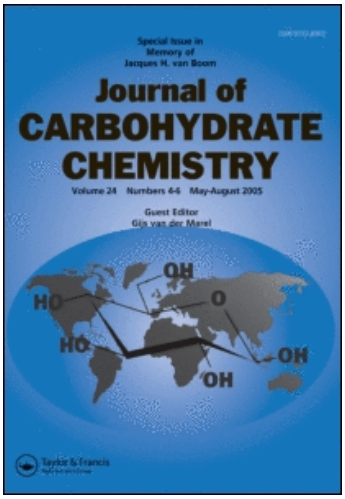


Journal of Carbohydrate Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

Total Asymmetric Synthesis of 5-Deoxy-5-thio-l-allose

Fabienne Emery[a]; Pierre Vogel[a]
[a] Section de chimie de l'Université de Lausanne, Lausanne, Switzerland

To cite this Article Emery, Fabienne and Vogel, Pierre(1994) 'Total Asymmetric Synthesis of 5-Deoxy-5-thio-l-allose', Journal of Carbohydrate Chemistry, 13: 4, 555 — 563
To link to this Article: DOI: 10.1080/07328309408011664
URL: http://dx.doi.org/10.1080/07328309408011664

J. CARBOHYDRATE CHEMISTRY, 13(4), 555-563 (1994)

TOTAL ASYMMETRIC SYNTHESIS OF 5-DEOXY-5-THIO-L-ALLOSE

Fabienne Emery and Pierre Vogel*

Section de chimie de l'Université de Lausanne
2, rue de la Barre, CH 1005 Lausanne, Switzerland

Received June 11, 1993 - Final Form January 7, 1994

ABSTRACT

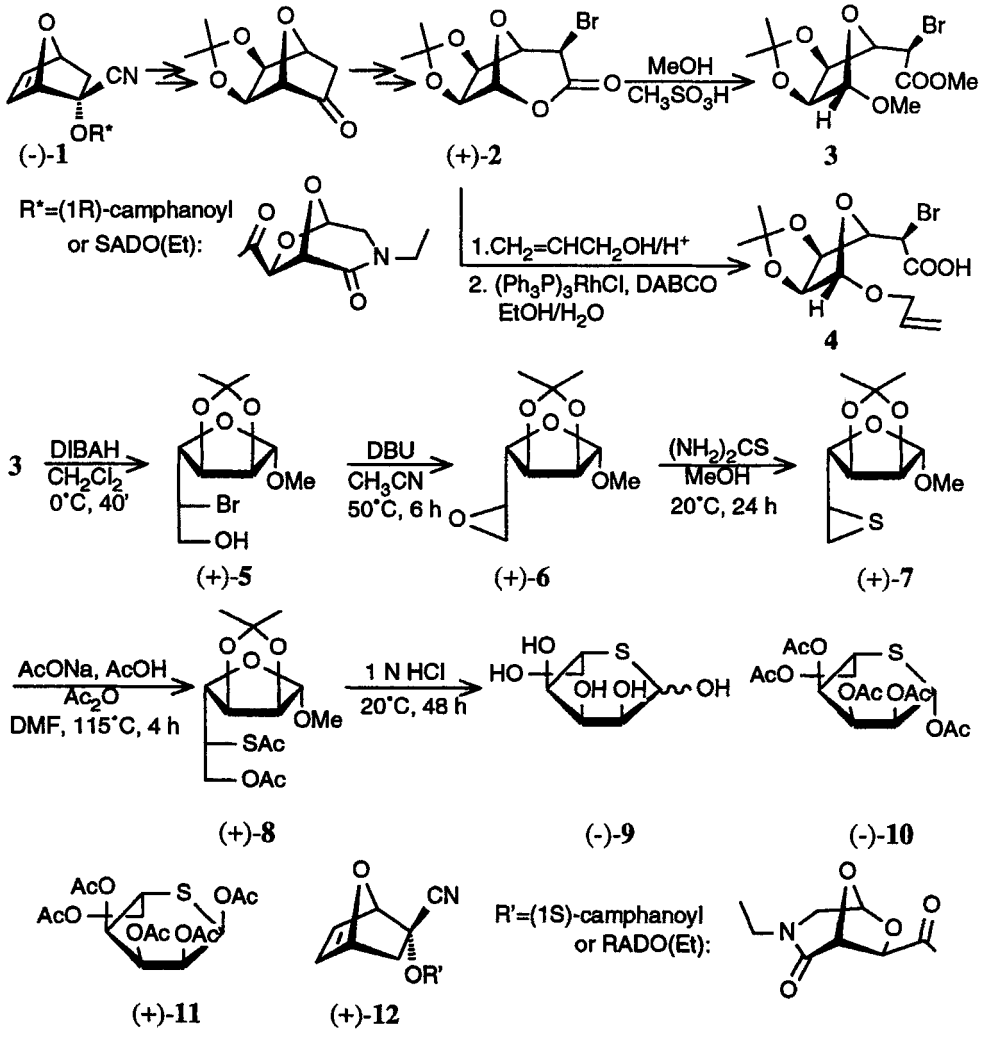
The optically pure Diels-Alder adduct of furan to 1-cyanovinyl (1*R*)-camphanate was converted to methyl(methyl 5-bromo-5-deoxy-2,3-*O*-isopropylidene-β-L-*allo*-hexofuranosid)uronate. Ester reduction, followed by HBr elimination afforded (+)-methyl 5,6-anhydro-2,3-*O*-isopropylidene-D-β-*talo*-hexofuranoside. Applying the method of Adley and Owen, (+)-methyl 5,6-dideoxy-5,6-epithio-2,3-*O*-isopropylidene-L-β-*allo*-hexofuranoside was obtained and acetolysed to give, after deprotection, (-)-5-deoxy-5-thio-L-allose.

INTRODUCTION

Sugars with a sulfur atom in the pyranose ring[1] or the furanose ring[2] have been examined as possible therapeutic agents. 5-Thio-D-mannose was isolated from the marine sponge *Clathria pyramida* (Lendenfeld)[3] and 5-amino-4,5-dideoxy-4-thio-L-*glycero*-L-*ido*-hepturonic acid is the sugar moiety of the albomycin antibiotics.[4] In 1961, Adley and Owen[5] reported the first synthetic thiosugar: 5-deoxy-5-thio-L-idose starting from D-glucose, the key-step in their procedure involving the acetolysis of a 5,6-dideoxy-5,6-epithio-hexofuranoside derivative.[6] Following analogous strategies Feather and Whistler[7] reported the first synthesis of methyl 5-deoxy-5-thio-D-glucopyranoside,[8] Shin and Perlin[9] prepared methyl 5-deoxy-5-thio-galactopyranoside, and Al-Masoudi and Hughes[10] obtained 5-deoxy-5-thio-D-allo- and altropyranose. Syntheses of 5-deoxy-5-

thio-L-fucose[11] and of 6-deoxy-6-thio-KDO[12] have also been reported recently. We report here the first total asymmetric synthesis of 5-deoxy-5-thio-L-allose starting with Diels-Alder adducts of furan to optically pure 1-cyanovinyl esters ((-)-**1**).[13] The method uses chemistry we had developed to convert (-)-**1** ("naked sugars"[14]) into L-allose, D-talose[15] and (-)-allonojirimycin;[16] the thio moiety is introduced following the original strategy of Adley and Owen.[5]

RESULTS AND DISCUSSION



The Diels-Alder adduct (-)-**1**[13] was converted into the bromouronolactone (+)-**2** applying known procedures[15] in 5 steps and an overall yield of 45%. Attempts to displace its bromide with KSCN, $PhCH_2SH$, or KSAc all failed to give any sulfur substituted derivatives. Acidic methanolysis of (+)-**2** afforded **3** (98%) the reaction of which with KSCN or KSAc gave epimerized products of bromide substitution. Similarly, the potassium 5-bromouronate **4** prepared according to Auberson[16] led also to mixtures of epimerized sulfide derivatives when treated with KSCN or KSAc. With $PhCH_2SH$ only products of decomposition were observed.

Reduction of **3** with diisobutylaluminium hydride (DIBAH) in CH_2Cl_2 at 0 °C afforded the corresponding alcohol (+)-**5** (68%) which led to the 5,6-anhydrofuranoside (+)-**6** (83%) on heating to 50 °C with two equivalents of DBU (1,8-diazabicyclo-[5.4.0]undec-7-ene). In the presence of thiourea in MeOH (20 °C) (+)-**6** was converted into the episulfide (+)-**7** (79%). On treatment with AcONa (10 equivalents) in $AcOH/Ac_2O$ (45 °C, 4 h), the protected thioallose derivative (+)-**8** was obtained in a yield of 93%. Complete deprotection was achieved with 1 N HCl at 20 °C (48 h) affording 5-deoxy-5-thio-L-allose ((-)-**9**) (86%) after purification with Amberlite IRA-68 resin. Complete characterization of (-)-**9** was realized by converting it into a 1.3:1 mixture of the polyacetates (-)-**10** and (+)-**11** which could be separated and purified by column chromatography on silica gel.

The new compounds described in this work were completely characterized by their spectral data, modes of formation and reactions (see Experimental Part).

CONCLUSION

The first total synthesis of 5-deoxy-5-thio-L-allose ((-)-**9**) has been realized. It converts the "naked sugar" (-)-**1** in 11 steps with an overall yield of 16%. This synthesis must be compared with that of Al-Masoudi and Hughes[10] who converted 5,6-anhydro-1,2-*O*-isopropylidene-L-idofuranose into (+)-**9** in 8 steps and an overall yield of 9%. Our approach can be applied to prepare 5-deoxy-5-thio-D-allose ((+)-**9**) since the Diels-Alder adduct (+)-**12** of furan to 1-cyanovinyl (1*S*)-camphanate (chiral auxiliary: (*S*)-camphanic acid or RADO(Et)OH) is readily available as (-)-**1**.[13] In principle, our synthetic strategy can also be applied to the total synthesis of 5-deoxy-5-thiohexoses with configurations different from that of allose and with other substituents than hydroxyl groups since the C(5) and C(6) centers of the starting materials (-)-**1** and (+)-**12** can be substituted with other moieties than two *exo*-hydroxyl groups.[14,17]

EXPERIMENTAL

General. Reagents (Fluka, Merck, Aldrich) were used without purification. Solvents were distilled prior to use. Anhydrous ether and THF (Na, benzophenone, Ar), CH_2Cl_2 (P_2O_5), pyridine and triethylamine (CaH_2) were prepared just before use. Flash column chromatography (FC) employed Merck silica gel (60, particle size 0.040-0.63 mm). All reactions were monitored by thin layer chromatography (TLC) on 0.25 mm Merck silica gel plates (60F-254) using *p*-anisaldehyde, UV light or phosphomolybdic acid/heat as developing means. Melting points (mp) obtained with a SMP-20 Büchi apparatus, were not corrected. Optical rotations were recorded with a Perkin-Elmer polarimeter. IR spectra (solvent) were recorded on Perkin Elmer 1430 spectrometer (ν, in cm^{-1}); ^1H NMR spectra (δ_H in ppm, *apparent multiplicity*, signal integration, apparent coupling constant in Hz, signal attributions) were recorded on a Bruker 250 FT (250 MHz), the signal from residual solvent ($\delta_H(CHCl_3)$ = 7.25 ppm, $\delta_H(CHDCl_2)$ = 5.35 ppm, δ_H(MeOH) = 3.35 ppm, $\delta_H(C_6HD_5)$ = 7.20 ppm) was used as the internal reference; ^{13}C NMR spectra (δ_C in ppm, *apparent multiplicity*, ^1J(C,H) coupling constant in Hz, signal attributions) on a Bruker 250 FT (62.9 MHz), the signal from residual solvent ($\delta_C(CHCl_3)$ = 77.0 ppm, δ_C (MeOH) = 49.0 ppm, $\delta_C(CH_2Cl_2)$ = 53.8 ppm) was used as the internal reference; mass spectra (MS) on a Nermag R10-10C machine using chemical ionization (CI-NH_3) or electronic ionization (70 eV) mode. Elemental analyses were performed by Ilse Beetz, Kronach, Germany. None of the procedures have been optimized.

(+)-Methyl 5-Bromo-5-deoxy-2,3-*O*-isopropylidene-β-L-*allo*-hexofuranoside ((+)-**5**). A mixture of (+)-**2**[15] (803 mg, 2.88 mmol), methanesulfonic acid (1.86 mL, 14.4 mmol), 2,2-dimethoxypropane (11.2 mL, 91.2 mmol) and methanol (21 mL) was stirred at 25 °C for 18 h. A 5% solution of $NaHCO_3$ (100 mL) was added, and the methanol was evaporated under reduced pressure. The residual aqueous phase was extracted with CH_2Cl_2 (50 mL, five times). The combined organic phases were washed with water (50 mL, twice), dried ($MgSO_4$) and the solvent evaporated *in vacuo*. The brown oily residue was dissolved in anhydrous CH_2Cl_2 (25 mL), cooled to 0 °C and a 1.2 molar solution of diisobutylaluminium hydride in toluene (DIBAH, 5.0 mL, 6.04 mmol) was added. After stirring at 0 °C for 40 min., MeOH (1 mL) was added dropwise to destroy the excess of DIBAH. The solution was washed with 1 N HCl (20 mL). The aqueous layers were combined and extracted with CH_2Cl_2 (20 mL, twice). The combined organic phases were dried ($MgSO_4$) and the solvent evaporated *in vacuo*. The residue was purified by column chromatography (70 g silica gel, EtOAc/light petroleum 1:3, R_f ((+)-**5**) = 0.19)

yielding 600 mg (69%), colorless oil. $[\alpha]_D^{26}$ +59 (*c* 1.0, CH_2Cl_2). IR (CH_2Cl_2) v: 3850, 2940, 2870, 1380, 1100, 865 cm^{-1}. ^1H NMR ($CDCl_3$) δ_H: 5.05 (s, H-1); 4.97 (dd, ^2J = 6.0, 1.0, H-3); 4.61 (d, ^2J = 6.0, H-2); 4.40 (dd, ^3J = 11, 1.0, H-4); 4.08-3.98 (m, H-5, 2 H-6); 3.39 (s, OMe); 1.50, 1.35 (2s, Me_2C). ^{13}C NMR ($CDCl_3$) δ_C: 112.7 (s), 110.1 (d, 172, C-1); 87.3 (d, 155), 84.6 (d, 159), 83.6 (d, 157, C-2, C-3, C-4); 64.6 (t, 146, C-6); 56.8 (d, 139, C-5); 55.9 (q, 144, MeO); 26.5, 25.0 (2q, 126-128, Me_2). MS (70 eV) m/z: 251 (4, $M^{+\cdot}$-Me-CH_2OH), 249 (3), 209 (4), 207 (4), 157 (10), 99 (36), 85 (28), 69 (19), 59 (100).

Anal. Calcd for $C_{10}H_{17}O_5Br$ (297.15): C 40.42, H 5.77, Br 26.89; Found: C 40.62, H 5.50, Br 27.01.

(±)-Methyl 5-Bromo-5-deoxy-2,3-*O*-isopropylidene-β-DL-*allo*-hexofuranoside ((±)-**5**). Prepared by the above procedure from (±)-**3** obtained from the Diels-Alder adduct of furan to 1-cyanovinyl acetate;[15,18] (±)-**5** had mp 79-80 °C (ether/hexane).

(+)-Methyl 5,6-Anhydro-2,3-*O*-isopropylidene-β-D-*talo*-hexofuranoside ((+)-**6**). A mixture of (+)-**5** (600 mg, 2.03 mmol), DBU (600 µL, 4.05 mmol) and CH_3CN (30 mL) was stirred at 50 °C for 6 h. The solution was filtered through a pad of silica gel (Merck 9385, 15 g) and the solvent was evaporated *in vacuo* yielding 363 mg (83%), colorless oil. $[\alpha]_D^{25}$ +57 (*c* 0.75, CH_2Cl_2). IR (CH_2Cl_2) v: 2940, 2870, 1370, 1100, 900, 865 cm^{-1}. ^1H NMR ($CDCl_3$) δ_H: 5.03 (s, H-1); 4.71 (dd, ^3J = 6.0, 1.0, H-3); 4.60 (d, ^2J = 6.0, H-2); 3.88 (dd, ^3J = 7.5, 1.0, H-4); 3.40 (s, MeO); 3.05 (ddd, $^2J_{4,5}$ = 7.5, $^3J_{5,trans\text{-}6}$ = 4.0, $^3J_{5,cis\text{-}6}$ = 2.5, H-5); 2.80 (dd, ^2J = 5.0, ^3J = 4.0, H_{trans}-6); 2.60 (dd, ^2J = 5.0, ^3J = 2.5, H_{cis}-6); 1.46, 1.30 (2s, Me_2C). ^{13}C NMR ($CDCl_3$) δ_C: 112.5 (s); 109.1 (d, 174, C-1); 88.4 (d, 152), 85.0 (d, 159), 81.3 (d, 147, C-2, C-3, C-4); 54.7 (q, 144, MeO); 52.7 (d, 145, C-5); 44.6 (t, 176, C-6); 26.3, 24.9 (2q, 126-128, Me_2). CI-MS (NH_3) m/z: 235 (11), 234 (100, M+NH_4^+), 218 (4), 217 (31, M+H^+), 202 (17), 201 (9, $M^{+\cdot}$-Me), 185 (5), 98 (3), 85 (6), 81 (3).

(±)-Methyl 5,6-Anhydro-2,3-*O*-isopropylidene-β-DL-*talo*-hexofuranoside ((±)-**6**). Prepared by the above procedure from (±)-**5**. (±)-**6** was a colorless oil.

(+)-Methyl 5,6-Dideoxy-5,6-epithio-2,3-*O*-isopropylidene-β-L-*allo*-hexofuranoside ((+)-**7**). A mixture of (+)-**6** (2.53 g, 11.8 mmol), thiourea (1.79 g, 23.6 mmol) and MeOH (100 mL) was stirred at 20 °C for 24 h. The solvent was evaporated *in vacuo*; the residue was dissolved in CH_2Cl_2 (50 mL) and the solution was washed with H_2O (50 mL). The aqueous layer was extracted with CH_2Cl_2 (50 mL, twice). The combined organic phases were dried ($MgSO_4$) and the solvent evaporated *in vacuo*. The residue was purified by column chromatography (Lobar C, Lichroprep Si 60, EtOAc/light petroleum 1:4, R_f ((+)-**7**) = 0.47) yielding 2.15 g (79%), colorless oil that

solidified slowly, mp 44-47 °C. $[\alpha]_D^{25}$ +75 (*c* 1.1, CH_2Cl_2). IR (CH_2Cl_2) ν: 2950, 2870, 1380, 1100, 865. ^1H NMR ($CDCl_3$) δ_H: 5.03 (s, H-1); 4.85 (dd, ^3J = 6.0, 0.5, H-3); 4.69 (d, ^3J = 6.0, H-2), 3.64 (dd, ^3J = 9.5, 0.5, H-4); 3.39 (s, MeO); 3.05 (ddd, $^3J_{4,5}$ = 9.5, $^3J_{5,cis\text{-}6} \cong {}^3J_{5,trans\text{-}6} \cong 6$, H-5); 2.59 (dd, ^3J = 6, ^2J = 1.5), 2.32 (dd, $^3J \cong 6$, ^2J = 1.5, 2 H-6); 1.47, 1.33 (2s, Me_2C). ^{13}C NMR ($CDCl_3$) δ_C: 112.4 (s); 109.4 (d, 174, C-1); 92.2 (d, 154, C-3); 85.1 (d, 159, C-2); 83.8 (d, 158, C-4); 54.7 (q, 146, MeO); 35.1 (d, 171, C-5); 26.3, 24.8 (2q, 127, Me_2), 24.8 (t, 170, C-6). CI-MS (NH_3) m/z: 251 (7), 250 (56, $M+NH_4^+$), 233 (6, $M+H^+$), 220 (6), 219 (6), 218 (44), 217 (4), 202 (11), 201 (27), 186 (13), 185 (5), 184 (5), 170 (9), 169 (100), 127 (6), 126 (3), 125 (5), 109 (11), 97 (18), 85 (18), 82 (12), 81 (18).

(±)-Methyl 5,6-Dideoxy-5,6-epithio-2,3-*O*-isopropylidene-β-DL-*allo*-hexofuranoside ((±)-**7**). Prepared by the above procedure from (±)-**6**. (±)-**7** was a colorless oil.

(+)-Methyl 6-*O*-Acetyl-5-acetylthio-5-deoxy-2,3-*O*-isopropylidene-β-L-*allo*-hexofuranoside ((+)-**8**). A mixture of (+)-**7** (153 mg, 0.66 mmol), AcONa (217 mg, 2.5 mmol), AcOH (378 μL, 6.6 mmol), Ac_2O (2.1 mL) and anhydrous DMF (50 mL) was heated under reflux for 4 h. After cooling to 20 °C the solvent was evaporated *in vacuo* and the residue was dissolved in CH_2Cl_2 (50 mL). The solution was washed with 0.5 N NaOH (50 mL). The aqueous layer was extracted with CH_2Cl_2 (50 mL, twice). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated *in vacuo*. The residue was purified by flash chromatography on silica gel (40 g, EtOAc/light petroleum 1:3, R_f ((+)-**8**) = 0.24) yielding 204 mg (93%), colorless crystals, mp 93.5-95 °C (EtOAc/light petroleum 1:4). $[\alpha]_D^{25}$ +62 (*c* 0.75, CH_2Cl_2). IR ($CDCl_3$) ν: 2990, 2935, 2870, 1740, 1695, 1375, 1355, 1100. ^1H NMR ($CDCl_3$) δ_H: 5.03 (s, H-1); 4.55 (d, ^3J = 6.0, H-2); 4.50 (dd, ^3J = 6.0, 1.0, H-3); 4.48, 4.35 (2dd, ^2J = 11.5, $^3J_{5,6} \cong 4$, $^3J_{5,6'} \cong 3$, 2 H-6); 4.23 (dd, ^3J = 12, 11, H-4); 3.80 (ddd, ^3J = 12, 4, 3, H-5); 3.43 (s, MeO); 2.40 (s, AcS); 2.08 (s, AcO); 1.50, 1.32 (2s, Me_2C). ^{13}C NMR ($CDCl_3$) δ_C: 194.0 (s, COS); 170.6 (s, COO); 112.6 (s); 110.6 (d, 175, C-1); 85.7 (d, 153), 85.2 (d, 160), 82.6 (d, 160, C-2, C-3, C-4); 64.1 (t, 151, C-6); 56.1 (q, 144, MeO); 45.3 (d, 142, C-5); 30.7 (q, 130), 26.5 (q, 129), 25.0 (q, 126), 20.7 (q, 130, 4 Me). MS (70 eV) m/z: 320 (3), 319 (18), 318 (12), 276 (2), 275 (2), 274 (1), 258 (4), 247 (12), 245 (11), 216 (22), 199 (15), 191 (17), 173 (79), 114 (69), 98 (47), 87 (67), 85 (100).

Anal. Calcd for $C_{14}H_{22}O_7S$ (334.39): C 50.29, H 6.63, S 9.59; Found: C 50.33, H 6.62, S 9.62.

(±)-Methyl 6-*O*-Acetyl-5-acetylthio-5-deoxy-2,3-*O*-isopropylidene-β-DL-*allo*-hexofuranoside ((±)-**8**). Prepared by the above procedure from (±)-**7**. (±)-**8**, colorless crystals, mp 82-83 °C (EtOAc/light petroleum 1:4).

(-)-5-Deoxy-5-thio-L-allose ((-)-**9**). A mixture of (+)-**8** (200 mg) and 1 N HCl (8 mL) was allowed to stand at 20 °C for 2 days. The solution was neutralized with Amberlite IRA-68 resin (10.7 g). After concentration *in vacuo* to *ca.* 10 mL, the mixture was filtered through a Dynagard 0.2 μm filter (Microgon Inc.) and the solution evaporated *in vacuo* to dryness. The residue was dissolved in toluene/CH_2Cl_2 5:1 (5 mL) and evaporated to dryness. This operation was repeated once, yielding 101 mg (86%), colorless crystals, mp 146-148 °C (dec.). $[\alpha]_D^{25}$ -73 (*c* 1.0, H_2O), lit.[10]: +75-+115 (*c* 1.0, H_2O) for 5-deoxy-5-thio-D-allose. IR (KBr) ν: 3360, 2470, 1055, 1025 cm^{-1}. ^{13}C NMR (D_2O, $CDCl_3$ as external reference) for α-pyranose, δ_C: 74.9 (d, 160, C-1); 73.3 (d, 146), 71.1 (d, 146), 70.9 (d, 138, C-2, C-3, C-4); 60.2 (t, 146, C-6); 38.2 (d, 141, C-5); β-pyranose, δ_C: 75.2 (d, 146, C-1); 74.7 (d, 141), 71.9 (d, 162), 70.8 (d, 144, C-2, C-3, C-4); 60.9 (t, 146, C-6); 44.12 (d, 141, C-5). CI-MS (NH_3) m/z: 214 (100, $M+NH_4^+$), 196 (28, $M^{+\cdot}$), 179 (8), 178 (9, $M^{+\cdot}-H_2O$), 161 (9), 160 (24), 144 (60), 127 (63).

Anal. Calcd for $C_6H_{12}O_5S$ (196.22): C 36.73, H 6.16, S 16.34; Found: C 36.87, H 6.17, S 16.12.

(±)-5-Deoxy-5-thio-DL-allose ((±)-**9**). Prepared by the above procedure from (±)-**8**. (±)-**9** was a colorless oil.

(-)-1,2,3,4,6-*O*-Pentaacetyl-5-deoxy-5-thio-α-L-*allo*-hexopyranose ((-)-**10**) **and (+)-1,2,3,4,6-*O*-Pentaacetyl-5-deoxy-5-thio-β-L-*allo*-hexopyranose** ((+)-**11**). A mixture of (-)-**9** (101 mg, 51.3 mmol), THF (1 mL), Ac_2O (0.6 mL), pyridine (0.5 mL) and 4-dimethylaminopyridine (5 mg) was stirred at 20 °C for 4 h. The mixture was filtered through a pad of silica gel (15 g, Merck 9385, THF) and the solvent was evaporated. The residue was purified by column chromatography (Lobar B, Lichroprep Si 60, EtOAc/light petroleum 1:1, R_f ((-)-**10**) = 0.30, R_f ((+)-**11**) = 0.36). A first fraction yielded 53.6 mg (26%) of (+)-**11**, a second fraction gave 69.3 mg (33%) of (-)-**10**).

Characteristics of (-)-**10**, colorless oil. $[\alpha]_D^{25}$ -157 (*c* 1.1, $CHCl_3$). IR (CH_2Cl_2) ν: 3060, 2990, 1755, 1220 cm^{-1}. ^1H NMR ($CDCl_3$) δ_H: 6.08 (d, ^3J = 3.5, H-1); 5.60 (dd, ^3J = 3.1, 3.0, H-3); 5.18 (dd, ^3J = 3.5, 3.0, H-2); 5.15 (dd, ^3J = 11.0, 3.1, H-4); 4.38 (dd, ^2J = 12.0, ^3J = 5.0, H-6); 4.19 (dd, ^2J = 12.0, ^3J = 3.0, H-6); 3.79 (ddd, ^3J = 11.0, 5.0, 3.0, H-5); 2.16, 2.15, 2.07, 2.02, 1.99 (5s, 5 AcO). ^{13}C NMR ($CDCl_3$) δ_C: 170.4, 169.6, 169.2, 169.1, 168.9 (5s, 5 CO); 71.4 (d, 152, C-1); 69.7 (d, 167), 69.6 (d, 155), 69.3 (d, 156, C-2, C-3, C-4); 61.4 (t, 151, C-6); 40.2 (d, 145, C-5); 20.6-20.5 (5q, 130, 5 Me). MS (70 eV) m/z: 286 (6, $M^{+\cdot}$-2 AcOH), 244 (20), 227 (64), 185 (100), 142 (30).

Anal. Calcd for $C_{16}H_{22}O_{10}S$ (406.4): C 47.29, H 5.46, S 7.89; Found: C 47.29, H 5.43, S 7.95.

Characteristics of (+)-**11**, colorless oil. $[\alpha]_D^{25}$ +24.3 (*c* 1.1, $CHCl_3$). IR (CH_2Cl_2) ν: 3060, 2990, 1755, 1220 cm^{-1}. ^1H NMR ($CDCl_3$) δ_H: 6.12 (d, ^3J = 9.0, H-1); 5.59 (dd, ^3J = 2.6, 2.5, H-3); 5.30 (dd, ^3J = 9.0, 2.6, H-2); 5.20 (dd, ^3J = 10.5, 2.5, H-4); 4.28 (dd, ^2J = 12.0, ^3J = 5.5, H-6); 4.20 (dd, ^2J = 12.0, ^3J = 3.5, H-6); 3.67 (ddd, ^3J = 10.5, 5.5, 3.5, H-5); 2.14, 2.07, 2.06, 2.01, 1.99 (5s, 5 AcO). ^{13}C NMR ($CDCl_3$) δ_C: 170.6, 169.9, 169.4, 169.3, 169.2 (5s, 5 CO); 70.1 (d, 161), 70.0 (d, 151), 69.8 (d, 146, C-2, C-3, C-4); 68.8 (d, 154, C-1); 60.9 (t, 151, C-6); 35.4 (d, 146, C-5); 20.9, 20.7, 20.6, 20.5, 20.4 (5q, 130, 5 Me). MS (70 eV) m/z: 286 (6, $M^{+\cdot}$-2 AcOH), 244 (20), 227 (64), 185 (100), 142 (30).

Anal. Calcd for $C_{16}H_{22}O_{10}S$ (406.4): C 47.29, H 5.46, S 7.89; Found: C 47.29, H 5.43, S 7.95.

(±)-1,2,3,4,6-*O*-Pentaacetyl-5-deoxy-5-thio-α-DL-*allo*-hexopyranose ((±)-10) and (±)-1,2,3,4,6-*O*-Pentaacetyl-5-deoxy-5-thio-β-DL-*allo*-hexopyranose ((±)-11). Prepared by the above procedure from (±)-**9**. (±)-**10** was a white solid, mp 117-118 °C; (±)-**11** was a white solid, mp 138.5-140 °C.

ACKNOWLEDGMENT

This work was supported by the Swiss National Science Foundation, the Fonds Herbette (Lausanne) and F. Hoffmann-La Roche & Co. AG (Basel). We thank Dr. Y. Auberson for his advice and assistance.

REFERENCES AND NOTES

1. D. Horton and J. Wander, *The Carbohydrates: Chemistry and Biochemistry*, Vol. 1B; W. Pigman and D. Horton, Eds.; Academic Press: New York, 1980, p 799-842; J. H. Kim, S. H. Sim, W. Hahn and C. W. Song, *Science*, **200**, 206 (1978); T. H. Maugh, II, *Ibid.*, **186**, 431 (1974).

2. O. Varela, D. Cicero and R. M. de Lederkremer, *J. Org. Chem.* **54**, 1884 (1989) and ref. cited therein.

3. R. J. Capon and J. K. MacLeod, *J. Chem. Soc., Chem. Commun.*, 1200 (1987).

4. G. Benz, L. Born, M. Brieden, R. Grosser, J. Kurz, H. Paulsen, V. Sinnwell and B. Weber, *Liebigs Ann. Chem.*, 1408 (1984); see also: M. W. Bredenkamp, C. W. Holzapfel and A. D. Swanepoel, *Tetrahedron Lett.*, **31**, 2759 (1990).

5. T. J. Adley and L. N. Owen, *Proc. Chem. Soc.*, 418 (1961); see also: T. J. Adley and L. N. Owen, *J. Chem. Soc. (C)*, 1287 (1966).

6. For alternative syntheses of 5-deoxy-5-thio-L-idose derivatives, see: N. A. Hughes, N. M. Munkombwe and N. D. Todhunter, *Carbohydr. Res.*, **216**, 119 (1991); H. Hashimoto, M. Kawanishi and H. Yuasa, *Tetrahedron Lett.*, **32**, 7087 (1991).

7. M. S. Feather and R. L. Whistler, *Tetrahedron Lett.*, 667 (1962); see also: R. M. Rowell and R. L. Whistler, *J. Org. Chem.*, **31**, 1514 (1966); U. G. Nayak and R. L. Whistler, *Ibid.*, **34**, 97 (1969); R. L. Whistler and W. L. Lake, *Meth. Carbohydr. Chem.*, **6**, 286 (1972); H. Driguez and B. Henrissat, *Tetrahedron Lett.*, **22**, 5061 (1981).

8. For transformations of 5-deoxy-5-thio-D-glucopyranoside derivatives into other thiosugars, see *e.g.*: H. Yuasa, J.-i., Tamura and H. Hashimoto, *J. Chem. Soc., Perkin Trans. I*, 2763 (1990); H. Yuasa, A. Takenaka and H. Hashimoto, *Bull. Chem. Soc. Jpn.*, **63**, 3473 (1990); N. A. L. Al-Masoudi, *Carbohydr. Res.*, **228**, 339 (1992); N. A. Al-Masoudi and W. Pfleiderer, *Ibid.*, **242**, 287 (1993).

9. J. E. Nam Shin and A. S. Perlin, *Carbohydr. Res.*, **76**, 165 (1979).

10. N. A. L. Al-Masoudi and N. A. Hughes, *Carbohydr. Res.*, **148**, 25 and 39 (1986).

11. S. Takahashi and H. Kuzuhara, *Chem. Lett.*, 21 (1992); H. Hashimoto and M. Izumi, *Ibid.*, 25 (1992).

12. B. Classon, P. J. Garegg, Z. Liu and B. Samuelsson, *Carbohydr. Res.*, **174**, 369 (1988); Z. Liu, B. Classon, P. J. Garegg and B. Samuelsson, *J. Carbohydr. Chem.*, **10**, 65 (1991).

13. E. Vieira and P. Vogel, *Helv. Chim. Acta*, **66**, 1965 (1983); J.-L. Reymond and P. Vogel, *Tetrahedron: Asymmetry*, **1**, 729 (1990); see also: R. Saf, K. Faber, G. Penn, H. Griengl, *Tetrahedron*, **44**, 389 (1988); B. Ronan, H. B. Kagan, *Tetrahedron: Asymmetry*, **2**, 75 (1991).

14. A. Warm and P. Vogel, *J. Org. Chem.* **51**, 5348 (1986); P. Vogel, Y. Auberson, M. Bimwala, E. de Guchteneere, E. Vieira and J. Wagner, in "*Trends in Synthetic Carbohydrate Chemistry*", ACS Symposium Series 386; D. Horton, L. D. Hawkins and G. J. McCarvey, Eds.; American Chemical Society, Washington, D. C. USA, 197 (1989); P. Vogel, D. Fattori, F. Gasparini, C. Le Drian, *Synlett*, 173 (1990); P. Vogel, *Bull. Soc. Chim. Belg.*, **99**, 395 (1990); P. Vogel, *Chimica Oggi*, 9 (1992).

15. Y. Auberson and P. Vogel, *Helv. Chim. Acta*, **72**, 278 (1989).

16. Y. Auberson and P. Vogel, *Angew. Chem. Int. Ed. Engl.*, **28**, 1498 (1989).

17. For stereoselective *cis-exo*-aminohydroxylations and *trans*-aminohydroxylations of "naked sugars", see: C. Nativi, J.-L. Reymond and P. Vogel, *Helv. Chim. Acta*, **72**, 882 (1989); S. Allemann and P. Vogel, *Synthesis*, 923 (1991); for 5-*exo*-azido-7-oxabicyclo[2.2.1]heptan-2-one, see: J.-M. Durgnat and P. Vogel, *Helv. Chim. Acta*, **76**, 222 (1993).

18. E. Vieira and P. Vogel, *Helv. Chim. Acta*, **65**, 1700 (1982); R. R. Schmidt, C. Beitzke and A. K. Forrest, *J. Chem. Soc., Chem. Commun.*, 909 (1982).