droxy-3-oxopregn-4-en-21-oate (50 mg) as in the preparation of **16a** from **15a** gave needles from methanol (35 mg, mp 208–210°; 9.1 mg, mp 204–206°) in a yield of 89%: $[\alpha]_{365}$ +579°, $[\alpha]_D$ +141°; λ_{max} 238 mμ, ε 15,200.

Anal. Calcd for $C_{24}H_{32}O_5$: C, 71.97; H, 8.05. Found: C, 71.65; H, 8.20.

16b from 14b.—Acetonation of 20β-hydroxy-3,11-dioxopregn-4-en-21-oic acid (100 mg) provided 68 mg of needles from methanol, mp 208–210°, which possessed an ir spectrum identical with that of **16b** prepared from **15b**.

20α,21-Isopropylidenedioxy-17-hydroxy-3,11-dioxopregn-4-en-21-oate (18a) from 17a.—Acetonation of 17,20α-dihydroxy-3,11-dioxopregn-4-en-21-oic acid (100 mg)[11] for 3.5 hr and crystallization of the product from methanol gave 76 mg (69%) of leaflets, mp 269–271°. The analytical sample had mp 271–272°; $[\alpha]_{365}$ +395°, $[\alpha]_D$ +85.7°; λ_{max} 238 mμ, ε 15,500.

Anal. Calcd for $C_{24}H_{32}O_6$: C, 69.19; H, 7.74. Found: C, 69.32; H, 7.65.

Treatment of **18a** (10 mg) in methanol (2.5 ml) with an equal volume of 0.1 *N* methanolic sodium hydroxide for 2 hr followed by dilution with methylene chloride and washing with water afforded 7.7 mg of prisms from acetone–ether, mp 197–198°. A mixture melting point with **methyl 17,20α-dihydroxy-3,11-dioxopregn-4-en-21-oate** (**19a**)[11] was 196–197.5°, and their ir spectra were identical.

20β,21-Isopropylidenedioxy-17-hydroxy-3,11-dioxopregn-4-en-21-oate (18b) from 17b.—Acetonation of 17,20β-dihydroxy-3,11-dioxopregn-4-en-21-oic acid (100 mg)[11] for 3.5 hr and crystallization from methanol provided 45 mg of needles, mp 293.5–294°. Fractionation of the mother liquor on a small silica gel column in ethyl acetate–isooctane (3:2) afforded an additional 35 mg of product, mp 293.5–294°, raising the yield to 72%: $[\alpha]_{365}$ +499°, $[\alpha]_D$ +107°; λ_{max} 238 mμ, ε 15,500.

Anal. Calcd for $C_{24}H_{32}O_6$: C, 69.19; H, 7.74. Found: C, 69.30; H, 7.68.

Treatment of **18b** (10 mg) with methanolic sodium hydroxide gave 8.4 mg of prisms from acetone–ether, mp 211.5–213°. The identity of this product with **methyl 17,20β-dihydroxy-3,11-dioxopregn-4-en-21-oate** (**19b**)[11] was shown by mixture melting point and ir comparisons.

Registry No.—**2**, 27149-60-6; **3**, 3941-62-6; **6**, 3941-65-9; **7**, 27149-63-9; **9**, 27149-64-0; **11a**, 27149-65-1; **11b**, 27149-66-2; **12a**, 27149-67-3; **12b**, 27149-68-4; **13a**, 27149-69-5; **13b**, 27149-70-8; **14a**, 27149-71-9; **14b**, 27149-72-0; **15a**, 27150-71-6; **15b**, 27150-72-7; **16a**, 27150-73-8; **16b**, 27150-74-9; **18a**, 27189-20-4; **18b**, 27189-21-5; methyl 20α-acetoxy-3,11-dioxopregn-4-en-21-oate, 27150-75-0.

Acknowledgment.—The author thanks Dr. John Schneider for his continued assistance.

Notes

Disulfides of 2-Mercaptocyclohexanol

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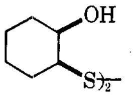
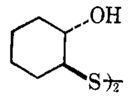
During the course of studies in our laboratory, we had need to prepare the disulfides **1** and **2** derived from *cis*- and *trans*-2-mercaptocyclohexanol, respectively. The trans,trans disulfide **2** has been reported by Mousseron[2] to be obtained by the reaction of sodium disulfide with *trans*-2-chlorocyclohexanol, while the cis,cis disulfide **1** has not been described in the literature.

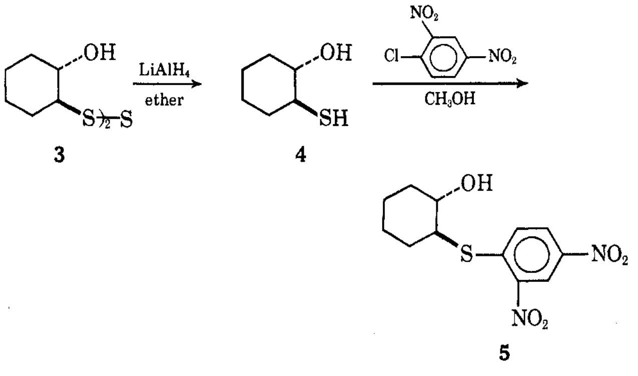


1



2

Repetition of Mousseron's procedure gave, as reported, a compound having a melting point of 156°. However, the molecular weight of this material, as determined by mass spectrometry, was found to be 294 rather than 262 as expected for the disulfide **2**. This difference of 32 mass units is indicative that Mousseron's product is the trisulfide **3** rather than the disulfide **2**. That this is the case was established by elemental analysis and by preparation, following a known procedure,[3] of the trisulfide **3**, which was shown to be identical with Mousseron's product. The trisulfide **3** has been reported[4] to possess a melting point of 157–158°. The all-trans stereochemistry of the trisulfide **3** was confirmed by reduction[5] with lithium aluminum hydride to give *trans*-2-mercaptocyclohexanol (**4**)[6] characterized as the known 2,4-dinitrophenyl thio ether derivative **5**.[4,6,7]



3 **4** **5**

The trans,trans disulfide **2** was obtained by oxidation of *trans*-2-mercaptocyclohexanol (**4**)[6] with iodine. The disulfide **2** has a melting point of 82–83°, gives a molecular ion peak at *m/e* 262, and upon reduction with lithium aluminum hydride regenerates **4**.

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[1] To whom inquiries should be sent.

[2] M. Mousseron, *Bull. Soc. Chim. Fr.*, 84 (1948).

[3] B. D. Vineyard, *J. Org. Chem.*, **31**, 601 (1966).

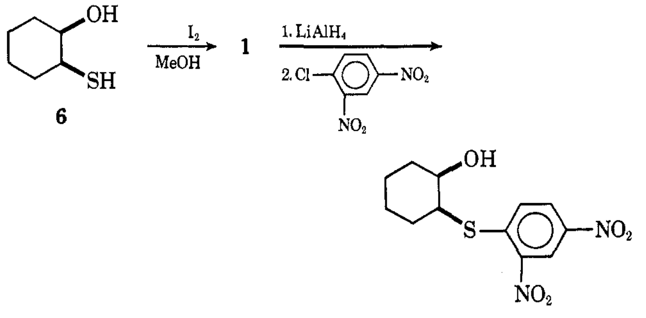
[4] J. Ebersberger, H. Holtschmidt, and R. Stroh, German Patent 1,098,937 (1961); *Chem. Abstr.*, **55**, 24680*h* (1961).

[5] M. Mousseron, R. Jacquier, M. Mousseron-Canet, and R. Zagoun, *Bull. Soc. Chim. Fr.*, 1042 (1952).

[6] C. C. J. Culvenor, W. Davis, and N. S. Heath, *J. Chem. Soc.*, 278 (1949).

[7] H. Behringer and W. Kley, *Justus Liebigs Ann. Chem.*, **595**, 160 (1955).

Oxidation of the known[7] *cis*-2-mercaptocyclohexanol (6) with iodine gave the cis,cis disulfide **1** melting at 85–88°. The molecular weight of the disulfide **1** was determined by mass spectrometry to be 262. The nonidentity of this material with the disulfide **2** was verified by depression of the mixture melting point and nonsuperposable ir and nmr spectra. The disulfide **1** was converted by reduction and derivatization to the known[7] *cis*-2-hydroxycyclohexyl 2,4-dinitrophenyl sulfide (**7**).



It is of interest to note that the nmr spectrum of the cis,cis disulfide **1** shows the C-1 carbinyl proton as a multiplet centered at τ 5.95 and appearing 0.50 ppm downfield from the corresponding carbinyl proton of the trans,trans disulfide **2**. This data establishes[8] that the hydroxyl group is axial and the disulfide group is equatorial in the disulfide **1**, while both function groups, as expected, are equatorial in the disulfide **2**.

Experimental Section

Melting points were determined on a Thomas–Hoover capillary apparatus and are uncorrected. Infrared spectra were obtained with Beckman IR-8 and IR-20A spectrophotometers. The nmr spectra were recorded at 60 MHz on a Varian A-60 spectrometer. Mass spectra were measured on a Hitachi Perkin-Elmer RMU-6E mass spectrometer. Solvents were removed *in vacuo* on a Buchler rotary evaporator.

***trans,trans*-Bis(2-hydroxycyclohexyl) Trisulfide (3).**—A modified procedure for the preparation of trisulfides reported by Vineyard[3] was employed. *trans*-2-Mercaptocyclohexanol (**4**,[6] 14.9 g, 0.113 mol) was stirred with 0.5 ml of *n*-butylamine at room temperature. Recrystallized sulfur (2.5 g, 0.078 mol) was added over a 1-hr period after which the reaction mixture was stirred overnight. Benzene was added to the mixture and any solid material present was removed by filtration. The organic phase was washed with water, 6 *N* hydrochloric acid, 6 *N* sodium hydroxide, and water. After the mixture was dried over magnesium sulfate, the solvent was removed *in vacuo* to yield an oil. White crystals (2.0 g, 14%) were deposited from a solution of the oil in benzene–ligroin (bp 60–90°), mp 156–157° (lit.[4] 157–158°). This material was identical (mixture melting point, ir, nmr, mass spectrum) with material prepared following Mousseron's procedure:[2] ir (KBr) 3280 cm^{-1} (OH); nmr (DMSO-d_6) τ 5.15–5.34 (d, 2 H, OH), 6.35–6.91 (m, 2 H, CHOH), 7.05–7.65 (m, 2 H, CHS), and 7.70–9.20 (m, 16 H, methylene); molecular ion, *m/e* 294.

Anal. Calcd for $C_{12}H_{22}O_2S_3$ (294.5): C, 48.9; H, 7.53; S, 32.7. Found: C, 48.8; H, 7.66; S, 32.4.

The trisulfide **3** was reduced with lithium aluminum hydride in ether to give, as previously reported,[5] *trans*-2-mercaptocyclohexanol (**4**) in 40% yield: bp 95–97° (15 mm) [lit.[6] bp 100° (18 mm)]. The 2,4-dinitrophenyl thio ether of **4** was prepared[9] in a yield of 56%, mp 133–134° (lit.[4,6,7] mp 135°).

***trans,trans*-Bis(2-hydroxycyclohexyl) Disulfide (2).**—To 4.4 g (0.033 mol) of *trans*-2-mercaptocyclohexanol (**4**), prepared according to Culvenor, *et al.*,[6] was added dropwise a solution containing 5.0 g of iodine/100 ml of methanol until a permanent brown color was obtained, following which the reaction mixture was stirred at room temperature for 16 hr. Saturated aqueous sodium bisulfite was added dropwise until a colorless mixture resulted. The methanol was evaporated *in vacuo* and the remaining aqueous phase was extracted with chloroform. The chloroform extract was dried over magnesium sulfate and evaporated *in vacuo* to yield a pale yellow oil. The oil was taken up in hot ethyl acetate–*n*-hexane, whereupon a white solid crystallized upon cooling. The solid (2.4 g, 55%) was collected by filtration and air-dried: mp 83–84°; ir ($CHCl_3$) 3400 (OH), no absorption at 2500–2600 cm^{-1} (no SH); nmr ($CDCl_3$) τ 6.15–6.70 (m, 4 H, CHOH), 6.90–7.50 (m, 2 H, -CHS-), and 7.60–8.80 (m, 16 H, methylene); molecular ion, *m/e* 262.

Anal. Calcd for $C_{12}H_{22}O_2S_2$ (262.4): C, 54.9; H, 8.45; S, 24.4. Found: C, 54.8; H, 8.43; S, 24.2.

The disulfide **2** was reduced[5] with lithium aluminum hydride in ether to the trans compound **4**, which was characterized as the 2,4-dinitrophenyl thio ether derivative **5**,[9] mp 133–134° (lit.[4,6,7] mp 135°).

***cis,cis*-Bis(2-hydroxycyclohexyl) Disulfide (1).**—*cis*-2-Mercaptocyclohexanol (**6**, 18.6 g, 0.14 mol), prepared according to procedure of Behringer and Kley,[7] was treated with iodine in methanol as was done in the preparation of the disulfide **2**. The pale yellow oil obtained was eluted through a silica gel column using benzene followed by chloroform. A small amount of white crystals formed within the oil; these crystals were collected and used as seed crystals in the subsequent recrystallization of **1**. The remaining oil was dissolved in hot ethyl acetate, to which ligroin (bp 60–90°) was added to the cloud point. After the solution was cooled to room temperature and seeded, white crystals of **1** were slowly deposited. The crystals were collected by filtration and air-dried (3.0 g, 18%): mp 82–85°; ir 3550 (OH), no absorption at 2500–2600 cm^{-1} (no SH); nmr ($CDCl_3$) τ 5.8–6.1 (m, 2 H, CHOH), 6.9–7.2 (m, 2 H, -CHS-), 7.58 (s, 2 H, OH), 7.9–8.9 (m, 16 H, methylene); molecular ion, *m/e* 262; with **2**, mmp 73–85°.

An analytical sample was prepared by recrystallization from ethyl acetate–ligroin (bp 60–90°), mp 85–88°.

Anal. Calcd for $C_{12}H_{22}O_2S_2$ (262.4): C, 54.9; H, 8.45. Found: C, 54.9; H, 8.60.

Reduction of the disulfide **1** with lithium aluminum hydride following the procedure reported[5] for the trans disulfide gave *cis*-2-mercaptocyclohexanol (**6**), as established by comparison of infrared spectra, in a yield of 70%. Following a previously reported procedure,[7] **6** was converted to *cis*-2-hydroxycyclohexyl 2,4-dinitrophenyl sulfide (**7**) in a yield of 33%, mp 141–143° (lit.[7] mp 143°).

Registry No.—**1**, 27040-92-2; **2**, 27040-93-3; **3**, 27040-94-4.

Acknowledgment.—Partial support is acknowledged to the U. S. Public Health Service, National Cancer Institute, Grant No. CA 10653.

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Hydroformylation of 5,6-Dideoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hex-5-enofuranose

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Hydroformylation of unsaturated sugar derivatives has posed a problem of great difficulty.[1] This difficulty

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[1] (a) A. Rosenthal and D. Abson, *J. Amer. Chem. Soc.*, **86**, 5356 (1964). (b) A. Rosenthal, D. Abson, T. D. Field, H. J. Koch, and R. E. J. Mitchell, *Can. J. Chem.*, **45**, 1525 (1967); A. Rosenthal, *Advan. Carbohyd. Chem.*, **23**, 59 (1968).