,7; 7·03–7·57, m, 13H, Ar; 7·89–8·05, m, 2H, Ph. ^{13}C n.m.r. (20·1 MHz) δ 17·7, C8; 55·4, OMe; 71·1, 74·0, 78·9, 80·0, C2,3,4,5; 73·5, 75·3, 2C, Ph**C**H$_2$; 98·4, C1; 128·1, 128·2, 128·5, 128·6, 129·0, 129·7, 130·2, 131·6, 133·1, 134·7, 18C, Ph, C6,7; 138·2, 138·5, 2C, Ph; 165·5, CO.

Epoxidation of the Alkene (23) with N-Bromosuccinimide

Treatment of the alkene (23) (500 mg) with *N*-bromosuccinimide gave an oil (600 mg), and subsequent base treatment (sodium methoxide) gave a yellow oil (350 mg). Flash chromatography (EtOAc/petrol, 3 : 7) gave the epoxide fraction (150 mg, 37%). The ^{13}C n.m.r. spectrum showed a mixture of the two hydroxy epoxides (21) and (22) in the ratio of 1 : 4. ^{13}C n.m.r. (20·1 MHz) δ 51·9, C6; 58·6, C7 for (21); 51·9, C6; 59·3, C7 for (22).

Attempts at Formation of the Trichloroacetimidate (26) from the Epoxy Alcohol (7)

(i) To a solution of the epoxy alcohol (7) (85 mg, 0·20 mmol) in dry CH_2Cl_2 (2 ml) were added trichloroacetonitrile (200 μl, 2·0 mmol) and potassium carbonate (200 mg), and the mixture was stirred (17 h). The mixture was filtered (Celite) and the filtrate concentrated to give a yellow oil (105 mg). The ^1H n.m.r. (60 MHz) spectrum indicated only the presence of starting material.

(ii) To petrol-washed sodium hydride (65 mg of 80%, 2 mmol) in dry tetrahydrofuran (10 ml) was added the epoxy alcohol (7) (215 mg, 0·54 mmol), and the mixture heated to reflux. Trichloroacetonitrile (100 μl, 1·0 mmol) was then added and the heating continued (20 min). Normal workup (Et_2O) gave a yellow oil (445 mg). Flash chromatography (EtOAc/petrol, 3 : 7) gave a clear oil (220 mg), homogeneous by t.l.c. $\bar{\nu}_{max}$ (thin film) 1760, 1720 cm^{-1} (CO), 1655 cm^{-1} (C=N).

(iii) The epoxy alcohol (7) (140 mg, 0·35 mmol) was dissolved in dry tetrahydrofuran (5 ml, argon atmosphere), the solution cooled (−20°) and BuLi (240 μl of 1·6 M, 0·38 mmol)

added. This was followed by trichloroacetonitrile (38 μl, 0·38 mmol), then shortly after (5 min) by Me_3SiCl (50 μl, 0·4 mmol). After standing (overnight) the mixture was diluted with EtOAc (30 ml), washed with water (×3) and brine, and dried and concentrated to give a brown oil (180 mg). Flash chromatography (EtOAc/petrol, 2 : 8) gave *methyl 4,7-anhydro-2,3-di-*O*-benzyl-8-deoxy-β-*L-erythro-D-galacto-*octoside* (29) as a colourless oil (65 mg, 46%), $[\alpha]_D$ +76·3°, R_F 0·45 (EtOAc/petrol, 1 : 1) (Found: C, 68·9; H, 6·9. $C_{23}H_{28}O_6$ requires C, 69·0; H, 7·0%). ^1H n.m.r. (300 MHz) δ 1·58, d, $J_{7,Me}$ 6·7 Hz, Me; 3·41, s, OMe; 3·74, d, $J_{5,6}$ 0·0, $J_{6,7}$ 9·0 Hz, H3; 4·05–4·06, m, H4; 4·13, dq, H7; 4·15–4·16, m, H5; 4·70, d, H1; 4·62–4·84, 2×ABq, 4H, PhC**H**$_2$; 7·26–7·38, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 21·36, C8; 55·72, OMe; 56·13, 65·57, C6,7; 71·57, 75·36, 77·69, 77·88, C2,3,4,5; 73·17, 73·56, 2C, Ph**C**H$_2$; 98·69, C1; 127·91, 128·09, 128·09, 128·45, 128·59, 129·76, 129·85, 10C, Ph; 137·84, 138·16, 2C, Ph.

(iv) To a solution of the epoxy alcohol (7) (120 mg, 0·3 mmol) in dry tetrahydrofuran (5 ml, argon atmosphere) was added chlorotrimethylsilane (125 μl, 1·0 mmol), and the mixture allowed to stand (3 days). The mixture was concentrated, dissolved in Et_2O, washed with water (×2) and brine, then dried and concentrated to give a colourless oil (100 mg). Preparative t.l.c. (EtOAc/petrol, 4 : 6) gave the 4,7-anhydro compound (29) (60 mg, 50%) (^1H n.m.r.).

(v) To a solution of the epoxy alcohol (7) (120 mg) in dry tetrahydrofuran (5 ml, argon atmosphere) was added potassium t-butoxide (10 mg, 0·1 mmol), and the mixture stirred (5 min). Trichloroacetonitrile (33 μl, 0·33 mmol) was then added, followed by further stirring (2 days). T.l.c. showed essentially complete conversion into a less polar material. EtOAc was added; the mixture was washed with water (×3) and brine, and dried and concentrated to give a pale yellow oil (165 mg). Flash chromatography (EtOAc/petrol, 1 : 3) gave a clear oil (80 mg), identified as the ester (27). $\bar{\nu}_{max}$ (thin film) 1760s, 1720w cm^{-1} (CO). ^1H n.m.r. (300 MHz) δ 1·28, d, $J_{7,Me}$ 5·2 Hz, Me; 2·83, dd, $J_{5,6}$ 5·9, $J_{6,7}$ 2·1 Hz, H6; 2·92, dq, H7; 3·41, s, OMe; 3·60, dd, $J_{4,5}$ 1·1 Hz, H5; 3·83, dd, $J_{1,2}$ 3·6, $J_{2,3}$ 10·0 Hz, H2; 4·04, dd, $J_{3,4}$ 3·3 Hz, H3; 4·62–4·86, 2×ABq, 4H, PhC**H**$_2$; 4·75, d, H1; 5·50, dd, H4; 7·25–7·39, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 17·03, C8; 50·95, C6; 55·74, OMe; 57·77, C7; 69·92, 74·16, 75·37, 75·42, C2,3,4,5; 72·62, 73·62, 2C, Ph**C**H$_2$; 98·87, C1; 127·56, 127·70, 127·92, 128·29, 128·35, 10C, Ph; 137·69, 137·81, 2C, Ph; 161·63, CO.

(vi) To petrol-washed potassium hydride (80 mg, 2 mmol) in tetrahydrofuran (4 ml, argon atmosphere) was added the epoxy alcohol (7) (120 mg). Once the evolution of gas had ceased the tetrahydrofuran was removed with a stream of dry argon and warming. Trichloroacetonitrile (2·0 ml, 20 mmol) was added and the mixture allowed to stand (overnight). T.l.c. showed only the presence of the epoxy alcohol (7).

(vii) To a solution of the epoxy alcohol (7) (120 mg) in dry dimethylformamide (5 ml, argon atmosphere) was added caesium carbonate (125 mg, 0·35 mmol), and the mixture stirred (5 min). After the addition of trichloroacetonitrile (33 μl, 0·33 mmol) and further stirring (3 days), t.l.c. showed no change. EtOAc was added; the mixture was washed with water (×3) and brine, and dried and concentrated to give a pale yellow oil (100 mg). Crystallization gave the epoxy alcohol (7) (55 mg), m.p. 120–122°.

*Methyl 4,7-Anhydro-2,3-di-*O*-benzyl-6-bromo-6,8-dideoxy-β-*L-erythro-D-galacto-*octoside (30)*

To a cooled (0°) solution of the alcohol (1) (355 mg, 0·92 mmol) in a mixture of CH_2Cl_2 (4·5 ml), acetic acid (4·5 ml) and water (250 μl) was added *N*-bromosuccinimide (182 mg, 0·92 mmol), and the mixture stirred (6 h) in the absence of light. Normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave a colourless oil (415 mg). Flash chromatography (EtOAc/petrol, 2 : 8) gave *methyl 4,7-anhydro-2,3-di-*O*-benzyl-6-bromo-6,8-dideoxy-β-*L-erythro-D-galacto-*octoside* (30) as an unstable colourless oil (335 mg, 78%), $[\alpha]_D$ +122·3°, R_F 0·45 (EtOAc/petrol, 4 : 6) (Found: C, 59·4; H, 5·6. $C_{23}H_{27}BrO_5$ requires C, 59·6; H, 5·9%). ^1H n.m.r. (300 MHz) δ 1·38, d, $J_{7,Me}$ 6·3 Hz, Me; 3·41, s, OMe; 3·76, dd, $J_{5,6}$ 3·3, $J_{6,7}$ 9·6 Hz, H6; 3·87, dd, $J_{1,2}$ 3·2, $J_{2,3}$ 9·9 Hz, H2; 4·00, dd, $J_{3,4}$ 3·8 Hz, H3; 4·05–4·07, m, H5; 4·27, dq, H7; 4·29, dd, $J_{4,5}$ Hz, H4; 4·65–4·90, m, 5H, PhC**H**$_2$, H1; 7·23–7·60, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 18·18, C8; 52·14, C6; 55·72, OMe; 71·86, 73·84, 74·74, 75·94, 79·74, C2,3,4,5,7; 72·10, 72·65, 2C, Ph**C**H$_2$; 99·40, C1; 127·64, 127·64, 127·76, 127·91, 128·31, 128·38, 10C, Ph;138·29, 138·34, 2C, Ph.

Methyl 6,7-Anhydro-2,3-di-O-benzyl-8-deoxy-4-O-methyl-α-D-threo-D-galacto-octoside (31)

(i) To a solution of the epoxy alcohol (7) (120 mg, 0·3 mmol) in dry tetrahydrofuran (5 ml, 0°, argon atmosphere) was added BuLi (300 μl of 1·65 M, 0·5 mmol), and the mixture stirred (5 min). Methyl iodide (38 μl, 0·6 mmol) was then added, but t.l.c. showed no reaction. The mixture was allowed to warm (overnight, room temperature), whereupon t.l.c. again showed mainly starting material. Normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave a yellow oil (125 mg). Preparative t.l.c. (EtOAc/petrol, 1 : 1) gave the epoxy alcohol (7) (65 mg), m.p. 122·5–124°.

(ii) To a solution of the epoxy alcohol (7) (120 mg) in dry tetrahydrofuran (5 ml, argon atmosphere) was added potassium t-butoxide (110 mg, 1·0 mmol), and the mixture stirred (5 min). Methyl iodide (63 μl, 1·0 mmol) was added, and immediately a white precipitate formed. After a short time (15 min), t.l.c. showed complete conversion into a less polar compound. Normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave *methyl 6,7-anhydro-2,3-di-O-benzyl-8-deoxy-4-O-methyl-α-D-threo-D-galacto-octoside* (31) as a colourless oil (110 mg, 89%), $[\alpha]_D$ +46·6°, R_F 0·35 (EtOAc/petrol, 1 : 1) (Found: C, 69·7; H, 7·5. $C_{24}H_{30}O_6$ requires C, 69·6; H, 7·3%). ^{1}H n.m.r. (80 MHz) δ 1·33, d, $J_{7,Me}$ 5·0 Hz, Me; 2·75–3·05, m, H6,7; 3·35, 3·59, 2s, 6H, OMe; 3·30–4·10, m, H2,3,4,5; 4·55–4·95, m, 5H, PhC**H**$_2$, H1; 7·10–7·50, m, 10H, Ph. ^{13}C n.m.r. (20·1 MHz) δ 17·3, C8; 51·1, C6; 55·5, OMe (C1); 58·8, C7; 61·4, OMe (C4); 71·9, 76·5, 78·5, 79·7, C2,3,4,5; 73·5, 73·8, 2C, Ph**C**H$_2$; 98·9, C1; 127·8, 128·2, 128·6, 10C, Ph; 138·7, 138·9, 2C, Ph.

Attempt at Formation of Methyl 6,7-Anhydro-2,3-di-O-benzyl-8-deoxy-4-O-(dimethylamidino)-α-D-threo-D-galacto-octoside (33)

To petrol-washed sodium hydride (75 mg of 50%, 1·6 mmol) was added the epoxy alcohol (7) (290 mg, 0·72 mmol) in dry dimethylcyanamide (2·0 ml), and the mixture stirred (10 min). T.l.c. appeared to show the presence of the epoxy alcohol (7), together with baseline material. The reaction mixture was diluted with EtOAc, washed with water (×3) and brine, then dried and concentrated to give a yellow-brown oil. Flash chromatography (EtOAc/petrol, 3 : 7) gave no fractions containing recognizable fragments of the starting material.

Methyl 6,7-Anhydro-2,3-di-O-benzyl-8-deoxy-4-O-(N-trichloroacetylcarbamoyl)-α-D-threo-D-galacto-octoside (36)

The epoxy alcohol (7) (200 mg, 0·5 mmol) was dissolved in dry tetrahydrofuran (4 ml, argon atmosphere), and trichloroacetyl isocyanate (65 μl, 0·55 mmol) added. T.l.c. showed that a less polar material had been formed and that no starting material was present. The mixture was concentrated to give a colourless oil (330 mg). $\bar{\nu}_{max}$ (thin film) 1720, 1790 cm^{-1} (CO). ^{1}H n.m.r. (60 MHz) δ 1·26, d, $J_{7,Me}$ 5 Hz, Me; 2·65–3·05, m, H6,7; 3·3, s, OMe; 3·45–4·2, m, H2,3,5; 4·4–4·9, m, 5H, PhC**H**$_2$; 5·4–5·5, m,, H4; 7·18, s, 10H, Ph. Flash chromatography (EtOAc/petrol, 2 : 8) of this oil did not provide any recognizable product.

Attempts to Open the Epoxide Ring of the Acylcarbamate (36)

(i) Trichloroacetyl isocyanate (70 μl, 0·6 mmol) was added to a solution of the epoxy alcohol (7) (200 mg, 0·5 mmol) in dry tetrahydrofuran (4 ml, argon atmosphere). After complete consumption of the starting material (t.l.c.), the volume of solvent was reduced to half with a stream of argon, and then potassium t-butoxide (60 mg, 0·6 mmol) added. After standing (overnight) the mixture was diluted with EtOAc, washed with water (×2) and brine, then dried and concentrated to give a colourless oil (300 mg). T.l.c., and the infrared and ^{1}H n.m.r. (60 MHz) spectra, indicated only the presence of the acylcarbamate (36).

(ii) The above experiment was repeated, but with the extra addition of 18-crown-6 ether (5 mg). Workup gave a yellow oil (310 mg), and flash chromatography (EtOAc/petrol, 1 : 1) gave *methyl 6,7-anhydro-2,3-di-O-benzyl-4-O-carbamoyl-8-deoxy-α-D-threo-D-galacto-octoside* (37) (125 mg, 56%), m.p. 148–150° (diisopropyl ether), $[\alpha]_D$ +74·8°. $\bar{\nu}_{max}$ (KBr) 1645 cm^{-1} (CO); R_F 0·20 (EtOAc/petrol, 1 : 1) (Found: C, 64·9, H, 6·7. $C_{24}H_{29}NO_7$ requires C, 65·0; H, 6·6%). ^{1}H n.m.r. (300 MHz) δ 1·28, d, $J_{7,Me}$ 5·2 Hz, Me; 2·79, dd, $J_{5,6}$ 5·3, $J_{6,7}$ 2·2 Hz, H6; 2·94, dq, H7; 3·38, s, OMe; 3·58, dd, $J_{4,5}$ 1·0 Hz, H5; 3·84, dd, B part of ABMX, $J_{1,2}$ 3·6, $J_{2,3}$ 10·1 Hz, H2; 3·95, dd, A part of ABMX, $J_{3,4}$ 3·5 Hz, H3; 4·58–4·88, 2×ABq, 4H,

PhC**H**$_2$; 4·73, d, H1; 5·45, dd, H4; 7·25–7·39, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 17·06, C8; 50·95, C6; 55·58, OMe; 58·15, C7; 69·71, 70·36, 75·50, 75·80, C2,3,4,5; 72·26, 73·58, 2C, Ph**C**H$_2$; 98·89, C1; 127·75, 127·88, 128·04, 128·35, 128·41, 10C, Ph; 137·89, 138·44, 2C, Ph.

(iii) To a solution of the epoxy alcohol (7) (200 mg) in dry tetrahydrofuran (2·5 ml, argon atmosphere) was added trichloroacetyl isocyanate (70 μl). After stirring (5 min), t.l.c. showed the absence of starting material. Methanol (2 ml) and potassium carbonate (50 mg) were added and the mixture was stirred (overnight). T.l.c. then showed the absence of both acylcarbamate (36) and epoxy alcohol (7). Concentration of the reaction mixture gave a white solid, from which the carbamate (37) (127 mg) was crystallized directly. Preparative t.l.c. (EtOAc/petrol, 1 : 1) of the mother liquors gave a further amount (55 mg: total 182 mg, 82%), m.p. 148–150° (diisopropyl ether/petrol).

Attempts to Open the Epoxide Ring of the Carbamate (37)

(i) The carbamate (37) (110 mg, 0·25 mmol) was dissolved in dry dimethylformamide (2 ml, argon atmosphere), and added to a suspension of petrol-washed potassium hydride (40 mg, 1·0 mmol) in dry dimethylformamide (1 ml, argon atmosphere). After standing (overnight) t.l.c. showed formation of the epoxy alcohol (7). The reaction mixture was diluted with Et_2O, washed with water (×3) and brine, then dried and concentrated to give a pale yellow oil (87 mg) which began to crystallize. Flash chromatography (EtOAc/petrol, 3 : 7) of this mixture gave the epoxy alcohol (7) (60 mg, 60%), m.p. 123–125°.

(ii) The carbamate (37) (55 mg, 0·12 mmol) was dissolved in dry tetrahydrofuran (2 ml, argon atmosphere). Potassium t-butoxide (25 mg, 0·2 mmol) was added and the mixture heated at reflux (2 h). T.l.c. then indicated only the presence of the epoxy alcohol (7). The mixture was concentrated and flash chromatography (EtOAc/petrol, 3 : 7) of this residue gave the epoxy alcohol (7) (38 mg, 77%), m.p. 124–126°.

(iii) The carbamate (37) (110 mg) was dissolved in dry tetrahydrofuran (2·5 ml, argon atmosphere), BuLi (300 μl of 1·65 M, 0·5 mmol) added and the mixture stirred (5 min). T.l.c. then indicated only the presence of the epoxy alcohol (7). The mixture was diluted with EtOAc, washed with water (×2) and brine, then dried and concentrated to give a pale yellow oil (105 mg) which crystallized. Flash chromatography (EtOAc/petrol, 3 : 7) of this residue gave the epoxy alcohol (7) (48 mg, 48%), m.p. 122–124°.

(iv) To a solution of the carbamate (37) (55 mg) in dry tetrahydrofuran (2·5 ml, argon atmosphere) was added a solution of lithium hexamethyldisilamide (0·2 mmol) in dry tetrahydrofuran (1·0 ml, argon atmosphere) [prepared from hexamethyldisilazane (46 μl, 0·22 mmol) and BuLi (125 μl of 1·6 M in hexane, 0·2 mmol)]. T.l.c. (5 min) showed only the presence of starting material. Later (2 h), t.l.c. showed formation of some epoxy alcohol (7). Methyl iodide (100 μl, 1·6 mmol) was then added and the mixture allowed to stand (overnight). A white precipitate had formed but t.l.c. showed no change. The mixture was diluted with EtOAc, and washed with $NaHSO_3$, water (×3) and brine; it was then dried and concentrated to give a yellow oil (55 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of this oil gave no fractions containing recognizable fragments of the starting material.

(v) To a solution of the carbamate (37) (70 mg, 0·16 mmol) in dry tetrahydrofuran (1·0 ml, −78°, argon atmosphere) was added a solution of potassium hexamethyldisilamide (0·9 mmol) in dry tetrahydrofuran (2·0 ml, argon atmosphere) [prepared from hexamethyldisilazane (210 μl, 1·0 mmol) and potassium hydride (35 mg, 0·9 mmol)]. T.l.c. (5 h) showed formation of the epoxy alcohol (7). The mixture was diluted with EtOAc, and washed with water (×3) and brine, then dried and concentrated to give a colourless solid (52 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of the solid gave the epoxy alcohol (7) (40 mg, 63%), m.p. 124–126°.

Methyl (E)-*2,3-Di*-O-*benzyl-4*-O-*carbamoyl-6,7,8-trideoxy-α*-D-galacto-*oct-6-enoside (39)*

To a solution of the alcohol (1) (580 mg, 1·5 mmol) in dry Et_2O (5 ml, argon atmosphere) was added trichloroacetyl isocyanate (180 μl, 1·5 mmol). After stirring (5 min) t.l.c. showed the absence of starting material. Methanol (3 ml) and potassium carbonate (250 mg) were added and the mixture was stirred (overnight). T.l.c. (EtOAc/petrol, 4 : 6) then showed the presence of a more polar compound. The mixture was diluted with Et_2O (15 ml), washed with water (×3) and brine, then dried and concentrated to give a colourless oil (830 mg). Flash chromatography (EtOAc/petrol, 3 : 7) of this oil gave *methyl* (E)-*2,3-di*-O-*benzyl-4*-O-

carbamoyl-6,7,8-trideoxy-α-D-galacto-*oct-6-enoside* (39) (500 mg, 78%), $[\alpha]_D$ +130°. $\bar{\nu}_{max}$ (thin film) 1720 (CO), 1600 cm^{-1} (C=C); R_F 0·25 (EtOAc/petrol, 4 : 6) (Found: C, 67·3; H, 7·1; N, 3·2. $C_{24}H_{29}NO_6$ requires C, 67·4; H, 6·8; N, 3·3%). ^1H n.m.r. (300 MHz) δ 1·63, dd, $J_{6,Me}$ 0·6, $J_{7,Me}$ 6·5 Hz, Me; 3·39, s, OMe; 3·86, dd, B part of ABMX, $J_{1,2}$ 3·6, $J_{2,3}$ 10·1 Hz, H2; 3·98, dd, A part of ABMX, $J_{3,4}$ 3·4 Hz, H3; 4·26–4·29, m, H5; 4·55–4·86, 2×ABq, 4H, PhC**H**$_2$; 4·74, d, H1; 5·34, dd, $J_{4,5}$ 1·1 Hz, H4; 5·44, ddq, $J_{5,6}$ 6·6, $J_{6,7}$ 15·4 Hz, H6; 5·79, ddq, $J_{5,7}$ 1·1 Hz, H7; 7·22–7·98, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 17·89, C8; 55·58, OMe; 69·48, 71·12, 75·49, 76·33, C2,3,4,5; 72·11, 73·56, 2C, Ph**C**H$_2$; 98·93, C1; 127·65, 127·69, 127·92, 128·14, 128·30, 128·31, 12C, Ph, C6,7; 137·97, 138·56, 2C, Ph; 156·49, CO.

Treatment of Methyl (E)*-2,3-Di-O-benzyl-4-O-carbamoyl-6,7,8-trideoxy-α*-D-galacto-*oct-6-enoside (39) with* N*-Bromosuccinimide*

To a cooled (0°) solution of the alkene (39) (190 mg, 0·45 mmol) in a mixture of CH_2Cl_2 (2·5 ml), acetic acid (2·5 ml) and water (120 μl) was added *N*-bromosuccinimide (77 mg, 0·44 mmol), and the mixture stirred (15 min) in the absence of light. T.l.c. showed essentially a single, less polar compound, and normal workup (EtOAc), with an initial $NaHSO_3$ wash, gave a colourless oil (210 mg) which slowly crystallized. Two recrystallizations gave a colourless solid (92 mg), m.p. 133–134·5° (diisopropyl ether), $[\alpha]_D$ +107°. $\bar{\nu}_{max}$ (thin film) 1730 cm^{-1} (C=N); R_F 0·35 (EtOAc/petrol, 1 : 1) (Found: C, 57·0; H, 5·4. $C_{24}H_{28}BrNO_6$ requires C, 56·9; H, 5·6%). The following data are for the major component of the apparent mixture (4 : 1), assigned as methyl 2,3-di-*O*-benzyl-7-bromo-4,6-*O*-carbonimidoyl-7,8-dideoxy-*β*-L-*threo*-D-*galacto*-octoside (41): ^1H n.m.r. (300 MHz) δ 1·83, d, $J_{7,Me}$ 5·2 Hz, Me; 3·47, s, OMe; 3·86, dd, B part of ABMX, $J_{1,2}$ 3·5, $J_{2,3}$ 9·9 Hz, H2; 3·98, dd, A part of ABMX, $J_{3,4}$ 3·0 Hz, H3; 4·26–4·32, m, H6,7; 4·48, s, H5; 4·61–4·62, m, H1,4; 4·62–4·90, 2×ABq, 4H, PhC**H**$_2$; 7·26–7·42, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 21·86, C8; 43·27, C7; 56·65, OMe; 62·54, C6; 74·83, 75·25, 76·73, 82·55, C2,3,4,5; 73·03, 74·24, 2C, Ph**C**H$_2$; 99·19, C1; 127·71, 127·76, 127·80, 128·17, 128·08, 128·52, 10C, Ph; 137·93, 138·03, 2C, Ph; 146·72, C=N.

Attempted Formation of the Fluoren-9-ylmethoxycarbonyl-Protected Amino Acid Ester (44)

(i) To a solution of the epoxy alcohol (7) (100 mg, 0·25 mmol) and the fluoren-9-ylmethoxycarbonyl-protected amino acid (43) (190 mg, 0·5 mmol) in dry CH_2Cl_2/dimethylformamide (5 ml, 4 : 1) was added 4-dimethylaminopyridine (70 mg, 0·5 mmol). A solution of dicyclohexylcarbodiimide (200 mg, 1·0 mmol) in dry CH_2Cl_2 (2 ml) was then added and the mixture allowed to stand (overnight). T.l.c. showed mainly the epoxy alcohol (7) with some less polar material present. Further amounts of the fluorenylmethoxycarbonyl-protected amino acid (43) (190 mg, 0·5 mmol), 4-dimethylaminopyridine (70 mg, 0·5 mmol) and dicyclohexylcarbodiimide (200 mg, 1·0 mmol) were added, and the mixture was allowed to stand overnight. T.l.c. showed no change from before, and normal workup (EtOAc) gave a yellow oil (200 mg). Flash chromatography (EtOAc/petrol, 3 : 7) gave firstly the less polar material as a yellow oil (50 mg), the ^1H n.m.r. (300 MHz) spectrum of which showed mainly a mixture of two compounds with three other minor components, one of which appeared to contain a fluorenylmethoxycarbonyl-protected amino group. The next material to be eluted was the epoxy alcohol (7) (50 mg), m.p. 123–125°.

(ii) To a solution of the epoxy alcohol (7) (80 mg, 0·2 mmol) and the fluorenylmethoxycarbonyl-protected amino acid (43) (150 mg, 0·4 mmol) in dry EtOAc (5 ml) was added pyridine (32 μl, 0·4 mmol). A solution of dicyclohexylcarbodiimide (80 mg, 0·4 ml) in dry EtOAc (2 ml) was added and the mixture heated at reflux (2 days). T.l.c. showed mainly the epoxy alcohol (7). Normal workup (EtOAc) gave a yellow oil (100 mg), and flash chromatography (EtOAc/petrol, 3 : 7) gave the epoxy alcohol (7) (60 mg), m.p. 123–125°.

(iii) To a solution of the epoxy alcohol (7) (100 mg) and the fluorenylmethoxycarbonyl-protected amino acid (43) (95 mg, 0·25 mmol) in dry CH_2Cl_2/dimethylformamide (5 ml, 4 : 1) was added a solution of dicyclohexylcarbodiimide (50 mg, 0·25 mmol) in dry CH_2Cl_2 (2 ml), and the mixture allowed to stand (2 days). T.l.c. showed mainly the epoxy alcohol (7) with some less polar material present. Further amounts of the fluorenylmethoxycarbonyl-protected amino acid (43) (95 mg) and dicyclohexylcarbodiimide (50 mg) were added, and the mixture was heated (100°, overnight). T.l.c. showed no change from before. Further amounts of

(43) (190 mg) and dicyclohexylcarbodiimide (50 mg, 0·25 mmol) were added together with 4-dimethylaminopyridine (35 mg), and heating was continued (overnight). T.l.c. showed mainly more polar material to be present. Normal workup (EtOAc) gave an orange oil (450 mg). Flash chromatography (EtOAc/petrol, 3 : 7) gave the more polar material as an orange oil (80 mg), the ^{1}H n.m.r. (60 MHz) spectrum of which showed no fluorenylmethoxycarbonyl-protected amino group or epoxide protons.

*Methyl 6,7-Anhydro-2,3-di-*O*-benzyl-4-*O*-(2-t-butoxycarbonylamino-2-phenylacetyl)-8-deoxy-α-*D*-threo-*D*-galacto-octoside (45)*

To a solution of the epoxy alcohol (7) (400 mg, 1·0 mmol) and 4-dimethylaminopyridine (250 mg, 2·0 mmol) in dry carbon tetrachloride (5 ml) was added a solution of the t-butoxycarbonyl-protected amino acid (46) (500 mg, 2·0 mmol) in dry carbon tetrachloride (5 ml). A solution of dicyclohexylcarbodiimide (800 mg, 4·0 mmol) in dry carbon tetrachloride (5 ml) was then added and the mixture stirred (3 h). T.l.c. showed none of the epoxy alcohol (7) present. The mixture was cooled in ice, then filtered through a pad of Celite, and the pad washed with ice-cold carbon tetrachloride. The filtrate was concentrated to give a yellow oil (680 mg). Flash chromatography (EtOAc/petrol, 3 : 7) gave the t-butoxycarbonyl-protected amino ester (45) (600 mg, 95%) as a colourless oil. $\bar{\nu}_{max}$ (thin film) 1720 cm^{-1} (CO); R_F 0·27 (EtOAc/petrol, 1 : 1). ^{1}H n.m.r. (60 MHz) δ 1·27, d, $J_{7,Me}$ 5 Hz, Me; 1·38, s, CMe_3; 2·6–3·0, m, H6,7; 3·29, s, OMe; 3·25–3·45, 3·65–4·75, 2m, 9H, H1,2,3,5, PhC**H**$_2$, Ph**CH**; 5·15–5·55, m, H4, NH; 6·9–7·4, m, 15H, Ph.

*6,7-Anhydro-1,2:3,4-di-*O*-isopropylidene-α-*D*-threo-*D*-galacto-octose (47)*

To a stirred solution of the allylic alcohol (2) (2·94 g, 8·8 mmol) in dry CH_2Cl_2 (140 ml, 0°) was added *m*-chloroperbenzoic acid (2·5 g of 85%, 12 mmol) in portions (0·5 h), and the mixture stirred (5 h, 0°). Normal workup (CH_2Cl_2), with an initial $NaHSO_3$ wash, gave a colourless oil (2·1 g). Flash chromatography (EtOAc/petrol, 1 : 1) of this oil eluted firstly the *β-L-threo* epoxide (48) (510 mg, 19%), $[\alpha]_D$ −97·5° (lit.[22] −90°), R_F 0·20 (EtOAc/petrol, 1 : 1). ^{1}H n.m.r. (300 MHz) δ 1·32, 1·37, 1·47, 1·49, 4s, 12H, CMe_2; 2·61, br s, OH; 3·17, ddd, $J_{6,7}$ 6·0, $J_{7,8}$ 2·7, 4·6 Hz, H7; 3·24, dd, $J_{5,6}$ 5·9 Hz, H6; 3·58, dd, $J_{4,5}$ 1·9 Hz, H5; 3·65, dd, B part of ABX, $J_{8,8}$ 12·7 Hz, H8; 3·91, dd, A part of ABX, H8; 4·32, dd, $J_{3,4}$ 7·9 Hz, H4; 4·35, dd, $J_{1,2}$ 4·9, $J_{2,3}$ 2·5 Hz, H2; 4·63, dd, H3; 5·52, d, H1. ^{13}C n.m.r. (75·4 MHz) δ 24·34, 24·86, 25·93, 26·03, 4C, C**Me**$_2$; 54·48, 57·89, C6,7; 61·56, C8; 67·80, 70·43, 70·46, 71·24, C2,3,4,5; 96·08, C1; 108·73, 109·51, 2C, **C**Me$_2$. The second compound to be eluted was the *α-D-threo* epoxide (47) (1·5 g, 57%) as a glass, $[\alpha]_D$ −57·8° (lit.[22] −65·6°), R_F 0·15 (EtOAc/petrol, 1 : 1). ^{1}H n.m.r. (300 MHz) δ 1·33, 1·35, 1·49, 3s, 12H, CMe_2; 2·54, br s, OH; 3·15, ddd, $J_{6,7}$ 5·9, $J_{7,8}$ 2·8, 4·4 Hz, H7; 3·25, dd, $J_{5,6}$ 6·0 Hz, H6; 3·52, dd, $J_{5,6}$ 6·0 Hz, H6; 3·52, dd, $J_{4,5}$ 1·9 Hz, H5; 3·69, dd, B part of ABX, $J_{8,8}$ 12·7 Hz, H8; 3·91, dd, A part of ABX, H8; 4·27, dd, $J_{3,4}$ 7·8 Hz, H4; 4·32, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 2·4 Hz, H2; 4·61, dd, H3; 5·57, d, H1. ^{13}C n.m.r. (75·4 MHz) δ 24·39, 24·87, 25·95, 26·06, 4C, C**Me**$_2$; 54·73, 55·16, C6,7; 61·54, C8; 69·25, 70·32, 70·65, 71·96, C2,3,4,5; 96·22, C1; 108·73, 109·79, 2C, **C**Me$_2$.

Peracid Epoxidation of Methyl (E)*-2,3-Di-*O*-benzyl-6,7-dideoxy-4-*O*-(4-methoxybenzyl)-α-*D*-galacto-oct-6-enoside (49)*

m-Chloroperbenzoic acid (880 mg of 80%, 4 mmol) was added to a solution of the alkene (49) (1·3 g, 2·5 mmol) in dry CH_2Cl_2 (50 ml, 0°), and the mixture stirred (10 h). Normal workup (CH_2Cl_2), with an initial $NaHSO_3$ wash, gave a colourless oil (1·1 g). Flash chromatography (EtOAc/petrol, 1 : 1) gave a material homogeneous by t.l.c. (620 mg, 46%) which crystallized (diisopropyl ether). The ^{13}C n.m.r. spectrum (20·1 MHz) showed a 1 : 1 mixture of the epoxides (50) and (51).

*7-Azido-7-deoxy-1,2:3,4-di-*O*-isopropylidene-β-L-erythro-D-galacto-octose (52)*

(i) To a solution of the epoxy alcohol (47) (300 mg, 1·0 mmol) in dry benzene (10 ml, N_2 atmosphere) were added titanium(IV) isopropoxide (440 μl, 1·5 mmol) and azidotrimethylsilane (395 μl, 3·0 mmol), and the mixture was heated at reflux (2 h). The benzene was removed,

the residue taken up in Et_2O (30 ml), dilute hydrochloric acid (15 ml of 1 M) added and the mixture stirred (0·5 h). The aqueous layer was separated and the organic layer washed with water, $NaHCO_3$ and brine, then dried and concentrated to give a yellow oil (150 mg). Flash chromatography of the oil gave the *azido diol* (52) (90 mg, 26%), m.p. 93–93·5° (diisopropyl ether/petrol), $[\alpha]_D$ −71·2°. $\bar{\nu}_{max}$ (thin film) 2090 cm^{-1} (N_3); R_F 0·25 (EtOAc/petrol, 1 : 1) (Found: C, 48·8; H, 6·6; N, 12·1. $C_{14}H_{23}N_3O_7$ requires C, 48·7; H, 6·7; N, 12·2%). ^1H n.m.r. (300 MHz) δ 1·35, 1·36, 1·50, 1·58, 4s, 12H, CMe_2; 2·55, br s, OH; 3·72, ddd, $J_{6,7}$ 9·3, $J_{7,8}$ 4·4, 4·5 Hz, H7; 3·89, dd, $J_{5,6}$ 2·3 Hz, H6; 3·93, dd, B part of ABX, $J_{8,8}$ 12·3 Hz, H8; 4·02, dd, A part of ABX, H8; 4·02, dd, $J_{4,5}$ 1·8 Hz, H5; 4·35, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 2·4 Hz, H2; 4·41, dd, $J_{3,4}$ 8·0 Hz, H4; 4·65, dd, H3; 5·64, d, H1. ^{13}C n.m.r. (75·4 MHz) δ 23·93, 24·95, 25·50, 25·70, 4C, C**Me**$_2$; 62·80, 64·34, C6,7; 62·94, C8; 70·94, 71·15, 72·32, 74·32, C2,3,4,5; 96·69, C1; 109·04, 109·93, 2C, **C**Me_2.

(ii) To a solution of the epoxy alcohol (47) (460 mg, 1·55 mmol) in dry benzene (20 ml, N_2 atmosphere) was added titanium(IV) diazide diisopropoxide (500 mg, 2 mmol), and the mixture heated at reflux (6 h). Water (2 ml) and acetic acid (2 ml) were then added and reflux was continued (2 h). Filtration through Celite and concentration, followed by azeotropic removal of traces of acetic acid and water with toluene, gave a yellow oil (415 mg). Flash chromatography (EtOAc/petrol, 1 : 1) of this oil gave firstly the azido diol (52) (260 mg, 49%) which crystallized on standing, m.p. 93–94°. The second compound to be eluted was the epoxide (47) (140 mg) (^1H n.m.r.).

*7-Azido-7-deoxy-1,2:3,4-di-*O*-isopropylidene-8-*O*-tosyl-β-*L*-*erythro*-*D*-galacto-octose*

The azido diol (52) (260 mg, 0·76 mmol) was dissolved in dry CH_2Cl_2 (10 ml); pyridine (2 ml) and tosyl chloride (300 mg, 1·5 mmol) were added, and the mixture was allowed to stand (24 h). Water (2 ml) was added and the mixture stirred (24 h); normal workup (CH_2Cl_2) then gave a clear oil (375 mg). Flash chromatography (EtOAc/petrol, 1 : 1) of this oil gave *7-azido-7-deoxy-1,2:3,4-di-*O*-isopropylidene-8-*O*-tosyl-β-*L*-erythro-octose* (335 mg, 88%) as a clear oil which crystallized, m.p. 84·5–85·5° (diisopropyl ether), $[\alpha]_D$ −46·3°. $\bar{\nu}_{max}$ (KBr) 2095 cm^{-1} (N_3); R_F 0·40 (EtOAc/petrol, 1 : 1) (Found: C, 50·6; H, 5·9. $C_{21}H_{29}N_3O_9S$ requires C, 50·5; H, 5·8%). ^1H n.m.r. (300 MHz) δ 1·33, 1·34, 1·47, 1·55, 4s, 12H, CMe_2; 2·45, s, Ar**Me**; 3·72, d, B part of ABXY, $J_{6,8}$ 0, $J_{7,8}$ 0, $J_{8,8}$ 9·8 Hz, H8; 3·82, s, OH; 3·87, ddd, A part of ABXY, $J_{6,8}$ 2·7, $J_{7,8}$ 7·2 Hz, H8; 3·96–4·01, m, H5; 4·21, dd, $J_{6,7}$ 10·2 Hz, H7; 4·34, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 2·4 Hz, H2; 4·37, dd, $J_{3,4}$ 8·0, $J_{4,5}$ 1·8 Hz, H4; 4·45, dd, $J_{5,6}$ 0 Hz, H6; 4·63, dd, H3; 5·61, d, H1; 7·33–7·38, BB′ part of AA′BB′, 2H, Ar; 7·81–7·84, AA′ part of AA′BB′, 2H, Ar. ^{13}C n.m.r. (75·4 MHz) δ 21·65, Ar**Me**; 23·88, 24·91, 25·37, 25·66, 4C, C**Me**$_2$; 60·49, C7; 63·65, C6; 69·82, C8; 70·44, 71·16, 72·00, 74·22, C2,3,4,5; 96·66, C1; 109·02, 109·95, 2C, **C**Me_2; 128·0, 129·89, 4C, Ar; 132·60, 144·9, 2C, Ar.

*7-Deoxy-7-diallylamino-1,2:3,4-di-*O*-isopropylidene-β-*L*-erythro-*D*-galacto-octose (53)*

To a solution of the epoxy alcohol (47) (550 mg, 1·8 mmol) in dry diallyamine (18 ml, room temperature, N_2 atmosphere) was added titanium(IV) isopropoxide (820 μl, 2·8 mmol), and the mixture allowed to stand (24 h). The solution was then diluted with Et_2O (20 ml), and a 5% NaOH in brine solution (10 ml) added. This mixture was filtered through a pad of Celite, and the pad washed with CH_2Cl_2. The organic layer of the filtrate was separated and concentrated to give a colourless glass (810 mg). Flash chromatography (EtOAc/petrol, 1 : 1) of this glass, followed by recrystallization, gave the *amino diol* (53) (435 mg, 60%), m.p. 124–124·5° (diisopropylether), $[\alpha]_D$ −45·8°. $\bar{\nu}_{max}$ (KBr) 1615 cm^{-1} (C=C); R_F 0·27 (EtOAc/petrol, 1 : 1) (Found: C, 60·3; H, 8·3; N, 3·5. $C_{20}H_{33}NO_7$ requires C, 60·1; H, 8·3; N, 3·5%). ^1H n.m.r. (300 MHz) δ 1·34, 1·35, 1·49, 1·53, 4s, 12H, CMe_2; 3·02–3·08, m, H7; 3·18–3·25, m, 4H, CH_2N; 3·72, dd, B part of ABX, $J_{7,8}$ 5·4, $J_{8,8}$ 11·4 Hz, H8; 3·83, dd, A part of ABX, $J_{7,8}$ 6·1 Hz, H8; 3·99, dd, $J_{4,5}$ 1·6, $J_{5,6}$ 3·9 Hz, H5; 4·17, dd, $J_{6,7}$ 6·2 Hz, H6; 4·33, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 2·3 Hz, H2; 4·34, dd, $J_{3,4}$ 8·0 Hz, H4; 4·62, dd, H3; 5·07–5·17, m, 4H, $=CH_2$; 5·61, d, H1; 5·74–5·88, m, 2H, =CH. ^{13}C n.m.r. (75·4 MHz) δ 23·97, 24·97, 25·82, 25·94, 4C, C**Me**$_2$; 53·45, 2C, CH_2N; 59·25, C8; 59·61, C7; 66·14, C6; 70·48, 70·80, 71·03, 73·44, C2,3,4,5; 96·58, C1; 108·76, 109·42, 2C, **C**Me_2; 117·09, 2C, $=CH_2$; 136·60, 2C, =CH.

*6,8-Di-O-acetyl-7-deoxy-7-diallylamino-1,2:3,4-di-O-isopropylidene-β-*L-erythro-D-galacto-*octose (54)*

The diol (53) (120 mg, 0·30 mmol) was dissolved in pyridine/CH_2Cl_2 (6 ml, 1 : 1), and acetic anhydride (1 ml) added. After standing (16 h), water (1 ml) was added and the mixture stirred (2 h). Dilution with EtOAc (20 ml), washing with water (×3) and brine, followed by drying and concentration gave a heavy yellow oil (135 mg). Flash chromatography (EtOAc/petrol, 2 : 8) of this oil gave the *diacetate* (54) as a colourless oil (125 mg, 86%), $[\alpha]_D$ −45°. $\bar{\nu}_{max}$ (thin film) 1730 (CO), 1635 cm^{-1} (C=C); R_F 0·50 (EtOAc/petrol, 1 : 1) (Found: C, 59·8; H, 7·8. $C_{24}H_{37}NO_9$ requires C, 59·6; H, 7·7%). ^1H n.m.r. (300 MHz) δ 1·29, 1·33, 1·44, 1·54, 4s, 12H, CMe_2; 2·02, 2·04, 2s, 6H, COMe; 3·04–3·11, m, CH_2N; 3·29–3·36, m, CH_2N; 3·45, ddd, $J_{6,7}$ 7·7, $J_{7,8}$ 5·6, $J_{7,8}$ 3·3 Hz, H7; 4·14, B part of ABX, $J_{8,8}$ 12·0 Hz, H8; 4·22, dd, $J_{4,5}$ 1·4, $J_{5,6}$ 4·0 Hz, H5; 4·24–4·29, m, H2,4,8; 4·56, dd, $J_{2,3}$ 7·9, $J_{3,4}$ 2·2 Hz, H3; 5·07–5·19, m, 4H, $=CH_2$; 5·53, dd, H6; 5·58, d, $J_{1,2}$ 5·0 Hz, H1; 5·77–5·89, m, 2H, =CH. ^{13}C n.m.r. (20·1 MHz) δ 20·96, 21·26, 2C, CO**Me**; 24·06, 24·89, 26·04, 4C, C**Me**$_2$; 53·64, 2C, CH_2N; 55·80, C7; 60·51, C8; 65·63, 69·51, 70·97, 71·23, 72·36, C2,3,4,5,6; 96·49, C1; 108·35, 109·04, 2C, **C**Me_2; 117·39, 2C, $=CH_2$; 136·46, 2C, =CH; 170·10, 170·59, 2C, CO.

*8-O-(t-Butyldiphenylsilyl)-7-deoxy-7-diallylamino-1,2,3,4-di-O-isopropylidene-β-*L-erythro-D-galacto-*octose (55)*

The amino diol (53) (400 mg, 1·0 mmol) was dissolved in dry CH_2Cl_2 (10 ml); triethylamine (1·0 ml) and t-butyldiphenylsilyl chloride (780 μl, 3·0 mmol) were added, and the solution was allowed to stand (1 day). The mixture was diluted with EtOAc, washed with water (×3) and brine, then dried and concentrated to give a yellow oil (600 mg). Flash chromatography (EtOAc/petrol, 1 : 9) of this oil gave the *silyl ether* (55) (535 mg, 84%) as a colourless oil, $[\alpha]_D$ −36·5°, R_F 0·27 (EtOAc/petrol, 3 : 7) (Found: C, 67·6; H, 8·0. $C_{36}H_{51}NO_7Si$ requires C, 67·8; H, 8·1%). ^1H n.m.r. (300 MHz) δ 1·08, s, CMe_3; 1·33, 1·34, 1·47, 1·54, 4s, 12H, CMe_2; 3·14, ddd, $J_{6,7}$ 8·6, $J_{7,8}$ 5·2, 6·2 Hz, H7; 3·17–3·50, m, 4H, CH_2N; 3·36, br s, OH; 3·90–4·04, AB part of ABX, $J_{8,8}$ 11·0 Hz, H8,8; 4·09, dd, $J_{5,6}$ 2·2 Hz, H6; 4·27, dd, $J_{4,5}$ 1·8 Hz, H5; 4·32, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 2·2 Hz, H2; 4·36, dd, $J_{3,4}$ 8·1 Hz, H4; 4·61, dd, H3; 5·00–5·11, m, 4H, $=CH_2$; 5·61, d, H1; 5·80–5·93, m, 2H, =CH; 7·32–7·76, m, 10H, Ph. ^{13}C n.m.r. (75·4 MHz) δ 19·7, **C**Me_3; 23·90, 25·01, 25·82, 26·02, 4C, C**Me**$_2$; 26·97, C**Me**$_3$; 54·77, 2C, CH_2N; 59·45, C7; 61·36, C8; 65·22, C6; 70·50, 71·07, 74·38, 76·61, C2,3,4,5; 96·57, C1; 108·58, 109·17, 2C, **C**Me_2; 116·32, 2C, $=CH_2$; 127·52, 127·58, 129·46, 133·48, 133·67, 135·71, 135·83, 137·85, 14C, =CH, Ph.

Treatment of the Silyl Ether (55) with Mesyl Chloride

To the silyl ether (55) (290 mg, 0·46 mmol) in dry CH_2Cl_2 (3·0 ml, 0°, argon atmosphere) were added triethylamine (1·0 ml) and mesyl chloride (78 μl, 1·0 mmol), and the solution was allowed to warm to room temperature (2 h). T.l.c. showed a mixture of compounds so further mesyl chloride (78 μl, 1·0 mmol) was added and the mixture allowed to stand (overnight). T.l.c. showed no change, and the reaction was abandoned.

*6-O-Acetyl-8-O-(t-butyldiphenylsilyl)-7-deoxy-7-diallylamino-1,2 : 3,4-di-O-isopropylidene-β-*L-erythro-D-galacto-*octose*

The silyl ether (55) (110 mg, 0·17 mmol) was dissolved in pyridine (1 ml); acetic anhydride (0·2 ml) was added and the mixture allowed to stand (overnight). T.l.c. indicated complete conversion into a slightly more polar compound. Concentration, followed by dilution with EtOAc, washing with water (×2) and brine, drying and concentration gave a colourless oil (125 mg). Preparative t.l.c. (EtOAc/petrol, 3 : 7) gave *6-O-acetyl-8-O-(t-butyldiphenylsilyl)-7-deoxy-7-diallylamino-1,2:3,4-di-O-isopropylidene-β-*L-erythro-D-galacto-*octose* as a colourless oil (75 mg, 65%), $[\alpha]_D$ −22·3°, R_F 0·40 (EtOAc/petrol, 3 : 7) (Found: C, 66·9; H, 7·6. $C_{38}H_{53}NO_8Si$ requires C, 67·1; H, 7·9%). ^1H n.m.r. (300 MHz) δ 1·07, s, CMe_3; 1·29, 1·30, 1·42, 1·48, 4s, 12H, CMe_2; 1·85, s, COMe; 3·06–3·41, m, 5H, CH_2N, H7; 3·76–3·86, AB part of ABX system, $J_{8,8}$ 11·0, $J_{7,8}$ 3·6, 5·2 Hz, H8,8; 4·20–4·23, m, H2,5; 4·25, dd, $J_{3,4}$ 7·9, $J_{4,5}$ 1·3 Hz, H4; 4·50, dd, $J_{2,3}$ 1·9 Hz, H3; 5·00–5·15, m, 4H, $=CH_2$; 5·53, dd, $J_{5,6}$ 7·8, $J_{6,7}$ 4·1 Hz, H6; 5·56, d, $J_{1,2}$ 5·0 Hz, H1; 5·75–5·88, m, 2H, =CH; 7·25–7·71, m, 10H,

Ph. ^{13}C n.m.r. (75·4 MHz) δ 18·95, **C**Me_3; 21·27, 24·01, 24·89, 26·09, 5C, C**Me**$_2$, CO**Me**; 26·92, C**Me**; 54·11, 2C, CH_2N; 58·41, C7; 60·85, C8; 66·18, 70·26, 71·16, 71·24, 72·25, C2,3,4,5,6; 96·40, C1; 108·22, 108·87, 2C, **C**Me_2; 116·59, 2C, =CH_2; 127·59, 135·78, 135·81, 137·27, 129·61, 133·16, 133·33, 14C, =CH, Ph; 170·12, CO.

*6,7-Anhydro-8-*O*-(t-butyldiphenylsilyl)-1,2:3,4-di-O-isopropylidene-β-*L*-threo-*D*-galacto-octose (58)*

The epoxy alcohol (47) (295 mg, 0·98 mmol) was dissolved in dry CH_2Cl_2 (5 ml) containing triethylamine (0·5 ml); t-butyldiphenylsilyl chloride (520 μl, 2·0 mmol) was added and the solution allowed to stand (16 h). The mixture was diluted with EtOAc (25 ml), washed with water (×3) and brine, then dried and concentrated to give a brown crystalline solid (840 mg). Recrystallization gave the *epoxy silyl ether* (58) (235 mg) as a colourless crystalline solid. Flash chromatography (EtOAc/petrol, 1 : 9) of the mother liquors gave a further amount of (58) (145 mg; total yield 380 mg, 72%), m.p. 151·5–153° (petrol), $[\alpha]_D$ −40·6°, R_F 0·50 (EtOAc/petrol, 3 : 7) (Found: C, 66·5; H, 7·2. $C_{30}H_{40}O_7Si$ requires C, 66·6; H, 7·4%). ^1H n.m.r. (80 MHz) δ 1·06, s, CMe_3; 1·32, 1·49, 2s, 12H, CMe_2; 3·06–3·27, m, H6,7; 3·48, dd, $J_{4,5}$ 1·6, $J_{5,6}$ 6·3 Hz, H5; 3·6–3·9, m, H8,8; 4·23, dd, $J_{1,2}$ 5·0, $J_{2,3}$ 7·8 Hz, H2; 4·31, dd, $J_{3,4}$ 2·4 Hz, H4; 4·61, dd, H3; 5·58, d, H1; 7·29–7·77, m, 10H, Ph. ^{13}C n.m.r. (20·1 MHz) δ 19·2, **C**Me_3; 24·5, 25·0, 26·1, 26·2, 4C, C**Me**$_2$; 26·8, C**Me**$_3$; 55·0, 55·3, C6,7; 63·9, C8; 69·9, 70·5, 70·8, 72·1, C2,3,4,5; 96·4, C1; 108·8, 109·8, 2C, **C**Me_2; 127·9, 129·9, 133·6, 135·8, 12C, Ph.

Attempted Opening of the Epoxide Ring of the Silyl Ether (58)

To a solution of the epoxy silyl ether (58) (265 mg, 0·50 mmol) in dry diallylamine (5 ml, room temperature, N_2 atmosphere) was added titanium(IV) isopropoxide (220 μl, 0·8 mmol), and the mixture allowed to stand (3 days). T.l.c. then indicated only starting material to be present and the solution was heated at reflux (8 h). T.l.c. again indicated only starting material present. Normal workup (Et_2O) gave the epoxy silyl ether (58) (255 mg), m.p. 151–152°.

*7,8-Dideoxy-1,2:3,4-di-*O*-isopropylidene-7-(tosylamino)-α-*D*-erythro-*D*-galacto-octose (60)*

To a solution of the (*Z*)-alkene (4) (270 mg, 1·0 mmol) in $CHCl_3$ (5 ml) were added OsO_4 (0·5 mg), chloramine-T (350 mg, 1·3 mmol), benzyltriethylammonium chloride (11·4 mg, 0·05 mmol) and water (5 ml). The mixture was stirred and heated (60°, 16 h), whereupon t.l.c. showed no starting material to be present. $NaHSO_3$ (500 mg) was added and the mixture heated at reflux (2 h). The mixture was filtered (Celite); the filtrate was concentrated and dissolved in EtOAc, washed with $NaHSO_3$, 1% NaOH in brine and brine, then dried and concentrated to give a yellow glass (415 mg). Flash chromatography (EtOAc/petrol, 1 : 1) of this glass gave *7,8-dideoxy-1,2:3,4-di-*O*-isopropylidene-7-(tosylamino)-α-*D*-erythro-*D*-galacto-octose* (60) (335 mg, 73%) as an oil, $[\alpha]_D$ −46·6°, R_F 0·27 (EtOAc/petrol, 1 : 1) (Found: C, 55·1; H, 6·8; N, 3·1. $C_{21}H_{31}NO_8S$ requires C, 55·3; H, 6·6; N, 2·9%). ^1H n.m.r. (300 MHz) δ 0·99, d, $J_{7,Me}$ 6·9 Hz, Me; 1·31, 1·33, 1·38, 1·50, 4s, 12H, CMe_2; 2·41, s, Ar**Me**; 3·21, br s, OH; 3·58, dd, $J_{4,5}$ 1·8, $J_{5,6}$ 9·3 Hz, H5; 3·59–3·69, m, H7; 3·84, dd, $J_{6,7}$ 2·8 Hz, H6; 3·36, br s, OH; 4·31, dd, $J_{1,2}$ 5·1, $J_{2,3}$ 2·5 Hz, H2; 4·39, dd, $J_{3,4}$ 7·8 Hz, H4; 4·60, dd, H3; 5·39, $J_{7,NH}$ 9·2 Hz, NH; 5·48, d, H1; 7·26–7·80, m, 4H, Ar. ^{13}C n.m.r. (75·4 MHz) δ 14·51, C8; 21·49, Ar**Me**; 24·61, 24·83, 25·74, 25·92, 4C, C**Me**$_2$; 51·32, C7; 67·36, C6; 70·32, 70·59, 70·66, 71·10, C2,3,4,5; 96·36, C1; 108·68, 109·34, 2C, **C**Me_2; 127·09, 129·66, 4C, Ar; 139·07, 143·15, 2C, Ar.

Attempted Aziridination of the (E)*-Alkene (3)*

The (*E*)-alkene (3) (135 mg, 0·50 mmol) was dissolved in CH_2Cl_2 (5 ml); *N*-aminophthalimide (84 mg, 0·50 mmol) was added, followed by powdered lead(IV) acetate (225 mg, 0·5 mmol) in several portions. The solution turned yellow and a flocculent precipitate formed; the mixture was filtered and the filtrate concentrated to give a yellow solid. The resulting solid was triturated with pentane, and filtered; the filtrate was concentrated to give the (*E*)-alkene (3) (120 mg) (^1H n.m.r.).

Table 1. Non-hydrogen atom coordinates for (7)

Atom	Molecule 1			Molecule 2		
	x	*y*	*z*	*x*	*y*	*z*
C(1)	0·3613(8)	0·6459(A)	0·6238(4)	0·2883(8)	0·2541(4)	0·8334(4)
C(11)	0·3143(8)	0·6237(4)	0·5333(3)	0·2589(8)	0·2773(4)	0·9170(3)
O(11)	0·2638(6)	0·6892(3)	0·4775(3)	0·2102(6)	0·2130(3)	0·9656(3)
C(12)	0·4190(9)	0·6481(4)	0·4781(4)	0·3679(9)	0·2521(5)	0·9921(4)
C(13)	0·4196(11)	0·6032(5)	0·3982(5)	0·3962(11)	0·3019(6)	1·0727(4)
C(2)	0·4657(7)	0·5737(4)	0·6759(3)	0·4136(8)	0·3117(4)	0·8107(4)
O(2)	0·3746(5)	0·5024(2)	0·6527(2)	0·3545(5)	0·3917(3)	0·8186(3)
C(3)	0·4901(7)	0·5927(4)	0·7668(3)	0·4321(7)	0·2955(4)	0·7214(4)
O(3)	0·5782(5)	0·5277(2)	0·8160(2)	0·5362(5)	0·3549(3)	0·6984(2)
C(31)	0·7187(10)	0·5531(5)	0·8761(5)	0·6675(9)	0·3235(5)	0·6647(5)
C(32)	0·7860(8)	0·4865(4)	0·9373(4)	0·7425(7)	0·3879(4)	0·6240(4)
C(33)	0·8241(11)	0·5023(5)	1·0218(5)	0·8693(10)	0·4359(5)	0·6602(5)
C(34)	0·8847(13)	0·4406(7)	1·0740(5)	0·9332(10)	0·4962(5)	0·6190(5)
C(35)	0·9062(13)	0·3674(6)	1·0473(5)	0·8620(12)	0·5042(5)	0·5359(6)
C(36)	0·8733(11)	0·3514(6)	0·9689(6)	0·7366(12)	0·4533(6)	0·4923(6)
C(37)	0·8108(10)	0·4106(5)	0·9080(5)	0·6789(10)	0·3992(5)	0·5393(5)
C(4)	0·3201(7)	0·6059(4)	0·7863(3)	0·2571(8)	0·2962(4)	0·6640(4)
O(4)	0·3421(5)	0·6198(3)	0·8749(2)	0·2746(5)	0·2801(3)	0·5799(2)
C(41)	0·2204(10)	0·5845(7)	0·9101(4)	0·1330(10)	0·3030(8)	0·5192(4)
C(42)	0·2656(9)	0·5844(5)	0·9998(4)	0·1781(8)	0·3077(5)	0·4356(4)
C(43)	0·1791(12)	0·6275(6)	1·0442(5)	0·1786(9)	0·2429(5)	0·3848(4)
C(44)	0·2300(15)	0·6251(6)	1·1353(6)	0·2189(10)	0·2496(7)	0·3113(5)
C(45)	0·3531(16)	0·5753(6)	1·1657(5)	0·2518(11)	0·3251(9)	0·2862(5)
C(46)	0·4437(15)	0·5346(7)	1·1217(5)	0·2522(16)	0·3871(8)	0·3333(6)
C(47)	0·3963(12)	0·5389(6)	1·0385(6)	0·2066(13)	0·3804(6)	0·4044(5)
C(5)	0·2321(8)	0·6742(4)	0·7353(4)	0·1455(8)	0·2354(4)	0·6926(4)
O(5)	0·3311(5)	0·7432(3)	0·7560(2)	0·2124(5)	0·1590(3)	0·6877(3)
C(51)	0·2539(10)	0·8135(5)	0·7192(4)	0·1056(12)	0·0962(5)	0·7019(6)
O(6)	0·2071(5)	0·6558(3)	0·6487(2)	0·1301(5)	0·2542(3)	0·7740(2)

[A] Defines origin.

Table 2. Non-hydrogen atom coordinates for (21)

Atom	*x*	*y*	*z*	Atom	*x*	*y*	*z*
C(1)	0·6195(3)	−0·1099(2)	0·8814(6)	C(37)	0·5582(3)	0·1181(3)	0·1571(8)
C(11)	0·6947(3)	−0·1067(3)	0·9808(7)	C(4)	0·4667(2)	−0·0463(2)	0·7993(5)
O(11)	0·7033(2)	−0·0439(2)	1·1124(5)	O(4)	0·3933(2)	−0·0541(2)	0·7163(4)
C(12)	0·7043(3)	−0·1279(3)	1·1697(8)	C(41)	0·3284(3)	−0·0330(3)	0·8267(7)
C(13)	0·7765(4)	−0·1563(4)	1·2512(9)	C(42)	0·2962(2)	0·0496(3)	0·7859(6)
C(2)	0·6106(3)	−0·0446(3)	0·7396(6)	C(43)	0·3326(3)	0·1031(3)	0·6710(6)
O(2)	0·6674(2)	−0·0581(2)	0·6032(4)	C(44)	0·2999(3)	0·1770(3)	0·6383(8)
C(3)	0·5305(3)	−0·0459(2)	0·6552(6)	C(45)	0·2298(3)	0·1986(3)	0·7158(10)
O(3)	0·5190(2)	0·0229(2)	0·5419(4)	C(46)	0·1941(3)	0·1462(3)	0·8302(10)
C(31)	0·5192(5)	0·0041(4)	0·3576(7)	C(47)	0·2251(3)	0·0720(3)	0·8657(7)
C(32)	0·5006(4)	0·0758(3)	0·2468(6)	C(5)	0·4824(2)	−0·1150(2)	0·9309(5)
C(33)	0·4229(4)	0·0993(4)	0·2331(8)	O(5)	0·4736(2)	−0·1877(2)	0·8399(4)
C(34)	0·4052(4)	0·1632(4)	0·1172(8)	C(51)	0·4751(3)	−0·2564(3)	0·9571(8)
C(35)	0·4636(5)	0·2048(4)	0·0308(8)	O(6)	0·5574(2)	−0·1059(2)	1·0095(3)
C(36)	0·5388(5)	0·1832(4)	0·0485(8)				

Table 3. Non-hydrogen atom coordinates for (52)

Atom	Molecule 1			Molecule 2		
	x	*y*	*z*	*x*	*y*	*z*
C(1)	0·7401(4)	0·7824(4)	0·7449(9)	0·4445(4)	0·8522(4)	0·1722(9)
C(11)	0·7126(4)	0·8107(4)	0·8887(9)	0·4606(4)	0·8136(5)	0·3111(9)
O(11)	0·6707(3)	0·8703(3)	0·8685(6)	0·4876(3)	0·7444(3)	0·2898(6)
C(12)	0·6716(4)	0·7575(5)	0·9755(10)	0·5068(4)	0·8549(5)	0·4059(10)
C(13)	0·6540(4)	0·7877(5)	1·1235(10)	0·5207(4)	0·8188(5)	0·5482(10)
O(13)	0·6227(3)	0·7331(3)	1·2068(7)	0·5663(4)	0·8641(4)	0·6305(8)
N(1)	0·7164(3)	0·6932(4)	0·9970(8)	0·4738(4)	0·9226(3)	0·4383(10)
N(2)	0·6807(4)	0·6351(4)	1·0036(9)	0·5139(5)	0·9729(4)	0·4435(11)
N(3)	0·6599(5)	0·5829(4)	1·0098(13)	0·5428(6)	1·0232(5)	0·4528(18)
C(2)	0·7874(4)	0·8287(4)	0·6713(10)	0·3942(4)	0·8154(4)	0·0802(10)
O(2)	0·7636(3)	0·8983(2)	0·6642(7)	0·4037(3)	0·7412(3)	0·0623(6)
C(3)	0·7985(4)	0·8077(4)	0·5114(10)	0·3919(4)	0·8426(4)	−0·0762(10)
O(3)	0·7722(3)	0·8626(3)	0·4310(7)	0·4166(3)	0·7892(3)	−0·1636(7)
C(23)	0·7753(5)	0·9233(4)	0·5202(11)	0·4248(4)	0·7248(4)	−0·0849(10)
C(231)	0·7194(5)	0·9713(5)	0·4782(13)	0·3727(5)	0·6695(6)	−0·1418(11)
C(232)	0·8400(5)	0·9624(5)	0·5121(14)	0·4901(5)	0·6992(5)	−0·0897(12)
C(4)	0·7686(4)	0·7405(4)	0·4676(10)	0·4326(4)	0·9097(5)	−0·1018(10)
O(4)	0·8050(2)	0·6816(3)	0·5267(6)	0·3990(3)	0·9680(3)	−0·0357(7)
C(5)	0·6971(4)	0·7297(4)	0·5265(9)	0·4984(4)	0·9079(5)	−0·0234(10)
O(5)	0·6967(3)	0·6552(3)	0·5639(6)	0·5074(3)	0·9773(3)	0·0336(7)
C(45)	0·7597(4)	0·6215(4)	0·5330(10)	0·4502(5)	1·0186(5)	−0·0007(12)
C(451)	0·7589(5)	0·5815(5)	0·3896(11)	0·4659(6)	1·0660(5)	−0·1312(13)
C(452)	0·7771(5)	0·5741(5)	0·6562(11)	0·4277(5)	1·0612(5)	0·1313(13)
O(6)	0·6826(2)	0·7708(3)	0·6502(5)	0·5028(2)	0·8562(3)	0·0879(6)

Table 4. Heterocyclic ring torsion angles (degrees) in (7), (21) and (52)

Atoms are denoted by number (oxygen atoms are italicized). Where two values are given, these are for molecules 1, 2

Features	Atoms	(7)	(21)	(52)
Core rings	*6*–1–2–3	−56·7(5), −53·6(7)	−52·6(4)	−44·9(8), −45·1(9)
	1–2–3–4	56·5(6), 52·8(7)	50·8(4)	−8·8(10), −9·6(10)
	2–3–4–5	−60·1(6), −56·9(7)	−53·0(4)	43·0(9), 40·9(10)
	3–4–5–*6*	60·8(6), 61·1(7)	58·2(4)	−22·3(10), −16·6(10)
	4–5–*6*–1	−62·8(6), −60·1(6)	−62·8(4)	−32·2(8), −41·2(9)
	5–*6*–1–2	60·2(5), 57·5(7)	59·4(4)	68·3(7), 74·0(8)
Fused rings	3–2–*2*–23			−13·6(8), 15·6(8)
	2–*2*–23–*3*			30·4(8), −10·3(8)
	2–23–*3*–3			−35·6(8), −0·5(11)
	23–*3*–3–2			26·3(8), 10·0(9)
	3–3–2–*2*			−7·8(8), −15·5(8)
	5–4–*4*–45			33·7(8), 33·2(8)
	4–*4*–45–*5*			−33·5(8), −32·7(9)
	4–45–*5*–5			20·3(8), 18·3(9)
	45–*5*–5–4			−0·2(17), 2·4(9)
	5–5–4–*4*			−20·3(8), −22·3(8)

Crystallography

Structure Determinations

Unique data sets were measured to the specified $2\theta_{max}$ limits at *c.* 295 K by using Syntex $P2_1$ and ENRAF–Nonius CAD-4 diffractometers (monochromatic Mo Kα radiation, λ 0·71073 Å; $2\theta/\theta$ scan mode). N independent reflections were obtained, N_o with $I > 2\sigma(I)$ being considered 'observed' and used in the 9×9 block-diagonal least-squares refinements without absorption correction after solution of the structures by direct methods. Anisotropic thermal parameters were refined for C, N, O [form: $\exp(-2\pi^2(U_{11}h^2a^{*2}+\cdots+2U_{23}klb^*c^*))$]; $(x,y,z,U_{iso})_H$ were constrained at estimated values. Conventional residuals on $|F|$ at convergence, R and R', are quoted, statistical reflection weights derivative of $\sigma^2(I) = \sigma^2(I_{diff})+10^{-4}n_w\sigma^4(I_{diff})$ being used. Neutral atom complex scattering factors were employed,[28] the chiralities adopted being those expected on chemical grounds; computation used the X-RAY program system[29] implemented by S. R. Hall. Pertinent results are given in Figs 1–3 and Tables 1–4; material deposited comprises structure factor amplitudes, hydrogen and thermal parameters and molecular non-hydrogen geometries.† Figs 1–3 show non-hydrogen atom labelling and 20% thermal ellipsoids; hydrogen atoms have arbitrary radii of 0·1 Å.

Crystal Data for Compounds (7), (21) and (52)

(7). $C_{23}H_{28}O_6$, M 400·5. Monoclinic, space group $P2_1$ (C_2^2, No. 4), a 8·180(8), b 16·69(1), c 16·443(8) Å, β 103·65(5)°, U 2182 Å^3. $D_c(Z=4)$ 1·21 g cm^{-3}. $F(000)$ 856. μ_{Mo} 0·94 cm^{-1}. Specimen: spheroid, 0·7 mm. $2\theta_{max}$ 50°, N 4127, N_o 2882. R 0·069, R' 0·071 ($n_w = 5$).

(21). $C_{23}H_{28}O_6$, M 400·5. Orthorhombic, space group $P2_12_12_1$ (D_2^4, No. 19), a 17·076(4), b 16·604(2), c 7·425(7) Å, U 2105 Å^3. $D_c(Z=4)$ 1·26 g cm^{-3}. $F(000)$ 856. μ_{Mo} 0·97 cm^{-1}. Specimen: 0·48 by 0·42 by 0·10 mm. $2\theta_{max}$ 55°, N 2678, N_o 1763. R 0·052, R' 0·061 ($n_w = 3$).

(52). $C_{14}H_{23}N_3O_7$, M 345·4. Orthorhombic, space group $P2_12_12_1$, a 20·43(2), b 18·80(1), c 9·209(2) Å, U 3536 Å^3. D_c ($Z=8$) 1·30 g cm^{-3}. $F(000)$ 1472. μ_{Mo} 1·12 cm^{-1}. Specimen: spheroid, 0·7 mm. $2\theta_{max}$ 50°, N 3379, N_o 2203. R 0·077, R' 0·066 ($n_w = 5$).

Abnormal Features

Both (7) and (52) diffracted poorly with measurable data to only about $2\theta \approx 40°$ for specimens of normal size (0·3 mm), incapable of yielding a solution for these fairly large non-centrosymmetric structures, both of which had two independent molecules in the asymmetric unit. Recrystallized material yielded larger specimens; spheroids about 0·7 mm were cut, and, although oversize, yielded useful bodies of data to $2\theta \approx 50°$ which, although weak, enabled solution and meaningful anisotropic refinement of non-hydrogen atoms. Data derivative of these crystals are quoted in this report, but should be used with caution because of the too large crystal size; the more limited conventional data sets were also refined, but lacked sufficient 'observed' data to enable meaningful anisotropic refinement and were discarded. Compound (21) behaved normally; 'observed' data are quoted at the $I > 3\sigma(I)$ level. In all cases, hydroxy hydrogen atoms were located in difference maps.

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† Copies are available on application to the Australian Journal of Chemistry, 314 Albert Street, East Melbourne, Vic. 3002.

[28] Ibers, J. A., and Hamilton, W. C., (Eds) 'International Tables for X-Ray Crystallography' Vol. 4 (Kynoch Press: Birmingham 1974).

[29] Hall, S. R., and Stewart, J. M., (Eds) "XTAL Users' Manual, Version 2.6", Universities of Western Australia and Maryland, 1989.