The product was converted to methyl 4,6-propylidene-α-D-glucoside as follows: 1.2 g. was boiled for 30 minutes with 100 ml. of ether containing a few drops of bromine. The excess bromine was destroyed by adding 5% sodium thiosulfate solution. The mixture was then made alkaline with 5% sodium bicarbonate solution and the ether removed with a stream of air. The aqueous mixture was filtered from 0.3 g. of the starting compound and the filtrate concentrated to dryness *in vacuo*. Extraction of the gummy residue with carbon tetrachloride yielded 0.8 g. of sirup which partly crystallized on standing. The mixture was dissolved in hot benzene, treated with decolorizing carbon and filtered. Addition of petroleum ether to the filtrate gave white needles (0.5 g.) which were recrystallized from petroleum ether–benzene (5:1) to yield methyl 4,6-propylidene-α-D-glucoside; m.p. 101.5–103°, not depressed by admixture with an authentic sample.

The oxido compound was also prepared from methyl 4,6-propylidene-α-D-glucoside (4.8 g.) by reaction with propionaldehyde (35 g.) and 4 drops of concentrated sulfuric acid at room temperature. After ten minutes the mixture was extracted with benzene, the benzene layer washed with sodium bicarbonate solution and water and dried over calcium chloride. Concentration of the benzene solution gave 3.2 g. of a white gummy solid, which after two recrystallizations from ethanol melted 141.5–142°; unchanged by mixing with the oxido compound.

Methyl 4,6-Propylidene-α-D-glucoside.—The combined filtrate and washings left after separation of the oxido compound obtained from methyl α-D-glucoside and propionaldehyde was neutralized with sodium bicarbonate and concentrated to dryness *in vacuo*. The residue was taken up in benzene, filtered, concentrated to dryness and triturated with ether. The insoluble crystals (5.5 g., 23%) were recrystallized from benzene–ether and from benzene–petroleum ether to yield microscopic white needles, m.p. 102–103.5°; $[\alpha]^{25}\mathrm{D}$ +122.1° (*c*, 1.83; chloroform).

Anal. Calcd. for $C_{10}H_{18}O_6$: C, 51.3; H, 7.7; OCH_3, 13.3. Found: C, 51.5; H, 7.8; OCH_3, 13.2.

Methyl 4,6-Benzylidene-2,3-dimethyl-α-D-glucoside from Methyl 4,6-Propylidene-α-D-glucoside.—Methyl 4,6-propylidene-α-D-glucoside (2.4 g.) was dissolved in 8 ml. of methanol, 16 ml. of methyl iodide added and the solution refluxed for 8 hours. During this period 14 g. of silver oxide was added in 3 portions.

The mixture was filtered and washed with hot methanol. Concentration *in vacuo* to dryness gave a sirup (2.7 g.), to which was added 16 ml. of redistilled benzaldehyde and 2.5 g. of pulverized anhydrous zinc chloride. The mixture was shaken for 48 hours. The solution obtained was then treated with 20% sodium bisulfite solution until the benzaldehyde had dissolved. Three 100-ml. portions of ether were used for extraction. The combined ether extract was washed with sodium bisulfite solution, dilute sodium hydroxide solution and water and dried over calcium chloride. Concentration *in vacuo* at 80–90° and 2 mm. left 2.4 g. of sirup, which crystallized on standing. The product was recrystallized twice from petroleum ether to give white needles; m.p. 121–122°, not depressed by admixture with an authentic sample of methyl 4,6-benzylidene-2,3-dimethyl-α-D-glucoside (m.p. 122–123°, prepared by Evans'[14] method); $[\alpha]^{25}\mathrm{D}$ +96.9° (*c*, 1.51; chloroform). Appel[3] gives m.p. 120–121° and $[\alpha]^{25}\mathrm{D}$ +96.2°, in chloroform.

Anal. Calcd. for $C_{16}H_{22}O_6$: C, 61.9; H, 7.1. Found: C, 62.0; H, 7.1.

Monostearylidene-D-sorbitol.—A mixture of 3.7 g. (0.02 mole) of D-sorbitol, 5.4 g. (0.02 mole) of stearaldehyde (m.p. 68–69°) and 0.1 g. of sulfosalicylic acid dihydrate was refluxed for 20 hours in 125 ml. of dioxane. All but a trace of the solid dissolved. Dioxane was removed *in vacuo* and the waxy residue was extracted with warm (35°) benzene to remove unreacted stearaldehyde. The residue was washed with water and filtered from 2.8 g. (32%) of an amorphous solid. Reprecipitation from ethanol and from ethanol–dioxane (4:1) gave a white, amorphous solid, melting at 133–137° to a clear gel which became liquid at 145°; $[\alpha]^{25}\mathrm{D}$ −8.7° (*c*, 2.36; pyridine).

Anal. Calcd. for $C_{24}H_{48}O_6$: C, 66.6; H, 11.2. Found: C, 66.4; H, 10.6.

Acknowledgment.—The authors are indebted to C. H. Van Etten of the Analytical and Physical Chemical Division of this Laboratory for the microanalyses reported in this paper.

Summary

Diethylidene-, dipropylidene-, dibutylidene- and diisobutylideneacetals of D-glucose have been prepared as sirupy compounds. Some of their physical properties have been determined. Monostearylidene-D-sorbitol has been obtained as an amorphous product.

The following crystalline cyclic acetals have been synthesized and their structures determined: 4,6-butylidene-α-D-glucose, methyl 4,6-butylidene-2,3-dimethyl-β-D-glucoside, methyl 4,6-propylidene-α-D-glucoside and methyl 2,3-oxidodipropylidene-4,6-propylidene-α-D-glucoside.

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The Reaction of Tribenzoyl-α-L-rhamnopyranosyl Bromide with Methanol. Various Benzoylated Derivatives of L-Rhamnose

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

In a recent publication[2] it was shown that tetrabenzoyl-α-D-mannopyranosyl bromide reacts directly with anhydrous methanol in the absence of an acid acceptor to form methyl α-D-mannopyranoside tetrabenzoate in a 69% yield. This earlier work was carried out with amorphous tribenzoyl-α-D-mannopyranosyl bromide and since extensive attempts to crystallize this halide as well as the corresponding chloride and iodide were without success, it was deemed desirable to extend the study to the closely related L-rhamnose (6-desoxy-L-mannose) series in the hope that crystalline benzoylated halides might then be obtained and allow a confirmation of the results obtained in the D-mannose series. This hope has now been realized.

The complete benzoylation of α-L-rhamnose hydrate led only to an amorphous product showing $[\alpha]^{20}\mathrm{D}$ +68° to +78° in chloroform. Similarly the complete benzoylation of β-L-rhamnose gave a sirupy tetrabenzoate of $[\alpha]^{20}\mathrm{D}$ +138° in chloroform; doubtless these two products represent crude α- and β-L-rhamnopyranose tetrabenzoates, respectively. On treatment with hydrogen bro-

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

[2] R. K. Ness, H. G. Fletcher, Jr., and C. S. Hudson, THIS JOURNAL, **72**, 2200 (1950).

mide in glacial acetic acid the first mixture readily gave in 88% yield the desired crystalline tribenzoyl-α-L-rhamnopyranosyl bromide (I). Like its amorphous analog of the D-mannose series tribenzoyl-α-L-rhamnopyranosyl bromide reacts rapidly with anhydrous methanol, the crystalline product formed being isolated in 84% yield and identified through comparison with authentic material as methyl α-L-rhamnopyranoside tribenzoate (II). The rate of the reaction was studied by dissolving a weighed quantity of the bromide in dioxane, diluting with methanol and observing the changing rotation polarimetrically. The data thus obtained are shown in Table I; from the first order reaction constants the approximately pseudo-unimolecular nature of the reaction is evident. The final rotational value corresponds to a specific rotation of +165° for methyl α-L-rhamnopyranoside tribenzoate, while a pure sample of this compound was found to show a specific rotation of +169° in the same solvent mixture.

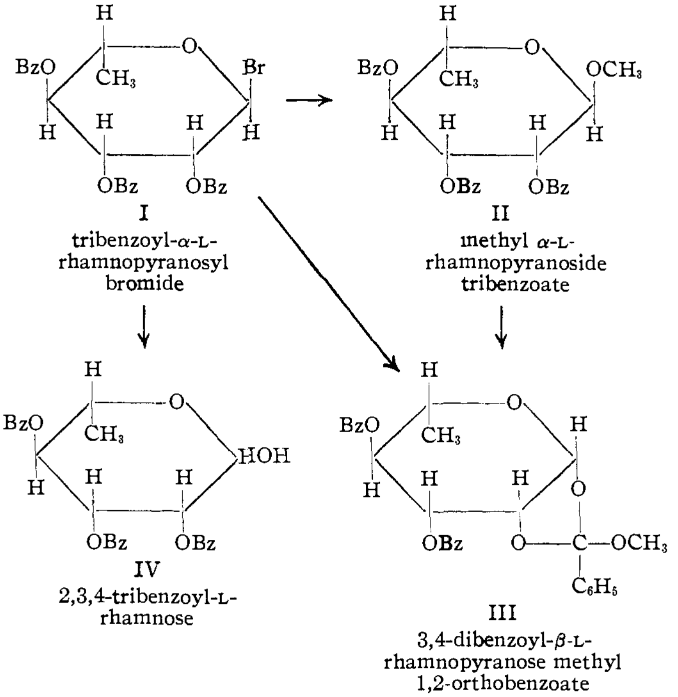
It is thus apparent that the behavior of crystalline tribenzoyl-α-L-rhamnopyranosyl bromide (I) with methanol in the absence of an acid acceptor is completely analogous to that of its amorphous analog of the D-mannose series previously studied. The α-L-halide is converted to a methyl α-L-glycoside tribenzoate; as discussed in a previous paper,[3] retention of configuration at carbon atom one is to be expected on the basis of the neighboring group theory when the halogen of a halide having a *trans* arrangement on carbon atoms 1 and 2 is replaced by methoxyl.

TABLE I

REACTION OF TRIBENZOYL-α-L-RHAMNOPYRANOSYL BROMIDE WITH 1:9 DIOXANE–METHANOL

0.2100 g. of substance in 50 ml. of solution at 20°

Time, min.	Observed rotation, αD, 2.5 dm., circular degrees	*k*, min., decimal logs
0	+0.60 extrap.	...
2.3	+0.66	0.023
7.5	+0.81	.018
16	+0.99	.016
26	+1.15	.015
40	+1.29	.014
59	+1.42	.014
90	+1.51	.014
203	+1.57	...
1380	+1.57	...



The reaction of benzoylated glycopyranosyl bromides with methanol in the absence of an acid acceptor has been reported for a number of different sugar series[2,3,4]; in each case studied, the yield of completely benzoylated methyl glycopyranoside was found to be high and no partially debenzoylated products were isolated. While Koenigs and Knorr[5] found that tetraacetyl-α-D-glucopyranosyl bromide reacted with methanol to give methyl β-D-glucopyranoside (cleavage of the acetyl groups having taken place in the acid medium) it was of interest to make a comparison of an acetohalogeno sugar with the corresponding benzohalogeno sugar in respect to reaction with methanol. The long-known, crystalline triacetyl-α-L-rhamnopyranosyl bromide was therefore allowed to react with methanol and there was isolated from the reaction mixture only a small quantity of methyl β-L-rhamnopyranoside triacetate. However, when the whole reaction product was reacetylated there was obtained in addition a much larger quantity of methyl α-L-rhamnopyranoside triacetate. These findings appear to demonstrate the superiority of the benzoylated over the acetylated glycopyranosyl halides for this type of glycoside synthesis.[6]

Like tribenzoyl-α-L-rhamnopyranosyl bromide, the corresponding chloride and iodide proved to be readily crystallizable substances. The rotations and melting points of these compounds are listed in Table II. It is to be noted that the molecular

TABLE II

ACETYLATED AND BENZOYLATED α-L-RHAMNOPYRANOSYL HALIDES

	Chloride	Bromide	Iodide
M. p. tribenzoate, °C.	165–166	162–163	143–144
$[\alpha]^{20}D$ tribenzoate, (dry $CHCl_3$)	+135.9	+64.8	−27.2
$[M]^{20}D$ tribenzoate, (dry $CHCl_3$)	+ 67,260	+34,950	−15,950
$[M]^{20}D$ triacetate	− 39,210 ($CHCl_3$)	−59,690 ($C_2H_2Cl_4$)	....

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(3) H. G. Fletcher, Jr., and C. S. Hudson, THIS JOURNAL, **72**, 4173 (1950).

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

(5) W. Koenigs and E. Knorr, *Ber.*, **34**, 957 (1901).

(6) That the reaction of acetylated glycopyranosyl halides with methanol is, save for deacetylation, essentially identical with the reaction of their benzoyl analogs is highly probable. However, while both of the possible anomeric methyl L-rhamnosides were obtained from the reaction of triacetyl-α-L-rhamnopyranosyl bromide with methanol, no benzoylated glycopyranosyl bromide has as yet been found to yield more than one methyl glycopyranoside benzoate, although, since the yields are not quantitative, it is not excluded that other isomers are formed. See R. K. Ness, H. G. Fletcher, Jr., and C. S. Hudson, THIS JOURNAL, **72**, 2200 (1950).

rotations of these halides stand in the order of levo-progression chloride > bromide > iodide, as is to be expected of such a group of halides of the α-L-series.[7]

With the crystalline tribenzoyl-α-L-rhamnopyranosyl bromide (II) in hand it was of interest to ascertain whether, in the presence of an acid acceptor, it might not be convertible into a methyl 1,2-orthobenzoate, since Fischer, Bergmann and Rabe[8] had found that triacetyl-α-L-rhamnopyranosyl bromide gave 3,4-diacetyl-β-L-rhamnopyranose methyl 1,2-orthoacetate. With a mixture of quinoline and methanol, tribenzoyl-α-L-rhamnopyranosyl bromide (I) was found to give a product which crystallized readily; that this was indeed the expected 3,4-dibenzoyl-β-L-rhamnopyranose methyl 1,2-orthobenzoate (III) was made highly probable through its analysis, the fact that only two of its benzoyl groups were labile to alkali and, finally, that on treatment with acidic methanol it gave methyl α-L-rhamnopyranoside tribenzoate (II) in 84% yield. As far as we are aware this compound constitutes the first methyl orthobenzoate reported in the sugar series. A representative of a closely related type of compound, D-talose 1,2-orthobenzoic acid, has been reported by Pigman and Isbell.[9]

While the complete benzoylation of L-rhamnose has as yet given only amorphous products, the benzoylation of α-L-rhamnose hydrate with a limited quantity of benzoyl chloride at a low temperature has been found to afford a crystalline L-rhamnose tribenzoate in substantial yield and an L-rhamnose dibenzoate in very small yield. The complete structure of neither of these L-rhamnose benzoates is known. That the tribenzoate retains the pyranose ring was demonstrated by the complete benzoylation of a sample to give a sirup which, in turn, readily gave crystalline tribenzoyl-α-L-rhamnopyranosyl bromide (I). Of the remaining four structures possible for this tribenzoate, only one has been eliminated from consideration: reaction of tribenzoyl-α-L-rhamnopyranosyl bromide (I) with moist acetone in the presence of silver carbonate gave 2,3,4-tribenzoyl-L-rhamnose (IV), a crystalline substance evidently not identical with the L-rhamnose tribenzoate.

Acknowledgment.—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[10]

Amorphous L-Rhamnopyranose Tetrabenzoates. (a) Low-Temperature Benzoylation of α-L-Rhamnopyranose Monohydrate.—To a mixture of 240 ml. of anhydrous pyridine and 90 ml. (0.776 mole, 6.4 molar equivalents) of benzoyl chloride, maintained at a temperature of −7 to −3°, was added with constant stirring and over a period of three hours 20 g. of α-L-rhamnose hydrate (0.122 mole). After the addition was complete the reaction mixture was heated at 60° for two hours. Cooled again to room temperature, the mixture was treated with 15 ml. of water and, after fifteen minutes, diluted with ethylene dichloride. After successive washings with cold water, cold 3 N H_2SO_4, aqueous sodium bicarbonate and water, the solution was dried with sodium sulfate, filtered through decolorizing carbon and concentrated *in vacuo* (45° bath). The amorphous residue, which could not be induced to crystallize, showed a rotation in chloroform of +68 to +78° (c, 0.9) in several preparations. A small fraction (0.1 g.) of the L-rhamnopyranose tribenzoate of m.p. 199–200°, the preparation of which is described below, was isolated after the amorphous tetrabenzoate had stood for a prolonged period in methanol solution.

(b) Low-Temperature Benzoylation of β-L-Rhamnopyranose.—β-L-Rhamnopyranose (m.p. 120–123°), prepared by the method of Jackson and Hudson,[11] and benzoylated as described above gave a solvent-free, sirupy product which showed in chloroform a rotation of +138° (c, 0.67).

L-Rhamnopyranose Tribenzoate.—To a well-stirred mixture of 6.4 ml. of benzoyl chloride and 80 ml. of dry pyridine, held at a temperature of −5 to +5°, was added 2.0 g. of α-L-rhamnose hydrate. During the succeeding ninety minutes, nine more simultaneous additions of 2.0 g. of α-L-rhamnose hydrate and 6.4 ml. of benzoyl chloride in 18.6 ml. of dry pyridine were made.[12] The reaction mixture was heated at 60° for one hour, cooled to room temperature and treated with 40 ml. of water. After four hours, ethylene dichloride was added and the solution washed successively with cold water, dilute sulfuric acid and sodium bicarbonate solution. Water was removed with sodium sulfate and the solution filtered through decolorizing carbon; concentration *in vacuo* (55° bath) gave a sirup which was diluted with 50 ml. of absolute ethanol and reconcentrated *in vacuo*. Solution of the residue in 80 ml. of methanol led to the formation of 14.0 g. (27%) of prismatic crystals melting at 198–200° and showing in chloroform a rotation of −26°. A second crop, 1.9 g., m.p. 197–199°, raised the total yield to 30%. Recrystallized successively from 20 parts of methanol and from 12 parts of 1:1 ethyl acetate–pentane, the substance melted without decomposition at 200–201° and showed in chloroform a rotation of −27.8° (c, 0.95). In dry pyridine (c, 0.42) a rotation of +19° was found, no mutarotation being detectable from three minutes to forty-five days. The substance is moderately soluble in acetone, ethyl acetate, chloroform and ether; slightly soluble in benzene, methanol and carbon tetrachloride and practically insoluble in pentane and water.

Anal. Calcd. for $C_{27}H_{24}O_8$: C, 68.06; H, 5.08. Found: C, 68.31; H, 5.18.

Further benzoylation of this L-rhamnose tribenzoate gave a sirup rotating in chloroform +70°. Treatment of this sirup with hydrogen bromide in glacial acetic acid solution as described below for the sirup obtained through the low-temperature benzoylation of α-L-rhamnose gave, in 79% yield crystalline tribenzoyl-α-L-rhamnopyranosyl bromide, identified by its melting point (162–164°) and through conversion by methanol into methyl α-L-rhamnopyranoside tribenzoate, m.p. 132–133°.

L-Rhamnose Dibenzoate.—To a cold mixture of 19.0 ml. of benzoyl chloride (6.0 molar equivalents) and 60 ml. of dry pyridine was added 5.0 g. of α-L-rhamnose hydrate. Ten minutes later the reaction mixture was heated at 60° for twenty minutes and then poured into ice-water; the amorphous precipitate was freed of water, dissolved in a mixture of 90 ml. of ether and 90 ml. of pentane. After about seventeen hours there was obtained 3.32 g. of crystalline material melting at 180–190°. From a solution in 50 ml. of methanol this deposited 2.40 g. of the tribenzoate described above; from the mother liquor there was subsequently isolated 0.41 g. of product melting at 179–181°. Recrystallization of this latter from methanol and from

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

(8) E. Fischer, M. Bergmann and A. Rabe, *Ber.*, **53**, 2362 (1920); W. N. Haworth, E. L. Hirst and H. Samuels, *J. Chem. Soc.*, 2861 (1931).

(9) W. W. Pigman and H. S. Isbell, *J. Research Natl. Bur. Standards*, **19**, 189 (1937).

(10) Melting points were measured with a calibrated Anschütz-type thermometer completely immersed in the bath liquid. Rotations are specific rotations (unless otherwise specified) for the D line of sodium at 20°; concentration is expressed in g. of substance per 100 ml. of solution.

(11) E. L. Jackson and C. S. Hudson, This Journal, **59**, 1076 (1937).

(12) The quantity of benzoyl chloride employed (5 molar equivalents) was chosen on the assumption that the water of hydration accompanying the sugar destroyed 2 moles of the acid halide, one mole of benzoic anhydride being formed. See C. F. H. Allen, C. J. Kibler, D. M. McLachlin and C. V. Wilson, *Org. Syntheses*, **26**, 1 (1946).

chloroform afforded 50 mg. (0.5%) of a pure L-rhamnose dibenzoate melting at 175–176° and rotating in pyridine +87° (*c*, 1.25) (no mutarotation in 50 minutes). The compound is soluble in pyridine, sparingly soluble in ethyl acetate, acetone and chloroform and practically insoluble in water and pentane.

Anal. Calcd. for $C_{20}H_{20}O_7$: C, 64.51; H, 5.41. Found: C, 64.54; H, 5.52.

Tribenzoyl-α-L-rhamnopyranosyl Bromide (I).—To a solution of 29.06 g. of amorphous L-rhamnose tetrabenzoate ($[\alpha]^{20}D$ +78° in chloroform; obtained through the benzoylation of α-L-rhamnose monohydrate as described above) in 29 ml. of glacial acetic acid was added 92 ml. of a solution of hydrogen bromide in glacial acetic acid (*ca.* 32% HBr). Crystallization of the product began within twenty minutes; after twenty hours at room temperature, ethylene dichloride was added and the resulting solution washed successively with ice water, saturated aqueous sodium bicarbonate and ice-water. The solution was then freed of water with sodium sulfate and concentrated *in vacuo* at 45°. The residue, which crystallized spontaneously, was recrystallized from 315 ml. of 1:2 benzene–pentane to give 22.4 g. (83%) of tribenzoyl-α-L-rhamnopyranosyl bromide melting at 161–163° and rotating in absolute chloroform +64.1°. An additional 1.4 g. (5.2%) of material melting at 162–164° was obtained from the mother liquor. After two recrystallizations from a mixture of benzene and pentane, the pure compound was obtained as clusters of clear, thin, elongated plates melting at 163–164° and rotating in absolute chloroform +64.8° (*c*, 1.44). Tribenzoyl-α-L-rhamnopyranosyl bromide is soluble in ethyl acetate, chloroform, benzene, acetone and carbon tetrachloride, slightly soluble in ether and methanol and practically insoluble in pentane and water.

Anal. Calcd. for $C_{27}H_{23}O_7Br$: C, 60.12; H, 4.30; Br, 14.82. Found: C, 60.27; H, 4.31; Br, 14.49.

Methyl α-L-Rhamnopyranoside Tribenzoate (II) from Tribenzoyl-α-L-rhamnopyranosyl Bromide (I).—Three grams of tribenzoyl-α-L-rhamnopyranosyl bromide was dissolved in 90 ml. of absolute methanol and the solution left at +5° for two days. Large, clear prisms (1.65 g.), m.p. 132–133°, $[\alpha]^{20}D$ +178° (chloroform, *c*, 0.89), were deposited; concentration of the mother liquor gave 0.65 g. of equally pure material, raising the total yield to 84%. Recrystallization from 9 parts of methanol failed to change the above-quoted physical constants significantly; a mixed melting point with an authentic sample of methyl α-L-rhamnopyranoside tribenzoate[13] was undepressed.

The Rate of Reaction of Tribenzoyl-α-L-rhamnopyranosyl Bromide (I) with 1:9 Dioxane–Methanol at 20°.—The pure bromide (0.2100 g.) was dissolved in 5 ml. of dioxane, the resulting solution diluted to 50 ml. with anhydrous methanol and the rotation followed polarimetrically in a 2.5 dm. tube at 20°; the observed rotations and first order rate constants calculated therefrom are listed in Table I.

2,3,4-Tribenzoyl-L-rhamnopyranose (IV).—Tribenzoyl-α-L-rhamnopyranosyl bromide (3.0 g.) was allowed to react with moist acetone and silver carbonate as described for the preparation of 2,3,4,6-tetrabenzoyl-D-mannose.[2] Seed crystals of the product were obtained by rubbing a small portion of the sirupy material with warm "Skellysolve E" (b.p. 100–140°). There was thus obtained from 15 ml. of methanol 2.31 g. (87%) of clear plates melting at 202–205° and rotating in chloroform +233°. After one recrystallization from 20 ml. of methanol and another from 30 ml. of 1:1 ethyl acetate–pentane, the product melted at 203–205° with decomposition and showed in U.S.P. chloroform a rotation of +231 (*c*, 1.0) (no mutarotation in three hours). In dry pyridine (*c*, 0.42) the compound mutarotated as follows: +158° (5 minutes), +133° (44 hours), +130° (138 hours).

2,3,4-Tribenzoyl-L-rhamnopyranose is readily soluble in ethyl acetate and acetone, moderately soluble in benzene and ether, difficultly soluble in methanol and practically insoluble in pentane and water.

Anal. Calcd. for $C_{27}H_{24}O_8$: C, 68.06; H, 5.08. Found: C, 67.95; H, 4.95.

3,4-Dibenzoyl-β-L-rhamnopyranose Methyl 1,2-Orthobenzoate (III).—The orthobenzoate was prepared in a manner similar to that reported for the preparation of the corresponding orthoacetate.[8] A solution of 5.0 g. of the bromide in 25 ml. of dry benzene and 3 ml. of dry synthetic quinoline was left at room temperature for one hour, diluted with 25 ml. of absolute methanol and then left for two days. After dilution with ether the solution was washed twice with cold water, dried with sodium sulfate, filtered through decolorizing carbon and then concentrated *in vacuo* (60° bath) to a thin sirup. Solution of this residue in 30 ml. of ether and 35 ml. of pentane gave 0.91 g. (20%) of clusters of heavy needles melting at 171–173°. The pure substance, obtained after two recrystallizations from 24 parts of a 1:3:4 ethyl acetate–ether–pentane mixture, melted at 174–175° and showed in chloroform a rotation of +37.5° (*c*, 0.98). The orthoester is soluble in ethyl acetate, acetone and benzene, slightly soluble in ether and difficultly soluble in methanol.

Anal. Calcd. for $C_{28}H_{26}O_8$: C, 68.56; H, 5.34; benzoyl hydrolyzed by alkali, 42.9. Found: C, 68.38; H, 5.56; benzoyl, 42.4.[14]

A solution of 0.1681 g. of the crystalline orthobenzoate in 20.00 ml. of absolute chloroform and 60.55 ml. of absolute methanol showed a specific rotation of +39.9°. Upon the addition of 0.55 ml. of 0.639 *N* hydrogen chloride in absolute methanol, the specific rotation changed rapidly: +144° (2 minutes), +159° (18 minutes) and +163° (20 hours). After concentration of the solution and dissolution of the residue in 1.5 ml. of methanol, 0.1286 g. (84%) of methyl α-L-rhamnopyranoside tribenzoate, melting at 132–133° either alone or in admixture with authentic material, was obtained.

Tribenzoyl-α-L-rhamnopyranosyl Chloride.—The procedure used was similar to that reported previously for the preparation of the analogous halide of the D-glucose series.[2] Four grams of amorphous L-rhamnose tetrabenzoate dissolved in a mixture of 25 ml. of absolute chloroform and 0.76 ml. of titanium tetrachloride was heated at 60° for five and one-half hours. Worked up as described in the earlier publication[2] the reaction mixture gave a crystalline residue. Recrystallized from 80 ml. of 1:3 benzene–pentane, the product (2.67 g., 79%) melted at 161–164°. Two further recrystallizations from four parts of ethyl acetate and from eight parts of 1:1 acetone–pentane afforded clear, elongated plates melting at 165–166° and rotating in chloroform +136° (*c*, 1.05). The compound is soluble in chloroform and moderately soluble in acetone and ethyl acetate.

Anal. Calcd. for $C_{27}H_{23}O_7Cl$: C, 65.52; H, 4.68; Cl, 7.16. Found: C, 65.43; H, 4.76; Cl, 7.31.

Tribenzoyl-α-L-rhamnopyranosyl Iodide.—Four grams of amorphous L-rhamnose tetrabenzoate, dissolved in 3 ml. of ethylene dichloride, was treated with 10 ml. of a solution of hydrogen iodide in glacial acetic acid[15] and left at room temperature for three hours. The crystalline material was removed by filtration, washed with 2 ml. of glacial acetic acid, 20 ml. of pentane and dried *in vacuo* over sodium hydroxide. The 3.16 g. (78%) of product thus obtained melted with decomposition at 137–140° and rotated in absolute chloroform −26.3°. Concentration of the mother liquor *in vacuo* gave a second crop of 0.34 g. (8.4%) of equally pure material. After successive crystallizations from three parts of ethyl acetate, four parts of 1:3 absolute chloroform–ether and from eight parts of 1:1 benzene–pentane, the pure compound was obtained, melting at 143–144° (dec.)[16] and showing in absolute chloroform a rotation of −27.1° (*c*, 1.42). The substance is readily soluble in chloroform, benzene, ethyl acetate and acetone; slightly soluble in ether and insoluble in pentane.

Anal. Calcd. for $C_{27}H_{23}O_7I$: C, 55.30; H, 3.95; I, 21.65. Found: C, 55.70; H, 4.20; I, 21.51.

Methyl α-L-Rhamnopyranoside Triacetate and Methyl β-L-Rhamnopyranoside Triacetate from Triacetyl-α-L-rhamnopyranosyl Bromide.—A solution of 4.953 g. of triacetyl-α-L-rhamnopyranosyl bromide[8] (m.p. 64–67°, $[\alpha]^{20}D$

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[13] W. T. Haskins, R. M. Hann and C. S. Hudson, This Journal, **68**, 628 (1946).

[14] The Kunz method for the determination of acetyl groups [A. Kunz and C. S. Hudson, *ibid.*, **48**, 1978 (1926)] was adapted to the semi-micro determination of the benzoyl group for this analysis.

[15] This solution was prepared by the cautious addition of 26.4 ml. of hydriodic acid (55–58%, sp. gr. 1.7) to 100 ml. of cold acetic anhydride.

[16] The melting point was determined by placing the sample in the bath at 138° while heating at 2° per minute.

−172° in absolute chloroform) in 5 ml. of benzene was diluted to 50.0 ml. with absolute methanol. The mutarotation of the resulting solution in circular degrees, observed polarimetrically in a 1-dm. tube at 20°, was as follows: (αD), −13.85° (2.16 minutes), −4.01° (26.5 minutes), −2.19° (40.5 minutes), −1.49° (49.5 minutes), −0.94° (69 minutes), −0.47° (3 hours), −1.21° (20.8 hours) and −1.56° (45 hours). The reaction mixture was concentrated *in vacuo* (25°) to a sirup which was diluted with 25 ml. of benzene and then reconcentrated. As a parallel experiment had shown that partial deacetylation had taken place, the residue was reacetylated with pyridine and acetic anhydride. The resulting product, from its solution in a mixture of 5 ml. of ether and 10 ml. of pentane, deposited 95 mg. (2.2%) of prismatic needles melting at 148–151°. After recrystallization from ether–pentane and from methanol this substance melted at 151–152° and rotated +44° in chloroform (*c*, 0.55). Fischer, Bergmann and Rabe[8] reported a melting point of 151–152° and a rotation in acetylene tetrachloride of +45.7° for methyl β-L-rhamnopyranoside triacetate. On concentration and seeding, the original mother liquor yielded 1.80 g. (41.6%) of crude methyl α-L-rhamnopyranoside triacetate melting at 81–87°. After purification, pure methyl α-L-rhamnopyranoside triacetate, melting at 88–89° either alone or in admixture with authentic material, was obtained. Fischer, Bergmann and Rabe[8] reported a melting point of 86–87° for this substance.

Summary

Tribenzoyl-α-L-rhamnopyranosyl bromide has been obtained in crystalline form and found to react with methanol in the absence of an acid acceptor to give methyl α-L-rhamnopyranoside tribenzoate in high yield.

The reaction of triacetyl-α-L-rhamnopyranosyl bromide with methanol in the absence of an acid acceptor leads to partial deacetylation; reacetylation of the product gave a relatively large yield of methyl α-L-rhamnopyranoside triacetate and a small yield of its anomer.

Tribenzoyl-α-L-rhamnopyranosyl chloride and the corresponding iodide have been obtained in crystalline form.

Partial benzoylation of α-L-rhamnose hydrate has given a small quantity of a crystalline L-rhamnose dibenzoate and substantial yields of a crystalline L-rhamnose tribenzoate. This latter compound appears to be different from the crystalline 2,3,4-tribenzoyl-L-rhamnose prepared by the partial hydrolysis of tribenzoyl-α-L-rhamnopyranosyl bromide.

The reaction of tribenzoyl-α-L-rhamnopyranosyl bromide with methanol in the presence of quinoline has given 3,4-dibenzoyl-β-L-rhamnopyranose methyl 1,2-orthobenzoate in crystalline form.

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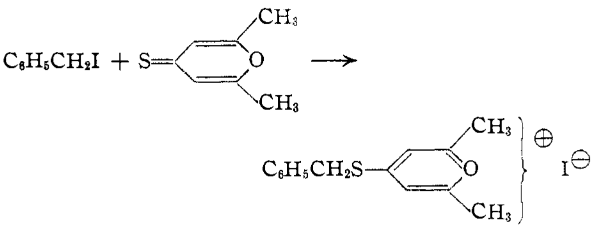
[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF NORTHWESTERN UNIVERSITY]

Preparation of Substituted Mercaptopyrylium Salts[1]

BY L. CARROLL KING, FRANCIS J. OZOG AND JAMES MOFFAT

Hantzsch[2] reported that 2,6-dimethyl-4-thiopyrone could be alkylated with methyl sulfate. This type of reaction has been examined in some detail, and it has been demonstrated that a variety of reactive alkylating agents on treatment with 2,6-dimethyl-4-thiopyrone give the corresponding mercaptopyrylium salt. Using benzyl iodide as an example, the reaction can be formulated as



The reaction gave crystalline products with a number of alkyl iodides, with phenacyl type bromides, and with benzyl *p*-bromobenzenesulfonate. The data for crystalline reaction products obtained in this study are listed in Table I. With alkyl chlorides or bromides the reaction was very slow, or the products were oils. Chloroacetone and chloromethyl ether reacted with 2,6-dimethyl-4-thiopyrone to give oily products. These were not further characterized. *p*-Nitrobenzyl chloride gave only 15% of salt after reacting for one month in benzene solution. The product obtained when 2,6-dimethyl-4-thiopyrone reacted with 2,4,6-trimethylphenacyl bromide was a black powder unstable at room temperature. The following compounds did not react with 2,6-dimethyl-4-thiopyrone: 2-phenyl-2-iodoethanol, 1-phenyl-2-bromo ethanol, benzyl chloride, triphenylchloromethane and 2-bromo-1,2,3,4-tetrahydro-1-phenanthrone.

The reaction can be carried out in benzene, ether or acetone as solvent. The yields obtained in the various solvents were comparable, but the reaction proceeded much more rapidly in acetone.

The crystalline mercaptopyrylium salts obtained in this study could not be crystallized from alcohol or water.[3] They were readily purified by washing with acetone or benzene, and analytical samples were obtained by dissolving the salt in nitromethane and precipitating with ether.

The assignment of the substituted mercaptopyrylium salt structure to the products of the reaction is based on the method of formation, and is supported in each case by analytical data. Further substantiation comes from the reactions of some of the salts to give compounds previously obtained by other methods. Thus, 2,6-dimethyl-4-methylmercaptopyrylium iodide on treatment with ammonium hydroxide gave the known[4] 4-methylmercapto-2,6-lutidine, and 2,6-dimethyl-4-benzylmercaptopyrylium iodide was converted to 4-benzylmercapto-2,6-lutidine by ammonium hydroxide[5] and to 2,6-dimethyl-4-benzylmercapto-

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(2) Hantzsch, *Ber.*, **52**, 1535 (1919).

(3) They appear to react with hydroxylated solvents. This observation is similar to that noted for 4-methoxy-2,6-dimethylpyrylium salts by Baeyer, *Ber.*, **43**, 2337 (1910).

(4) Marckwald, Klemm and Trabert, *ibid.*, **33**, 1562 (1900).

(5) Anker and Cook, *J. Chem. Soc.*, 117 (1946).