man model DU quartz spectrophotometer at concentrations of approximately 3×10^{-4} *M* in ethanol. The infrared spectra were run with a Perkin-Elmer model 112 in the region 3200–3700 cm.$^{-1}$ using a lithium fluoride prism. Each compound was run at two different concentrations (0.5 and 2.0 *M*) in carbon disulfide.

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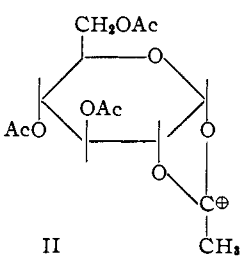
A Study of the Reaction of β-D-Glucose Pentaacetate with Phosphorus Pentachloride

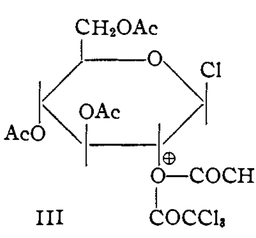
BY WILLIAM G. DAUBEN AND C. WHEATON VAUGHAN

RECEIVED JULY 6, 1954

The reaction of β-D-glucose pentaacetate with phosphorus pentachloride to yield β-2-trichloroacetyl-3,4,6-triacetylglucosyl chloride (I) has received attention in recent years with regard to the mechanistic pathways involved in the reaction sequence. Marcy and Scattergood,[1] as well as Lemieux,[2] have postulated that the reaction proceeds through the positive ion of type II which, in turn, is chlorinated.



II



III

On the other hand, Abramovitch[3] has suggested that trichlorination is due solely to the -I effect of the C_1-chlorine. An entirely different suggestion has been made by Brigl[4] who viewed the reaction as proceeding *via* an exchange reaction between the C_2-acetyl group and the trichloroacetyl chloride formed from the original C_1-acetyl group. In view of the recent demonstration of an intramolecular exchange reaction with acid chlorides[5] it was believed of interest to investigate the possibility of an intermolecular exchange, proceeding through an ion of type III, in this reaction of glucose pentaacetate.

C^{14}-Labeled pentaacetate was prepared by allowing carboxyl-labeled acetyl chloride to react with 2,3,4,6-tetraacetyl-D-glucose in pyridine solution. The highly purified β-pentaacetate, after isotopic dilution, was allowed to react with phosphorus pentachloride and the two reaction products, acetyl chloride and I, were isolated and purified. The radioactivity was found to reside in the acetyl chloride fraction, the glucose derivative being entirely inactive. Such results clearly rule out any exchange reaction but they are entirely in accord with the other mechanisms.

It was of further interest to investigate whether acetyl chloride did trichlorinate under the conditions of the reaction. To obtain some information pertaining to this reaction, the volatile phosphorus residues of the reaction were diluted with non-labeled trichloroacetyl chloride which, in turn, was recovered by distillation. The chloride was found to possess a small amount of radioactivity, indicating that some trichlorination of acetyl chloride indeed had occurred. Unfortunately, the counting error introduced by the low activity of the highly diluted trichloroacetyl chloride makes inexact any estimate of the degree of the chlorination reaction. However, it appears that a value of 6 ± 3% is reasonable.

Acknowledgment.—The authors are indebted to Dr. E. Hardegger of the Organisch-chemisches Laboratorium der Eidg. Technischen Hochschule, Zurich, for kindly supplying the tetraacetylglucose employed in this study.

Experimental[6]

1-Acetyl-labeled β-D-Glucose Pentaacetate.—A mixture of carboxyl-labeled sodium acetate (0.707 g., 8.6 mmoles, 50 μc.) and benzoyl chloride (2.42 g., 17 mmoles) was heated and the acetyl chloride allowed to distil. The product (0.5 ml.) was added, with stirring, to a solution of 2.99 g. (8.6 mmoles) of β-D-2,3,4,6-tetraacetylglucose (m.p. 130–131°) in 3.4 ml. of anhydrous pyridine at 0°. Upon standing for 20 hours, the solution was poured, with stirring, into 15 ml. of water and allowed to stand one hour. Filtration, followed by recrystallization from 95% ethanol, yielded 1.15 g. of pure β-D-glucose pentaacetate, m.p. 132.5–133°. A mixed melting point of the product with an authentic sample showed no depression. The active product was diluted with 22 g. of inactive material and recrystallized from ethanol. The specific activity was 14.1 cts./min./mg. $BaCO_3$ (corrected, 225 cts./min./mg. $BaCO_3$).[7]

Anal. Calcd. for $C_{16}H_{22}O_{11}$: C, 49.23; H, 5.69. Found: C, 49.16; H, 5.88.

β-D-2-Trichloroacetyl-3,4,6-triacetylglucosyl Chloride (I).—Labeled β-D-glucose pentaacetate (23.0 g., 59 mmoles) was well ground with phosphorus pentachloride (61.5 g., 0.3 mole) in a flask which subsequently was fitted with a reflux condenser. The mixture was heated on a steam-bath for 2.5 hours during which time all the solids had turned to a viscous sirup. The placement of a cold trap (cooled by Dry Ice) after the reflux condenser was essential to condense the evolved acetyl chloride. The crude acid chloride then was distilled through a small column packed with glass helices: b.p. 51.5°, specific activity 112 cts./min./mg. $BaCO_3$ (corrected, 224). The anilide prepared from the acetyl chloride melts from 114–115° (lit. 114°).

After completion of the heating period, the volatile compounds of phosphorus were removed from the reaction mixture by distillation at 1 mm. pressure and the distillate was collected in a cold trap. The residue after this operation was dissolved in ether and allowed to stand at 0° overnight.

The crystalline material from the ether solution was filtered and the solid ground under 10 ml. of absolute methanol and then filtered immediately. A second wash with 5 ml. of methanol was performed and the product dried at room temperature at reduced pressure, m.p. 139–141° (lit.[4] 142°), yield 3.0 g., specific activity 0.0 cts./min./mg. $BaCO_3$.

Anal. Calcd. for $C_{14}H_{16}O_9Cl$: C, 35.77; H, 3.44; Cl, 30.26. Found: C, 35.64; H, 3.64; Cl, 30.08.

Isotopic Dilution of Trichloroacetyl Chloride.—Trichloroacetyl chloride (24.0 g., 0.132 mole) was added to the

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[1] W. Marcy and A. Scattergood, Abstracts of the 115th Meeting of the A.C.S., San Francisco, Calif., 1949, p. 46-L.

[2] R. U. Lemieux, *Can. J. Chem.*, **29**, 1079 (1951); **31**, 1040 (1953).

[3] R. A. Abramovitch, *J. Chem. Soc.*, 2996 (1951).

[4] P. Brigl, *Z. physiol. Chem.*, **116**, 1 (1921).

[5] For leading references concerning intramolecular exchange of this type, see J. Cason and R. D. Smith, *J. Org. Chem.*, **18**, 1201 (1953).

[6] Analyses and combustion of the C^{14}-labeled materials were performed by the Microanalytical Laboratory of the Department of Chemistry and Chemical Engineering, University of California, Berkeley. All melting points are corrected. All boiling points are uncorrected.

[7] The corrected specific activity is obtained by multiplying the original specific activity by the number of carbon atoms in the molecule. This value then corresponds to the specific activity of the singly labeled carbon atom.

volatile phosphorus compounds isolated above. The mixture was refluxed for 0.5 hour and then distilled through an efficient column. The forerun boiling from 80–110° was discarded and the fraction boiling 110–112° accepted. A portion of this fraction was added to concentrated aqueous ammonia at 0° and the amide formed was recrystallized twice from water, m.p. 142–143° (lit. 141°), specific activity 3.0 cts./min./mg. $BaCO_3$ (corrected, 6.0).

Radioactivity Determinations.—All C^{14}-containing compounds were oxidized under reduced pressure with the oxidation mixture of Van Slyke and Folch,[8] the carbon dioxide collected in sodium hydroxide and precipitated in the usual manner.[9] The radioactivity was determined with thin uniform layers of barium carbonate, using a thin mica-windowed Geiger–Müller tube.

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(8) D. D. Van Slyke and J. Folch, *J. Biol. Chem.*, **136**, 509 (1940).

(9) W. G. Dauben, J. C. Reid and P. E. Yankwich, *Anal. Chem.*, **19**, 828 (1947).

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The Acid-catalyzed Condensation of Tertiary Alcohols with Benzaldehyde[1]

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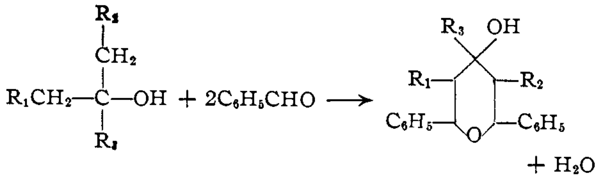
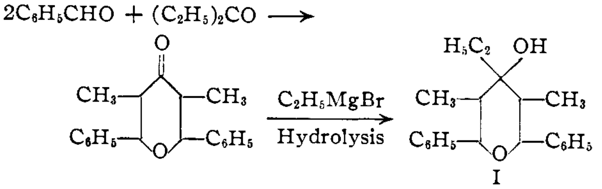
RECEIVED OCTOBER 11, 1954

Primary and secondary alcohols have been shown to be oxidized by aromatic aldehydes.[2] Tertiary alcohols react with benzaldehyde to produce eventually colored products without oxidation. This evidence of reaction led us to try to isolate and independently synthesize some products of the reaction. It was found that the reaction follows the scheme



These tetrahydropyranols have not been reported previously. The reaction conditions suggest that the actual reactants are the aliphatic olefin with the conjugate acid of the aldehyde.[3] The condensation of triethylcarbinol with benzaldehyde yielded 2,6-diphenyl-3,5-dimethyl-4-ethyl-4-tetrahydropyranol (I) the structure of which was proved by the synthesis



I

The reaction of the ketone with ethylmagnesium bromide yielded a product identical in all respects with I. Since a large number of isomers is possible (4 *meso* forms and 6 racemates) it is noteworthy that both routes lead to the same compound.

2,6-Diphenyl-4-methyl-4-tetrahydropyranol was prepared by condensation of *t*-butyl alcohol and benzaldehyde. Reaction of the higher melting isomer of 2,6-diphenyl-4-tetrahydropyrone with methylmagnesium iodide gave the same product in low yield.

Dimethylethylcarbinol and methyldiethylcarbinol yielded crystalline products in the reaction, but both proved to be different from any compounds prepared by the other route.

Experimental

2,6-Diphenyl-4-methyl-4-tetrahydropyranol by Acid Condensation.—Twenty-five ml. each of benzaldehyde and *t*-butyl alcohol and 100 ml. of 20% (volume) sulfuric acid were added to a one-liter flask equipped with a sealed stirrer and condenser. The reaction mixture was maintained at a temperature of between 120 and 130° for one hour, with vigorous stirring. The unreacted benzaldehyde was then steam distilled out of the reaction mixture and the remaining viscous oily substance was dissolved in boiling petroleum ligroin. Upon cooling, clusters of colorless needles appeared which were recrystallized and washed with petroleum ligroin. The yield was 1.6 g. of crystals melting at 143–144°. The residue (200 mg.) remaining in solution in the petroleum ligroin was chromatographed on a Magnesol–Celite column,[4] using progressively richer mixtures of benzene in hexane.

The major (88 mg.) crystalline substance separated was identical with that isolated above. Minor amounts of crystalline mixtures appeared both before and after this product in the chromatogram. *Anal.* Calcd. for $C_{18}H_{20}O_2$: C, 80.6; H, 7.51; mol. wt., 268. Found: C, 80.7; H, 7.62; mol. wt., 287 (Rast, using exaltone).

2,6-Diphenyl-3,5-dimethyl-4-ethyl-4-tetrahydropyranol by Acid Condensation. Method I.—Twenty-five ml. of benzaldehyde, 26 ml. of triethylcarbinol and 100 ml. of 20% (by volume) H_2SO_4 were treated as above, except that the temperature was 140° and the time three hours. The yield was 0.3 g. of crystalline substance melting at 177–178°.

Method II.—Forty-five grams of benzaldehyde, 20 g. of triethylcarbinol, 250 ml. of 95% alcohol and 320 ml. of 50% (by volume) sulfuric acid were mixed in a one liter flask. The flask was shaken at room temperature for 18 days. Before steam distillation, the mixture was partially neutralized by adding 50 g. of potassium hydroxide pellets with stirring and cooling. From here the procedure parallels that of method I. Chromatography of the residue on a Magnesol–Celite column yielded together with the original crop of crystals 3.7 g. of product melting 178–180°.

Anal. Calcd. for $C_{21}H_{26}O_2$: C, 81.3; H, 8.45; mol. wt., 310. Found: C, 81.2; H, 8.52; mol. wt. (Rast), 313.

Crystalline Substance from Dimethylethylcarbinol.—Sixty-six grams of benzaldehyde, 23 g. of *t*-amyl alcohol, 200 ml. of 95% ethanol and 100 ml. of distilled water were mixed in a two-liter round-bottom flask. With constant stirring and cooling, 90 ml. of concentrated H_2SO_4 was slowly added to the mixture. After stirring for two hours, 100 ml. of distilled water and 3 moles of KOH pellets were added slowly with cooling. The mixture was steam distilled, decanted and the oil dissolved in petroleum ligroin. The compound, separated by chromatography on the Magnesol–Celite column, melted at 142–143°, yield 0.5 g., is probably a 2,6-diphenyl-3,4-dimethyl-4-tetrahydropyranol.

Anal. Calcd. for $C_{19}H_{22}O_2$: C, 80.8; H, 7.85. Found: C, 80.8; H, 7.98.

Crystalline Substance from Methyldiethylcarbinol.—The procedure was essentially the same as that for *t*-amyl alcohol, except that the ethanol was not used, and the sulfuric acid and water were mixed and cooled before adding to the organic mixture. The whole was shaken for 50 hours. The yield was one gram of material melting from 161 to 162°. *Anal.* Calcd. for $C_{20}H_{24}O_2$: C, 81.0; H, 8.16. Found: C, 81.0; H, 8.37. The compound is probably a 2,6-diphenyl-3,4,5-trimethyl-4-tetrahydropyranol.

Racemic 2,6-Diphenyl-4-methyl-4-tetrahydropyranol.—Seventy ml. of a benzene solution containing 1.2 g. (0.0048 mole) of *trans*-2,6-diphenyl-4-tetrahydropyrone[5,6] were

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(1) Work was performed in the Ames Laboratory of the Atomic Energy Commission.

(2) F. R. Duke, *Anal. Chem.*, **19**, 661 (1947).

(3) E. Arundale and L. A. Mikeska, *Chem. Revs.*, **51**, 505 (1952).

(4) G. S. Hammond and A. Raave, THIS JOURNAL, **73**, 1891 (1951).

(5) P. Petrenko-Kritschenko and D. Plotnikoff, *Ber.*, **30**, 2802 (1897).

(6) R. Cornubert and J. Viroit, *Compt. rend.*, **224**, 1114 (1947).