Trimethylsilylation of Ketoses: Structures and Gas Chromatography of the Products of Two-step Reactions from Hexuloses and Heptuloses

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Summary Hexuloses and heptuloses are identified on g.l.c. or t.l.c. by the products of two-step trimethylsilylation whose initial product is, or contains, the trimethylsilyl ether in which the hemiacetal hydroxy-group is free.

ALTHOUGH g.l.c. of trimethylsilyl ethers from some crystalline hexuloses has been reported to exhibit a single peak,[1] we have found that some hexuloses and heptuloses, most of which are considered to consist of one anomer, exhibit two peaks due to trimethylsilyl ethers produced by two-step reactions.

In addition to the peak due to the initial trimethylsilylated product, which is virtually the only one detectable (g.l.c.†) in the case of ketoses (Table) a few minutes after the reagent is added,‡ another peak is observed after prolonged trimethylsilylation. Growth of the latter product at the expense of the initial product is observed, until finally the new product becomes the sole constituent. The R_{Glu} values (retention time relative to α-D-glucose) are shown in the Table. The times elapsing before the amounts of the two products become approximately equal (*ca.* 20°) from D-*manno*-heptulose, sedoheptulose, D-*gluco*-heptulose,

† G.l.c. was run on Shimadzu GC-1C with hydrogen flame ionization detector, using a stainless-steel column, 225 cm. × 4 mm., packed with 1·5% Se-30 on Chromosorb W.

‡ The reagent mixture was prepared according to the method of Sweeley *et al.*[1] The mixtures of partially trimethylsilylated derivatives which may be formed very quickly, likewise those from aldoses,[2] are excluded from the present consideration.

and L-sorbose are *ca.* 0·5 hr., 1 hr., 1·5 hr. and 2 hr., respectively.§

The retention time relative to α-D-*glucose of trimethylsilyl derivatives*

Ketose	Initial product		Final product	
	R_{Glu}	$[\alpha]_D$[a]	R_{Glu}	$[\alpha]_D$
D-Fructose	0·77	+79·0°	0·77	−73·8°
L-Sorbose	1·02	+13·0°	0·92	−16·4°
Sedoheptulose	1·39	+27·3°	1·66	+18·0°
D-*gluco*-Heptulose	1·72	+24·2°	2·06	+36·0°
D-*manno*-Heptulose ..	1·82	+15·5°	1·94	+30·4°

[a] In n-hexane at 20°.

D-Fructose shows essentially a single peak throughout the experiment. However, the difference of the initial product from the final product is evident on t.l.c. (activated silicic acid[3] developed with anhydrous benzene), the latter moving much faster than the former.

The initial product from each ketose, which is best prepared by trimethylsilylation at lower temperatures, or with a limited amount of the reagent, has been purified by vacuum distillation (bath temp. 120—150°, at 1 mm.Hg). The product from each hexulose has been analysed as $C_{18}H_{44}O_6Si_4$, and that from each heptulose as $C_{22}H_{54}O_7Si_5$. These molecular formulae are supported by the $M - 18$ peaks in the mass spectra. The initial products show the OH absorption peak between 3550 and 3400 cm.$^{-1}$ in their i.r. spectra. The hydroxy-proton also appears between τ 4·2 and 5·0 in the n.m.r. spectra (Me_2SO or Me_2SO–$CD_3{\cdot}CO{\cdot}CD_3$) and disappears on treatment with D_2O. The n.m.r. spectra of the initial products from L-sorbose and D-*manno*-heptulose in dimethyl sulphoxide show the hydroxy-proton as a singlet, indicating that the hemiacetal hydroxy-group is free in these products. Therefore, these products are regarded as 1,3,4,5-tetrakis-*O*-trimethylsilyl-α-L-sorbopyranose and 1,3,4,5,7-pentakis-*O*-trimethylsilyl-α-D-*manno*-heptulopyranose, based on the ring structure of the starting material.[4] The initial product from D-fructose, which shows a single spot on t.l.c., shows the hydroxy-proton in the n.m.r. spectrum in dimethyl sulphoxide as two signals: a singlet and a doublet (J 2 c./sec.) between τ 4·5 and 5·0. The initial products from the other two heptuloses, which show contamination on g.l.c. after distillation, exhibit a singlet (O-*H*) accompanied by other hydroxy-group signals.

The final product from each ketose has also been purified by vacuum distillation after prolonged trimethylsilylation. Each product from the hexuloses has been analysed as $C_{21}H_{52}O_6Si_5$, and those from the heptuloses as $C_{25}H_{62}O_7Si_6$. Absence of a hydroxy-group in each product is shown by the i.r. and n.m.r. spectra.

The mass spectra of the final products (except that from sedoheptulose) exhibit an intense *m/e* 204 fragment $(Me_3SiOCH{=}CHOSiMe_3)^+$ as shown by Curtius *et al.*[5] with pertrimethylsilyl ethers of D-fructopyranose, and are in agreement with the pyranose formation[4] of the four ketoses. The intensity of the *m/e* 204 peak in pertrimethylsilyl sedoheptulose relative to that of the base peak at *m/e* 73 is *ca.* 5% while that of the *m/e* 217 peak is 34%; these intensities are in the furanose rather than the pyranose range.

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§ These times may vary depending on the powder size of sugar, the ratio of the amount of sugar and reagent, and also the stirring conditions.

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[4] E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Wiley, New York, 1965, p. 408.
[5] H.-Ch. Curtius, M. Müller, and J. A. Völlmin, *J. Chromatog.*, 1968, **37**, 216.