tion of 100 mg. of XI in 5 ml. of 3*N* hydrochloric acid was heated on the steam bath for 3 hr. After evaporation to dryness the residue was left in a desiccator over soda lime; then it was dissolved in methanol and filtered through Celite and Darco G-60 to give a quantitative yield of a colorless sirup; $[\alpha]^{26}_{D}$ +84 ± 1° (in water, *c* 1.09).

Anal. Calcd. for $C_8H_{18}O_6NCl$: C, 39.43; H, 7.44; Cl, 14.55; OCH_3, 25.47. Found: C, 39.34; H, 7.54; Cl, 14.52; OCH_3, 25.34.

*2-Acetamido-2-deoxy-3,6-di-O-methyl-α-*D*-glucopyranose* (XVI)[12]. The *N*-acetylation of XV was carried out with acetic anhydride in methanol in presence of silver acetate as previously described.[6] After recrystallization from a mixture of ethanol, ether, and pentane, the reaction of 11.7 mg. of XV gave 10 mg. (83%) of needles, m.p. 232–233°. The product showed mutarotation, from $[\alpha]^{25}_{D}$ +90° (after 15 min.) to $[\alpha]^{25}_{D}$ +35 ± 5° (after 24 hr., in water, *c* 0.29).

Anal. Calcd. for $C_{10}H_{19}O_6N$: C, 48.18; H, 7.68. Found: C, 48.35; H, 7.86.

*2-Deoxy-2-(2'-hydroxynaphthylidenamino)-3,6-di-O-methyl-*D*-glycopyranose* (XVII). A solution of 47 mg. of XV in 1 ml. of water was treated as previously described[6] with 90 mg. of 2-hydroxynaphthaldehyde and 25 mg. of sodium acetate trihydrate. Purification was obtained by chromatography on silicic acid. Elution with acetone and a mixture of acetone and methanol 4:1 gave crystalline fractions. The product being sparingly soluble in methanol was recrystallized from a mixture of pyridine and pentane to give 35 mg. (51%) of yellow prisms, m.p. 215–218° dec $[\alpha]^{25}_{5461}$ +305 ± 5° (at equilibrium, in methanol, *c* 0.15).

Anal. Calcd. for $C_{19}H_{23}O_6N$: C, 63.14; H, 6.41. Found: C, 63.16; H, 6.42.

*Methyl 2-acetamido-4,6-di-O-benzoyl-2-deoxy-3-O-methyl-α-*D*-glucopyranoside* (IV). To a solution precooled at −20° of 17 mg. of methyl 2-acetamido-2-deoxy-3-*O*-methyl-α-D-glucopyranoside (V)[3] in 1 ml. of anhydrous pyridine, was added 0.025 ml. of benzoyl chloride. After standing one day at 0°, the solution was diluted with chloroform, washed a few times each with 2*N* sulfuric acid, saturated sodium bicarbonate, then water, and dried over sodium sulfate. After evaporation, the residue was dissolved in benzene and chromatographed on silicic acid. Elution with a mixture of benzene and ether 2:1 and pure ether gave crystalline fractions. Recrystallization from a mixture of acetone, ether, and pentane gave 12 mg. (39%) of needles, m.p. 123–125°, $[\alpha]^{24}_{D}$ +85 ± 2° (in chloroform, *c* 0.74).

Anal. Calcd. for $C_{24}H_{27}O_8N$: C, 63.01; H, 5.95. Found: C, 62.56; H, 5.98.

*Methyl 2-acetamido-6-O-benzoyl-2-deoxy-3-O-methyl-α-*D*-glucopyranoside* (XIV)[13]. Twenty milligrams of V was cooled to −20° before addition of 0.20 ml. of pyridine and 0.01 ml. of benzoyl chloride previously cooled to −20°. After 1 day at 0°, 10 ml. of chloroform was added and the solution washed once with cold water, and twice each with cold 2*N* sulfuric acid, saturated sodium bicarbonate, and water. Concentration of the solution after drying over anhydrous sodium sulfate yielded 14 mg. (50%) that was crystallized from a mixture of chloroform and ether, m.p. 195–197°; $[\alpha]^{30}_{D}$ +84 ± 2° (in chloroform, *c* 0.39). In admixture with the product described above, the m.p. was not depressed.

*Methyl 2-acetamido-6-O-benzoyl-2-deoxy-3,4-di-O-methyl-α-*D*-glucopyranoside* (VII)[13]. To a cold solution of 10 mg. of methyl 2-acetamido-2-deoxy-3,4-di-*O*-methyl-α-D-glucopyranoside (VI)[6] in 0.1 ml. of pyridine was added 0.1 ml. of benzoyl chloride previously cooled to −20°. After standing overnight at 0° and at room temperature for an additional 24 hr., 10 ml. of chloroform was added and VII was isolated as outlined above for XIV. Crystallization from a mixture of chloroform and ether yielded 7 mg. (50%) of needles, m.p. 192–194°, $[\alpha]^{27}_{D}$ +110 ± 2° (in chloroform, *c* 0.25).

Anal. Calcd. for $C_{18}H_{25}O_7N$: C, 58.84; H, 6.86. Found: C, 58.79, H, 6.95.

Acknowledgment. The author wishes to thank Miss Ann Foley and Mrs. Shirley Butterworth for technical assistance.

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[12] This product was prepared by Dr. M. Cleland-Trémège and was described in thesis No. 1282 of the University of Geneva, Switzerland.

[13] This product was prepared by Dr. D. K. Stearns.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING, STANFORD UNIVERSITY]

The Anomers of Tetra-*O*-acetyl-2-deoxy-D-glucose

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The optically pure α- and β-anomers of tetra-*O*-acetyl-2-deoxy-D-glucose have been prepared for the first time by acetylation of 2-deoxy-D-glucose with acetic anhydride in pyridine, followed by fractional crystallization of the crude acetylation product. The β-anomer has been subjected to sulfuric acid catalyzed anomerization in 1:1 acetic anhydride–acetic acid solvent and found to yield a 91:9/α:β-anomer mixture. The anomerization using $10^{-3}M$ catalyst proceeded at a rate comparable to that of penta-*O*-acetyl-β-D-glucose using 0.5*M* catalyst, indicating an abnormally high rate of anomerization for the acetylated 2-deoxy-D-glucoses.

Although the 2-deoxyladoses constitute a chemically interesting and biologically important class of compounds[1] and although the first 2-deoxyhexose, 2-deoxy-D-glucose, was first described by Fischer in 1920,[2] the anomeric tetra-*O*-acetates of the latter substance appear to have been prepared only once. In 1949 Overend, Stacy and Staněk[3] reported the preparation of tetra-*O*-acetyl-2-deoxy-α-D-glucose, m.p. 91°, $[\alpha]^{20}_{D}$ +12.3° (C_2H_5OH) by acetylation of 2-deoxy-D-glucose with acetic anhydride in pyridine at 0°, and tetra-*O*-acetyl-2-deoxy-β-D-glucose, m.p. 75–78°, $[\alpha]^{20}_{D}$ +30° (C_2H_5OH) by acetylation with hot acetic anhy-

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[1] *Cf.* W. G. Overend and M. Stacey, *Advances in Carbohydrate Chem.*, **8**, 45–105 (1953).

[2] E. Fischer, M. Bergmann, and H. Schotte, *Ber.*, **53**, 509 (1920); *cf.* also M. Bergmann, H. Schotte, and W. Lechinsky, *Ber.*, **55**, 158 (1922); **56**, 1052 (1923).

[3] W. G. Overend, M. Stacey, and J. Staněk, *J. Chem. Soc.*, 2841 (1949).

dride and sodium acetate. These same substances appear later to have been employed as samples in an extensive investigation of the infrared absorption frequencies of carbohydrate derivatives,[4] but no new preparations or properties were given. *Aldehydo* tetra-*O*-acetyl-2-deoxy-D-glucose, m.p. 100°, $[\alpha]_D^{14}$ +23° ($CHCl_3$), prepared *via* the diethylmercaptal and characterized as several aldehyde derivatives, has also recently been described.[5] A need for the anomers of tetra-*O*-acetyl-2-deoxy-D-glucose in connection with studies on the mechanism of poly-*O*-acetylaldose anomerization has prompted us to reinvestigate the acetylation of 2-deoxy-D-glucose, particularly since the optical rotations recorded by Stacy and co-workers[3] do not accord with the nomenclature assigments customarily applying to anomeric pairs.

By acetylation of 2-deoxy-D-glucose at room temperature or 0° with acetic anhydride in pyridine, we have obtained a syrupy tetra-*O*-acetate, $[\alpha]_D^{25}$ +34.4° ($CHCl_3$) in quantitative yield. Solution of this material in 2-propanol led to the gradual deposition of two types of crystals, hard prisms, and fluffy needles, which could be separated mechanically and used for seed in further fractional crystallization. Such a procedure led ultimately to optically pure tetra-*O*-acetyl-2-deoxy-α-D-glucose, long needles, m.p. 109.7–110.7°, $[\alpha]_D^{25}$ +107.7° ($CHCl_3$), as well as to the β-anomer, heavy prisms, m.p. 92.2–93.2° $[\alpha]_D^{25}$ −2.82° ($CHCl_3$). By subjecting the syrupy residue from the mother liquors of such a fractional crystallization to the anomerizing conditions described below, additional quantities of the α-anomer were readily obtainable. From these results it is clear that the anomeric acetates described by Overend, Stacey, and Staněk were in reality incompletely separated mixtures of the above pure anomers, and in fact we encountered mixtures whose properties approximated those described by these workers during our fractional crystallizations. We have also found that the acetylation of 2-deoxy-D-glucose with hot acetic anhydride and sodium acetate led to a crude product, $[\alpha]_D^{25}$ + 68.4° ($CHCl_3$) containing predominately the α-anomer (65%), from which the latter could be readily separated by fractional crystallization.

Both of the anomers of tetra-*O*-acetyl-2-deoxy-D glucose have been found to be obtainable directly from tri-*O*-acetyl-D-glucal, albeit in somewhat lower and less reproducible yield. Thus the action of hydrogen bromide on tri-*O*-acetyl-D-glucal in the presence of benzoyl peroxide, followed by treatment with silver acetate in adaptation of the procedure of Davoll and Lythgoe,[6] led to the crude acetylated β-anomer in 48% yield. Alternatively, solution of tri-*O*-acetyl-D-glucal in a 1:1 acetic anhydride–acetic acid solvent 0.5*M* in sulfuric acid, followed by customary processing within a period of two or three minutes, resulted in the formation of crude tetra-*O*- acetyl-2-deoxy-α-D-glucose. The latter preparation was somewhat improved using perchloric acid catalyst.

The sulfuric acid catalyzed anomerization of tetra-*O*-acetyl-2-deoxy-β-D-glucose was found to vary both quantitatively and qualitatively from that of penta-*O*-acetyl-β-D-glucose and related acetylated aldoses.[7] Thus 500- to 1000-fold lower acid catalyst concentrations sufficed to engender anomerization of tetra-*O*-acetyl-2-deoxy-β-D-glucose in 1:1 acetic anhydride–acetic acid solvent at rates comparable to those observed in the anomerization of acetylated aldoses. Also, if the customary higher acid catalyst concentrations (*ca.* 0.5*M*) were employed, secondary reactions ensued resulting in water-soluble sulfur-containing products rather than the anticipated equilibrium mixture of anomeric tetra-*O*-acetyl-2-deoxy-D-glucoses. The identity of these products is currently under investigation. Furthermore, both the simple pseudo-first-order kinetics[7] and the linear relationship between acid catalyst concentration and anomerization rate[7] observed for penta-*O*-acetyl-D-glucoses and related anomers have been found to break down in the case of tetra-*O*-acetyl-2-deoxy-β-D-glucose. Examination of Table I indicates the non-linearity of $k_1 + k_2$ with acid catalyst concentration over a 20-fold concentration range, as well as the more accentuated and occasionally somewhat random drifts of $k_1 + k_2$ as a function of time. Probable reasons for these observations will be discussed in a later manuscript concerning the anomerization mechanism.

Application of Hudson's Isorotation Rule calculations[8] to the anomers of tetra-*O*-acetyl-2-deoxy-D-glucose indicates a molecular rotation difference (2A) of 36,726, in good agreement with 2A of 38,220 for the anomeric penta-*O*-acetyl-D-glucoses.[9] The molecular rotation sum (2B) for acetylated 2-deoxy-D-glucoses, 34,852, lies intermediate between the 2B values of 41,180 for acetylated D-glucoses and 1,630 for acetylated D-mannoses.[9] 2A Values for methyl 2-deoxy-D-gluco-, 2-deoxy-D-galacto-, and 2-deoxy-L-arabinopyranosides have already been shown to be "normal."[1]

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[4] S. A. Barker, E. J. Bourne, R. Stephens, and P. H. Whiffen, *J. Chem. Soc.*, 3468, 4211 (1954).

[5] J. L. Barclay, A. J. Cleaver, A. B. Foster, and W. G. Overend, *J. Chem. Soc.*, 789 (1956).

[6] J. Davoll and B. Lythgoe, *J. Chem. Soc.*, 2526 (1949).

[7] W. A. Bonner, *J. Am. Chem. Soc.*, **73**, 2659 (1951); **81**, 1448, 5171 (1959); E. B. Painter, *J. Am. Chem. Soc.*, **75**, 1137 (1953); R. U. Lemieux and C. Brice, *Can. J. Chem.*, **30**, 295 (1952); R. U. Lemieux, C. Brice and G. Huber, *Can. J. Chem.*, **33**, 134 (1955).

[8] C. S. Gudson, *J. Am. Chem. Soc.*, **31**, 66 (1909).

[9] F. J. Bates and associates, *Polarimetry, Saccharimetry and the Sugars*, Natl. Bur. Stand. Circ. C440, U. S. Govt. Printing Office, Washington (1942); p. 729, 746.

TABLE I

SULFURIC ACID CATALYZED ANOMERIZATION OF 0.10*M* TETRA-*O*-ACETYL-2-DEOXY-β-D-GLUCOSE IN 1:1 ACETIC ANHYDRIDE–ACETIC ACID SOLVENT

	t, min.			Rotation, ° per 2 dcm.			$k_1 + k_2$, min.$^{-1}$		
$[H_2SO_4]$, *M*	0.0005	0.001	0.002	0.0005	0.001	0.002	0.0005	0.001	0.002
	0	0	0	0.04[a]	0.04[a]	0.04[a]	—	—	—
	1	1.5	1	.18	0.85	3.57	0.0267	0.0861	0.751
	3	3	1.5	.43	1.35	4.47	.0223	.0728	.725
	9	5	2	.83	2.00	5.08	.0140	.0695	.703
	28	7	2.5	1.95	2.56	5.46	.0120	.0677	.667
	47	9	3	2.96	3.10	5.76	.0122	.0681	.647
	86	12	3.5	4.29	3.78	5.96	.0118	.0684	.621
	114	15	4	5.22	4.35	6.13	.0131	.0693	.607
	137	18	4.5	5.30	4.83	6.24	.0113	.0702	.586
	169	21	5	5.77	5.20	6.29	.0115	.0705	.549
	202	24		6.04	5.50		.0113	.0708	
		30			5.93			.0712	
		35			6.17			.0714	
		165 (∞)[b]			6.72[c]				
				Extrapolated value of $k_1 + k_2$ at t_0:			.0123	.0700[d]	.800

[a] The "zero-time" rotations of the β-anomer as 0.04° and the α-anomer as 7.40° (2 dcm. tube) were established by observing the rotations of a 0.10*M* solution of each anomer in 1:1 acetic anhydride–acetic acid solvent lacking sulfuric acid, under which conditions the substances were optically stable. [b] This value remained unchanged during 3 days at room temperature. [c] This value corresponds to an equilibrium constant of 0.102, as calculated by the relation $k_e = [\beta]/[\alpha] = (r_\alpha - r_e)/(r_e - r_\beta)$. [d] Average value disregarding first point; average deviation, ±0.0013 min.$^{-1}$

EXPERIMENTAL

Acetylation of 2-deoxy-D-glucose. 2-Deoxy-D-glucose (5.00 g.; Nutritional Biochemicals corporation) was dissolved in pyridine (20 ml.). Acetic anhydride (15 ml.) was added and the mixture was stirred with water cooling until the solute had dissolved, then allowed to stand overnight. It was then poured into water (200 ml.), and stirred for 1 hr., and then extracted three times with chloroform. The extract was washed with 20% hydrochloric acid, water, and finally saturated sodium bicarbonate solution, then dried (anhydrous sodium sulfate), filtered, and stripped of solvent in a rotary vacuum evaporator yielding 10.64 g. (105%) of clear, crude, syrupy product, $[\alpha]^{25}_{\rm D}$ + 34.4° (*c* 3.573; $CHCl_3$). This optical rotation corresponds to a mixture containing 33.5% α-anomer and 66.5% β-anomer. The crude product was dissolved in 2-propanol (25 ml.) and seeded with tetra-*O*-acetyl-2-deoxy-β-D-glucose obtained from a previous acetylation. The solution was allowed to stand undisturbed for 15 hr., whereupon the fluffy solid material on top of the underlying mass of hard prisms was mechanically loosened and decanted with the mother liquor. The underlying hard crystalline mass was crushed, filtered and rinsed with a small amount of 2-propanol. The fraction weighed 6.16 g., m.p. 83–91°. Successive fractional recrystallization of this material from 2-propanol at room temperature ultimately produced 3.86 g. of tetra-*O*-acetyl-2-deoxy-β-D-glucose, sturdy prisms, m.p. 92.2–93.2°, $[\alpha]^{25}_{\rm D}$ −2.82° (*c*, 3.54; $CHCl_3$), + 0.6° (*c* ,3.32; 1:1 mixture acetic anhydride–acetic acid).

Anal. Calcd. for $C_{14}H_{20}O_9$ (332.3): C, 50.60; H, 6.07. Found: C, 50.72, 50.89; H, 6.06, 6.21.

The original fluffy needles obtained on the first crystalization of the above crude acetylation product were combined with similar material obtained during the subsequent fractional crystallization leading to the β-anomer. This fluffy material was recrystallized repeatedly from 2-propanol, ultimately yielding 1.14 g. of pure tetra-*O*-acetyl-2-deoxy-α-D-glucose, long needles, m.p. 109.7–110.7°, $[\alpha]^{25}_{\rm D}$ + 107.7° (*c* 1.133; $CHCl_3$); + 111.4° (*c* ,3.32; 1:1 mixture of acetic anhydride–acetic acid).

Anal. Calcd. for $C_{14}H_{20}O_9$ (332.3): C, 50.60; H, 6.07. Found: C, 50.56, 50.72; H, 6.00, 6.10.

The mother liquors from the above fractional crystalizations were stripped of their solvent *in vacuo*, yielding 4.70 g. of amber syrup. This was combined with similar material from a previous acetylation, and the resulting 5.32 g. was dissolved in 30 ml. of a 1:1 mixture of acetic anhydride and acetic acid. To the solution was added 1.6 ml. of 1.0 *M* sulfuric acid in a 1:1 mixture of acetic anhydride and acetic acid as solvent (final catalyst concentration, 0.05*M*). The solution was allowed to stand for 5 min., then added to water (150 ml.), stirred for 1 hr., and finally extracted four times with chloroform. The extract was washed with water then with saturated sodium bicarbonate solution and finally dried over anhydrous sodium sulfate. Solvent removal yielded 5.65 g. of sryup which immediately crystallized spontaneously. This was dissolved in 2-propanol (15 ml.), seeded with the above α-anomer and cooled gradually to 0°, producing 3.63 g. of additional tetra-*O*-acetyl-2 deoxy-α-D-glucose, m.p. 109–110°

When 1 g. of 2-deoxy-D-glucose was acetylated with acetic anhydride (10 ml.) and anhydrous sodium acetate (1.5 g.) by heating under reflux for 1.5 hr., the mixture darkened considerably. It was poured into ice water, stirred 2.5 hr., and processed in the usual fashion. The resulting crude dark syrup was dissolved in ether, decolorized by filtration through Norit, and stripped of solvent to yield 2.13 g. (105%) of white oil which crystallized spontaneously, $[\alpha]^{25}_{\rm D}$ +68.4° (*c*, 2.54; $CHCl_3$), corresponding to 65% α- and 35% β-anomer. Several recrystallizations of this material from 2-propanol afforded pure α-anomer

Tetra-O-acetyl-2-deoxy-β-D-glucose from triacetylglucal. Triacetylglucal[10] (4.00 g.) and benzoyl peroxide (*ca.* 50 mg.) were dissolved in benzene (30 ml.). The solution was cooled in ice and saturated with hydrogen bromide gas.[6] After saturation, the excess hydrogen bromide was removed by washing the benzene solution once with a large volume of ice water, then with iced sodium bicarbonate solution. The solution was dried immediately over anhydrous sodium sulfate, filtered, and diluted to 40 ml., whereupon it had an optical rotation of 14.60° per dcm., corresponding to $[\alpha]^{25}_{\rm D}$ + 112.3° (*c*,13;benzene) calculated for tetra-*O*-acetyl-2-deoxy-α-D-glucopyranosyl bromide. The solution was chilled in ice, then treated with a mixture of 30 ml. chilled acetic acid containing silver acetate (6 g.) and glass beads. The heterogeneous mixture was shaken for a period of 3 hr., filtered, rinsed and the filtrate was poured into water. The aqueous

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(10) E. Fischer, *Ber.*, **47**, 196 (1914).

mixture was extracted three times with chloroform, and the extract was washed with water and then sodium bicarbonate solution. After drying (anhydrous sodium sulfate) the solvent was removed by rotary evaporation *in vacuo*, yielding 2.35 g. (48%) of amber syrup, $[\alpha]_D^{25}$ + 20.7° (*c*, 2.17; $CHCl_3$). The crude syrup was dissolved in a mixture of ethanol (5 ml.) and ligroin (5 ml.) and the solution was chilled and seeded with authentic β-anomer. After 4 days there resulted 0.80 g. of tetra-*O*-acetyl-2-deoxy-β-D-glucose, m.p. 88–90°. After several recrystallizations from a mixture of ethanol and ligroin, pure β-anomer resulted having m.p. 92.2–92.7°, $[\alpha]_D^{25}$ − 2.64° (*c*,2.23;$CHCl_3$) and displaying an infrared spectrum in chloroform solution identical with that of the authentic β-anomer described above.

Tetra-O-acetyl-2-deoxy-α-D-glucose from triacetyl-D-glucal. Triacetyl-D-glucal (2.00 g.) was treated with 10 ml. of a 1:1 mixture of acetic anhydride–acetic acid 0.5*M* in sulfuric acid. The mixture was allowed to stand for 3 min. at room temperature, then poured into water (60 ml.), treated with sodium bicarbonate (2 g.), and allowed to stand for 30 min. The solution was extracted three times with chloroform and the extract was washed with saturated sodium bicarbonate solution, dried, and stripped of solvent. There resulted 1.08 g. of clear syrup, $[\alpha]_D^{25}$ +77.2° (*c*, 2.99;$CHCl_3$). This was dissolved in ethanol (1.5 ml.) and ligroin (1.5 ml.), then chilled at 0°. There resulted 0.20 g. of crude tetra-*O*-acetyl-2-deoxy-α-D-glucose, m.p. 105.5–106.5°, mixed m.p. with authentic α-anomer, 108.9–109.6°.

In another experiment 60% perchloric acid (1.68 g.) was added slowly with stirring to acetic anhydride (13 ml.) chilled in ice, after the general procedure of Seaman Allen.[11] A chilled solution of tri-*O*-acetyl-D-glucal (2.00 g.) in acetic acid (5.5 ml.) was gradually added with stirring, to the above perchloric acid solution, giving a final mixture calculated to be approximately 0.5 *M* in perchloric acid and 1:1 in acetic anhydride–acetic acid composition. The mixture was allowed to stand at 0° for 10 min., during which it darkened considerably. It was then treated with a solution of sodium acetate (1.0 g.) dissolved in acetic acid (15 ml.), causing the color to lighten. The mixture was added to ice water, stirred for 90 min., extracted three times with chloroform and then processed as usual. The crude amber syrupy product was redissolved in ether, the solution decolorized by filtration through Norit, and stripped of solvent. There resulted 2.40 g. (98.4%) of clear syrup, $[\alpha]_D^{25}$ +70.2° (*c*,-2.85;$CHCl_3$), corresponding to 71% α- and 29% β-anomers. Crystallization of the crude syrup from a mixture of ethanol (2 ml.) and ligroin (2 ml.) afforded 0.44 g. of pure tetra-*O*-acetyl-2-deoxy-α-D-glucose, m.p. 108.7–109.7°, mixed m.p. with authentic α-anomer undepressed, $[\alpha]_D^{25}$ +106.9° (*c*,1.54;$CHCl_3$). In a duplicate of this experiment the infrared spectrum of the crude syrupy product was found to be identical with that of a mixture of authentic α- and β-anomers of comparable composition.

The anomerization of tetra-O-acetyl-2-deoxy-β-D-glucose. The above β-anomer (332.3 mg.) was dissolved in a 1:1 mixture of acetic anhydride and acetic acid (9.0 ml.). A 0.01*M* solution of sulfuric acid in the same solvent mixture was prepared. Both solutions were thermostated at 25 ± 0.2°, whereupon 1.0 ml. of the catalyst solution was added to the β-anomer solution at time = 0. The mixture was transferred rapidly to a 2-dcm. jacketed polarimeter tube, through whose jacket water at 25 ± 0.2° was circulated, and optical rotation readings at various time intervals were recorded until an equilibrium value had been obtained. The data so obtained are presented in Table I. The equilibrium rotation recorded in Table I was stable for a period of 3 days at room temperature. The other data in Table I were obtained in a similar fashion, varying only the quantity of solvent and catalyst solutions. Kinetic calculations for the rate constant sum, $k_1 + k_2$, were obtained by the usual integrated polarimetric first order rate expression of Hudson,[12]

$$k_1 + k_2 = (2.3/t) \log [(r_0 - r_e)/(r_t - r_e)]$$

In preliminary anomerization experiments using anomerically nonhomogeneous starting materials, results similar to those in Table I were obtained. In several of these experiments the product was isolated as follows. The equilibrium anomerization reaction mixture was poured into an excess of water, treated with sufficient solid sodium bicarbonate to neutralize the sulfuric acid, and allowed to stand for a period of approximately 30 min. The mixture was then extracted with ether several times and the extract was washed with sodium bicarbonate solution, dried over anhydrous sodium sulfate, filtered, and stripped of solvent *in vacuo*. There resulted a 95–105% yield of crude syrup which immediately underwent spontaneous crystallization. This crude material, after vacuum drying, had $[\alpha]_D^{25}$ + 90.6° (*c*,2.163;$CHCl_3$), corresponding to a mixture of 85% α- and 15% β-anomers of tetra-*O*-acetyl-2-deoxy-D-glucose. When this crude product was recrystallized from small quantities of a 1:1 mixture of ethanol and ligroin there resulted in a single crystallization essentially pure tetra-*O*-acetyl-2-deoxy-α-D-glucose, m.p. 109.2–109.7° in about 75% yield.

With solutions more concentrated in sulfuric acid catalyst, for example, the 0.1–0.5*M* solutions in 1:1 acetic anhydride–acetic acid used in our earlier anomerization studies,[7] the present anomerization reaction was complete essentially "instantaneously", that is the equilibrium rotation prevailed within less than 1 to 2 min. reaction time. As indicated above, if such a mixture were processed for product after this time interval, a good yield of equilibrated anomeric products could be obtained, from which the α-anomer was readily crystallizable. If, however, such an anomerized mixture containing 0.5*M* sulfuric acid catalyst were allowed to stand for longer periods of time a second gradual mutarotation to a much more dextrorotatory value was observed. Attempts to isolate the product of this second reaction indicated that the carbohydrate material was to be found in the aqueous layer rather than the organic layer during subsequent processing. This product could be isolated in impure form by neutralization and vacuum evaporation of the aqueous layer from such processing. The water soluble product from such an isolation proved to be very strongly dextrorotatory, $[\alpha]_D^{25}$ approximately 160° (water), and to contain sulfur. Thus, under anomerization conditions employing higher sulfuric acid catalyst concentrations, the initial anomerization reaction is followed by a subsequent reaction leading to a sulfur-containing, water soluble product. The chemical identity of this product is currently under investigation and will be the subject of a future communication.

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(11) W. Seaman and E. Allen, *Anal. Chem.*, **23**, 593 (1951).

(12) C. S. Hudson, *Z. physik. Chem.*, **44**, 487 (1903).