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SYNTHESIS OF A SERIES OF FULLY METHYLATED ALDOBIOURONIC ACIDS, AND β-ELIMINATION REACTIONS OF THEIR SYNTHETIC PRECURSORS*

PAVOL KOVÁČ, JÁN HIRSCH, AND VLADIMÍR KOVÁČIK
Institute of Chemistry, Slovak Academy of Sciences, 809 33 Bratislava (Czechoslovakia)
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ABSTRACT

Treatment of methyl 2,3,4-tri-*O*-acetyl-1-bromo-1-deoxy-α-D-glucopyranuronate severally with 2,4,6-, 2,3,6-, and 2,3,4-tri-*O*-methyl derivatives of methyl α-D-glucopyranoside and with methyl 4,6-*O*-benzylidene-3-*O*-methyl-α-D-glucopyranoside, in the presence of silver carbonate, afforded crystalline aldobiouronic acid derivatives in high yield Deacetylation followed by methylation gave a series of fully methylated derivatives of laminaribiouronic, cellobiouronic, and gentiobiouronic acids, and the (1→2)-linked analogue Methylation with methyl iodide and silver oxide in *N*,*N*-dimethylformamide was invariably accompanied by a small amount of β-elimination, with the formation of olefinic disaccharides which were also obtained by β-elimination reactions of the precursor acetates followed by methylation Methyl 4,5-unsaturated 4-deoxyhexopyranosyluronate derivatives were the main products of the reaction, but these underwent further degradation with cleavage of the interglycosidic linkage and formation of 6-methoxycarbonyl-4-pyrone

INTRODUCTION

Studies of the degradation of uronic acid-containing substances by base required pseudoaldobiouronic and aldobiouronic acid derivatives as substrates Syntheses of three fully methylated pseudoaldobiouronic acids have been reported[2,3], and we now describe the synthesis of the fully methylated aldobiouronic acids **16**–**19**

Derivatives of D-galacturonic acid undergo[4] β-elimination reactions more easily than do their D-glucuronic acid analogues Treatment of methyl (methyl 2,3,4-tri-*O*-methyl-α-D-gluco- and -galactopyranosid)uronates with weak base gave the corresponding C-5-epimer and methyl (methyl 4-deoxy-2,3-di-*O*-methyl-β-L-*threo*-hex-4-enopyranosid)uronate only from the *galacto* compound When each of a series of pseudoaldobiouronic acid derivatives, having a D-galacturonic acid moiety as the reducing end-unit, was methylated by the Kuhn[5] procedure, partial degradation by β-elimination was observed We now report on the Kuhn methylation of the

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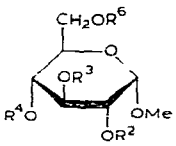
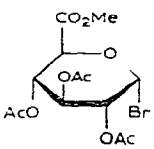
aldobiouronic acids **12–15** which contain a D-glucuronic acid moiety as the non-reducing end-unit

RESULTS AND DISCUSSION

The yields of oligosaccharides obtained by the Koenigs–Knorr reaction[6] are affected by complex stereoelectronic effects The reactivity of the hydroxyl groups of the carbohydrate derivative in these reactions depends[7,8], at least to some extent, upon the nature of the neighbouring substituents For instance, in the L-fucose series, much higher yields of oligosaccharides were obtained in syntheses involving partially benzylated L-fucoses as nucleophiles than when related acyl derivatives were used The acyl groups may[8] cyclize with neighbouring hydroxyl groups, thus lowering their reactivity

When each of the partially methylated derivatives (**2–5**) of methyl α-D-glucopyranoside was treated with methyl 2,3,4-tri-*O*-acetyl-1-bromo-1-deoxy-α-D-glucopyranuronate[9] (**1**) in the presence of silver carbonate, the crystalline aldobiouronic





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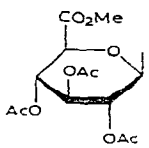

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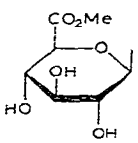

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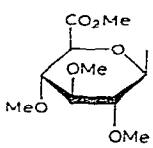

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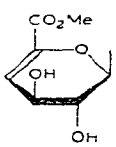

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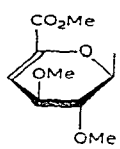


E

	R^2	R^3	R^4	R^6
2	H	Me	−C(Ph H)−	
3	Me	H	Me	Me
4	Me	Me	H	Me
5	Me	Me	Me	H
6	A	Me	−C(Ph H)−	
7	A	Me	H	H
8	A	Me	Me	Me
9	Me	A	Me	Me
10	Me	Me	A	Me
11	Me	Me	Me	A
12	B	Me	H	H
13	Me	B	Me	Me
14	Me	Me	B	Me
15	Me	Me	Me	B
16	C	Me	Me	Me
17	Me	C	Me	Me
18	Me	Me	C	Me
19	Me	Me	Me	C
20	D	Me	H	H
21	Me	D	Me	Me
22	Me	Me	D	Me
23	Me	Me	Me	D
24	E	Me	Me	Me
25	Me	E	Me	Me
26	Me	Me	E	Me
27	Me	Me	Me	E
31	H	Me	H	H

acid derivatives **6** and **9–11** were obtained in yields of 70–80% Catalytic hydrogenolysis of **6**, followed by Purdie methylation of the product **7**, yielded the crystalline derivative **8** of the (1→2)-linked aldobiouronic acid, analogous to the partially methylated derivatives (**9–11**) of laminaribiouronic, cellobiouronic, and gentiobiouronic acids

The structures **6** and **8–11**, expected by the route of synthesis, were confirmed by mass spectrometry A molecular ion and an $[M-1]^+$ peak were present in the spectrum of **6**, confirming its molecular weight (612) The most intense peaks in the spectrum were at *m/e* 317, 257, 215, 197, 173, and 127, corresponding to the ions formed[10] through Series aA, and reflected the presence of the peracetylated uronic acid residue The peaks at *m/e* 463 and 149 were formed *via* h-rupture, characteristic[11,12] of the fragmentation of 4,6-*O*-benzylidenehexopyranoside derivatives The MeO-1 and MeO-3 groups of the hexose unit gave rise[13] to the ions of the F and J series at *m/e* 101 and 75

The molecular weight of **9** was calculated[14] from the equation $M = aA_1 + bA_1 + 16$ (317+219+16) Complete acetylation and methylation of the uronic acid and hexose moiety, respectively, followed from the *m/e* values of the fragments of the aA and bA series The spectrum was not informative as to the type of the interglycosidic linkage Compound **10** gave a mass spectrum containing intense baB_1 and baF_1 ion peaks at *m/e* 478 and 403, respectively, diagnostic[14,15] of permethylated (1→2)- and (1→4)-linked disaccharides, and from which the molecular weight (552) was calculated The same value was obtained by employing the calculation applied to **9**, using the *m/e* values of aA_1 and bA_1 ion peaks The (1→4)-linkage in **10** followed from the peak at *m/e* 161, negligible in the spectrum of **8**, which was otherwise similar to that of **10** The intense baD_1 ion peak at *m/e* 451, present in the spectrum of **11**, confirmed the presence of a (1→6)-linkage The same peak, together with those of the ions aA_1 and bA_1, permitted calculation of the molecular weight (552)

To obtain the series of fully methylated aldobiouronic acid derivatives, **7** and **9–11** were deacetylated and the products **12–15** were methylated As in the syntheses of related pseudoaldobiouronic acid derivatives[2,3], Kuhn methylation of **12–15** was accompanied by β-elimination, giving small amounts of fully methylated, unsaturated oligosaccharides **24–27** as by-products, the structures of the fully methylated products **16–19** and **24–27** were confirmed by mass spectrometry

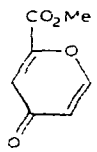
The calculated molecular weight of **16–19** (M = 219+233+16) proved that methylation was complete The (1→4)- and (1→6)-linkages in **18** and **19**, respectively, were proved by the presence of ion peaks at *m/e* 161 in the spectrum of **18**, and of the baD_1 ion peak[14] at *m/e* 367 in the spectrum of **19** The molecular weights of **24–27** were calculated from the *m/e* values of the A_1 ions (M = 201+219+16 = 436) present in their mass spectra, thus proving that methylation was complete

Aspinall *et al* [16] recorded that treatment of methyl (methyl 2,3,4-tri-*O*-methyl-β-D-glucopyranosid)uronate with methyl iodide and silver oxide in *N,N*-dimethylformamide for 8 days did not result in the formation of olefinic products The formation of **24–27** during methylation of **12–15** suggests that the β-elimination occurred

at the beginning of the reaction At that stage, a hydroxyl group, which is a better leaving-group[17] than a methoxyl group, was present at C-4 of the uronic acid moiety When a still better leaving-group was present (as in the conversion **7**→**8**), the main reaction observed under the conditions of Kuhn methylation was β-elimination (see Experimental)

Olefins **24–27** were prepared on a larger scale from the acetates **7** and **9–11** by effecting β-elimination with sodium hydride in 1,2-dimethoxyethane[3] followed by methylation of the deacetylated products **20–23** Compounds **24–27** thus obtained were identical with the unsaturated by-products formed during Kuhn methylation of **12–15**

Although the olefinic deacetylated disaccharides were obtained in good yields, other products were formed in the conversions of **7** and **9–11**→**20–23** T l c of the reaction mixtures after deacetylation and esterification indicated that substances resulting from cleavage of the inter-glycosidic linkages, as a result of further elimination, were also present Such a cleavage reaction was observed when a specifically modified lactose was treated with base[18] The non-olefinic by-products had the chromatographic mobilities of the partially methylated methyl α-D-glucopyranosides **3–5** and **31**, and the fact that the optically inactive, minor olefin (**28**) present in these reaction mixtures was not detected with the sulphuric acid spray suggested that it might be related to the 4-pyrone derivative **30** isolated[19,20] as a by-product of further elimination of monomeric derivatives **29** This relationship was also suggested by the i r bands at 1650 (C=O), 1680, and 1590 cm^{-1} (C=C), which are characteristic[21] of 4-pyrone derivatives



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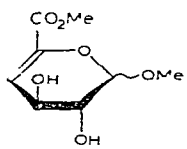

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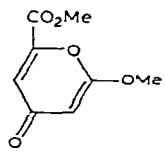

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The formulation of **28** as 6-methoxycarbonyl-4-pyrone was accomplished on the basis of the following data The molecular formula of **28**, calculated from the analytical data, was confirmed by exact mass measurements of the molecular ions (*m/e* 154) The formation of fragments $[M-59]^+$, $[C_3HO_2]^+$, and $[C_3HO]^+$ at *m/e* 95, 69, and 53, respectively, was analogous to the fragmentation of 2-methoxy-6-methoxycarbonyl-4-pyrone[20] (**30**) The p m r spectrum of **28** contained signals at δ 7 85 (d, 1 H, $J_{2,3}$ 5 7 Hz, H-2), 6 46 (q, 1 H, $J_{3,5}$ 2 6 Hz, H-3), 7 13 (d, 1 H, H-5), and 3 96 (s, 3 H, COOMe) The formation of **28** as a by-product in the β-elimination reactions of **7** and **9–11** constitutes a proof, additional to that presented earlier[19,20], that 4,5-unsaturated 4-deoxyhexopyranuronate derivatives can undergo further elimination under the conditions of their formation Moreover, the presence of different substituents at position 2 in **28** and **30** suggests that the mechanism depends

not only on the base used but also on the mode of substitution (*cf* Refs 19 and 20) at the anomeric centre

Although the contrary has been claimed[22], convincing evidence was presented[23–25] showing that acidic oligo- and poly-saccharides undergo degradation by β-elimination when methylated with methylsulphinyl carbanion[26] The isolation of **24–27** from the reaction mixtures following Kuhn methylation of **12–15**, together with our previous observations[2 3], suggests that acidic polysaccharides are likely to undergo depolymerization during this process, and this possibility should be taken into account in evaluating the results of methylation analysis

EXPERIMENTAL

M p s were determined on a Kofler hot-stage Optical rotations were measured on chloroform solutions (*c* 1), unless stated otherwise, with a Perkin–Elmer automatic polarimeter Model 141 P m r spectra ($CDCl_3$, internal Me_4Si) were measured at 80 MHz with a Tesla BS-487-B spectrometer Mass spectra (74 eV) were measured with a JMS-100D instrument, and exact mass measurements were performed at a resolution of 10,000 The evaporation temperature was 130–150° and that of the ionizing chamber was 180° I r spectra (5% solutions in chloroform) were recorded with a Perkin–Elmer Model 457 spectrometer

T l c was performed on Silica gel G, and column chromatography on dry-packed silica gel (Merck, 9385), with *A*, benzene–acetone (10 1), *B*, chloroform–methanol (15 1); *C*, benzene–acetone (6 1), *D*, benzene–methyl acetate (2 1), *E*, chloroform–methanol (4 1), *F*, cyclohexane–acetone (7 2), *G*, chloroform–methanol (8 1), *H*, chloroform–acetone (10 1), *I*, chloroform–acetone (4 1), *J*, benzene–acetone (4 1), *K*, chloroform–methanol (25 1), and *L*, benzene–methyl acetate (4 1) Detection was effected with 0 1% potassium permanganate in acetone (olefins immediately gave yellow spots on a violet background) or by charring with 5% sulphuric acid in ethanol

Silver oxide and silver carbonate were prepared as previously described[27 28] *N*,*N*-dimethylformamide was dried[29] and freshly distilled, and dry[29] 1,2-dimethoxyethane was stored over sodium hydride Unless otherwise stated solutions were concentrated under diminished pressure at <40°

Methyl 3-O-methyl- and 3,4,6-tri-O-methyl-2-O-(methyl 2,3,4-tri-O-acetyl-β-D-glucopyranosyluronate)-α-D-glucopyranoside (**7** *and* **8**) — A mixture of **2**[30] (4 5 g, 15 2 mmol), Drierite (14 g), silver carbonate (6 75 g), and dry benzene (70 ml) was stirred in the dark at room temperature for 4 h After the addition of iodine (1 2 g), a solution of **1** (9 g, 22 7 mmol) in dry benzene (40 ml) was added dropwise during 1 h, and the mixture was stirred for 4 h at room temperature T l c (solvent *A*) then showed the absence of **1** (R_F 0 6) and the presence of methyl 4,6-*O*-benzylidene-3-*O*-methyl-2-*O*-(methyl 2.3,4-tri-*O*-acetyl-β-D-glucopyranosyluronate)-α-D-glucopyranoside (**6**, R_F 0 3), together with small proportions of **2** (R_F 0 2) and the product of hydrolysis (R_F 0 15) of **1** The mixture was filtered and concentrated, and the residue

was crystallized from methanol to give **6** (3 4 g) The material in the mother liquor was chromatographed to give an additional crop (total yield, 7 1 g, 76 3% based on **2**), m p 195–197°, $[\alpha]_D^{24}$ +15 5° (Found C, 55 00, H, 6 12, $C_{28}H_{36}O_{15}$ calc C, 54 90, H, 5 92%)

A solution of **6** (7 g) in methanol (150 ml) was hydrogenolysed over palladium–charcoal at room temperature (~1 h) and then worked-up in the usual manner The chromatographically pure product (5 5 g, 91 8%, R_F 0 35, solvent *B*) was crystallized from methanol and recrystallized from acetone to give **7**, m p 197–198°, $[\alpha]_D^{22}$ +26° (Found C, 48 07, H, 5 90 $C_{21}H_{32}O_{15}$ calc C, 48 09, H, 6 15%)

A mixture of **7** (2 g), acetone (30 ml), methyl iodide (4 7 ml), and silver oxide (18 g) was shaken in the dark for 24 h at room temperature The partially methylated product, now soluble in methyl iodide, was treated with methyl iodide (15 ml) and silver oxide (9 g) for 24 h After five such treatments, methylation was incomplete, as shown by t l c (solvent *C*) The product was fractionated by chromatography to give **8**, m p 112 5–114 5° (from ether), $[\alpha]_D^{23}$ +26° (Found C, 49 92, H, 6 65 $C_{23}H_{36}O_{15}$ calc C, 49 99, H, 6 57%)

When **7** was treated with methyl iodide–silver oxide–*N*,*N*-dimethylformamide for 24 h, the main products, as shown by t l c , were compounds that were detectable by the sulphuric acid and permanganate reagents, these products were not further examined

Methyl 2,4,6-tri-O-*methyl-3*-O-(*methyl 2,3,4-tri*-O-*acetyl*-β-D-*glucopyranosyl-uronate*)-α-D-*glucopyranoside* (**9**) — A mixture of $\mathbf{3}^{31}$ (2 g, 8 46 mmol), Drierite (6 g), silver carbonate (2 4 g), and dry benzene (30 ml) was stirred in the dark for 4 h After the addition of iodine (0 5 g), **1** (3 5 g, 8 8 mmol) was added, followed, after 4 h, by fresh portions of silver carbonate (1 2 g) and **1** (1 7 g, 4 28 mmol), the mixture was then stirred for 16 h T l c (solvent *D*) then showed **9** (R_F 0 3), together with small proportions of **3** (R_F 0 15) and the product of hydrolysis (R_F 0 4) of **1** Chromatography of the mixture gave **9** (3 4 g, 72 7% based on **3**), m p 110 5–112 5° (from ether), $[\alpha]_D^{21}$ +46° (Found C, 50 20, H, 6 36 $C_{23}H_{36}O_{15}$ calc C, 49 99, H, 6 57%)

Methyl 2,3,6-tri-O-*methyl-4*-O-(*methyl 2,3,4-tri*-O-*acetyl*-β-D-*glucopyranosyl-uronate*)-α-D-*glucopyranoside* (**10**) — Compound $\mathbf{4}^{32\ 33}$ (2 g, 8 46 mmol) was treated with **1** (total amount, 5 2 g, 13 1 mmol) as described for **9**, to give, after chromatography, **10** (3 6 g, 77% based on **4**), R_F 0 3 (solvent *D*), m p 119 5–120 5° (from ether), $[\alpha]_D^{22}$ +58° (Found C, 50 10, H, 6 60 $C_{23}H_{36}O_{15}$ calc C, 49 99, H, 6 57%)

Methyl 2,3,4-tri-O-*methyl-6*-O-(*methyl 2,3,4-tri*-O-*acetyl*-β-D-*glucopyranosyl-uronate*)-α-D-*glucopyranoside* (**11**) — Treatment of $\mathbf{5}^{34}$ (2 g, 8 46 mmol) with **1** (total amount, 5 2 g, 13 1 mmol), as described for **9**, gave, after chromatography, **11** (3 7 g, 78 5% based on **5**), R_F 0 3 (solvent *D*), m p 124–126° (from ether), $[\alpha]_D^{24}$ +46° (Found C, 50 20, H, 6 40 $C_{23}H_{36}O_{15}$ calc C, 49 99, H, 6 57%)

Methyl 3,4,6-tri-O-*methyl-2*-O-(*methyl 2,3,4-tri*-O-*methyl*-β-D-*glucopyranosyl-uronate*)-α-D-*glucopyranoside* (**16**) — Water (5 ml) was added to a solution of **7** (0 7 g) in 1,2-dimethoxyethane (10 ml), the solution was cooled in ice, and M potassium

hydroxide (2 35 ml) was added slowly with stirring More M potassium hydroxide (7 ml) was added after 30 min, and the solution was kept at 55° for 2 h, then cooled in ice, deionized with Dowex-50W (H^+) resin, filtered, and concentrated with co-distillation with water to remove acetic acid A solution of the residue in methanol was treated with ethereal diazomethane to give crude **12** (R_F 0 2, solvent *E*) which was slightly contaminated with a product having R_F 0 35 Chromatography of the mixture gave pure **12** (0 48 g, 1 2 mmol, 90 6%) as a hygroscopic foam, a solution of which in *N*,*N*-dimethylformamide (12 ml) was shaken in the dark with methyl iodide (1 9 ml, 30 mmol) and silver oxide (7 g, 30 mmol) for 24 h After the addition of chloroform (10 ml), the mixture was filtered and concentrated at 70° T l c then showed **16** (R_F 0 3, solvent *F*), together with a small proportion of an olefinic substance (R_F 0 25), and products (R_F 0 15 and 0 2) resulting from undermethylation Chromatography afforded **16** (0 43 g, 76 8% based on **12**), m p 70 5–72° (from hexane), $[\alpha]_D^{23}$ +45° (Found C, 51 10, H, 7 75 $C_{20}H_{36}O_{12}$ calc C, 51 27, H, 7 75%)

The olefinic component (R_F 0 25, 0 035 g, 6 65% based on **12**) gave a mass spectrum identical with that of **24** described below

Methyl 2,4,6-tri-O-methyl-3-O-(methyl 2,3,4-tri-O-methyl-β-D-glucopyranosyl-uronate)-α-D-glucopyranoside (**17**) — Deacetylation of **9** (0 5 g), as described for **12**, gave, after chromatography, **13** (0 36 g, 93 3%), R_F 0 25 (solvent *B*), as a hygroscopic thick syrup, which was methylated as described for **16** Chromatography (solvent *F*) removed some undermethylated material (R_F 0 15), traces of an olefinic substance (R_F 0 25, the mass spectrum of which was identical with that of **25** described below), and **17** (0 34 g, 86% based on **13**), R_F 0 3, m p 110–111 5° (from ether), $[\alpha]_D^{22}$ +66° (Found C, 51 35, H, 7 70 $C_{20}H_{36}O_{12}$ calc C, 51 27, H, 7 75%)

Methyl 2,3,6-tri-O-methyl-4-O-(methyl 2,3,4-tri-O-methyl-β-D-glucopyranosyl-uronate)-α-D-glucopyranoside (**18**) — Compound **10** (0 5 g) was converted into **14** as described for **12**, and the resulting hygroscopic foam (0 365 g, 94 6%, R_F 0 25, solvent *B*) was methylated, as described for **16**, to give, after chromatography, **18** (0 34 g, 85%, based on **14**, R_F 0 3, solvent *F*), a trace of an olefin (R_F 0 25) identical (m s) with **26** (see below), and undermethylated material (R_F 0 15) When crystallized from isopropyl ether, **18** had m p 77 5–79 5°, $[\alpha]_D^{22}$ +68° (Found C, 51 20 H, 7 65 $C_{20}H_{36}O_{12}$ calc C, 51 27, H, 7 75%)

Methyl 2,3,4-tri-O-methyl-6-O-(methyl 2,3,4-tri-O-methyl-β-D-glucopyranosyl-uronate)-α-D-glucopyranoside (**19**) — Compound **11** (0 5 g) was treated as described for **12**, and the deacetylated product **15**, obtained after chromatography as a yellow, hygroscopic, thick syrup (0 375 g, 97%, R_F 0 25, solvent *B*), was methylated as described for **16** Chromatography then gave a small proportion of undermethylated material (R_F 0 15, solvent *F*), an olefin (0 03 g, 5 7% based on **15**, R_F 0 25), the mass spectrum of which confirmed its identity with **27**, and **19** (0 315 g, 76 3% based on **15**, R_F 0 3, solvent *F*) which, when crystallized from ether–isopropyl ether (1 2), had m p 108–109°, $[\alpha]_D^{22}$ +53° (Found C, 51 04, H, 7 51 $C_{20}H_{36}O_{12}$ calc C, 51 27, H, 7 75%)

Methyl 3-O-methyl-2-O-(methyl 4-deoxy-α-L-threo-hex-4-enopyranosyluronate)-α-D-glucopyranoside (**20**) — A mixture of **7** (1 g, 1 9 mmol), sodium hydride (0 23 g, 9 6 mmol), and dry 1,2-dimethoxyethane (30 ml) was stirred at 80° for 24 h with the exclusion of moisture and carbon dioxide T l c (solvent *B*) then showed the absence of **7**, and the presence of several olefinic products (R_F 0 2–0 55) The olefin having the highest R_F value was detected only with potassium permanganate spray, and had the same mobility as the 4-pyrone derivative **28** described below The mixture was cooled in ice, diluted with methanol, deionized with Dowex-50W (H^+) resin, filtered, and concentrated, and an excess of ethereal diazomethane was added to the solution of the residue in methanol T l c (solvent *E*) then showed the presence of **20** (R_F 0 4, detection with both reagents), and small proportions of **12** (R_F 0 2), methyl 3-*O*-methyl-α-D-glucopyranoside (**31**, R_F 0 35), and **28** (R_F 0 8) Chromatography (solvent *G*) gave **20** (0 58 g, 80%) as a colourless foam, $[\alpha]_D^{23}$ +40° (Found C, 47 58, H, 6 50 $C_{15}H_{24}O_{11}$ calc C, 47 36, H, 6 36%)

Methyl 2,4,6-tri-O-methyl-3-O-(methyl 4-deoxy-α-L-threo-hex-4-enopyranosyluronate)-α-D-glucopyranoside (**21**) — When **9** (1 g) was treated for 24 h, as described for **20**, t l c (solvent *H*) showed the presence of an olefinic product (R_F 0 5, detection with both reagents), traces of **9** (R_F 0 45), and material at the base line When the mixture was worked-up as described above, t l c (solvent *I*) revealed **21** (R_F 0 2), and small proportions of **3** (R_F 0 3), **28** (R_F 0 55), and **13** (R_F 0 05) Chromatography gave **21** (0 625 g, 84 6%) which crystallized from benzene–hexane, but the product liquefied on contact with air and had $[\alpha]_D^{23}$ +40° (Found C, 49 71, H, 6 85 $C_{17}H_{28}O_{11}$ calc C, 49 99, H, 6 91%)

Methyl 2,3,6-tri-O-methyl-4-O-(methyl 4-deoxy-α-L-threo-hex-4-enopyranosyluronate)-α-D-glucopyranoside (**22**) — When **10** (1 g) was treated as described for **20**, t l c (solvent *H*) revealed an olefinic substance (R_F 0 55, detection with both reagents) and a small proportion of base-line material The mixture was worked-up as described above, and t l c then revealed **22** (R_F 0 2, solvent *I*), together with small proportions of **4** and **28** (R_F 0 35 and 0 55) Chromatography afforded **22** as a clear syrup (0 62 g, 84%), $[\alpha]_D^{23}$ +57° (Found C, 50 20, H, 7 00 $C_{17}H_{28}O_{11}$ calc C, 49 99, H, 6 91%)

Methyl 2,3,4-tri-O-methyl-6-O-(methyl 4-deoxy-α-L-threo-hex-4-enopyranosyluronate)-α-D-glucopyranoside (**23**) — When **11** (3 g) was treated as described for **20**, the reaction mixture still contained ~20% of **11** (t l c, solvent *J*) Sodium hydride (0 1 g) was added and, after 3 h at 80°, no starting material remained (t l c), but an olefin (R_F 0 4, detection with both reagents) and base-line material were present After work-up, the mixture contained mainly **23** (R_F 0 35, solvent *B*), together with small proportions of **5** and **28** (R_F 0 5 and 0 65), and traces of **15** (R_F 0 1) Chromatography (solvent *K*) gave **23** as a syrup (1 9 g, 85 6%), $[\alpha]_D^{23}$ +58° (Found C, 49 73, H, 6 64%) The mixture of faster-moving components was rechromatographed (solvent *L*) to give **28** (0 037 g, 4 4%), m p 85 5–86 5° (from acetone–ether), $[\alpha]_D^{23}$ ~0° (*c* 1, methanol) (Found C, 54 38, H, 3 95 $C_7H_6O_4$ calc C, 54 55, H, 3 92%)

Methyl 3,4,6-tri-O-methyl-2-O-(methyl 4-deoxy-2,3-di-O-methyl-α-L-threo-hex-

4-enopyranosyluronate)-α-D-glucopyranoside (**24**) — Methylation of **20** (0 42 g), as described for **16** and followed by chromatography (solvent *C*), gave **24** as a colourless syrup (0 39 g, 81%), $[\alpha]_D^{24}$ +69° (Found C, 51 95, H, 7 30 $C_{19}H_{32}O_{11}$ calc C, 52 28, H, 7 39%)

Similar methylations of **21**, **22**, and **23** gave, after purification by chromatography, **25** (84 6%), $[\alpha]_D^{22}$ +50° (Found C, 52 02, H, 7 27%), **26** (91%), $[\alpha]_D^{24}$ +68° (Found C, 52 47, H, 7 31%), and **27** (88%), m p 60 5–62° (from isopropyl ether), $[\alpha]_D^{23}$ +68° (Found C, 52 35, H, 7 35%)

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