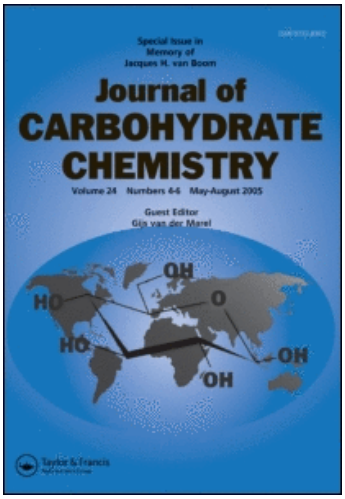

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Elimination Reactions of 2-Deoxy 2-C-Methyl Sugars : Application to the Synthesis of Methyl 2,3,4-Trideoxy-2,4-Di-C-Methyl-6-O-Triphenylmethyl α-D-Lyxo Hexopyranoside and its X Ray Crystal Structure

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ELIMINATION REACTIONS OF 2-DEOXY 2-C-METHYL SUGARS : APPLICATION TO THE SYNTHESIS OF METHYL 2,3,4-TRIDEOXY-2,4-DI-C-METHYL-6-O-TRIPHENYLMETHYL α-D-LYXO HEXOPYRANOSIDE AND ITS X RAY CRYSTAL STRUCTURE

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ABSTRACT

A facile and regiospecific dehydration of 2-deoxy 2-C-methyl sugars using the triphenylphosphine-diethylazodicarboxylate reagent is reported. This reaction allowed us to prepare the title compound which is a crucial intermediate in the total synthesis of natural products. Its absolute configuration is firmly established by X Ray analysis.

The utility of partly deoxygenated carbohydrates as chiral synthons is now well established.[1-3] The deoxygenation reaction may be accomplished by different routes[4-13] and particularly via the creation of a double bond followed by hydrogenation.[4-11] At

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A preliminary account of this work was presented at the X Journées des Glucides, Paris, 5 juillet 1982. A part of this work is taken from the Thesis of F.G. Nancy, mars 1982.

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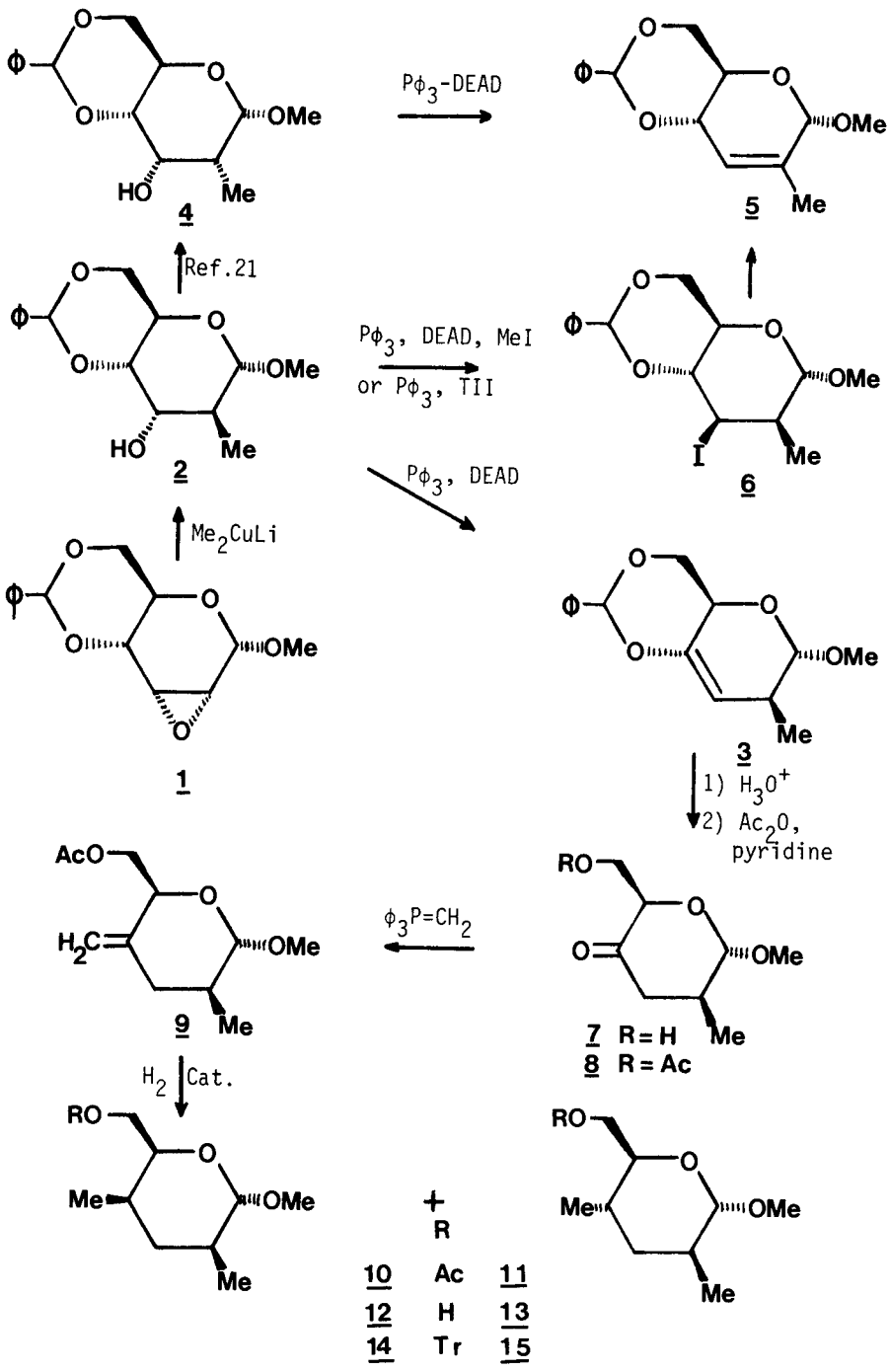
this stage the use of the template effect of sugars can ensure the stereospecific hydrogenation on one side of the molecule.[9]
For these reasons the study of elimination reactions in the carbohydrate series is of interest and we decided to investigate the creation of double bonds onto 2-deoxy 2-C-methyl sugars. These compounds are readily available from glucose[5] or mannose,[14] and their transformation into chiral synthons has been reported. For example, methyl 2,3,4-trideoxy-2,4-di-C-methyl hexopyranosides have been used in the synthesis of pheromones[7,11,13] and antibiotics.[8,10] We describe in this paper a new synthesis of such a chiral intermediate, the structure of which has been confirmed by X Ray analysis.

Using a modification of the method of Fraser-Reid,[5] we prepared the 2-C-methyl derivative 2 from 1.[15] We found that 2 was smoothly dehydrated by treatment with the Mitsunobu's reagent[16] (triphenylphosphine-diethylazodicarboxylate, PPh_3-DEAD) into the olefin 3 (80 %). This reaction proceeds via the formation of triphenyloxyphosphonium[17] followed by E2 elimination. Such a process has been mentioned in the literature only as a side reaction during substitution,[18] or in the dehydration of β hydroxy α amino-acids.[19] Formation of the positional isomer 5 was not detected.[20]

We examined the behaviour of the 2-C-methyl derivative 4 under the same conditions.[21] We found that in this case the elimination afforded only the 2,3 unsaturated derivative 5 and in high yield (82 %). In 4 both H_4 and H_2 are antiperiplanar to the leaving



group. The fact that elimination gave only the 2,3 unsaturated derivative 5 could be explained in terms of "kinetic anomeric effect".[22]

Alternatively when 2 was submitted to reaction with the PPh_3-DEAD-MeI system,[23] the formation of the iodo derivative 6 (21 %) together with 3 was observed. On the other hand Garegg's reagent, PPh_3-triiodoimidazole,[24] effected the iodination of 2 to 6 although anomerization of the latter was observed. Compound 6 was found to be an ideal precursor to 5, and, indeed, treatment of 6 by sodium azide in N,N-dimethylformamide afforded 5 in quantitative yield. No attempts were made to find other conditions.[25]

These results showed that two different olefins may be obtained from 2 in a completely stereospecific manner. Both compounds 3 and 5 are of interest in total synthesis of enantiomerically pure compounds.

Thus we attempted to transform 3 into a widely used chiral intermediate 12. Mild hydrolysis of 3 with dilute hydrochloric acid in ethanol-water mixture furnished the hydroxy-ketone 7 without by-products. Direct acetylation of the crude mixture gave the ketone 8 in 80 % yield from 3. Wittig olefination of 8 with methylene triphenyl-phosphorane yielded the olefin 9 (75 %) after reacetylation.

At this stage, the crucial step was the catalytic hydrogenation of the double bond. The reaction was assumed to proceed on the less hindered α face of the molecule. The stereochemical course of the hydrogenation has been found to depend upon the nature of the

catalyst. Whereas reduction of 9 with Pd on charcoal afforded a 1.5/1 mixture of 10 and 11, use of Wilkinsen's catalyst in benzene gave a 6/1 mixture of 10 and 11. Our findings were in good agreement with those previously reported for a tritylated analogue of 10.[4,6,7]

Compounds 10 and 11 were deacetylated into a mixture of 12 and 13 which can be easily separated by column chromatography. We prepared crystalline 14 and 15 by tritylation of 12 and 13 respectively. Compound 14 gave the same physical data as was previously reported in preliminary accounts.[4,10,11] The structure was determined by ^1H NMR spectroscopy and by transformation into a few natural products.[4,10,11] Nevertheless, the reported spectroscopic data were not fully convincing.

Our own analysis of the 360 MHz ^1H NMR spectrum (see experimental) showed $J_{1,2}$ = 5.5 Hz and $J_{4,5}$ = 5 Hz. These values could be rationalized by an axial-equatorial relationship between H_1 and H_2 and H_4 and H_5 which would then suggest that complete anomerization had occured during the synthesis. In comparison 15, the C_4 epimer of 14, showed a $J_{1,2}$ < 1 Hz which is typical of equatorial-equatorial relationships of H_1 and H_2 in the $^4C_1$ D conformation. The same $J_{1,2}$ magnitude was observed in compound 2, the conformation of which was biased by the benzylidene group.

After the completion of this part of our work, two reports have appeared, suggesting the possibility of an unusual conformation of 14.[7,11] These facts prompted us to determine the relative configuration of 14 in the solid state. We found that 14 adopted

the $^4C_1$ D conformation in the solid state with three axial groups.

We concluded that in solution, 14 may be in conformational equilibrium between $^4C_1$ chair and the $^1C_4$ D chair in which substituents were equatorial. This could explain the mean value of $J_{1,2}$.

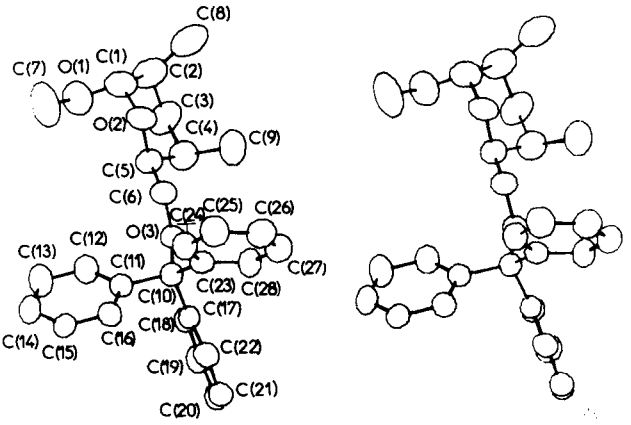
In summarizing we have proposed a new access to unsaturated sugars 3 and 5 from the same progenitor using a phosphorous based reaction.

The usefulness of 3 has been demonstrated by the synthesis of the important intermediate 14. There is no doubt that 3 could be used in synthesis as a precursor of ketone enolate[14]; the chemistry of this compound is under current investigation.

EXPERIMENTAL

General procedures. Melting points were determined on a Kofler block. Elemental analyses were performed by the Service Central de Microanalyses du CNRS, LYON (France). ^1H NMR spectra were recorded in $CDCl_3$ (PERKIN ELMER R 12 B, CAMECA 250, BRUKER WH 360) and IR spectra using a PERKIN ELMER 580 B. TLC were carried out on precoated silica gel plates (Merck) with the following eluents : A (AcOEt 9/hexane 1), B (toluene 10/ether 1), C (toluene 95/ether 5), D (AcOEt 4/hexane 6), E (AcOEt 3/hexane 7), F (AcOEt 2/hexane 8).

Column chromatography was carried out using silica gel 60 (Merck 0.063-0.2 mm). Optical rotations were measured with a PERKIN ELMER 141 in a 1 dm path cell. Gas chromatography was carried out



Figure

A stereoscopic view of 14 showing atoms numbering.

on a CARLO ERBA chromatograph using a glass column (2 m x 5 mm) packed with 3 % OV 225 on Gas-Chrom Q (110-120 Mesh) at 135°C. The injection temperature was 270°C and the nitrogen pressure 0.5 kg/ cm^2.

Methyl 4,6-O-phenylmethylene 2-deoxy 2-C-methyl α-D-altropyranoside 2. This compound was prepared in 85 % yield using a modification of the known procedure.[5] A solution of methyllithium (90 mM, 1.4 M sol., 64 ml) was added to a suspension of copper iodide (8.56 g, 45 mM) in 300 ml of anhydrous ether at 0°C under argon. A solution of the epoxide 1 (4 g, 15 mM) in 60 ml of dichloromethane was added within 15 minutes. The mixture was stirred at 0°C during 2 h. Hydrolysis by saturated ammonium chloride solution and extraction with dichloromethane (3 x 100 ml) yielded after drying over sodium sulfate the crude mixture of 2 and 4,6-O-phenylmethylene-1,2-

dideoxy-D-ribo-hexenopyranose. Column chromatography (A) allowed the separation of pure 2 (3.6 g, 85 %) and the by-product (483 mg, 13 %).

2 : mp 114°C ; $[\alpha]_D^{25}$ +108° (c 0.6, $CHCl_3$) lit.[5] mp 111-3°C $[\alpha]_D^{23}$ +122.5°.

Methyl-4,6-O-phenylmethylene-2,3-dideoxy-2-C-methyl α-D-threo-hex-3-enopyranoside 3. Triphenylphosphine (5 mM, 1.3 g) and 2 (560 mg, 2 mM) were dissolved in 10 ml of dry tetrahydrofuran. DEAD (870 mg, 5 mM) was added dropwise over a period of 5 min. The mixture was stirred at room temperature overnight and then diluted with ether, washed with water and dried over sodium sulfate. After removal of the solvent the residue was chromatographed (B) yielding 419 mg of 3 (80 %). Rf 0.44 (B) ; mp 64-66° ; $[\alpha]_D^{25}$ +184° (c 1, $CHCl_3$) ; IR 1700 cm^{-1} ( ) ; ^1H NMR : δ, 1.12 (d, 3 H, J_{2,CH_3} 7.25, CH_3), 3.45 (s, 3 H, OCH_3), 3.71 (dd, 1 H, $H_{6'}$), 4.27-4.4 (m, 2 H, H_5, H_6), 4.5 (s, 1 H, H_1), 5.26 (m, 1 H, H_3), 5.5 (s, 1 H, $H_{benz.}$), 7.2-7.5 (m, 5 H, Ph).

Anal. Calcd for $C_{15}H_{18}O_4$: C, 68.68 ; H, 6.91. Found : C, 68.10 ; H, 6.78.

Methyl-4,6-O-phenylmethylene-2,3-dideoxy-2-C-methyl α-D-erythro-hex-2-enopyranoside 3. Compound 3 was obtained by the procedure described above using the alcohol 4. Purification was achieved by chromatography (C) yielding 3 (429 mg, 82 %). Rf 0.44 (H) ; mp 141-2° ; $[\alpha]_D^{25}$ +104° (c 0.5, $CHCl_3$). Lit.[5] mp 141-142° ; [α] +105.7° (c 4.72, $CHCl_3$).

Methyl-4,6-O-phenylmethylene-2,3-dideoxy-3-iodo-2-C-methyl α-D-mannopyranoside 6 : Using PPh_3-DEAD-methyl iodide.[23] To a solution of 2 (350 mg, 1.25 mM), triphenylphosphine (394 mg, 1.5 mM) and methyl iodide (213 mg, 1.5 mM) was added DEAD (263 mg, 1.5 mM). The solution was refluxed for 4 h. After this time the reaction was worked-up as described for the preparation of 3. Column chromatography (C) allowed the separation of 6 (102 mg, 21 %), 3 (30 mg, 9 %) and the unreacted starting material (175 mg, 50 %).

Using PPh_3-triiodoimidazole.[24] A solution of 2 (1 g, 3.5 mM), triphenylphosphine (2,3 g, 8.75 mM) and triiodoimidazole (2 g, 4.5 mM) in 30 ml of toluene was refluxed for 3 h. After cooling ether was added (100 ml). The organic phase was washed with aqueous sodium thiosulfate (2 x 50 ml) and water, and then dried over sodium sulfate. Evaporation of the solvent yield the crude product. Careful chromatography (C) yielded 6 (791 mg, 58 %). Rf 0.5 (C) ; Gum ; $[\alpha]_D^{25}$ +69.6° (c 1.2, $CHCl_3$) ; ^1H NMR : δ, 1.36 (d, 3 H, $J_{2,Me}$ 7.25 Hz, CH_3), 2.39 (dq, 1 H, $J_{2,3}$ 4.75 Hz, H_2), 3.3 (s, 3 H, OCH_3) 3.66 (dd, 1 H, $J_{5,6}$ 10 Hz, H_6), 3.7 (dd, 1 H, $J_{4,5}$ 9 Hz, H_4), 3.84 (dq, 1 H, $J_{5,6'}$ 4.5 Hz, H_5), 4.1 (dd, 1 H, $J_{6,6'}$ 10 Hz, $H_{6'}$), 4.46 (s, 1 H, H_1), 4.67 (dd, 1 H, $J_{3,4}$ 11 Hz, H_3), 5.5 (s, 1 H, $H_{benz.}$), 7.3-7.5 (m, 5 H, Ph).

Anal. Calcd for $C_{15}H_{19}IO_4$: C, 46.17 ; H, 4.91 ; I, 32.52. Found : C, 46.03 ; H, 5.16 ; I, 32.40.

Methyl-6-O-acetyl-2,3-dideoxy-2-C-methyl-4-ulo α-D-threo-hexopyranoside 8. The enol ether 2 (1.31 g, 5 mM) was dissolved in 20 ml of ethanol, 10 ml of water were added and then five drops of 12 N HCl. The mixture was stirred during 9 h. Neutralisation was carried out

with resin (Amberlite IR OH^-). After filtration, the mixture was evaporated and dried by codistillation with toluene. TLC (D) showed a single product. Acetylation with acetic anhydride (1 ml) in 5 ml of pyridine within 2 h yielded crude 8. After evaporation of pyridine, the mixture was extracted with ether (3 x 50 ml) washed with dilute hydrochloric acid and aqueous sodium bicarbonate and finally water. The organic layer was dried over magnesium sulfate and evaporated. The crude residue was chromatographed on silica gel (E) to give pure 8 (864 mg, 80 %). Rf 0.6 (D) ; gum ; $[\alpha]_D^{25}$ +94° (c 1, $CHCl_3$) ; IR 1730 ; ^1H NMR : δ, 1.1 (d, 3 H, J 7 Hz, CH_3), 2.05 (s, 3 H, CH_3CO), 2-2.8 (m, 3 H, H_2 H_3 $H_{3'}$), 3.45 (s, 3 H, OCH_3), 4-4.5 (m, 3 H, $H_{6,6'}$ H_5), 4.6 (d, 1 H, $J_{1,2}$ 3 Hz, H_1).
Anal. Calcd for $C_{10}H_{16}O_5$: C, 55.55 ; H, 7.46. Found : C, 55.49 ; H, 7.50.

Methyl-6-O-acetyl-2,3-dideoxy-2-C-methyl-4-C-methylene α-D-threo-hexopyranoside 9. To a suspension of methyltriphenylphosphonium bromide (2.47 g, 7 mM) in 50 ml of toluene under argon at 0°C, was added with a syringe 4.4 ml of a 1.6 M solution of BuLi in hexane. The mixture was stirred within 30 min at this temperature and the ketone 8 (1 g, 4.6 mM) in 10 ml of toluene was added. After 2 h at room temperature, the excess of phosphorane was destroyed with acetone and the mixture was diluted with ethyl acetate. The precipitate was removed by filtration on a pad of silica gel. The crude residue was acetylated as described for 8. TLC (F) showed a single product (743 mg, 75 %). Rf 0.7 (F). GC retention time (I) 6 min, sample was

purified : oil, $[\alpha]_D$ +130° (c 1, $CHCl_3$). ^1H NMR : δ, 1 (d, 3 H, J 7 Hz, CH_3), 1.9 (m, 1 H, H_2), 1.98 (m, 1 H, H_3), 2.62 (m, 1 H, $H_{3'}$), 3.4 (s, 3 H, OCH_3), 4.27 (dd, 1 H, $J_{5,6}$ 8 Hz, $J_{6,6'}$ 12 Hz, H_6), 4.40 (m, 2 H, H_5, $H_{6'}$), 4.44 (d, 1 H, $J_{1,2}$ 2.5 Hz, H_1), 4.82 (d, 2 H, $=CH_2$).

Anal. Calcd for $C_{11}H_{18}O_4$: C, 61.66 ; H, 8.47. Found : C, 61.69 ; H, 8.42.

Hydrogenation of 9.

Using Pd on charcoal. The olefin 9 (214 mg, 1 mM) was dissolved in ethyl acetate (10 ml). The flask was purged with nitrogen and 100 mg of 5 % Pd on charcoal was introduced. The vessel was placed under a hydrogen atmosphere. The reaction was monitored by GC indicating the formation of 11 (RT 5.4 min) and 10 (RT 7.5 min) in the ratio 1.5/1 after 4 h of time.

Using tris(triphenylphosphine)rhodium chloride catalyst. The procedure described above was used. The catalyst was added in portion of 50 mg. The total amount of catalyst was 450 mg for 1 mM of olefin 9. GLC analysis of the reaction indicated a 6/1 mixture of 10 and 11. The mixture of 10 and 11 was isolated through filtration on silica gel and elution with ether yielding 172 mg of 10 and 11.

Deacetylation of 10 and 11 was carried out directly by action of a catalytic amount of sodium methoxide in methanol. Column chromatography (F) allowed separation of 13 and 12.

Methyl-2,3,4-trideoxy-2,4-di-C-methyl α-D-lyxo-hexopyranoside 12 was an oil, $[\alpha]_D^{25}$ +92.6° (c 0.3, $CHCl_3$). Lit.[10] $[\alpha]_D$ +101.7° ; Lit.[11]

$[\alpha]_D$ +112° ; Rf 0.5 (F) ; Retention time 4.7 min. ^1H NMR : δ, 0.88 (d, 3 H, J 7 Hz, CH_3), 0.99 (d, 3 H, J 7 Hz, CH_3-C_2), 1.07 (dt, 1 H, $J_{2,3} = J_{3,4}$ = 9 Hz, H_3), 1.68 (m, 1 H, H_2), 1.78 (dt, 1 H, $J_{2,3'} = J_{3',4}$ = 5 Hz, $J_{3,3'}$ 12.5 Hz, $H_{3'}$), 1.99 (m, 1 H, H_4), 2.32 (m, 1 H, OH), 3.43 (s, 3 H, OCH_3), 3.55 (dd, 1 H, $J_{5,6}$ 4 Hz, $J_{6,6'}$ 11 Hz, H_6), 3.76 (dd, 1 H, $J_{5,6'}$ 9.5 Hz, H_6), 3.99 (ddd, 1 H, $J_{4,5}$ 5 Hz, H_5), 4.27 (d, 1 H, $J_{1,2}$ 6 Hz, H_1).

Methyl-2,3,4-trideoxy-2,4-di-C-methyl α-D-arabino-hexopyranoside 13 was an oil, $[\alpha]_D^{25}$ +103° (c 0.3, $CHCl_3$) ; Rf 0.48 (F) ; Retention time GLC 2.5 min ; ^1H NMR : δ, 0.82 (d, 3 H, J 7 Hz, CH_3-C_4), 1.06 (d, 3 H, J 7 Hz, CH_3-C_2), 1.37 (dt, $J_{2,3}$ 3 Hz, $J_{3,4}$ 3 Hz, H_3), 1.66 (ddd, $J_{2,3'}$ 5 Hz, $J_{4,3'}$ 12 Hz, $J_{3,3'}$ 12.5 Hz, $H_{3'}$), 1.7-1.8 (m, 2 H, H_2 H_4), 3.35 (s, 3 H, OCH_3), 3.42 (m, 1 H, H_5), 3.60 (dd, 1 H, $J_{5,6}$ 2.5 Hz, $J_{6,6'}$ 11.5 Hz, H_6), 3.8 (dd, 1 H, $J_{5,6'}$ 6 Hz, $H_{6'}$), 4.4 (s, 1 H, H_1)

Anal. Calcd for $C_9H_{18}O_3$: C, 62.04 ; H, 10.41. Found : C, 62.10 ; H, 10.31.

Tritylation of 12 and 13. 1 mM of 12 or 13 (174 mg) was dissolved in 5 ml of pyridine. Trityl chloride (1.5 mM, 417 mg) was added with 50 mg of 4-N,N-dimethylaminopyridine. The mixture was stirred overnight at room temperature and then concentrated. The residue was dissolved in ether and washed with dilute hydrochloric acid, aqueous sodium hydroxide and water. The organic layer was dried over magnesium sulfate, filtered and evaporated to dryness. The residue was purified by column chromatography (F).

Methyl-2,3,4-trideoxy-2,4-di-C-methyl-6-O-phenylmethylene α-D-lyxo hexopyranoside 14 (374 mg, 90 %). mp 140-2° ; $[\alpha]_D^{25}$ +29.8° (c 0.8, $CHCl_3$) ; Rf 0.7. Lit.[4] mp 140-2° ; $[\alpha]_D$ +27.0°. Lit.[7] mp 138-40° ; $[\alpha]_D^{23}$ +29.1°. Lit.[10] mp 143-5° ; $[\alpha]_D^{22}$ +30.4°. ^1H NMR (360 MHz) δ : 0.73 (d, 2 H, J 7 Hz, CH_3-C_4), 0.98 (d, 2 H, J 6.5 Hz, CH_3-C_2), 1.03 (dt, 1 H, $J_{2,3} = J_{4,3}$ = 9 Hz, $J_{3,3'}$ = 13 Hz, H_3), 1.68 (m, 1 H, H_2), 1.77 (dt, 1 H, $J_{2,3'} = J_{2,4'}$ = 5.2 Hz, $H_{3'}$), 1.91 (m, 1 H, H_4), 3.08 (dd, 1 H, $J_{5,6}$ 4.5 Hz, $J_{6,6'}$ 9.5 Hz, H_6), 3.29 (dd, 1 H, $J_{5,6'}$ 7.5 Hz, $H_{6'}$), 3.50 (s, 3 H, OCH_3), 4.10 (m, 1 H, $J_{4,5}$ 5 Hz, H_5), 4.28 (d, 1 H, $J_{1,2}$ 5.75 Hz, H_2), 7.3-7.6 (m, 15 H, OTr).

Methyl-2,3,4-trideoxy-2,4-di-C-methyl-6-O-phenylmethylene α-D-arabino-hexopyranoside 15 (365 mg, 87 %). mp 130-2° ; $[\alpha]_D^{23}$ +45° (c 0.2, $CHCl_3$) ; Rf 0.7 (F) ; ^1H NMR (360 MHz) δ : 0.58 (d, 3 H, J 6.5 Hz, CH_3-C_4), 1.09 (d, 3 H, J 7 Hz, CH_3-C_4), 1.31 (ddd, 1 H, J 3 Hz, J 4 Hz, $J_{3,3'}$ 13 Hz, $H_{3eq.}$), 1.60 (ddd, 1 H, $J_{2,3}$ 5 Hz, $J_{3,4}$ 12 Hz, $J_{3ax.}$), 1.81 (m, 2 H, H_2 H_4), 3.09 (dd, 1 H, $J_{5,6}$ 5 Hz, $J_{6,6'}$ 10 Hz, H_6), 3.26 (dd, 1 H, $J_{5,6'}$ 2.5 Hz, $H_{6'}$), 3.42 (s, 3 H, OCH_3), 3.45 (m, 1 H, H_5), 4.45 (s, 1 H, H_1), 7.2-7.6 (m, 15 H, OTr).

Anal. Calcd for $C_{28}H_{32}O_3$: C, 80.73 ; H, 7.74. Found : C, 80.72 ; H, 7.69.

X-Ray diffraction. Crystals were grown by slow evaporation of hexane solution and are orthorhombic space group $P_{2_12_12_1}$ with a = 11.269 (3), b = 12.405 (2), c = 16.945 (3) Å V = 2367 Å (3) Z = 4. Data were collected at room temperature on a CAD4 Enraf

TABLE 1

Fractional coordinates (X 10^4) and equivalent thermal coefficients ($Å^2$) with standard deviations.

	x	y	z	B_{eq}
C-1	8898 (5)	-1106 (6)	-2439 (5)	5.6 (2)
C-2	9887 (6)	-1110 (6)	-3035 (5)	6.4 (2)
C-3	10136 (5)	52 (7)	-3333 (5)	6.3 (2)
C-4	9030 (5)	695 (6)	-3555 (4)	5.5 (2)
C-5	8145 (4)	601 (4)	-2873 (3)	4.1 (1)
C-6	6927 (5)	1077 (4)	-3012 (4)	4.2 (1)
C-7	8485 (12)	-761 (14)	-1088 (7)	10.4 (4)
C-8	9672 (10)	-1921 (9)	-3692 (7)	8.2 (3)
C-9	8498 (7)	414 (9)	-4351 (4)	6.9 (2)
C-10	6045 (4)	2852 (4)	-3078 (3)	3.6 (1)
C-11	5855 (4)	3030 (4)	-2186 (3)	3.6 (1)
C-12	6778 (5)	2840 (5)	-1666 (3)	4.6 (1)
C-13	6647 (7)	3054 (6)	-865 (4)	5.9 (2)
C-14	5603 (7)	3486 (5)	-585 (4)	5.7 (2)
C-15	4682 (7)	3673 (5)	-1099 (4)	5.0 (2)
C-16	4801 (5)	3459 (4)	-1892 (3)	4.5 (1)
C-17	6337 (4)	3954 (4)	-3426 (3)	3.7 (1)
C-18	7508 (5)	4292 (5)	-3482 (3)	4.2 (1)
C-19	7789 (6)	5320 (5)	-3740 (4)	5.4 (2)
C-20	6896 (7)	6027 (5)	-3959 (3)	5.4 (2)
C-21	5734 (6)	5698 (5)	-3915 (4)	5.2 (2)
C-22	5440 (5)	4669 (4)	-3636 (3)	4.4 (1)
C-23	4992 (4)	2320 (4)	-3507 (3)	3.7 (1)
C-24	4143 (5)	1704 (4)	-3123 (4)	4.5 (1)
C-25	3271 (6)	1158 (6)	-3544 (4)	5.5 (2)
C-26	3226 (6)	1227 (5)	-4352 (4)	5.5 (2)
C-27	4070 (7)	1814 (5)	-4744 (4)	5.5 (2)
C-28	4952 (6)	2353 (5)	-4328 (3)	4.8 (1)
O-1	9331 (4)	-691 (5)	-1730 (3)	6.7 (1)
O-2	7894 (3)	-508 (3)	-2707 (2)	4.6 (1)
O-3	7079 (3)	2199 (3)	-3197 (2)	3.9 (1)

Nonius diffractometer equipped with a graphite monochromator and CuKα radiation in the θ/2θ scanning mode (θ ⩽ 70°). The absorption was disregarded ($\mu R \ll 1$) and intensities were corrected for Lorentz and polarisation factors. Scattering factors used were those listed in Vol. IV of the international tables for X-Ray crystallography. 2543 reflections were collected and 1600 reflections with $I < \sigma(I)$ were retained to resolve the structure.

Structure was solved by the MULTAN program.[26] E-maps revealed the complete molecule except hydrogen atoms. The structure was refined through the least square procedure with the complete matrix of normal equations.[27] Non hydrogen atoms were affected by anisotropic thermal parameters. Hydrogen atoms appeared on E-map differences and were affected by an isotropic thermal factor equal to that of the bonded heavy atom. During the last cycle of the refinement, a weighting scheme was applied ($W = 1/\sigma^2 (F_o)$) and final R and R_w values were respectively 0.039 and 0.043. Atomic coordinates and equivalent thermal coefficients are given in table 1. The figure gives a stereoscopic view[28] of the molecule and the

TABLE 2

Principal torsionnal angles (°) with standard deviations.

C-1-C-2-C-3-C-4	-46.5 (9)	C-4-C-5-C-6-O-3	-58.1 (6)
C-2-C-3-C-4-C-5	+49.3 (8)	C-7-O-1-C-1-O-2	+62.7 (9)
C-3-C-4-C-5-O-2	-56.2 (6)	C-6-C-5-C-4-C-3	-173.3 (5)
C-4-C-5-O-2-C-1	+63.9 (6)	O-1-C-1-C-2-C-3	-74.5 (7)
C-5-O-2-C-1-C-2	-59.8 (7)	C-9-C-4-C-3-C-2	-78.0 (9)
O-2-C-1-C-2-C-3	+48.7 (7)	C-8-C-2-C-3-C-4	+80.7 (9)
O-2-C-5-C-6-O-3	-179.1 (4)		

numbered atoms. Interatomic distances and angles are in good agreement with the standard values for similar molecules*. Table 2 gives the principal torsional angles in the molecule.

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