Decitrated Lemon Juice.—Decitrated lemon juice was obtained in a manner similar to the above example except that the grinding was performed in the presence of calcium carbonate. The ground extract was centrifuged and 5 cc. of the centrifugate was taken and 35 cc. of absolute ethanol added to it. The mixture was centrifuged and 30 cc. of this centrifugate was chromatographed with 6 cc. of 90% ethanol as additional developer. This amount of developer resulted in developing most of the components below the ascorbic acid zone off the column. The 2,6-dichlorophenolindophenol streak showed the ascorbic acid zone to be at the 3.4–6.2 cm. region. The congo red streak showed the presence of three acid zones above the ascorbic acid zone.

Delactonization of D-Gluconolactones.—It was found that the rates of delactonization of D-glucono-γ-lactone and D-glucono-δ-lactone may be followed by means of this chromatographic method. A solution of each of the lactones was made by dissolving 0.1 g. of the material in 0.5 cc. of water. At definite time intervals, 0.05 cc. of the solution was added to 0.95 cc. of absolute ethanol. The addition of this amount of ethanol to the solution "quenched" the delactonization to such an extent that the rate was practically zero. An amount of 0.05 cc. of this alcoholic solution was then chromatographed on a 0.9 × 5 cm. column with 2.0 cc. of 95% ethanol as developer. It was found that within three minutes the solution of D-glucono-δ-lactone showed the presence of free acid and that this rapidly increased over a period of about three hours. The solution of D-glucono-γ-lactone did not show the presence of any free acid zone after standing for six hours, but did after standing for one day.

α-D-Galacturonic Acid, D-Galactose, D-Glucose, D-Xylose and L-Rhamnose.—Approximately 0.2 mg. of each of these compounds in 0.5 cc. of 95% isopropyl alcohol was chromatographed on a 0.9 × 9.5 cm. column with 7 cc. of 94% isopropyl alcohol as developer. The streaked column showed that the five components had been resolved into five separate zones as follows, measured in cm. from the top of the column: α-D-galacturonic acid, 0–0.3; D-galactose, 0.7–1.4; D-glucose, 2.0–2.8; D-xylose, 3.7–4.9; L-rhamnose, 6.0–7.5. The order follows by reference to the adsorption series, assuming that no reversals in order occurred on changing the developer from ethyl alcohol to isopropyl alcohol. In this case, separate chromatograms of each component showed that no reversals had occurred.

Summary

1. A method for the chromatographic analysis of the unsubstituted sugars and related compounds has been established.
2. A number of sugars and related compounds have been arranged in a chromatographic adsorption series.
3. A mixture of D-glucose and sorbitol was separated and each zone analyzed to show a quantitative separation.
4. The following mixtures were separated and their components recovered in nearly quantitative yields: D-mannitol and dulcitol; sucrose and raffinose; pentaerythritol and dipentaerythritol.
5. The separation of the components of the following mixtures was demonstrated qualitatively: three dianhydrohexitols; sorbitol (98%) and D-mannitol (2%); ascorbic acid in lemon juice; D-gluconic acid and its lactones; a five-component sugar mixture.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE OHIO STATE UNIVERSITY]

D-Gluco-L-*tagato*-octose[1]

BY M. L. WOLFROM AND ALVA THOMPSON[2]

In previous communications of this series we have reported the development of a general method for the preparation of ketoses from the lactones of the sugar acids possessing one less carbon atom. We now wish to describe the application of this method to the synthesis of the first eight-carbon atom ketose, D-gluco-L-*tagato*-octose from D-gluco-D-*gulo*-heptono-γ-lactone (the D-α-glucoheptonolactone of E. Fischer[3]). The nomenclature which we have used for the new ketose is an extension of the device introduced by Hudson[4] for aldoses of higher-carbon content.

The immediate starting point for our work was the crystalline D-gluco-D-*gulo*-heptonic acid hexaacetate monohydrate.[5] The course of reaction in this synthesis runs: D-gluco-D-*gulo*-heptonic acid monohydrate (I) → sodium D-gluco-D-*gulo*-heptonate hexaacetate trihydrate (II) → D-gluco-D-*gulo*-heptonyl chloride hexaacetate (III) → 1-diazo-1-desoxy-*keto*-D-gluco-L-*tagato*-octose hexaacetate (IV) → *keto*-D-gluco-L-*tagato*-octose hexaacetate (V) → D-gluco-L-*tagato*-octose (VI). All members of this series were crystalline with the exception of the acid chloride (III) and the keto-octose (VI). The latter was isolated as an amorphous solid characterized by its known phenylosazone, *keto*-acetate, elementary analysis and rotation. It was not fermented by yeast. It failed to give a Seliwanoff ketose reaction, although D-glucoheptulose exhibits a weak Seliwanoff test.

The solubility of the sodium salt (II) was unusual. It was soluble in water, benzene and chloroform. These solubilities allow of some comparisons in optical rotatory power. The salt possessed a molecular rotation $[M]^{20}D$ in chloroform of +11,600° while that of the free acid[5a] in the same solvent was +3000°. This difference might be interpreted to indicate that this hydrated salt ionized in chloroform solution.

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(1) Paper No. 9 in the series entitled "The Action of Diazomethane upon Acylic Sugar Derivatives;" previous communication, M. L. Wolfrom and A. Thompson, THIS JOURNAL, **68**, 791 (1946).

(2) Research Foundation Associate of the Graduate School.

(3) (a) E. Fischer, *Ann.*, **270**, 64 (1892); (b) *cf.* H. Kiliani, *Ber.*, **19**, 767 (1886).

(4) C. S. Hudson, THIS JOURNAL, **60**, 1537 (1938); "Advances in Carbohydrate Chem.," **1**, 12, 28 (1945).

(5) (a) M. L. Wolfrom, M. Konigsberg and D. I. Weisblat, THIS JOURNAL, **61**, 574 (1939); (b) G. B. Robbins and F. W. Upson, *ibid.*, **62**, 1074 (1940).

Although the acid chloride (III) did not crystallize and could not be purified, it gave a rather good yield of the crystalline methyl D-gluco-D-*gulo*-heptonate hexaacetate. The diazomethyl ketone (IV) was however obtained initially in a very impure state. As high as nine recrystallizations failed to effect complete removal of impurities. Adequate purification of this substance and also of the *keto*-acetate (V) was accomplished by the general chromatographic procedures previously reported[6] from this Laboratory. The *keto*-acetate (V) exhibited a carbonyl absorption band in the ultraviolet spectral region.

Experimental

Sodium D-Gluco-D-*gulo*-heptonate Hexaacetate Trihydrate.—Twenty grams of D-gluco-D-*gulo*-heptonic acid hexaacetate monohydrate[5a] was suspended in a solution of 3.36 g. of sodium bicarbonate in 50 cc. of water and stirred occasionally until it was all in solution. The solution, after treatment with decolorizing carbon, was evaporated under reduced pressure at 50° to a sirup. The sirup was dissolved in ethanol and placed at ice-box temperature to crystallize; yield 15 g. Recrystallization from ethanol gave pure material; m. p. 46–48°, $[\alpha]^{20}_D$ +6.1° (*c* 3.9, water), $[\alpha]^{20}_D$ +21° (*c* 4, abs. chloroform). The salt was soluble in chloroform, benzene, ethanol, acetone and water; slightly so in ether; and was insoluble in petroleum ether.

Anal. Calcd. for $C_6H_7O_6(CH_3CO)_6COONa \cdot 3H_2O$: Na, 4.14; sapon. value, 10.82 cc. of 0.1 *N* sodium hydroxide per 100 mg. Found: Na, 4.11; sapon. value, 10.82 cc.

Methyl D-Gluco-D-*gulo*-heptonate Hexaacetate.—Five grams of D-gluco-D-*gulo*-heptonic acid hexaacetate monohydrate[5a] was suspended in dry ether and diazomethane (slightly in excess of one mole) in ether solution was added and allowed to stand for four hours. After filtration and evaporation to a sirup, the substance crystallized; yield 4.5 g. Four recrystallizations from ethanol gave pure material; m. p. 94–95°, $[\alpha]^{20}_D$ +13.1° (*c* 4, abs. chloroform). The substance had the usual sugar acetate solubilities.

Anal. Calcd. for $C_6H_7O_6(CH_3CO)_6COOCH_3$: C, 48.77; H, 5.73; sapon. value (7 equivs.), 14.22 cc. of 0.1 *N* sodium hydroxide per 100 mg. Found: C, 48.50; H, 5.72; sapon. value, 14.37 cc.

1-Diazo-1-desoxy-*keto*-D-gluco-L-*tagato*-octose Hexaacetate.—Sodium D-gluco-D-*gulo*-heptonate hexaacetate trihydrate (17 g.) was repeatedly dissolved in benzene and the solvent removed under reduced pressure at 50°. The resulting sirup was dissolved in 50 cc. of benzene, 10 cc. of specially purified[7] thionyl chloride added and the whole refluxed for twenty minutes. The volatile material was removed by distillation under reduced pressure at 50°. The resultant sirup was repeatedly dissolved in benzene and the solvent distilled under reduced pressure until all of the excess thionyl chloride had been removed. The sirup, after solution in dry ether, was poured slowly into an ether solution of diazomethane (slightly in excess of two moles per mole of acid chloride). The ether solution was filtered and evaporated to a sirup which was dissolved in the smallest possible amount of benzene, diluted with ether and petroleum ether and allowed to crystallize at ice-box temperature; yield, 12 g., m. p. 102–105°. Further recrystallization (nine times) failed to produce pure material. Five grams of the once crystallized material was dissolved in 50 cc. of benzene and placed on a chromatographic column[6] (240 mm. × 80 mm.[8]) containing 400 g. of "Magnesol"[9] (sifted through a 200 mesh screen) and developed with 2500 cc. of benzene–ethanol (100–1[10]). The main zone containing the diazomethyl ketone was above the middle of the column. The product was removed from the cut zone by elution with 300 cc. of acetone. The sirup obtained by evaporation of the acetone was further purified by two more chromatographic treatments effected in the same manner; yield 0.5 g., m. p. 110–111°, $[\alpha]^{20}_D$ +84.6° (*c* 4.3, abs. chloroform). The substance possessed a light cream color.

Anal. Calcd. for $C_8H_8O_7(CH_3CO)_6N_2$: C, 47.81; H, 5.22; N, 5.57; CH_3CO, 11.94 cc. of 0.1 *N* sodium hydroxide per 100 mg. Found: C, 48.06; H, 5.18; N, 5.54; CH_3CO, 12.12 cc.

***keto*-D-Gluco-L-*tagato*-octose Heptaacetate.**—Five grams of crude 1-diazo-1-desoxy-*keto*-D-gluco-L-*tagato*-octose hexaacetate was dissolved in 100 cc. of glacial acetic acid, heated to boiling and a trace of copper acetate (0.01 g.) was added. As soon as the violent reaction had subsided the solution was evaporated under reduced pressure at 50° to about 15 cc. The solution was then diluted with 50 cc. of chloroform and washed three times with water, dried with anhydrous sodium sulfate and evaporated under reduced pressure to a sirup. Previous experience with this reaction has indicated that considerable deacetylation takes place. The sirup was therefore completely acetylated by treatment with 50 cc. of acetic anhydride containing 0.5 g. of zinc chloride. After standing overnight at room temperature the acetic anhydride was hydrolyzed with 200 g. of ice and water. The acetate was extracted with chloroform, the chloroform solution washed with water, dried and evaporated under reduced pressure to a sirup. The sirup failed to crystallize.

The sirup was dissolved in 50 cc. of benzene and placed on a chromatographic column (240 × 80 mm.[8]) containing 400 g. of "Magnesol"[9] and developed with 2500 cc. of benzene–ethanol (100–101[10]). The principal zone near the top, after elution with 300 cc. of acetone produced crystalline material; yield 1 g., m. p. 65–69°. The pure substance was obtained after two crystallizations from ethanol-water; m. p. 77–79°, $[\alpha]^{21}_D$ +35° (*c* 4.2, abs. chloroform). The absorption spectrum[11] showed a maximum at 2790 Å. log $\epsilon_{max.}$[12] = 1.61 (*c* 0.0124 molar in U. S. P. chloroform, 1 cm. cell, Beckman ultraviolet spectrophotometer). The substance gave a positive Pacsu[13] test for *keto*-acetates.

Anal. Calcd. for $C_8H_9O_8(CH_3CO)_7$: C, 49.43; H, 5.65; CH_3CO, 13.10 cc. of 0.1 *N* sodium hydroxide per 100 mg. Found: C, 49.36; H, 5.53; CH_3CO, 13.19 cc.

D-Gluco-L-*tagato*-octose.—Three grams of *keto*-D-gluco-L-*tagato*-octose heptaacetate was deacetylated with barium hydroxide as described for *keto*-D-psicose pentaacetate[14] and the resultant amorphous solid isolated in the same manner; yield 1.0 g. of amorphous material, $[\alpha]^{23}_D$ +30.8° (*c* 3.9, water, no detectable mutarotation).

Anal. Calcd. for $C_8H_{16}O_8$: C, 40.00; H, 6.72. Found: C, 40.06; H, 6.60.

The ketose reduced Fehling solution. It failed to give typical color reactions in hydrochloric acid with resorcinol (Seliwanoff ketose reaction), phloroglucinol and orcinol. Apparently these reactions are most applicable to the ketohexoses. In the case of D-glucoheptulose the colors[15] appear slowly and are followed by heavy dark precipitates. The ketoöctose formed precipitates before the color phase could be observed. The new ketoöctose was not fermented by yeast. It possessed a sweet taste.

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(6) W. H. McNeely, W. W. Binkley and M. L. Wolfrom, This Journal, **67**, 527 (1945).

(7) J. W. E. Glattfeld and B. D. Kribben, *ibid.*, **61**, 1720 (1939).

(8) Dimensions of the column of adsorbent.

(9) A product of Westvaco Chlorine Products Corp., South Charleston, West Virginia.

(10) Volume ratio.

(11) We are indebted to Mr. E. E. Pickett of this Laboratory for this analysis.

(12) $\epsilon_{max.} = E_{max.} \times$ mol. wt./$C \times D$; C = g./l., D = cell thickness in cm.

(13) E. Pacsu and F. V. Rich, This Journal, **55**, 3018 (1933). F. B. Cramer and E. Pacsu, *ibid.*, **59**, 1467 (1937).

(14) M. L. Wolfrom, A. Thompson and E. F. Evans, *ibid.*, **67**, 1793 (1945).

(15) G. Bertrand and G. Nitzberg, *Bull. soc. chim.*, [4] **43**, 1019 (1928).

The substance produced a phenylosazone in the usual manner; m. p. 208° (dec., uncor.) which is in good agreement with the reported[16] value of 210–212° (dec., uncor.).

Anal. Calcd. for $C_{20}H_{24}O_6N_4$: C, 57.40; H, 6.26; N, 13.36. Found: C, 57.48; H, 6.08; N, 13.40.

Acknowledgment.—One of us (A. T.) acknowledges a stipend from the funds of The Ohio State University Research Foundation administered by the Graduate School.

Summary

1. D-Gluco-L-*tagato*-octose has been synthesized in amorphous form.

2. Sodium D-gluco-D-*gulo*-heptonate hexaacetate trihydrate, 1-diazo-1-desoxy-*keto*-D-gluco-L-*tagato*-octose hexaacetate, *keto*-D-gluco-L-*tagato*-octose heptaacetate and methyl D-gluco-D-*gulo*-heptonate hexaacetate have been synthesized in crystalline form.

COLUMBUS, OHIO RECEIVED APRIL 1, 1946

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[16] Ref. 3a, p. 98.

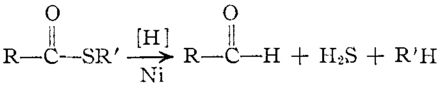
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE OHIO STATE UNIVERSITY]

A New Aldehyde Synthesis[1]

BY M. L. WOLFROM AND J. V. KARABINOS

In their important studies on the desulfurization and reducing action of Raney nickel, Bougault, Cattelain and Chabrier[2] attempted to prepare acetaldehyde from thioacetic acid. Using Raney nickel in aqueous ethanol, the only product they isolated was acetic acid, apparently obtained by simple hydrolysis. Mention was made by these workers that acetaldehyde was formed when absolute ethanol was employed as a solvent, a result that is vitiated by the fact that ethanol has been shown[3] to produce acetaldehyde under these conditions.

In an attempt to extend the desulfurization reaction to the synthesis of aldehydes, particularly in connection with *aldehydo*-sugar studies, we have resorted to the reduction of the thiol esters.[1]



$$R-\overset{\overset{\displaystyle O}{\|}}{C}-SR' \xrightarrow[Ni]{[H]} R-\overset{\overset{\displaystyle O}{\|}}{C}-H + H_2S + R'H$$

The thiol esters were prepared by the reaction of the acid chloride with an excess of ethyl mercaptan in pyridine or by reaction of the acid chloride with lead mercaptide in dry ether. The hydrogenolyses were carried out with Raney nickel in 70–80% ethanol under reflux essentially as described[3] for the hydrogenolysis of thioacetals. The above reaction was established by hydrogenolysis of the thiol esters of benzoic, propionic and tetraacetyl-D-ribonic acids which gave benzaldehyde, propionaldehyde and *aldehydo*-D-ribose tetraacetate, respectively.

The method described herein thus establishes another direct route for the reduction of the carboxyl group to the aldehyde stage and is alternative to the acid chloride reduction of Rosenmund.[4,4a]

Experimental

Hydrogenolysis of Ethyl Thiolbenzoate.—Ethyl thiolbenzoate, b. p. 155–156° at 52 mm., $n^{20}\text{D}$ 1.5721 and $d^{20}{}_4$ 1.1003,[5] was prepared by the reaction of benzoyl chloride with an excess of ethyl mercaptan in pyridine. Ten grams of the thiol ester was dissolved in 200 cc. of 70% ethanol containing 50 g. of Raney nickel and refluxed for six hours. After removal of the catalyst, the ethanolic solution was distilled and the aldehyde isolated from the distillate by treatment with sodium bisulfite; yield 8.0 g. (62%) of benzaldehyde sodium bisulfite complex. The aldehyde was regenerated from the complex; $n^{20}\text{D}$ 1.547, melting point of 2,4-dinitrophenylhydrazone 233–235° (accepted values[6] are $n^{20}\text{D}$ 1.5460 and m. p. 237°).

Ethyl Thiolpropionate.—Lead ethylmercaptide[7] (132 g.) was covered with 1500 cc. of ethyl ether and 72 g. of propionyl chloride added dropwise. After standing overnight, the filtered solution was concentrated on a steam-bath to an oil which was distilled through a column of ten theoretical plates; yield of ethyl thiolpropionate 77 g. (82%), b. p. 136°, $n^{20}\text{D}$ 1.4584, $d^{20}{}_4$ 0.9608, m. p. −95°.

Anal. Calcd. for $C_5H_{10}OS$: C, 50.80; H, 8.44; S, 27.12. Found: C, 50.90; H, 8.65; S, 26.89.

Hydrogenolysis of Ethyl Thiolpropionate.—Five grams of ethyl thiolpropionate was treated as described above with 50 g. of Raney nickel in 200 cc. of 80% ethanol and the product was isolated in the same manner; yield 5.0 g. (73%) of propionaldehyde sodium bisulfite complex. The 2,4-dinitrophenylhydrazone was prepared; m. p. 153–154° unchanged on admixture with an authentic sample of like melting point.

Ethyl Thiol-D-ribonate Tetraacetate.—D-Ribonyl chloride tetraacetate[8] was treated with an excess of ethyl

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[1] An outline of this work was reported in a preliminary communication: M. L. Wolfrom and J. V. Karabinos, THIS JOURNAL, **68**, 724 (1946).

[2] J. Bougault, E. Cattelain and P. Chabrier, *Compt. rend.*, **208**, 657 (1939); *Bull. soc. chim.*, [5] **7**, 781 (1940).

[3] M. L. Wolfrom and J. V. Karabinos, THIS JOURNAL, **66**, 909 (1944).

[4] K. W. Rosenmund, *Ber.*, **51**, 585 (1918).

[4a] Added during the reading of the proof: V. Prelog, J. Norymberski and O. Jeger, *Helv. Chim. Acta*, **29**, 360 (1946), and O. Jeger, J. Norymberski, S. Szpilfogel and V. Prelog, *ibid.*, **29**, 684 (1946), employing similar conditions but using 95% ethanol ("Feinsprit") have reported the reduction of thiol esters to primary alcohols.

[5] L. S. Pratt and E. E. Reid, THIS JOURNAL, **37**, 1937 (1915), reported b. p. 146° at 31 mm. and $d^{25}{}_{25}$ 1.0977.

[6] Huntress and Mulliken, "Identification of Pure Organic Compounds, Order I," John Wiley and Sons, Inc., New York, N. Y., 1941, p. 60.

[7] P. Borgstrom, L. M. Ellis, Jr., and E. E. Reid, THIS JOURNAL, **51**, 3649 (1929).

[8] R. Pasternack and E. V. Brown, U. S. Patent 2,237,263 (1941); M. L. Wolfrom, A. Thompson and E. F. Evans, THIS JOURNAL, **67**, 1793 (1945).