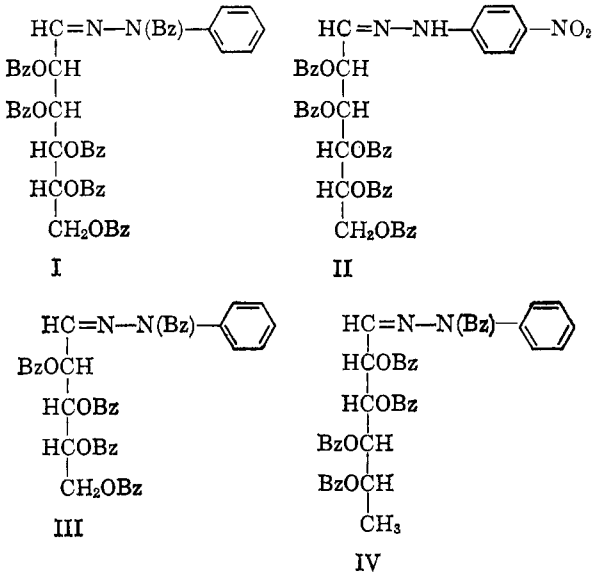
derivative, they were acyclic and possessed both *O*- and *N*-benzoyl groups. They were therefore designated *N*-benzoyltetra-*O*-benzoyl-*aldehydo*-D-arabinose phenylhydrazone (III) and *N*-benzoyltetra-*O*-benzoyl-*aldehydo*-L-rhamnose phenylhydrazone (IV), respectively. It seems that benzoyl chloride in pyridine,



being a more vigorous reagent than acetic anhydride in pyridine, leads in the case of acyclic sugar hydrazones to the acylation of the OH and NH groups and not merely the former ones. The *N*-benzoylated derivatives produced like the *N*-acetylated ones studied earlier[3] do not give azoethylene compounds on boiling with ethanolic pyridine.

Experimental[5]

N-Benzoylpenta-*O*-benzoyl-*aldehydo*-D-mannose Phenylhydrazone (I).—D-Mannose phenylhydrazone[6] (10 g.) was suspended in pyridine (70 ml.) and treated with benzoyl chloride (40 ml.). The reaction mixture warmed up spontaneously, darkened, and after 2 hr. returned to room temperature. It was left overnight, then poured onto crushed ice (1 kg.). The viscous residue that separated was washed repeatedly with water, then with aqueous sodium hydrogen carbonate to remove benzoic acid. After 2 days the *N*-benzoylpenta-*O*-benzoyl-*aldehydo*-D-mannose phenylhydrazone solidified and crystallized from ethanol as needles, yield 30 g. (91%), $[\alpha]^{20}D$ 62.5° (*c*, 1, chloroform), m.p. 169°; λ_{max}^{KBr} 1610 (C=N), 1660 (NBz), 1725 (OBz) cm.$^{-1}$; X-ray powder diffraction pattern[7]: 13.50 s, 12.11 w, 9.80 m, 8.00 vw, 6.86 w, 6.11 w, 5.54 m, 5.12 w, 4.82 s, 4.75 s, 4.08 s, 3.65 m, 3.59 m, 3.43 w, 3.11 m, 2.93 w.

Anal. Calcd. for $C_{54}H_{42}N_2O_{11}$: C, 72.47; H, 4.73; N, 3.13. Found: C, 72.35; H, 4.90; N, 3.18.

Penta-*O*-benzoyl-*aldehydo*-D-mannose *p*-Nitrophenylhydrazone (II).—*N*-Benzoylpenta-*O*-benzoyl-*aldehydo*-D-mannose phenylhydrazone (1 g.) was refluxed for 3 hr. with a solution of *p*-nitrophenylhydrazine (0.4 g.) in ethanol (50 ml.). The mixture was concentrated to 20 ml., whereupon some unchanged hydrazone separated and was filtered. The penta-*O*-benzoyl-*aldehydo*-D-mannose *p*-nitrophenylhydrazone subsequently crystallized from ethanol as yellow needles, yield 0.4 g. (48%), m.p. 105°; λ_{max}^{KBr} 1605 (C=N), 1730 (OBz) cm.$^{-1}$.

Anal. Calcd. for $C_{47}H_{37}N_3O_{12}$: C, 67.54; H, 4.46; N, 5.03. Found: C, 67.56; H, 4.59; N, 5.29.

N-Benzoyltetra-*O*-benzoyl-*aldehydo*-D-arabinose Phenylhydrazone (III).—D-Arabinose phenylhydrazone[8] (10 g.) was treated with pyridine (70 ml.) followed by benzoyl chloride (40 ml.), left to stand overnight at room temperature, then poured onto crushed ice (1 kg.). The viscous residue that separated was washed repeatedly with water, and crystallized by the addition of a few drops of ethanol. The *N*-benzoyltetra-*O*-benzoyl-*aldehydo*-D-arabinose phenylhydrazone was recrystallized from a mixture of ethanol and acetone as needles, yield 30 g. (95%), $[\alpha]^{20}D$ 52.5° (*c* 1, chloroform), m.p. 134°; ν_{max}^{KBr} 1605 (C=N), 1670 (NBz), 1725 (OBz) cm.$^{-1}$; X-ray powder diffraction pattern: 11.79 vs. 9.10 m, 8.67 vw, 7.90 m, 6.92 vw, 6.24 w, 5.80 w, 5.15 s, 5.07 s, 4.79 w, 4.55 vs, 4.13 m, 3.76 m, 3.49 m.

Anal. Calcd. for $C_{46}H_{36}N_2O_9$: C, 72.61; H, 4.77; N, 3.68. Found: C, 72.42; H, 4.64; N, 3.82.

N-Benzoyltetra-*O*-benzoyl-*aldehydo*-L-rhamnose Phenylhydrazone (IV).—L-Rhamnose phenylhydrazone[9] (10 g.) was benzoylated by the procedure used for the arabinose derivative and the product was purified by repeatedly dissolving it in ethanol and precipitating with water. After four such precipitations *N*-benzoyl tetra-*O*-benzoyl-*aldehydo*-L-rhamnose phenylhydrazone was dried in a vacuum desiccator, yield 25 g. (86%), $[\alpha]^{20}D$ 31.6° (*c* 1.3, chloroform), m.p. 95°; λ_{max}^{KBr} 1610 (C=N), 1680 (NBz), 1730 (OBz) cm.$^{-1}$.

Anal. Calcd. for $C_{47}H_{38}N_2O_9$: C, 72.85; H, 4.95; N, 3.62. Found: C, 72.14; H, 5.21; N, 3.36.

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(5) Melting points are corrected; infrared spectra were measured with a Perkin-Elmer Infracord spectrophotometer. Microanalyses were by W. N. Rond, The Ohio State University.

(6) E. Fisher, *Ber.*, **20**, 821 (1887); E. Fischer and J. Hirshberger, *ibid.*, **21**, 1805 (1888).

(7) Interplanar spacing, Å., Cu Kα radiation. Relative intensities estimated visually: s, strong; m, medium; w, weak; v, very.

(8) C. Tanret, *Bull. soc. chim. France*, [3]**23**, 395 (1902).

(9) E. Fischer and J. Tafel, *Ber.*, **20**, 2566 (1887).

5-Deoxy-D-glucose (5-Deoxy-D-*xylo*-hexose)[1]

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Deoxy sugars and their derivatives have been evaluated in biological systems as potent glycolytic inhibitors of various tumor tissues,[2-4] as intermediates for the preparation of antimetabolites, and as potential anticancer agents.[5]

This paper describes a convenient method for the preparation of 5-deoxy-D-*xylo*-hexose. The yield from D-glucose is 25%.

3-*O*-Acetyl-1,2-*O*-isopropylidene-α-D-glucofuranose[6] (I), prepared from 3-*O*-acetyl-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose, is the starting compound. It is tritylated and tosylated in one operation to produce 3-*O*-acetyl-1,2-*O*-isopropylidene-5-*O*-*p*-tolyl-

(1) Journal Paper No. 2297 of the Purdue University Agricultural Experiment Station.

(2) G. E. Woodword and M. T. Hudson, *Cancer Res.*, **14**, 599 (1954).

(3) J. O. Ely, *J. Franklin Inst.*, **258**, 157 (1954).

(4) J. Laszlo, B. Landau, K. Wight, and D. Burk, *J. Natl. Cancer Inst.*, **21**, 475 (1958).

(5) M. Dahlgard and E. Kaufmann, *J. Org. Chem.*, **25**, 781 (1960).

(6) K. Josephson, *Ann.*, **472**, 217 (1929).

sulfonyl-6-*O*-triphenylmethyl-α-D-glucofuranose (II) in 67% yield. Desulfonyloxylation and β-elimination of compound II with sodium methoxide affords crystalline 5-deoxy-1,2-*O*-isopropylidene-6-*O*-triphenylmethyl-α-D-*xylo*-hexofuran-5-enose (III) in 90% yield. A complete structure proof of compound III is described elsewhere.[7]

Hydrogenation of compound III, with palladium-on-carbon catalyst, produces pure, crystalline 5-deoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hexofuranose (5-deoxy-monoacetone-D-glucose, IV) in 80% yield. This compound on hydrolysis of the isopropylidene group with Amberlite IR-120(H^+) resin produces 5-deoxy-D-*xylo*-hexose.

Experimental

Analytical Methods.—Purity of crystalline products was determined by thin layer chromatography on silica gel G-coated[8] glass plates, irrigated with (A) chloroform–acetone (1:1 v./v.) and (B) 1-butanol saturated with water. Plates were sprayed with 5% ethanolic sulfuric acid and charred at 110° until permanent spots were visible. A calibrated Fisher-Johns apparatus was used for melting point determinations. Evaporations were done at reduced pressure.

3-*O*-Acetyl-1,2-*O*-isopropylidene-α-D-glucofuranose (I).—Acetylation of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in acetic anhydride and pyridine gave 3-*O*-acetyl-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose.[6] The acetyl derivative was dissolved in a 60% solution of aqueous acetic acid, allowed to stand for 5 hr. at 37°, and evaporated below 50° to a sirup which crystallized as a solid white mass of compound I. This was recrystallized from warm ethyl acetate, m.p. 126°, lit.[6] m.p. 125–126°.

3-*O*-Acetyl-1,2-*O*-isopropylidene-5-*O*-*p*-tolylsulfonyl-6-*O*-triphenylmethyl-α-D-glucofuranose (II).—Compound I (180 g.) was dissolved in 900 ml. of dry pyridine to which was added 200 g. of trityl chloride (chlorotriphenylmethane). After 2 days at 25°, 400 ml. of pyridine was added and the solution was cooled to 5°. While the mixture was continuously stirred, 500 ml. of alcohol-free chloroform containing 350 g. of tosyl chloride (*p*-tolylsulfonyl chloride) was slowly added. After 3 days at 37°, the reaction mixture was cooled to 0° and 20 ml. of water was added to hydrolyze excess tosyl chloride. Within 0.5 hr., the solution was poured into a mixture of ice and water. The water layer was drawn off, extracted twice with chloroform, and the chloroform solution washed free of pyridine with several portions of chilled 15% aqueous acetic acid. Upon neutralization with a solution of sodium bicarbonate, the chloroform was washed free of salts and dried over anhydrous magnesium sulfate. After filtration and evaporation, a dark brown sirup was obtained; the yield was 450 g. which contained 300 g. of solids (compound II).

5-Deoxy-1,2-*O*-isopropylidene-6-*O*-triphenylmethyl-α-D-*xylo*-hexofuran-5-enose (III).—A 225-g. portion of this dark brown sirup, obtained above was dissolved in 1685 ml. of chloroform. While this solution was stirred continuously and externally cooled, 900 ml. of a methanol solution containing 12.5% of sodium methylate was added. After 2 hr., the reaction mixture was slowly warmed to 25° where it was held for 16 hr. Then 100 ml. of a saturated solution of potassium bicarbonate was added and the mixture evaporated to remove methanol. The residue was extracted four times with chloroform, the chloroform was washed with water, dried over anhydrous magnesium sulfate, and evaporated. The residue was crystallized from a mixture of benzene and petroleum ether (b.p. 40–60°) yielding 90 g. (90%), of III, m.p. 83°, $[\alpha]^{25}D$ −15.4° (*c* 1.4, chloroform).

Anal. Calcd. for $C_{28}H_{28}O_5$ (444.50): C, 75.66; H, 6.34. Found: C, 75.4; H, 6.42.

5-Deoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hexofuranose (IV).—Compound III (45 g.) was dissolved in 325 ml. of absolute ethanol to which was added 325 ml. of an ethanol slurry containing 20 g. of 5% palladium on carbon. This mixture was subjected to 600 p.s.i. of hydrogen pressure and stirred for 2 hr. at 60°. During this period, the pressure dropped about 400 p.s.i. The pressure was again adjusted to 600 p.s.i. and the hydrogenation continued at 60° for 18 hr. The mixture was filtered and evaporated to a sirup which was dissolved in a mixture of petroleum ether and water. Triphenylmethane was reclaimed from the ether phase. The water phase contained compound IV. This solution was evaporated to a colorless sirup which was crystallized from a mixture of benzene and petroleum ether yielding 16 g. of IV, m.p. 94°, $[\alpha]^{25}D$ −10.0° (*c* 0.71, chloroform). The yield from compound I was 48%. The product migrated as a single component in irrigants A and B. An X-ray powder diffraction pattern of compound IV and an authentic sample[9] was identical.

Anal. Calcd. for $C_9H_{16}O_5$ (204.22): C, 52.94; H, 7.89. Found: C, 53.0; H, 7.98.

5-Deoxy-D-*xylo*-hexose.—Two grams of compound IV was dissolved in 50 ml. of water and stirred for 2.5 hr. at 60° with 8 g. of Amberlite IR-120(H^+) resin. The solution was filtered and concentrated to a colorless sirup, $[\alpha]^{25}D$ +40° (*c* 1.7, in water). The sugar was converted to the known[10] crystalline 5-deoxy-D-*threo*-hexose phenylosazone, m.p. 151°.

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(7) R. E. Gramera, T. R. Ingle, and R. L. Whistler, *J. Org. Chem.*, **29** 1083 (1964).

(8) Brinkmann Instruments, Inc., Great Neck, Long Island, N. Y.

(9) T. E. Whiteley (Ohio State University, Columbus): *Univ. Microfilms*, Ann Arbor Mich., L. C. Card No. Mic. 60-6419, 122 pp.; *Dissertation Abstr.*, **21**, 2121 (1961).

(10) P. P. Regna, *J. Am. Chem. Soc.*, **69**, 246 (1947).

3-Deoxy-D-*glycero*-D-*ido*-octonic γ-Lactone

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Recently Richtmyer and Bodenheimer[2] described an octosaccharinic lactone isolated from the mother liquors of the sodium amalgam reduction of D-*erythro*-L-*talo*-octonic lactone, it being the first higher carbon saccharinic acid obtained from a sugar–alkali reaction.[3] The lactone[4] consumed 3 moles of sodium periodate in 15 min. and this value remained constant for 8 hr. Since Richards, *et al.*,[5] have shown that D-glucoisosaccharinic lactone is rapidly and completely degraded by periodate ion, the isosaccharinic acid structure is excluded for Richtmyer's lactone, **1**. The decision between the metasaccharinic acid and the saccharinic acid structure was made by comparing the proton magnetic resonance spectra of 3-deoxy-D-*arabino*-hexonic γ-lactone[6a] (β-D-glucometasaccharin),[6b] 2-*C*-methyl-D-*ribo*-pentonic γ-lactone[7a] (α-D-glucosaccharin),[7b] and the octonic lactone in the region τ 8.0–

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(2) N. K. Richtmyer and T. S. Bodenheimer, *J. Org. Chem.*, **27**, 1892 (1962).

(3) J. C. Sowden, *Advan. Carbohydrate Chem.*, **12**, 35 (1957).

(4) The author is indebted to Dr. N. K. Richtmyer, NIAMD, National Institutes of Health, for a gift of this lactone.

(5) G. N. Richards and H. H. Sephton, *J. Chem. Soc.*, 4492 (1957).

(6) (a) A gift from Dr. H. G. Fletcher, Jr., NIAMD, National Institutes of Health; (b) J. U. Nef, *Ann.*, **376**, 1 (1910).

(7) (a) J. C. Sowden and D. R. Strobach, *J. Am. Chem. Soc.*, **82**, 3707 (1960); (b) H. Kiliani, *Chem. Ber.*, **15**, 2953 (1882).