Isomerization of D-*manno*-3-Heptulose.—A solution of 0.114 g. of β-D-*manno*-3-heptulose monohydrate in 7.5 ml. of water was mixed with 2.5 ml. of limewater (prepared at 8°). After storage in the dark for about 1 week at room temperature, the slightly yellow solution was passed through a column containing 3 ml. of Amberlite IR-120 H^+ and 5 ml. of Duolite A-4, and then concentrated. The sirup was taken up in a little methanol and 95% ethanol, and seeded with compound II, whereupon nearly pure II crystallized, 0 0375 g., $[\alpha]^{26}D$ +67°, m.p. 169-173°. Its infrared spectrum corresponded to that of authentic material.[15] The mother liquor was chromatographed on Whatman No. 3 MM paper, using the solvents and techniques previously described for separating these isomeric heptuloses.[12] Three sirupy fractions, consisting principally of II, IV, and VI, respectively, were obtained. On seeding the fractions, 0.003 g. of additional II was obtained, and 0.003 g. of VI was isolated as a hydrate. The latter was identified by its chromatographic behavior and by comparison of its infrared spectrum with that of an authentic specimen.[11] The fraction containing IV was heated for 70 hr. at 50° in 0.2 *N* hydrochloric acid,[16] and, after deionization and concentration, was obtained as crystalline V, weight 0.004 g. Compound V was identified by comparison of its infrared spectrum[15] and chromatographic behavior with those of authentic material. The orcinol-sprayed chromatogram of the reaction mixture at the conclusion of the reaction showed neither the color nor the fluorescence of the starting material.

Acknowledgment.—The interest and support of Dr. H. S. Isbell throughout this work is gratefully acknowledged. The author also thanks Mr. R. Paulson and Mr. R. J. Hall of the National Bureau of Standards for the elemental analyses.

---

[15] R. S. Tipson and H. S. Isbell, *J. Res. Natl. Bur. Std.*, **66A**, 31 (1962).

[16] N. K. Richtmyer and J. W. Pratt, *J. Am. Chem. Soc.*, **78**, 4717 (1956).

Sorboses. IV. Syntheses of Thio Derivatives of 2,3-*O*-Isopropylidene-α-L-sorbofuranose[1]

KANJI TOKUYAMA AND MASUMI KIYOKAWA

Shionogi Research Laboratory, Shionogi and Company, Ltd., Fukushima-ku, Osaka, Japan

Received January 29, 1964

Derivatives of 1-thio- and 6-thio-2,3-*O*-isopropylidene-α-L-sorbofuranoses were prepared *via* the corresponding benzylthio-L-sorbofuranoses, which were readily obtainable by the reactions of *O*-*p*-toluenesulfonyl-L-sorbofuranoses with sodium benzylthiolate in liquid ammonia, not in alcohol.

Although thio sugars have received renewed attention in recent years not only from the standpoint of the chemistry involved but from biochemical and metabolic interest, only one paper has been published on the preparation of thioketoses,[2] because tosyloxy groups in ketoses undergo nucleophilic displacement except when they are hindered.[2-4] The present paper reports a new method of synthesis of thio derivatives of 2,3-*O*-isopropylidene-α-L-sorbofuranose.

The treatment of 1,6-di-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (II)[5] with sodium benzylthiolate (I) in absolute methanol[6] gave colorless crystals (IV′), which had only one benzylthio group per sugar. This was also obtained from 6-*O*-*p*-toluenesulfonyl-1,4-anhydro-2,3-*O*-isopropylidene-α-L-sorbofuranose (III).[7] The acid-catalyzed acetonization of IV′ gave no acetonized compounds. Therefore, the structure of IV′ was considered to be 6-*S*-benzyl-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IV). In order to prove the structure, the reaction of 6-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (V) with I was carried out under the same conditions employed above. However, V was not converted into IV but into 2,3-*O*-isopropylidene-α-L-sorbofuranose (VI),[8] which was considered as the reaction product of V with a trace of water in the solvent. Dehydrating all the reagents or substituting I by other thio compounds such as thiol acetate brought no improvement. The treatment of V with I in liquid ammonia solution, which was prepared from metallic sodium and α-toluenethiol in liquid ammonia, at room temperature for 2 weeks gave IV. This was identical with IV′ by comparison of its rotation, infrared spectrum, and mixture melting point. Amino sugar was not isolated in this reaction. Furthermore, the treatment of II with I in liquid ammonia gave 1,6-di-*S*-benzyl-2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (VII) in good yield. (See Chart I.)

The tosylation of IV in pyridine gave 1-*O*-*p*-toluenesulfonyl-6-*S*-benzyl-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (VIII), which was converted into 1-anilino-6-*S*-benzyl-1-deoxy-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IX) on heating with aniline. IX was also obtainable on treating I in liquid ammonia with 1-anilino-6-*O*-*p*-toluenesulfonyl-1-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (X), which was derived from the tosylation of 1-anilino-1-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XI).

Derivatives of 1-*S*-benzyl-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XV) were obtained in a similar manner. The treatment of 1-*O*-*p*-toluenesulfonyl-2,3:4,6-di-*O*-isopropylidene-α-L-sorbofuranose (XII)[9] or its partially hydrolyzed product, 1-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (XIII), with I yielded, in liquid ammonia, 1-*S*-benzyl-2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XIV) or XV, but in methanol solvent, 2,3:4,6-di-*O*-isopropylidene-α-L-sorbofuranose (XVI)[8] or VI, respectively. (See Chart II.)

The tosylation of XV, which was also prepared by partial hydrolysis of XIV, afforded 1-*S*-benzyl-6-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XVII). This was converted into 1-*S*-benzyl-

---

[1] Part III: K. Tokuyama and E. Honda, *Bull. Chem. Soc. Japan*, **37**, 4 (1964).

[2] M. S. Feather and R. L. Whistler, *J. Org. Chem.*, **28**, 2567 (1963).

[3] H. Muller and T. Reichstein, *Helv. Chim. Acta*, **21**, 263 (1938).

[4] P. A. Levene and R. S. Tipson, *J. Biol. Chem.*, **120**, 607 (1937).

[5] H. Ohle, *Ber.*, **71**, 562 (1938).

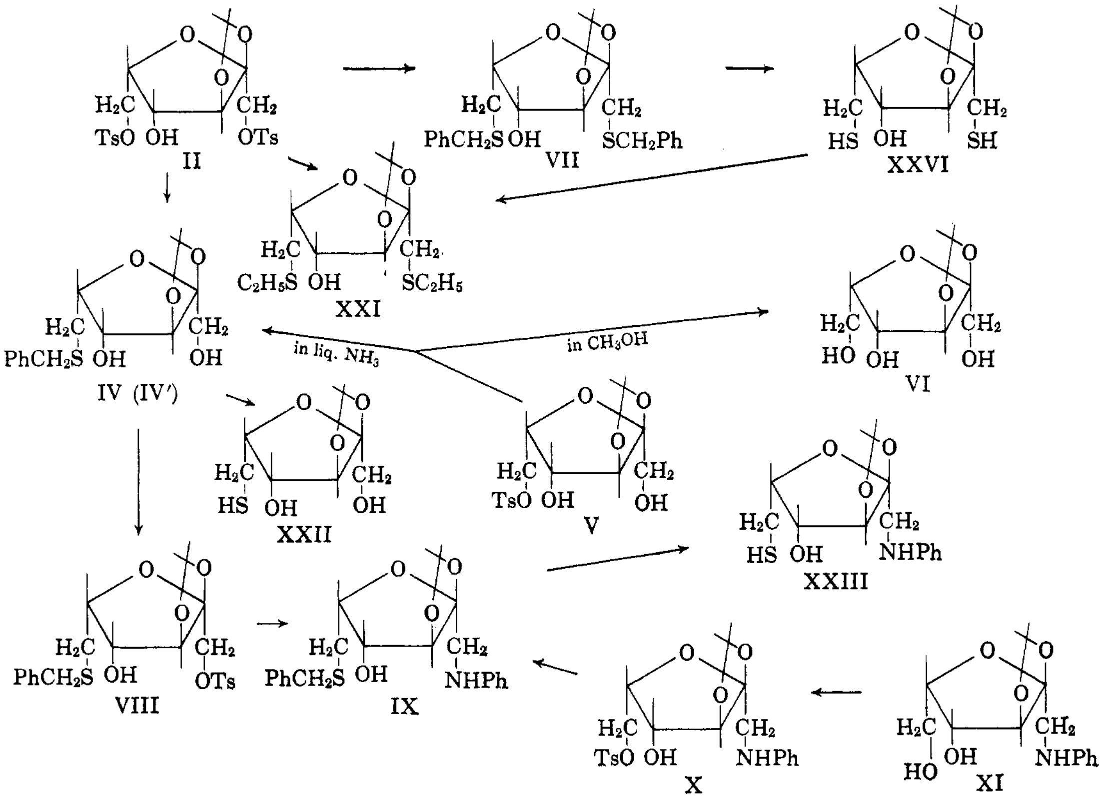
[6] N. C. Jamieson and R. K. Brown, *Can. J. Chem.*, **39**, 1765 (1961).

[7] K. Tokuyama, M. Kiyokawa, and N. Hōki, *Bull. Chem. Soc. Japan*, **36**, 1392 (1963).

[8] T. Reichstein, *Helv. Chim. Acta*, **17**, 311 (1934).

[9] W. Sullivan, *J. Am. Chem. Soc.*, **67**, 837 (1945).

CHART I



6-anilino-6-deoxy-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XVIII) on heating with aniline. XVIII was also obtained by the reaction of I in liquid ammonia with 1-*O*-*p*-toluenesulfonyl-6-anilino-6-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XIX) which was available by the tosylation of 6-anilino-6-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XX).[7]

The aforementioned replacement reaction of the tosyloxy group of L-sorbose by a benzylthio group showing almost no formation of amino-L-sorbose was only successful in a solvent of liquid ammonia. This reaction in liquid ammonia proceeded faster at higher temperatures in slightly lower yields.

As an example of the introduction of another thiolate, the reaction of II with sodium ethylthiolate in liquid ammonia was carried out yielding 1,6-di-*S*-ethyl-2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (XXI), which was also obtainable by ethylation of 2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (XXVI).

In recent years, Shimo and his co-workers[10,11] reported that sodium hydroxide in liquid ammonia can be used as a base like sodium amide. The treatment of II with α-toluenethiol in liquid ammonia in the presence of an equimolecular amount of sodium hydroxide yielded VII with slow dissolution of sodium hydroxide. At higher temperatures, VII was obtained even in the absence of sodium hydroxide. Instead of sodium hydroxide, use of alcoholic sodium alcoholate in liquid ammonia gave better results, indicating that these are excellent methods for the preparation of thio sugars.

The debenzylation of the above-described benzylthio-L-sorbofuranoses had been achieved by the use of sodium in liquid ammonia at low temperatures.[6] Thus, the treatment of IV, VII, IX, XV, XVIII, and XIV with sodium in liquid ammonia gave the corresponding thio-L-sorboses, 6-thio- (XXII), 1,6-dithio- (XXVI), 1-anilino-1-deoxy-6-thio- (XXIII), 1-thio- (XXIV), and 6-anilino-6-deoxy-1-thio-2,3-*O*-isopropylidene-α-L-sorbofuranose (XXV), and 2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XXVII), respectively.

Thus the use of liquid ammonia as a solvent has proved to be a new and excellent method for the preparation of thio sugars.

Experimental

6-*S*-Benzyl-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IV). A.—Sodium (4 g.) was dissolved in methanol (80 ml.) containing α-toluenethiol (5.2 g.), and to this was added 1,6-di-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (II, 10.6 g.). The mixture was refluxed under nitrogen for 2 hr. After cooling and dilution with water, the mixture was extracted with chloroform. The extract was washed with water, dried, and evaporated. Recrystallization of the residue from benzene and petroleum ether (b.p. 40–70°) gave colorless needles (4.2 g.), m.p. 99–100°, $[\alpha]^{25.5}_D$ +54.6° (*c* 1.105, acetone).

Anal. Calcd. for $C_{16}H_{22}O_5S$: C, 58.90; H, 6.75; S, 9.81. Found: C, 59.10; H, 6.79; S, 9.81.

B.—To a solution of α-toluenethiol (2.2 g.) and sodium (0.4 g.) in liquid ammonia (8 ml.) was added a solution of II (1 g.) in liquid ammonia (8 ml.). (a) After standing at room temperature for 2 weeks, ammonia was allowed to evaporate and the residue was diluted with water. This was extracted with chloroform, and the extract was washed with water and dried. After removal of the solvent, the residue was recrystallized from benzene and petroleum ether to give colorless needles (0.6 g.). (b) After heating on a boiling water bath for 40 hr., IV (0.5 g.) was also obtained by the above work-up.

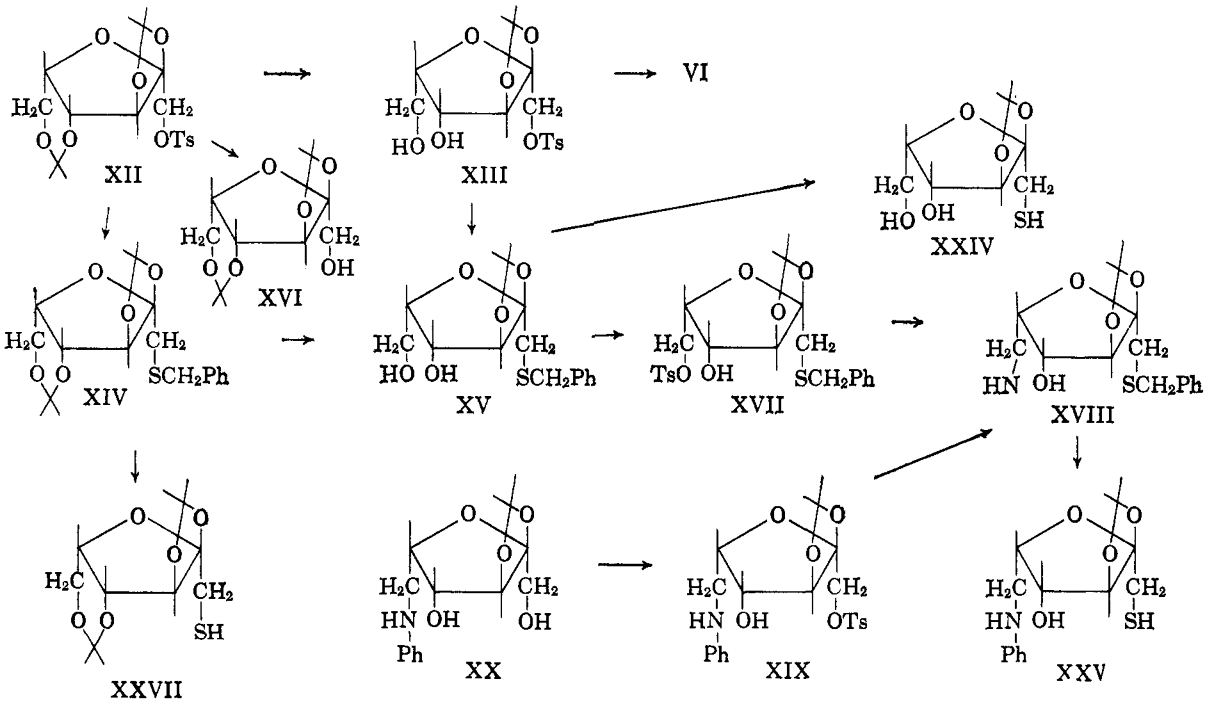
1-*O*-*p*-Toluenesulfonyl-6-*S*-benzyl-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (VIII).—To a solution of IV (0.5 g.) in dry pyridine (1 ml.) was added *p*-toluenesulfonyl chloride (0.34 g.). After stirring at room temperature for 5 hr., the reaction mixture was poured into a saturated potassium hydroxide solution (5 ml.)

---

(10) R. Asami and K. Shimo, *Sci. Rept. Research Inst., Tohoku Univ.*, **9A**, 341 (1957); *Chem. Abstr.*, **52**, 3677 (1958).

(11) K. Shimo and S. Wakamatsu, *J. Org. Chem.*, **24**, 19 (1959).

CHART II



and then extracted with chloroform. The chloroform solution was washed with water, dried, and evaporated to dryness under reduced pressure. Recrystallization of the residue from benzene and petroleum ether gave colorless needles (0.69 g.), m.p. 137–139.5°, $[\alpha]^{23}D$ +49° (*c* 1.090, acetone).

Anal. Calcd. for $C_{23}H_{28}O_7S_2$: C, 57.50; H, 5.84; S, 13.33. Found: C, 57.56; H, 5.91; S, 13.64.

1-Anilino-6-*S*-benzyl-1-deoxy-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IX). A.—A solution of VIII (1 g.) and potassium carbonate (1 g.) in aniline (10 ml.) was heated at 170–180° for 10 hr. with stirring. The reaction mixture was cooled, extracted with chloroform, washed with water, dried, and evaporated under reduced pressure, leaving a dark brown sirup. Recrystallization of the sirup from methanol gave colorless needles (0.27 g.), m.p. 129°, $[\alpha]^{23}D$ +20.9° (*c* 1.090, chloroform).

Anal. Calcd. for $C_{22}H_{27}NO_4S$: C, 65.84; H, 6.73; N, 3.49; S, 7.98. Found: C, 65.57; H, 6.68; N, 3.42; S, 7.89.

B.—A solution of α-toluenethiol (1.1 g.) and sodium (0.2 g.) in liquid ammonia (8 ml.) was mixed with a solution of 1-anilino-6-*O*-*p*-toluenesulfonyl-1-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (X, 0.5 g.) in liquid ammonia (10 ml.). After heating the solution on a boiling-water bath for 42 hr., IX (0.1 g.) was isolated by the above-described procedure for IV.

1-*O*-*p*-Toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (XIII).—1-*O*-*p*-Toluenesulfonyl-2,3:4,6-di-*O*-isopropylidene-α-L-sorbofuranose (XII, 1 g.) was dissolved in 60% acetic acid (10 ml.). The solution was warmed at 70° for 30 min., diluted with water, and extracted with chloroform. The chloroform solution was washed with water, dried, and evaporated. The residue was recrystallized from ethyl acetate and *n*-hexane to give colorless needles (0.5 g.), m.p. 120–121°, $[\alpha]^{22.5}D$ +12.6° (*c* 0.991, methanol).

Anal. Calcd. for $C_{16}H_{22}O_8S$: C, 51.34; H, 5.88; S, 8.56. Found: C, 51.70; H, 6.14; S, 8.81.

1-Anilino-1-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XI).—A solution of XIII (1 g.) and potassium carbonate (1 g.) in aniline (10 ml.) was heated at 170–180° for 10 hr. with stirring. XI (0.31 g.) was obtained in a manner similar to XIV. XI had m.p. 98°, $[\alpha]^{23}D$ +35.0° (*c* 1.045, chloroform).

Anal. Calcd. for $C_{15}H_{21}NO_5$: C, 61.02; H, 7.12; N, 4.75. Found: C, 61.29; H, 7.26; N, 4.87.

1-Anilino-6-*O*-*p*-toluenesulfonyl-1-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (X).—To a solution of XI (1.47 g.) in dry pyridine (5 ml.) was added *p*-toluenesulfonyl chloride (0.968 g.). After stirring at room temperature for 5 hr., X (1.82 g.) was obtained by the same work-up as that of VIII. It had m.p. 135° dec., $[\alpha]^{23}D$ +40.6° (*c* 0.903, chloroform).

Anal. Calcd. for $C_{22}H_{27}NO_7S$: C, 58.80; H, 6.01; N, 3.12. Found: C, 58.98; H, 6.17; N, 2.91.

1,6-Di-*S*-benzyl-2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (VII). A.—A solution of α-toluenethiol (4.4 g.) and sodium (0.8 g.) in liquid ammonia (10 ml.) was mixed with a solution of 1,6-di-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (II, 4.5 g.) in liquid ammonia (20 ml.). (a) After standing at room temperature for 2 weeks, ammonia was allowed to evaporate and the residue was washed with water, dried, and recrystallized from *n*-hexane. Colorless needles (2.53 g.) were obtained, m.p. 86°, $[\alpha]^{25.5}D$ +112.0° (*c* 1.038, chloroform).

Anal. Calcd. for $C_{23}H_{28}O_4S_2$: C, 63.89; H, 6.48; S, 14.81. Found: C, 63.77; H, 6.69; S, 14.55.

(b) After heating on a boiling-water bath for 40 hr., VII (2.7 g.) was obtained by the above-described procedure.

B.—To a mixture of α-toluenethiol (2.5 g.) and powdered sodium hydroxide (0.8 g.) was added a solution of II (3.0 g.) in liquid ammonia (10 ml.). Dissolution of sodium hydroxide was completed after 2 weeks at room temperature with occasional shaking. VII (1.5 g.) was obtained in the above-described way.

C.—A solution of α-toluenethiol (2.0 g.) and II (3.0 g.) in liquid ammonia (10 ml.) was heated on a boiling-water bath for 45 hr. VII (0.35 g.) was isolated by the above-described procedure.

D.—To a methanol solution (5 ml.) of sodium (1.0 g.) and α-toluenethiol (5.5 g.) was added a solution of II (8.5 g.) in liquid ammonia (30 ml.), and the mixture then was heated on a boiling-water bath for 30 hr. VII (4.2 g.) was obtained in the above-described manner.

1-*S*-Benzyl-2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XIV).—A solution of α-toluenethiol (1.3 g.) and sodium (0.24 g.) in liquid ammonia (10 ml.) was mixed with a solution of 1-*O*-*p*-toluenesulfonyl-2,3:4,6-di-*O*-isopropylidene-α-L-sorbofuranose (XII, 1 g.) in liquid ammonia (8 ml.). The solution was kept at room temperature for 2 weeks, or heated on a boiling-water bath for 40 hr. After removal of liquid ammonia, the residue was diluted with water, and then extracted with chloroform. The chloroform extract was washed with water, dried, and evaporated under reduced pressure, to give a yellow sirup. The sirup was fractionated by chromatography with silica gel (16 g.): first fraction (benzene), 250 ml.; second fraction (benzene–ether, 9:1, v./v.), 200 ml.; and third fraction (benzene–ether, 8:2, v./v.), 250 ml. From the second and third fractions, XIV (320 mg.) was obtained as a sirup, $[\alpha]^{23}D$ −62.7° (*c* 1.056, chloroform).

Anal. Calcd. for $C_{19}H_{26}O_5S$: C, 62.30; H, 7.10; S, 8.74. Found: C, 62.50; H, 7.27; S, 8.95.

1-*S*-Benzyl-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XV). A.—To a solution of sodium (0.8 g.) and α-toluenethiol (4.4 g.) in liquid ammonia (10 ml.) was added a solution of XIII (4 g.) in liquid ammonia (15 ml.). The solution was kept at room temperature for 2 weeks or heated on a boiling-water bath for 40 hr. Ammonia was allowed to evaporate and the residue was diluted with water and then extracted with chloroform. The chloroform extract was washed with water, dried, and evaporated. The residue was fractionated by chromatography with silica gel (40 g.): first fraction (benzene), 300 ml.; second fraction (benzene–ether, 9:1, v./v.), 200 ml.; third fraction (benzene–ether, 8:2, v./v.), 200 ml.; and fourth fraction (ether), 300 ml. From the fourth fraction, XV (2.0 g.) was obtained. It had m.p. 67° (recrystallized from ether and *n*-hexane), $[\alpha]^{25.5}\mathrm{D}$ +84.5° (*c* 1.026 chloroform).

Anal. Calcd. for $C_{16}H_{22}O_5S$: C, 58.90; H, 6.75; S, 9.81. Found: C, 59.06; H, 6.77; S, 9.87.

B.—1-*S*-Benzyl-2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XIV) (2 g.) was dissolved in 60% acetic acid (30 ml.). The solution was warmed at 70° for 30 min., diluted with water, neutralized with sodium hydroxide, and extracted with chloroform. This was washed with water, dried, and evaporated. Recrystallization of the residue gave XV (0.8 g.), m.p. 67°.

1-*S*-Benzyl-6-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XVII).—To a solution of XV (3.37 g.) in dry pyridine (20 ml.) was added *p*-toluenesulfonyl chloride (2.0 g.). After stirring at room temperature for 5 hr., the reaction mixture was poured into a saturated sodium hydroxide solution (20 ml.) and extracted with chloroform. The chloroform extract was washed with water, dried, and evaporated to dryness under reduced pressure. Recrystallization of the residue from ether and *n*-hexane gave colorless needles (2.1 g.), m.p. 117°, $[\alpha]^{25.5}\mathrm{D}$ +91.4° (*c* 1.034, chloroform).

Anal. Calcd. for $C_{23}H_{28}O_7S_2$: C, 57.50; H, 5.84; S, 13.34. Found: C, 57.36; H, 6.04; S, 13.58.

1-*O*-*p*-Toluenesulfonyl-6-anilino-6-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XIX) was obtained from the reaction of 6-anilino-6-deoxy-2,3-*O*-isopropylidene-α-L-sorbofuranose (XX) (0.1 g.) with *p*-toluenesulfonyl chloride (66 mg.) in dry pyridine (1 ml.) according to the same procedure for X. The yield was 0.12 g., m.p. 98° (recrystallized from benzene and petroleum ether), $[\alpha]^{26.5}\mathrm{D}$ +6.5° (*c* 0.642, chloroform).

Anal. Calcd. for $C_{22}H_{27}NO_7S$: C, 58.80; H, 6.01; N, 3.12; S, 7.13. Found: C, 59.08; H, 6.26; N, 3.12; S, 7.02.

1-*S*-Benzyl-6-anilino-6-deoxy-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XVIII). **A.**—A solution of α-toluenethiol (3 g.) and sodium (0.4 g.) in liquid ammonia (6 ml.) was mixed with a solution of XIX (1 g.) in liquid ammonia (8 ml.). It was kept at room temperature for 2 weeks or heated on a boiling-water bath for 40 hr. XVIII (0.5 g.) was obtained by the same procedure for IX and had m.p. 137° (recrystallized from ethyl acetate and *n*-hexane), $[\alpha]^{23}\mathrm{D}$ +107.1° (*c* 1.070, chloroform).

Anal. Calcd. for $C_{22}H_{27}NO_4S$: C, 65.84; H, 6.73; N, 3.49; S, 7.98. Found: C, 65.74; H, 6.89; N, 3.60; S, 8.15.

B.—A solution of XVII (1 g.) and potassium carbonate (1 g.) in aniline (10 ml.) was heated at 170–180° for 10 hr. XVIII (0.6 g.) was obtained by the above-described procedure for IX.

1,6-Di-*S*-ethyl-2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (XXI). **A.**—To a solution of ethanethiol (5 g.) and sodium (0.7 g.) was added a solution of 1,6-di-*O*-*p*-toluenesulfonyl-2,3-*O*-isopropylidene-α-L-sorbofuranose (II, 5 g.) in liquid ammonia (26 ml.). The solution was kept at room temperature for 2 weeks or heated on a boiling-water bath for 40 hr. After removal of ammonia, the residue was diluted with water and extracted with chloroform. The chloroform was washed with water and dried; the solvent was removed. Distillation of the residue gave a sirup (1.9 g.), b.p. 173° at 3 mm., which crystallized immediately, giving XXI, m.p. 48°, $[\alpha]^{26}\mathrm{D}$ +82.5° (*c* 1.009, chloroform).

Anal. Calcd. for $C_{13}H_{24}O_4S_2$: C, 50.64; H, 7.79; S, 20.80. Found: C, 50.88; H, 7.88; S, 20.64.

B.—A solution of I (5 g.) and ethanethiol (5 g.) in liquid ammonia (10 ml.) was heated on a boiling-water bath for 40 hr.; XXI (0.9 g.) was obtained in the above-described way.

Reduction of Benzylthio-L-sorboses.[6] **General Procedure.**—With constant stirring at −40°, to a solution of benzylthio-L-sorbose in liquid ammonia were added enough small pieces of sodium metal for the blue color to persist for 20 min. After that, ammonium chloride was added to discharge the blue color. Ammonia was allowed to evaporate, and the residue was extracted with chloroform which, upon evaporation, left a colorless sirup. The sirup was purified by recrystallization or by silica gel chromatography with benzene and ether.

6-*S*-Benzyl-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IV, 1 g.) yielded 2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (XXII, 0.42 g.), m.p. 161° (recrystallized from *n*-hexane and ethyl acetate), $[\alpha]^{22}\mathrm{D}$ +29.9° (*c* 1.030, methanol).

Anal. Calcd. for $C_9H_{16}O_5S$: C, 45.76; H, 6.78; S, 13.56. Found: C, 46.62; H, 6.88; S, 13.46.

1-Anilino-6-*S*-benzyl-1-deoxy-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (IX, 1 g.) yielded 1-anilino-1-deoxy-2,3-*O*-isopropylidene-6-thio-α-L-sorbofuranose (XXIII, 0.46 g.), m.p., 108° (recrystallized from ethyl acetate), $[\alpha]^{24.5}\mathrm{D}$ +51.1° (*c* 1.094 chloroform).

Anal. Calcd. for $C_{15}H_{21}NO_4S$: C, 57.87; H, 6.75; N, 4.50; S, 10.28. Found: C, 57.97; H, 6.87; N, 4.42; S, 10.19.

1-*S*-Benzyl-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XV, 2.0 g.) yielded 2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XXIV, 0.5 g.) as a sirup, $[\alpha]^{26.5}\mathrm{D}$ −6.7° (*c* 1.362, chloroform).

Anal. Calcd. for $C_9H_{16}O_5S$: C, 45.76; H, 6.78; S, 13.56. Found: C, 46.70; H, 7.10; S, 13.45.

1-*S*-Benzyl-6-anilino-6-deoxy-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XVIII, 2 g.) yielded 6-anilino-6-deoxy-2,3-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XXV, 0.2 g.), m.p. 128° (recrystallized from ethyl acetate and *n*-hexane), $[\alpha]^{23}\mathrm{D}$ +22.8° (*c* 1.040, chloroform).

Anal. Calcd. for $C_{15}H_{21}NO_4S$: C, 57.87; H, 6.75; N, 4.50; S, 10.28. Found: C, 57.35; H, 6.76; N, 4.82; S, 10.07.

1,6-Di-*S*-benzyl-2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (VII, 2 g.) yielded 2,3-*O*-isopropylidene-1,6-dithio-α-L-sorbofuranose (XXVI, 200 mg.), m.p. 82° (recrystallized from ethyl acetate and *n*-hexane), $[\alpha]^{28}\mathrm{D}$ +103.9° (*c* 1.116, chloroform).

Anal. Calcd. for $C_9H_{16}O_4S_2$: C, 42.86; H, 6.35; S, 25.40. Found: C, 42.92; H, 6.60; S, 25.21.

1-*S*-Benzyl-2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XIV, 1 g.) yielded 2,3:4,6-di-*O*-isopropylidene-1-thio-α-L-sorbofuranose (XXVII, 0.1 g.), m.p. 136° (recrystallized from *n*-hexane), $[\alpha]^{23}\mathrm{D}$ −17.3° (*c* 0.931, chloroform).

Anal. Calcd. for $C_{12}H_{20}O_5S$: C, 52.17; H, 7.25; S, 11.59. Found: C, 52.38; H, 7.10; S, 11.69.

Acknowledgment.—The authors express their deep gratitude to Dr. K. Takeda, director of this laboratory, and Dr. K. Hamamoto, assistant direct of this laboratory, for their encouragement.