## Preliminary communication

## Acid-catalyzed isomerization of methyl 2,3,4,5-tetra-O-acetyl- $\alpha$ -L-xylo-2-hexulopyranosonate. A model for degradation of L-xylo-hexulosonic acid'

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The mechanism of conversion of L-ascorbic acid into 2-furaldehyde (7) in acidic media under anaerobic conditions is still not clear, although extensive studies have been reported<sup>1-4</sup>. Especially, it is of interest to know whether or not the conversion proceeds via L-xylo-hexulosonic acid<sup>3,4</sup>. We attempted to study the pathway of isomerization of the acid to 7 by using methyl 2,3,4,5-tetra-O-acetyl- $\alpha$ -L-xylo-2-hexulopyranosonate (1) as a model compound.

The starting material (1) was prepared by acetylation of the methyl ester of L-xylo-hexulosonic acid<sup>5</sup>. However, heating 1 in 1 : 9 (v/v) acetic acid—water gave only hydrolytic products. This fact suggested that the degradation of 1 is much slower than its hydrolysis, and that studies under anhydrous conditions would be required.

When 1 in dry benzene was treated with boron trifluoride-etherate the reaction proceeded at reflux temperature. Preparative t.l.c. of the product gave compounds\* 5, 6 and 9; trace amounts of other components were not isolated. The u.v. and i.r. spectra of compounds 5 and 9 revealed bands indicative of an  $\alpha,\beta$ -unsaturated ketone. The p.m.r. spectra for the ring protons were quite similar to those previously reported<sup>6</sup> for 18. The spectra also suggested the presence of one acetoxymethyl group in 5 and of one phenyl group in 9. These data established their structures. The mass spectrum of 6 was similar to that<sup>7</sup> of 7 and its i.r. spectrum showed the presence of C=O and CO<sub>2</sub>R groups. The structure of 6 was thus identified. P.m.r. and u.v. spectral data also supported this structure.

To elucidate the reaction pathway, the reaction was performed under milder conditions. When 1 was treated at  $60^{\circ}$ , the formation\* of 2 and 5 was initially observed<sup>8</sup> This fact suggested that 1 was first isomerized to 2. Consequently, the reaction with 2 as a starting material was studied.

First of all, reactions in benzene were examined. Treatment of 2 in boiling benzene containing boron trifluoride-etherate resulted\*\* in the formation of 5, 6, and

<sup>\*</sup>Compounds 2 and 9 were obtained as racemates.

<sup>\*\*</sup>When 75% of 2 disappeared, 2 was recovered as a racemate. This fact suggested that racemization of 2 took place.

9 (major) and 10 and 13a (Ref. 8) (minor). Proof of the structure of 10 was provided by acetylation. The formation of 5 was observed initially. When the reaction was allowed to proceed for a longer period, the products 6 and 9 increased at the expense of 5. Further, acid-catalyzed reaction of 5 or 10 afforded 6 and 9, but the other products were recovered unchanged after this further treatment. A possible mechanism for the reaction involves an initial  $4 \rightarrow 2$  migration of the acetoxy group at C-4 ( $2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6$ , path a) and an initial elimination of the acetoxy group from C-5 ( $2 \rightarrow 11 \rightarrow 12 \rightarrow 13a$ , path b).

The furan derivatives 6 and 7 were also obtained from the reaction of 2 in 1:9 (v/v) aceticacid—water, but the yields were very low. The major products were 13a and 13b, as previously reported<sup>8</sup>. Furthermore, by acetylation of the water-soluble part of the reaction mixture, it was possible to obtain oxalic acid, and compounds 16 and 17. The structures of 16 and 17 were determined by the p.m.r. spectra (compound 17 could not be isolated pure, but spectral data supported the structure assigned). The newly



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isolated compounds were considered to arise by further degradation of 13, and this idea was confirmed experimentally.

On the basis of the foregoing facts, the pathway of the acid-catalyzed degradation of 1 is concluded to be that shown in Scheme 1. It is surprising that the pathway forming furans is not a major one in aqueous media. This fact suggests that L-xylo-hexulosonic acid is not a probable intermediate in the acid-catalyzed degradation of L-ascorbic acid.

Data for new compounds are as follows (p.m.r. spectra were measured in CDCl<sub>a</sub> and chemical shifts are given on the  $\tau$  scale. Optical rotations and u.v. spectra were measured in chloroform and 95% ethanol, respectively): 1, m.p. 118–119°,  $[\alpha]_D^{25}$ –73.9° (c 0.973); (Found: C, 47.92; H, 5.37.  $C_{15}H_{20}O_{11}$  calc.: C, 47.87; H, 5.36). 5, m.p. 95.5–96.5°,  $[\alpha]_D^{25.2}$  0° (a mixture of  $\alpha$  and  $\beta$  anomers); $\lambda_{max}^{KBr}$  1762, 1700, 1629 cm<sup>-1</sup> (C=O, C=C);  $\lambda_{max}$  226 ( $\epsilon$  9800), 335 nm (70); p.m.r. 7.83 s (OAc), 6.15 s (CO<sub>2</sub>Me),  $3.75 \text{ m} (\text{H}-4, J_{4,5} \ 10.5 \text{ Hz}, J_{4,6} \ 2 \text{ Hz}), 2.88 \text{ m} (\text{H}-5, J_{5,6} = J_{5,6'} \ 3 \text{ Hz});$  (Found: C, 50.65; H, 4.57. C<sub>9</sub>H<sub>10</sub>O<sub>6</sub> calc.: C, 50.47; H, 4.71). 6, m.p. 42–42.5°;  $\lambda \frac{\text{KBr}}{\text{max}}$  1740, 1667 (C=O), 1557, 885 cm<sup>-1</sup> (furan);  $\lambda_{max}$  233 ( $\epsilon$  2200), 291.5 nm (12000); p.m.r. 6.03 s (CO<sub>2</sub>Me), 3.37 q (H-4, J<sub>3,4</sub> 3.5 Hz, J<sub>4.5</sub> 1.5 Hz), 2.2-2.35 m (H-3 and H-5); (Found: C, 54.59; H, 3.97.  $C_7 H_6 O_4$  calc.: C, 54.55; H, 3.92). 9, syrup,  $[\alpha]_D^{25.7} + 1.4^\circ$  (c 0.633) (a mixture of  $\alpha$  and  $\beta$  anomers);  $\lambda_{\text{max}}^{\text{film}}$  1745, 1685, 1627 (C=O, C=C), 1598, 747, 694 cm<sup>-1</sup> (Ph);  $\lambda_{\text{max}}$  296 nm ( $\epsilon$  350); p.m.r. 6.92 s (CO<sub>2</sub>CH<sub>3</sub>), 5.35, 5.60 m (H-6 and H-6',  $J_{6,6'} \simeq$ ~ 19.5 Hz), 3.78 m (H-4,  $J_{4,5}$  10.5 Hz,  $J_{4,6} = J_{4,6}$ ' 2.0 Hz), 3.03 m (H-5,  $J_{5,6}$ ' 3.0 Hz), 2.45-2.73 (Ph, 5H); (Found: C, 67.27; H, 5.45. C<sub>13</sub>H<sub>12</sub>O<sub>4</sub> calc.: C, 67.23; H, 5.21). 10, m.p. 48–49°,  $[\alpha]_D^{21.5}$  0° (a mixture of  $\alpha$  and  $\beta$  anomers);  $\lambda_{max}^{KBr}$  3450 (OH), 1755, 1688, 1623 cm<sup>-1</sup> (C=O, C=C); λ<sub>max</sub> 226 nm (ε 9900); p.m.r. 6.25 s (CO<sub>2</sub>Me), 5.55, 5.25 m (H-6 and H-6',  $J_{6,6'} \simeq 19.0$  Hz), 5.25 (OH), 3.75 m (H-4,  $J_{4,5}$  10.5 Hz,  $J_{4,6} = J_{4,6}'$  2 Hz), 2.83 m (H-5,  $J_{5,6} = J_{5,6}'$  3 Hz); (Found: C, 48.96; H, 4.66. C<sub>7</sub>H<sub>8</sub>O<sub>5</sub> calc.: C, 48.84; H, 4.68 ). 16, syrup,  $\lambda_{\text{max}}^{\text{film}}$  1745 cm<sup>-1</sup> (OAc); p.m.r. 7.85 s, 8.00 s (OAc), 7.25 t (2H), 5.65 t (2H) (-CH<sub>2</sub>-CH<sub>2</sub>-), 5.35 s (2H, -CH<sub>2</sub>-); (Found: C, 51.14; H, 6.35. C<sub>8</sub>H<sub>12</sub>O<sub>5</sub> calc.: C, 51.06; H, 6.43). 17, syrup, λ<sub>max</sub><sup>film</sup> 1760, 1670, 1620 cm<sup>-1</sup> (C=O, C=C); p.m.r. 7.81 s (OAc), 7.31 q (H-4 and H-4'), 5.47 q (H-5 and H-5'), 2.62 s (H-1).

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