Carbohydrate Research, 39 (1975) 87–96

TWO DIASTEREOISOMERIC 2,3:5,6-DI-*O*-ETHYLIDENE-β-D-ALLOSES AND RELATED DERIVATIVES

WILLIAM E. DICK, JR. AND DAVID WEISLEDER

Northern Regional Research Laboratory, Peoria, Illinois 61604 (U. S. A.)*

(Received June 6th, 1974; accepted in revised form, September 23rd, 1974)

ABSTRACT

Direct condensation of β-D-allose with acetaldehyde in the presence of sulfuric acid formed two of eight possible 2,3:5,6-di-*O*-ethylidene-D-alloses in overall yields of 84–96%. Conditions of the reaction were varied to favor formation of either isomer. The presence of a furanose ring in both isomers was established by converting the diastereoisomers into 1,4-di-*O*-acetyl-D-allitol analogs. P.m.r. analysis of the reducing isomers, their 3-deuterio analogs, their 1-*O*-acetyl derivatives, and the 1,5,6-triacetate of a common hydrolysis product, 2,3-*O*-ethylidene-D-allose, established the anomeric configuration of D-allose as β-, and the C-2′ atom in the 2,3-*O*-ethylidene ring as *R* and as either *R* or *S* in the 5,6-*O*-ethylidene ring.

DISCUSSION

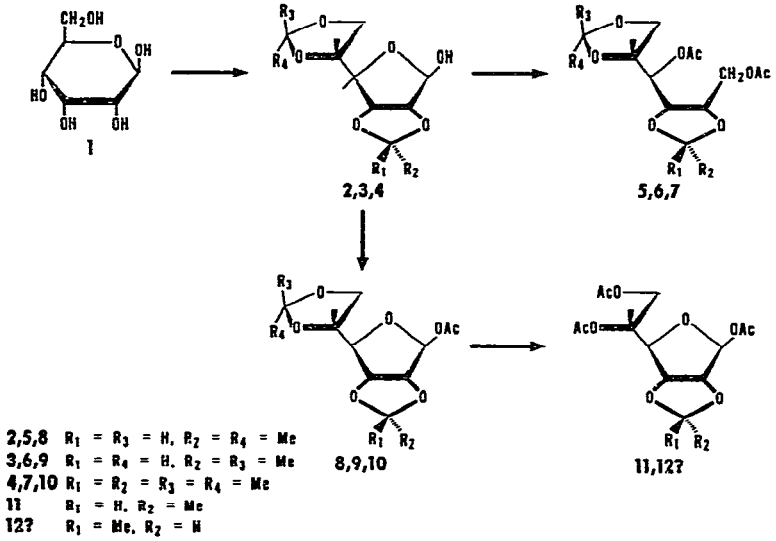
Except for the direct condensation of D-allose with acetone to form 2,3:5,6-di-*O*-isopropylidene-β-D-allose[1,2] (**4**), present knowledge of acetals of D-allose is limited to derivatives obtained indirectly from other hexose analogs[3,4]. Because acetaldehyde is far more prone than acetone to form dioxane rings[5], and because such ethylidene derivatives would be useful as starting compounds for further syntheses, the direct condensation of β-D-allopyranose (**1**) with acetaldehyde was investigated.

Initially, a mono-*O*-ethylidene derivative of D-allose (**1**) was sought from the reaction of **1** at 25° with paraldehyde and sulfuric acid—the conditions used to prepare 4,6-*O*-ethylidene-D-glucose from α-D-glucose[6]. After 48 h, t.l.c. showed only traces of two mono-*O*-ethylidene derivatives, as judged by R_F values, and approximately equal amounts of **1** together with a major band of product that ran near the solvent front and reduced 2,3,5-triphenyltetrazolium chloride–alcoholic potassium hydroxide spray-reagent[7]. G.l.c. established that the major band contained two components

*Agricultural Research Service, U.S. Department of Agriculture. Mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

that could be chromatographed either before or after formation of trimethylsilyl ethers. Small proportions of other, similarly volatile, components were also detected.

The two major products were separated on a column of silica gel. The first to be eluted was a syrup that slowly formed a waxy solid (**2** in the reaction scheme), and the second formed crystalline needles (**3**).



Scheme 1.

The p.m.r. spectra of **2** and **3** indicated that each was a di-*O*-ethylidene derivative whose structure was probably analogous to that of 2,3:5,6-di-*O*-isopropylidene-D-allose (**4**). The spectral data obtained by first-order analysis of **2**, **3**, and **4** are listed in Table I. Assignment of H-3 for **2** and **3** was made by comparison of each spectrum with those of the 3-deuterio analogs. Assignment of H-3 in **4** was made by analogy with **2** and **3**.

Although the size of the D-allose ring in **2** and **3** could not be established conclusively by p.m.r. analysis, each has a mass spectrum consistent with a D-allofuranose structure. The prevalance of C-4–C-5 cleavages in furanose derivatives is well established[8,9], and the two ions characteristic for such cleavages, *m/e* 87 and 145, can be seen in the mass spectra of **2** and **3**.

Other important cleavages include the loss of water (M−18, *m/e* 214) or OH (M−17, *m/e* 215) from the reducing center, and two fragmentations that can be attributed to the rupture of the *O*-ethylidene rings: loss of a proton (M−1, *m/e* 231) and loss of a methyl group (M−15, *m/e* 217). Examples of the last two cleavages are known for six-membered *O*-ethylidene derivatives of alditols[9].

Although the fragmentation patterns of five-membered *O*-ethylidene rings are not so well-established as the patterns reported for the *O*-isopropylidene analogs,

TABLE I

P.M.R. PARAMETERS FOR 2,3-*O*- AND 2,3:5,6-DI-*O*-ALKYLIDENE DERIVATIVES OF D-ALLOSE[a]

Compound	*Solvent*	*Chemical shift, τ*					*Dioxolane*		*Coupling constants J (Hz)*				
		H-1	*H-2*	*H-3*	*H-4*	*H-5*	*H-2'*	*CH_3-2'*	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	J_{CH_3-CH-}
2	$CDCl_3$	4.67 d	5.57 d	5.31 d			4.99 q, 5.04 q	8.61 d, 8.64 d	0	6.2			5, 5
	C_6D_6	4.47 d	5.58 d	5.31 d	5.78 d		5.23 q, 5.23 q	8.69 d, 8.79 d	<1	6.3	<1	6.3	5, 5
3	CDCl	4.63 d	5.53 d	5.25 d			4.82 q, 5.02 q	8.63 d, 8.68 d	0	6.3			5, 5
	C_6D_6	4.63 d	5.69 d	5.40 d	5.87 d		5.11 q, 5.28 q	8.71 d, 8.84 d	<1	6.3	<1	6.3	5, 5
4	$CDCl_3$	4.68 d	5.45 d	5.19 d				8.56 s(2), 8.68 s, 8.70 s	0	6			
	C_6D_6	4.48 d	5.42 d	5.12 d	5.82 d			8.53 s, 8.67 s, 8.79 s, 8.82 s	<1	6	<1	6	
5	$CDCl_3$				4.73 dd		4.97 q, 5.05 q	8.62 d, 8.67 d				3,6.1	5, 5
	C_6D_6				4.58 dd		5.17 d, 5.19 q	8.74 d, 8.78 d				3,6	5, 5
6	$CDCl_3$				4.75 dd		4.92 q, 4.95 q	8.61 d, 8.69 d			3.2, 5.5		5, 5
	C_6D_6				4.61 dd		4.92 q, 5.18 q	8.71 d, 8.78 d			3.4, 5.8		5, 5
7	$CDCl_3$				4.71 dd			8.55 s, 8.64 s, 8.66 s(2)			3.4, 7		
	C_6D_6				4.53 dd			8.66 s, 8.69 s, 8.73 s, 8.83 s			3.4, 7.2		
8	$CDCl_3$	3.82 s	5.43 d	5.22 d			4.96 q, 5.01 q	8.61 d, 8.63 d	0	6.2			5, 5
	C_6D_6	3.58 s	5.69 d	5.31 d	5.74 d		5.12 q, 5.24 q	8.75 d, 8.77 d	<1	6.1	<1	9	5, 5
9	$CDCl_3$	3.82 s	5.41 d	5.20 d			4.89 q, 4.97 q	8.61 d, 8.67 d	0	6.2			5, 5
	C_6D_6	3.62 s	5.71 d	5.33 d	5.74 d		5.12 q, 5.23 q	8.74 d, 8.76 d	<1	6.1	<1	9	5, 5
10	$CDCl_3$	3.86 s	5.32 d	5.11 d				8.53 s, 8.58 s, 8.66 s, 8.67 s	0	6			
	C_6D_6	3.69 s	5.48 d	5.13 d				8.58 s, 8.65 s, 8.70 s, 8.79 s	1	6	1		
11	$CDCl_3$	3.79 s	5.38 s	5.38 s	5.62 d	4.92 m	4.95 q	8.63 d	0			9	5
	C_6D_6	3.54 s	5.61 d	5.55 d	5.55 d	4.77 m	5.19 q	8.71 d	0	6		9.4	5

[a] 100 MHz, d = doublet, dd = doublet of doublets, m = multiplet, q = quartet, s = singlet.

similarities are probable for compounds of approximately equivalent structure. *O*-Isopropylidene derivatives generally eliminate a methyl group (M−15), rearrange, and then eliminate acetic acid (60 daltons). If a second *O*-isopropylidene ring is present in the parent molecule, acetone is eliminated, either before or after acetic acid is eliminated[8,9]. The mass spectrum of **4** displays these cleavages[2].

By analogy with the *O*-isopropylidene group fragmentations, the rearrangement following loss of a proton or methyl group from one *O*-ethylidene ring should involve elimination of either acetic acid (60 daltons) or of formic acid (46 daltons), respectively, and should produce an M−61 (*m/e* 171) peak. Additionally, the *O*-ethylidene ring unaffected by the initial cleavage should lose acetaldehyde (44 daltons) either before or after loss of an acid molecule, and should form M−45 (1+44, *m/e* 187), M−59 (15+44, *m/e* 173) and M−105 (61+44, *m/e* 127) ions. Each of the ions was observed, although mechanisms other than those discussed could contribute to the abundance of each; for example, M−105 could also arise by C-4–C-5 cleavage followed by dehydration (87+18 mass units).

The presence of a furanose ring in **2** and **3** was established by a two-step process whereby each acetal was reduced to the corresponding alditol and then acetylated to give **5** and **6**. N.m.r. analysis of the D-allitol diacetates and of the 1,4-di-*O*-acetyl isopropylidene analog (**7**) showed for each a low-field doublet of doublets. This is characteristic of H-4 if the C-4 hydroxyl group had been acetylated following the opening of a furanose ring. If acetylation of the C-5 hydroxyl group had occurred after opening of a pyranose ring, an eight-line pattern would be predicted for H-5.

Direct acetylation of **2** and **3** gave quantitative yields of a single 1-acetate (**8** and **9**) for each. The low optical rotations observed for the four compounds, and the lack of coupling of H-1 to H-2 in the p.m.r. spectra, suggest the β-D-*allo* configuration for each. The β-D-*allo* configuration has been reported[2] for **4** and **10**.

To determine which two of the four possible 2,3:5,6-di-*O*-ethylidene-β-D-alloses had been isolated (**2**, **3**), samples of their 1-acetates (**8** and **9**) were subjected to mild hydrolysis under conditions that would not open the D-allofuranose ring. Subsequent acetylation of each hydrolysis product formed a common isomer of 1,5,6-tri-*O*-acetyl-2,3-*O*-ethylidene-β-D-allose (**11**), eliminating any possibility that **8** and **9** had been diastereoisomeric in terms of configuration of the 2,3-*O*-ethylidene ring. The p.m.r. data (Table I) were used to predict which of the resonances recorded for **5**–**6** and **8**–**9** probably arise from C-2′ substituents on the 2,3-*O*-ethylidene ring of each compound. In chloroform-*d*, values nearest τ 4.95 and 8.63 were considered to be analogous to those of **11**. Assignment of the quartets at τ 5.04 and 5.02, as well as of the doublets at τ 8.64 and 8.63, as being C-2′ substituent analogs on the 2,3-*O*-ethylidene rings of **2** and **3** is reasonable, because the configuration of this ring at C-2′ should be constant also for the precursors of **8**–**9**. Chemical-shift variations in benzene-d_6 make correlations paralleling those made in chloroform-*d* impractical.

Earlier investigations with 2,4-di- and 2,4-*cis*-5-trialkyl-1,3-dioxolanes have established that the resonance position of a C-2 substituent (equivalent to C-2′ in the present series) *cis* to alkyl substituents at C-4 and C-5 is invariably downfield from the

corresponding signal of the *trans* isomer and also that the deshielding effect is cumulative in terms of the number of *cis* alkyl groups opposing the C-2 (2′) substituent[10–13]. This method has been used for a number of other compounds[14–17]. Furthermore, the isomer showing an upfield shift for the C-2 (2′) proton is usually the more stable thermodynamically[16,17].

For the three pairs of diastereoisomers, **2**–**3**, **5**–**6**, and **8**–**9**, the chemical shifts of the C-2′ substituents of the 5,6-*O*-ethylidene ring move in opposite directions as the configuration is inverted to place a given substituent in a *cis* (deshielded) or *trans* (shielded) relationship to C-4 of D-allose.

On the basis of chemical shifts noted for the C-2′ protons and on the mutual deshielding of H-4 and the C-2′ methyl group in **2** (benzene-d_6), an *R* configuration (*endo*-methyl) was assigned for the 5,6-*O*-ethylidene ring in **2**, **5**, and **8**.

To determine the configuration of C-2′ in the 2,3-*O*-ethylidene ring, a sample of **11** in chloroform-*d* was treated with acetaldehyde and hydrogen chloride. Progress of the isomerization of the dioxolane was monitored for 60 h by p.m.r. Within 0.5 h, a new quartet was observed downfield (τ 4.62) from the original position, but the presumed new isomer (**12**?) never increased in yield beyond an estimated 5–6% of the total product-mixture. The appearance at lower field of the H-2′ resonance suggests that the proton is *cis* (*endo*) to C-2 and C-3 of D-allose in the new isomer (*S* configuration at C-2′), and thermodynamically disfavored[16,17].

The proportions of **2** and **3** at the time of isolation can be varied substantially by changing the conditions of the reaction. Although condensation of **1** with paraldehyde or a combination of paraldehyde–acetaldehyde diethyl acetal produces liquid phases containing **2** and **3** in a 16:9 ratio that is presumed to be the thermodynamic equilibrium, **3** crystallizes from solutions that lack acetaldehyde diethyl acetal in an amount that depends on the quantity of paraldehyde present and on the duration of the reaction. The overall effect is to bias the reaction in favor of **3**, as preformed **2** is isomerized to reestablish the equilibrium concentration of **3** in the liquid phase. Ratios of **2**:**3** as high as 27:73 were realized by this technique.

In addition to solubilizing **3**, however, acetaldehyde diethyl acetal also increases the rate at which **2** and **3** are formed and decomposed in the solution. When present, yields of **2** and **3** reached 84% within 4–5 h and then decreased to 70% after 48 h. When absent, **1** was converted into **2** and **3** in overall yields of 97%, but the reaction period had to be extended to 24–48 h for complete reaction. Furthermore, 3 to 4 days was required for maximum formation of **3**, with a subsequent decrease in yield (87% **2**+**3**).

The ease with which **2** and **3** are formed in high yields, by a technique that favors formation of the easily separable crystalline isomer **3**, may make **3** as desirable a reaction intermediate as the previously available **4**.

EXPERIMENTAL

General. — N.m.r. spectra were recorded at 100 MHz with a Varian HA-100

spectrometer with tetramethylsilane ($\tau = 10.0$) as the internal standard. Solute concentrations were approximately 20% (w/v or v/v). Chemical shifts and coupling constants are first-order, measured directly from spectral spacings. A Hewlett–Packard research chromatograph, Model 5750, equipped with an electronic integrator, was used for g.l.c. The column was 1/8-in. (o.d.) × 8 ft stainless-steel tubing packed with 3% 8BP (cyclohexane dimethanol succinate, Applied Science Labs, Inc.) on Chromosorb W (80–100 mesh). Column programming was isothermal, with helium as the carrier gas and with flame-ionization detection. Mass spectra were obtained by direct-probe techniques on a Nuclide Model 1290 DF spectrometer operated at 70 eV and at a source temperature of 100°.

Melting points were determined in capillary tubes. Optical rotations were measured at 546.1 nm in a 0.2-dm cell with a Bendix recording polarimeter, Model 1169. Multiplication of the reported specific rotations by 0.85 allows comparison with values reported at the D-line of a sodium lamp. Solutions were evaporated under diminished pressure. Precoated plates of Silica Gel F-254 (E. Merck, Darmstadt, Germany) were used for t.l.c. Layer thickness was 0.25 mm for analytical separations and 2.0 mm for preparative. Reducing sugars were detected with a formazan spray[7] (alternate applications of a saturated chloroform solution of 2,3,5-triphenyltetrazolium chloride and 2.5M alcoholic potassium hydroxide). The red formazan color was developed at 150° on a hot plate. For column chromatography, Baker Analyzed Silica Gel No. 3405 (J. T. Baker Chemical Co., Phillipsburg, N.J.) was used without pretreatment. All chromatographic solvents were proportioned on a v/v basis.

Reduction of 1,2:5,6-di-O-cyclohexylidene-α-D-ribo-hexos-3-ulose (**13**). — Two crystalline samples of **13**, prepared from 1,2:5,6-di-*O*-cyclohexylidene-α-D-glucose[18] as described by Kawana and coworkers[19], were converted into 1,2:5,6-di-*O*-cyclohexylidene-α-D-allose (**14**) and its 3-deuterio analog **15** as follows: Method I. A solution of **13** (100 g) in ether (3 l) was cooled to +5°, treated with a mixture of sodium borohydride (25 g), water (50 ml), and ethanol (50 ml), and then stirred with cooling for 2 h. The mixture was kept for 18 h at 25°, washed twice with water (500-ml portions), and then dried. Evaporation gave crude **14** (90 g), which was recrystallized from heptane; m.p. 124–125° (lit.[19] 125–126°).

Method II. A solution of **13** (85 g) in 1,2-dimethoxyethane (500 ml) was cooled to +5°, treated with sodium borodeuteride (Merck, Sharp & Dohme of Canada, Ltd., 5.3 g), and then stirred for 48 h at 25°. Ethyl acetate (800 ml) was added and the brown mixture was washed twice with water (500-ml portions). The combined washes were extracted with fresh ethyl acetate (250 ml), which was itself washed once more with water. The combined ethyl acetate extracts were evaporated to afford crude **15** (76.6 g), which was recrystallized from heptane; 69 g, m.p. 122–123°. Small amounts of the 3-deuterio-D-glucose analog were noted in the mother liquors by t.l.c. (9:1 benzene–ether, 2 ascents).

Hydrolyses of **14** *and* **15**. — Both **14** and **15** were hydrolyzed in two steps. Samples of each (75 g, 39 g) were heated for 45 min at 100° in solutions of acetic acid and water (840 ml and 360 ml, 420 ml and 180 ml) and then were evaporated. The

residues, largely mono-*O*-cyclohexylidene derivatives by t.l.c. (9:1 ethyl acetate–methanol), were then heated for 2.5 h at 100° in 1% aqueous sulfuric acid (500 ml and 250 ml). The solutions were cooled, extracted twice with ether, and then neutralized by stirring with Amberlite IR-45 resin. The final products were decolorized and crystallized from aqueous methanol (**1**, 35 g, m.p. 133–134°, lit.[20] 131–132°; 3-deuterio-β-D-allose, 18 g, 133–134°).

Acetaldehyde condensations. — Twelve 50-mg samples of **1** were weighed into 15 × 45 mm snap-cap bottles and divided into three equal groups (A, B, C). Group A members were treated with 50-mg portions of a solution containing sulfuric acid (20 mg) in paraldehyde (1 ml); group B members, with 100 mg. The bottles were manipulated so that all solids became uniformly wet, and then set aside at 25°. The solids rapidly formed a plastic mass that slowly changed into a mass of crystals deposited in a thin liquor. Reactions of each series were terminated after 7, 24, 48, and 98 h by adding 1 ml of chloroform containing pyridine (0.1 ml). Complete conversion of **1** into products, as judged by complete dissolution of the sample in chloroform–pyridine, was noted after 48 h for group A and after 24 h for group B.

Each member of group C was allowed to react with 100 mg of a solution of sulfuric acid (20 mg) in paraldehyde (1 ml) and acetaldehyde diethyl acetal (acetal, 1 ml). All samples liquefied within 4 h and reactions were terminated as already described after 4, 24, 48, and 98 h. Members of all three series were analyzed by g.l.c. (155°) without a silylation step. Product ratios and overall yields are based on materials soluble in chloroform at the time of analysis. Found: *t* in h (**2**:**3**, %**2**+**3**). For A, 7 (56:44, 96); 24 (40:60, 95); 48 (33:67, 92); 98 (27:73, 87). For B, 7 (64:36, 97); 24 (61:39, 94); 48 (58:42, 93); 98 (53:47, 88). For C, 4 (64:36, 84); 24 (64:36, 74); 48 (63:37, 71); and 98 (64:36, 68).

Isolation of **2**, **3**. — Several repetitions, at two- to fivefold proportions of the following preparations, were required to obtain sufficient quantities of **2** and **3**: Method I. A solution of paraldehyde (5 ml), acetaldehyde diethyl acetal (5 ml), and conc. sulfuric acid (110 mg) was added to **1** (5 g) and the mixture was then kept for 48 h at 25°. The solution was dissolved in a mixture of chloroform (100 ml) and pyridine (1 ml), stirred for 18 h with potassium carbonate (5 g), and then filtered through a pad of Celite 535. The filtrate was evaporated and then fractionated on a 40 × 300 mm column of silica gel packed and irrigated with chloroform. Fractions were monitored by g.l.c. without a silylation step (155°) and combined to yield **2** (2 g), **3** (1.4 g), and a mixture of **2** and **3** (0.8 g).

Method II. A solution of paraldehyde (5 ml) and conc. sulfuric acid (110 mg) was allowed to react with **1** (5 g) for 3 days at 25° and the reaction was terminated as already described. Fractional crystallization from ether gave **3** (2.8 g). The liquors were evaporated and fractionated on silica gel to yield **2** (1.5 g), **3** (1 g), and a mixture of **2** and **3** (0.2 g). Combined fractions of **2** were distilled (180°/0.1 mtorr) to give a syrup that slowly solidified; m.p. 27–29°, $[\alpha]_{546}^{26}$ −38.8° (*c* 1.2, chloroform).

Anal. Calc. for $C_{10}H_{16}O_6$: C, 51.72; H, 6.94. Found: C, 51.64; H, 6.85.

Recrystallization from ether gave pure **3**; m.p. 132–132.5°, $[\alpha]_{546}^{26}$ −26.7° (*c* 0.86, chloroform).

Anal. Calc. for $C_{10}H_{16}O_6$: C, 51.72; H, 6.94. Found: C, 51.62; H, 6.90.

Preparation of **4**. — A modification of the method of Ballard and Stacey[1] was used .A mixture of **1** (6 g), 2,2-dimethoxypropane (10 ml), anhydrous acetone (350 ml), and conc. sulfuric acid (0.9 ml) was kept for 18 h at 25° with stirring. The solids dissolved within 1 h. The mixture was neutralized with an excess of potassium carbonate, as described for **2** and **3**, and compared to a mixture wherein **1** (6 g) had been condensed with acetone in the presence of cupric sulfate[1]. G.l.c. analysis (155°) showed both mixtures to be equivalent in composition, and so both mixtures were co-chromatographed on silica gel, as described for **2**–**3**, until **4** was detected in the eluate. Elution of **4** was then speeded by changing the irrigant to 9:1 chloroform–acetone. Pure **4** (10 g, 57%) was crystallized from pentane; m.p. 65–67.5°, $[\alpha]_{546}^{26}$ −26.4° (*c* 1, chloroform) (lit.[1] m.p. 65–67°).

Reduction with sodium borohydride. — Solutions of **2**, **3**, or **4** (1 g) in *N,N*-dimethylformamide (11 ml) were separately treated with 0.3-g portions of sodium borohydride and stored for 24 h at 25°. Volatiles were evaporated (<50°) and the residues were kept for 48 h at 25° in mixtures of pyridine (5 ml) and acetic anhydride (5 ml). The brown, gelatinous products were diluted with chloroform (10 ml) and filtered through a Celite 535 pad. Each filtrate was evaporated and the residue purified by preparative t.l.c. (4:1 hexane–acetone, 2 ascents). Product bands were located by combining the adhesive-tape method of plate sampling[21] with a ferric hydroxamate spray[22] for visualization. The products (**5**, **6**, and **7**) did not char well when sprayed with 5% sulfuric acid in 2-propanol (v/v) and then heated at 110°. Each product, after recovery from the plate, was distilled (180–200°/0.1 mtorr) to obtain a pure syrup. Compound **5**: syrup, $[\alpha]_{546}^{26}$ −4.3° (*c* 1, chloroform).

Anal. Calc. for $C_{14}H_{22}O_8$: C, 52.83; H, 6.97. Found: C, 52.64; H, 6.96.

Compound **6**: syrup, $[\alpha]_{546}^{26}$ −9.1° (*c* 1.1, chloroform).

Anal. Calc. for $C_{14}H_{22}O_8$: C, 52.83; H, 6.97. Found: C, 53.01; H, 7.09.

Compound **7**: syrup, $[\alpha]_{546}^{26}$ −8.2° (*c* 1.3, chloroform).

Anal. Calc. for $C_{16}H_{26}O_8$: C, 55.51; H, 7.52. Found: C, 55.77; H, 7.81.

Preparation of **8**, **9**, *and* **10**. — Separate solutions containing **2**, **3**, or **4** (5 g) in pyridine (10 ml) and acetic anhydride (10 ml) were kept for 48 h at 25°. Volatiles were removed by evaporation, and the residue was taken up in ethyl acetate (200 ml) and washed twice with water. Samples of **8** and **9** were crystallized from ethanol, and **10** was distilled (180–200°/0.1 mtorr) to yield a syrup that solidified on standing.

Compound **8**: m.p. 103–104.5°, $[\alpha]_{546}^{26}$ −66.7° (*c* 0.99, chloroform).

Anal. Calc. for $C_{12}H_{18}O_7$: C, 52.55; H, 6.61. Found: C, 52.84; H, 7.00.

Compound **9**: m.p. 94–94.5°, $[\alpha]_{546}^{26}$ −62.8°, (*c* 0.98, chloroform).

Anal. Calc. for $C_{12}H_{18}O_7$: C, 52.55; H, 6.61. Found: C, 52.65; H, 6.91.

Compound **10**: m.p. 42–45°, $[\alpha]_{546}^{26}$ −45.1° (*c* 1.24, chloroform) (lit.[2] m.p. 51–51.5°).

Anal. Calc. for $C_{14}H_{22}O_7$: C, 55.62; H, 7.34. Found: C, 55.79; H, 7.55.

The mass spectra of **8** and **9** were essentially identical as regards relative abundance and *m/e* values of the ions. Fragmentation patterns were noted corresponding to M−1 (*m/e* 273), M−15 (*m/e* 259), M−59 (OAc, *m/e* 215), and C-4–C-5 cleavage (*m/e* 87, 187).

Formation of **11**. — Both **8** and **9** were partially hydrolyzed by heating separate samples (1.5 g) of each in acetic acid–water (20 ml, 3:1 v/v) for 0.5 h at 100°. T.l.c. (ethyl acetate–ether, 1:1) indicated that approximately 80–90% of each reactant had hydrolyzed and formed one major product. Each solution was evaporated and the residual mixture purified by preparative t.l.c. (2:1 ethyl acetate–ether, 1 ascent). The isolated products were separately acetylated in solutions of pyridine (1 ml) and acetic anhydride (1 ml) for 24 h at 25°. Volatiles were removed by evaporation, and the residual syrups were then distilled (180°/0.1 mtorr). The product from **8** weighed 0.4 g, and that from **9** weighed 0.5 g. The samples were identical, as judged by n.m.r., and the structure was assigned as **11**; $[\alpha]_{546}^{22}$ −59.6° (*c* 0.7, chloroform). The following fragmentations were noted in the mass spectrum: M−1 (*m/e* 331); M−15 (*m/e* 317); M−43 (*m/e* 289); M−59 (*m/e* 273); C-4–C-5 cleavage (*m/e* 145 and 187).

Isomerization of **11**. — A sample of **11** (0.1 g) in chloroform-*d* (0.4 ml) was placed in an n.m.r. tube (0.196 × 7 in), scanned in a Varian HA-100 spectrometer, and then treated with paraldehyde (0.25 μl). Air above the sample was displaced with anhydrous hydrogen chloride, and the tube was stoppered and shaken. Isomerization of the C-2′ center of the 2,3-*O*-ethylidene ring to form the diastereoisomer (**12**?) was noted within 0.5 h (see Scheme 1). After 60 h, the sample was diluted with chloroform (5 ml), neutralized with solid sodium borohydride, and then kept for 18 h at 25°. The mixture was filtered, and the filtrate evaporated under diminished pressure to recover the sample.

ACKNOWLEDGMENTS

Mass spectra were recorded by Dr. W. K. Rohwedder and Mr. R. Kleiman and the microanalyses by Mrs. Bonita R. Heaton. Constructive criticisms by Dr. H. B. Sinclair were especially helpful.

REFERENCES

1 J. M. BALLARD AND B. E. STACEY, *Carbohyd. Res.*, 12 (1970) 37.
2 M. HAGA, M. TAKANO, AND S. TEJIMA, *Carbohyd. Res.*, 14 (1970) 237.
3 A. N. DE BELDER, *Advan. Carbohyd. Chem.*, 20 (1965) 219.
4 A. B. FOSTER, in W. PIGMAN AND D. HORTON (Eds.), *The Carbohydrates, Chemistry/Biochemistry*, Vol. IA, Academic Press, New York, 1972, pp. 391–402.
5 J. A. MILLS, *Advan. Carbohyd. Chem.*, 10 (1955) 1.
6 R. BARKER AND D. L. MACDONALD, *J. Amer. Chem. Soc.*, 82 (1960) 2301.
7 W. E. TREVELYAN, D. P. PROCTER, AND J. S. HARRISON, *Nature*, 166 (1950) 444.
8 H. BUDZIKIEWICZ, C. DJERASSI, AND D. H. WILLIAMS, *Structure Elucidation of Natural Products by Mass Spectroscopy II*, Holden-Day, San Francisco, 1964, pp. 203–240.
9 N. K. KOCHETKOV AND O. S. CHIZHOV, *Advan. Carbohyd. Chem.*, 21 (1966) 39.
10 N. BAGGETT, K. W. BUCK, A. B. FOSTER, R. JEFFERIS, B. H. REES, AND J. M. WEBBER, *J. Chem. Soc.*, (1965) 3382.

11 N. BAGGETT, J. M. DUXBURY, A. B. FOSTER, AND J. M. WEBBER, *J. Chem. Soc., C*, (1966) 208.
12 N. BAGGETT, K. W. BUCK, A. B. FOSTER, AND J. M. WEBBER, *J. Chem. Soc.*, (1965) 3401.
13 N. BAGGETT, K. W. BUCK, A. B. FOSTER, M. H. RANDALL, AND J. M. WEBBER, *J. Chem. Soc.*, (1965) 3394.
14 S. FORSEN, B. LINDBERG, AND B. G. SILVANDER, *Acta Chem. Scand.*, 19 (1965) 359.
15 R. J. FERRIER AND L. R. HATTON, *Carbohyd. Res.*, 5 (1967) 132.
16 J. G. BUCHANAN AND A. R. EDGAR, *Chem. Commun.*, (1967) 29.
17 W. E. WILLY, G. BINSCH, AND E. L. ELIEL, *J. Amer. Chem. Soc.*, 92 (1970) 5394.
18 R. C. HOCKETT, R. E. MILLER, AND A. SCATTERGOOD, *J. Amer. Chem. Soc.*, 71 (1949) 3072.
19 M. KAWANA, H. OHRUI, AND S. EMOTO, *Bull. Chem. Soc.* (Japan), 41 (1968) 2199.
20 R. AHLUWAHLIA, S. J. ANGYAL, AND M. H. RANDALL, *Carbohyd. Res.*, 4 (1967) 478.
21 D. HORTON AND T. TSUCHIYA, *Carbohyd. Res.*, 5 (1967) 426.
22 M. E. TATE AND C. T. BISHOP, *Can. J. Chem.*, 40 (1962) 1043.