observations limits the calculation of reliable reaction constants to mannosan concentrations between 0.008 and 0.016 molar, there is excellent agreement over the entire investigated range between the observed concentrations of complex and those calculated for a bimolecular reaction having an equilibrium constant of $2.5 \times 10^3$. The quality of this agreement is illustrated by Fig. 2.

By four independent techniques the reaction between cuprammonium and a glycol grouping in D-mannosan is shown to be a bimolecular association. This is considerably simpler than mechanisms which have been advanced to explain the reaction between cuprammonium and cellulose.[6,7] In fact, the present results appear to warrant a reinvestigation of the latter reaction by a variety of techniques in order to discover whether several types of stoichiometric reactions actually occur when cellulose and cuprammonium combine.

## Experimental Methods

The cuprammonium employed in this work has been designated as cupra A in a preceding communication.[8] It is a standard dilute cuprammonium solution containing 0.01 mole of copper, 3 moles of ammonia and 10 ml. of ethanol per liter.

Conductivity measurements were made at 25 ± 0.2° with a commercial 1000-cycle bridge using a dip-type cell. The cell constant, determined against 0.1 *M* potassium chloride, was found to be 0.116.

Optical rotations were measured at 25 ± 2° in a Gaertner polarimeter employing 2-dm. tubes. The mercury blue line (436 mμ) was isolated by means of Corning filters 511 and 038.

Absorption measurements at 650 mμ were made in a Coleman model 11 spectrophotometer. The absorption curves from 320 to 800 mμ and the optical density measurements at 350 mμ were made with the Beckman spectrophotometer. All observations were made at room temperature, which was 25 ± 2°.

**Acknowledgment.**—Some of the absorption measurements were made by Miss Dorothy C. Heinzelman of the Analytical and Physical Division.

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[6] Emil Heuser, "The Chemistry of Cellulose," John Wiley and Sons Inc., New York, N. Y., 1944.

[7] Kurt Hess, "Die Chemie der Zellulose und ihrer Begleiter," Leipzig, 1928.

[8] Reeves and Jung, THIS JOURNAL, 71, 209 (1949).

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# New Tribenzoyl-D-ribopyranosyl Halides and Their Reactions with Methanol

BY ROBERT K. NESS,[1] HEWITT G. FLETCHER, JR., AND C. S. HUDSON

Tribenzoyl-α-D-ribopyranosyl bromide, tribenzoyl-α-D-ribopyranosyl chloride and tribenzoyl-β-D-ribopyranosyl chloride have been obtained in crystalline form. Evidence supporting the assignments of structure and configuration to these three halides, as well as to the previously known tribenzoyl-β-D-ribopyranosyl bromide has been adduced through a study of the behavior of these substances with methanol, both in the presence and in the absence of an acid acceptor. The preparation of crystalline 2,3,4-tribenzoyl-D-ribose is described. Tribenzoyl-β-D-ribopyranosyl bromide is shown to give β-D-ribopyranose tetrabenzoate in 92% yield when reacting with silver benzoate.

In earlier publications[2,3] crystalline tribenzoyl-β-D-ribopyranosyl bromide (II) was described and shown to react with methanol in the absence of a catalyst to give methyl β-D-ribopyranoside tribenzoate (V) in high yield; subsequent researches[4] have shown a variety of benzoylated glycopyranosyl halides to react similarly with methanol. A recent reinvestigation of this general reaction in the D-ribose series has led to the discovery of a second tribenzoyl-D-ribopyranosyl bromide as well as two isomeric tribenzoyl-D-ribopyranosyl chlorides. The present paper will describe the preparation and some of the properties of these new halides.

When β-D-ribopyranose tetrabenzoate[2] is treated with a solution of hydrogen bromide in glacial acetic acid there is obtained in high yield, 71 to 85%, of the previously described[2] tribenzoyl-β-D-ribopyranosyl bromide as well-shaped prismatic crystals. At the same time there is formed in relatively meager quantity (5% yield) a second compound crystallizing in long needles; elementary analysis shows this substance to be an isomer of the major product of the reaction. With anhydrous methanol in the absence of a catalyst this minor product gave methyl β-D-ribopyranoside tribenzoate and thus possesses a pyranose ring like its previously known isomer. The physical constants of this new halide, listed in Table I, are seen to differ markedly from those of its isomer; in contrast to the strongly levorotatory nature of the bromide first prepared, the new substance is dextrorotatory. It seems highly probable, therefore, that the two substances represent an anomeric pair, the levorotatory bromide being a β-D-halide as previously assumed[2] and the new bromide representing tribenzoyl-α-D-

TABLE I

BENZOYLATED D-RIBOPYRANOSYL HALIDES

| | M.p., °C. | $[\alpha]^{20}D$ (abs. $CHCl_3$) | $[M]^{20}D$ |
|---|---|---|---|
| Tribenzoyl-α-D-ribopyranosyl bromide (IV) | 164–166 | + 78° | + 41,000 |
| Tribenzoyl-β-D-ribopyranosyl bromide (II) | 152–154 | −202° | −106,000 |
| Tribenzoyl-α-D-ribopyranosyl chloride (III) | 203–204 | + 60° | + 28,900 |
| Tribenzoyl-β-D-ribopyranosyl chloride (I) | 162–163 | −147° | − 70,700 |

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[1] Senior Research Fellow, National Institutes of Health, 1948–1950.

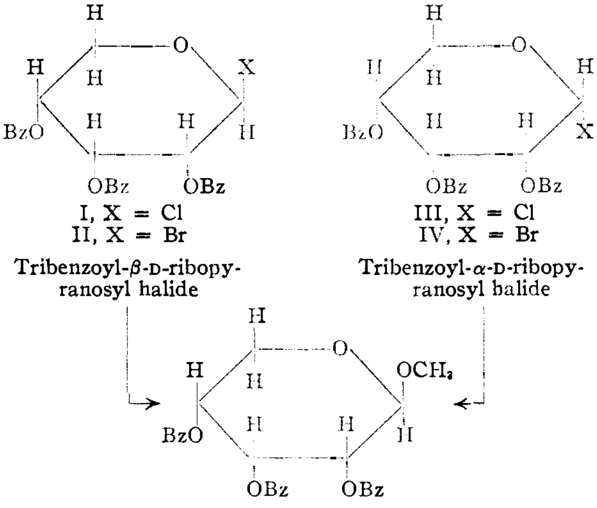
[2] R. Jeanloz, H. G. Fletcher, Jr., and C. S. Hudson, THIS JOURNAL, 70, 4052 (1948).

[3] R. Jeanloz, H. G. Fletcher, Jr., and C. S. Hudson, *ibid.*, 70, 4055 (1948).

[4] (a) R. K. Ness, H. G. Fletcher, Jr., and C. S. Hudson, *ibid.*, 72, 2200 (1950); (b) H. G. Fletcher, Jr., and C. S. Hudson, *ibid.*, 72, 4173 (1950); (c) R. K. Ness, H. G. Fletcher, Jr., and C. S. Hudson, *ibid.*, 73, 296 (1951).

ribopyranosyl bromide (IV). Evidence discussed below tends to confirm this view.

Treatment of the levorotatory isomer, II, with a solution of hydrogen bromide in glacial acetic acid led to the isolation of the dextrorotatory isomer, IV, in 1.3% yield; it seems probable, therefore, that an equilibrium is established between the two forms under strongly acidic conditions.



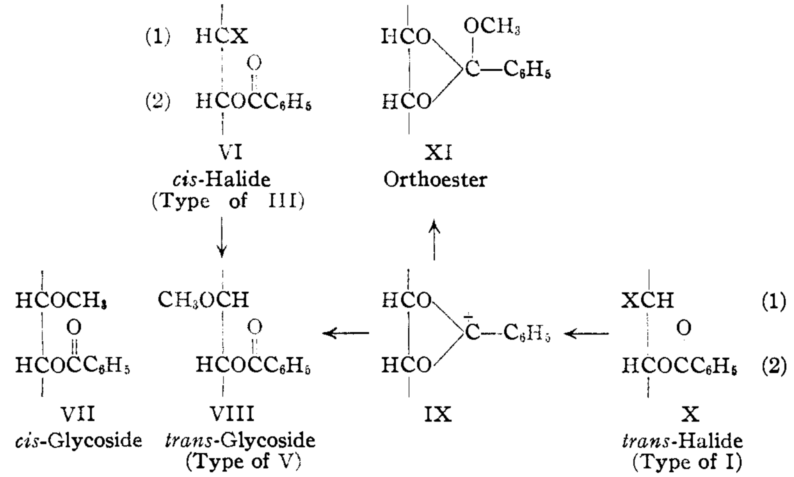
I, X = Cl
II, X = Br
Tribenzoyl-β-D-ribopyranosyl halide

III, X = Cl
IV, X = Br
Tribenzoyl-α-D-ribopyranosyl halide

V
Methyl β-D-ribopyranoside tribenzoate

A completely analogous situation was found to exist with the corresponding chlorides. Reaction of β-D-ribopyranose tetrabenzoate with titanium chloride in chloroform solution gives a substantial yield (56%) of a strongly levorotatory tribenzoylpentosyl chloride, crystallizing as prisms, together with a relatively small yield (5%) of an isomeric, dextrorotatory substance in the form of needles (Table I). Since both isomers were found to react with anhydrous methanol in the absence of an acid acceptor to give methyl β-D-ribopyranoside tribenzoate (V), it again appears probable that these isomers represent an anomeric pair, the levorotatory substance being tribenzoyl-β-D-ribopyranosyl chloride (I) and the dextrorotatory compound tribenzoyl-α-D-ribopyranosyl chloride (III).

Comparison of the rotations given in Table I tends to confirm these configurational assignments: of the dextrorotatory halides, the bromide is the more dextrorotatory as would be expected of such a pair in the α-D-series.[4,5] Likewise, of the levorotatory halides, the bromide is more levorotatory, indicating that the pair belongs to the β-D-series.



VI
*cis*-Halide
(Type of III)

XI
Orthoester

VII
*cis*-Glycoside

VIII
*trans*-Glycoside
(Type of V)

IX

X
*trans*-Halide
(Type of I)

If the configurations at carbon atom 1 of these halides have been assigned correctly, the first two carbon atoms of the α-D-halides may be represented by formula VI. Likewise, the groups around the first two carbon atoms of the β-D-halides have the relationship shown by X. As pointed out in a previous paper[4b] the present theory of the role of neighboring groups in replacement reactions[6] predicts that displacement of the halogen of structure VI, where the groups are initially in a *cis* position, proceeds with simple inversion at carbon atom 1 to give structure VIII. On the other hand, a similar reaction in structure X is considered to be facilitated by the acyloxy group on carbon 2 which occupies a *trans* position with respect to the halogen; displacement here proceeds through the intermediate ion IX which reacts to give an orthoester, XI, and a *trans* product, VIII. Since orthoesters are acid labile, the *trans* product is to be expected as the sole product when the reaction is carried out in the absence of an acid acceptor. Isbell and Frush,[7] in discussing the reaction of acetylated glycopyranosyl halides with methanol in the presence of an acid acceptor, have pointed out that, while *cis* halides of type VI react to give *trans* glycosides such as VIII, *trans* halides may react both through an intermediate ion such as IX and directly by simple Walden inversion. Thus all three products, the *cis* glycoside, VII, the *trans* glycoside, VIII, and the orthoester, XI, are formed, the relative proportions of these varying with the conditions of the reaction. In the absence of an acid acceptor, *i.e.*, under acidic conditions, only VII and VIII would be expected as products from X.

In the light of these considerations, the rates of reaction of the four tribenzoyl-D-ribopyranosyl halides (I–IV) with 1:9 dioxane–methanol[8] at 20° in the absence of an acid acceptor were studied. The information thus obtained is listed in Table II. It is to be noted that each of the two *trans* halides, having the β-D-configuration, reacts much more rapidly than the corresponding α-D-*cis* halide; this behavior is in conformity with the theory since

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(5) C. S. Hudson, This Journal, **46**, 462 (1924).

(6) See, for example, S. Winstein and R. E. Buckles, *ibid.*, **64**, 2780 (1942); S. Winstein, H. O. Hess and R. E. Buckles, *ibid.*, **64**, 2796 (1942); A. E. Remick, "Electronic Interpretations of Organic Chemistry," 2nd ed., John Wiley & Sons, Inc., New York, N. Y., 1949, p. 339.

(7) H. S. Isbell and H. L. Frush, *J. Research Natl. Bur. Standards*, **43**, 161 (1949).

(8) The solubility in methanol at 20° of all the benzoylated glycopyranosyl halides thus far studied is of such a low order as to prevent direct measurement of the rates of reaction in this solvent alone.

the latter indicates that, other things being equal, a *trans* acyloxy group will have a greater influence than a *cis* acyloxy group in facilitating the removal of the halogen ion. Attention is now turned to the last column of Table II. Here are tabulated the specific rotations which have been calculated from each final and constant observed rotation, using as a basis the weight of methyl D-riboside tribenzoate that would be expected on complete reaction. As is to be expected from the foregoing discussion, the α-D-halides, having a *cis* relationship between the groups attached to carbon atoms 1 and 2, attain final rotations corresponding to that of methyl β-D-ribopyranoside tribenzoate, simple inversion having taken place at carbon 1. On the other hand, the final rotations attained by the *trans* β-D-halides are more dextrorotatory than would be expected on the basis of the formation of methyl β-D-ribopyranoside tribenzoate alone and it is to be suspected that some methyl α-D-ribopyranoside tribenzoate corresponding to VII is formed,[9] although efforts to isolate such have not been successful.

TABLE II

REACTION OF TRIBENZOYL-D-RIBOPYRANOSYL HALIDES WITH 1:9 DIOXANE–METHANOL AT 20°

| | $k \times 10^4$ (min., decimal logs) | Time of "half-change," min. | Final $[\alpha]^{20}_{D}$[a] |
|---|---|---|---|
| Tribenzoyl-α-D-ribopyranosyl bromide | 40 | 75 | −68° |
| Tribenzoyl-β-D-ribopyranosyl bromide | 760 | 4.0 | −53° |
| Tribenzoyl-α-D-ribopyranosyl chloride | 0.62 | 4900 | −65° |
| Tribenzoyl-β-D-ribopyranosyl chloride | 53 | 57 | −49° |

[a] Calculated on the assumption that each halide was quantitatively converted to methyl pentoside tribenzoate. Methyl β-D-ribopyranoside tribenzoate shows a specific rotation of −65.2° in 1:9 dioxane–methanol.

If the two levorotatory halides actually belong to the β-D-series it is to be expected that they would react with methanol *in the presence of an acid acceptor* to give a mixture of the two anomeric methyl D-ribopyranoside tribenzoates as well as methyl 1,2-orthobenzoate corresponding to structure XI. Experiment showed that, in the presence of silver carbonate, both levorotatory halides gave amorphous dextrorotatory products which, upon acidification in methanol solution, rapidly became levorotatory, the final rotation being more positive than would be expected were methyl β-D-ribopyranoside tribenzoate alone formed. The formation of a methyl 1,2-orthobenzoate here is, therefore, rendered highly probable.

On the other hand, tribenzoyl-α-D-ribopyranosyl bromide (IV), having a *cis* relationship between the groups on carbon atoms 1 and 2, readily gave crystalline methyl β-D-ribopyranoside tribenzoate when treated with methanol in the presence of silver carbonate.

Anomeric pairs of acetylated glycopyranosyl chlorides have been reported in the D-glucose,[10] D-galactose[11] and D-gluco-D-*gulo*-heptose[12] series. In each case the action of so-called "active silver chloride" on an acetylated glycopyranosyl bromide has given an acetylated glycopyranosyl chloride isomeric with that obtained by the usual procedures. A similar reaction was attempted in the D-ribose series and tribenzoyl-β-D-ribopyranosyl chloride was obtained in 85% yield. We do not, however, regard this single experiment as definitive since, as has been remarked,[12] the yields of the various anomeric products in this type of reaction are quite erratic.

2,3,4-Tribenzoyl-D-ribose, previously reported[3] as an amorphous product, has now been obtained and characterized in crystalline form.

The reaction of tribenzoyl-β-D-ribopyranosyl bromide with silver benzoate has been found to give β-D-ribopyranose tetrabenzoate in 92% yield.

**Acknowledgments.**—We are indebted to Mr. William C. Alford, Mrs. Margaret M. Ledyard and Mrs. Evelyn G. Peake for analytical determinations incident to this research.

## Experimental[13]

**Tribenzoyl-α-D-ribopyranosyl Bromide (IV) (a) From β-D-Ribopyranose Tetrabenzoate.**—The procedure employed was similar to that used previously[2] for the β-anomer. β-D-Ribopyranose tetrabenzoate (7.74 g., $[\alpha]^{20}_{D}$ −100° in $CHCl_3$) was dissolved in 15 ml. of ethylene dichloride and treated with 15 ml. of a solution of hydrogen bromide in glacial acetic acid (*ca*. 32% HBr). After 2.5 hours at room temperature the reaction mixture was diluted with ethylene dichloride and washed successively with cold water, sodium bicarbonate solution and water. The solution was dried with sodium sulfate and concentrated *in vacuo* (45°) to give a crystalline magma. From its solution in a mixture of 20 ml. of ethyl acetate and 20 ml. of absolute ether, there crystallized, on standing overnight at +5°, 5.11 g. (71%) of the β-anomer previously described[2]: m.p. 150–154°; $[\alpha]^{20}_{D}$ −202° in absolute chloroform, *c*, 0.95. The mother liquor was concentrated to a sirup and dissolved in a mixture of 9 ml. of ethyl acetate, 9 ml. of ether and 90 ml. of pentane; large rosettes of needles (1.38 g.) rotating −80° in absolute chloroform formed rapidly. When dissolved in a mixture of 1.8 parts of ethyl acetate and 5.8 parts of ether, this material deposited both needles and compact prisms. The prisms (0.61 g.) proved to be more of the β-anomer; the needles (0.31 g. together with 0.12 g. subsequently obtained) were recrystallized from 28 ml. of 1:2:4 ethyl acetate–ether–pentane to give 0.38 g. (5.2%) of material rotating +74° in absolute chloroform. Two further recrystallizations from ethyl acetate–pentane gave pure tribenzoyl-α-D-ribopyranosyl bromide melting at 164–166° (rapid heating) and showing +78° in absolute chloroform (*c*, 1.47).

*Anal.* Calcd. for $C_{26}H_{21}O_7Br$: C, 59.44; H, 4.03; Br, 15.21. Found: C, 59.45; H, 4.41; Br, 15.02.

**(b) From Tribenzoyl-β-D-ribopyranosyl Bromide (II).**—Pure tribenzoyl-β-D-ribopyranosyl bromide (469 mg., $[\alpha]^{20}_{D}$ −202° in absolute $CHCl_3$) was dissolved in 20 ml. of glacial acetic acid with warming and treated with 5.5 ml. of a

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[9] A similar phenomenon has not, however, been observed in the case of the corresponding *trans* halides of the D-mannose and L-rhamnose series (ref. 4c). When allowed to react with 1:9 dioxane–methanol at 20°, tetrabenzoyl-α-D-mannopyranosyl bromide shows a final rotation identical with that of methyl α-D-mannopyranoside tetrabenzoate while the closely related tribenzoyl-α-L-rhamnopyranosyl bromide, under the same conditions, comes to a final rotation very close to that of methyl α-L-rhamnopyranoside tribenzoate.

[10] (a) H. H. Schlubach, *Ber.*, **59**, 840 (1926); (b) H. H. Schlubach, P. Stadler and I. Wolf, *ibid.*, **61**, 287 (1928).

[11] H. H. Schlubach and R. Gilbert, *ibid.*, **63**, 2292 (1930).

[12] W. N. Haworth, E. L. Hirst and M. Stacey, *J. Chem. Soc.*, 2864 (1931).

[13] Unless otherwise specified, melting points were measured with a calibrated Anschütz-type thermometer completely immersed in the bath liquid. Except where definitely stated otherwise, rotations are specific rotations for the D line of sodium at 20°; concentration is expressed in g. of substance per 100 ml. of solution.

solution of hydrogen bromide in glacial acetic acid (*ca.* 32% HBr). Worked up in a manner similar to that described in (a) above, the reaction mixture gave 452 mg. (96%) of the starting material and 6.1 mg. (1.3%) of tribenzoyl-α-D-ribopyranosyl bromide which melted at 162–165° (Kofler block); a mixed melting point with material prepared in (a) was undepressed.

**Tribenzoyl-α-D-ribopyranosyl Chloride (III) and Tribenzoyl-β-D-ribopyranosyl Chloride (I).**—The general procedure employed was that used for the preparation of tetrabenzoyl-α-D-glucopyranosyl chloride.[4a] Twelve grams of pure β-D-ribopyranose tetrabenzoate and 2.40 ml. of freshly distilled titanium tetrachloride were dissolved in sufficient absolute chloroform to make a total volume of 100 ml. and then heated at 60° for 7 hours—a period chosen on the basis of a similar, previous run which had been followed polarimetrically. The reaction mixture was diluted with ethylene dichloride, washed successively with ice-water, cold aqueous sodium bicarbonate, ice-water and dried with sodium sulfate. After filtration through carbon, the solution was concentrated *in vacuo* (45°) to a crystalline magma. Upon solution of this latter in a mixture of 30 ml. of absolute chloroform and 200 ml. of anhydrous ether, prismatic crystals began to form immediately; an hour later, needle-shaped crystals were seen to be growing. Mechanical separation gave 1.34 g. of the needle-shaped material, representing the crude tribenzoyl-α-D-ribopyranosyl chloride; recrystallization from chloroform–ether followed by another mechanical separation gave 0.35 g. of nearly pure product showing a rotation of +55° in absolute chloroform. Two further recrystallizations of this material combined with further crops obtained from the mother liquors gave 0.50 g. (5%) of pure tribenzoyl-α-D-ribopyranosyl chloride melting at 203–204° and rotating in absolute chloroform +60° (*c*, 0.85).

*Anal.* Calcd. for $C_{26}H_{21}O_7Cl$: C, 64.93; H, 4.40; Cl, 7.37. Found: C, 64.88; H, 4.47; Cl, 7.85, 7.61, 8.38.

The prismatic crystals (6.55 g.) obtained above, representing crude tribenzoyl-β-D-ribopyranosyl chloride, were recrystallized from 210 ml. of a 1:6 mixture of chloroform–ether to give 5.69 g. (56%) of the pure compound melting at 162–163° and rotating in absolute chloroform −147° (*c*, 1.17).

*Anal.* Calcd. for $C_{26}H_{21}O_7Cl$: C, 64.93; H, 4.40; Cl, 7.37. Found: C, 64.82; H, 4.46; Cl, 7.91, 8.07, 8.14, 8.44.

**Tribenzoyl-β-D-ribopyranosyl Chloride from Tribenzoyl-β-D-ribopyranosyl Bromide.**—The procedure of Haworth, Hirst and Stacey[12] was used. Tribenzoyl-β-D-ribopyranosyl bromide (800 mg.) was dissolved in a mixture of 5 ml. of dry benzene and 20 ml. of anhydrous ether, treated with 1.0 g. of freshly prepared, active silver chloride[10a,11] and boiled under anhydrous conditions for 5 minutes. After removal of the yellow silver bromide, the reaction mixture was concentrated to a crystalline mass which was dissolved in a mixture of methylene dichloride and ether. The large, clear prisms (300 mg.) which formed melted at 161–163° either alone or in admixture with tribenzoyl-β-D-ribopyranosyl chloride prepared as described above. Further crops of slightly less pure material (320 mg.) subsequently obtained raised the yield to 85% of theory.

**Reaction of Tribenzoyl-α-D-ribopyranosyl Bromide (IV) with Methanol (a) in the Absence of an Acid Acceptor.**—Tribenzoyl-α-D-ribopyranosyl bromide (37.3 mg.) was dissolved in 5 ml. of warm absolute methanol and left at +5° for 5 days. Upon concentration of the solution to a volume of 1 ml., there was obtained 18.0 mg. (53%) of crystalline material melting at 108–110°; no depression of melting point was observed on admixture with authentic methyl β-D-ribopyranoside tribenzoate.

Tribenzoyl-α-D-ribopyranosyl bromide (43.0 mg.) was dissolved in 2.5 ml. of purified dioxane and the solution diluted to 25.0 ml. with anhydrous methanol; the resulting solution was examined polarimetrically in a 1.5-dm. tube at 20°. The data obtained, together with the first order rate constants calculated therefrom, are

| Time, min. | Obsd. rotation, $\alpha_D$ (1.5 dm., circular degrees) | *k*, min., decimal logs |
|---|---|---|
| 0 | +0.20 (extrapolated) | .... |
| 3.3 | +0.19 | 0.0039 |
| 11.1 | +0.17 | .0034 |
| 18.2 | +0.14 | .0044 |
| 48 | +0.06 | .0045 |
| 109 | −0.03 | .0041 |
| 226 | −0.12 | .0042 |
| 477 | −0.15 | .0033 |
| 1440 | −0.16 | .... |

The final rotational value corresponds to a specific rotation of −68° if it be assumed that conversion of the halide to methyl pentoside tribenzoate is quantitative. Methyl β-D-ribopyranoside tribenzoate has a specific rotation of −65.2° in 1:9 dioxane–methanol.

(b) **In the Presence of Silver Carbonate.**—Tribenzoyl-α-D-ribopyranosyl bromide (99.4 mg.) was shaken with a suspension of 90 mg. of silver carbonate in 20 ml. of absolute methanol for 22 hours. The reaction mixture was then filtered through carbon and the halogen-free filtrate concentrated *in vacuo* to a sirup which was dissolved in 2 ml. of methanol. There was thus obtained 43.9 mg. (50%) of crystalline product melting at 107–109°; mixed with authentic methyl β-D-ribopyranoside tribenzoate the material melted at 108–110°. From the mother liquor 16.8 mg. (19%) of additional material melting at 105–108° was subsequently recovered.

**Reaction of Tribenzoyl-β-D-ribopyranosyl Bromide (II) with Methanol (a) in the Absence of an Acid Acceptor.**—As described in a previous publication[3] tribenzoyl-β-D-ribopyranosyl bromide reacts with methanol in the absence of an acid acceptor to give methyl β-D-ribopyranoside tribenzoate in 88% yield.

The rate of reaction of tribenzoyl-β-D-ribopyranosyl bromide with 1:9 dioxane–methanol was measured as follows: 0.2308 g. of the halide was dissolved in 2.5 ml. of dioxane and the solution diluted to 25.0 ml. with anhydrous methanol. The rotation of a sample of the resulting solution in a 1.5-dm. tube at 20° was observed to change as shown:

| Time, min. | Obsd. rotation, $\alpha_D$ (1.5 dm., circular degrees) | *k*, min., decimal logs |
|---|---|---|
| 0 | −1.35 (extrapd.) | ... |
| 1.7 | −1.21 | 0.059 |
| 3.8 | −1.08 | .058 |
| 7.3 | −0.86 | .076 |
| 12.5 | −0.70 | .11 |
| 30.7 | −0.67 | ... |
| 90 | −0.66 | ... |
| 1110 | −0.67 | ... |

The final value corresponds to a specific rotation of −53° on the assumption that the bromide was wholly converted to methyl riboside tribenzoate.

(b) **In the Presence of Silver Oxide.**—One gram of tribenzoyl-β-D-ribopyranosyl bromide was shaken at 0° with 20 ml. of methanol and 0.9 g. of silver oxide for 110 minutes and then for 40 minutes at room temperature. The solution was filtered through carbon and the filtrate concentrated *in vacuo* to a sirup. Efforts to obtain crystalline material from this residue were unsuccessful; chromatography of a sample on activated alumina gave amorphous fractions rotating in 1:4 benzene–hexane between +105° and +130°. Another sample of the sirup (75.6 mg.) was dissolved in a mixture of 20 ml. of chloroform and 60 ml. of methanol and examined polarimetrically in a 4-dm. tube. The rotation observed was +0.37°; after the addition of 0.50 ml. of 0.639 *N* hydrogen chloride in absolute methanol the following rotations were observed: +0.23° (25 sec.), +0.04° (2.0 min.), −0.08° (4.2 min.), −0.22° (24 min.), −0.17° (23 hr.) and −0.17° (48 hr.). The final rotation corresponds to a specific rotation of −50°. After removal of the solvent and solution of the residual sirup in 1 ml. of methanol, there was obtained 33.4 mg. (51%) of crystalline material melting at 102–104°. On recrystallization from methanol the melting point became 106–109°; a mixture with authentic methyl β-D-ribopyranoside tribenzoate melted at 107–109°.

**Reaction of Tribenzoyl-α-D-ribopyranosyl Chloride (III) with Methanol in the Absence of an Acid Acceptor.**—Tribenzoyl-α-D-ribopyranosyl chloride (10 mg.) was treated with 4 ml. of absolute methanol, heated at 55° for 6 hours and then left at room temperature for 8 days. The reaction mixture, concentrated to a sirup and dissolved in 0.2 ml. of methanol, gave 7.7 mg. of crystalline material melting at 104–108°. Recrystallization from 1:1 ether–pentane afforded 4.1 mg. (47%) of product melting at 108–110° either alone or in admixture with authentic methyl β-D-ribopyranoside tribenzoate.

Tribenzoyl-α-D-ribopyranosyl chloride (46.6 mg.) was dissolved in 100 ml. of 1:9 dioxane–methanol and the rotation of the resulting solution at 20° examined polarimetrically in a 4-dm. tube, the following data (and first order reaction constants calculated therefrom) being obtained:

| Time, min. | Obsd. rotation, αD (4 dm., circular degrees) | k, min., decimal logs |
|---|---|---|
| 0 | +0.11° (extrapolated) | ...... |
| 10 | +0.11 | ...... |
| 1,410 | +0.07 | 0.000059 |
| 5,700 | −0.02 | .000063 |
| 12,000 | −0.08 | .000063 |
| 27,600 | −0.12 | ...... |
| 29,000 | −0.12 | ...... |

The final observed rotation corresponds to a specific rotation of −65° on the assumption that the halide was completely converted to methyl pentoside tribenzoate. The specific rotation of methyl β-D-ribopyranoside tribenzoate in 1:9 dioxane–methanol is −65.2°.

**Reaction of Tribenzoyl-β-D-ribopyranosyl Chloride (I) with Methanol (a) in the Absence of an Acid Acceptor.**—A solution of 0.29 g. of tribenzoyl-β-D-ribopyranosyl chloride in 3 ml. of absolute chloroform was diluted with 25 ml. of absolute methanol. After 5 days at +5°, the solution was concentrated *in vacuo* to a volume of 3 ml. The product (0.10 g., 35%) melted at 105–107°; after recrystallization from methanol the melting point was 106–108°, undepressed on admixture with authentic methyl β-D-ribopyranoside tribenzoate.

A solution of pure tribenzoyl-β-D-ribopyranosyl chloride (0.1001 g.) in 1:9 dioxane–methanol (25.0 ml. total volume) was examined polarimetrically at 20° in a 1.5-dm. tube. The data obtained, together with the first order constants calculated therefrom, are

| Time, min. | Obsd. rotation, αD (1.5 dm., circular degrees) | k, min., decimal logs |
|---|---|---|
| 0 | −0.88 (extrapd.) | .... |
| 2.7 | −0.80 | 0.024 |
| 49 | −0.56 | .0069 |
| 100 | −0.47 | .0052 |
| 164 | −0.40 | .0045 |
| 215 | −0.35 | .0046 |
| 338 | −0.30 | .0052 |
| 1260 | −0.29 | .... |
| 5760 | −0.29 | .... |

The constant value attained corresponds to a specific rotation of −49° if it be assumed that the halide was wholly converted to methyl pentoside tribenzoate.

(b) **In the Presence of Silver Carbonate.**—To a solution of 1.11 g. of tribenzoyl-β-D-ribopyranosyl chloride in 2.5 ml. of absolute chloroform was added 1.1 g. of silver carbonate and then 15 ml. of absolute methanol. After shaking for 3 hours at room temperature the mixture was filtered through carbon and the filtrate concentrated to a sirup. A portion of this sirup (0.2165 g.), dissolved in a mixture of 20 ml. of absolute chloroform and 60 ml. of absolute methanol, was examined polarimetrically in a 4-dm. tube. The initial angular rotation observed (+0.38°) changed rapidly upon the addition of 0.75 ml. of 0.639 *N* anhydrous methanolic hydrogen chloride, the following rotations being observed: +0.07° (37 sec.), −0.46° (3.5 min.), −0.58° (5 min.), −0.63° (40 min.), −0.56° (3.5 hr.), −0.53° (6.5 hr.) and −0.53° (6 days). The final observed rotation corresponds to a specific rotation of −49°.

**β-D-Ribopyranose Tetrabenzoate from Tribenzoyl-β-D-ribopyranosyl Bromide (II).**—Under rigorously anhydrous conditions 1.0 g. of tribenzoyl-β-D-ribopyranosyl bromide dissolved in 25 ml. of benzene (dried over sodium) was shaken with dry silver benzoate for 1 hour. After filtering through carbon the solution was concentrated *in vacuo* and the residual sirup dissolved in a mixture of 5 ml. of ether and 5 ml. of pentane. There was thus obtained 0.99 g. (92%) of crystalline material as dense rosettes of prismatic needles rotating in chloroform −100° and melting at 129–131°; an undepressed mixed melting point with authentic β-D-ribopyranose tetrabenzoate confirmed its identity.

**2,3,4-Tribenzoyl-D-ribose.**—The preparation of crude, amorphous 2,3,4-tribenzoyl-D-ribose, having a rotation of −27.9° in chloroform, through the reaction of tribenzoyl-β-D-ribopyranosyl bromide with moist acetone in the presence of silver carbonate has been reported in a previous paper.[3] In the course of the present research the amorphous tribenzoate was found to crystallize readily from a mixture of ether and pentane to give a 55% yield of crude, crystalline 2,3,4-tribenzoyl-D-ribose melting at 132–133°. Two recrystallizations from ether–pentane gave clusters of needles melting at 133–134° and rotating in chloroform −42° (*c*, 0.77).

*Anal.* Calcd. for $C_{26}H_{22}O_8$: C, 67.52; H, 4.80. Found: C, 67.38; H, 4.91.

BETHESDA, MARYLAND

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