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Synthesis and crystal structure of methyl 2-amino-2,6-dideoxy-α-D-glucopyranoside-6-sulfonic acid

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ABSTRACT

Methyl 2-amino-2,6-dideoxy-α-D-glucopyranoside-6-sulfonic acid (**8**) was prepared by oxidation of methyl 3,4-di-*O*-acetyl-6-*S*-acetyl-2-benzamido-2-deoxy-6-thio-α-D-glucopyranoside with hydrogen peroxide in acetic acid followed by *N*- and *O*-deacylation with aqueous sodium hydroxide. Compound **8** was also obtained by oxidation of methyl 3,4-di-*O*-acetyl-6-*S*-acetyl-2-deoxy-2-[(2,2-dimethoxycarbonylvinyl)amino]-6-thio-α-D-glucopyranoside followed by deacetylation with Amberlite IR-120 (H^+) resin. An X-ray analysis of **8**, crystallised as a dihydrate, was carried out.

INTRODUCTION

There is a growing interest in the synthesis of sugar sulfonic acids[1–6] and nucleoside sulfonic acids[7] which are chemically and biologically more stable than the corresponding sulfates. Few natural[8] and synthetic[9–13] amino sugar sulfonic acids are known. They can be obtained as zwitterions[8,9,11,12] in which the sulfonic acid is neutralised with the amino group, forming an inner salt.

We have described[11] the preparation of 2-amino-2,6-dideoxy-D-glucopyranose-6-sulfonic acid (**5**) by oxidation of 2-acetamido-1,3,4-tri-*O*-acetyl-6-*S*-acetyl-2-deoxy-6-thio-β-D-glucopyranose with hydrogen peroxide in acetic acid. We now report the preparation of methyl 2-amino-2,6-dideoxy-α-D-glucopyranoside-6-sulfonic acid (**8**) which cannot be formed by acid-catalysed glycosylation of **5** due to the protonation of the amino group[14].

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TABLE I

^{1}H NMR data (δ in ppm, J in Hz) for solutions of **2**, **4**, **10**, and **11** in $CDCl_3$

Compound	H-1	H-2	H-3	H-4	H-5	H-6a	H-6b	NH	OMe	OAc	SAc	HC=	COOMe	MeAr
2	4.79	4.50	5.32	5.07	3.89	3.26	3.05	6.38	3.39	1.19 2.10	2.34			
4	4.85	4.52	5.36	5.04	4.03	2.91	2.91	6.39	3.45	1.99 2.10				
10	4.80	3.40	5.25	4.93	4.01	4.13	4.12	9.01	3.43	1.96 1.97		7.87	3.70 3.78	2.46
11	4.80	3.44	5.26	4.90	3.96	3.18	3.11	9.01	3.46	1.96 2.07	2.34	7.89	3.69 3.77	

	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6a}$	$J_{5,6b}$	$J_{6a,6b}$	$J_{2,NH}$	$J_{1',NH}$
2	3.6	10.7	9.6	9.6	2.9	7.1	−14.2	9.4	
4	3.6	10.7	9.6	9.6				9.4	
10	3.5	10.0	9.6	9.6			−11.0	9.4	13.8
11	3.6	10.0	9.7	9.7	3.2	6.1	−14.2	10.0	13.9

TABLE II

^{13}C NMR data (δ in ppm) for solutions of **2**, **4**, **10** and **11** in $CDCl_3$

Compound	C-1	C-2	C-3	C-4	C-5	C-6	OMe	OAc		SAc		Enamino			
								Me	COO	Me	COS	HC=	=C	C=O	OMe
2	97.9	52.4	71.0	70.4	68.8	30.1	55.3	20.6 (2)	177.5 171.5	30.3	194.7				
4	97.9	52.5	71.2	71.0	68.0	41.3	55.4	20.6 20.7	171.5 169.6						
10	97.7	61.9	71.1	67.9	67.4	67.1	55.7	20.4 20.3	169.7 169.4			91.2	158.7	168.7 165.8	51.3 51.2
11	97.6	61.9	71.1	68.5	70.1	29.7	55.5	20.5 20.3	169.8 169.6	30.2	194.2	91.0	158.7	168.6 165.8	51.1 51.2

TABLE III

^{1}H NMR data (δ in ppm, J in Hz) for **3** and **8**

Compound	H-1	H-2	H-3	H-4	H-5	H-6a	H-6b	NH	OMe	HO-2	HO-3
3 [a]	4.71	3.94	3.71	3.13	3.65	3.28	2.84	8.22	3.28	4.91	5.35
8 [b]	4.91	3.28	3.78	3.27	4.01	3.35	3.04		3.42		
	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6a}$	$J_{5,6b}$	$J_{6a,6b}$	$J_{2,NH}$			
3 [a]	3.6	10.6	8.7	9.5	2.5	8.6	−13.5	8.0			
8 [b]	3.7	10.6	9.0	9.6	1.8	9.8	−14.8				

[a] In $(CD_3)_2SO$. [b] In D_2O.

TABLE IV

^{13}C NMR data (δ in ppm) for **3** and **8**

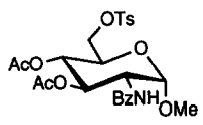
Compound	C-1	C-2	C-3	C-4	C-5	C-6	OMe	PhCO
3 [a]	98.2	55.0	70.4	74.0	70.4	41.8	55.4	167.3
8 [b]	96.6	54.6	70.6	73.0	68.9	52.5	56.3	

[a] In $(CD_3)_2SO$. [b] In D_2O.

RESULTS AND DISCUSSION

Methyl 3,4-di-*O*-acetyl-6-*S*-acetyl-2-benzamido-2-deoxy-6-thio-α-D-glucopyranoside (**2**) was prepared from **1**[15] by nucleophilic displacement of the tosyloxy group with potassium thioacetate in butanone. Deacetylation of **2** with methanolic sodium methoxide afforded the crystalline disulfide **3**, which was characterised as the tetraacetate **4**. The structures **2**–**4** were assigned on the basis of analytical, IR, and NMR data (Tables I–IV). Oxidation of **2** with hydrogen peroxide in acetic acid containing sodium acetate gave sulfonate **6** together with a small amount of partially deacetylated sulfonates, as deduced by ^1H NMR spectroscopy. Compound **6** did not crystallise, and was deprotected by treatment with boiling aqueous sodium hydroxide for 60 h followed by deionisation with Amberlite IR-120(H^+) resin to give crystalline **8**.

The aminosulfonic acid **8** was also prepared by oxidation of thioacetate **11**, in which the amino group is protected by the 2,2-dimethoxycarbonylvinyl group[17]. The oxidation of **11** with hydrogen peroxide in acetic acid buffered with sodium acetate gave **7** together with products of partial deacetylation of **7** as deduced by



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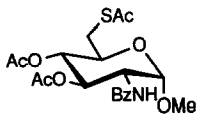

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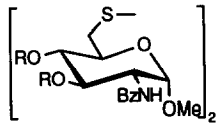

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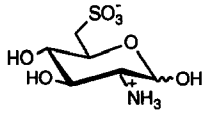
4 R = Ac



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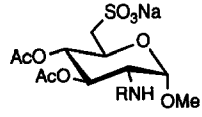
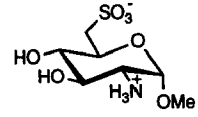


6 R = Bz

7 R = H



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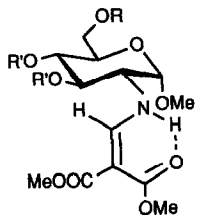
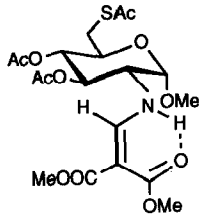


9 R = R' = H

10 R = Ts, R' = Ac



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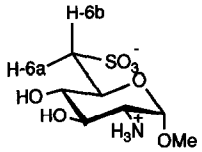

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^{1}H NMR spectroscopy. Treatment of the mixture with Amberlite IR-120 (H^+) resin gave **8** in a quantitative yield. Deprotection of the amino group with chlorine in chloroform as the oxidising agent has been described[16,17].

Compound **11** was prepared from glycoside **9**[17] by conventional tosylation with tosyl chloride in pyridine followed by acetylation with acetic anhydride and nucleophilic displacement of the tosyloxy group with potassium thioacetate. The chelated structure of **10** and **11** was confirmed by NMR[17] (Tables I and II) and IR data[17,18] (see Experimental). The mass spectrum of **10** and **11** contained peaks for M^+. The structures assigned to fragments of **10** and **11** (see Experimental) are similar to those reported for acylated 2-deoxy-2-[(2,2-diethoxycarbonylvinyl)amino]-D-glucopyranose[19].

Compound **8** crystallised as a dihydrate, as deduced from the analytical data and from the X-ray crystallography study (see below). The $^4C_1$ conformation for **8** was evident from the $^3J_{HH}$ values (Table III). The $J_{5,6a}$ and $J_{5,6b}$ values indicate[20,21] that the preferred conformation about the C-5–C-6 bond is *gauche–trans*[22] (*gt*) (**12**) corresponding to ω = O-5–C-5–C-6–S values of 60°. Assignments of the ^{13}C signals of **8** (Table IV) were based on heteronuclear 2D correlated experiments.

The structure of **8** was confirmed by X-ray analysis, and an ORTEP[23] view of the molecule along the *a* axis together with the atomic numbering is shown in Fig. 1. The atomic coordinates are listed in Table V. Bond lengths and angles, shown in Table VI, conform to the tabulated values of carbohydrates[24,25], and the typical asymmetry of endocyclic bonds O-5–C-1 and O-5–C-5 (1.415 and 1.443 Å, respectively) caused by the anomeric effect is observed[26].

The geometry observed for the pyranoid ring is consistent with a $^4C_1$ conformation, with no significant distortion from a perfect chair. The ring substituents O-3 and C-6 are on one side, and N, O-1, and O-4 are on the other side of the best plane defined by C-1, C-2, C-3, C-4, C-5, and O-5. In terms of ring-puckering coordinates (Cremer and Pople[27]), amplitude and phase magnitudes are Q = 0.563(3) Å, $\phi = -82(4)°$, and $\theta = 3.9(3)°$ for the sequence O-5–C-1–C-2–C-3–C-4–C-5. The asymmetry parameters[28] are ΔC_s (C-2) = 0.005(2) and ΔC_2 (C-2–C-1) = 0.009(1).

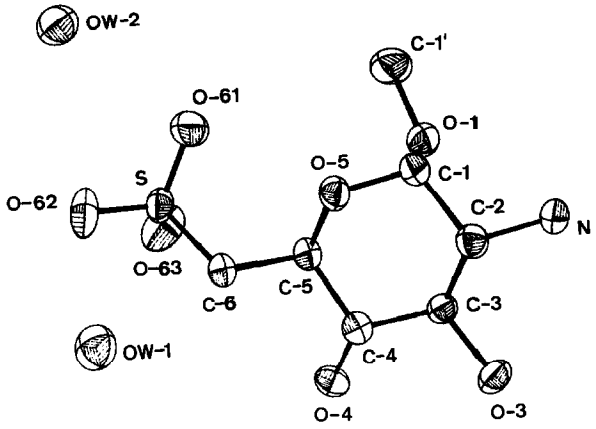


Fig. 1. ORTEP view of **8** along the *a* axis, showing the atomic numbering. The ellipsoids enclose 50% probability.

The C–S bond length and the bond lengths and angles about the sulfonate group are comparable to those reported for the sulfonic acid **5**[29] and for other sulfonic acid structures[30,31]. The lengths of the three S–O bonds are practically the same, indicating that the negative charge on the the SO_3^- group is delocalized over all the oxygen atoms.

Some selected Newman projections are shown in Fig. 2. The glycosidic torsion angle ϕ = O-5–C-1–O-1–C-1′ is 73° according to the exo-anomeric effect[26,32]. The torsional angle ω = O-5–C-5–C-6–S is 85°, with a 25° deviation from the *gt*

TABLE V

Atom coordinates ($\times 10^4$) and eqU_{iso}($\times 10^4$)

Atom	*x*/*a*	*y*/*b*	*z*/*c*	eq U_{iso}
S	3064(1)	8615(1)	8824(1)	357(2)
N	8211(3)	8597(2)	3384(3)	338(8)
O-1	7323(2)	7992(1)	6148(3)	392(7)
O-3	6878(3)	10267(1)	3400(2)	378(7)
O-4	5085(2)	10589(1)	6057(2)	324(8)
O-5	4925(2)	8213(1)	5623(2)	336(7)
O-61	3758(3)	7768(1)	8761(3)	523(10)
O-62	1549(2)	8521(2)	9010(3)	602(11)
O-63	3705(4)	9185(2)	9943(3)	631(12)
C-1	6279(3)	8030(2)	5016(4)	326(10)
C-2	6711(3)	8742(2)	3885(4)	298(9)
C-3	6592(3)	9651(2)	4582(3)	280(9)
C-4	5131(3)	9772(2)	5255(3)	283(9)
C-5	4815(3)	9046(2)	6392(3)	278(9)
C-6	3313(3)	9124(2)	7000(4)	345(10)
C-1′	7242(5)	7227(3)	7080(5)	585(16)
OW-1	14(3)	9215(2)	5701(3)	490(10)
OW-2	1675(3)	6461(2)	9849(3)	522(10)

TABLE VI

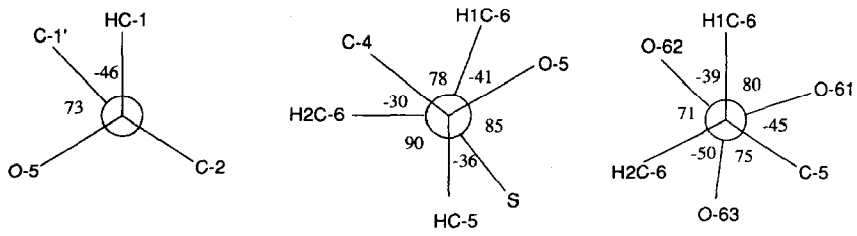
Bond lengths (Å) and angles (°) for **8**

S–C-6	1.785(3)	O-5–C-1	1.415(4)
S–O-62	1.451(2)	C-2–C-1	1.525(4)
S–O-61	1.454(3)	C-2–C-3	1.521(4)
S–O-63	1.442(3)	O-1–C-1	1.398(4)
O-3–C-3	1.422(4)	O-1–C-1′	1.427(5)
N–C-2	1.502(4)	C-5–C-6	1.522(4)
O-4–C-4	1.432(4)	C-5–C-4	1.518(4)
O-5–C-5	1.443(4)	C-4–C-3	1.514(4)
O-61–S–O-63	111.9(2)	O-5–C-5–C-6	107.3(2)
O-62–S–O-63	113.5(2)	C-6–C-5–C-4	110.7(2)
O-62–S–O-61	111.2(2)	S–C-6–C-5	113.5(2)
C-6–S–O-63	106.4(2)	C-2–C-1–O-1	107.2(2)
C-6–S–O-61	107.2(1)	O-5–C-1–O-1	112.6(2)
C-6–S–O-62	105.8(1)	O-5–C-1–C-2	110.0(2)
C-5–O-5–C-1	114.4(2)	O-4–C-4–C-5	108.3(2)
N–C-2–C-3	108.7(2)	C-5–C-4–C-3	110.0(2)
N–C-2–C-1	109.6(2)	O-4–C-4–C-3	108.8(2)
C-1–C-2–C-3	112.0(2)	C-2–C-3–C-4	109.5(2)
C-1–O-1–C-1′	113.4(3)	O-3–C-3–C-4	111.9(2)
O-5–C-5–C-4	109.1(2)	O-3–C-3–C-2	107.6(2)

conformation found in solution. The torsional angles C-5–C-6–S–O-63 (75°) and C-5–C-6–S–O-61 (−45°) present a 15° deviation on the staggered form.

The crystal structure is stabilised by an extensive system of intermolecular hydrogen bonds (Table VII). The network of some of these hydrogen bonds is shown in the (*a*, *b*) projection[33] of the packing in Fig. 3.

The molecules pack to form a compacted structure where there are two water-of-hydration molecules, accepting and donating H-bonds to symmetry-related pairs of molecules. Each molecule of **8** is hydrogen-bonded to two other molecules by bonds between N and O-61, forming "molecular chains" in which an amino group of a molecule is linked to the sulfonic group of the next one. There



C-1–O-1 C-5–C-6 C-6–S

Fig. 2. Some selected Newman projections.

TABLE VII

Geometry of the hydrogen-bonding system

Donor-H ··· acceptor	D ··· A [a]	D–H [a]	H ··· A [a]	D–H ··· A [b]
N–H ··· O-61($x+1/2, -y+3/2, -z+1$)	2.85	0.94	1.95	156
N–H ··· O-4($-x+3/2, -y+2, z-1/2$)	2.87	0.96	2.03	145
N–H ··· OW-1($x+1, y, z$)	2.80	0.95	1.92	154
OW-1–H ··· O-63($-x+1/2, -y+2, z-1/2$)	2.80	1.00	1.86	155
OW-2–H ··· O-61(x, y, z)	2.96	0.97	2.05	154
OW-2–H ··· O-63($x-1/2, -y+3/2, -z+2$)	2.98	0.94	2.24	133

[a] (Å), [b] (°).

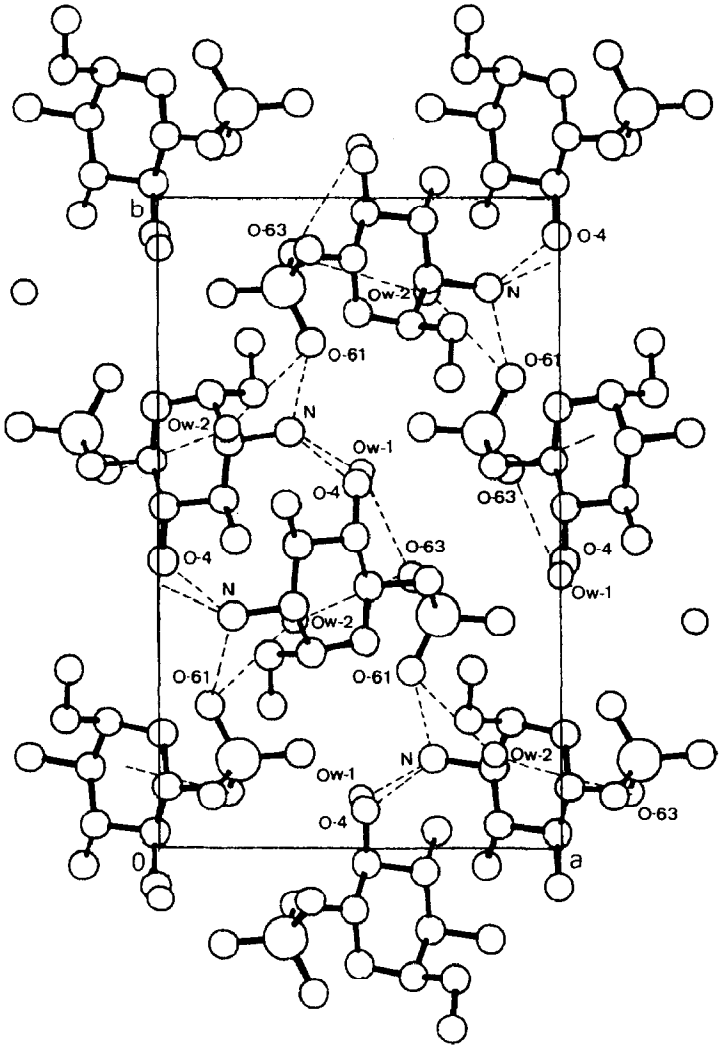


Fig. 3. PLUTO drawing of **8** in the unit cell.

are also two N · · · O-4 hydrogen bonds between units of two chains. The two water molecules are involved in four hydrogen bonds, in three as donor and in one as acceptor, reinforcing H_2O-2 the cohesion into the chain and H_2O-1 the cohesion between the chains.

EXPERIMENTAL

General methods.—Melting points are uncorrected. Optical rotations were measured with a Perkin–Elmer 241 polarimeter. FTIR spectra (KBr discs) were recorded with a Bomem MB-120 spectrometer. ^1H (200 MHz) and ^{13}C NMR (50.3 MHz) spectra were recorded with a Varian XL-200 for solutions in $CDCl_3$ and $(CD_3)_2SO$. ^1H (300 MHz) and ^{13}C NMR (75.5 MHz) spectra were recorded with a Bruker AMX-300 for solutions in D_2O (internal DOH 4.75 ppm and internal 1,4-dioxane at 67.4 ppm). Heteronuclear 2D correlated spectra were obtained in order to assist in signal assignments. EI (70 eV)- and CI (150 eV)-mass spectra were obtained using a Kratos MS-80 RFA instrument, with an ionising current of 100 and 500 μA, respectively, an accelerating voltage of 4 kV, and a resolution of 1000 (10% valley definition). The elemental composition of the ions was determined with a resolution of 10 000 (10% valley definition).

Methyl 3,4-di-O-acetyl-6-S-acetyl-2-benzamido-2-deoxy-6-thio-α-D-glucopyranoside (**2**).—To a solution of **1**[15] (10.3 g, 19.2 mmol) in butanone (80 mL) was added potassium thioacetate (3 g, 26.3 mmol), and the mixture was boiled under reflux for 4 h. Insoluble material was collected and washed with acetone (20 mL), the combined filtrate and washings were concentrated to dryness, and a solution of the residue in CH_2Cl_2 (50 mL) was washed with water (2 × 50 mL), dried ($MgSO_4$), and concentrated. The residue was crystallised from EtOH to give **2** (7.6 g, 90%), mp 159–161°C, $[\alpha]_D^{22}$ +120°, $[\alpha]_{578}^{22}$ +124°, $[\alpha]_{546}^{22}$ +141°, $[\alpha]_{435}^{22}$ +238° (*c* 1, CH_2Cl_2); R_f 0.85 (20:1 EtOAc–hexane); ν_{max} 3350 (NH), 1746 (C=O acetate), 1694 (C=O thioacetate), 1649 (Amide I), 1543 (Amide II), 1240 (acetate), 1605, 1581, 1491, and 723 cm^{-1} (phenyl). Mass spectrum (CI): *m/z* 440 (M^+ + 1, 100%), 408 (M^+ − MeO, 86), 380 (M^+ − AcO, 8), 366 (M^+ − MeO − CH_2CO, 16), 348 (M^+ − MeO − AcOH, 5), 336 (M^+ − AcOH − Ac, 4), 304 (M^+ − AcOH − AcS, 10), 105 ($PhCO^+$, 50). The ^1H and ^{13}C NMR are given in Tables I and II. Anal. Calcd for $C_{20}H_{25}NO_8S$: C, 54.67; H, 5.73; N, 3.19. Found: C, 54.86; H, 5.73; N, 3.37.

6,6'-Dithiobis(methyl 2-benzamido-2,6-dideoxy-α-D-glucopyranoside) (**3**).—A mixture of **2** (7.6 g, 17.3 mmol) and methanolic 1% NaOMe (25 mL, 4.6 mmol) was stirred overnight at room temperature. TLC (9:1 CH_2Cl_2–MeOH) showed complete conversion of **2** into the thiol (R_f 0.75) together with the disulfide **3** (R_f 0.43). The mixture kept at 0°C gave several crops of crystalline **3** (4.5 g, 84%), mp 258–260°C (from MeOH), $[\alpha]_D^{22}$ +265°, $[\alpha]_{578}^{22}$ +272°, $[\alpha]_{546}^{22}$ +315°, $[\alpha]_{435}^{22}$ +548° (*c* 1, pyridine); ν_{max} 3450, 3300 (NH, OH), 2834 (MeO), 1638 (Amide I), 1535, 1531 (Amide II), 1603, 1578, 1489, 716, and 690 cm^{-1} (phenyl). Mass spectrum (EI): *m/z* 312 ($M^+/2$, 0.5%), 262 ($M^+/2 - S - H_2O$, 5), 105 ($PhCO^+$, 100), 77 (Ph^+,

38). The ^1H and ^{13}C NMR are given in Tables III and IV. Anal. Calcd for $C_{28}H_{36}N_2O_{10}S_2$: C, 53.84; H, 5.81, N, 4.47, S, 10.27. Found: C, 53.64; H, 5.94; N, 4.16; S, 10.41.

6,6'-Dithiobis(methyl 3,4-di-O-acetyl-2-benzamido-2,6-dideoxy-α-D-glucopyranoside) (**4**).—Conventional acetylation of **3** (0.15 g, 0.24 mmol) with pyridine (1.5 mL) and Ac_2O (1.5 mL) gave **4** (0.16 g, 93%), mp 224–226° (from EtOH), $[\alpha]_D^{22}$ +249°, $[\alpha]_{578}^{22}$ +257°, $[\alpha]_{546}^{22}$ +295°, $[\alpha]_{435}^{22}$ +511° (*c* 1, CH_2Cl_2), R_f 0.92 (10:1 ethyl ether–hexane); ν_{max} 3339 (NH), 2838 (MeO), 1753, 1740 (C=O acetate), 1649 (Amide I), 1526 (Amide II), 1242, 1225 (acetate), 1603, 1582, 1490, 716, and 692 cm^{-1} (phenyl). Mass spectrum (EI): *m/z* 792 (M^+, 5%), 429 ($M^+/2$ + SH, 2), 397 ($M^+/2$ + 1, 5), 276 ($M^+/2$ − 2AcOH, 10), 105 ($PhCO^+$, 100), 77 (Ph^+, 20). The ^1H and ^{13}C NMR are given in Tables I and II. Anal. Calcd for $C_{36}H_{44}N_2O_{14}S_2$: C, 54.53; H, 5.59; N, 3.53. Found: C, 54.43; H, 5.70; N, 3.75.

Methyl 3,4-di-O-acetyl-2-deoxy-2-[(2,2-dimethoxycarbonylvinyl)amino]-6-O-toluene-p-sulfonyl-α-D-glucopyranoside (**10**).—To a stirred solution of **9**[17] (0.7 g, 2.09 mmol) in pyridine (7 mL) at −15°C was added slowly solid *p*-toluenesulfonyl chloride (0.79 g, 4.18 mmol) followed, after 3 h, by Ac_2O (7 mL). The mixture was stored for 12 h at 0°C, poured into ice–water and extracted into CH_2Cl_2 (15 mL), washed with 2 M HCl, satd aq $NaHCO_3$, and water, and dried ($MgSO_4$). Flash chromatography (CH_2Cl_2) gave **10** (0.59 g, 55%) as a syrup, $[\alpha]_D^{21}$ +144°, $[\alpha]_{578}^{21}$ +151°, $[\alpha]_{546}^{21}$ +175°, $[\alpha]_{435}^{21}$ +334° (*c* 1, CH_2Cl_2); R_f 0.27 (5:1 ethyl ether–hexane); ν_{max} 3280, 3202 (NH), 2846 (CH_3O), 1755 (C=O acetate), 1719 (C=O free), 1665 (C=O chelated), 1610 (C=C and NH), 1232 (acetate), 1190, 1179 (SO_2), 804 (aromatic and C–O–S). Mass spectrum (EI): *m/z* 573.1494 (M^+, 19%, calcd 573.1516), 542 (M^+ − MeO, 17), 513 (M^+ − AcOH, 8), 453 (M^+ − 2AcOH, 6), 411 (M^+ − 2AcOH − CH_2CO, 7), 201 [$CHOCH_2NHC(COOMe)_2^+$, 100], 169 [$CNCHC(COOMe)_2^+$, 39], 155 ($MeC_6H_4SO_2^+$, 41), 91 ($MeC_6H_4^+$, 44). The ^1H and ^{13}C NMR are given in Tables I and II. Anal. Calcd for $C_{24}H_{31}NO_{13}S$: C, 50.26; H, 5.45; N, 2.46, S, 5.59. Found: C, 50.27; H, 5.55; N, 2.87; S, 5.48.

Methyl 3,4-di-O-acetyl-6-S-acetyl-2-deoxy-2-[(2,2-dimethoxycarbonylvinyl)amino]-6-thio-α-D-glucopyranoside (**11**).—To a solution of **10** (0.8 g, 1.47 mmol) in butanone (10 mL) was added potassium thioacetate (0.2 g, 1.75 mmol), and the mixture was boiled under reflux for 4 h. Insoluble material was collected and washed with acetone, the combined filtrate and washings were concentrated to dryness, and a solution of the residue in CH_2Cl_2 was washed with water, dried ($MgSO_4$), and concentrated to yield **11** (0.62 g, 93%) which was sufficiently pure for the next step. An analytical sample, purified by preparative TLC (5:1 ethyl ether–hexane), was isolated as a syrup, $[\alpha]_D^{22}$ +130°, $[\alpha]_{578}^{22}$ +137°, $[\alpha]_{546}^{22}$ +161°, $[\alpha]_{435}^{22}$ +314° (*c* 1, CH_2Cl_2); R_f 0.48 (5:1 ethyl ether–hexane); ν_{max} 3279, 3260 (NH), 2841 (MeO), 1753 (C=O acetate), 1719 (C=O free), 1695 (thioacetate), 1665 (C=O chelated), 1609 (C=C and NH), 1231 (acetate). Mass spectrum (EI): *m/z* 477.1313 (M^+, 32%; calcd 477.1305), 446 (M^+ − MeO, 20), 417 (M^+ − AcOH, 10), 201 [$OCHCH_2NHCHC(COOMe)_2^+$, 92], 198 [$AcSCH_2CHCOAcCCH^+$, 100], 169

[CNCHC(COOMe)$_2$, 40]. The ^{1}H and ^{13}C NMR are given in Tables I and II. Anal. Calcd for $C_{19}H_{27}NO_{11}S$: C, 47.79; H, 5.70; N, 2.93; S, 6.72. Found: C, 48.15; H, 5.37; N, 3.00; S, 6.47.

Methyl 2-amino-2,6-dideoxy-α-D-glucopyranoside-6-sulfonic acid (**8**).—*Procedure A.* To a solution of **2** (2.27 g, 5.16 mmol) and NaOAc (0.423 g, 5.16 mmol) in AcOH (20 mL) was added aq 33% w/v hydrogen peroxide (4.8 mL, 46.44 mmol). After 24 h at 35°C, TLC (6:2:1:1 EtOAc–MeOH–AcOH–water) showed complete conversion of **2** (R_f 1) into a major product (**6**, R_f 0.72) together with a small amount of a more polar by-product. The solution was concentrated (0.5 mmHg) and then coconcentrated with EtOH (3 × 10 mL). A solution of the residue (2.40 g) in 1 M NaOH (5 mL) was boiled under reflux for 60 h, then deionised with Amberlite IR-120(H$^+$) resin and concentrated. The residue was washed with ethyl ether and hot EtOH, and crystallised from EtOH–water to give **8** (1.09 g, 72%), $[\alpha]_D^{21}$ +104°, $[\alpha]_{578}^{21}$ +105°, $[\alpha]_{546}^{21}$ +124°, $[\alpha]_{435}^{21}$ +208° (*c* 1, H_2O), R_f 0.15; ν_{max} 3528, 3455, 3310, 3130 (NH_3^+, OH), 2845 (CH_3O), 1638, 1630, 1538 (NH_3^+), 1232, 1204 and 1169 cm^{-1} (SO_3^-). The ^{1}H and ^{13}C NMR are given in Tables III and IV. Anal. Calcd for $C_7H_{15}NO_7S \cdot 2H_2O$: C, 28.67; H, 6.52; N, 4.77; S, 10.93. Found: C, 29.01; H, 6.58; N, 4.73; S, 11.44.

Procedure B. To a solution of **11** (0.23 g, 0.48 mmol) and NaOAc (0.044 g, 0.54 mmol) in AcOH (3 mL) was added aq 33% w/v hydrogen peroxide (0.6 mL, 5.8 mmol). After 24 h at 35°C, the solution was concentated (0.5 mmHg) and then coconcentrated with EtOH. The ^{1}H NMR spectrum of the crude mixture showed a mixture of two main compounds lacking the enamino group. A solution of the mixture (0.223 g) in water (20 mL) containing Amberlite IR-120(H$^+$) resin was heated under reflux for 5 h, filtered, concentrated, and coconcentrated with EtOH. The NMR spectrum of the residue (0.143 g, 100%) showed pure **8**.

*Crystal analysis**.—Compound **8** crystallised as prisms from EtOH–water. A systematic search in reciprocal space, using an Enraf–Nonius CAD-4 diffractometer, showed that crystals belonged to the orthorhombic system. The unit-cell dimensions and their standard deviations, obtained and refined at room temperature with Mo$K\alpha$ radiation (λ = 0.7107 Å) by using 25 selected reflections and the standard CAD-4 software, were a = 9.466(1), b = 15.299(6), c = 8.715(1) Å, Z = 4. The unit cell volume (V) was 1262.1(5) Å^3 and the absorption coefficient (μ) was 2.86 cm^{-1}. D_c was 1.54 g cm^{-3} and D_m measured by flotation was 1.53 g cm^{-3}; $F(000)$ = 624; space group $P2_12_12_1$.

A single crystal of 0.32 × 0.32 × 0.56 mm^3 was glued at the end of a glass wire mounted on a rotation-free goniometer head. All quantitative data were obtained using graphite-monochromated radiation. The vertical and horizontal apertures in front of the scintillation counter were adjusted so as to minimize the background

* Atomic coordinates for this structure have been deposited with the Cambridge Crystallographic Data Centre. The coordinates may be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK.

counts without loss of the net peak intensity. The $\omega/2\theta$ scan mode was used; 2100 reflections were recorded ($2° < \theta < 30°$). The resulting data-set was transferred to a VAX computer; for all subsequent calculations, the X-Ray System package[34] was used.

Two standard reflections measured every hour during the entire data collection period showed no significant trend. The raw step-can data were converted into intensities and corrected for Lorentz and polarization factors. From 2100 measured reflections, 1742 having $I > 3\sigma(I)$ were used to determine and refine the structure, $R_{int} = 0.005$. The structure was solved using MULTAN-80[35]. Isotropic least-squares refinement converged to $R = 0.11$. Further empirical absorption correction DIFABS[36] was applied. Maximum and minimum absorption correction factors were 1.40 and 0.80, respectively. Anisotropic refinement, followed by difference Fourier synthesis, allowed the location of most of the H atoms. Positional parameters and anisotropic thermal parameters of the non-H atoms were refined. The H atoms were introduced in the structure factor calculations with isotropic thermal parameters as the atoms to which they were bonded, but not refined. The final conventional agreement factors were $R = 0.042$ and $R_w = 0.043$ for 1742 observed reflections and 163 variables; maximum shift/error = 0.012 and the goodness of fit = 1.97. The function minimised was $\Sigma w(|F_o| - |F_c|)^2$ with $\omega = 1/\sigma^2(F_o)$. A final difference map revealed no significant maxima ($\Delta\rho = \pm 0.4$ eÅ^{-3}). Atomic scattering factors were taken from the International Tables for X-Ray Crystallography[37].

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