taining 6.93 g. per 100 cc. was —90.9, which agrees with the recorded value for fructose at this concentration and temperature.

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

A FOURTH CRYSTALLINE PENTACETATE OF GALACTOSE AND SOME RELATED COMPOUNDS.

BY C. S. HUDSON AND J. M. JOHNSON.

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The method of preparation of the second pentacetate of galactose by heating the first pentacetate with acetic anhydride and a trace of $ZnCl_2$[1] furnishes an indication that the two isomers are an alpha and beta pair, because this method of rearrangement changes the beta acetates of glucose, mannose, lactose, cellose, maltose and xylose to the corresponding alpha acetates. We have now sought to transform in similar manner the third pentacetate of galactose, which one of us recently found in the mother liquors of the preparation of the first pentacetate,[2] into an isomeric form, and we find that there is produced a fourth crystalline pentacetate of galactose having properties quite distinct from those of the three known isomers.

Rearrangement of the Third Galactose Pentacetate to a Fourth Form.—A supply of 135 g. of the third pentacetate was obtained along with 940 g. of the first pentacetate by the acetylation of one kilo of pure galactose, according to the previously published directions. The specific levorotation of the recrystallized pure third form in benzene was —43.6 in 10% solution, in 99.5% glacial acetic acid —42.4 in 10% solution, both these values being near that reported previously for chloroform solution, —41.6.

On combustion 0.2003 and 0.1987 g. subs. gave 0.3622 and 0.3595 g. CO_2, and 0.1046 and 0.1020 g. H_2O.

Found: C, 49.32 and 49.34%; H, 5.84 and 5.74%. Theoretical: 49.21 and 5.68% for a galactose pentacetate.

Twenty-five grams of this third pentacetate dissolved to 100 cc. with acetic anhydride were heated with 2.5 g. $ZnCl_2$ on the steam bath until the specific rotation changed from its initial value of —41 to the constant rotation —16, which required less than fifteen minutes. On pouring the solution into water a crystallization of some unchanged third pentacetate took place. The water was extracted with chloroform, the extract was washed with $NaHCO_3$ solution and with water, dried with $CaCl_2$ and the chloroform evaporated. From the sirup, crystals of the third

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[1] Hudson and Parker, THIS JOURNAL, 37, 1589 (1915).

[2] Hudson, *Ibid.*, 37, 1591 (1915).

pentacetate were again obtained, but the mother liquor from them yielded after a few days crystals of a different appearance, which were recrystallized from 95% alcohol, and were found to melt at 87° and to show a specific dextrorotation of +61 in chloroform. The yield was only 2.5 g. Analysis proved the substance to be a pentacetate of galactose.

On combustion 0.2074 and 0.2355 g. subs. yielded 0.3766 and 0.4248 g. CO_2, and 0.1038 and 0.1209 g. H_2O.

Found: C, 49.52 and 49.20%; H, 5.60 and 5.74%. Theoretical: 49.21 and 5.68% for a galactose pentacetate.

Mol. wt. (benzene soln. by f. p. method) gave values between 341 and 365. Theoretical 390.

The saponification of two half-gram portions of the substance by boiling three hours with 0.25 N H_2SO_4 gave values of 54.73 and 55.11% CH_3CO, the calculated value for galactose pentacetate being 55.13. The saponification of the substance with alcoholic potash yielded crystalline galactose which was identified by its specific rotation.

A comparison of the values found for the melting point and specific rotation in chloroform of this galactose pentacetate with those of the three known pentacetates leaves no doubt that the substance is a fourth isomer.

First galactose pentacetate, m. p. 142°, $[\alpha]_D = +23$; second galactose pentacetate, m. p. 96°, $[\alpha]_D = +107$; third galactose pentacetate, m. p. 98°, $[\alpha]_D = -42$; fourth galactose pentacetate, m. p. 87°, $[\alpha]_D = +61$.

After the preparation of a larger quantity of the fourth pentacetate and the recrystallization of the product from 95% alcohol until the rotatory power became constant the following specific dextrorotations were observed: $[\alpha]_D^{20} = +61.2$ in chloroform[1] (4.28 g. per 100 cc.), +60.6 in chloroform (10.12 g. per 100 cc.), +44.8 in benzene (3.52 g. per 100 cc.), +62.4 in 99.5% glacial acetic acid (3.04 g. per 100 cc.), and +70.2 in acetic anhydride (5.08 g. per 100 cc.). The substance is bitter in taste, very soluble in chloroform, benzene and glacial acetic acid, less soluble in alcohol and ether, and only slightly soluble in water. The crystals are colorless, transparent prisms sometimes a centimeter long.

The Equilibrium between the Third and Fourth Pentacetates.—Since the specific rotations in acetic anhydride of the third and fourth isomers are —41 and +70, respectively, and the constant equilibrium rotation in the presence of $ZnCl_2$, which acts as a catalyst of the reversible change, is —16, it appears that the third pentacetate makes up the greater part (77%) of the equilibrium mixture. This affords an explanation for the low yields (10%) in transforming the third into the fourth pentacetate and crystallizing the latter. On this view one would expect that the reverse transformation would be more readily accomplished and with a larger yield; experiment has verified this conclusion. The heating of

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[1] *Chloroformum purificatum*, U. S. P.

1.27 g. of the fourth pentacetate in 25 cc. of acetic anhydride containing a little $ZnCl_2$ changed the specific rotation in fifteen minutes from +70.2 to the constant value —15.4, and on pouring the solution into water and crystallizing in the usual way, a sufficient quantity of the third pentacetate was obtained (about 0.3 g.) to permit identification by its melting point and specific rotation.

Division of the Four Galactose Pentacetates into Two Pairs of Alpha and Beta Forms.—The reversible equilibrium in acetic anhydride solution containing $ZnCl_2$, between the third and fourth pentacetates is entirely similar to the balanced reaction in this solvent between the first and second pentacetates. On the other hand, we have never noticed any indication that during either one of these reactions a member of the other pair was produced; in other words, the first and second isomers are interconvertible by direct rearrangement, likewise the third and fourth isomers, but the only way now known by which it is possible to pass from the first or second form to the third or fourth form, or *vice versa*, is by saponifying the chosen pentacetate and acetylating the resulting galactose with acetic anhydride and sodium acetate, under which conditions the first and third pentacetates are formed in admixture. These relationships may be accounted for by assuming that the four galactose pentacetates constitute two pairs of substances, the pairs differing by the position of the lactonyl ring, and the two members of each pair constituting the possible alpha and beta forms that must be assumed to exist for each ring position. On account of the fact that the first pentacetate is produced from galactose in large yield, while the third isomer is present only in small amount, it appears probable that the readily formed γ-ring is in the structure of the first and second pentacetates. The position of the ring for the third and fourth isomers is at present left undecided. Since the second isomer is more dextrorotatory than the first, it is to be considered the alpha form of that pair, and likewise the fourth isomer is the alpha form of the second pair. On this view the first and second pentacetates of galactose may be designated, respectively, as the *beta* and *alpha* forms of *pentacetyl γ-cyclo galactose*, and the third and fourth pentacetates as the *beta* and *alpha* forms of *pentacetyl* (α, β, δ or η)-*cyclo galactose*.

It has been suggested by the late J. U. Nef[1] that the alpha and beta pentacetates of glucose should be regarded as having different rings, rather than as being the possible alpha and beta forms of a common ring structure, probably a γ-ring. The data now at hand concerning the four pentacetates of galactose appear to us to show that the two glucose pentacetates must have the same ring because they pass readily one into the other in acetic anhydride containing $ZnCl_2$.

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[1] *Ann.*, 403, 331 (1914). The contrary view has been upheld by E. Fischer, *Ber.*, 47, 1980 (1914), and by Irvine, *J. Chem. Soc.*, 107, 524 (1915).

Since the ring formation remains fixed in these pentacetates of galactose, it is to be expected that each ring will give rise to a series of derivatives. Thus the acetochlorogalactose that has been prepared by Skraup and Kremann[1] from the first pentacetate is to be considered a γ-cyclo derivative, and there should exist a second acetochlorogalactose related to the third pentacetate by a common ring structure. Experiments are in progress in this laboratory for the purpose of correlating the derivatives of galactose with the two pairs of pentacetates, wherever possible, and the present opportunity is taken to record the preparation of three derivatives from the third galactose pentacetate, namely, the expected second form of acetochlorogalactose, a new tetracetyl galactose, and its phenylhydrazone.

A Second Acetochlorogalactose.—Twenty grams of the third galactose pentacetate were dissolved in 60 cc. dry chloroform and boiled two hours with 5 g. $AlCl_3$ and 13 g. PCl_5, according to the method of Skraup and Kremann.[2] After washing with ice water and bicarbonate solution, and drying with $CaCl_2$, the solution was distilled *in vacuo* to a sirup which crystallized on the addition of absolute ether. After several recrystallizations from ether, 11.6 g. of crystals were obtained which did not change in specific rotation on further crystallization. They melted at 67° (corr.). Chlorine estimations were made by dissolving the substance in alcohol and adding a solution of $AgNO_3$ in 50% alcohol.

0.2184 and 0.5681 g. substance (dried over H_2SO_4 in a desiccator) gave 0.0840 and 0.2200 g. AgCl, respectively.

Found: 9.51 and 9.57% Cl. Theoretical: 9.67% for a tetracetylchlorogalactose.

The substance is strongly levorotatory in chloroform: 6.2 g. per 100 cc. chloroform[3] solution read —9.85 circular degrees in a 2 dcm. tube, hence $[\alpha]_D^{20} = -79.1°$; 3.96 g. per 100 cc. read —6.10°, hence $[\alpha]_D^{20} = -77.1°$. The previously known acetochlorogalactose was reported by Skraup and Kremann to be strongly dextrorotatory, +213 in chloroform. It appears, therefore, that the substance which we have prepared is an isomeric acetochlorogalactose having the same ring as exists in the third and fourth pentacetates.

A Third Tetracetate of Galactose and Its Phenylhydrazone.—Two isomeric tetracetates of galactose are recorded in the literature. One, which will be here designated the first tetracetate, was prepared by Skraup and Kremann[4] from the first known form of acetochlorogalactose (γ-cyclo), and found to melt at 145° and to have the specific dextrorotation +137 in chloroform. The other tetracetate, here designated the second form,

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[1] *Monatsh.*, **22**, 375 (1901).

[2] *Ibid.*, **22**, 379 (1901).

[3] *Chloroformum purificatum*, U. S. P.

[4] *Monatsh.*, **22**, 1045 (1901).

was prepared by Unna[1] from acetobromogalactose (γ-cyclo) and found to melt at 102° and to have the specific dextrorotation +71 in water. The preparation of these tetracetates from the acetohalogen galactoses is proof that the free hydroxyl group has the position of the halogen atom, namely, on the end lactonyl carbon. Since both tetracetates are derived from γ-cyclo galactose derivatives, they may be considered as forming an alpha and beta pair in that series, the first tetracetate being *α-tetracetyl γ-cyclo galactose* and the second the beta form.[2]

Starting with the third galactose pentacetate, we have prepared a crystalline tetracetate which has entirely different properties from those of the two known tetracetates, and is accordingly designated the third isomer. Twenty grams of the third pentacetate were dissolved in 25 cc. acetic anhydride, the solution was cooled in an ice bath, 75 cc. of a saturated solution of HBr in acetic acid were added and the mixture allowed to stand ice cold ten minutes. Chloroform was then added, and the solution was washed in the usual way for the preparation of the acetohalogen sugars, with bicarbonate solution and water. The chloroform solution was then dried with $CaCl_2$ and evaporated. The sirup which remained could not be brought to crystallization, but its method of preparation and its subsequent conversion to the new tetracetate indicate that it is a bromoacetyl derivative of the third pentacetate. Fifteen grams of this sirup, dissolved in 150 cc. methyl alcohol, were shaken with 15 g. dry, freshly prepared Ag_2CO_3 until the solution gave no bromine reaction, the solution was filtered and evaporated to a sirup, which crystallized after a few weeks yielding 4.9 g. A larger quantity of the crystals were then prepared in the same manner and recrystallized from methyl alcohol until the specific rotation became constant. The substance proved to be a third tetracetate of galactose.

On combustion 0.1762 and 0.1803 g. subs. yielded 0.3126 and 0.3194 g. CO_2, and 0.0936 and 0.0937 g. H_2O.

Found: C, 48.35 and 48.31%; H, 5.94 and 5.82%. Theoretical: 48.25 and 5.79% for a galactose tetracetate.

An acetyl determination made by boiling 0.3349 g. substance with 100 cc. 0.25 normal H_2SO_4 three hours in a quartz flask gave 50.2% CH_3CO, and a second analysis, using 0.2817 g. substance, gave 50.4%. Theoretical for a galactose tetracetate, 49.4%.

Saponification of 2 g. of the substance with alcoholic potash gave a yield of 90% of the theoretical amount of pure galactose, which was identified by its reducing power and specific rotation.

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[1] *Inaugural Dissertation*, Berlin, **1911**, p. 22.

[2] It may be mentioned in confirmation of this view that Dr. E. Yanovsky has recently correlated the first and second tetracetates with the alpha and beta forms of pentacetyl γ-cyclo galactose, respectively, by acetylating the tetracetates at low temperature in pyridine solution with acetic anhydride. Publication will be made later.

The following specific rotations of the pure tetracetate in different solvents were found, using a 2 dcm. tube: in chloroform[1] solution $[\alpha]_D^{20}$ = —17.8 (4.7 g. per 100 cc.), in benzene —23.4 (3.5 g. per 100 cc.), in 99.5% glacial acetic acid —11.0 (4.1 g. per 100 cc.), in ethyl alcohol —6.2 (4.4 g. per 100 cc.), and in water —12.9 (4.4 g. per 100 cc.). The substance shows mutarotation. Thus the specific rotation in chloroform gradually changed at room temperature from its initial value —17.8 to —6.9 in one day, —3.1 in six days, and —1.9 in three months. An aqueous solution changed in specific rotation from —12.9 to +21 in four months.

Fehling's solution is readily reduced by the tetracetate. The melting point of the pure substance is 71–73° (corr.).

By the acetylation of 1 g. of the tetracetate with acetic anhydride and sodium acetate 0.6 g. of the crystalline third pentacetate of galactose was obtained, which was identified by its melting point and specific rotation. This conversion proves that the ring in the pentacetate structure is not changed during the transformation through the bromoacetyl compound to the tetracetate. Since the tetracetate shows mutarotation towards increasing dextrorotation, it is to be regarded as the beta form.

A crystalline phenylhydrazone of the new tetracetate was prepared through the interaction of seven g. of the tetracetate and 5 cc. phenyl hydrazine in ether solution. Two estimations of nitrogen in the crystals gave 6.68 and 6.61%, in comparison with the theoretical value of 6.41% for a tetracetyl galactose phenylhydrazone. The substance melted at 95° and showed a specific dextrorotation of +15.5 in chloroform.

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THE METHYL ESTER OF ORTHOBENZOYL-BENZOIC ACID.

By T. C. McMullen.

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Plascuda[2] described the methyl ester of *o*-benzoyl-benzoic acid and Haller and Guyot,[3] later, prepared it in five different ways, one of which was by the action of methyl alcohol on the acid chloride prepared from phosphorous pentachloride. In each case they obtained the same ester as described by Plascuda (m. p. 51–52°).

Meyer[4] prepared the ester by the action of methyl alcohol on the acid chloride. The acid chloride was prepared in three ways: By (*a*) thionyl chloride, (*b*) phosphorus pentachloride, and (*c*) phosphorous trichloride. In the second case he obtained the ester already described, but in the other

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[1] *Chloroformum purificatum*, U. S. P.

[2] *Ber.*, 7, 987 (1874).

[3] *Bull. soc. chim.*, [3] 25, 54 (1901).

[4] *Monatsh.*, 25, 475 (1904).