# Synthesis of Ethyl 4-Thio-α-D-lyxofuranoside and Related Compounds

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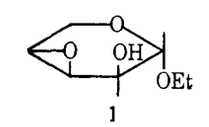
The reaction of ethyl 3,4-anhydro-β-L-ribopyranoside (**1**) with sodium benzyl mercaptide at −20° leads selectively to the formation of crystalline ethyl *S*-benzyl-4-thio-α-D-lyxopyranoside (**2**) in high yield. Small amounts of ethyl *S*-benzyl-3-thio-β-L-xylopyranoside (**3**) are formed in comparable reactions at room temperature or above. Desulfurization of **2** gave ethyl 4-deoxy-β-L-*erythro*-pentoside (**5**), acid hydrolysis of which gave 4-deoxy-L-*erythro*-pentose which was characterized by reduction and benzoylation giving crystalline 1,3,5,6-tetra-*O*-benzoyl-2-deoxy-D-*erythro*-pentitol. Treatment of **2** with sodium in liquid ammonia followed by immediate equilibration with methanolic hydrogen chloride gave a mixture of the the α and β forms of methyl 4-thio-D-lyxofuranoside (**8a**) from which a crystalline tri-*O*-*p*-nitrobenzoate was obtained. Treatment of **2** with sodium in ammonia alone gave crystalline ethyl 4-thio-α-D-lyxopyranoside (**9**) which upon subsequent equilibration with ethanolic hydrogen chloride gave a low yield of crystalline ethyl 4-thio-α-D-lyxofuranoside (**11**). Crystalline ethyl 4-thio-β-D-ribofuranoside (**13**) has also been prepared by treatment of 1,2,3,5-tetra-*O*-acetyl-4-thio-D-ribofuranose (**12**) with ethanolic hydrogen chloride.

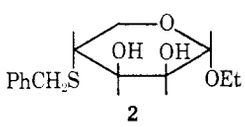
Recently syntheses of a number of sugars containing sulfur as part of a furanose or pyranose ring have been described.[1] These syntheses involve the preparation of appropriately substituted 4-thio or 5-thio sugars which show a strong tendency toward glycoside formation with inclusion of the sulfur in the acetal ring. Since conversion of a primary hydroxyl group into a suitable sulfur-containing substituent is relatively straightforward, a number of 5-thiopentopyranosides are now known.[1] The corresponding 5-thiohexoses are, however, less accessible and only syntheses of 5-thio-D-glucopyranose[2] and 5-thio-L-idopyranose[3] derivatives have been achieved, both *via* the appropriate 5,6-dideoxy-5,6-episulfides. Other methods have led to 6-acetamido-6-deoxy-5-thio-L-idopyranose[4] and 6-deoxy-5-thio-L-talopyranose.[5]

As part of another study in this institute we were stimulated to attempt the synthesis of a 5-thio-β-D-galactopyranoside for evaluation as an inducer of the enzyme β-galactosidase. Since preparation of a suitable derivative of 5-thiogalactose would appear to require either a lengthy sequence from D-galactose *via* the episulfide route or use of an inaccessible L sugar we have examined an alternative route *via* homologation of a more easily prepared 4-thiopentose. In this paper we describe the synthesis of a suitable 4-thio-D-lyxose derivative and its conversion into ethyl 4-thio-α-D-lyxofuranoside. Our studies on the homologation reaction will be reported separately.[6]

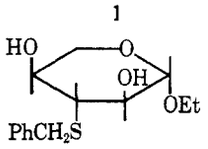
The known ethyl 3,4-anhydro-β-L-ribopyranoside (**1**) appeared to be a suitable precursor of 4-thio-D-lyxose derivatives and its synthesis was achieved in an over-all yield of 42% from ethyl α-D-lyxopyranoside *via* modifications of the four-step route previously described.[7] Reaction of **1** with sodium benzyl mercaptide at −20° led to apparently completely specific diaxial opening with formation of crystalline ethyl *S*-benzyl-4-thio-α-D-lyxopyranoside (**2**) in 83% yield.[8] Similar reactions at room temperature or above were less specific and a small amount of ethyl *S*-benzyl-3-thio-β-L-xylopyranoside (**3**) was detected by thin layer chromatography. Isolation of this minor product in crystalline form was facilitated by conversion of the major product (**2**) into its isopropylidene derivative (**4**) followed by chromatography on silicic acid.



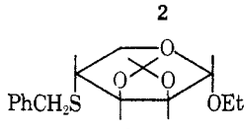

**1**




**2**

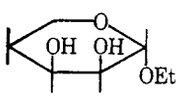



**3**




**4**

Treatment of **2** with an excess of a sponge nickel catalyst[9] led to very rapid desulfurization and formation of ethyl 4-deoxy-β-L-*erythro*-pentopyranoside (**5**) as an analytically pure, distillable syrup. Hydrolysis of the glycoside gave 4-deoxy-L-*erythro*-pentose (**6**) as a homogeneous reducing syrup with an optical rotation very similar to that reported earlier by a different route.[8a] Reduction of **6** with sodium borohydride followed by benzoylation gave crystalline 1,3,4,5-tetra-*O*-benzoyl-2-deoxy-D-*erythro*-pentitol (**7**) which was identical in every way with a sample of the same product obtained by reduction and benzoylation of 2-deoxy-D-ribose.[10]

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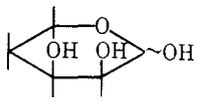
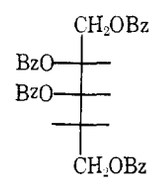



**6**




**7**

The availability of **2** made the synthesis of 4-thio-D-lyxofuranosides an attractive goal. Removal of the benzyl group from **2** was achieved by treatment with sodium in liquid ammonia, and, in view of the known

(1) H. Paulsen, *Angew. Chem. Intern. Ed. Engl.*, **5**, 495 (1966).

(2) (a) M. S. Feather and R. L. Whistler, *Tetrahedron Lett.*, 667 (1962); (b) R. M. Rowell and R. L. Whistler, *J. Org. Chem.*, **31**, 1515 (1966).

(3) T. J. Adley and L. N. Owen, *Proc. Chem. Soc.*, 418 (1961).

(4) L. Goodman and J. E. Christensen, *J. Org. Chem.*, **29**, 1787 (1964).

(5) C. L. Stevens, R. P. Glinski, G. E. Gutowski, and J. P. Dickerson, *Tetrahedron Lett.*, 649 (1967).

(6) J. P. H. Verheyden and J. G. Moffatt, unpublished results.

(7) J. Piotrovsky, J. P. H. Verheyden, and P. J. Stoffyn, *Bull. Soc. Chim. Belges*, **73**, 969 (1964).

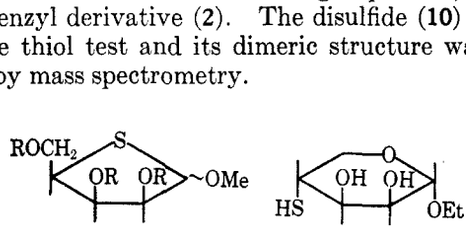
(8) The related methyl 3,4-anhydro-β-L-ribopyranoside has been opened by hydrogen bromide, amines, and sodium methyl mercaptide: (a) P. W. Kent and P. F. V. Ward, *J. Chem. Soc.*, 416 (1953); (b) W. G. Overend, A. C. White, and N. R. Williams, *Chem. Ind.*, 1840 (1963); (c) N. A. Hughes, R. Robson, and S. A. Saeed, *Chem. Commun.*, 1381 (1968).

(9) Davidson Chemical Division, W. R. Grace and Co., Cincinnati, Ohio.

(10) S. David and P. Jaymond, *Bull. Soc. Chim. Fr.*, 157 (1959).

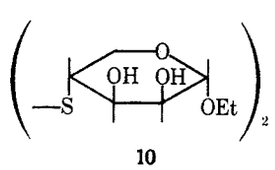
ease of disulfide formation from thio sugars,[11] the crude product was directly treated with 6% methanolic hydrogen chloride for 24 hr. These conditions would be expected to lead to equilibration of the glycosidic grouping with selective formation of the thiofuranosides as has been previously demonstrated in the D-ribothiofuranose[12a,b] and D-arabinothiofuranose[12c] series. The reaction mixture contained at least five components by thin layer chromatography and the three major ones have been isolated. The most abundant of these (27%) was a syrup containing two products with very similar thin layer chromatographic mobilities. These gave negative nitroprusside tests for thiols[13] and were shown by nmr spectroscopy to be a roughly 2:1 mixture of the desired anomeric methyl 4-thio-D-lyxofuranosides (**8a**). The methyl glycosides appeared as two sharp singlets at 3.36 and 3.40 ppm and the anomeric proton as a pair of overlapping doublets at 4.88–4.97 ppm. All other protons were in an unresolved envelope at 3.59–4.67 ppm. Upon addition of trichloroacetylisocyanate[14] the spectrum was simplified, the methyl groups now appearing as a broadened singlet at 3.41 ppm and the anomeric protons as well-resolved doublets at 5.35 ppm ($J$ = 2 Hz) and 5.21 ppm ($J$ = 3 Hz). The $C_2$ and $C_3$ protons were shifted downfield roughly 1.2 ppm, but the $C_5$ methylene group, being associated with a primary alcohol, shifted much less and appeared as a multiplet at 4.63 ppm. *p*-Nitrobenzoylation of the mixture gave a crystalline triester (**8b**) which appeared to be a single anomer, the anomeric proton appearing as a sharp doublet ($J$ = 2.8 Hz) at 5.35 ppm. The magnitude of this coupling constant does not permit definitive assignment of anomeric configuration.[15]

The other major products were obtained in crystalline form and proved to be ethyl 4-thio-α-D-lyxopyranoside (**9**) and the corresponding disulfide (**10**) in yields of 11 and 14%. The thiol (**9**) showed unexpected stability (see later) and was unchanged after prolonged storage. The small coupling constant (2 Hz) of the anomeric proton of **9** indicates that the molecule exists in a conformation with both the 1-OEt and 2-OH groups axial, as does the *S*-benzyl derivative (**2**). The disulfide (**10**) gave a negative thiol test and its dimeric structure was confirmed by mass spectrometry.




**8** a, R = H
b, R = *p*-$NO_2$Bz

**9**




**10**

(11) R. L. Whistler and R. M. Rowell, *J. Org. Chem.*, **29**, 1259 (1964).

(12) (a) R. L. Whistler, W. E. Dick, T. R. Ingle, R. M. Rowell, and B. Urbuss, *ibid.*, **29**, 3723 (1964); (b) E. J. Reist, D. E. Gueffroy, and L. Goodman, *J. Amer. Chem. Soc.*, **86**, 5658 (1964); (c) R. L. Whistler, U. G. Nayak, and A. W. Perkins, *Chem. Commun.*, 1339 (1968).

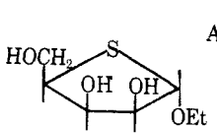
(13) G. Toennies and J. J. Kolb, *Anal. Chem.*, **23**, 823 (1951).

(14) V. W. Goodlett, *ibid.*, **37**, 431 (1965).

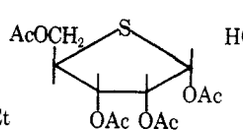
(15) R. L. Tolman, R. K. Robins, and L. B. Townsend, *J. Heterocycl. Chem.*, **4**, 230 (1967).

The above experiment indicates that acid-catalyzed equilibration of the glycoside does not very readily occur with these compounds and this stability is also reflected in the unusual difficulties encountered during hydrolysis of **2**.[6] Treatment of **2** with sodium in liquid ammonia without subsequent acidic treatment led to isolation of the crystalline thiol **9** in quantitative yield. Subsequent treatment of **9** with 1% ethanolic hydrogen chloride led to very slow disappearance of the thiol group, 50% being still present by colorimetric assay[16] after 4 days at room temperature. Even brief reactions at 80°, however, led to a plethora of products. Treatment of **9** with ethanolic hydrogen chloride under a variety of conditions led to the isolation of crystalline ethyl 4-thio-α-D-lyxofuranoside (**11**) but only in yields of 7–8%. The assigned structure is based upon elemental analysis, the absence of a free thiol grouping, and nmr spectroscopy. The coupling constant of the anomeric proton (4 Hz) does not permit assignment of configuration but the large positive optical rotation (+331°) strongly suggests it to be α.

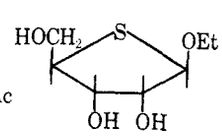
For purposes of comparison we have also prepared crystalline ethyl 4-thio-β-D-ribofuranoside (**13**) in 45% yield by methanolysis of 1,2,3,5-tetra-*O*-acetyl-4-thio-β-D-ribofuranose[12b] (**12**) under conditions similar to those above. The β configuration for **13** is confirmed by both the small coupling constant (1 Hz) of the anomeric proton and the large negative rotation of −144°. The related methyl β-glycoside has been obtained as a syrup by Whistler.[12a]




**11**




**12**




**13**

## Experimental Section

**General Methods.**—Thin layer chromatography (tlc) was performed using 0.25-mm layers of Merck silica gel GF and preparative tlc on 20 × 100 cm glass plates coated with 1.3-mm layers of Merck silica gel HF. Column chromatography was done using 100–200 mesh Davidson grade 923 silica gel or Merck silica gel with 0.05–0.20-mm particles, Nuclear magnetic resonance (nmr) spectra were obtained using Varian A-60 or HA-100 spectrometers and mass spectra using an Atlas CH-4 instrument with a direct inlet system and an ionizing voltage of 70 eV. Optical rotatory dispersion (ORD) spectra were determined using a JASCO ORD/UV-5 instrument. Elemental analyses were performed by Dr. A. Bernhardt, Mülheim, Germany. We are grateful to Mr. John Murphy and Miss Janice Tremble, and to Dr. Laszlo Tökes for their assistance in obtaining nmr and mass spectra, respectively.

**Ethyl 3,4-Anhydro-β-L-ribopyranoside** (1).—This compound was prepared in an over-all yield of 42% from ethyl α-D-lyxopyranoside by modifications of a reported procedure.[7] The main improvements were in the use of perchloric acid for preparing the acetonide, and not purifying any of the intermediates. The final distilled product had mp 49–50°; $[\alpha]^{21}D$ +148° (*c* 1.0, MeOH); nmr (DMSO-$d_6$) 4.20 ppm (d, 1, $J_{1,2}$ = 4.6 Hz, $C_1$-H), 1.08 ppm (t, 3, $J$ = 7 Hz, $CH_3CH_2$), 5.05 ppm (d, 1, $J$ = 5 Hz, OH).

**Ethyl *S*-Benzyl-4-thio-α-D-lyxopyranoside** (2).—Benzyl mercaptan (17 ml, 145 mmol) and 1 (17.0 g, 106 mmol) were dissolved in cold 1.25 *M* methanolic sodium methoxide (100 ml) and the solution was immediately cooled to −20° and stored for 5 days. Aqueous acetic acid (200 ml of 1.75 *M*) was added followed by water (250 ml) and the white crystalline product was collected

(16) R. E. Basford and F. M. Huennekens, *J. Amer. Chem. Soc.*, **77**, 3873 (1955).

and washed with water giving 25 g (83%) of **2** with mp 134–136°, unchanged upon recrystallization from aqueous methanol; $\lambda_{max}^{MeOH}$ 261 mμ sh (ε 3400) and 267 sh (2200); $[\alpha]^{21}D$ +84° (*c* 0.33, MeOH); ORD (MeOH) plain positive ; nmr ($CDCl_3$) 4.80 (d, 1, $J_{1,2}$ = 1.5 Hz, $C_1$-H), 7.30 (s, 5, Ar), 1.19 (t, 3, *J* = 7 Hz, $CH_3CH_2$), 2.5–2.7 ppm (br, s, 2, two OH).

*Anal.* Calcd for $C_{14}H_{20}O_4S$: C, 59.14; H, 7.09; S, 11.25. Found: C, 59.31; H, 7.31; S, 11.45.

**Ethyl *S*-Benzyl-2,3-*O*-isopropylidene-4-thio-α-D-lyxopyranoside (4).**—Phosphorus pentoxide (100 mg) was added with shaking to a solution of **2** (284 mg, 1 mmol) in anhydrous acetone (10 ml). After 3 min the mixture was filtered and the filtrate shaken with an excess of $BaCO_3$. After filtration the solution was evaporated to dryness and the residue (335 mg) was chromatographed on a column of Davidson silica gel using a gradient of chloroform in benzene. Homogeneous **4** (250 mg, 75%) was distilled in a Kugelrohr apparatus[17] at 125° ($10^{-3}$ mm): nmr ($CDCl_3$) 1.32 (s, 6, $CMe_2$), 4.92 (d, 1, $J_{1,2}$ = 1 Hz, $C_1$-H), 7.33 (br, s, 5, $C_6H_5$), 3.84 (s, 2, $SCH_2$), 1.19 (t, 3, *J* = 7 Hz, $CH_3CH_2$); $\lambda_{max}^{MeOH}$ 260 mμ (ε 3100), 265 (2200); $[\alpha]^{21}D$ +7° (*c* 0.1, MeOH); ORD $[\alpha]_{255}$ +208° (pk), $[\alpha]_{240}$ 0°, $[\alpha]_{224}$ −2200° (tr).

*Anal.* Calcd for $C_{17}H_{24}O_4S$: C, 62.95; H, 7.46; S, 9.87. Found: C, 63.15; H, 7.30; S, 9.75.

**Ethyl *S*-Benzyl-3-thio-β-L-xylopyranoside (3).**—Benzyl mercaptan (2.6 ml, 6.3 mmol) and **1** (900 mg, 5.6 mmol) were heated overnight under reflux in 5 ml of 1.25 *M* methanolic sodium methoxide. After neutralization with acetic acid the mixture was evaporated and the residue partitioned between chloroform and water giving an organic phase which contained two close moving spots by tlc using $CHCl_3$–EtOAc (1:1). After evaporation of the solvent 400 mg of pure **2** was obtained by crystallization from chloroform–hexane. The mother liquors were evaporated and the partially crystalline residue (1.19 g) was treated with acetone (5 ml), 2,2-dimethoxypropane (0.5 ml), and $HClO_4$ (20 μl). After 15 min, $NH_4OH$ (0.1 ml) was added and the solvent was evaporated. The residue was dissolved in benzene, extracted with water, and chromatographed on a column of Davidson silica gel (120 g). Elution with benzene gave 650 mg of pure **4** and elution with chloroform and crystallization from benzene–hexane gave 60 mg of **3** with mp 86–87°; $\lambda_{max}^{MeOH}$ 265 mμ (ε 2100), 260 (3100); $[\alpha]^{21}D$ +41° (*c* 0.33, MeOH); nmr 4.27 (d, 1, $J_{1,2}$ = 6.5 Hz, $C_1$-H), 7.30 (s, 5, $C_6H_5$), 3.88 (s, 2, $SCH_2$), 1.24 (t, 3, *J* = 7 Hz, $CH_3CH_2$).

*Anal.* Calcd for $C_{14}H_{20}O_4S$: C, 59.14; H, 7.09. Found: C, 59.23; H, 7.01.

**Ethyl 4-Deoxy-β-L-erythro-pentoside (5).**—A mixture of Davidson sponge nickel (5 g) and **2** (0.50 g) were stirred in methanol for 30 min and then filtered through Celite. Evaporation of the filtrates and short-path distillation at 90° ($10^{-3}$ mm) gave 140 mg (50%) of **5** as a clear syrup: $[\alpha]^{21}D$ +104°; nmr (DMSO-$d_6$) 4.59 (d, 1, $J_{1,2}$ = 3 Hz, $C_1$-H), 4.50 (d, 1, *J* = 5 Hz, OH), 4.37 (d, 1, *J* = 6 Hz, OH), 1.6 (m, 2, $C_4$-$H_2$), 1.12 ppm (t, 3, *J* = 7 Hz, $CH_3CH_2$).

*Anal.* Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70. Found: C, Found: C, 52.08; H, 8.81.

**4-Deoxy-L-*erythro*-pentose (6).**—A solution of **5** (100 mg) in 1 *N* $H_2SO_4$ (20 ml) was heated at 100° for 4 hr. After neutralization with $Ba(OH)_2$, treatment with $CO_2$ and evaporation the residue was extracted with hot acetone giving 70 mg (85%) of pure **6** as a colorless syrup: $[\alpha]^{21}D$ +28.5° (*c* 0.2 $H_2O$) (lit.[8a] $[\alpha]^{21}D$ +23.1°); nmr (DMSO-$d_6$) 4.77 (t, 1, $J_{1,2}$ = 4 Hz, $J_{H,OH}$ = 5 Hz giving d, $J_{1,2}$ = 4 Hz with $D_2O$, $C_1$-H), 6.05 (d, 1, $J_{H,OH}$ = 5 Hz, $C_1$-OH), 4.37 ppm [br, s, 2, $(OH)_2$].

**1,3,4,5-Tetra-*O*-benzoyl-2-deoxy-D-*erythro*-pentitol (7).**—Sodium borohydride (15 mg) and **6** (60 mg) were dissolved in water (4 ml) and after 30 min at 25° Dowex 50 ($H^+$) resin (2 ml) was added. After filtration, evaporation of the solvent, and several evaporations with methanol, the residue was treated with benzoyl chloride (0.25 ml) in pyridine (0.5 ml) at 100° for 10 min. Addition of water gave crystalline **7** (213 mg, 86%) that was recrystallized from ethanol with mp 129–130°, $[\alpha]^{21}D$ −14.5° (*c* 1.8, $CHCl_3$), both identical with those of **7** prepared by reduction and benzoylation of 2-deoxyribose:[10] nmr ($CDCl_3$) 7.5 (br, s, 12, $C_6H_5$), 8.0 (br, s, 8, $C_6H_5$), 2.43 (m, 2, $C_2$-$H_2$), 2.43 (m, 4, $CH_2O$), 5.9 ppm (m, 2, $C_3$-H, $C_4$-H).

**Debenzylation and Equilibration of 2.**—Sodium chips (230 mg, 10 mg-atoms) were slowly added to a stirred solution of **2** (710 mg, 2.5 mmol) in anhydrous $NH_3$ (50 ml). $NH_4Cl$ (600 mg) was then added and after careful evaporation of the solvent the residue was dissolved in 6% methanolic hydrogen chloride (50 ml). After 24 hr the solution was neutralized with $PbCO_3$, filtered, evaporated, and chromatographed on a column of 100 g of Davidson silicic acid using $CH_2Cl_2$–$CH_3OH$ (19:1). The first peak contained 55 mg (11%) of **9** with mp 103.5–105° (see below). The second peak contained 120 mg (27%) of a syrup showing two close spots on tlc with $CHCl_3$–MeOH (9:1) and shown by nmr (see text) to be a 2:1 mixture of the anomers of **8a**. Reaction with *p*-nitrobenzoyl chloride in pyridine followed by preparative tlc using three consecutive developments with chloroform–hexane (2:1) separated two close bands. Elution and crystallization from aqueous acetone of the more intense, faster band gave pure **8b** of mp 76–78°; $[\alpha]^{21}D$ +13° (*c* 0.1, $CHCl_3$); nmr 5.35 (d, 1, $J_{1,2}$ = 2.8 Hz, $C_1$-H), 3.47 ppm (s, 3, $OCH_3$).

*Anal.* Calcd for $C_{27}H_{21}N_3O_{13}S$: C, 51.67; H, 3.37. Found: C, 52.16; H, 3.35.

The third major peak contained 68 mg (14%) of disulfide **10** of mp 130–135° after crystallization from acetone–hexane; nmr pyridine-$d_5$) 5.52 (d, 2, $J_{1,2}$ = 2.5 Hz, 1-H, 1′-H), 4.35 (t, 2, $J_{1,2}$ = $J_{2,3}$ = 2.5 Hz, 2-H, 2′-H), 1.14 ppm (t, 6, *J* = 7 Hz, $OCH_3$); mass spectrum *m/e* 386 ($M^+$), 341 ($M^+$ − OEt), 193 ($M^+/2$), 148 ($M^+/2$ − OEt).

*Anal.* Calcd for $C_{14}H_{26}O_8S_2$: C, 43.52; H, 6.78; S, 16.57. Found: C, 43.31; H, 6.64; S, 16.78.

**Ethyl 4-Thio-α-D-lyxopyranoside (9).**—Sodium chips (690 mg, 30 mg-atoms) were added slowly to a solution of **2** (2.13 g, 7.5 mmol) in anhydrous $NH_3$ (500 ml) until a blue solution persisted. After addition of $NH_4Cl$ (1.8 g) the $NH_3$ was evaporated and the residue extracted with acetone. Evaporation of the extracts left 1.46 g (100%) of white, crystalline **9** of mp 108–109°. Two recrystallizations from acetone–hexane gave mp 109.5–110.5°; ir (KBr) 2575 $cm^{-1}$ (SH); $[\alpha]^{21}D$ +53° (*c* 0.1, $H_2O$); ORD (plain positive) $[\alpha]_{300}$ +265°, $[\alpha]_{240}$ +730°, $[\alpha]_{218}$ +1920°; nmr (DMSO-$d_6$) 4.69 (d, 1, $J_{1,2}$ = 2 Hz, $C_1$-H), 2.10 (s, 1, SH), 4.73 (d, 1, $J_{H,OH}$ = 5 Hz, OH), 4.67 (d, 1, $J_{H,OH}$ = 3 Hz, OH), 1.13 ppm (t, 3, *J* = 7 Hz, $CH_3CH_2$).

*Anal.* Calcd for $C_7H_{14}O_4S$: C, 43.29; H, 7.27; S, 16.48. Found: C, 43.41; H, 7.08; S, 16.61.

**Ethyl 4-Thio-α-D-lyxofuranoside (11).**—A solution of **9** (500 mg) in 6% ethanolic hydrogen chloride (17 ml) was kept at room temperature for 21 hr, then diluted with ethanol and neutralized with $PbCO_3$. Evaporation of the filtrate left a brown syrup (460 mg) that was purified by preparative tlc using chloroform–acetone (2:1). The product bands were detected with a heated wire[18] and eluted with ethanol. The fastest band gave 70 mg (14%) of starting material and was followed by 50 mg (10%) of **11**. Crystallization from acetone–ethyl acetate gave 40 mg (8%) of pure **11** of mp 95–96°; $[\alpha]^{21}D$ +331° (*c* 2.8, MeOH); nmr (pyridine-$d_5$) 5.48 (d, 1, $J_{1,2}$ = 4 Hz, $C_1$-H), 4.63 (t, 1, $J_{1,2}$ = $J_{2,3}$ = 4 Hz, $C_2$-H), 4.94 (q, 1, $J_{2,3}$ = 4 Hz, $J_{3,4}$ = 6 Hz, $C_3$-H), 4.10 (br, q, 1, $J_{3,4}$ = 6 Hz, $J_{4,5}$ = 5 Hz, $C_4$-H), 4.30 (d, 2, $J_{4,5}$ = 5 Hz, $C_5$-$H_2$), 1.11 (t, 3, *J* = 7 Hz, $CH_3CH_2$), 3.6 ppm (m, 2, $CH_3CH_2$); mass spectrum *m/e* 176 ($M^+$ − $H_2O$), 159, 146, 131, 117.

*Anal.* Calcd for $C_7H_{14}O_4S$: C, 43.29; H, 7.27; S, 16.48. Found: C, 43.39; H, 7.12; S, 16.25.

The slowest band contained 200 mg (40%) of **10**.

**Ethyl 4-Thio-β-D-ribofuranoside (13).**—A solution of **12**[19] (85 mg) in 6% ethanolic hydrogen chloride (3 ml) was kept under nitrogen for 17 hr, neutralized with $PbCO_3$, and evaporated to dryness giving 36 mg of a brown syrup. This was decolorized with carbon and crystallized from acetone giving 22 mg (45%) of **13** with mp 92–93°; $[\alpha]^{21}D$ −144° (*c* 2.5, EtOH); nmr (pyridine-$d_5$) 5.29 (d, 1, $J_{1,2}$ = 1 Hz, $C_1$-H), 1.08 (t, 3, *J* = 7 Hz, $CH_3CH_2$), 3.55 ppm (m, 2, $CH_2CH_3$); mass spectrum *m/e* 194 ($M^+$), 176 ($M^+$ − $H_2O$), 159, 146, 131, 117, 91.

*Anal.* Calcd for $C_7H_{14}O_4S$: C, 43.29; H, 7.27. Found: C, 43.54; H, 6.92.

**Registry No.**—**1**, 2773-65-1; **2**, 20072-93-9; **3**, 20072-94-0; **4**, 20072-95-1; **5**, 20072-96-2; **6**, 20072-97-3; **7**, 20072-98-4; **8b**, 20072-99-5; **9**, 20073-00-1; **10**, 20073-01-2; **11**, 20073-02-3; **13**, 20073-03-4.

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(19) We are grateful to Dr. Leon Goodman for a sample of this compound.[12b]