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Studies on Aminosugars. XXIV. The Facile Elimination of the Derivatives of a Pyranosid-4-ulose*1

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Methyl 3-azido-3-deoxy-α and β-D-xylopyranoside are prepared. The oxidation of the 2-*O*-benzoylated derivative of the above-mentioned α-anomer with the Pfitzner-Moffatt reagent leads to the facile elimination of the elements of benzoic acid and the formation of the 4-azido derivative of 5,6-dihydro-α-pyran-5-one. The 3-ethoxycarbonylamido derivative obtained from the above-mentioned 3-azido derivative is oxidized similarly to afford the 4-ethoxycarbonylamido derivative of 5,6-dihydro-α-pyran-5-one. The mechanisms of these elimination reactions are discussed.

In recent years, it has been shown that the oxidation of suitably-protected carbohydrates with dimethyl sulfoxide in the presence of dicyclohexylcarbodiimide and a proton source,[1] phosphorous pentoxide[2] or acid anhydride[3] is a unique and mild method of general application. The reagents oxidize either primary or secondary sugar hydroxyl groups into aldehydes or ketones which are versatile and which are, especially, of potential importance in the synthesis of branched-chain sugars. On the other hand, the oxidation of a secondary hydroxyl group of sugars into a ketone group sometimes results in the elimination of an acyloxyl group and proton in addition to oxidation affording such enones as pyranoid derivatives. Elimination of this kind is useful for introducing a double bond into the pyranoside ring.

In this paper we will present a study of the oxidation of several protected 3-azido-3-deoxy and 3-ethoxycarbonylamido pyranosides with the above-mentioned reagents; this oxidation resulted in the formation of 4-azido and 4-ethoxycarbonylamido derivatives of 5,6-dihydro-2*H*-pyran-5-one.

The first objective of the synthesis was methyl 3-azido-3-deoxy-α-D-xylopyranoside (VIII). 1,2-*O*-Isopropylidene-α-D-xylopyranose (II) was prepared from D-xylose through 1,2 : 3,5-di-*O*-isopropylidene-α-D-xylofuranose (I) by the method of Levene and Raymond[4] and was tritylated to give the 5-*O*-trityl derivative (III). The oxidation of III with the Pfitzner-Moffatt reagent[1] gave a 3-keto derivative (IV) which, on reduction with sodium borohydride, afforded 1,2-*O*-isopropylidene-5-*O*-trityl-D-ribose (V).[5] It should be noted that, when the oxidation of III was effected with dimethyl sulfoxide-acetic anhydride, 1,2-*O*-isopropylidene - 3 - *O* - methylthiomethyl - 5 - *O* - trityl-α-D-xylofuranose (IV′) was obtained in addition to IV. A mesyl derivative (VI) prepared from V was treated with sodium azide in dimethyl formamide to afford 3-azido-3-deoxy-1,2-*O*-isopropylidene-5-*O*-trityl-D-xylose (VII). The inversion at C-3 of VI was confirmed by a comparison of the NMR spectra of VI, VII, and the 3-*O*-mesyl derivative (VI′) of III.

The treatment of VII with acidic methanol afforded the desired methyl 3-azido-3-deoxy-D-xylopyranoside in the form of an anomeric mixture. The separation of anomers was effected by column chromatography with Dowex 1×2 (OH form) resin; the α-form (VIII) and β-form (VIII′) were thus obtained in approximately equal amounts. Catalytic hydrogenation over platinum oxide gave the α-form(IX) and β-form (IX′) of methyl 3-amino-3-deoxy-D-xyloside respectively. The melting points and optical rotations of IX and IX′ agreed well with those reported for the corresponding substances prepared by entirely different methods;[6,7] this confirmed the pyranoside structure of the azido compounds. The overall yield of

*1 Presented at the 22nd Annual Meeting of the Chemical Society of Japan, Tokyo, April, 1969. (See Preprints for the Meeting, Vol. 3, p. 1898.)

1) K. E. Pfitzner and J. G. Moffatt, *J. Amer. Chem. Soc.*, **85**, 3027 (1963); for a review, see W. W. Epstein and F. W. Sweat, *Chem. Rev.*, **67**, 247 (1967).

2) K. Onodera, S. Hirano and N. Kashimura, *J. Amer. Chem. Soc.*, **87**, 4651 (1965).

3) J. D. Albright and L. Goldman, *J. Amer. Chem. Soc.*, **87**, 4214 (1965); W. Sowa and G. H. S. Thomas, *Can. J. Chem.*, **44**, 836 (1966).

4) P. A. Levene and A. L. Raymond, *J. Biol. Chem.*, **102**, 317 (1933).

5) The same sequence was developed independently by Sowa in his synthesis of 3-amino-3-deoxy-D-ribose; W. Sowa, *Can. J. Chem.*, **46**, 1586 (1968).

6) R. E. Schaub and M. J. Weiss, *J. Amer. Chem. Soc.*, **80**, 4683 (1958).

7) H. H. Bear and H. O. L. Fischer, *ibid.*, **81**, 5184 (1959).

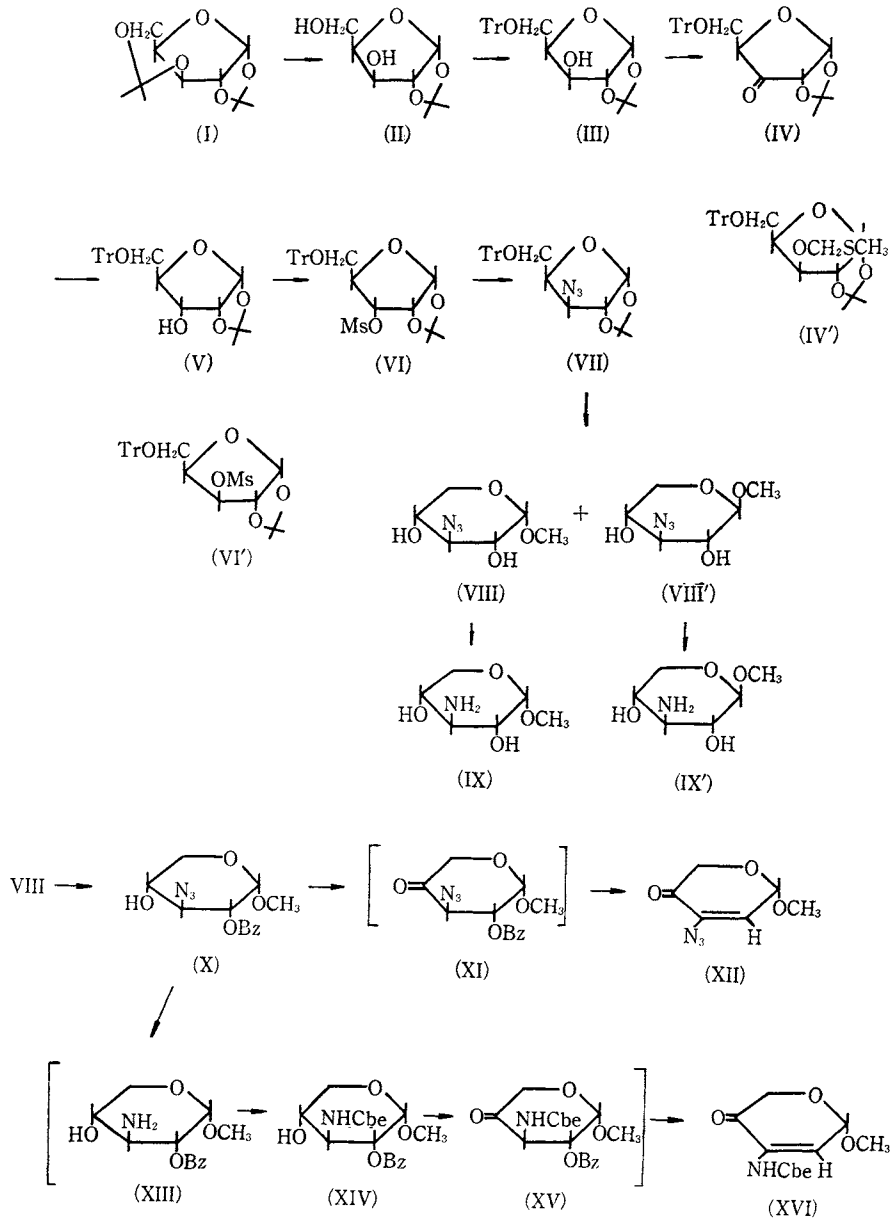


Chart 1. Cbe : $COOC_2H_5$, Bz : COPh, Ms : SO_2CH_3, Tr : CPh_3

the total of IX and IX′ from xylose was about 25%.

The selective benzoylation of the α-anomer (VIII) with benzoyl chloride in pyridine gave 2-*O*-benzoyl derivative (X) in a 70% yield. It is of interest to note that the β-anomer yielded 2 and 4-*O*-benzoylated products in low yields, suggesting that the selectivity is peculiar to the α-anomer.

When the 2-*O*-benzoyl derivative was oxidized with dimethyl sulfoxide-dicyclohexylcarbodiimide-trifluoroacetic acid - pyridine, the product was found to be an azido-ketonic derivative of dihydropyran (XII) which showed a characteristic absorption maximum at 273 mμ (ε 7500). The structural proofs were obtained by infrared and NMR spectroscopy; the patterns, shown in Fig. 1, indicated the structure of XII to be (2S)-4-azido-5,6-dihydro-2-methoxy-α-pyran-5-one. The absence of the expected oxidative product (XI) in the crude product was shown by thin-layer chromatography.

On the other hand, the 2-*O*-benzoyl derivative (X) was hydrogenated over platinum oxide to give an amino derivative (XIII), which was then caused to react with ethyl chloroformate in the presence of sodium bicarbonate to give an ethoxycarbonylamido derivative (XIV). The oxidation

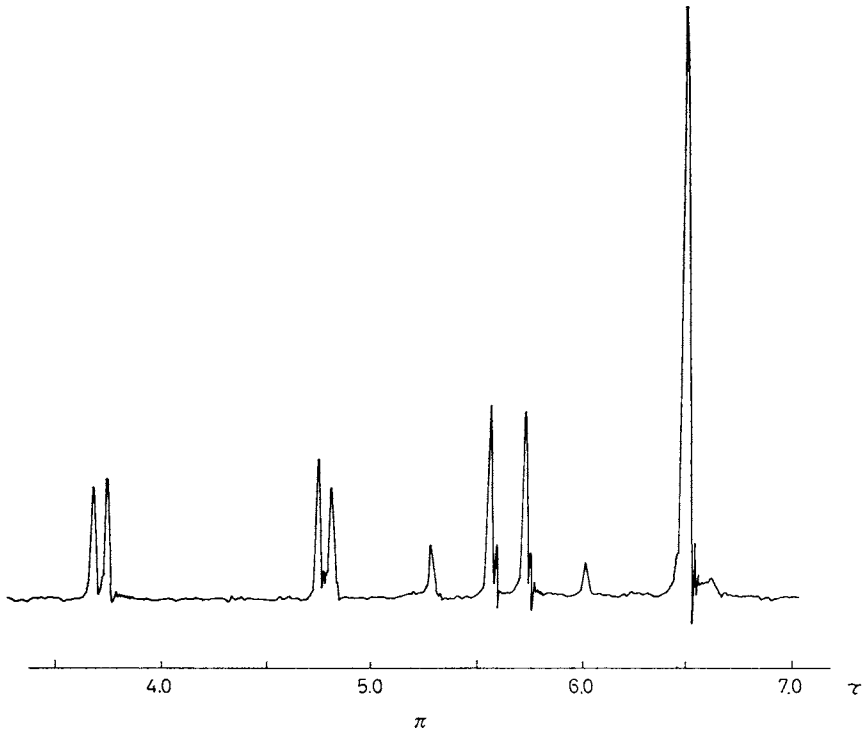


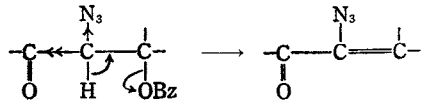
Fig. 1. The NMR spectrum of (2S)-4-azido-5,6-dihydro-2-methoxy-α-pyran-5-one (XII) at 60 MHz in chloroform-*d*.

of XIV with dimethyl sulfoxide-acetic anhydride again afforded a dihydropyran derivative, namely, (2S)-5,6-dihydro-4-ethoxycarbonylamido-2-methoxy-α-pyran-5-one (XVI).

Discussion

Though such an elimination reaction as has been described above appears to be rarely encountered, several definite examples have recently been described. Beynon *et al.*[8] reported that the methyl-3,4,6-tri-*O*-benzoyl-α-D-*arabino*-hexopyranosidulose obtained from methyl 3,4,6-tri-*O*-benzoyl-α-D-glucoside by oxidation with ruthenium tetroxide underwent facile elimination to give an enone, 2-D-*glycero*-benzoyloxymethyl-4-benzoyloxy-6-D-*glycero*-methoxy-5,6-dihydro-α-pyran-5-one. Shibata *et al.*[9] reported that the oxidation of methy 3-acetamido-4,6-di-*O*-acetyl-3-deoxy-α-D-mannopyranoside with the Pfitzner-Moffatt reagent resulted in the formation of 2-D-*glycero*-acetyloxymethyl-4-acetylamido-6-D-*glycero*-methoxy-5,6-dihydro-α-pyran-5-one. Cree *at al.*[10] also found that the oxidation of some partially-acetylated monosaccharides with dimethyl sulfoxide-sulfur trioxide-pyridine-triethyl amine led to the elimination of acetic acid and the formation of 6-aldehydo-4-hexenopyranosides.

Whichever detailed mechanism is involved, these reactions are β-eliminations; the driving force of the elimination is the energy released in forming the double bond, while a potent influence is exerted by the carbonyl and azide group (in the case of XI) in facilitating elimination, as is depicted



(XVII)

by XVII. The substrates (XI and XV) are favorable for carbanion formation, and, in the elimination, the H and OBz removed are *cis*; those findings support an ElcB mechanism, but not an E2 mechanism, as in the case of the elimination of acetic acid from 2-phenyl-2-acetoxy-1-nitrocyclohexane, in which the H and OAc are *cis*.[11]

A possible alternative mechanism may proceed through such an enol-form as is shown by XI'.

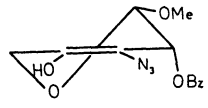
8) P. J. Beynon, P. M. Collins, P. T. Doganges and W. G. Overend, *J. Chem. Soc.*, **1966**, 1131.

9) H. Shibata, I. Takeshita, N. Kurihara and M. Nakajima, *Agr. Biol. Chem.*, **32**, 1006 (1968).

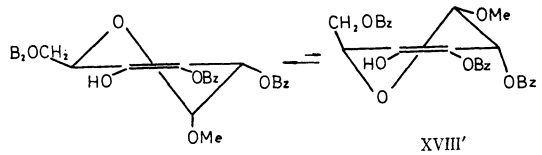
10) G. M. Cree, D. W. Mackie and A. S. Perlin, *Can. J. Chem.*, **47**, 511 (1969).

11) F. G. Bordwell and E. W. Garbisch, Jr., *J. Org. Chem.*, **28**, 1765 (1963); F. G. Bordwell, R. L. Arnold and J. B. Biranowski, *ibid.*, **28**, 2496 (1963).

The electron-withdrawing benzoyloxy group may be oriented pseudoaxially, because a pseudoaxial group at an allylic position is better disposed for a π-orbital overlap than a pseudoequatorial one; thus, carbonium ion formation at the allylic position proceeds more readily upon the departure of a pseudoaxial group than upon the departure of a pseudoequatorial one,[12] and the resulting carbonium ion is stabilized by the allylic delocalization of the positive charge.



XI'



XVIII XVIII'

In connection with the mechanism, we should like to cite the finding by Gabriel,[13] who prepared methyl 2,3,6-tri-*O*-benzoyl-α-D-*xylo*-hexopyranosid-4-ulose by the oxidation of methyl 2,3,6-tri-*O*-benzoyl-α-D-galactopyranoside with dimethyl sulfoxide-acetic anhydride and found it unstable, although he made no study of the decomposition product. This 4-keto-derivative is closely related to our XI and XV; both are derivatives of α-D-xylopyranosid-4-ulose. However, XI and XV differ from the 4-keto-derivative in having no benzoyloxymethyl group (equatorial) at C-5 and in having an azido or ethoxycarbonylamido group at C-3 instead of a benzoyloxy group. When elimination occurs, the 4-keto-derivative may be transformed into a half-chair conformation, XVIII', which has an axial benzoyloxy group at C-2 (allylic position). As compared with the stability of the conformation XI', the stability of the conformation XVIII' differs in having an instability factor caused by a pseudodiaxial interaction between the 5-benzoyloxymethyl group and the anomeric hydrogen atom, the same anomeric effects and $\Delta 2$ effects being involved in both conformations. Consequently, the 4-keto-derivative may have more of a tendency to take a stable conformation such as that of XVIII rather than one such as XI'. This may be the reason why XI and XV are more labile than the 4-keto-derivative.

12) For a general discussion, see E. L. Eliel, N. L. Allinger, S. J. Angyal and G. A. Morrison, "Conformational Analysis," Interscience Publishers, New York (1965), p. 111.

13) O. Gabriel, *Carbohyd. Res.*, **6**, 319 (1968).

Experimental

The NMR spectra were measured with a Varian A-60D spectrometer. Tetramethylsilane (τ 10.00; for the solutions of deuteriochloroform) and sodium 4,4-dimethyl-4-silapentane-1-sulfonate (τ 10.00; for the solutions of deuterium oxide) were used as the internal standards. The abbreviations used were as follows: p: proton, s: singlet, d: doublet, t: triplet, q: quartet, m: multiplet, d.d: doublet of doublets. Thin-layer chromatograms were visualized by spraying them with sulfuric acid at room temperature or by heating them at 110°C.

1,2-*O*-Isopropylidene-5-*O*-trityl-α-D-erythro-pentofuranos-3-ulose (IV). *a)* To a solution of 1,2-*O*-isopropylidene-5-*O*-trityl-α-D-xylofuranose (III) (8.77 g) in anhydrous benzene (60 m*l*) containing dry dimethyl sulfoxide (DMSO) (10 g), pyridine (3.2 m*l*), and trifluoroacetic acid (1.6 m*l*) was added dicyclohexylcarbodiimide (3.5 g×2, at an interval of 0.5 hr); the suspension was then stirred for 2 hr at room temperature. Ether (300 m*l*) and a solution of oxalic acid (2.6 g) in methanol (20 m*l*) were added in turns. After the evolution of gas had ceased, water (150 m*l*) was added, and an insoluble material was filtered off. The ether-layer was washed with a sodium bicarbonate solution and with water successively. After having been dried over sodium sulfate, the ether solution was evaporated to give a syrup which, on trituration with ether or ethanol, gave crystals. The addition of petroleum ether completed the crystallization; 6.97 g (80%), recrystallized from isopropanol; mp 131—132°C, $[\alpha]_D^{25}$ +132° (*c* 1, chloroform). (Sowa[5] reported mp 132°C and $[\alpha]_D$+132°). Found: C, 75.83; H, 6.42%. Calcd for $C_{27}H_{28}O_5$: C, 75.33; H, 6.09%. R_f 0.60 (benzene-ethyl acetate 30 : 1).

IR (KBr): 1775 (C=O), 1388, 1375 (isopropyl), 703 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.53 (6-p. s., isopropylidene), 6.67, 6.52 (each 1-p. q., H-5, 5'), 5.60 (1-p. m., H-4), 5.45 (1-p. d.d., H-2), 3.68 (1-p. d., H-1), 2.5—2.85 (15-p. m., phenyl); $J_{1,2}$ 4.5 Hz, $J_{2,4}$ 1 Hz, $J_{5,5'}$ 10.2 Hz, $J_{4,5}$ 2.7 Hz, $J_{4,5'}$ 2.6 Hz.

b) With DMSO-Ac_2O. To an ice-cold solution of III (37.05 g) in DMSO (120 m*l*), acetic anhydride (80 m*l*) was added; the mixture was set aside for 2 hr at that temperature and then for 3 days at room temperature. On thin-layer chromatography (TLC) (silica gel, benzene-ethyl acetate 30 : 1), three spots (R_f 0.67 (IV'), 0.60 (IV), and 0.22 (III)) were detected. Evaporation *in vacuo* gave a syrup, which was then dissolved in chloroform (200 m*l*). The solution was washed with a sodium bicarbonate solution and water successively. After having been dried over sodium sulfate, the solution was evaporated to give a syrup. As the separation of IV and IV' by column chromatography was unsuccessful, the syrup was reduced with sodium borohydride. To a suspension of the syrup in aqueous ethanol (1 : 3, 750 m*l*), sodium borohydride (3.35 g) was added; the mixture was then agitated for 5 hr. The syrup obtained by evaporation was dissolved in ethyl acetate (900 m*l*) and washed thoroughly with water. Drying over sodium sulfate, followed by evaporation, gave a syrup which was subjected to column chromatography (silica gel, 450 g) with benzene-ethyl acetate (15 : 1). Fractionation gave IV' between 930

and 1250 m*l* (yield 17.6 g), V between 1330 and 1590 m*l* (12.3 g), III+V between 1590 and 2100 m*l* (11 g), and III between 1200 and 3000 m*l* (4 g). V was recrystallized from benzene-*n*-hexane (1 : 25); 9.39 g; mp 99—100°C. IV′ was recrystallized from ethanol and proved to be 1,2-*O*-isopropylidene-3-*O*-methylthiomethyl-5-*O*-trityl-α-D-xylofuranose (14.6 g); mp 102—103°C, $[\alpha]_D^{15}$ −59.0° (*c* 1, chloroform).

Found: C, 70.94; H, 6.54; S, 6.57%. Calcd for $C_{29}H_{32}SO_5$: C, 70.70; H, 6.55; S, 6.51%.

IR (KBr); 1383, 1375 (isopropyl), 705 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.68 (3-p. s., isopropylidene), 8.46 (3-p. s., isopropylidene), 8.10 (3-p, s., SCH_3), 6.80 (1-p. q., H-5), 6.48 (1-p. q.. H-5′), 5.75 (1-p. d., H-2 or H-3), 5.3—5.7 (4-p. m., H-3 or H-2, H-4, OCH_2-SCH_3), 4.12 (1-p. d., H-1), 2.35—2.90 (15-p. m., trityl); $J_{1,2}$ 3.9 Hz, $J_{2,3}$ ~0 Hz, $J_{4,5}$ 6.2 Hz, $J_{4,5'}$ 5.8 Hz, $J_{5,5'}$ 9.7 Hz.

1,2-*O*-Isopropylidene-5-*O*-trityl-D-ribofuranose (V). To a suspension of IV (6.97 g) in aqueous ethanol (1 : 3, 80 m*l*), sodium borohydride (0.37 g) was added; the mixture was then shaken gently for a while, a clear solution soon resulted, and then crystals were gradually deposited. After 1 hr's standing, the whole mixture was concentrated to a small volume, and the resultant precipitate was dissolved in ethyl acetate. The solution was washed with water, dried over sodium sulfate, and evaporated to give a solid. To a solution of the solid in benzene (10 m*l*), a 75-m*l* portion of petroleum ether was added all at once; the mixture was then stimulated with a glass rod to give needles (6.1 g); mp 99—100°C, $[\alpha]_D^{18}$ +25.0° (*c* 1, chloroform) (reported[5] mp 117°C, $[\alpha]_D$ +25.8°), R_f 0.53 (silica gel, benzene-ethyl acetate 6 : 1).

Found: C, 75.07; H, 6.45%. Calcd for $C_{27}H_{28}O_5$: C, 74.98; H, 6.52%.

The product was chromatographically homogeneous, and no contamination of the xylo-isomer (III, R_f 0.40) was shown.

IR (KBr): 3460 (OH), 1385, 1377 (isopropyl), 700 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.64 (3-p. s., isopropylidene), 8.45 (3-p. s., isopropylidene), 7.7 (1-p. d., disappeared on deuteration, OH). 6.63 (2-p. m., H-5, 5′), 6.2—5.95 (2-p. m., H-3, H-4; irradiation at τ 5.49 changed the pattern of this area), 5.49 (1-p. triplet-like pattern, H-2), 4.16 (1-p. d., H-1; collapsed to a singlet on irradiation at τ 5.49), 2.35—2.95 (15-p. m., trityl); $J_{1,2}$ 4.0 Hz.

1,2-*O*-Isopropylidene-3-*O*-mesyl-5-*O*-trityl-D-ribofuranose (VI). To an ice-cold solution of V (6.55 g) in pyridine (60 m*l*), methanesulfonyl chloride (1.77 m*l*) was added drop by drop; the mixture was then allowed to stand for 1 hr under ice-cooling, and then for 24 hr at room temperature. The evaporation of the solution gave a syrup which was then dissolved in chloroform and washed successively with water, a sodium bicarbonate solution, and water. After having been dried over sodium sulfate, the solution was treated with charcoal and coevaporated with toluene to give a thick syrup (7.70 g). The product was chromatographically homogeneous (R_f 0.49 with silica gel, benzene-ethyl acetate 30 : 1) and sufficiently pure for the subsequent reaction. The syrup was crystallized from aqueous 50% ethanol; mp 123—125°C, $[\alpha]_D^{15}$ +64.6° (*c* 0.8, chloroform).

Found: C, 66.11; H, 5.97; S, 6.30%. Calcd for $C_{28}H_{30}O_7S$: C, 65.86; H, 5.92; S, 6.28%.

IR (KBr): ~1365 (broad, isopropylidene), 1180, 835 (mesyl), 703 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.64 (3-p. s., isopropylidene), 8.45 (3-p. s., isopropylidene), 7.13 (3-p. s., SO_2CH_3), 6.83 (H-5) and 6.47 (H-5′)(eight-line signals, with the inner four being most intense, typical for the AB part of an ABX system), 5.79 (1-p., doublet of triplets in appearance, H-4), 5.17 (1-p. q., H-2), 5.04 (1-p. q., H-3), 4.08 (1-p. d., H-1), 2.9—2.4 (15-p. m., trityl); $J_{1,2}$ 3.5 Hz, $J_{2,3}$ 4.6 Hz, $J_{3,4}$ 8.5 Hz, $J_{4,5}$ 3.5 Hz, $J_{4,5'}$ 2.5 Hz, $J_{5,5'}$ 11.2 Hz. The irradiation at the frequency of H-5 causes H-5′ to become a doublet ($J_{4,5'}$ 2.5 Hz) and H-4 to become a doublet of doublets; the irradiation at the frequency of H-5′ causes H-5 to become a doublet ($J_{4'5}$ 3.5 Hz) and H-4 to become a doublet of doublets; the irradiation at the frequency of H-1 causes H-2 to become a doublet ($J_{2,3}$ 4.6 Hz); the irradiation at the frequency of H-4 causes H-5 and H-5′ to become an AB quartet ($J_{5,5'}$ 11.2 Hz) and H-3 to become a doublet ($J_{2,3}$ 4.6 Hz).

1,2-*O*-Isopropylidene-3-*O*-methyl-5-*O*-trityl-D-xylofuranose (VI′). This compound was prepared from III as has been described in the procedure for the D-ribo isomer (VI); mp 116—117°C, $[\alpha]_D^{15}$ −55.0° (*c* 1, chloroform).

Found: C, 65.69; H, 6.16; S, 5.95%. Calcd for $C_{28}H_{30}O_7S$: C, 65.86; H, 5.92; S, 6.28%.

IR (KBr): 1370 (isopropylidene), 1175, 837 (mesyl), 700 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.70 (3-p, s., isopropylidene), 8.49 (3-p. s., isopropylidene), 7.28 (3-p. s., SO_2CH_3), 6.72 (H-5) and 6.40 (H-5′)(eight-line signals typical for the AB part of an ABX system), 5.56 (1-p. clear-cut octet, H-4), 5.20 (1-p. d., H-2), 4.90 (1-p. d., H-3). 4.10 (1-p. d., H-1), 2.84—2.4 (15-p. m., trityl); $J_{1,2}$ 3.8 Hz, $J_{2,3}$ 0 Hz, $J_{3,4}$ 3.0 Hz, $J_{4,5}$ 7.6 Hz, $J_{5,5'}$ 9.7 Hz.

3-Azido-3-deoxy-1,2-*O*-isopropylidene-5-*O*-trityl-D-xylofuranose (VII). To a solution of VI (6.38 g) in anhydrous dimethyl formamide (60 m*l*, dried over CaH_2) was added sodium azide (2.1 g). The suspension was heated at 150°C under stirring, and the reaction was pursued by TLC (silica gel, developed with benzene). After 24 hr, the reaction was completed. The organic layer was evaporated *in vacuo*. The resultant brown syrup was dissolved in benzene and passed through a column of silica gel (100 g) with the aid of benzene; after the initial benzene solution had thus been absorbed in the column, the column was set aside for several hours and then treated with benzene as usual. This procedure gave a completely decolorized eluate. The fraction containing the substance with an R_f value of 0.51 was collected and evaporated to give a clear thick syrup: 4.48 g (78%), $[\alpha]_D^{15}$ −42.5° (*c* 0.9, chloroform), IR (KBr): 2108 (N_3), 1385, 1375 (isopropylidene), 703, 697 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 8.72 (3-p. s., isopropylidene), 8.50 (3-p. s., isopropylidene), 6.70 (H-5) and 6.46 (H-5′) (eight-line signals typical for the AB part of an ABX system), 6.00 (1-p. d., H-3), 5.67 (1-p. octet, H-4), 5.43 (1-p. d., H-2), 4.20 (1-p. d., H-1), 2.45—2.85 (15-p. m., trityl); $J_{1,2}$ 3.8 Hz, $J_{2,3}$ 0 Hz, $J_{3,4}$ 3.2 Hz, $J_{4,5}$ 7.3 Hz, $J_{4,5'}$ 5.6 Hz, $J_{5,5'}$ 9.7 Hz.

Methyl 3-Azido-3-deoxy-α and β-D-xylopyranoside (VIII, VIII′). A solution of VII (15.26 g) in 1.5% hydrochloric acid in methanol (200 m*l*) was ref-

luxed for 20 hr. Powdered sodium bicarbonate was then gradually stirred in until all gas evolution had ceased. After filtration, the solution was evaporated to give a solid; this solid was boiled with water (30 ml) for a while and then cooled, and the solution was filtered from an insoluble material. The filtrate was evaporated to give a solid, and the procedure was repeated twice more. The resultant solid (6.83 g), which contained a trace amount of tritylcarbinol, was dissolved in a small amount of water and slowly chromatographed on a column of Dowex 1×2 (OH form) resin (220 ml, 20×700 mm) with water. After the removal of the early eluate of 350 ml of water, the fractions were cut into 13-ml portions. An unknown substance (R_f 0.24 with silica gel and benzene - methyl ethyl ketone 3 : 1) appeared between Nos. 6—9 (170 mg after dried), and next the α-anomer (VIII, R_f 0.39) appeared between Nos. 11—37. The β-anomer (VIII', R_f 0.36) appeared between Nos. 42—80. The second and the third fractions were collected and evaporated to give the α-anomer (2.28 g) and the β-anomer (2.73 g) respectively.

The α-anomer was dissolved in chloroform (30 ml), and filtered, and the filtrate was evaporated to about 5 ml. Gradual cooling at 5°C gave cubic crystals (2.22 g); mp 93—93.5°C, $[\alpha]_D^{20}$ +147° (*c* 0.6, water).

Found: C, 38.29; H, 5.89; N, 22.18%. Calcd for $C_6H_{11}O_4N_3$: C, 38.10; H, 5.86; N, 22.21%.

The β-anomer was crystallized by a similar procedure; cubic crystals (2.48 g), mp 88—89°C, $[\alpha]_D^{20}$ −65.7° (*c* 0.6, water).

Found: C, 38.27; H, 5.89; N, 22.11%.

IR (KBr): α and β-Anomers: 3300—3500 (broad, OH), 2100 (N_3) cm^{-1}. NMR (D_2O) α-Anomer (VIII): τ: 5.31 (1-p. d., H-1), 6.53 (3-p. s., OCH_3); $J_{1,2}$ 2.3 Hz. β-Anomer (VIII'): τ: 5.64 (1-p. d., H-1), 6.45 (3-p. s., OCH_3); $J_{1,2}$ 7.5 Hz.

Methyl 3-Amino-3-deoxy-α- and β-D-xylopyranoside (IX, IX'). Compound VIII (107 mg), dissolved in 50% aqueous ethanol (2 ml), was hydrogenated with hydrogen (50 lb/sq. inch) and preactivated platinum oxide (47 mg) for 2 hr at room temperature. After filtration, the solution was then evaporated to give a solid; this solid was subsequently recrystallized from ethanol to give needles (70 mg); mp 193—195°C (decomp.), $[\alpha]_D^{20}$ +158° (*c* 0.4, water) (lit,[6] mp 195—196°C, $[\alpha]_D$ +155° (*c* 1, pyridine)).

Found: C, 44.54; H, 8.31; N, 8.31%. Calcd for $C_6H_{13}O_4N$: C, 44.16; H, 8.03; N, 8.58%.

β-Anomer (IX') was obtained by a procedure similar to that used for VIII'; needles, mp 196—199°C (decomp.), $[\alpha]_D^{20}$ −63.2° (*c* 0.5, water) (lit,[7] mp 196—197°C, $[\alpha]_D$ −65° (*c* 1, water)).

The α and β-anomers showed the same R_f values (0.6) on paper chromatography (Toyo Roshi No. 50, sprayed with ninhydrin) with *n*-butanol-pyridine-water-acetic acid (6 : 4 : 3 : 1).

Methyl 3-Azido-2-*O*-benzoyl-3-deoxy-α-D-xylopyranoside (X). Into an ice-cold solution of VIII (6.45 g) in anhydrous pyridine (100 ml), benzoyl chloride (6.78 g) was gradually stirred in; the solution was then set aside for 0.5 hr under ice-cooling, and subsequently for one day at room temperature. TLC (silica gel, benzene-ethyl acetate 6 : 1) showed that the reaction mixture contained three components, with R_f values of 0.82 (dibenzoate), 0.37 (X, main), and 0.09 (VIII). Evaporation *in vacuo* gave a syrup; this syrup was dissolved in chloroform, and the solution was washed successively with a potassium bisulfate solution, water, a sodium bicarbonate solution, and with water again. After drying over sodium sulfate, followed by evaporation, the resultant syrup was chromatographed on silica gel (100 g) with benzene - ethyl acetate (6 : 1). After the removal of the early eluate (120 ml), the fractions were cut into 15-ml portions. Dibenzoate appeared between Nos. 1—5, and X appeared between Nos. 6—20. The latter fractions were collected and evaporated to give a syrup. A solution of the syrup in chloroform was washed with water, dried over sodium sulfate, and concentrated. The addition of petroleum ether gave a syrup. This syrup did not crystallize; 7.02 g (70%), $[\alpha]_D^{16}$ +202.0° (*c* 0.5, chloroform).

Found: C, 53.53; H, 5.49; N, 13.81%. Calcd for $C_{13}H_{15}O_5N_3$: C, 53.24; H, 5.16; N, 14.33%.

IR (KBr): 3450 (OH), 2100 (N_3), 1725 (ester), 710 cm^{-1} (phenyl).

NMR ($CDCl_3$): τ: 6.9 (OH, disappeared on deuteration), 6.62 (3-p. s., OCH_3), 5.88—6.44 (4-p. m., H-3, 4, 5, 5'), 5.10 (1-p. q., H-2), 4.97 (1-p. d., H-1), 1.86—1.97 (2-p.) and 2.3—2.75 (3-p.)(benzoyl); $J_{1,2}$ 3.2 Hz, $J_{2,3}$ 10.0 Hz.

The NMR pattern indicated X to be 2-*O*-benzoate, not 4-*O*-benzozte.

(2S) - 4 - Azido -5,6-dihydro-2-methoxy-α-pyran-5-one (XII). To a solution of X (569 mg) in a mixture of anhydrous benzene (6 ml), dimethyl sulfoxide (6 ml), pyridine (0.32 ml), and trifluoroacetic acid (0.16 ml) was added dicyclohexylcarbodiimide (2.0 g); the suspension was then stirred for 2 hr at room temperature. Ether (50 ml) and a solution of oxalic acid (1.1 g) in methanol (10 ml) were then added in turn. After the evoluation of gas had ceased, water (50 ml) was added; an insoluble material was subsequenty filtered off. The ethereal layer was washed several times with a sodium bicarbonate solution and with water. After having been dried over sodium sulfate, the ethereal solution was evaporated. The resultant syrup was dissolved in a mixture of benzene-ethyl acetate (30 : 1) and chromatographed on a column of silica gel (45 g) with the above-described solvent system. The fractions containing XII were collected and evaporated to give a pale yellow solid; 246 mg (76.3%); mp 58—58.5°C, $[\alpha]_D^{16}$ −23.1° (*c* 0.4, chloroform), λ_{max}^{MeOH} 273 mμ (ε 7500), R_f 0.63 (silica gel, benzene-ethyl acetate 30 : 1).

Found: C, 42.53; H, 4.15; N, 24.40%. Calcd for $C_6H_7O_3N_3$: C, 42.60; H, 4.17; N, 24.85%.

IR (KBr): 2120 (N_3), 1705 (C=O), 1630 (C=C) cm^{-1}.

NMR ($CDCl_3$): τ: 6.49 (3-p. s., OCH_3), 5.80, 5.52 (2-proton AB quartet, H-6, 6'), 4.80 (1-p. d., H-2), 3.71 (1-p. d., H-3); $J_{2,3}$ 3.8 Hz, $J_{6,6'}$ 17.3 Hz.

This substance gradually changes during storage.

(2S) - 4 - Carboethoxyamido-5,6-dihydro-2-methoxy-α-pyran-5-one (XVI). A solution of X (194 mg) in a mixture (2 ml) of equal volumes of 1 N hydrochloric acid and ethanol was hydrogenated with preactivated platinum oxide (30 mg) and hydrogen under pressure (50 lb/sq. inch) for 2 hr. After filtration, the solution was evaporated and an aqueous solution of the residue was treated with charcoal. The aqueous solution was evaporated to give a solid (184 mg), which showed no absorption of the azide group (~2100 cm^{-1}) in the infrared spectrum: it was positive for ninhydrin

coloration.

To an aqueous-acetone (1 : 1) solution (3 ml) of the solid (179 mg) was added ethyl chloroformate (73.2 mg) in the presence of sodium bicarbonate (107 mg); the mixture was then stirred for 1 hr. Evaporation of the solution to about a half volume deposited an oily precipitate; this precipitate was extracted with ether, and the ethereal solution was washed with water, dried over sodium sulfate, and evaporated. The resultant solid (151 mg) was homogeneous on TLC, showing an R_f value of 0.62 with silica gel and ether.

A solution of the solid (104 mg) in DMSO (1.5 ml) and acetic anhydride (0.3 ml) was allowed to stand overnight at room temperature. On TLC (silica gel and chloroform), three sports, with R_f values of 0.05 (starting material), 0.20, and 0.30 (XV), were discerned. After the addition of a saturated sodium bicarbonate solution (15 ml), the reaction mixture was extracted with ether; the ethereal layer was washed thoroughly with water, dried over sodium sulfate, and concentrated. The residue was chromatographed on a silica-gel column with chloroform. The fraction containing XV was evaporated to give a solid; this solid was then recrystallized from ethanol to afford needles (38 mg); mp 64—65°C, $[\alpha]_D^{15}$ +73.8° (*c* 0.4, chloroform), λ_{max}^{MeOH} 271 mμ (ε 8500).

Found: C, 50.50; H, 6.32; N, 6.51%. Calcd for $C_9H_{13}O_5N$: C, 50.23; H, 6.09; N, 6.51%.

IR (KBr): 1745, 1705 (C=O), 1660 (C=O) cm^{-1}.

NMR ($CDCl_3$): τ: 8.72 (3-p. t., CH_2CH_3, J=7.1 Hz), 6.49 (3-p. s., OCH_3), 5.80 (2-p. q., CH_2CH_3), 5.77, 5.47 (2-proton AB quartet, H-6, 6′), 4.71 (1-p. d., H-2), 2.77 (1-p. d., H-3); $J_{2,3}$ 3.8 Hz, $J_{6,6'}$ 17.3 Hz.

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