SUCROCHEMISTRY

PART I. NEW DERIVATIVES OF SUCROSE PREPARED FROM THE 6,6′-DI-*O*-TOSYL AND THE OCTA-*O*-MESYL DERIVATIVES

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ABSTRACT

Treatment of 6,6′di-*O*-tosylsucrose hexa-acetate with sodium methoxide gave 3,6;3′,6′-dianhydrosucrose. Benzoylation of 6,6′-di-*O*-tosylsucrose with cooling gave the hexabenzoate (**6**) in high yield, whereas at room temperature significant quantities of 6,6′-dichloro-6,6′-dideoxysucrose hexabenzoate (**7**) and a monochloro-monodeoxy-mono-*O*-tosylsucrose hexabenzoate were also obtained. The 6,6′-dichloro derivative **7** was obtained from **6** by nucleophilic substitution using pyridinium hydrochloride. Treatment of **6** with iodide gave the 6,6′-di-iodo derivative **9** which on hydrogenation was converted into 6,6′-dideoxysucrose hexabenzaote (**10**). Treatment of **9** with silver fluoride in pyridine afforded the 5,5′-diene. Substitution reactions on **6** with azide and thiocyanate gave 6,6′-diazido and 6,6′-dithiocyanato derivatives of sucrose as their hexabenzoates. Octa-*O*-mesylsucrose underwent selective substitution reactions with various nucleophiles. With iodide, it gave the 6,6′-dideoxy-6,6′-di-iodo derivative **15** which was identical with that prepared by mesylation of 6,6′-di-*O*-tosylsucrose followed by treatment with iodide. Reduction of **15** gave 6,6′-dideoxysucrose hexamethanesulphonate, which was synthesized also from the dideoxy hexabenzoate **10** by de-esterification and mesylation. 5,5′-Dieno, 6,6′di-azido, and 6,6′dithiocyanato derivatives of sucrose hexamethanesulphonate were prepared. A triazido-sucrose pentamethanesulphonate was prepared from the octamethanesulphonate.

INTRODUCTION

Many attempts have been made to exploit the chemistry of sucrose in order to find new applications, such as the use of mono-esters of sucrose as detergents[1], sugar-modified melamine resins[2], the calcium salt of sucrose monophosphate as an inhibitor of dental caries[3], and sodium and aluminium salts of sucrose octasulphate as anti-pepsin, anti-ulcer agents[4]. We have studied the synthesis of new derivatives

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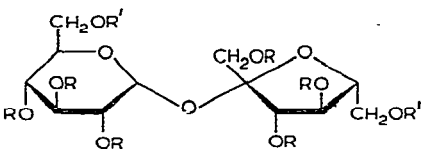
of sucrose by the action of various nucleophilic reagents on sulphonic esters of sucrose. Our objectives were threefold: to investigate the properties of the new derivatives, to prepare bifunctional derivatives with a view to the synthesis of linear polymers and copolymers, and to study differences in chemical reactivity at the various positions in the sucrose molecule[5]. Previous evidence on the nucleophilic substitution[6] of sulphonic esters of D-glucopyranoid[7] and D-fructofuranoid[8] derivatives suggested that the 6 and 6′ positions of sucrose would be the most reactive. Consequently, we have studied the replacement reactions of the sulphonyloxy groups in 6,6′-di-*O*-tosylsucrose[9] (**1**) and octa-*O*-mesylsucrose (**14**).

RESULTS AND DISCUSSION

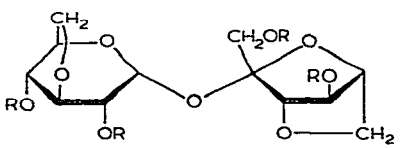
6,6′-Di-*O*-tosylsucrose (**1**) was isolated in 18% yield, after column chromatography of the complex mixture produced on partial tosylation of sucrose[9], and then converted into further crystalline derivatives, including the hexa-acetate (**2**), hexabenzoate (**6**), and hexamethanesulphonate (**16**). Attempts to isolate these derivatives directly from the mixed tosylsucroses, and so obviate column chromatography, were unsuccessful. Treatment of the disulphonate **1** with sodium methoxide gave the expected 3,6;3,′6′-dianhydrosucrose (**3**) as a syrup which was not oxidized by periodate and was converted into a crystalline 2,4,1′,4′-tetra-acetate (**4**). In similar reactions, a crude, syrupy 6,1′,6′-tri-*O*-tosylsucrose gave 1′,2;3,6;3′,6′-trianhydrosucrose[10], whereas the 2,3,4,3′,4′-pentaacetate afforded 1′,4′;3,6;3′,6′-trianhydrosucrose[11].

Replacement of the tosyloxy substituents in 6,6′-di-*O*-tosylsucrose hexa-acetate

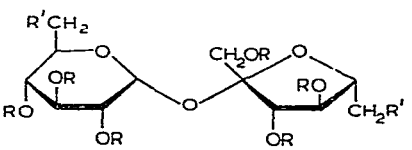


1 R = H, R′ = Ts
2 R = Ac, R′ = Ts
6 R = Bz, R′ = Ts

14 R = R′ = Ms
16 R = Ms, R′ = Ts

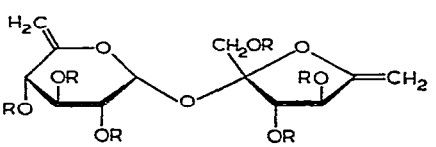


3 R = H
4 R = Ac



5 R = Ac, R′ = SCN
7 R = Bz, R′ = Cl
8 R = Bz, R′ = Cl, R′ = Ts
9 R = Bz, R′ = I
10 R = Bz, R′ = H
12 R = Bz, R′ = SCN

13 R = Bz, R′ = N_3
15 R = Ms, R′ = I
17 R = Ms, R′ = H
19 R = Ms, R′ = N_3
20 R = Ms, R′ = SCN



11 R = Bz
18 R = Ms

(2) by various nucleophiles in *N,N*-dimethylformamide was examined but, apart from the isolation of 17% of a crystalline 6,6′-dithiocyanato derivative (5) after column chromatography, the results were unsatisfactory. Consequently, the use of the hexabenzoate 6 was explored.

When the reaction of the ditosyl derivative 1 with benzoyl chloride in pyridine was cooled, a high yield of the 1′,2,3,3′,4,4′-hexabenzoate 6 was readily obtained, but at room temperature the yield of 6 was greatly decreased and the product was contaminated with significant quantities of 6,6′-dichloro-6,6′-dideoxysucrose hexabenzoate (7) and a monochloro-monodeoxy derivative 8. These contaminants arise, in a similar way to 2-acetamido-2-deoxy-D-glucopyranoid derivatives[12], by nucleophilic substitution of the tosyloxy substitutents by the chloride ion of pyridinium chloride. The isolation of a crystalline monochloro-monodeoxysucrose 8 revealed a difference in reactivity of the sulphonyloxy substituents at C-6 and C-6′, also observed in selective mono-esterifications of sucrose[13]. Steric and other factors[14] favour position 6 of the D-glucopyranoid ring for enhanced reactivity.

6,6′-Dideoxy-6,6′-di-iodosucrose hexabenzoate (9) was obtained by treating the 6,6′-di-*O*-tosyl derivative 6 with sodium iodide in refluxing butanone; subsequent catalytic hydrogenation gave 6,6′-dideoxysucrose hexabenzoate (10). The n.m.r. spectrum confirmed the methyl groups at C-5 and C-5′ since they appeared as doublets at τ 8.53 and 8.8; the presence of a methyl group at C-2′ would give a singlet. Similar treatment of sucrose octamethanesulphonate (14) with iodide gave 6,6′-dideoxy-6,6′-di-iodosucrose hexamethanesulphonate (15) which was also prepared from 6,6′-di-*O*-tosylsucrose hexamethanesulphonate (16). Thus, the substituents at the primary positions (C-6 and C-6′) of sucrose octamethanesulphonate undergo faster, selective, nucleophilic substitution reactions than those at other positions, in particular C-1′ the other primary position. Exploitation of this observation should now permit the selective synthesis of a range of bifunctional derivatives from sucrose octamethanesulphonate. Reduction of the di-iodo derivative 15 by either catalytic hydrogenation or ethanolic Raney nickel gave 6,6′-dideoxysucrose hexamethanesulphonate (17), which was identical with the methanesulphonate prepared from 6,6′-dideoxysucrose hexabenzoate (10).

Elimination of hydrogen halide from the 6,6′-di-iodo derivatives 9 and 15, by means of silver fluoride in pyridine[15], destroyed the asymmetry at C-5 and C-5′ to give the corresponding exocyclic vinyl ethers, namely 6-deoxy-β-D-*xylo*-hex-5-enopyranosyl 6′-deoxy-β-D-*threo*-hex-5′-enofuranoside hexabenzoate (11) and hexamethanesulphonate (18), respectively. They showed the well-known allylic coupling[8] between the protons at C-4 and C-6, and C-4′ and C-6′.

The synthesis of amino derivatives was then explored by preparing the precursor azido derivatives from the di-*O*-tosyl (6) and octa-*O*-mesyl (14) derivatives by nucleophilic substitution. 6,6′-Diazido-6,6′dideoxysucrose hexabenzoate (13) was isolated when 6 was heated with sodium azide in *N,N*-dimethylformamide, followed by re-benzoylation. When 14 was treated with sodium azide in butanone–*N,N*-dimethylformamide at 105° for 2 days, 6,6′-diazido-6,6′-dideoxysucrose hexamethane-

sulphonate (**19**) was obtained in 75% yield. The structure of **19** was proven by its identity with the hexa-*O*-mesyl derivative prepared from the hexabenzoate **13** by de-esterification and subsequent mesylation. Under more-forcing conditions (130°; 24 h), the octa-*O*-mesylsucrose **14** reacted with azide to give a triazido-trideoxysucrose pentamethanesulphonate (m.p. 153–5°; $[\alpha]_D$ +43.6°) which is probably the 4′,6,6′ derivative[14]. The product described by Umezawa *et al.*[16] as the 1′,6,6′-triazido derivative is probably the 1′,4,6′ isomer because of the method of synthesis[10].

6,6′-Dideoxy-6,6′-dithiocyanatosucrose hexamethanesulphonate (**20**) was also obtained directly in 85% yield from the octa-*O*-mesyl derivative **14** by selective nucleophilic substitution with thiocyanate.

EXPERIMENTAL

General. — All evaporations were carried out under reduced pressure. Melting points were determined on a Kofler hot-stage apparatus. Optical rotations were determined at 24°, unless otherwise stated, on a Perkin–Elmer 141 polarimeter. Silica gel G (Merck) was used for t.l.c. with ether–light petroleum (4:1) as the mobile phase, unless indicated otherwise. The separated materials were detected by spraying the plates with 5% methanolic sulphuric acid and heating at 120–125° for ~10 min. Dry pyridine, freshly distilled from potassium hydroxide, was used throughout. N.m.r. spectra were measured for solutions in $CDCl_3$ at 100 MHz (Varian HA-100) with tetramethylsilane as internal standard.

6,6′-Di-O-tosylsucrose (**1**). — A solution of sucrose (50 g) in pyridine (1450 ml) was rapidly cooled to 0°, and a cooled solution of toluene-*p*-sulphonyl chloride (58 g) in pyridine (100 ml) was added, dropwise, over a period of 2 h. The reaction mixture was stored at 0° for 6 days. Water (5 ml) was added to the reaction mixture, and the whole was concentrated to a syrup which was then dissolved in chloroform. The solution was washed successively with cold 2M hydrochloric acid, water, saturated, aqueous sodium hydrogen carbonate, and finally water. The chloroform layer was dried (Na_2SO_4) and evaporated. The resulting syrup (85 g) was separated on a column of silica gel (900 g, Hopkin and Williams M.F.C.); the fast-moving products were first eluted with chloroform–acetone (1:1), usually in ~24 h, followed by 6,6′-di-*O*-tosylsucrose which was eluted with acetone; it slowly crystallized whilst in the tubes of the fraction collector. The appropriate fractions containing **1** were concentrated to a syrup (17 g, 18%) which crystallised from acetone; m.p. 112–114°, $[\alpha]_D$ +60° (*c* 1.2, pyridine), $[\alpha]_D$ +56.7° (*c* 1.15, ethanol); lit.[9] m.p. 108–110°, $[\alpha]_D$ +54° (ethanol).

1′,2,3,3′,4,4′-Hexa-O-acetyl-6,6′-di-O-tosylsucrose (**2**). — To a solution of **1** (9 g) in pyridine (54 ml), acetic anhydride (18 ml) was added, and the mixture was stored for 48 h at room temperature. The reaction mixture was poured into ice–water, and the precipitate was filtered off, thoroughly washed with water, and then dried over phosphoric oxide under reduced pressure to give the acetate **2** (12 g, 96%), m.p. 64–67° $[\alpha]_D$ +55.5° (*c* 2.4, methylene chloride) (Found C, 50.5; H, 5.2; S, 7.0. $C_{38}H_{46}O_{21}S_2$ calc.: C, 50.6; H, 5.1; S, 7.1%). N.m.r. data; τ 4.57 (*d*, 1 proton, $J_{1,2}$ 3.5 Hz,

H-1), 5.30 (*q*, 1 proton, $J_{2,3}$ 10 Hz, H-2), 4.6 (*t*, 1 proton, $J_{3,4}$ 10 Hz, H-3), 4.60 (*d*, 1 proton, $J_{3',4'}$ 5.3 Hz, H-3'), 5.04 (*t*, 1 proton, $J_{4,5}$ 10 Hz, H-4), 4.64 (*t*, 1 proton, $J_{4',5'}$ 6.5 Hz, H-4'), 7.54 (*s*, 6 protons, 2 tosyl-CH_3), 7.83 [*s*(six), 18 protons, 6 Ac].

3,6;3',6'-Dianhydrosucrose (**3**) *and its tetra-acetate* (**4**). — A mixture of **1** (0.5 g), dry ethanol (20 ml), and M sodium ethoxide (6.5 ml) was left for 16 h at room temperature. The solution was evaporated to a syrup, and the residue was taken up in water and de-ionised with Dowex-1 x8 and Amberlite IRC-50-H resins. Concentration gave **3** as a syrup (0.2 g, 85%) that did not react with sodium metaperiodate. To a solution of **3** (0.1 g) in pyridine (1.5 ml), acetic anhydride (0.5 ml) was added, and the reaction was stored for 24 h at room temperature. After evaporation, the residue was dissolved in chloroform, and the solution was washed successively with 2M hydrochloric acid, water, aqueous sodium hydrogen carbonate, and water, and then dried (Na_2SO_4) and concentrated. The syrup (0.11 g, 77%) was crystallized from ether–light petroleum to give **4**, m.p. 69–72°, $[\alpha]_D$ +32.5° (*c* 1.0 chloroform) (Found: C, 50.3; H, 5.5. $C_{20}H_{26}O_{13}$ calc.: C, 50.6; H, 5.5%). N.m.r. data: τ 4.43 (*d*, 1 proton, $J_{1,2}$ 3.0 Hz, H-1), 4.91 (*d*, 1 proton, $J_{2,3}$ 2.5 Hz, H-2), 7.85–7.95 [*s*(four), 12 protons, 4 Ac].

1',2,3,3',4,4'-Hexa-O-acetyl-6,6'-dideoxy-6,6'-dithiocyanatosucrose (**5**). — A solution of the di-*O*-tosylsucrose **2** (2 g) in *N,N*-dimethylformamide (50 ml) containing potassium thiocyanate (1.2 g) was heated at 130° for 24 h. T.l.c. (ether–light petroleum, 4:1) then showed a mixture of four products. The bulk of the solvent was removed on a rotary evaporator and the last traces in a vacuum over at 35–40° for 24 h. The residue was mixed with chloroform, the inorganic salt was filtered off, and the filtrate was concentrated to a syrup which was eluted from silica gel (150 g; Davidson; grade 950, 60–200 mesh) with ether–light petroleum (1:1). Evaporation of the eluate gave **5** (150 mg, 17%), m.p. 169–171°, $[\alpha]_D$ +71° (*c* 1.0, chloroform) (Found: C, 46.4; H, 4.6; N, 4.6; S, 9.7. $C_{26}H_{32}N_2O_{15}S_2$ calc.: C, 46.1; H, 4.9; N,4.1; S, 9.5%). N.m.r. data: τ 4.46 (*d*, 1 proton, $J_{1,2}$ 3.3 Hz, H-1), 5.88 (*s*, 2 protons, CH_2-1'), 5.15 (*q*, 1 proton, $J_{2,3}$ 10.0 Hz, H-2), 4.62 (*q*, 1 proton, $J_{3,4}$ 10 Hz, H-3), 4.60 (*d*, 1 proton, $J_{3',4'}$ 5.3 Hz, H-3'), 5.02 (*q*, 1 proton, $J_{4,5}$ 10 Hz, H-4), 4.7 (*t*, 1 proton, $J_{4',5'}$ 6.6 Hz, H-4'), 7.85–8.03 [*s* (six), 18 protons, 6 Ac].

1',2,3,3',4,4'-Hexa-O-benzoyl-6,6'-di-O-tosylsucrose (**6**). — Benzoyl chloride (7.8 g, 6.5 ml) was added to a cooled solution (ice–water) of 6,6'-di-*O*-tosylsucrose (**1**, 5 g) in pyridine (50 ml). After storage for 40 h at room temperature, the reaction mixture was poured into ice–water, and the benzoate was filtered off, washed with water, dried, and crystallized from ethanol to give **6** (7.0 g, 71%), m.p. 93–96°, $[\alpha]_D$ +26.3° (*c* 1.1, methylene chloride) (Found: C, 64.0; H, 4.6; S, 5.0. $C_{68}H_{58}O_{21}S_2$ calc.: C, 64.0; H, 4.5; S, 5.2%).

When benzoyl chloride (3 g) was added to an uncooled solution of **1** (2 g) in pyridine (25 ml) and the reaction mixture was set aside at room temperature for 36 h, t.l.c. showed the slow-moving hexabenzoate and two fast-moving products. After addition of a little water, the reaction mixture was concentrated, and the residue was taken up in chloroform. The chloroform solution was washed successively with cold

2M hydrochloric acid, water, aqueous sodium hydrogen carbonate, and water, and then dried (Na_2SO_4) and concentrated. The syrupy residue was eluted from silica gel (150 g; Davidson grade 950, 60–200 mesh) with ether–light petroleum (1:1). The following three products were isolated after crystallization from ethanol: (*a*) 1′,2,3,3′,4,4′-hexa-*O*-benzoyl-6,6′-dichloro-6,6′-dideoxysucrose (**7**) (200 mg, 7%), m.p. 84–87°, $[\alpha]_D$ +5.8° (*c* 1.0, chloroform) (Found: C, 64.4; H, 4.5; Cl, 6.9. $C_{54}H_{44}Cl_2O_{15}$ calc.: C, 64.6; H, 4.4; Cl, 7.1%); (*b*) 1′,2,3,3′,4,4′-hexa-*O*-benzoyl-6-(or 6′)-chloro-6(or 6′)-deoxy-6-(or 6′)-*O*-tosylsucrose (**8**) (550 mg, 16%), m.p. 85–88°, $[\alpha]_D$ +22.3° (*c*, 2.0, chloroform) (Found: C, 64.1; H, 4.5; Cl, 3.0; S, 3.1. $C_{61}H_{52}ClO_{18}S$ calc.: C, 64.2; H, 4.6; Cl, 3.1; S, 2.8%); (*c*) 1′,2,3,3′,4,4′-hexa-*O*-benzoyl-6,6′-di-*O*-tosylsucrose (**6**) (900 mg, 23%).

1′,2,3,3′,4,4′-Hexa-O-benzoyl-6,6′-dichloro-6,6′-dideoxysucrose (**7**). — A solution of the di-*O*-tosylsucrose **6** (250 mg) in pyridine (5 ml), containing a two-fold excess of pyridinium hydrochloride, was warmed at 40° for 24 h; t.l.c. then showed one major and one minor component. A few drops of water were added, the solution was concentrated, and the residue was taken up in chloroform. The chloroform solution was washed successively with cold 2M hydrochloric acid, water, aqueous sodium hydrogen carbonate, and water, and then dried (Na_2SO_4) and concentrated. The syrupy residue (100 mg, 50%) crystallized from ethanol to give **7**, m.p. and mixed m.p. 85–87°, $[\alpha]_D$ +5.8° (*c* 1.0, chloroform) (Found: C, 64.6; H, 4.5; Cl, 6.9. $C_{54}H_{44}Cl_2O_{15}$ calc.: C, 64.6; H, 4.4; Cl, 7.1%).

1′,2,3,3′,4,4′-Hexa-O-benzoyl-6,6′-dideoxy-6,6′-di-iodosucrose (**9**). — A solution of **6** (7 g) in butanone (200 ml) containing sodium iodide (2.5 g) was refluxed for 24 h. Insoluble salts were filtered off, and the filtrate was concentrated to dryness. The residue was partitioned between chloroform (200 ml) and water (75 ml), and the chloroform layer was separated, washed successively with water, aqueous sodium thiosulphate, and water, and then dried (Na_2SO_4) and concentrated to a syrup. Crystallization from ethanol gave the di-iodo compound **9** (4 g, 61%) which, after recrystallization from methanol, had m.p. 178–179°, $[\alpha]_D$ −1.6° (*c* 1.5, chloroform) (Found: C, 54.8; H, 3.8; I, 21.2. $C_{54}H_{44}I_2O_{15}$ calc.: C, 54.6; H, 3.7; I, 21.4%). N.m.r. data: τ 3.98 (*d*, 1 proton, $J_{1,2}$ 3.0 Hz, H-1), 4.64 (*q*, 1 proton, $J_{2,3}$ 10.0 Hz, H-2), 3.88 and 4.57 (*t*, each 1 proton, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-3 and H-4), 4.1 (*d*, 1 proton, $J_{3',4'}$ 6.0 Hz, H-3′), 4.22 (*t*, 1 proton, $J_{4',5'}$ 6.0 Hz, H-4′), 5.48 (*s*, 2 protons, CH_2-1′), 1.85–3.01 (*m*, 30 protons, 6 Ph).

1′,2,3,3′,4,4′-Hexa-O-benzoyl-6,6′-dideoxysucrose (**10**). — The di-iodo derivative **9** (500 mg) in methanol (100 ml) containing Raney nickel (700 mg) and barium carbonate was hydrogenated at room temperature and normal pressure for 6 h. The filtered mixture was evaporated to dryness, and the residue was eluted from silica gel with chloroform to give the dideoxy derivative **10** (370 mg; 63%), m.p. 118–120° (from methanol), $[\alpha]_D$ +19.6° (*c* 1.42, chloroform) (Found: C, 69.6; H, 4.9. $C_{54}H_{46}O_{15}$ calc.: 69.4; H, 4.9%). N.m.r. data: τ 4.11 (*d*, 1 proton, $J_{1,2}$ 3.0 Hz, H-1), 4.72 (*q*, 1 proton, $J_{2,3}$ 10.0 Hz, H-2), 3.94 (*t*, 1 proton, $J_{3,4}$ 10.0 Hz, H-3), 4.74 (*t*, 1 proton, $J_{4,5}$ 10.0 Hz, H-4), 4.14 (*d*, 1 proton, $J_{3',4'}$ 7.2 Hz, H-3′), 4.38 (*t*, 1 proton, $J_{4',5'}$

7.2 Hz, H-4'), 5.61 (*s*, 2 protons, CH_2-1'), 8.5 and 8.8 (*d* (two) 3 protons each, *J* 6.4 and 6.0 Hz, CH_3-6 and CH_3-6'), 1.85–3.02 (*m*, 30 protons, 6 Ph).

*2,3,4-Tri-*O*-benzoyl-6-deoxy-β-*D*-xylo-hex-5-enopyranosyl 1',3',4'-tri-*O*-benzoyl-6'-deoxy-β-*D*-threo-hex-5'-enofuranoside* (**11**). — A mixture of the di-iodo derivative **9** (4 g), dry pyridine (40 ml), and anhydrous silver fluoride (4 g) was shaken for 24 h. The black reaction mixture was diluted with ether (100 ml), the supernatant liquid was decanted off, and the residue was shaken with ether (3 × 100 ml). The combined ether–pyridine solution was concentrated, and the resulting syrup was dissolved in ether and decolourized by passage through a small column of silica gel. The colourless eluate was evaporated to give a syrup which crystallized from methanol to give **11** (1.5 g, 63%), m.p. 145–147°, $[\alpha]_D$ −5° (*c* 1.0, chloroform) (Found: C, 69.6; H, 4.4. $C_{54}H_{42}O_{15}$ calc.: C, 69.4; H, 4.5%). N.m.r. data: τ 3.95 (*d*, 1 proton, $J_{1,2}$ 3.0 Hz, H-1), 4.6 (*q*, 1 proton, $J_{2,3}$ 10.0 Hz, H-2), 3.83 (*d*, 1 proton, $J_{3,4}$ 10.0 Hz, H-4), 4.06 (*d*, 1 proton, $J_{3',4'}$ 8.0 Hz, H-3'), 3.64 (*d*, 1 proton, H-4'), 5.0 (*s*, 2 protons, CH_2-1'), 1.82–3.26 (*m*, 30 protons, 6 Ph).

*1',2,3,3',4,4'-Hexa-*O*-benzyol-6,6'-dideoxy-6,6'-dithiocyanatosucrose* (**12**). — A solution of the di-*O*-tosylsucrose **6** (2.6 g) in *N*,*N*-dimethylformamide (30 ml) containing potassium thiocyanate (1 g) was refluxed at 130° for 3 days. The solution was concentrated to dryness, the residue was taken up in dry pyridine, and inorganic material was filtered off. The filtrate was cooled to 0°, benzoyl chloride (3 g) was added, and the reaction mixture was stored for about 40 h at room temperature. The solution was poured into ice–water, and the precipitate was filtered off, washed well with water, and dried. The amorphous solid (1.7 g, 80%) was crystallized from ethanol–water to give **12**, m.p. 92–95°, $[\alpha]_D$ +31.9° (*c* 1.4, methylene chloride) (Found: C, 64.4; H, 4.4; N, 2.4; S, 6.3; $C_{56}H_{44}N_2O_{15}S_2$ calc.: C, 64.1; H, 4.2; N, 2.7; S, 6.2%).

*6,6'-Diazido-1',2,3,3',4,4'-hexa-*O*-benzoyl-6,6'-dideoxysucrose* (**13**). — A mixture of **6** (5 g) and sodium azide (2 g) in *N*,*N*-dimethylformamide (50 ml) was heated at 130° for 3 days. The solution was concentrated to dryness, and the residue was dissolved in pyridine. The filtered solution was then cooled to 0°, benzoyl chloride (5 g) was added, and the reaction mixture was stored for 40 h at room temperature. The solvent was evaporated, and the residue was taken up in chloroform. The chloroform extract was washed successively with cold 2M hydrochloric acid, water, aqueous sodium hydrogen carbonate, and water, and then dried (Na_2SO_4) and concentrated to a syrup. Crystallization from ethanol–water gave the diazide (**13**) (2 g, 48%), m.p. 75–78°, $[\alpha]_D$ +42.5° (*c* 1.6, methylene chloride) (Found: C, 63.9; H, 4.4; N, 8.1. $C_{54}H_{44}N_6O_{15}$ calc.: C, 63.8; H, 4.3; N, 8.3%).

*Octa-*O*-mesylsucrose* (**14**). — Methanesulphonyl chloride (165 ml) was added with stirring to a cooled (−5°) solution of sucrose (75 g) in pyridine (1,500 ml) over a period of 3 h, and the mixture was allowed to gradually attain room temperature. After standing overnight, the reaction mixture was poured into ice–water, and the precipitate was filtered off, washed well with water, dried, and crystallized from acetone–light petroleum to give **14** (150 g, 85%), m.p. 205–206°, $[\alpha]_D$ +47° (*c* 1.85,

acetone) (Found: C, 24.9; H, 3.9; S, 26.5. $C_{20}H_{38}O_{27}S_8$ calc.: C, 24.9; H, 4.0; S, 26.5%). Hockett and Zief[17] reported m.p. 86–94° and $[\alpha]_D$ +44° for amorphous materials.

*6,6'-Dideoxy-6,6'-di-iodo-1',2,3,3',4,4'-hexa-*O*-mesylsucrose* (**15**). — (*a*) A solution of octa-*O*-mesylsucrose (**14**, 2 g) in dry butanone (100 ml) containing sodium iodide (1.5 g) was refluxed for 30 h. Insoluble salts were filtered off, the filtrate was concentrated to dryness, and the residue was partitioned between chloroform and water. The chloroform extract was separated, washed successively with water, aqueous sodium thiosulphate, and water, and then dried (Na_2SO_4). Concentration to a colourless syrup and crystallization from acetone–petroleum light gave **15** (1.6 g, 75%), m.p. 218–219°, $[\alpha]_D$ +41.8° (*c* 2.0 acetone) (Found: C, 21.6; H, 3.1; I, 24.5; S, 18.4. $C_{18}H_{32}I_2O_{21}S_6$ calc.: C, 21.0; H, 3.1; I, 24.6; S, 18.6%).

(*b*) 6,6'-Di-*O*-tosylsucrose (**1**, 0.28 g) was dissolved in warm pyridine (6 ml), and the solution was cooled in an ice–bath and treated with methanesulphonyl chloride (10.7 ml). The mixture was stirred at room temperature overnight and then poured into ice–water, and the precipitate (0.4 g) was filtered off and crystallized from acetone to give 6,6'-di-*O*-tosylsucrose hexamethanesulphonate (**16**), m.p. 97–100°, $[\alpha]_D$ +32° (*c* 2.0, chloroform) (Found: C, 33.8, H, 4.3; S, 22.7. $C_{32}H_{46}O_{27}S_8$ calc.: C, 33.35; H, 4.1; S, 22.9%). When **16** (0.21 g) was treated with sodium iodide (85 mg) in butanone (6 ml) as in (*a*), the di-iodo derivative **15** (0.13 g; 68%) was obtained and was identical (m.p., i.r. spectrum, and t.l.c.) with the product of (*a*). N.m.r. data (CD_3COCD_3): τ 4.05 (*d*, 1 proton, $J_{1,2}$ 3.5 Hz, H-1), 5.02 (*q*, 1 proton, $J_{2,3}$ 9.5 Hz, H-2), 4.88 (*q*, 1 proton, $J_{3,4} = J_{4,5}$ 9.5 Hz, H-3), 5.1 (*t*, 1 proton), 4.45 (*d*, 1 proton, $J_{3',4'}$ 7.2 Hz, H-3'), 5.2 (*t*, 1 proton, $J_{4,5}$ 9.5 Hz, H-4), 4.73 (*t*, 1 proton, $J_{4',5'}$ 7.2 Hz, H-4'), 5.43 (*s*, 2 protons, CH_2-1'), 6.62–6.78 (*m*, 18 protons, 6 mesyl-CH_3).

*6,6'-Dideoxy-1',2,3,3',4,4'-hexa-*O*-mesylsucrose* (**17**). — (*a*) A solution of the 6,6'-di-iodo derivative **15** (0.5 g) in ethyl acetate (50 ml) was hydrogenated in the presence of Raney nickel at room temperature and normal pressure for 15 h. The catalyst was filtered off, the filtrate was concentrated to a syrup which was dissolved in chloroform, and the solution was passed through a small column of silica gel. The eluate was concentrated to dryness, and the residue was crystallized from methanol to give the dideoxy derivative **17** (210 mg, 66%), m.p. 191–192°, $[\alpha]_D$ +44.4° (*c* 2.45, acetone) (Found: C, 27.2; H, 4.2; S, 24.2. $C_{18}H_{34}O_{21}S_6$ calc.: C, 27.8; H, 4.4; S, 24.7%). N.m.r. data (CD_3COCD_3): τ 4.31 (*d*, 1 proton, $J_{1,2}$ 3.1 Hz, H-1), 5.05 (*q*, 1 proton, $J_{2,3}$ 9.2 Hz, H-2), 5.43 (*t*, 1 proton, $J_{4,5}$ 9.2 Hz, H-4), 4.64 (*d*, 1 proton, $J_{3',4'}$ 8.0 Hz, H-3'), 5.0 (*t*, 1 proton, $J_{4',5'}$ 8.0 Hz, H-4'), 5.65 (*s*, 2 protons, H-1'), 9.51 and 9.62 [*d* (two), 3 protons each, *J* 6.2 and 6.0 Hz, CH_3-6 and CH_3-6'], 6.68–6.84 (*m*, 18 protons, 6 mesyl-CH_3).

(*b*) A solution of **15** in ethanol was mixed with an excess of freshly prepared Raney nickel and refluxed for 12 h. T.l.c. (chloroform–acetone, 4:1) then showed that the product and the starting material were coincident, but distinguishable due to a marked difference in colour. The catalyst was filtered off, and the filtrate was concentrated to a syrup, which crystallized from methanol to give **17**.

(*c*) Gaseous ammonia was passed through a solution of the 6,6′-dideoxysucrose hexabenzoate (**10**, 500 mg) in dry methanol at 0° for 0.5 h. The mixture was then kept at 0° for 24 h and thereafter concentrated to a syrup; t.l.c. (butyl alcohol–acetic acid–water, 12:3:5) showed one product. To a solution of the syrup in pyridine at −5°, methanesulphonyl chloride (1 ml) was added during 0.5 h. The reaction mixture was allowed to attain room temperature and then stored for 24 h; t.l.c. (chloroform–acetone, 4:1) showed one product which was coincident with the 6,6′-dideoxysucrose hexamethanesulphonate (**17**) obtained above. The solution was concentrated, the residue was extracted with chloroform, and the extract was washed successively with cold 2M hydrochloric acid, water, and aqueous sodium hydrogen carbonate, and then dried (Na_2SO_4) and evaporated. The syrupy residue was crystallized from methanol to give **17** (250 mg, 60%), m.p. and mixed m.p. 219–220°, $[\alpha]_D$ +44.1° (*c* 1.0, acetone) (Found: C, 27.7; H, 4.5; S, 25.2. $C_{18}H_{34}O_{21}S_6$ calc.: C, 27.8; H, 4.4; S, 24.7%).

*6-Deoxy-2,3,4-tri-*O*-mesyl-β-*D-xylo*-hex-5-enopyranosyl 6′-deoxy-1′,3′,4′-tri-*O*-mesyl-β-*D-threo*-hex-5′-enofuranoside* (**18**).— A solution of the 6,6′-di-iodo derivative **15** (2 g) in pyridine (50 ml) was shaken with anhydrous silver fluoride (2 g) for 24 h. The dark reaction mixture was diluted with acetone and decolourized by passage through a small column of silica gel. The colourless eluate was evaporated to syrup, which crystallized from hot methanol to give the diene **18** (650 mg, 25%), m.p. 110–111°, $[\alpha]_D$ +13.7° (*c* 1.9, acetone) (Found: C, 28.2; H, 3.7; S, 25.2. $C_{18}H_{30}O_{21}S_6$ calc.: C, 27.9; H, 3.9; S, 24.8%). N.m.r. data (C_5D_5N): τ 3.5 (*d*, 1 proton, $J_{1,2}$ 3.2 Hz, H-1), 4.26 (*q*, 1 proton, $J_{2,3}$ 9.8 Hz, H-2), 4.54 (*t*, 1 proton, $J_{3,4}$ 9.8 Hz, H-3), 4.41 (*d*, 1 proton, H-4), 4.04 (*d*, 1 proton, $J_{3',4'}$ 8.0 Hz, H-3′), 3.84 (*d*, 1 proton, H-4′), 5.30 (*s*, 2 protons, CH_2-1′), 6.48–6.68 (*m*, 18 protons, 6 mesyl-CH_3).

*6,6′-Diazido-6,6′-dideoxy-1′,2,3,3′,4,4′-hexa-*O*-mesylsucrose* (**19**). — (*a*) A solution of octa-*O*-mesylsucrose (**14**, 1 g) in butanone–*N*,*N*-dimethylformamide (50 ml, 10:1) containing sodium azide (700 mg) was heated at 105–108° for 48 h. T.l.c. (chloroform–acetone, 4:1) then showed a major and a minor product. The reaction mixture was poured into ice–water, and the precipitate was filtered off, washed with water, dried, and crystallized from hot methanol to give the diazide **19** (820 mg, 75%), m.p. 189–190°, $[\alpha]_D$ +41.4° (*c* 1.2, pyridine) (Found: C, 25.5; H, 3.8; N, 9.3; S, 22.1. $C_{18}H_{32}N_6O_{21}S_6$ calc.: C, 25.1; H, 3.7; N, 9.8; S, 22.3%). N.m.r. data (C_5D_5N): τ 3.51 (*d*, 1 proton, $J_{1,2}$ 2.8 Hz, H-1), 4.08 (*d*, 1 proton, $J_{3',4'}$ 7.8 Hz, H-3′), 4.25 (*t*, 1 proton, $J_{4',5'}$ 7.8 Hz, H-4′), 5.14 (*s*, 2 protons, CH_2-1′), 6.5–6.69 (*m*, 18 protons, 6 mesyl-CH_3).

(*b*) A solution of the hexabenzoate **13** in dry methanol (45 ml) was treated with ammonia gas at 0° for 0.5 h and then kept at 0° for 24 h. Concentration afforded a syrup (150 mg, 77%); t.l.c. (butyl alcohol–acetic acid–water, 12:3:5) showed one product. To a solution of the syrup in dry pyridine (5 ml) at 5°, methanesulphonyl chloride (1 ml) was added over a period of 0.5 h. The reaction mixture was stored at room temperature for 24 h, and t.l.c. (chloroform–acetone, 4:1) then showed one spot, which was coincident to the above diazido derivative. The solution was concentrated, and the residue was taken up in chloroform, washed successively with

cold 2M hydrochloric acid, water, aqueous sodium hydrogen carbonate, and water, dried (Na_2SO_4), and concentrated to a syrup which crystallized from methanol to give the diazide **19** (100 mg, 45%), m.p. and mixed m.p. 188–190°, $[\alpha]_D$ +42° (*c* 1.95, pyridine).

Triazido-trideoxy-penta-O-mesylsucrose. — A solution of octa-*O*-mesylsucrose (**14**, 5 g) in butanone–*N*,*N*-dimethylformamide (100 ml, 1:2) containing sodium azide (2.5 g) was heated at 130° for 24 h. T.l.c. (chloroform–acetone, 4:1) then showed one major product, which moved faster than the diazido derivative **19**, and two minor products. The reaction mixture was filtered, the filtrate was concentrated to dryness, and the residue was partitioned between chloroform and water. The chloroform layer was separated, dried (Na_2SO_4), and concentrated to a syrup which crystallized from hot methanol to give the triazide (1.15 g, 20%), m.p. 153–155°, $[\alpha]_D$ +43.6° (*c* 1.9, acetone) (Found: C, 25.4; H, 3.5; N, 15.5; S, 20.1. $C_{17}H_{29}N_9O_{18}S_5$ calc.: C, 25.3; H, 3.3; N, 15.6; S, 19.8%).

6,6'-Dideoxy-1,2,3,3',4,4'-hexa-O-mesyl-6,6'-dithiocyanatosucrose (**20**). — A solution of octa-*O*-mesylsucrose (**14**, 5 g) in butanone–*N*,*N*-dimethylformamide (100 ml, 10:1) containing potassium thiocyanate (2.5 g) was heated at 100–105° for 30 h. T.l.c. (chloroform–acetone, 4:1) then showed a major, fast-moving product. The reaction mixture was poured into ice–water, and the precipitate was filtered off, dried (4 g, 85%) and crystallised from methanol to give **20**, m.p. 177–180°, $[\alpha]_D$ +68.5° (*c* 1.2, acetone) (Found: C, 26.9; H, 3.5; N, 2.9; S, 28.6.$C_{20}H_{32}N_2O_{21}S_8$ calc.: C, 26.9; H, 3.6; N, 3.1; S, 28.7%). N.m.r. data (C_5D_5N): τ 3.51 (*d*, 1 proton, $J_{1,2}$ 3.0 Hz, H-1), 3.96 (*d*, 1 proton, $J_{3',4'}$ 7.6 Hz, H-3'), 4.3 (*t*, 1 proton, $J_{4',5'}$ 7.6 Hz, H-4'), 5.0 (*s*, 2 protons, CH_2-1'), 7.44–7.62 (*m*, 18 protons, 6 mesyl-CH_3).

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