ACTA CHEMICA SCANDINAVICA 26 (1972) 2695–2702

Preparation of Derivatives of Methyl 4-Amino-3, 4-dideoxy-D-hexopyranosides

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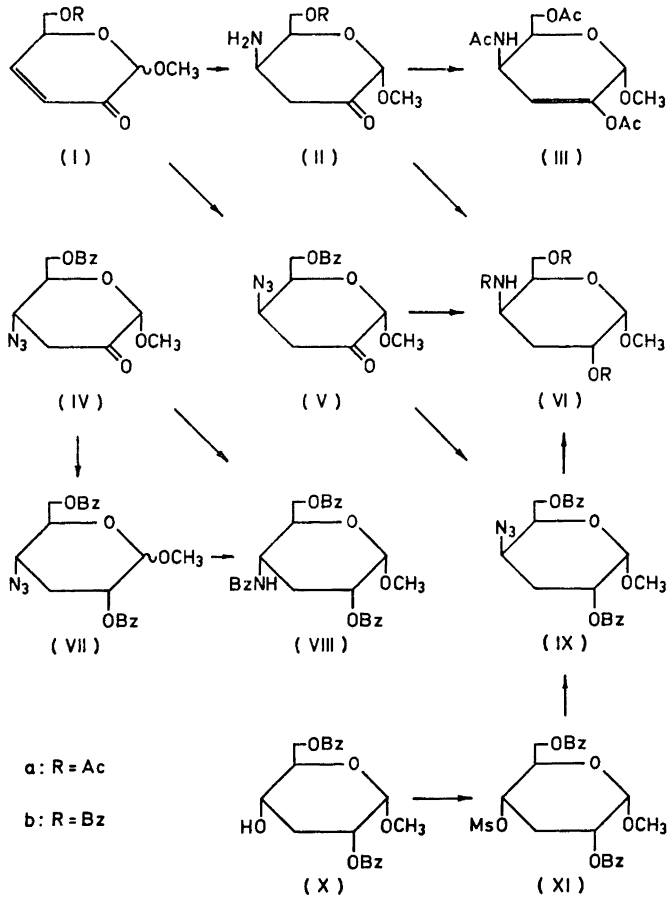
Treatment of methyl 6-*O*-benzoyl-3,4-dideoxy-α-D-*glycero*-*hex*-3-enopyranosid-2-ulose (α-Ib) with ammonia gave an unstable addition compound (IIb) which by reduction and benzoylation yielded methyl 4-benzamido-2,6-*O*-benzoyl-3,4-dideoxy-α-D-*xylo*-hexopyranoside (VIb). Reaction of (Ib) with sodium azide in acetic acid gave methyl 4-azido-6-*O*-benzoyl-3,4-dideoxy-α-D-*erythro*-hexopyranosid-2-ulose (IV) in a thermodynamically controlled reaction. Reduction of (IV) with borohydride and benzoylation yielded methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*ribo*-hexopyranoside (α-VII), whereas reduction with lithium aluminium hydride and benzoylation gave methyl 4-benzamido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*ribo*-hexopyranoside (VIII). The addition of hydrazoic acid to (Ib) under strongly acidic conditions was kinetically controlled and yielded methyl 4-azido-6-*O*-benzoyl-3,4-dideoxy-α-D-*threo*-hexopyranosid-2-ulose (V). Reduction of the latter and benzoylation gave methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*xylo*-hexopyranoside (IX) and the corresponding 4-benzamidocompound (VIb). Compounds (VIb) and (IX) were also synthesized by unambiguous methods.

In a previous paper[1] it was shown that methyl 6-*O*-acyl-3,4-dideoxy-α,β-D-*glycero*-hex-3-enopyranosid-2-ulose (I) could be prepared readily and in good yield by treatment of tetra-*O*-acyl-1-deoxy-D-*arabino*-hex-1-enopyranose with anhydrous hydrogen fluoride, followed by reaction with methanol and boron trifluoride. The methyl glycoside (I) is a rather reactive compound and it was of interest to study some of its properties, especially its ability to undergo conjugate addition to the α,β-unsaturated carbonyl system. In the present paper the reaction of (I) with ammonia and with hydrazoic azid, leading to derivatives of methyl 4-amino-3,4-dideoxy-hexosides, is described.

Treatment of methyl 6-*O*-acetyl-3,4-dideoxy-α-D-*glycero*-hex-3-enopyranosid-2-ulose (α-Ia) with methanolic ammonia gave an unstable product, presumably the addition compound (IIa). Acetylation of this product yielded the enolic acetate (III) in 24 % yield. The same product was obtained when an α,β-mixture of (Ia) was used (the α:β ratio of this mixture was 7:1). Reaction



of (α-Ia), or of the α,β-mixture, with ammonia followed by reduction of the keto group with sodium borohydride and acetylation gave a rather low yield of methyl 4-acetamido-2,6-di-*O*-acetyl-3,4-dideoxy-α-D-*xylo*-hexopyranoside (VIa).

When the benzoylated methyl glycoside (α-Ib) was treated with ammonia and then reduced and benzoylated a 48 % yield of methyl 4-benzamido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*xylo*-hexopyranoside (α-VIb) was obtained.

Reaction of the β-anomer (β-Ib) with ammonia led to decomposition and no pure products could be obtained. The addition of ammonia to (α-Ia or b) is apparently highly stereoselective yielding only (α-IIa or b). None of the C – 4 epimeric products could be isolated. The low yields obtained from the acetylated glycoside (α-Ia) is presumably due to decomposition of the starting material or of the primary addition product (α-IIa). The corresponding benzoate (α-Ib) is more stable and therefore a better yield of the 4-benzamido-compound (VIb) is obtained.

Since (I) is rather unstable under alkaline conditions it was of interest to study its reaction in neutral or acidic media. The reaction of hydrazoic acid with the benzoylated methyl glycoside (Ib) was therefore studied.[2] Treatment of (α-Ib) with sodium azide in acetic acid led to the formation of methyl 4-azido-6-*O*-benzoyl-3,4-dideoxy-α-D-*erythro*-hexopyranosid-2-ulose (IV) in *ca.* 90 % yield. The product was somewhat unstable, but the NMR-spectrum (Table 1) clearly established its structure. Thus the addition of hydrazoic acid to (Ib) is also highly stereoselective, but it yields the opposite C – 4 isomer of that obtained by addition of ammonia.

Attempts to carry out an enolic acetylation of (IV) with acetic anhydride in pyridine led to elimination of the azido group. Reduction of (IV) with sodium borohydride and benzoylation gave methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*ribo*-hexopyranoside (α-VII). With lithium aluminium hydride[3] both the carbonyl group and the azido group were reduced and this gave, after benzoylation, methyl 4-benzamido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*ribo*-hexopyranoside (VIII) in 32 % yield. The same product was also obtained in rather low yield by catalytic reduction of the azide (α-VII).

When the β-glycoside (β-Ib) was treated with sodium azide in acetic acid, followed by reduction of the carbonyl group with sodium borohydride and benzoylation, a mixture of products was obtained. In this case the azide addition is apparently less stereoselective since a small amount of the C – 4 epimeric azide was isolated. Furthermore, the borohydride reduction produced equal amounts of the C – 2 epimeric products.

The difference in the stereochemistry of the reaction with ammonia and with sodium azide in acetic acid led us to study the reaction of hydrazoic acid with (α-Ib) under various conditions to see whether the stereochemistry might depend on the conditions used in the reaction. It was found that treatment of (α-Ib) with hydrazoic acid in benzene-acetic acid in the presence of a small amount of toluene sulfonic acid gave the azide (V) with the same stereochemistry as that obtained by addition of ammonia to (α-Ib). Reduction of (V) with borohydride and benzoylation gave methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-α-D-*xylo*-hexopyranoside (IX). Reduction of (V) with lithium aluminium hydride and benzoylation yielded (VI), identical with the product obtained *via* the addition of ammonia to (Ib).

When the azide (V) was treated with sodium azide in acetic acid, the conditions used for the preparation of the epimeric azide (IV), it was almost completely converted into (IV). When, on the other hand, (IV) was treated with hydrazoic acid in benzene – acetic acid – toluene-sulfonic acid no epimerisation took place. Hence it must be concluded that (V) is formed in a kinetically controlled reaction whereas treatment of (I) or of (V) with sodium azide in acetic acid yields the thermodynamically most stable product (IV). The latter product has the azido group equatorially oriented in the predominant $^4C_1$ conformation, and it is therefore reasonable that it is more stable than (V).

The structures of the products described above were determined from their NMR spectra, details of which are presented in Table 1. The majority of the spectra were well resolved; however, some of them, especially those of (VIa and b) and of (IX), were difficult to analyse. In order to confirm the

Table 1. NMR data of 4-acylamino- and 4-azido-3,4-dideoxy-hexosides. δ-Values were measured in deuteriochloroform.

Compound	Solvent	H_1	H_2	H_{3e}	H_{3a}	H_4	H_5	H_6	$H_{6'}$	NH	OCH_3
III	$CDCl_3$	4.95 $J_{13}\simeq 0$;		5.73 $J_{34}=6.1$;	$J_{45}=2.5$;	4.72	4.25–4.45 $J_{4NH}=9.6$;			5.94	3.45
VIa	$CDCl_3$	4.90 $J_{12}=3.4$;	5.00	1.8–2.4 $J_{23e}=5.4$;	$J_{23a}=11.2$;	4.44	4.0–4.2 $J_{45}<4$;		$J_{4NH}=9.4$;	6.88	3.44
VIb	$CDCl_3$ $(CD_3)_2CO$	5.08 $J_{12}=3.4$;	5.33	2.2–2.6 $J_{23e}=5.6$;	$J_{23a}=11.0$;	4.77	4.3–4.6 $J_{45}<2$;	$J_{4NH}=9.0$;		7.07	3.44
IV	$CDCl_3$	4.58 $J_{3e4}=7.6$;		2.8–2.9 $J_{3a4}=9.0$;	$J_{45}=10.2$;	3.88	4.33 $J_{56}=4.6$;	4.53	4.70 $J_{56'}=2.4$;	3.48 $J_{66'}=11.6$;	
α-VII	$CDCl_3$	4.98 $J_{12}=3.4$;	5.12 $J_{23e}=5.0$;	2.44 $J_{23a}=11.0$;	2.26 $J_{33'}=11.0$;	3.65	3.92 $J_{43e}=4.8$;	4.50 $J_{43a}=11.0$;	4.63 $J_{45}=10.0$;	3.47 $J_{66'}=12.0$; $J_{56}=4.7$;	$J_{56'}=2.6$;
VIII	$CDCl_3$ $(CD_3)_2CO$ C_5D_5N	5.01 $J_{12}=3.4$;	5.12 $J_{23e}=5.6$;	2.1–2.4 $J_{23a}=11.0$;	$J_{45}=10.0$;	4.45	4.10 $J_{56}=5.6$;	4.40 $J_{56'}=2.6$;	4.67 $J_{66'}=11.4$;	7.14 $J_{4NH}=9.0$;	3.39
V	$CDCl_3$	4.61 $J_{13e}=1.1$;		2.75 $J_{3e4}=2.8$;	3.10 $J_{3a4}=4.3$;	4.22	4.40–4.70 $J_{45}\approx 4$;				3.47
IX	$CDCl_3$	5.04 $J_{12}=3.4$;	5.35	2.3–2.5 $J_{23e}=6.8$;	$J_{23a}=10.0$;	4.02	4.25 $J_{45}<2$;	4.5			3.45
β-VII	$CDCl_3$ C_6D_6	4.57 $J_{12}=7.6$;	5.04 $J_{23e}=4.8$;	2.74 $J_{23a}=10.6$;	1.83 $J_{43e}=4.8$;	4.60–4.80 $J_{43a}=11.6$;		4.48 $J_{56}=4.6$;	4.68 $J_{56'}=1.8$;	3.51 $J_{45}\sim 9.5$; $J_{33'}=12.4$;	$J_{66'}=12.0$
A	$CDCl_3$	4.62 $J_{12}=1.3$;	5.43 $J_{23e}=4.0$;	2.54 $J_{23a}=2.8$;	1.96 $J_{43e}=4.0$;	4.95 $J_{43a}=10.3$;	3.76	4.57 $J_{45}=9.4$;	4.75 $J_{56}=4.0$;	3.49 $J_{66'}=11.6$; $J_{56'}=2.8$;	$J_{33'}=13.6$;
B	$CDCl_3$ C_6D_6	4.62 $J_{12}=1.8$;	5.32 $J_{23e}=4.0$;	2.52 $J_{23a}=4.0$;	2.16 $J_{43e}=4.0$;	3.88 $J_{43a}=4.0$;	4.10	4.65 $J_{45}=2.8$;	$J_{56}=7.0$;	3.52 $J_{66'}=11.4$; $J_{56'}=5.8$;	$J_{33'}=15.0$;
XI	$CDCl_3$	4.99 $J_{12}=3.5$;	5.11 $J_{23e}=6.0$;	2.63 $J_{23a}=11.5$;	2.42 $J_{3e4}=5.0$;	4.88 $J_{3a4}=10.5$;	4.09	4.51 $J_{45}=10.0$;	4.66 $J_{56}=2.5$;	3.46 $J_{56'}=4.5$;	$J_{66'}=12.0$;

A: Methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-β-D-*arabino*-hexopyranoside.
B: Methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-β-D-*lyxo*-hexopyranoside.

structures of (VIb) and (IX) they were therefore prepared by an unambiguous method.

Selective benzoylation of methyl 2-*O*-benzoyl-3-deoxy-α-D-*ribo*-hexopyranoside [4] with benzoylimidazole [5] gave the 2,6-di-*O*-benzoate (X) in good yield. Mesylation of this product furnished the 4-*O*-mesyl derivative (XI) which, by subsequent treatment with sodium azide, gave the 4-azido compound (IX), identical with the product described above. Reduction and benzoylation finally yielded the 4-benzamido compound (VI).

EXPERIMENTAL

Melting points are uncorrected. NMR spectra were obtained on Varian A−60 and HA−100 instruments using tetramethylsilane as internal reference. IR spectra were measured in potassium bromide. For thin layer chromatography (TLC) silica gel PF_{254} (Merck) was used. Preparative TLC was done with 1 mm thick layers on 20 × 40 cm plates. Zones were detected under UV light (benzoates) or by charring with a hot wire (acetates).

The methyl 6-*O*-acetyl-3,4-dideoxy-α- and β-D-*glycero*-hex-3-enopyranosid-2-uloses (α- and β-Ia) were prepared as described previously.[1] The mixture of anomers could be purified by distillation, b.p. 95−105°C (0.1 mm). The anomers were separated by chromatography.

The corresponding benzoates (α- and β-Ib) were also prepared as described before.[1] Crystallization from ether gave 41 % of the α-anomer (α-Ib), m.p. 77−81°C. The material in the mother liquors from this crystallization could be distilled, b.p. 170°C (0.1 mm), to give a 3:1 mixture of the α- and β-anomers.

*Methyl 2,6-di-*O*-acetyl-4-acetamido-3,4-dideoxy*-α-D-threo-*hex-2-enopyranoside* (III). To a solution of (α-Ia) (540 mg) in methanol (5 ml) was added 3 ml of 3 N methanolic ammonia. The solution was kept at +5°C for 30 min, and the solvent was then removed *in vacuo*. The residue was dissolved in pyridine (3 ml) and acetic anhydride (2 ml) and kept for 20 h at room temperature. Ice and water was then added followed by methylene chloride. The organic phase was washed with 4 N sulphuric acid and with aqueous sodium hydrogen carbonate and dried. Removal of the solvent left a semi-crystalline residue which was recrystallized from ether giving 194 mg (24 %) of (III). Three additional recrystallizations gave a pure sample, m.p. 142−143.5°C, $[\alpha]_D^{23} = -96.1°$ (*c* 1.3, $CHCl_3$). (Found: C 51.63; H 6.22; N 4.57. Calc. for $C_{13}H_{19}NO_7$: C 51.81; H 6.36; N 4.65.) An IR spectrum showed bands at 3290 cm^{-1} (>N−H), 1760 (enolic acetate), 1740 (acetate), and 1630 cm^{-1} (amide).

When a mixture of the anomeric glycosides (Ia) (α:β-ratio = 7:1) was used the product (III) was obtained in 17 % yield by crystallization. Preparative TLC of the material in the mother liquors gave an additional 6 % of (III).

*Methyl 4-acetamido-2,6-di-*O*-acetyl-3,4-dideoxy*-α-D-xylo-*hexopyranoside* (α-VIa). A solution of (α-Ia) (407 mg) in methanol (4ml) was mixed with 2 ml of 3 N methanolic ammonia and kept at +5°C for 30 min. The solvent was removed *in vacuo* and the residue was dissolved in methanol (50 ml). Sodium borohydride (210 mg) was then added in three portions during 30 min at 0° C and the solution was kept for an additional 30 min at room temperature. Acetic acid was then added to a pH of *ca.* 4 and the solvent was evaporated. The residue was reevaporated twice with methanol and it was then acetylated with acetic anhydride (2 ml) in pyridine (2 ml) as described above. The crude product (492 mg) thus obtained was purified by preparative TLC using ether−pentane (2:1) as eluent. The main fraction was rechromatographed (chloroform−methanol 9:1) to give 148 mg (25 %) of syrupy (α-VIa) which crystallized when kept in ether−pentane solution at +5°C for two months, m.p. 95−96°C, $[\alpha]_D^{23} = +84.0°$ (*c* 1.0, $CHCl_3$). (Found: C 51.53; H 7.10; N 4.49. Calc. for $C_{13}H_{21}NO_7$: C 51.46; H 6.98; N 4.62.) An IR spectrum showed bands at 3300 cm^{-1} (>N−H), 1740 (ester C=O), and 1650 (amide C=O).

When a mixture of the anomeric glycosides (Ia) was used a 20 % yield (α-VIa) was obtained.

Methyl 4-benzamido-2,6-di-O-benzoyl-3,4-dideoxy-α-D-xylo-hexopyranoside(α-VIb). The α-glycoside (α-Ib) (300 mg) in methanol (5 ml) was treated with 10 ml of 1 N methanolic ammonia at 0°C for 1 h. The solvent was then removed and the residue was dissolved in methanol (40 ml) and reduced with sodium borohydride (300 mg) as described above. The methanolic solution was treated with 25 ml of ion-exchange resin (IR – 120) for 30 min. The solvent was then evaporated and the residue was benzoylated with benzoyl chloride (1 ml) in pyridine (3 ml). Work up in the usual manner gave 375 mg of a product which was crystallized from ethyl acetate – chloroform – pentane to give 272 mg (48 %) of a rather impure product, m.p. 60 – 70°C. Further recrystallizations from chloroform – pentane gave pure (α-VIb), m.p. 83 – 84°C, $[\alpha]_D^{23} = +86.2°$ (*c* 1.0, $CHCl_3$). (Found: C 68.51; H 5.68; N 2.74. Calc. for $C_{28}H_{27}NO_7$: C 68.69; H 5.56; N 2.86.) An IR spectrum gave bands at 3400, 1710 – 1720, and 1640 – 1650 cm^{-1}.

When a mixture of the anomeric glycosides (α,β-Ib) (α:β ratio 3:1) was used (α-VIb) was obtained in 33 % yield.

Methyl 4-azido-6-O-benzoyl-3,4-dideoxy-α-D-erythro-hexopyranosid-2-ulose (IV). To a solution of (α-Ib) (566 mg) in glacial acetic acid (2.5 ml) was added a solution of sodium azide (600 mg) in water (1.2 ml) and the mixture was kept at room temperature for 24 h. Water was then added and the mixture was extracted four times with ether. The ether solution was washed with water and with aqueous sodium hydrogen carbonate and dried. Evaporation left a pale yellow syrup (638 mg, 97 %), which could not be induced to crystallize. Attempts to purify the product by chromatography led to decomposition. An IR spectrum showed bands at 2100 ($-N_3$) and at 1720 cm^{-1} (C=O). An NMR spectrum (Table 1) showed that the products contained more than 90 % of the azide (IV).

Methyl 4-benzamido-2,6-di-O-benzoyl-3,4-dideoxy-α-D-ribo-hexopyranoside (α-VIII). To a solution of the crude azide (IV) (277 mg) in ether (20 ml) was slowly added a suspension of lithium aluminium hydride (200 mg) on ether (20 ml). The mixture was heated to reflux for 2 h. and excess of $LiAlH_4$ was then destroyed by careful addition of water (1 ml). After 15 min the mixture was diluted with methanol (50 ml) and filtered through activated carbon. The solvents were removed *in vacuo* and the residue was benzoylated with benzoyl chloride (2 ml) in pyridine (10 ml) in the usual manner. The product (1.34 g) was extracted with pentane to remove most of the benzyl benzoate and the residue was purified by preparative TLC (benzene – ethyl acetate 8:2) to give 160 mg (44 %) of (α-VIII). This product crystallized from chloroform – pentane to give 117 mg (32 %) of pure (α-VIII), m.p. 118 – 119°C, $[\alpha]_D^{25} = +68.3°$ (*c* 1.4, $CHCl_3$). (Found: C 68.46; H 5.57; N 2.80. Calc. for $C_{28}H_{27}NO_7$: C 68.69; H 5.56; N 2.86.) An IR spectrum showed bands at 3300, 1715, and 1635 cm^{-1}.

In a separate experiment the product was isolated by direct crystallization without the chromatographic purification. This gave 25 % of (α-VIII).

Methyl 4-azido-2,6-di-O-benzoyl-3,4-dideoxy-α-D-ribo-hexopyranoside (α-VII). The crude azide (IV) (427 mg) was dissolved in methanol (40 ml) and cooled to 0°C. Sodium borohydride (3 × 100 mg) was then added in the course of 30 min and the mixture was kept at room temperature for an additional 30 min. It was then treated with Amberlite IR 120 and the methanol was evaporated. The residue was benzoylated in the usual manner with benzoyl chloride (0.6 ml) in pyridine (3 ml). The product (489 mg) was purified by preparative TLC (benzene – ethyl acetate 19:1) to give 370 mg (65 %) of (α-VII) as a syrup. An NMR spectrum indicated that this product contained a small amount of the C-4 epimeric compound (IX), which could not be removed by chromatography in several different solvents. $[\alpha]_D^{22} = +114°$ (*c* 1.2, $CHCl_3$). (Found: C 61.12; H 5.31; N 10.04. Calc. for $C_{21}H_{21}N_3O_6$: C 61.31; H 5.15; N 10.22.) An IR spectrum showed bands at 2100 ($-N_3$) and at 1720 cm^{-1}.

The azide (α-VII) (365 mg) was dissolved in methanol (30 ml) and reduced with palladium oxide (30 mg) and hydrogen at 1 atm. and room temperature for 3.5 h. The product, obtained after filtration and evaporation, was benzoylated in the usual way to give 266 mg of a syrup. Crystallization from ethyl acetate – chloroform – pentane gave 200 mg (46 %) of (VIII) which was further purified by recrystallization from chloroform-hexane, m.p. 118 – 119°C, $[\alpha]_D^{25} = +68.8°$ (*c* 1.1, $CHCl_3$). Spectra showed that the product was identical with that described above.

Reaction of (β-Ib) with sodium azide in acetic acid. To a solution of (β-Ib) (502 mg) in glacial acetic acid (5 ml) was added a solution of sodium azide (600 mg) in water (2.5 ml). After 4 h at room temperature more water (25 ml) was added and the mixture

was extracted 5 times with ether. The ether solution was washed with water and aqueous sodium hydrogen carbonate, dried and evaporated leaving 495 mg of a syrup. This was dissolved in methanol (40 ml) and cooled to 0°C while sodium borohydride (3 × 120 mg) was added during 30 min. The solution was kept for 30 min at room temperature and it was then treated with Amberlite IR – 120 (20 ml). The solvent was evaporated and the residue was benzoylated with benzoyl chloride (0.7 ml) in pyridine (3 ml). The product (611 mg) was separated into three fractions by preparative TLC (benzene – ethyl acetate 19:1). The fastest moving fraction gave 219 mg (33 %) of methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-β-D-*ribo*-hexopyranoside (β-VII). The next fraction consisted of 150 mg (23 %) of methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-β-D-*arabino*-hexopyranoside and the last fraction gave 55 mg (8 %) of methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-β-D-*lyxo*-hexopyranoside. The three products were not purified further and their structures were only determined through their NMR spectra (Table 1) which were well resolved.

*Methyl 4-azido-6-*O*-benzoyl-3,4-dideoxy-*α-D-threo-*hexopyranosid-2-ulose* (V). The α-glycoside (α-Ib) (634 mg) was dissolved in a 2 N solution of hydrazoic acid in benzene (20 ml). The solution was cooled in ice and acetic acid (2.5 ml) and *p*-toluenesulfonic acid monohydrate (500 mg) were added. The solution was allowed to warm up to room temperature over night. Water was then added and the mixture was extracted five times with ether. The ether solution was washed with aqueous hydrogen carbonate, dried and evaporated. The residue (598 mg, 81 %) was a pale yellow syrup which was too unstable to be purified. An IR spectrum showed bands at 2110 cm^{-1} ($-N_3$) and at 1720 cm^{-1}. An NMR spectrum (Table 1) indicated that the product consisted mainly of the azide (V).

*Methyl 4-benzamido-2,6-di-*O*-benzoyl-3,4-dideoxy-*α-D-xylo-*hexopyranoside* (VI). The crude azide (V) (238 mg) was reduced with lithium aluminium hydride (100 mg) as described above. The product was benzoylated and the material thus obtained (440 mg) was purified by preparative TLC (benzene – ethyl acetate 8:2) to give 138 mg (36 %) of rather impure (VI). The compound crystallized with some difficulty from ethyl acetate – chloroform – pentane to give 48 mg of product with m.p. 68 – 78°C. An NMR spectrum showed that the product was identical with that described below.

*Methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-*α-D-xylo-*hexopyranoside* (IX). The crude azide (V) (373 mg) was reduced with sodium borohydride (3 × 100 mg) as described above and the product was benzoylated. This gave 472 mg of crude product which was purified by preparative TLC (benzene – ethyl acetate 19:1) to give 351 mg (70 %) of rather impure (IX). An IR spectrum showed bands at 2100 ($-N_3$) and 1710 – 1720 cm^{-1}. An NMR spectrum showed that the product consisted mainly of the azide (IX), identical with the authentic material described below.

*Isomerization of methyl 4-azido-6-*O*-benzoyl-3,4-dideoxy-*α-D-threo-*hexopyranosid-2-ulose* (V). To a solution of (V) (117 mg) in acetic acid (0.5 ml) was added sodium azide (120 mg) in water (0.3 ml) and the mixture was kept at room temperature for 24 h. Work up as described above gave 94 mg of a syrup, which was almost pure (IV) as seen from an NMR spectrum.

Preparation of authentic compounds

*Methyl 2,6-di-*O*-benzoyl-3-deoxy-*α-D-ribo-*hexopyranoside* (X). Methyl 2-*O*-benzoyl-3-deoxy-α-D-*ribo*-hexopyranoside[4] was benzoylated at C – 6 using the method of Chittenden.[5] Imidiazole (383 mg) in chloroform was treated with benzoyl chloride (0.33 ml) at 0°C. The hydrochloride was filtered off and washed with chloroform. The combined filtrate was added to a solution of methyl 2-*O*-benzoyl-3-deoxy-α-D-*ribo*-hexopyranoside (792 mg) in chloroform (10 ml) and the solution was heated to reflux for 18 h. It was then washed with aqueous sodium hydrogen carbonate, dried and evaporated. The residue (1.26 g) was purified by preparative TLC (benzene – ethyl acetate 8:2) to give 760 mg (70 %) of pure (X) as seen from an NMR spectrum. The product was a syrup.

*Methyl 2,6-di-*O*-benzoyl-3-deoxy-4-O-mesyl-*α-D-ribo-*hexopyranoside* (XI). To a solution of (X) (900 mg) in pyridine (5 ml) was added mesyl chloride (0.2 ml) and the mixture was kept at 0°C for 18 h. Work up in the usual way gave 1.03 g (96 %) of rather pure (XI) which could not be induced to crystallize. Preparative TLC gave a pure sample as a syrup, $[\alpha]_D^{23} = +83.5°$ (*c* 2.1; $CHCl_3$). (Found: C 56.74; H 5.40; S 6.77. Calc. for $C_{22}H_{24}O_9S$: C 56.87; H 5.21; S 6.90.)

*Methyl 4-azido-2,6-di-*O*-benzoyl-3,4-dideoxy-*α*-*D*-xylo-hexopyranoside* (IX). The mesyl compound (XII) (1.032 g) was dissolved in hexamethylphosphoric triamide (8 ml) and heated with sodium azide (600 mg) to 80°C for 3.5 h. The mixture was then diluted with water and extracted with ether; the ether solution was washed with water, dried and evaporated. The residue (933 mg) was purified by preparative TLC (ether – pentane 1:1) to give 803 mg (85 %) of the azide (IX). An analytical sample was obtained by chromatography using benzene – methanol (19:1) as eluent. $[\alpha]_D^{23} = +21.4°$ (*c* 0.7, $CHCl_3$). (Found: C 61.22; H 5.31; N 10.35. Calc. for $C_{21}H_{21}N_3O_6$: C 61.31; H 5.15; N 10.22.)

*Methyl 4-benzamido-2,6-di-*O*-benzoyl-3,4-dideoxy-*α*-*D*-xylo-hexopyranoside* (VI). The azide (IX) (465 mg) was dissolved in methanol (30 ml) and hydrogenated at 1 atm. in the presence of 5 % palladium on carbon (200 mg) for 1.5 h. The catalyst was filtered off and the solvent was removed. The residue was benzoylated with benzoyl chloride (0.5 ml) in pyridine (3 ml). The crude product (262 mg) was purified by preparative TLC (benzene – ethyl acetate 8:2) to give 196 mg (37 %) of pure (VI). The product crystallized from chloroform – pentane, m.p. 82 – 83.5°C, $[\alpha]_D^{23} = +85.5°$ (*c* 1.4, $CHCl_3$). (Found: C 68.47; H 5.67; N 2.70; O 22.66. Calc. for $C_{28}H_{27}NO_7$: C 68.69; H 5.56; N 2.86; O 22.88.) An IR spectrum showed bands at 3400, 1710 – 1720, and 1640 cm^{-1}. The product was identical with the compound described above.

Microanalyses were carried out by Dr. A. Bernhardt.

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Received November 30, 1971.