crystals (0.855 g.) were obtained, $[\alpha]^{25}D$ +11.59° (*c* 1.61 water). Recrystallization of this material from aqueous acetone–alcohol gave the strychnine salt A (0.33 g.), $[\alpha]^{25}D$ +20.08° (*c* 0.6 water), m.p. 217–220° dec. *Anal.* Calcd. for $C_{26}H_{33}O_{10}N_2P$: C, 55.33; H, 5.85; N, 4.97; P, 5.50. Found: C, 55.23; H, 5.71; N, 4.70; P, 5.51. Drying of the salt showed absence of solvent of crystallization.

For reconversion to the barium salt, the strychnine salt B (1.042 g.) in aqueous solution (250 cc.) was treated with aqueous NaOH to raise the *p*H from 7 to 10 and the separating strychnine base extracted 5 times with chloroform (100 cc.) precooled to 0°. The clear aqueous solution of *p*H 8–8.5 was concentrated *in vacuo* to *ca.* 70 cc., treated with an aqueous solution (30 cc.) of barium acetate (0.625 g.) and, after separating the inorganic phosphate (27 mg.), the barium salt of β-D-xylose 1-phosphate (0.325 g.) was isolated in the usual manner. This salt, after purification by reprecipitation from alcohol–water (3:1, showed $[\alpha]^{25}D$ −13.30° (*c* 1.5, 5% aqueous acetic acid). *Anal.* Calcd. for the dehydrated salt $C_5H_9O_8PBa$: C, 16.43; H, 2.46. Found: C, 16.51; H, 2.54. Calcd. for the hydrate $C_5H_9O_8PBa \cdot 1.5H_2O$: P, 7.89; drying weight loss, 6.88. Found: total P, 7.64; acid-labile P, 7.45; drying weight loss, 6.33. An aqueous solution of this barium salt, treated with the stoichiometric amount of $K_2SO_4$, failed to give a crystalline potassium salt.

The strychnine salt A (0.256 g.) was similarly converted to the barium salt (0.142 g.) of α-D-xylose 1-phosphate. This barium salt showed an $[\alpha]^{25}D$ +70.88° (*c* 1.425, 5% aqueous acetic acid) and an infrared spectrum identical with that of the corresponding salt obtained by procedure Ib above.

(II) **Silver Diphenyl Phosphate[34] Phosphorylations. (a) Room Temperature Reaction.**—A benzene solution (70 cc.) of acetobromoxylose (1 g.) was treated with silver diphenyl phosphate (1.58 g.) at room temperature in the dark for 2 hours and the silver salts were separated in the usual manner. The sirupy product was hydrogenolyzed with Adams catalyst (0.2 g.) in alcohol solution (100 cc.). Gas absorption was complete in *ca.* 1 hour. The catalyst was filtered off and washed with alcohol. The combined filtrate and washings were concentrated *in vacuo*, the product deacetylated and worked up in the usual manner to give inorganic phosphate (0.398 g.) and the barium salt (0.396 g.) of α-D-xylose 1-phosphate (infrared spectral identity established). This salt, after purification by reprecipitation, showed $[\alpha]^{25}D$ +67.26° (*c* 1.56, 5% aqueous acetic acid). *Anal.* Calcd. for $C_5H_9O_8PBa \cdot 1.5H_2O$: P, 7.89. Found: total P, 7.71; acid-labile P, 7.71. The barium salt readily gave a crystalline dipotassium salt of α-D-xylose 1-phosphate (infrared spectral identity established) with $[\alpha]^{25}D$ +77.5° (*c* 1.6, water).

(b) **Reaction in Refluxing Benzene.**—The bromo compound (5 g.) was treated with silver diphenyl phosphate (7.91 g.) in refluxing benzene solution (50 cc.) as in procedure Ia and the silver salts separated in the usual manner. After precipitating off the excess phosphorylating agent with ether as before, the sirupy product gave a crystalline compound (0.6 g.) from $CCl_4$–ether. Recrystallized from ether–pentane, this compound showed a m.p. 129–131°, the absence of phosphorus and a pentose content of 50.9%. An infrared spectrum established the identity of this compound with 2,3,4-tri-*O*-acetyl-α-D-xylopyranose obtained by another procedure.[24] The rest of the phosphorylation product was not worked up any further, as it was found to have suffered extensive decomposition during the attempts made to crystallize the intermediate tri-*O*-acetyl-D-xylose 1-(diphenylphosphate).

(III) **Trisilver Phosphate[35] Phosphorylation.**—The barium salt of α-D-xylose 1-phosphate was prepared by interaction of acetobromoxylose with trisilver phosphate in the manner of Meagher and Hassid.[4] The entire quantity (0.393 g.) was converted to the strychnine salt and fractionally crystallized from aqueous dioxane. The first four crops of crystals with nearly constant $[\alpha]D$ values were combined (0.3 g.) and recrystallized from aqueous dioxane–acetone to give the strychnine salt (0.26 g.) of α-D-xylose 1-phosphate, $[\alpha]^{25}D$ +20° (*c* 0.475 water), m.p. 217–219° dec. *Anal.* Calcd. for $C_{26}H_{33}O_{10}N_2P$: C, 55.33; H, 5.85; N, 4.97; P, 5.50. Found: C, 55.45; H, 5.87; N, 5.00; P, 5.77. An infrared spectrum was identical with that of strychnine salt A obtained by procedure Ic above. No evidence of the formation of strychnine salt B was obtained from the attempted crystallization of the mother liquors from the four crystal crops taken above.

**Acknowledgment.**—The authors gratefully acknowledge the technical assistance of Mr. F. Rollin in making the infrared spectrograms.

(34) Prepared by the procedure of T. Posternak (ref. 12).

(35) Prepared by the procedure of C. F. Cori, S. P. Colowick and G. T. Cori (ref. 11).

OTTAWA 2, CANADA

---

[CONTRIBUTION FROM THE DIVISION OF APPLIED BIOLOGY, NATIONAL RESEARCH LABORATORIES]

# The Isomeric Xylopyranose Triacetates Produced by Solvolysis of 2,3,4-Tri-*O*-acetyl-α-D-xylopyranosyl Bromide[1]

BY NAVAL J. ANTIA[2]

RECEIVED APRIL 24, 1958

The action of aqueous acetone, with or without silver carbonate, on 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide gave rise to a mixture of three isomeric tri-*O*-acetyl-D-xylopyranoses. The ready mutarotation of isomers B and C showed that they must be the α- and β-anomers, respectively, of the pentose 2,3,4-triacetate. Isomer A failed to mutarotate in chloroform and was converted by the action of aqueous pyridine to isomer B, suggesting a $C_1 \rightarrow C_2$ acetyl migration. Quantitative infrared spectrometric measurements showed the presence of three carbonyl groups in isomer A, ruling out a possible $C_1C_2$-orthoacid structure and assigning the structure of 1,3,4-tri-*O*-acetyl-α-D-xylopyranose to this isomer. The mechanism of the formation and interconversion of the isomers is discussed. The $C_2 \rightarrow C_1$ acetyl migration, shown by 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide, appears to occur without $C_2$-neighboring-group participation in dissociation of the $C_1$–halogen bond.

In a previous paper,[3] it was reported that attempts to crystallize the product of a phosphorylation reaction of 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide with silver diphenyl phosphate led to the isolation of a phosphorus-free triacetylxylose. Wright and Khorana,[4] in attempting to crystallize the product of a phosphorylation reaction of 2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl bromide had similarly obtained a tribenzoylribose, which did not contain phosphorus and was shown by Ness and Fletcher,[5,6] to be 1,3,5-tri-*O*-benzoyl-α-D-ribofura-

(1) Issued as N.R.C. No. 4916.

(2) National Research Council Postdoctorate Fellow, 1955–1957. Process and Products Research Group, Textile Fibres Division, Canadian Industries Ltd., P. O. Box 124, Kingston, Ontario.

(3) N. J. Antia and R. W. Watson, THIS JOURNAL, **80**, 6134 (1958).

(4) R. S. Wright and H. G. Khorana, *ibid.*, **78**, 811 (1956).

(5) R. K. Ness and H. G. Fletcher, Jr., *ibid.*, **76**, 1663 (1954).

(6) R. K. Ness and H. G. Fletcher, Jr., *ibid.*, **78**, 4710 (1956).

nose. The latter authors observed that the action of aqueous acetone on tri-*O*-benzoylribofuranosyl bromide gave rise to two isomeric tribenzoylriboses, one of which was identical with Khorana's compound and the other was shown to be 2,3,5-tri-*O*-benzoyl-β-D-ribofuranose. With a view to establishing the structure of the triacetylxylose obtained from the phosphorylation reaction mentioned earlier, the solvolysis of tri-*O*-acetylxylopyranosyl bromide was examined and this paper reports the results of investigations arising therefrom.

The action of aqueous acetone on tri-*O*-acetylxylopyranosyl bromide was found to give rise to a mixture of isomeric triacetylxyloses, which was fractionated by crystallization from ether–pentane into isomer A, m.p. 136–139°, $[\alpha]^{25}D$ +126.5°, and isomer B, m.p. 143–145°, $[\alpha]^{25}D$ +54.8°. A chromatographic examination of the mixture showed the presence of a trace of a third isomer, C, m.p. 140–142°, $[\alpha]^{25}D$ −20°. Isomer A gave a marked mixed melting-point depression with either isomer B or C. However, the latter two isomers each showed an erratic melting point behavior and their mixed melting point showed no significant depression. All the three isomers showed characteristically different infrared absorption spectra and these were used to identify them rather than the melting points. The infrared spectra showed isomer B to be identical with the triacetylxylose obtained earlier from the phosphorylation reaction of tri-*O*-acetylxylopyranosyl bromide with silver diphenyl phosphate.

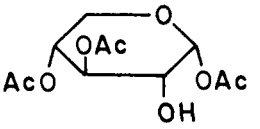
Hudson and Dale[7] reported the formation of a tri-*O*-acetyl-α-D-xylopyranose by the combined action of aqueous acetone and silver carbonate on tri-*O*-acetylxylopyranosyl bromide. Their product melted at 138–141° and showed an initial $[\alpha]^{23}D$ +70.1° (*c* 1.82, $CHCl_3$) changing in about 10 days to a constant value of $[\alpha]^{21}D$ +40.8°. In repeating Hudson and Dale's experiment and carefully fractionating the product by repeated crystallization, it was observed that all the three isomeric triacetylxyloses A, B and C are formed, the first named only in traces and the other two in appreciable quantities. The separation of isomers B and C was followed spectrophotometrically (infrared) and the purest specimen of C obtained still showed slight contamination from B. The close correspondence in the physical constants and mutarotation behavior of isomer B with those of Hudson and Dale's product showed them to be identical compounds.

The isomer A did not show any change in optical rotation in chloroform solution on standing *ca.* 14 days at room temperature and an infrared spectrum of the product obtained from the solution showed virtually unchanged isomer A. Isomer B was observed to mutarotate slowly in chloroform solution, changing from an initial $[\alpha]^{25}D$ +46.1° to a final $[\alpha]^{25}D$ +38.6° after *ca.* 14 days at room temperature. Under the same conditions, isomer C mutarotated more rapidly, changing from an initial $[\alpha]^{25}D$ −20° to a final value of +32.8°. The mutarotation products from isomers B and C showed virtually identical infrared spectra, thereby indicating that these two must be members of an anomeric pair.

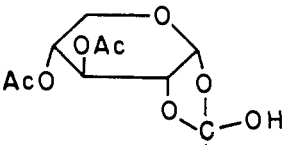
(7) C. S. Hudson and J. K. Dale, THIS JOURNAL, **40**, 997 (1918).

Hudson and Dale[7] already had shown that their tri-*O*-acetyl-α-D-xylose (identical with isomer B) was a pyranose by converting it to the known 1,2,3,-4-tetra-*O*-acetyl-β-D-xylopyranose by the action of acetic anhydride and sodium acetate. The available evidence thus showed that isomers B and C must be, respectively, the α- and β-anomers of 2,3,4-tri-*O*-acetyl-D-xylopyranose (see Chart I).

That isomer A did not mutarotate in chloroform suggested that the $C_1$-position might be blocked as a result of a migration of or an attachment from the neighboring $C_2$-acetyl group leading to either a $C_1$-acetate structure (I), with a free hydroxyl at $C_2$, or to a $C_1C_2$-orthoacid structure (II). Either structure would be expected to revert to the $C_2$-acetate, with a free hydroxyl at $C_1$, under the influence of a mild base, as was shown by Ness and Fletcher[5,6] in the case of the tri-*O*-benzoylribofuranoses. As expected, the action of aqueous pyridine on isomer A at room temperature showed a slow continuous change in the optical rotation from an initial $[\alpha]^{25}D$ +115.4° to a final $[\alpha]^{25}D$ +55.8° over a period of about 3 days and an infrared spectrum of the product showed it to be the pure isomer B.




I



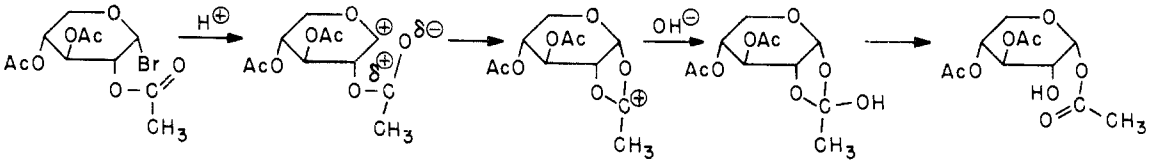

II

In order to be able to distinguish between structures I and II for the isomer A, recourse was had to a quantitative infrared spectroscopic examination of the compound in the region for carbonyl absorption and to a comparison of the results with data from a similar examination of isomers B, C and the known 1,2,3,4-tetra-*O*-acetyl-β-D-xylopyranose. Structure I should show an absorption corresponding to 3 carbonyl groups as should also the isomers B and C. Structure II should absorb for only 2 carbonyls, whereas the tetraacetylxylopyranose would absorb in proportion to 4 carbonyls. Jones, Ramsay, Keir and Dobriner[8] have worked out a method for estimating the number of carbonyl groups in a compound where two or more such groups show superimposed bands in the region around 1700 cm.$^{-1}$ of the infrared spectrum. They found that the value of the apparent molecular extinction coefficient at the absorption maximum ($E^{(a)}_{max}$)[9] was not reliable enough for the purpose and that it was preferable to determine the integrated absorption intensity of the band ($A$), which is a measure of the area under the absorption envelope. In a subsequent simplification of this method, due to Roberts, Gallagher and Jones,[10] the integrated absorption band intensity ($A$), using a spectrometer

(8) R. N. Jones, D. A. Ramsay, D. S. Keir and K. Dobriner, *ibid.*, **74**, 80 (1952).

(9) $E^{(a)}_{max} = \frac{l}{cl} \times \log_{10}\left(\frac{T_0}{T}\right)_{max}$, where $l$ is the cell length in cm., $c$ the concentration in moles per liter of solution and $\log_{10}(T_0/T)_{max}$ is the optical density observed when the spectrophotometer is set on the maximum of the absorption band.

(10) G. Roberts, B. S. Gallagher and R. N. Jones, "Infrared Absorption Spectra of Steroids, An Atlas," Vol. II, Interscience Publishers, Inc., New York, N. Y., in press.



III IV V

with a sodium chloride prism, may be calculated directly from the expression

$$A = 3.5 \times E^{(a)}_{max} \times \Delta\gamma^{(a)}_{1/2}$$

where $\Delta\gamma^{(a)}_{1/2}$ is the width of the band in cm.$^{-1}$ at $E^{(a)} = 0.5\ E^{(a)}_{max}$. The apparent integrated absorption intensity ($A$) was thus determined for the four compounds in chloroform solution at three different comparable concentrations and the average value of $A$ for each compound divided by the number of carbonyls expected gave the results listed in Table I.

TABLE I

APPARENT INTEGRATED ABSORPTION INTENSITIES AT 1745–1752 CM.$^{-1}$

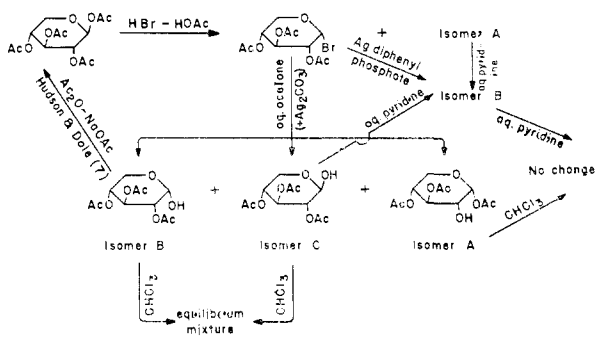
| Compound | Average value of $A$ ($\times 10^{-4}$) mole$^{-1}$ liter cm.$^{-2}$ | Number of carbonyls expected | $\frac{A^a}{\text{Number of carbonyls}}$ |
|---|---|---|---|
| Isomer A | | | |
| Structure I | 11.813 | 3 | 3.94 |
| Structure II | 11.813 | 2 | 5.91 |
| Isomer B | 11.473 | 3 | 3.82 |
| Isomer C | 11.030 | 3 | 3.68 |
| Tetraacetylxylose | 16.243 | 4 | 4.06 |

[a] For carbonyl absorption bands above 1700 cm.$^{-1}$ in the steroid series, measured in $CS_2$ or $CCl_4$ solution, Roberts, *et al.*,[10] quote values of $A$ in the range of 1.8 to 3.25 intensity units per carbonyl. The higher values obtained with the acetylxyloses may be due to the difference in the solvent used.

It is obvious from the figures in the last column of this table that isomer A should contain 3 carbonyl groups and that therefore the available evidence points to structure I for this compound. Isomer A must therefore be 1,3,4-tri-*O*-acetyl-α-D-xylopyranose.

The network of reactions involving the interconversion of isomers A, B and C and their formation from and conversion to other related compounds is summed up in Chart I.

Chart I




The formation of isomer A appears to be favored under acid hydrolysis conditions, for it was noted that during preparation of acetobromoxylose by the action of anhydrous hydrogen bromide in glacial acetic acid on 1,2,3,4-tetra-*O*-acetyl-β-D-xylopyranose, the mother liquors from crystallization of the bromo compound yielded exclusively a small quantity of this isomer.

An interesting mutarotation behavior was shown by isomers B and C in aqueous pyridine. Isomer B did not mutarotate in this solvent system and was recovered virtually unchanged from solution after *ca.* 4.25 days at room temperature. However, isomer C mutarotated rapidly under these conditions, changing almost entirely to B. That aqueous pyridine accelerates the rate of mutarotation of reducing sugars has been shown by Lowry and Faulkner,[11] but that this solvent system should alter the position of the equilibrium so as to favor the formation of almost entirely the α-anomer seemed somewhat surprising. The equilibrium in chloroform solution is already largely in favor of the α-anomer and it is possible that the pyridine combines with the α-anomer in solution to favor a further shift of the equilibrium toward that anomer. The combination of pyridine with specific anomers of reducing sugars is known.[12]

## Discussion

Ness and Fletcher[6] explained the migration they had observed, of the $C_2$-benzoyl of tri-*O*-benzoyl-D-ribofuranosyl bromide to $C_1$ on acidic or neutral hydrolysis, by suggesting that the bromide must be the β-anomer ($C_1C_2$-*trans*)[13] to enable the $C_2$-acyloxy group to participate in dissociation of the $C_1$–halogen bond with the formation of an unstable, cyclic $C_1C_2$-orthoacid structure, rearranging rapidly to the $C_1$-benzoate. Evidently the $C_1C_2$-*trans* condition is a prerequisite to a $C_2 \rightarrow C_1$ acyl migration only when such migration involves neighboring-group participation of the $C_2$–acyl in dissociation of the $C_1$–halogen bond. In the formation of 1,3,4-tri-*O*-acetyl-α-D-xylopyranose by solvolysis of tri-*O*-acetylxylopyranosyl bromide, a $C_2 \rightarrow C_1$ acyl migration has occurred with a prior $C_1C_2$-*cis* condition. This would require a primary dissociation of the $C_1$–halogen bond without neighboring group participation to give the carbonium ion III, which can rearrange to the cyclic ion IV and proceed through a labile orthoacid structure V to the $C_1$-acetate.

A similar mechanism was proposed by Hurd and Holysz[14] to account for the formation of 1,2-ketal derivatives of 3,4,6-tri-*O*-acetyl-α-D-glucopyranose on interaction of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide with dialkyl cadmium.

The re-migration of acetyl from $C_1$ to $C_2$ obtained

(11) T. M. Lowry and I. J. Faulkner, *J. Chem. Soc.*, **127**, 2883 (1925).

(12) F. J. Bates, *et al.*, "Polarimetry, Saccharimetry and the Sugars," U. S. Dept. of Commerce, Circular of the National Bureau of Standards of C440, p. 453.

(13) These abbreviated terms denote the steric relationship of the bulkier substituents at the corresponding members of the pyranose ring structure.

(14) C. D. Hurd and R. P. Holysz, THIS JOURNAL, **72**, 2005 (1950).

in the conversion of isomer A to isomer B under basic conditions may be accounted for by a mechanism involving a rapid sequence of reactions analogous to those proposed by Ness and Fletcher[6] to explain a similar migration in the benzoylribofuranose series.

The 2,3,4-tri-*O*-acetyl-α-D-xylopyranose isolated from a silver diphenyl phosphate phosphorylation of tri-*O*-acetylxylopyranosyl bromide was formed presumably by solvolysis of a labile $C_1$-diphenyl phosphate intermediate. The exclusive formation of isomer B in this reaction suggests that the $C_1$-phosphate intermediate must be the α-anomer, for solvolysis of the β-anomer (or even of a mixture of anomers) would be expected to form (at least in part) either the β-$C_2$-acetate (isomer C) or an α-$C_1$-acetate (isomer A) as a consequence of the $C_2$-neighboring-group effect.[15] This observation appears to substantiate the view expressed previously[3] that the phosphorylation reaction is most probably stereospecific and leads exclusively to α-D-xylose 1-phosphate.

The observed formation of the α-$C_1$-acetate (isomer A) from β-xylose tetraacetate under the influence of HBr–acetic acid may have involved neighboring-group participation of the $C_2$-acetyl in dissociation of the $C_1$–acetyl linkage of the tetraacetate or of the $C_1$–halogen bond of a fleeting labile β-bromotriacetylxylose intermediate. Alternatively, this isomer may have arisen from acid hydrolysis of preformed α-bromotriacetylxylose paralleling the solvolysis discussed before.

## Experimental

All melting points reported are uncorrected. The infrared spectra were made with a Perkin–Elmer double-beam recording infrared spectrophotometer (model 21, NaCl prism).

**Preparation of Isomers A and B.**—Acetobromoxylose (3.69 g.) was dissolved in 20:1 acetone–$H_2O$ (21 cc.) and kept standing at room temperature for *ca.* 75 minutes. The mass slowly turned brown as reaction proceeded. This was taken up in cold chloroform (125 cc.), washed (a) twice with ice-cold 8% $NaHCO_3$ solution (100 cc. per washing) and (b) twice with water, and the washed solution dried ($Na_2SO_4$, 2 hours). The chloroform was expelled *in vacuo* and some ether–pentane (2:1) added to the sirupy residue. An immediate crystallization was observed which was allowed to proceed overnight at 0–5°. The crystalline mass was filtered by suction (1.4 g., m.p. 98–105°) and was recrystallized from ether–pentane to give clusters of needles of isomer A (0.484 g., m.p. 136–139°). The m.p. was unchanged on further crystallization. *Anal.* Calcd. for $C_{11}H_{16}O_8$ (isomer A): C, 47.83; H, 5.80. Found: C, 47.98; H, 5.63.

The mother liquors from the first crystallization of isomer A were evaporated *in vacuo* to dryness, the residue taken up in ether (25 cc.) and pentane added dropwise to the clear solution to incipient turbidity. Crystallization was initiated by scratching. The crystals formed (0.263 g., m.p. 105–110°) were similarly recrystallized 3 times to give rosettes of prisms of isomer B (m.p. 141–143°). A further crystallization gave m.p. 143–145°. *Anal.* Calcd. for $C_{11}H_{16}O_8$ (isomer B): C, 47.83; H, 5.80. Found: C, 48.20; H, 5.94. A mixed m.p. of isomers A and B showed a marked depression (115–120°).

All attempts to separate larger amounts of isomers A and B from the combined mother liquors (from the above crystallizations) by fractional crystallization from different solvents gave only mixtures. The combined mother liquors were evaporated *in vacuo* to dryness and the residue (0.813 g.), dissolved in dry benzene (75 cc.), was chromatographed over a column (13 cm. × 1.7 cm. diameter) of Merck acid-washed alumina (25 g.). Elution with benzene (200 cc.) gave no material. Next, elution with 1:1 benzene–ether (100 cc.) gave prisms of isomer B, m.p. 135–137° (ether–pentane),[16] which showed contamination from a trace of isomer A (infrared spectrum). Further elution with the same solvent system (400 cc.) gave a mixture of isomers A and B. Next, elutions with ether (300 cc.) and 1:1 ether–chloroform (200 cc.) gave traces of crystalline matter which were not examined. An ensuing elution with chloroform (400 cc.) gave a significant amount of crystals, m.p. 135–137° (ether–pentane),[16] which an infrared spectrum showed to be a mixture of isomers B and C. As isomer C was obtained fairly pure by another procedure described later, no attempt was made to separate it from isomer B at this stage. The three isomers showed the following optical rotations: A, $[\alpha]^{25}D$ +126.5° (*c* 2.04, $CHCl_3$); B, $[\alpha]^{25}D$ +54.8° (*c* 2.08, $CHCl_3$); C, $[\alpha]^{25}D$ −20.0° (*c* 1.00, $CHCl_3$).

The frequencies ($cm.^{-1}$) of the absorption bands shown by the infrared spectra of the three isomers in Nujol are: A: 673, 715, 909, 932, 938, 952, 994, 1018, 1046, 1056, 1091, 1111, 1122, 1142, 1165, 1232, 1252, 1268, 1305, 1324, 1660, 1732, 1743, 3520; B: 648, 670, 760, 879, 888, 916, 929, 950, 972, 986, 1007, 1042, 1050, 1054, 1071, 1107, 1145, 1176, 1235, 1248, 1268, 1285, 1325, 1718, 1742, 3328; C: 650, 695, 875, 892, 908, 937, 960, 987, 1000, 1045, 1062, 1080, 1108, 1136, 1168, 1233, 1262, 1310, 1330, 1732, 1745, 3510.

Of these frequencies, a permutation-combination of the following characteristics proved particularly helpful in following the separation or purification of any one isomer from a mixture of the isomers, as well as in the mutarotation studies described later. Isomer A showed a low-intensity band at 715 $cm.^{-1}$, absence of absorption in the region 800–900 $cm.^{-1}$, strong doublets at 932, 938 $cm.^{-1}$ and in the carbonyl region at 1732, 1743 $cm.^{-1}$ and a typical low broad band in the OH region at 3520 $cm.^{-1}$. Isomer B showed a medium-intensity band at 760 $cm.^{-1}$, characteristic strong twin peaks in the carbonyl region at 1718 and 1742 $cm.^{-1}$ and a strong band at 3328 $cm.^{-1}$ in the OH region. Isomer C showed absence of absorption in region[17] 700–800 $cm.^{-1}$, characteristic twin peaks of medium intensity at 987 and 1000 $cm.^{-1}$, a strong doublet in the carbonyl region at 1732, 1745 $cm.^{-1}$ and a medium-intensity band at 3510 $cm.^{-1}$ in the OH region.

**Preparation of Isomer C.**—To a solution of acetobromoxylose (5 g.) in 25:1 acetone–water (26 cc.) was added some silver carbonate and the suspension mechanically agitated in the dark at room temperature. More silver carbonate was added in portions at a time till no more evolution of gas was observed and a test of the supernatant from the reaction mass showed absence of halogen. The silver salts were centrifuged off and washed with acetone and the combined supernatant and washings evaporated *in vacuo* to near dryness. On adding some ether, the residual sirup crystallized. After cooling overnight at 0–5°, the mass was filtered by suction and the crystals, sucked dry on the filter, weighed 2.9 g. (m.p. 110–115°). Recrystallized from ether–pentane, the product (1.3 g.) melted at 138–140°. A mixed m.p. with isomer B gave the value 135–137°, whereas that with isomer A showed 110–112° (marked depression). An infrared spectrum showed this material to be a mixture of isomers B and C. The product was submitted to 3 more recrystallizations from ether–pentane and the purification of isomer C was followed by infrared spectrophotometry. With each crystallization, the absorption peaks at 760 and 3328 $cm.^{-1}$ due to contamination from isomer B were reduced in intensity, until after the last crystallization the product showed only a trace of these peaks. Erratic melting point behavior was observed during

(15) R. S. Wright and H. G. Khorana (ref. 4), during a phosphorylation of tri-*O*-benzoyl-D-ribofuranosyl bromide (leading normally to β-D-ribofuranose 1-phosphate), isolated 1,3,5-tri-O-benzoyl-α-D-ribofuranose and the exclusive formation of this isomer showed that a $C_2$-acyloxy neighboring-group participation must have occurred in severing a β-$C_1$–phosphate linkage.

(16) All m.p. determinations of the isomers were made after crystallization from this solvent system.

(17) According to S. A. Barker, E. J. Bourne, R. Stephens and D. H. Whiffen (*J. Chem. Soc.*, 3468 (1954)), the absence of absorption at 749 ± 10 $cm.^{-1}$ is characteristic of β-forms of D-xylopyranose derivatives, while the α-forms normally absorb in this region. The absorption of isomers B and C is in agreement with this observation. However, isomer A (an α-form) does not absorb in this range and the nearest absorption band observed is at 715 $cm.^{-1}$.

the crystallizations. Whereas during earlier crystallizations the product melted at 140–142°, the purest isomer C (fine needles, different in appearance from those of isomer A) from the final crystallization melted sharply at 135–136°. *Anal.* Calcd. for $C_{11}H_{16}O_8$ (isomer C): C, 47.83; H, 5.80. Found: C, 47.84; H, 5.81.

The mother liquors from the original crystallization gave, on concentration *in vacuo*, a second crop of crystals (0.58 g., m.p. 112–115°). Repeated recrystallization of these from ether–pentane (2:1) gave a minute amount of needles of isomer A (infrared spectral identity established).

**Optical Rotation Behavior of Isomers A, B and C in Solutions.**—A.C.S. reagent grade chloroform or pyridine was used. Rotations were made in a half-decimeter polarimeter tube. All solutions were left standing at room temperature for the periods stated.

**Chloroform Solutions.**—Isomer A: For a solution with *c* 1.015, an initial value of $[\alpha]^{25}D$ +108.4° had not changed in 46.5 hours. A solution with *c* 1.06 gave, after standing *ca.* 14 days, a final $[\alpha]^{25}D$ +115.4°. In each case, the product, after expelling the $CHCl_3$ *in vacuo* and crystallizing the residue from ether–pentane, gave an infrared spectrum identical with that of unchanged isomer A.

Isomer B: A solution with *c* 1.05 showed an initial $[\alpha]^{25}D$ +46.1° and after 28.5 hours a final $[\alpha]^{25}D$ +30.5°. The infrared spectrum of the product, crystallized from ether–pentane, showed significant differences from that of isomer B, but did not reveal conclusive evidence of the appearance of absorption bands characteristic of isomer C. A solution with *c* 1.00 showed a final $[\alpha]^{25}D$ +38.6° after *ca.* 14 days and an infrared spectrum of the product was identical with that from the product of a similar mutarotation study of isomer C.

Isomer C: A solution with *c* 1.00 showed an initial $[\alpha]^{25}D$ −20.0° which changed in *ca.* 22 hours to a value of $[\alpha]^{25}D$ +6.6°. An infrared spectrum of the product, crystallized from ether–pentane, showed enhancement of intensity of the peaks at 760 and 3328 cm.$^{-1}$ characteristic of isomer B. A solution with *c* 1.005 showed a final $[\alpha]^{25}D$ +32.8° after *ca.* 14 days and an infrared spectrum of the product was identical with that from the product of a similar mutarotation study of isomer B.

**5:1 Pyridine–Water Solutions.**—Isomer A: A solution with *c* 1.04 showed an initial $[\alpha]^{25}D$ +115.4° and after *ca.* 3 days an $[\alpha]^{25}D$ +55.8°, which did not change on further standing. An infrared spectrum of the product, crystallized from ether–pentane, was identical with that of isomer B.

Isomer B: A solution with *c* 1.0125 showed an initial $[\alpha]^{25}D$ +50.4° and after *ca.* 4.25 days an $[\alpha]^{25}D$ +51.4°. An infrared spectrum of the product, crystallized from ether–pentane, showed unchanged isomer B.

Isomer C: A solution with *c* 1.0125 showed an $[\alpha]^{25}D$ +46.4° 15 minutes after dissolution of the compound. The rotation values observed 4 hours thereafter and after a total period of *ca.* 4.25 days were $[\alpha]^{25}D$ +54.3 and +59.8°, respectively. An infrared spectrum of the product (from the solution kept 4.25 days), crystallized from ether–pentane, appeared to be identical with that from isomer B.

**Quantitative Comparison of the Infrared Absorption in the Carbonyl Region by Isomers A, B, C and Tetra-*O*-acetyl-β-D-xylopyranose.**—Freshly dried chloroform was used for making the solutions. An NaCl cell of thickness $l$ = 0.0502 cm. was used. The spectrophotometer slit width was constant at 46 μ during the measurements. The results of the measurements at the different comparable concentrations are summed up in Table II.

TABLE II

| Compound | $\nu_{max}$, cm.$^{-1}$ | Concn., *c*, mole/liter | $E^{(a)}_{max} \times cl$ ($= \log_{10}(T_0/T)_{max}$) | $\Delta\nu^{(a)}_{1/2}$ cm.$^{-1}$ | Apparent integrated absorption intensity $A(\times 10^{-4})$, mole$^{-1}$ l. cm.$^{-2}$ |
|---|---|---|---|---|---|
| | | 0.018170 | 0.710 | 46.0 | 12.54 |
| Isomer A | 1745 | .009085 | .370 | 40.0 | 11.36 |
| | | .004543 | .188 | 40.0 | 11.54 |
| | | .018840 | .790 | 42.0 | 12.27 |
| Isomer B | 1747 | .009421 | .423 | 37.0 | 11.58 |
| | | .004711 | .210 | 34.0 | 10.57 |
| | | .018190 | .795 | 40.0 | 12.19 |
| Isomer C | 1745 | .009095 | .421 | 35.0 | 11.30 |
| | | .004548 | .202 | 31.0 | 9.60 |
| | | .015720 | .900 | 46.5 | 18.50 |
| Tetraacetyl-xylose | 1752 | .007860 | .456 | 40.0 | 16.18 |
| | | .003930 | .220 | 36.0 | 14.05 |

**Acknowledgments.**—The author wishes to thank Dr. R. N. Jones for advice received in making the quantitative infrared studies and for making available information from the manuscript of reference 10 while still in press. Deep gratitude is expressed to Dr. R. W. Watson for the keen interest shown in this work and to Dr. C. T. Bishop for useful suggestions and criticism received. The technical assistance of Mr. F. Rollin in making the infrared spectrograms is gratefully acknowledged.

OTTAWA 2, CANADA

---

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, IOWA STATE COLLEGE]

# Studies on the Schardinger Dextrins. X. The Interaction of Cyclohexaamylose, Iodine and Iodide. Part I. Spectrophotometric Studies[1]

BY JOHN A. THOMA[2] AND DEXTER FRENCH[3]

RECEIVED JUNE 23, 1958

The cyclohexaamylose, $I_2$, $I^-$ system was studied as a model for the starch, $I_2$, $I^-$ system. Using the method of continuous variation it was found that α-dextrin in aqueous $I_2$ forms an $\alpha I_2$ complex in the absence of $I^-$ and an $\alpha I_3^-$ complex in the presence of $I^-$. The method of continuous variation has been extended to some special ternary systems.

## Introduction

The Schardinger dextrins, and particularly cyclohexaamylose (referred to hereafter as α), have been of very considerable interest because of their ability to form highly colored, crystalline iodine complexes resembling the starch–iodine complex.[4] The unique molecular structure of α (cyclic molecule consisting of six α-1 → 4-linked D-glucopyranose units) makes it possible to form inclusion compound *in solution* as well as in the solid state. Thus systems containing α and complexing agents are particularly favorable for study as models of the far more complicated starch systems.

Although the understanding of the starch–iodine reaction has advanced substantially in recent years, several aspects remain controversial. Some con-

(1) This work was supported in part by grants from Union Carbide and Carbon Corporation and General Foods Corporation.

(2) Union Carbide and Carbon Fellow 1957–1958.

(3) To whom inquiries concerning this article should be made.

(4) D. French, *Adv. Carbohydrate Chem.*, **12**, 189 (1957).