acetate for seven days yielded only 0.35 g. of triphenylcarbinol and 2.6 g. of peroxide, showing that the latter ester did not react as readily as did isoamyl acetate. When phenyl benzoate and ethyl benzoate were used as the solvents and heated for seven days each, the products were chiefly tar and unchanged triphenylmethyl. The latter was shown by the separation of 0.75 and 0.5 g. of peroxide, respectively. From ethyl oxalate, heated for three and one-half days, an oil yielding a slight amount of *p*-benzhydryltetraphenylmethane was obtained. When a reaction with ethyl oxalate was stopped at the end of two and one-half days, 3.5 g. of peroxide, which required over two hours of standing in an open beaker to complete the precipitation, was obtained.

Summary

Triphenylmethyl has been shown to react with ether, ethyl acetate, and acetone. The major product is triphenylcarbinol. Copper and cuprous chloride catalyze the reaction. Silver has little, if any, effect.

CAMBRIDGE, MASSACHUSETTS RECEIVED OCTOBER 1, 1932
PUBLISHED JUNE 6, 1933

[CONTRIBUTION FROM THE FRICK CHEMICAL LABORATORY OF PRINCETON UNIVERSITY]

Studies in the Ketone Sugar Series. II. The Preparation and the Structure of the Heptaacetate and of the Methylglycosidic Derivatives of Turanose

BY EUGENE PACSU

It has been shown in Part I[1] that the stable crystalline halogeno-acetylturanoses differ profoundly from the common halogeno-acetyl sugars in that they are derivatives of the hypothetical orthoacetyl halides as represented in Formula I. In order to learn the general behavior in simple substitution reactions of this type of halogeno-acetyl sugars, it was considered desirable to study the replacement of the halogen atom in the stable bromoacetylturanose with such radicals as hydroxyl and methoxyl. The product of the replacement of halogen by hydroxyl was a crystalline heptaacetate. Simple as this transformation at first appears, it took on an added significance when it was found that the reactions carried out in order to determine the exact constitution of this heptaacetate led to contradictory results.

In the first of these reactions, the heptaacetate, on treatment with hydrobromic acid dissolved in glacial acetic acid, gave back the original bromo compound (I). From this result, in compliance with the principle of the least possible alteration in structure, it may be concluded that the heptaacetate possesses an ortho ester structure as represented by IV. If such be the case, then the exchange between OH and Br, and *vice versa*, would be a direct process, involving no tautomeric change. Such a simple procedure has been shown in Part I to occur between the acetoxyl residue and the bromine atom when the octaacetates II and III possessing an ortho ester structure were treated with hydrogen bromide dissolved in acetic acid.

(1) THIS JOURNAL, **54**, 3649 (1932).

An entirely different result was obtained after the heptaacetate, in a second reaction, had been submitted to methylation with Purdie's reagent, giving rise to a crystalline heptaacetyl-β-methylturanoside. Since the properties of this compound agreed with those for a normal methylbioside heptaacetate, it must have the constitution as represented by VI, which, in turn, indicates a normal structure for the heptaacetylturanose (VII). The formation of a normal glycoside on methylation of a compound which, according to the former conclusion, belongs to the ortho ester type, is interesting, since it seems to contradict a fundamental hypothesis in sugar chemistry, namely, that methylation causes no change in the structure of the molecule. However, it must be clearly recognized that this principle extensively employed in recent years by Haworth and co-workers in their studies on the structures of the glycosidic derivatives of the simple sugars as well as on those of the polysaccharides, appears to be less axiomatic when applied to sugar derivatives with an ortho ester structure, or to partially acetylated sugars and glycosides. Indeed, it can be stated that it is hardly possible to find a case in the literature where compounds belonging to such groups do not suffer a deep-seated change in their structure during the methylation process. For instance, it has been recorded[2] that on methylation by active silver oxide of "γ"-(2)-monoacetyl-β-methyl-*l*-rhamnoside with an ortho ester structure, the acetyl group was split off to some extent and normal trimethyl-β-methylrhamnoside could be obtained.[3] A similar profound change of structure took place on methylation by means of dimethyl sulfate and alkali of "γ"-tetraacetyl-β-methylmannoside, yielding about 40% of a mixture of α- and β-forms of normal tetramethylmethylmannoside.[4] Another kind of change in structure occurred[5] during methylation of a partially acetylated sugar, namely, 1,2,3,4-tetraacetyl-β-glucose$<1,5>$, resulting in the formation of normal tetraacetyl-β-methylglucoside. It is especially interesting to consider the behavior on methylation of Helferich's supposed 1,2,3,6-tetraacetyl-β-glucose[6] to which substance, according to Haworth, Hirst and Teece[5] a "1,6-ortho ester" structure should be assigned. As the substance gave normal tetraacetyl-β-methylglucoside on methylation by means of the silver oxide reaction, we have a case rather similar to that of heptaacetylturanose which, if it were of the ortho ester type, could still give normal glycoside on methylation with Purdie's reagent. For later reference it should be noted that on acetylation with pyridine and acetic anhydride Helferich's compound gave normal β-glucosepentaacetate. This

(2) Haworth, Hirst and Miller, *J. Chem. Soc.*, 2469 (1929).

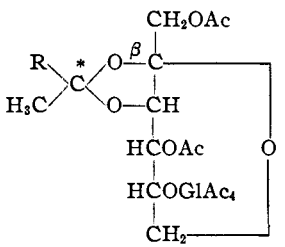
(3) This transformation necessarily means the *removal* of the rhamnosidic methyl group as well as that of the acetyl group during the first stage of methylation, and also the transitory formation of a reducing group in the molecule.

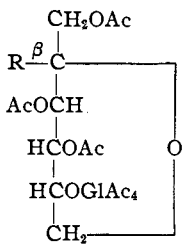
(4) Bott, Haworth and Hirst, *J. Chem. Soc.*, 1395 (1930); see also Haworth, Hirst and Samuels, *ibid.*, 2861 (1931).

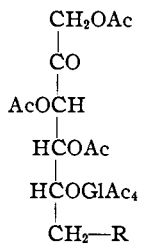
(5) Haworth, Hirst and Teece, *ibid.*, 1405 (1930).

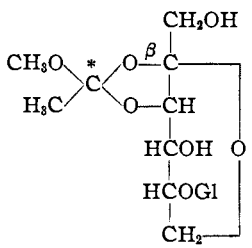
(6) Helferich and Klein, *Ann.*, **455**, 173 (1927).

result indicates that a tautomeric change of the orthoacetate into the normal form took place under the influence of these reagents. The most radical change in structure caused by Purdie's reagent occurred when 2,3,4-triacetyl-α-methylglucoside was submitted to methylation giving rise to 3,4,6-triacetyl-2-methyl-α-methylglucoside, as reported by Haworth and co-workers.[7] The latter transformation led the authors to the statement that "little credence can be attached to methods of this kind which are intended to prove the orientation of a free hydroxyl group in a partly acetylated hexose." In view of the above examples, the conclusion is inevitable that in determining the structure of heptaacetylturanose the methylation method must be discarded as unreliable, and the result attained by its application cannot be used as evidence against the ortho ester structure.









XII

I R = *l*-Hlg
II R = *l*-OOCCH$_3$
III R = *d*-OOCCH$_3$
IV R = *l*-OH
V R = *d*-OCH$_3$
VI R = —OCH$_3$
VII R = —OH
VIII R = (α)-Br
IX R = (α)-OOCCH$_3$
X R = —OOCCH$_3$
XI R = —OH

A striking result was obtained in a third experiment, when the heptaacetate in question was acetylated with acetic anhydride using zinc chloride as a catalyst. Besides a small amount of II, a large quantity of X was isolated. In the course of a special investigation, the details of which will be discussed in Part III of this series, the latter substance was recognized as being a derivative of an open-chain fructose. From the formation of this compound an open-chain structure of the heptaacetate as represented by Formula XI, may be deduced. If that were accepted then the reactions yielding I and VI from the heptaacetate would be connected with certain tautomeric changes which, although in themselves not inconceivable, yet are without analogy in sugar chemistry. Neither can Formula VII be assigned to heptaacetylturanose, because experiments showed that on acetylation in presence of zinc chloride the α-stereoisomeride of VII obtainable from the α-bromoacetyl derivative (VIII) gives rise exclusively to the α-octaacetylturanose (IX) with a normal structure. Only Formula IV remains, therefore, to be taken into consideration, and it must account for the formation of the "octaacetyl-*keto*-turanose" (X).

(7) Haworth, Hirst and Teece, *J. Chem. Soc.*, 2858 (1931).

Lastly, it has been found that acetylation at room temperature of the heptaacetylturanose with pyridine and acetic anhydride gives only a very small amount of II, the bulk of the starting material being recovered unchanged. It follows, therefore, that, in this medium, the heptaacetate forms an equilibrium mixture in which one component resistant to direct acetylation predominates. Evidently, the structure of this compound cannot be represented by the open-chain formula (XI) having an unsubstituted primary alcoholic group, because substances containing such a radical are known to acetylate readily. It is probable, therefore, that the heptaacetate in pyridine–acetic anhydride solution consists mainly of the normal form (VII) which originated by a partial rearrangement from IV. This view is supported by the fact that Helferich's β-glucose tetraacetate[8] was found to give normal β-pentaacetate on acetylation with acetic anhydride and pyridine. In this case we may assume that under the influence of pyridine, the orthoacetate suffers rearrangement into the normal β-tetraacetylglucose which, unlike turanoseheptaacetate and also tetraacetylfructose of Hudson and Brauns[9] readily undergoes acetylation since it contains a secondary alcoholic group in contrast to a tertiary hydroxyl present in those ketose derivatives. It is seen, therefore, that in the acetylation of substances of the ortho ester type both the zinc chloride and pyridine methods may cause deep-seated changes in the molecular structure.

In view of the above conclusions it appears that turanoseheptaacetate very probably possesses an ortho ester structure (IV) with an *l*-configuration of its free hydroxyl group around the new asymmetric carbon atom. However, the substance may easily undergo tautomeric changes which would account for the results attained in the various transformations.

The heptaacetate as a rule was prepared by shaking the acetone solution of the bromo compound (I) with silver carbonate in the presence of a little water. However, it could be obtained in excellent yield when the solution of (I) in glacial acetic acid was shaken with silver acetate. This reaction was originally carried out for the purpose of replacing the bromine atom with an acetoxyl residue. It was not possible to detect the formation of any of the four known octaacetylturanoses or of any products other than the heptaacetate. The latter substance could also be obtained when

(8) See notes 5 and 6; Helferich and Klein, *Ann.*, **450**, 228 (1926).

(9) Hudson and Brauns, THIS JOURNAL, **37**, 2738 (1915); Brauns, *Verslag K. Akad. Wetensch.*, Amsterdam, 1908, p. 577. The tetraacetylfructose of Helferich [Helferich and Bredereck, *Ann.*, **465**, 166 (1928)] obtained by him in about 1.4% yield from crystalline fructose through the monotrityl derivative of that sugar, is claimed to give rise on acetylation with pyridine and acetic anhydride to "α-pentaacetylfructose." From his experimental results Helferich concluded that the tetraacetate has the structure of a 2,3,4,5-tetraacetylfructose$<2,6>$. The fact alone that the substance exhibits mutarotation in water solution makes the allocated structure appear highly improbable. Inasmuch as the "α-pentaacetylfructose" has now been recognized as containing no ring in the molecule [Pacsu and Rich, THIS JOURNAL, **54**, 1697 (1932)], the formation of this compound from Helferich's tetraacetate suggests that the latter substance as well as the acetate of the synthetic disaccharide, 1-glucosidofructose, which has been prepared from it, might be derivatives of an open-chain fructose.

(I) was shaken in absolute methyl alcohol with silver carbonate. The other crystalline product of this reaction was found to be a heptaacetyl-β-methylturanoside with an ortho ester structure (V). The heptaacetylturanose shows the phenomenon of dimorphism. It crystallizes from ether in long needles melting at 140–141°, while crystallization from a mixture of ether and petrol ether yields well developed short prisms melting at 147°. The specific rotations of the two modifications were identical ($[\alpha]_D^{20}$ 47.2° in alcohol, and $[\alpha]_D^{20}$ 37° in chloroform). The heptaacetate does not exhibit mutarotation in alcohol. However, a slight change was observed in chloroform solution, the specific rotation becoming constant at $[\alpha]_D^{20}$ 41.7, after two days.

The replacement with a methoxyl group of the halogen atom in the stable acetobromoturanose (I) gave, as just stated, a mixture of heptaacetylturanose and a heptaacetylmethylturanoside (V). The latter substance, showing $[\alpha]_D^{20}$ 80° in chloroform solution, was recognized as a structural isomeride of the normal turanoside (VI) which had been obtained from the heptaacetate by means of Purdie's reagent. It possesses certain unique properties which are characteristic of glycosides with an "ortho ester" structure.[10] Thus, six of its seven acetyl groups are easily removable by cold alkalies, but the seventh is resistant to hydrolysis even by hot sodium hydroxide solution. Furthermore, the methoxyl of its orthoacetic ester group is easily removed by acid hydrolysis. In 0.063 N alcoholic hydrogen chloride solution the substance lost its methoxyl group in less than three hours at room temperature and heptaacetylturanose could be crystallized from the solution. As the velocity coefficient of this transformation calculated for a unimolecular reaction was constant within the experimental error, it is to be concluded that only one change was occasioned by the catalytic action of the acid, namely, the removal of the methoxyl group. Consequently, the substance formed during the hydrolysis must have preserved its ortho ester structure. The rotation of the solution after hydrolysis ($[\alpha]_D^{20}$ 47.2°) agreed with that of the crystalline heptaacetate in the same solvent. In a second experiment the substance was dissolved in 75% alcohol and the acid concentration was reduced to 0.009 N. The solution had no effect on Fehling's solution until several minutes after addition of the acid, but the reducing power developed gradually during three hours in parallel with the hydrolysis of the glycosidic group. The whole process of hydrolysis differs from that of "γ"-monoacetylmethylrhamnoside and its dimethyl derivative,[10d] where complete removal of the methylglycosidic group was effected in less than thirty seconds and the change was strongly catalyzed by hydrogen ions.

On removal of the six acetyl groups from V, either by alcoholic ammonia

(10) (a) Freudenberg, *Naturwissenschaften*, **18**, 393 (1930); (b) Freudenberg and Scholz, *Ber.*, **63**, 1969 (1930); (c) Bott, Haworth and Hirst, *J. Chem. Soc.*, 1395 (1930); (d) Haworth, Hirst and Samuels, *ibid.*, 2861 (1931).

or by a trace of sodium methoxide according to the method of Zemplén and the author,[11] crystalline "γ"-(3)-monoacetyl-β-methylturanoside (XII) was obtained. This substance, like V, was devoid of action toward Fehling's solution, and showed $[\alpha]_D^{20}$ 114.6° in water solution. In acid solution the substance was extraordinarily labile, consistent with compounds of the "ortho ester" type.[10d] On the addition of hydrochloric acid sufficient to make the concentration 0.002 *N*, the specific rotation fell in about thirty minutes to a constant value of $[\alpha]_D^{20}$ 70.5°. At this stage the product strongly reduced Fehling's solution, indicating the elimination of the methylglycosidic group. The acetyl group was now readily hydrolyzable and could be removed at 0° by 0.1 *N* alkali. Even in neutral aqueous solution the monoacetylmethylturanoside lost its methylglycosidic group, the original specific rotation, $[\alpha]_D^{20}$ 113.3°, changing to a constant value of $[\alpha]_D^{20}$ 72.4° during sixty-four hours.

It is interesting to note that in spite of the high specific rotations, $[\alpha]_D^{20}$ 80° and $[\alpha]_D^{20}$ 114.6°, respectively, V and XII belong to the β-series. The high values are evidently due to the *d*-configuration of the methoxyl group around the new asymmetric carbon atom in the molecule.

As has been stated above, the conversion of I to V is accompanied as a rule by the formation of turanoseheptaacetate. From the chemical properties of I and V this result can now be interpreted as being due partly to the sensitiveness of I toward water, and partly to the facility with which V loses its methylglycosidic group in presence of acid. As the use of silver carbonate in the preparation of alkylglycosides necessarily produces water, the highest possible yield of V from the water-sensitive I cannot exceed 50% of the theoretical. Besides, the almost inevitable transitory formation of free hydrobromic acid in the reaction mixture causes a secondary production of heptaacetylturanose from V. As an illustration of the effect of the acidic medium on the yield of V it should be stated that in one experiment when anhydrous copper sulfate had previously been added to the methyl alcoholic solution of I to remove the water which was being produced on neutralizing with silver carbonate the hydrobromic acid formed during the process, not a trace of V could be obtained due to the acidity of the copper sulfate.

Experimental Part

Preparation of Heptaacetylturanose.—(1) Five grams of the stable bromoacetylturanose (I) was added to 50 cc. of acetone containing 1 cc. of water and 5 g. of silver carbonate. The mixture was shaken for a few minutes at room temperature. After filtration through activated carbon the solution was evaporated under reduced pressure to dryness. The residue was crystallized from alcohol, the total yield being practically quantitative. From the ether solution of the substance long needles separated at 0°; m. p. 140–141°; $[\alpha]_D^{20}$ 37°, $[\alpha]_C^{20}$ 29.3° and $[\alpha]_{HgI}^{20}$ 43.4°, respectively, in chloroform (0.5038 g. of substance, 25 cc. of solution, 2-dm. tube; rotation 1.49°, 1.18° and 1.75°

(11) Zemplén and Pacsu, *Ber.*, **62**, 1613 (1929).

to the right, respectively); in 95% alcohol $[\alpha]_D^{20}$ 47.2°, $[\alpha]_C^{20}$ 37.9° and $[\alpha]_{HgI}^{20}$ 54.9°, respectively (0.2937 g. of substance, 25 cc. of solution, 2-dm. tube; rotation 1.11°, 0.89° and 1.29° to the right, respectively). The optical rotation of the alcoholic solution remained unchanged, whereas the activity of the chloroform solution increased to the constant value of $[\alpha]_D^{20}$ 40.4°, $[\alpha]_C^{20}$ 32.7° and $[\alpha]_{HgI}^{20}$ 47.1°, respectively, during two days. In an acetyl estimation 0.4 g. of heptaacetate neutralized 40.9 cc. of decinormal alkali; calcd. 41.3 cc. On addition of petrol ether to the ether solution of the heptaacetate, short prisms were obtained. This modification melted at 147° and had in chloroform solution $[\alpha]_D^{20}$ 38.7°. After two days this value changed to $[\alpha]_D^{20}$ 41.7°, where it remained constant. In alcoholic solution the compound had $[\alpha]_D^{20}$ 47.1° and no subsequent change in the rotation could be detected. An acetyl estimation showed the presence of seven acetyl groups. The heptaacetylturanose strongly reduces Fehling's solution and is readily soluble in most organic solvents, but difficultly in hot water. (2) Fourteen grams of the stable bromoacetylturanose (I) was added to 50 cc. of glacial acetic acid (99.5%) containing 10 g. of silver acetate. The mixture was shaken for forty-five minutes at room temperature, then the silver salts were filtered off through activated carbon and washed with a little acetic acid. On addition of water (200 cc.), the cooled solution deposited fine needles of heptaacetylturanose. The crystals were collected upon a filter and the mother liquor was neutralized with sodium bicarbonate. The colored precipitate so obtained was united with the first crop, then the whole recrystallized from alcohol; yield, 11.6 g. On recrystallization from ether and petrol ether the respective modifications of the dimorphous heptaacetylturanose were obtained, which showed the correct melting points and rotations. Another method for its formation will be described below in connection with the preparation of V from I.

For the conversion to the stable bromoacetylturanose (I), 3 g. of the heptaacetate was added to 20 cc. of a 40% solution of hydrogen bromide in glacial acetic acid. After two hours' standing at room temperature the somewhat colored solution was worked up in the usual way; yield, 2 g. of crystalline bromoacetylturanose, showing the correct m. p. 133° and $[\alpha]_D^{20}$ −30.3° in chloroform solution.

Acetylation of Heptaacetylturanose by the Zinc Chloride Method.—One and a half grams of heptaacetylturanose was dissolved in 15 cc. of acetic anhydride containing 0.15 g. of fused zinc chloride. After heating for ten minutes on the water-bath the dark solution was poured into 150 cc. of ice water. The precipitated sirup soon solidified. The substance was filtered off and the filtrate was neutralized with sodium bicarbonate. The gummy precipitate so obtained was added to the original solidified product, dissolved in chloroform, the solution washed with water, dried with calcium chloride, and concentrated under reduced pressure to a thick sirup. On trituration with cold alcohol 0.25 g. of the "first octaacetylturanose" (II) was obtained; m. p. 215–217°; $[\alpha]_D^{20}$ 20.9° in chloroform solution. The original alcoholic mother liquor was evaporated under reduced pressure to a sirup which was dissolved in chloroform, the solution dried with calcium chloride and concentrated *in vacuo*. On the addition of ether the "third octaacetate of turanose" (X) crystallized out in large hexagonal prisms from the ice-cold solution; yield, 1 g. showing the correct m. p. 95–96° and $[\alpha]_D^{20}$ 125.9° in chloroform solution.

Preparation of α-Heptaacetylturanose from the Unstable α-Bromoacetylturanose (VIII) and its Acetylation by the Zinc Chloride Method.—Two and a half grams of crystalline α-octaacetylturanose (IX) was converted into the α-bromo-acetyl derivative (VIII) according to the procedure described in Part I of this series. The chloroform solution of the bromo compound was concentrated under reduced pressure to a sirup which was immediately dissolved in acetone containing a little water and an excess of silver carbonate. The replacement of the bromine atom by the hydroxyl group was

accomplished by shaking the mixture at room temperature for a few minutes. After filtration the solution was concentrated *in vacuo* to a sirup. This was dissolved in ether and the solution evaporated in a desiccator to a stiff sirup. Without any further purification the crude product (2 g.), which consists mainly of α-heptaacetylturanose, was acetylated with 13 cc. of acetic anhydride containing 0.2 g. of fused zinc chloride. The solution, which showed about $[\alpha]_D$ 90°, was heated for three minutes on the water-bath. It was poured into ice water and worked up in the customary manner; yield, 1.3 g. of pure α-octaacetylturanose (IX) showing the correct m. p. 158° and $[\alpha]_D^{20}$ 106.2° in chloroform.

Attempted Acetylation of Heptaacetylturanose by the Pyridine Method.—Three and a half grams of heptaacetylturanose (m. p. 147°) was dissolved in ice-cold pyridine containing 4 cc. of acetic anhydride. The solution was allowed to stand for thirty-six hours at 0°, then for the same period of time at room temperature. On concentration under reduced pressure the liquid turned into a crystalline mass. It was dissolved in chloroform and the solution washed with dilute sulfuric acid, then with sodium bicarbonate solution and finally with water. After drying with calcium chloride, the solution was evaporated *in vacuo* to a sirup which was dissolved in hot alcohol. About 0.8 g. of fine needles crystallized from the solution at room temperature. After several recrystallizations from alcohol, finally from chloroform and ether, 0.35 g. of pure octaacetylturanose (II) was obtained showing the correct m. p. 216–217° and $[\alpha]_D^{20}$ 20.5° in chloroform solution. The original alcoholic mother liquor of the crude material was concentrated under reduced pressure to a sirup which was dissolved in boiling ether. On addition of petrol ether 2.1 g. of short prisms separated from the solution. The substance proved to be the unchanged starting material.

A sample of the tetraacetylfructose of Hudson and Brauns, which was dissolved in a mixture of pyridine and acetic anhydride, did not show any appreciable change of the original rotation during two days at room temperature.

Preparation of Normal β-Methylturanoside Heptaacetate (VI) from Heptaacetylturanose.—Three grams of turanose heptaacetate, 10 g. of silver oxide and 20 cc. of methyl iodide were refluxed on the water-bath for twenty-four hours. The mixture was diluted with ether, filtered and the silver salts washed with ether. The filtrate was evaporated to dryness, and the hot alcoholic solution of the residue was treated with activated carbon. After filtration the solution was allowed to stand for several hours at room temperature until crystallization was complete. The yield of the pure heptaacetyl β-methylturanoside was 2.1 g. It crystallized in beautiful prismatic needles which melted at 188–189°. The substance is soluble in most of the organic solvents except cold alcohol and petrol ether, and it is devoid of action toward Fehling's solution. The specific rotation in chloroform solution was $[\alpha]_D^{20}$ 27.5°, $[\alpha]_C^{20}$ 21.7° and $[\alpha]_{HgI}^{20}$ 32.4°, respectively (0.4323 g. of substance, 25 cc. of solution; 2-dm. tube; rotation 0.95°, 0.75° and 1.12° to the right, respectively). A second recrystallization from alcohol did not change the rotatory power or melting point; found, methoxyl, 4.51; calcd., 4.77. In an acetyl estimation 0.5546 g. of the substance required 59.3 cc. of decinormal alkali; calcd. 59.7 cc. The titrated solution, which contained 0.3038 g. of β-methylturanoside, was made up with distilled water to 100 cc. The solution read 0.06° to the right in a 4-dm. tube at 20° with sodium light, hence $[\alpha]_D^{20}$ 4.9°.

Although the heptaacetyl-β-methylturanoside has been deacetylated by several methods, it has not been possible to obtain the β-methylturanoside in a crystalline state. The substance was isolated from its alcoholic solution as a white amorphous powder which did not reduce Fehling's solution, and on reacetylation gave back the crystalline heptaacetate. A sample of the material which had been dried over phosphorus pentoxide in a vacuum desiccator showed $[\alpha]_D^{20}$ 3.5° in water solution.

Preparation and Properties of Heptaacetyl-β-methylturanoside (V) with an Ortho

Ester Structure.—(1) Ten grams of the stable bromoacetylturanose (I) was added to 100 cc. of absolute methyl alcohol containing 9 g. of silver carbonate. After shaking at room temperature for three hours, the solution was filtered. The filtrate, which gave a negative halogen test, was evaporated under reduced pressure to a sirup which soon turned into a crystalline mass. Recrystallized from hot alcohol there was obtained 3.5 g. of beautiful prismatic needles. This substance is heptaacetyl-β-methylturanoside with an ortho ester structure. The alcoholic mother liquor strongly reduced Fehling's solution, so presumably contained heptaacetylturanose mixed with some unidentified products. After recrystallization from alcohol, the turanoside melted at 162–164° and showed $[\alpha]_D^{20}$ 80° in chloroform solution (0.6655 g. of substance, 25 cc. of solution, 2-dm. tube; rotation 1.34° to the right). The product is soluble in most organic solvents except cold alcohol and petrol ether, and it is devoid of action toward Fehling's solution; found, methoxyl, 4.64; calcd., 4.77. In an acetyl estimation the

TABLE I

HYDROLYSIS OF THE METHYLGLYCOSIDIC GROUP OF THE HEPTAACETYLMETHYLTURANOSIDE (V) AT 20° BY HYDROCHLORIC ACID DISSOLVED IN ALCOHOL

Expt.	Concentration	Time, minutes	α	$k = \frac{1}{t} \log \frac{\alpha_\infty - \alpha_0}{\alpha_\infty - \alpha}$	Action on Fehling's solution
		0	[+1.34]	.....	
		3	1.29	0.01379	
		8	1.24	.01014	
	0.2133 g./25 cc.	15	1.15	.01227	
	of a 0.0632 *N*	25	1.08	.01112	
1	solution of	40	1.00	.01045	
	hydrochloric	60	0.91	.01102	
	acid in 95%	90	0.84	.01157	
	alcohol	130	0.81	.01107	
		150	0.80	.01160	
		1110	0.79	.....	
				$k = 0.01114$	
		0	[+1.94]	.....	Negative
		0.75	1.94	.....	
		1	1.93	[0.00554]	
		1.5	1.92	.00743	
		2	1.91	.00841	
		3	1.89	.00937	Very slightly positive
		7	1.84	.00840	
	0.3147 g./25 cc.	10	1.81	.00781	
	of a 0.0091 *N*	15	1.76	.00750	
2	solution of	20	1.70	.00786	Positive
	hydrochloric	25	1.65	.00795	
	acid in 75%	30	1.60	.00814	
	alcohol	35	1.55	.00844	
		40	1.51	.00853	
		45	1.47	.00872	
		50	1.44	.00870	
		60	1.40	.00830	
		80	1.32	.00834	
		90	1.28	.00870	
		1080	1.15	.....	Very strongly positive
				$k = 0.00829$	

quantity of acetic acid obtained corresponded to the quantity calculated by assuming the hydrolysis of only six of the seven acetyl groups; 0.6048 g. of the substance required 56.2 cc. of 0.1 *N* sodium hydroxide solution while the values calculated for the hydrolysis of six and seven acetyl groups are 55.8 cc. and 65.1 cc., respectively. The titrated solution, which contained 0.3703 g. of "γ"-(3)-monoacetyl-β-methylturanoside (XII) and was devoid of action toward Fehling's solution, was made up with distilled water to 100 cc. in a measuring flask. The solution read 1.72° to the right in a 4-dm. tube at 20° with sodium light, hence $[\alpha]_D^{20}$ 116.1°.

The velocity constant of hydrolysis of the methylglycosidic group of the heptaacetylmethylturanoside by means of hydrochloric acid in alcoholic solution corresponded to that of a unimolecular reaction (Table I).

At the end-point of the hydrolysis the alcoholic solution of the sample employed in the first experiment contained 0.2087 g. of heptaacetylturanose, hence $[\alpha]_D^{20}$ 47.3°. This value agrees with the specific rotation, $[\alpha]_D^{20}$ 47.2°, found for the crystalline heptaacetate in alcoholic solution. An acetyl estimation made after the free hydrochloric acid of the solution had been neutralized showed that 0.1202 g. of the heptaacetylturanose present in an aliquot part of the original solution required 13.5 cc. of 0.1 *N* alkali for the hydrolysis of its acetyl groups. The calculated values for six and seven acetyl groups are 11.3 and 13.2 cc., respectively. This experiment clearly indicates that after the elimination of the methylglycosidic group all the seven acetyl groups, including the resistant acetyl radical of the ortho ester group, can be removed readily by alkaline hydrolysis. (2) The same experiment was carried out with the exception that the mixture was shaken at 0° instead of at room temperature. Glittering needles made their appearance in the reaction mixture during the period of shaking. After filtration, the alcoholic solution was worked up as before; yield, 3.3 g. of pure crystalline heptaacetylmethylturanoside (V). The silver salts on the filter were thoroughly washed with chloroform which dissolved the needles embedded in the precipitate. From the chloroform solution 1.7 g. of pure heptaacetylturanose showing $[\alpha]_D^{20}$ 36.9° was obtained.

Deacetylation of Heptaacetylmethylturanoside (V) to "γ"-(3)-Monoacetyl-β-methylturanoside (XII).—One gram of V was dissolved in absolute alcohol which previously had been saturated with ammonia at 0°. After standing at room temperature for twelve hours, the solution was evaporated under reduced pressure to a sirup which was extracted with hot ethyl acetate to remove acetamide. The solid residue was crystallized from alcohol, yielding 0.4 g. of tabular crystals of monoacetylturanoside. The same substance was obtained when a concentrated methyl alcoholic solution of V was deacetylated with a trace of sodium methoxide according to the method of Zemplén and the author.[11] The compound did not reduce Fehling's solution. It melted at 137° and had $[\alpha]_D^{20}$ 114.6°, $[\alpha]_C^{20}$ 91.5° and $[\alpha]_{Hgl}^{20}$ 134.4°, respectively (0.2335 g. of substance, 25 cc. of water solution, 2-dm. tube; rotation 2.14, 1.71 and 2.51° to the right, respectively). The first of these values agrees fairly well with the value ($[\alpha]_D^{20}$ 116.1°) obtained previously from the rotation of the titrated solution resulting from the estimation of the acetyl groups of V; found, methoxyl, 7.47; calcd., 7.79. Although hydrolysis with alkalies gives a negative result, one acetyl group is still present which cannot be eliminated until the methylglycosidic group with which it is intimately linked in the ortho ester formation has been removed. This methylglycosidic group is extremely labile in the presence of very dilute acid. When hydrochloric acid was added to the above aqueous solution of XII to make the concentration of acid 0.002 *N*, the following rotations were observed at 20° after 1, 1.75, 2.25, 3, 5, 7, 10, 15, 20 and 30 minutes, respectively: 1.80, 1.71, 1.68, 1.63, 1.56, 1.50, 1.40, 1.36, 1.33 and 1.30° to the right. After thirty minutes the rotation was virtually constant ($[\alpha]_D^{20}$ 70.5°). At this point the solution contained 0.2305 g. of 3-monoacetylturanose. It strongly

reduced Fehling's solution. The acetyl group was now readily hydrolyzable and was quantitatively removed in three hours at 0° by 0.1 *N* alkali; found, acetyl, 10.3; calcd., 11.2. In another experiment, when the acid concentration was reduced to 0.00053 *N*, the rotation fell to the constant value of $[\alpha]_D^{20}$ 70° in about thirty-five minutes. The instability of the substance in water solution is illustrated by the following experiment. A sample of 0.703 g. was dissolved in 25 cc. of distilled water. The solution, which was without action on Fehling's solution, read after ten minutes 6.37° to the right in a 2-dm. tube, hence $[\alpha]_D^{20}$ 113.3°. The following rotations were observed after twenty-five minutes, two, eighteen, twenty-four, forty, forty-eight and sixty-four hours, respectively: 6.30, 5.97, 4.37, 4.15, 3.96, 3.94 and 3.93° to the right. At this point the solution containing 0.6782 g. of 3-monoacetylturanose strongly reduced Fehling's solution and had $[\alpha]_D^{20}$ 72.4°.

Summary

1. Heptaacetylturanose has been prepared from the stable bromoacetylturanose (I) by several methods. The substance exists in dimorphous modifications which possess different melting points, but the same specific rotation.

2. The various reactions carried out to prove the structure of the heptaacetate lead to three competing formulas (IV, VII and XI): the replacement of the hydroxyl group of the heptaacetate by a bromine atom resulting in the production of I suggests Formula IV; the formation of a normal heptaacetyl-β-methylturanoside (VI) by methylation with Purdie's reagent supports Formula VII; the formation of an octaacetylturanose (X) with an open-chain fructose constituent in the molecule by acetylation with acetic anhydride in the presence of zinc chloride leads to Formula XI. Acetylation of the heptaacetate by means of the pyridine methods results only in the formation of a small amount of II, the bulk of the starting material being recovered unchanged.

3. A survey of the literature together with the experimental results recorded above indicates that the ortho ester structure (IV) is the most probable for crystalline turanose heptaacetate.

4. By replacement of the halogen atom in I with a methoxyl group, heptaacetyl-β-methylturanoside (V) with an ortho ester structure has been obtained. The hydrolysis of its methylglycosidic group was found to be different from that of "γ"-monoacetylmethylrhamnoside and its dimethyl derivative.

5. On deacetylation of (V) with alkali the substance loses only six of its seven acetyl groups giving "γ"-(3)-monoacetyl-β-methylturanoside (XII). The extreme sensitiveness of this compound toward very dilute acid has been illustrated by several experiments.

PRINCETON, NEW JERSEY RECEIVED OCTOBER 26, 1932
PUBLISHED JUNE 6, 1933