was separated and dried over a little anhydrous calcium chloride. The product boiling at 45–55° (11 mm.) weighed 31 g.

The experiment was repeated using half quantities. The anisole thus obtained amounted to 15.7 g.

Alkylation with Methylethyl Sulfate.—The same procedure was followed as described for dimethyl sulfate; 27.3 g. (1 molecular equivalent) of methylethyl sulfate was used; yield of anisole 11.4 g., of phenetole 3.2 g.

Acknowledgment

The writer wishes to thank Dr. Roger Adams for helpful criticism during the prosecution of this work.

Summary

1. The new compound, methylethyl sulfate, was prepared.

2. Phenol was alkylated with one molecular equivalent of methylethyl sulfate under conditions standardized by the use of dimethyl sulfate. Of the total amount of alkylation performed upon the phenol by methylethyl sulfate, the methyl group was responsible for 80.2% and the ethyl group for only 19.8%.

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[CONTRIBUTION FROM THE CARBOHYDRATE LABORATORY, BUREAU OF CHEMISTRY, UNITED STATES DEPARTMENT OF AGRICULTURE]

THREE ISOMERIC CRYSTALLINE TETRA-ACETYL-METHYL-d-MANNOSIDES

BY J. K. DALE

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The generally accepted butylene oxide structure accounts for the existence of two isomeric forms of each of the mutarotating sugars and for two isomeric forms of many of their derivatives. Evidence that more than two isomers of these sugars and their derivatives may exist was first brought out by Fischer[1] who obtained in sirup form a third methyl-*d*-glucoside having properties markedly different from those of the previously known alpha and beta forms. Shortly afterwards, Hudson[2] crystallized a third form of *d*-galactose penta-acetate and later isolated a fourth crystalline isomer. Irvine[3] and his co-workers have also produced evidence of the existence of more than two isomeric forms of some of the mutarotating sugars, while Fischer, Bergmann and Rabe[4] have prepared three crystalline isomeric triacetyl-methyl-*l*-rhamnosides.

This article describes the preparation and properties of three crystalline tetra-acetyl-methyl-*d*-mannosides. Direct acetylation of methyl-*d*-man-

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[1] Fischer, *Ber.*, **47**, 1980 (1914).

[2] Hudson, THIS JOURNAL, **37**, 1591 (1915); **38**, 1223 (1916).

[3] Irvine and others, *J. Chem. Soc.*, **107**, 524 (1915); **109**, 1305 (1916).

[4] Fischer, Bergmann and Rabe, *Ber.*, **53**, 2362 (1920).

noside with acetic anhydride and sodium acetate yields a crystalline compound designated in this paper, *α*-tetra-acetyl-methyl-*d*-mannoside. *β*-*d*-Mannose penta-acetate dissolved in glacial acetic acid saturated with hydrobromic acid yields a sirupy product containing bromine, presumably bromo-acetyl-*d*-mannose. When this sirup is dissolved in methyl alcohol and the solution shaken with silver carbonate a second crystalline tetra-acetyl-methyl-*d*-mannoside, which has been distinguished by the prefix gamma (*γ*), is produced. The discovery of this compound, which had properties not generally characteristic of the acetylated glucosidic derivatives of the sugars, led to the isolation of a third crystalline isomer, *β*-tetra-acetyl-methyl-*d*-mannoside.

This third isomer was discovered as a result of observations made upon the behavior of various methyl glucosidic and acetylated glucosidic compounds when dissolved in methyl alcohol containing hydrochloric acid. The compounds available included *α*- and *β*-methyl-*d*-glucoside, *α*- and *β*-methyl-*d*-galactoside, methyl-*d*-mannoside, *α*- and *β*-tetra-acetyl-methyl-*d*-glucoside, *α*- and *β*-tetra-acetyl-methyl-*d*-galactoside, *α*- and *β*-triacetyl-methyl-*d*-xyloside, and the *α*- and *γ*-tetra-acetyl-methyl-*d*-mannosides described in this article. With the exception of *γ*-tetra-acetyl-methyl-*d*-mannoside the rotation of the solution of each of these compounds at room temperature increased or decreased very slowly, requiring several days to reach a constant value. Under the same conditions, however, the rotation of the solution of *γ*-tetra-acetyl-methyl-*d*-mannoside changed very rapidly, reaching a constant value in a few minutes. At this point of constant rotation, or equilibrium, the solution was neutralized with silver carbonate, the silver salts were filtered off, and the filtrate was evaporated to a thick sirup which on standing for several days partially crystallized. The crystalline material proved to be a third tetra-acetyl-methyl-*d*-mannoside. Although the rotation of the solution had increased, changing from a negative to a positive value, the new compound showed an even greater negative specific rotation than the mother compound, *γ*-tetra-acetyl-methyl-*d*-mannoside, thus leading to the conclusion that a product or products of dextrorotation had been formed at the same time and in large proportions. This conclusion is supported by the fact that the yield of this third isomer, *β*-tetra-acetyl-methyl-*d*-mannoside, was only 7%, thereby leaving a very large proportion of mother liquor to contain one or more additional compounds. All attempts, however, to obtain more crystalline material from this mother liquor failed.

A second exceptional reaction of *γ*-tetra-acetyl-methyl-*d*-mannoside was its behavior upon alkaline hydrolysis. When this compound was shaken with dilute alkalies in glass-stoppered bottles immersed in ice only three of the four acetyl groups were split off, the result being the same whether the strength of the alkali was 0.1 N or 0.5 N and whether the period of hydrolysis was two hours, four hours, or even 20 hours. On the other hand, boiling with dil. sulfuric acid readily effected hydrolysis of all four acetyl groups.

The close parallel in the properties[5] of the three triacetyl-methyl-*l*-rhamnosides prepared by Fischer, Bergmann and Rabe[4] and the three tetra-acetyl-methyl-*d*-mannosides described in this article is interesting. It is especially marked in respect to the reaction under alkaline hydrolysis of the gamma isomers and in respect to the specific rotations of the compounds. γ-Triacetyl-methyl-*l*-rhamnoside is incompletely hydrolyzed by dilute alkalies, paralleling in this respect our γ-tetra-acetyl-methyl-*d*-mannoside, one acetyl group in each case resisting hydrolysis. The reactions of these two compounds with alkalies constitute the first observed instances of incomplete alkaline hydrolysis of the acetylated sugars or glucosides. 0.1 *N* Alkali effects complete hydrolysis of the acetyl groups in the alpha and beta isomers. In regard to the specific rotations of the mannose and rhamnose compounds, the conspicuous similarity manifested is not so surprising when it is recalled that from the point of view of structural formulas rhamnose is a reduction product of mannose, the end primary alcohol group of mannose, CH_2OH, being considered as reduced to CH_3. The agreement of the specific rotations of the corresponding mannose and rhamnose compounds is marked. For tetra-acetyl-methyl-*d*-mannoside,[6] $[\alpha]^{20}_D$ of the α form is +49.1; β form, —46.8; γ form, —26.6. For triacetyl-methyl-*l*-rhamnoside,[7] α form, —53.5; β form, +45.7; γ form, +28.0. Since mannose belongs to the *d*-series of sugars and rhamnose belongs to the *l*-series, the specific rotations of the corresponding derivatives are opposite in sign.

Experimental Part

Alpha-tetra-acetyl-methyl-*d*-mannoside.—To a boiling solution of 10 g. of anhydrous sodium acetate in 200 cc. of acetic anhydride 40 g. of methyl-*d*-mannoside was gradually added. After boiling for two minutes the reaction mixture was poured into 2 liters of cold water, an insoluble sirup then separating which when stirred soon crystallized. The supernatant acid liquor was neutralized with sodium bicarbonate and then yielded another portion of gummy material which also soon solidified to a crystalline mass. The two lots of impure crystalline material were united and recrystallized from 150 cc. of 40% alcohol. The yield was 41 g. It was further recrystallized from dilute alcohol until its specific rotation became constant. The pure substance melted at 65° (corr.). In chloroform (U. S. P.) solution 1.1084 g. of the compound in 25 cc. of the solution gave a reading to the right of +4.34° in a 2dcm. tube, with sodium light; hence $[\alpha]^{20}_D = +48.9°$. After another recrystallization, $[\alpha]^{20}_D = +49.1°$.

Acetyl determinations made by shaking 0.30 g. of the compound with 75 cc. of 0.1

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[5] This investigation was completed without knowledge of, and before the appearance of Fischer, Bergmann and Rabe's work. Publication has been delayed in the hope that an opportunity would be presented for further study of these mannose compounds.

[6] In chloroform.

[7] In acetylene tetrachloride. Figures of Fischer, Bergmann and Rabe, Ref. 4.

N sodium hydroxide solution in glass-stoppered bottles at 0° for one-half and one hour gave, respectively, 66.59% and 66.65% of acetic acid. Calculated for tetra-acetyl-methyl-mannoside, 66.30%.

Analyses. Calc. for $C_{15}H_{22}O_{10}$: C, 49.70; H, 6.12. Found: C, 49.95, 49.98, H, 6.18, 5.99.

Gamma-tetra-acetyl-methyl-*d*-mannoside.—A solution of 25 g. of β-*d*-mannose-penta-acetate[8] in a mixture of 40 cc. of glacial acetic acid and 100 cc. of a saturated solution of hydrogen bromide in glacial acetic acid was kept at room temperature about one-half hour or until samples withdrawn from the flask and read in the polariscope showed no further change. The solution was then poured into 500 cc. of chloroform and this clear, straw-colored solution was twice washed with cold water, once with enough sodium bicarbonate solution to neutralize the remaining dissolved acids and then once more with water. After drying with calcium chloride, the chloroform solution was evaporated under diminished pressure to a thick sirup. This sirup was dissolved in dry ether and this solution evaporated to a thick sirup. All attempts to obtain a crystalline bromo-acetyl-mannose from this sirup failed, so the sirup itself without further purification was used.

The sirup was dissolved in 250 cc. of methyl alcohol and this solution shaken with 35 g. of freshly prepared silver carbonate until a little of the filtered solution no longer showed a test for bromine with silver nitrate. The solution was then filtered from the silver salts and the filtrate was evaporated to a thin sirup which when cooled and stirred readily crystallized. The crystals were filtered from the mother liquor and recrystallized from ether; yield, 11.7 g. The substance was further recrystallized from ether until its specific rotation became constant. The pure substance melted at 105° (corr.). In chloroform (U. S. P.) solution 1.0374 g. of the compound in 25 cc. of the solution gave a reading to the left of —2.19° in a two dm. tube, with sodium light; hence $[\alpha]_D^{20} = -26.4°$. After another recrystallization, $[\alpha]_D^{20} = -26.6°$.

Determination of carbon and hydrogen by combustion and of the methoxy group by the method of Zeisel[9] gave figures agreeing with the calculated value for tetra-acetyl-methyl-mannoside. The distillation of the compound with 20% sulfuric acid and determination of the amount of volatile acid which distilled gave figures equal to the percentage of acetic acid that would be split off by complete hydrolysis of a tetra-acetyl-methyl-hexoside. Hydrolysis by alkalies gave a different result. The percentage of acetic acid liberated corresponded to the quantity calculated, assuming the hydrolysis of only three acetyl groups. 0.30-G. samples of the compound, shaken with 20 cc. of 0.5 *N* sodium hydroxide solution in glass-stoppered bottles at 0° for 2, 2$^1/_2$ and 3 hours gave, respectively, 49.82%, 49.64% and 49.80% of acetic acid; 0.3-g. samples of the compound, shaken in glass-stoppered bottles at 0° with 75 cc. of 0.1 *N* sodium hydroxide solution for 3, 5 and 20 hours, gave 49.76%, 49.55% and 49.84% of acetic acid while that calculated for three acetyl groups removed from tetra-acetyl-methyl-mannoside 49.73% of acetic acid.

Five-tenths g. of the compound was distilled with 50 cc. of 20% sulfuric acid, water being gradually added to replace that lost by distillation, and the distillate was collected in 0.1 *N* sodium hydroxide solution. Two analyses gave, respectively, 66.41% and 66.17% of acetic acid, while that calculated for completely hydrolyzed tetra-acetyl-methyl-hexoside is 66.30%.

Analyses. Calc. for $C_{15}H_{22}O_{10}$: C, 49.70; H, 6.12; CH_3O, 8.56. Found: C, 49.95, 49.88; H, 6.01, 6.14; CH_3O (Zeisel), 8.67.

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[8] THIS JOURNAL, **37,** 1280 (1915).

[9] Zeisel, *Monatsh.*, **7,** 406 (1886).

Preparation of Beta-tetra-acetyl-methyl-*d*-mannoside.—A solution of 10.5 g. of the compound designated as γ-tetra-acetyl-methyl-*d*-mannoside in absolute methyl alcohol was increased to 100 cc., then showing a negative specific rotation, $[\alpha]_D^{20} = -26.2$. After an interval of 15 minutes no change in polarization took place. One cc. of a saturated solution of hydrogen chloride in methyl alcohol was then added. A rapid change towards dextrorotation occurred, the rate becoming slower as an apparent constant value was approached. When this point was reached, the solution, now showing a positive specific rotation, $[\alpha]_D^{20} = +10.4$, was neutralized with silver carbonate, filtered free from the insoluble silver salts, and the filtrate was evaporated to a sirup which partially crystallized on standing; 0.7 g. of material, m. p. 158°, was obtained. A total of 45 g. of the previously designated γ-tetra-acetyl-methyl-*d*-mannoside subjected to this procedure yielded a total of 3.5 g. of crystalline material having a melting point from 158° to 160°.

After recrystallization from ether the melting point was 161° (corr.). In chloroform (U. S. P.) solution 0.3206 g. of the substance in 25 cc. of the solution gave a reading to the left of —1.20°, in a 2dm. tube, with sodium light; hence, $[\alpha]_D^{20} = -46.8°$. After a second recrystallization of the crystals from ether the melting point was 162° (corr.) and $[\alpha]_D^{20} = -47.0°$.

Two acetyl determinations made by shaking 0.3 g. of the compound with 100 cc. of 0.1 *N* sodium hydroxide solution for 5 hours gave 66.64% and 66.58% of acetic acid, while that calculated is 66.30%.

Analyses. Calc. for $C_{15}H_{22}O_{10}$: C, 49.70; H, 6.12; CH_3O, 8.56. Found: C, 49.63, 49.70; H, 6.17, 6.17; CH_3O (Zeisel), 8.24.

Some attempts, although by no means exhaustive ones, were made to isolate in a crystalline condition a compound which presumably would be a monoacetyl-methylmannoside, from the hydrolysis products of γ-tetra-acetyl-methyl-*d*-mannoside with alkali. The γ-tetra-acetyl-methyl-*d*-mannoside was shaken with 0.1 *N* barium hydroxide instead of with sodium hydroxide. The same values were obtained as when sodium hydroxide was used, showing the hydrolysis of only three acetyl groups. The solution was carefully neutralized with sulfuric acid, the barium sulfate was filtered off, and the filtrate was evaporated to a sirup. However, no crystalline material was obtained and pressure of other work prevented further investigation of this product.

α-Tetra-acetyl-methyl-*d*-mannoside dissolved in methyl alcohol containing a little dry hydrogen chloride showed a slow change in rotation which became constant after several days. From this solution methyl-*d*-mannoside was easily obtained. When dissolved in methyl alcohol containing a little hydrochloric acid, γ-tetra-acetyl-methyl-*d*-mannoside showed a very rapid change in polarization, reaching what was apparently by comparison a constant value in a few hours and yielding at this point β-tetra-acetyl-methyl-*d*-mannoside. This was not a true equilibrium point, however, for unless the solution was neutralized, a further but much slower change in polarization took place, a constant value being reached only after several days. Neutralization of the acid, filtration and evaporation then resulted in the crystallization of methyl-*d*-mannoside.

For the preparation of γ-tetra-acetyl-methyl-*d*-mannoside, the beta isomer of mannose penta-acetate, the easier of the two known isomers to prepare, was generally used. In one experiment, however, the alpha isomer was employed in the same manner, the resulting crystalline product being identical in all respects with the γ-tetra-acetyl-methyl-*d*-mannoside obtained from β-mannose-penta-acetate.

I take pleasure in expressing my gratitude to Dr. C. S. Hudson who suggested this work with a view to learning more about the derivatives of mannose and their properties.

Summary

1. Three isomeric crystalline tetra-acetyl-methyl-*d*-mannosides have been prepared and their melting points and specific rotations determined.

2. The isomer designated as γ-tetra-acetyl-methyl-*d*-mannoside exhibited properties not generally characteristic of the acetylated glucosidic derivatives of the sugars. When subjected to alkaline hydrolysis only three of the four acetyl groups were removed and when dissolved in methyl alcohol containing hydrogen chloride it was converted or transformed wholly or partially into other compounds.

3. A small yield of the new crystalline compound designated as β-tetra-acetyl-methyl-*d*-mannoside was obtained from the apparent equilibrium mixture resulting from the solution of γ-tetra-acetyl-methyl-*d*-mannoside in methyl alcohol containing hydrogen chloride.

4. These three crystalline tetra-acetyl-methyl-*d*-mannosides parallel closely the three triacetyl-methyl-*l*-rhamnosides, prepared by Fischer, Bergmann and Rabe, in specific rotation and in behavior upon hydrolysis. This analogy is interesting in view of the similarity in structure of mannose and rhamnose.

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[CONTRIBUTION FROM THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LABORATORY OF ORGANIC CHEMISTRY]

COLOR TESTS FOR NITRO DERIVATIVES OF DIPHENYLAMINE[1]

BY TENNEY L. DAVIS AND AVERY A. ASHDOWN

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Means for the identification of the nitro derivatives of diphenylamine are to be desired for the reason that certain of these substances occur in aged smokeless powder. Diphenylamine is incorporated with the nitrocellulose which is used in the manufacture of smokeless powder in order that it may combine with the oxides of nitrogen which arise from the spontaneous decomposition of the nitrocellulose and so may prevent them from encouraging further decomposition. Nitrocellulose decomposes less rapidly when mixed with a little diphenylamine than when exposed to the acid products of its own decomposition. The diphenylamine is converted first into diphenylnitrosamine and later into nitro derivatives. A knowledge of the nitro derivatives of diphenylamine which occur in a sample of old smokeless powder will tell much about the past history of the powder, its present stability, and its fitness for future storage.

Experimentation is now in progress in this Laboratory on the isolation of nitro derivatives of diphenylamine from old smokeless powder. In

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[1] This experimentation was carried out in connection with a contract between the Ordnance Department and the Massachusetts Institute of Technology, and the present paper is published by permission of the Chief of Ordnance.