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Synthesis of methyl 3-deoxy-3-nitroheptoseptanosides

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ABSTRACT

The reaction of the dioxepane **2**, obtained by periodate oxidation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside, with nitromethane, using potassium fluoride as catalyst, gave methyl 5,7-*O*-benzylidene-3-deoxy-3-nitro-D-*glycero*-α-D-*ido*-heptoseptanoside (**2**) as the major product. The reaction of **4** with methyl nitroacetate followed by acetylation gave methyl 2,4-di-*O*-acetyl-5,7-*O*-benzylidene-3-deoxy-3-*C*-methoxycarbonyl-*3*-nitro-D-*glycero*-α-D-*talo*- (**6**) and -D-*glycero*-α-D-*ido*-heptoseptanoside (**7**).

INTRODUCTION

Few syntheses of septanosides have been described. One method involves the cyclisation of the dialdehydes obtained by periodate oxidation of methyl 4,6-*O*-ethylidene- or 4,6-*O*-benzylidene-α-D-glucopyranoside with nitroalkanes. Baschang[1] reported the synthesis of methyl 3-deoxy-5,7-*O*-ethylidene-3-nitro-D-*glycero*-α-D-*manno*-heptoseptanoside (41%) by the reaction of the product of periodate oxidation of methyl 4,6-*O*-ethylidene-α-D-glucopyranoside with nitromethane in the presence of sodium methoxide. Reduction, *N*-acetylation, and hydrolysis then afforded 3-acetamido-3-deoxy-D-*glycero*-D-*manno*-heptose. Wolfrom *et al.*[2] applied the method to the product of periodate oxidation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside and obtained four isomeric 3-deoxy-3-nitroheptoseptanosides, but the configurations were not assigned. Butcher *et al.*[3] have studied the reactions of the products of periodate oxidation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside with nitromethane, nitroethane, 1-nitropropane, 1-nitromethylcyclohexene, phenylnitromethane, and ethyl and methyl nitroacetate. The type of product obtained[3] (dioxepane or septanoside) depends on the nature of the active methylene compounds used, the basic catalyst, and the solvent. We have reported[4] the synthesis of 3-cyano-3-deoxyheptoseptanosides by cyclisation of **2** with ethyl and *tert*-butyl cyanoacetate and cyanoacetamide. Potassium fluoride is an efficient catalyst in the cyclisation reactions of dialdehydes [thiodiglycolaldehyde, diglycolaldehyde, α-(*S*)-(3-ethoxycarbonyl-2-methylfur-5-yl)diglycolaldehyde, and (2*R*,3*R*,5*S*,6*S*)-3,5-dihydroxy-2-methoxy-6-methyl-1,4-dioxane] with nitro compounds[5]. These results prompted a study of the use of potassium fluoride in the cyclisation of **2** with nitromethane and methyl nitroacetate for the synthesis of 3-nitro-3-deoxyseptanoside derivatives.

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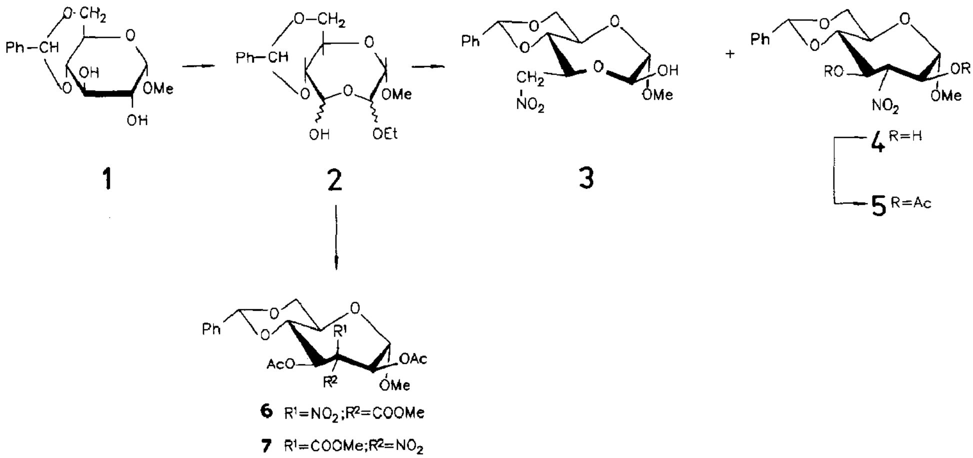
RESULTS AND DISCUSSION

The reactions were carried out at ~45° using potassium fluoride–dibenzo-18-crown-6 as catalyst and acetonitrile as solvent. The reaction of **2** with nitromethane gave the 1,4-dioxepane **3** (10%) and the septanoside **4** (68%). The formation of a sole septanoside **4** reflects high stereoselectivity, in contrast to the results when sodium methoxide was used as the catalyst[2]. Treatment of **4** with acetic acid–acetic anhydride–acetyl chloride afforded the 2,4-diacetate **5** (49%). The reaction of **2** with methyl nitroacetate followed by acetylation gave the septanoside diacetates **6** (29%) and **7** (26%). The structures of **3**–**7** were established on the basis of elemental analyses and spectroscopic data.



The configurations at C-2 and C-4, and the preferred $^{O,3}C_6$(D) conformation in **4**–**7**, were deduced from the ^{1}H-n.m.r. data (see Table I), n.O.e. difference experiments (for **5**), and molecular mechanics calculations (for **4** and **5**). The $J_{1,2}$ values for **4**–**7** were in the range 6.3–6.6 Hz, in accord with H-1*eq*, 2*ax*. The $J_{4,5} + J_{5,6}$ value of 18.0 Hz for **4** and the $J_{4,5}$ values of 8.6–8.7 Hz for **5** and **7** indicated H-4,5 to be *trans*-diaxial. These J values are similar to those reported[4] for methyl 3-alkoxycarbonyl-(or carbamoyl)-5,7-*O*-benzylidene-3-*C*-cyano-3-deoxy-D-*glycero*-α-D-*ido*-heptoseptanosides. The $J_{2,3} + J_{3,4}$ values of 21.0 Hz for **4** and **5** reflected an antiperiplanar relationship between H-3 and H-2,4. Confirmation of these assignments was achieved by n.O.e. difference spectroscopy of **5**. Irradiation of H-2 and H-3 resulted in positive responses from H-4,6 and H-1,5, respectively.

The configuration at C-3 for **6** and **7** (isolated by column chromatography of the materials that remained after the crystallisation of **6**) were deduced from COLOC experiments[6] that showed cross-peaks between COOMe and H-2,4 for **7**, and indicated[6c] an *ax*,*ax*,*ax* disposition. No cross-peaks were observed for **6**. The $J_{1,2}$ and $J_{4,5}$ values of **6** and **7** were similar, suggesting the same configuration at C-2 and C-4, which means that they are C-3 epimers.

TABLE I

^{1}H-N.m.r. data for **4**–**7**

Compound	*H-1*	*H-2*	*H-4*	*H-5*	*H-6*	*H-7*eq	*H-7*ax	*OMe*	*Ph*CH	*Others*[a]
4[a]	4.42d	—4.15–3.95m—		3.58[c]	3.73[c]	4.15–3.95m	3.56[d]	3.31s	5.55s	6.28 (d, 1 H, *J* 7.1 Hz, OH)[e], 6.11 (d, 1 H, *J* 6.3 Hz, OH)[e], and 4.67 (pseudo-t, 1 H, $J_{2,3} + J_{3,4}$ 21.0 Hz, H-3)
5[f]	4.60d	5.66dd	5.86dd	3.77dd	3.98[c]	4.22dd	3.62[d]	3.47s	5.43s	5.05 (pseudo-t, $J_{2,3} + J_{3,4}$ 21.1 Hz, H-3), and 2.04, 2.01 (2 s, 6 H, 2 Ac)
6[f]	4.71d	5.87d	5.93d	———4.20–4.05m———			3.62dd	3.36s	5.45s	3.72 (s, 3 H, COOMe), and 2.09, 2.05 (2 s, 6 H, 2 Ac)
7[f]	4.70d	5.90d	6.03d	4.10[d]	4.09[d]	4.15dd	3.61dd	3.36s	5.44s	3.98 (s, 3 H, COOMe), and 2.04, 2.01 (2 s, 6 H, 2 Ac)

Coupling constants (Hz)

	$J_{1,2}$	$J_{4,5}$	$J_{2,3} + J_{3,4}$	*Others*
4	6.3	18.0[g]	21.0	$J_{5,6} + J_{6,7ax}$ 19.6, $J_{7ax,7eq} + J_{6,7ax}$ 20.5, and $J_{6,7eq}$ 5.3
4[h]	6.1	9.3	19.8	$J_{5,6}$ 9.5, $J_{6,7ax}$ 9.5, and $J_{6,7eq}$ 4.8
5	6.5	8.7	21.1	$J_{5,6} \approx J_{6,7ax} \approx$ 9.8, $J_{6,7eq}$ 5.5, and $J_{7ax,7eq}$ 10.8
5[h]	6.0	9.1	20.2	$J_{5,6}$ 9.0, $J_{6,7ax}$ 9.1, and $J_{6,7eq}$ 5.7
6	6.5	8.6	-	$J_{7ax,7eq}$ 10.0 and $J_{6,7ax}$ 8.5
7	6.6	8.6	-	$J_{6,7eq}$ 5.1, $J_{7ax,7eq}$ 10.5, and $J_{5,6} \approx J_{6,7ax} \approx$ 10.0

[a] Phenyl proton multiplets at δ 7.50–7.20 in **4**–**7**. [b] For solution in $(CD_3)_2SO$. [c] dpseudo-t. [d] pseudo-t. [e] Exchangeable with D_2O. [f] For solution in $CDCl_3$ (internal Me_4Si). [g] $J_{4,5} + J_{5,6}J_{2,3} + J_{3,4}$. [h] Obtained from molecular mechanics calculations.

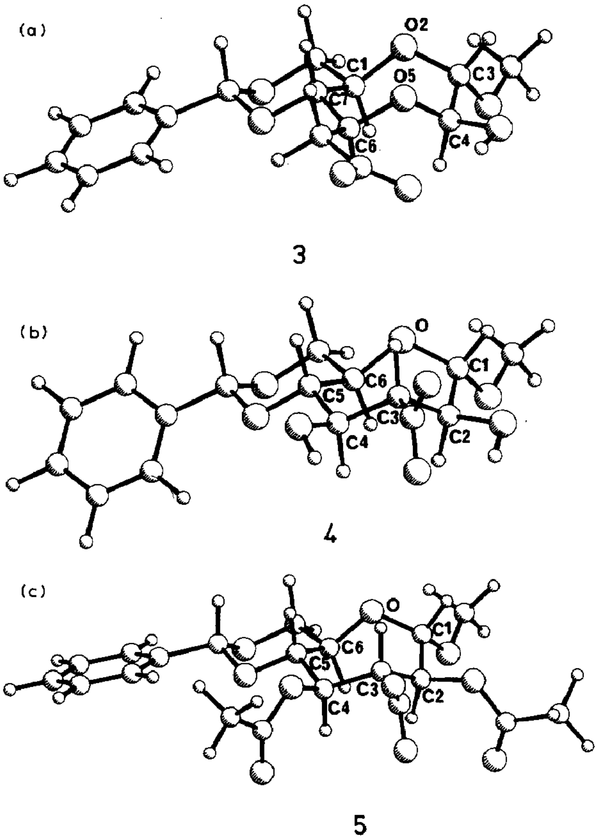


Fig. 1. Lowest energy conformations, predicted by molecular mechanics calculations, of **3**–**5** (see Appendices I–III).

TABLE II

Theoretical[a] and experimental coupling constants (Hz) and theoretical[a] dihedral angles (ϕ°) for **3**

	Theoretical	*Experimental*
$J_{3,4}$	5.3	5.9
$\phi_{3,4}$	−156.7	
$J_{6,7}$	8.6	9.3
$\phi_{6,7}$	−179.2	
$J_{1,7}$	9.5	18.7[b]
$\phi_{1,7}$	170.8	
$J_{1,11eq}$	6.1	5.3
$\phi_{1,11eq}$	−52.5	
$J_{1,11ax}$	10.5	19.0[c]
$\phi_{1,11ax}$	170.8	

[a] Obtained from molecular mechanics calculations ($D = 1.5$). [b] $J_{1,7} + J_{6,7}$. [c] $J_{1,7} + J_{1,11ax}$.

The geometries of **4** and **5** were obtained from molecular mechanics calculations, using an implementation of the Allinger algorithm[7]. The optimised structures of lowest energy (Fig. 1), based on the configuration established by the ^{1}H-n.m.r. data and n.O.e. difference experiments, were predicted with the seven- and six-membered rings in the $^{O,3}C_6$ and ^7C_O conformations, respectively. Using the generalised Karplus equation[8] (see Table II), $J_{1,2}$ values of 6.0 and 6.1 Hz were calculated for the predicted H-1–C–C–H-2 dihedral angles of $-155°$ and $-156°$, respectively, $J_{4,5}$ values of 9.1 and 9.3 Hz for the predicted H-4–C–C–H-5 dihedral angles of 172° and 175°, respectively, and $J_{2,3} + J_{3,4}$ values of 19.8 and 20.2 Hz for the predicted H-2–C–C–H-3 and H-3–C–C–H-4 dihedral angles of $-147°$ and 158°, and $-161°$ and 175°, respectively.

Compound **3** showed i.r. bands at 3424 (OH) and 1546 (NO_2) cm^{-1}. The 1,4-dioxepane structure was established on the basis of a signal at δ 7.12 (d, J 6.4 Hz) for OH and signals at δ 104.2, 99.6, and 98.6 (C-3,4, C_6H_5CH), and 77.0 (CH_2NO_2). The configurations at C-4,6 and the preferred conformation $^{O,O}C_1$ for the seven-membered ring were established by the $J_{6,7}$ and $J_{6,7} + J_{7,1}$ values of 9.3 and 18.7 Hz, respectively, which indicated H-1,6,7 to be axial. The $J_{3,4}$ value of 5.9 Hz accords with an *eq,ax* relationship of H-3,4.

The geometry of **3** (Fig. 1) was obtained from molecular mechanics calculations that gave ^3J values consistent with the Experimental data (see Table II).

EXPERIMENTAL

General methods. — Melting points were determined with an electrothermal apparatus and are uncorrected. Spectra were recorded with Perkin–Elmer 983G (i.r.), Perkin–Elmer 141 ($[\alpha]_D$, room temperature), and Bruker AM 300 (n.m.r.) instruments. Column chromatography was performed on silica gel (Merck 70–230 mesh, ASTM).

Molecular mechanics and coupling constant calculations were carried out on a Mitac 386 microcomputer, using the programs PCMODEL (Serena Software, Bloomington, IN, U.S.A.), MMX[7], and 3JHH[8]. The ^3J values for the appropiate low-energy geometries were calculated with 3JHH[8] which uses the parameters of Hasnoot *et al.*[9]. The program PCDISPLAY (Serena Software) was used for molecular graphics display. Calculations were performed using an effective dielectric constant (D) of 1.5. The nitro group was modeled using N+ (41 MMX type), O− (42 MMX type), and O (7 MMX type) (see Appendices I–III).

Reactions of nitromethane and methyl nitroacetate with **2**. — To a solution of **2** (ref. 10) [1 g (3.0 mmol) when nitromethane was used or 1.26 g (3.8 mmol) when methyl nitroacetate was used] in acetonitrile (35 mL) was added nitromethane (3.6 equiv.) or methyl nitroacetate (1 equiv.), potassium fluoride (0.1 equiv.), and dibenzo-18-crown-6 ether (0.1 equiv.). The mixture was stirred at ~45° and then concentrated. Water (30 mL) was added to the residue, the mixture was extracted with ethyl acetate (3 × 50 mL), and the combined extracts were dried, filtered, and concentrated to give a crude product.

APPENDIX I

Final atomic co-ordinates and bonded atoms for **3**

Atom	x	y	z	*Type*	*Bound to atoms*
C(1)	−0.20050	1.49117	4.33667	(1)	2, 7, 11, 40
O(2)	−0.44167	1.25029	5.72837	(6)	1, 3,
C(3)	0.18209	2.15788	6.65183	(1)	2, 4, 22, 43
C(4)	1.65596	2.41902	6.29543	(1)	3, 5, 21, 42
O(5)	2.21404	1.23028	5.77208	(6)	4, 6,
C(6)	2.33616	1.28208	4.36141	(1)	5, 7, 13, 41
C(7)	1.02550	0.69715	3.80348	(1)	1, 6, 8, 39
O(8)	1.08019	0.76214	2.38394	(6)	9, 7,
C(9)	−0.12377	0.27594	1.79253	(1)	8, 10, 15, 38
O(10)	−1.21956	1.11167	2.16519	(6)	9, 11,
C(11)	−1.45432	1.03599	3.56456	(1)	1, 10, 27, 28
C(12)	−1.76769	3.33526	7.31127	(1)	22, 25, 29, 30
C(13)	3.67511	0.58825	4.03222	(1)	6, 24, 31, 32
O−(14)	4.81081	2.17302	5.43077	(42)	24,
C(15)	−0.01785	0.18337	0.27736	(2)	9, 16, 20,
C(16)	−1.12782	0.02701	−0.46937	(2)	15, 17, 33,
C(17)	−1.06676	−0.06431	−1.80709	(2)	16, 18, 34,
C(18)	0.11950	−0.00379	−2.42940	(2)	17, 19, 35,
C(19)	1.23649	0.14771	−1.70253	(2)	18, 20, 36,
C(20)	1.16442	0.24027	−0.36476	(2)	15, 19, 37,
O(21)	2.49587	2.74458	7.38881	(6)	4, 26,
O(22)	−0.48345	3.41819	6.71215	(6)	3, 14,
O(23)	5.95842	0.69285	4.57364	(7)	24,
N+(24)	4.87114	1.18130	4.73096	(41)	13, 14, 23,
H(25)	−2.20808	4.35971	7.31966	(5)	12,
H(26)	3.37098	2.63376	7.01198	(21)	21,
H(27)	−1.74367	−0.00892	3.83397	(5)	11,
H(28)	−2.32162	1.70018	3.79842	(5)	11,
H(29)	−2.43277	2.66554	6.71723	(5)	12,
H(30)	−1.68074	2.97444	8.36322	(5)	12,
H(31)	3.58845	−0.48925	4.30944	(5)	13,
H(32)	3.83803	0.61973	2.92833	(5)	13,
H(33)	−2.11702	−0.03221	0.01518	(5)	16,
H(34)	−1.99175	−0.19151	−2.39637	(5)	17,
H(35)	0.17614	−0.07983	−3.52931	(5)	18,
H(36)	2.21697	0.19626	−2.20798	(5)	19,
H(37)	2.10528	0.36214	0.19692	(5)	20,
H(38)	−0.31006	−0.77026	2.14444	(5)	9,
H(39)	0.94752	−0.37732	4.10410	(5)	7,
H(40)	−0.07496	2.58644	4.15555	(5)	1,
H(41)	2.44186	2.32450	3.97299	(5)	6,
H(42)	1.73569	3.28581	5.59380	(5)	4,
H(43)	0.14215	1.67307	7.65957	(5)	3,

APPENDIX II

Final atomic co-ordinates and bonded atoms for **4**

Atom	x	y	z	*Type*	*Bound to atoms*
C(1)	−2.11669	−1.27568	0.87873	(1)	2, 18, 21, 43
C(2)	−0.67699	−0.77276	1.11632	(1)	1, 3, 20, 42
C(3)	−0.09882	−0.01444	−0.10218	(1)	2, 4, 23, 41
C(4)	−0.41684	1.48641	0.08599	(1)	3, 5, 19, 40
C(5)	−1.86629	1.82547	−0.29941	(1)	4, 6, 16, 38
C(6)	−2.88889	0.98581	0.50405	(1)	5, 7, 18, 39
C(7)	−4.30570	1.54270	0.26174	(1)	6, 17, 28, 29
C(8)	−3.39656	3.61362	−0.32225	(1)	9, 16, 17, 37
C(9)	−3.56479	5.11394	−0.16335	(2)	8, 10, 14,
C(10)	−4.62573	5.72802	−0.71911	(2)	9, 11, 32,
C(11)	−4.79987	7.05397	−0.60594	(2)	10, 12, 33,
C(12)	−3.90752	7.79161	0.07127	(2)	11, 13, 34,
C(13)	−2.84722	7.19373	0.63460	(2)	12, 14, 35,
C(14)	−2.68111	5.86682	0.51771	(2)	9, 13, 36,
C(15)	−3.90760	−2.33559	2.01584	(1)	21, 25, 30, 31
O(16)	−2.06548	3.20684	−0.02266	(6)	5, 8,
O(17)	−4.33124	2.94052	0.51674	(6)	7, 8,
O(18)	−2.87730	−0.37393	0.07122	(6)	1, 6,
O(19)	0.51330	2.20639	−0.70188	(6)	4, 26,
O(20)	0.20015	−1.85251	1.38866	(6)	2, 27,
O(21)	−2.73223	−1.54673	2.13715	(6)	1, 15,
O(22)	1.88006	−0.88047	−1.11842	(7)	23,
N+(23)	1.37710	−0.21924	−0.25128	(41)	3, 22, 24,
O−(24)	2.04231	0.13480	0.69067	(42)	23,
H(25)	−4.32946	−2.47998	3.03791	(5)	15,
H(26)	1.35383	2.11467	−0.26471	(21)	19,
H(27)	1.04515	−1.46319	1.60473	(21)	20,
H(28)	−4.64581	1.35382	−0.78562	(5)	7,
H(29)	−5.04029	1.05916	0.95061	(5)	7,
H(30)	−4.66520	−1.81187	1.38690	(5)	15,
H(31)	−3.65931	−3.33480	1.58647	(5)	15,
H(32)	−5.36929	5.13646	−1.28046	(5)	10,
H(33)	−5.67626	7.53861	−1.07069	(5)	11,
H(34)	−4.04595	8.88276	0.16621	(5)	12,
H(35)	−2.11071	7.79562	1.19530	(5)	13,
H(36)	−1.79905	5.40755	0.99397	(5)	14,
H(37)	−3.61008	3.37284	−1.39484	(5)	8,
H(38)	−2.00301	1.65842	−1.39666	(5)	5,
H(39)	−2.68092	1.05251	1.59938	(5)	6,
H(40)	−0.24107	1.82002	1.13892	(5)	4,
H(41)	−0.56764	−0.38428	−1.04549	(5)	3,
H(42)	−0.65382	−0.14074	2.03778	(5)	2,
H(43)	−2.04851	−2.23057	0.29848	(5)	1,

APPENDIX III

Final atomic co-ordinates and bonded atoms for **5**

Atom	x	y	z	*Type*	*Bound to atoms*
C(1)	0.18970	0.31498	6.75959	(1)	2, 22, 25, 53
C(2)	1.40869	1.25913	6.63924	(1)	1, 3, 24, 52
C(3)	2.56940	0.74655	5.74023	(1)	2, 4, 29, 51
C(4)	2.30872	1.03198	4.23452	(1)	3, 5, 23, 50
C(5)	1.14709	0.22164	3.62316	(1)	4, 6, 20, 48
C(6)	−0.18493	0.39510	4.38161	(1)	5, 7, 22, 49
C(7)	−1.37716	−0.12873	3.55228	(1)	6, 21, 34, 35
C(8)	−0.05478	−0.10267	1.63623	(1)	9, 20, 21, 47
C(9)	−0.02353	0.03967	0.12427	(2)	8, 10, 14,
C(10)	−1.15313	0.01234	−0.60810	(2)	9, 11, 42,
C(11)	−1.11956	0.11138	−1.94645	(2)	10, 12, 43,
C(12)	0.05440	0.23936	−2.58198	(2)	11, 13, 44,
C(13)	1.18975	0.26762	−1.86882	(2)	12, 14, 45,
C(14)	1.14615	0.16711	−0.53101	(2)	9, 13, 46,
C(15)	−1.96251	0.24478	7.75865	(1)	25, 31, 36, 37
C(16)	4.05132	1.59147	2.67428	(3)	17, 23, 27,
C(17)	5.24951	0.97001	1.99100	(1)	16, 32, 38, 39
C(18)	1.77302	2.57303	8.62300	(3)	19, 24, 28,
C(19)	2.38559	2.45569	10.00143	(1)	18, 33, 40, 41
O(20)	0.99821	0.62398	2.26494	(6)	5, 8,
O(21)	−1.29657	0.30948	2.20305	(6)	7, 8,
O(22)	−0.12330	−0.39112	5.56642	(6)	1, 6,
O(23)	3.48809	0.69031	3.51077	(6)	4, 16,
O(24)	1.90666	1.39802	7.96717	(6)	2, 18,
O(25)	−0.91048	1.06533	7.27102	(6)	1, 15,
O(26)	3.95190	2.61386	6.14819	(7)	29,
O(27)	3.65112	2.71726	2.48898	(7)	16,
O(28)	1.24447	3.56538	8.17792	(7)	18,
N+(29)	3.85696	1.41553	6.15229	(41)	12, 26, 30,
O−(30)	4.89413	0.79089	6.12582	(42)	29,
H(31)	−2.77187	0.91469	8.13209	(5)	15,
H(32)	5.79106	1.72995	1.38303	(5)	17,
H(33)	2.21967	3.38993	10.58464	(5)	19,
H(34)	−1.41718	−1.24556	3.56206	(5)	7,
H(35)	−2.34260	0.24105	3.97553	(5)	7,
H(36)	−2.37376	−0.38966	6.93890	(5)	15,
H(37)	−1.60134	−0.38541	8.60530	(5)	15,
H(38)	5.96066	0.55759	2.74276	(5)	17,
H(39)	4.92023	0.15026	1.31232	(5)	17,
H(40)	1.92471	1.61066	10.56225	(5)	19,
H(41)	3.48348	2.28482	9.92147	(5)	19,
H(42)	−2.13553	−0.09965	−0.12032	(5)	10,
H(43)	−2.05844	0.08507	−2.52694	(5)	11,
H(44)	0.08606	0.31982	−3.68258	(5)	12,
H(45)	2.16061	0.37102	−2.38444	(5)	13,
H(46)	2.09919	0.18518	0.02403	(5)	14,
H(47)	0.09037	−1.19969	1.80539	(5)	8,
H(48)	1.43604	−0.85946	3.62806	(5)	5,
H(49)	−0.37738	1.47012	4.61386	(5)	6,
H(50)	2.08649	2.11918	4.12132	(5)	4,
H(51)	2.63357	−0.36023	5.88752	(5)	3,
H(52)	1.08868	2.25402	6.25066	(5)	2,
H(53)	0.45326	−0.47440	7.50946	(5)	1,

TABLE III

^{13}C-N.m.r. chemical shifts (p.p.m.) for **4**–**7**

Compound	*C-1*	*C-2*	*C-4*	*C-3*	*C-5*	*C-6*	*C-7*	*Others*[a]
4[b]	103.9	69.6	72.4	92.0	81.6	60.1	68.2	55.2 (MeO)
5[c,d]	101.9	69.6	72.6	86.3	80.1	60.8	69.0	168.3, 167.7 (2 CO), 56.2 (MeO), and 20.6 (*Me*CO)
6[c]	101.6	72.2	73.3	97.6	78.4	61.8	68.9	168.1 (2 CO), 162.7 (*C*OOMe), 56.4 (MeO), 54.0 (COO*Me*), and 20.6 (2 *Me*CO)
7[c]	101.5	72.5	74.4	95.2	78.5	61.5	68.9	168.4, 167.8 (2 CO), 162.2 (*C*OOMe), 56.3 (MeO), 53.7 (COO*Me*), and 20.5 (2 *Me*CO)

[a] All benzylidene derivatives showed 4 signals (Ph) in the range δ 137.5–125.9, and a signal for Ph*C*H at δ 10.10–100.0. [b] For solution in $(CD_3)_2SO$. [c] For solution in $CDCl_3$ (internal Me_4Si). [d] The assignment was confirmed with 2D-n.m.r. carbon–proton correlation.

(*a*) *With nitromethane.* Column chromatography (1:3 ether–hexane) of the crude product (32-h reaction) gave, first, (1*R*,3*S*,4*S*,6*S*,7*S*,9*R*)-4-hydroxy-3-methoxy-6-nitromethyl-9-phenyl-2,5,8,10-tetra-oxabicyclo[5,4,$O^{1,7}$]undecane (**3**; 0.10 g, 10%), m.p. 185–186°, $[\alpha]_D^{25}$ +77° (*c* 1, acetone); ν_{max}^{KBr} 3424, 1546, 1383, 1144, 1105, 970, and 748 cm^{-1}. N.m.r. data [$(CD_3)_2SO$]: ^1H, δ 7.50–7.35 (m, 5 H, Ph), 7.02 (d, 1 H, *J* 6.4 Hz, exchangeable with D_2O, OH), 5.57 (s, 1 H, PhC*H*), 4.90 (dd, 1 H, *J* 13.4 and 2.3 Hz, CH_2NO_2), 4.75 (pseudo-t, 1 H, $J_{4.OH} + J_{3,4}$ 12.3 Hz, H-4), 4.67 (dd, 1 H, *J* 13.4 and 9.4 Hz, CH_2NO_2), 4.34 (dpseudo-t, 1 H, $J_{6,7} \approx J_{6,CHN} \approx$ 9.3, $J_{6,CH'N}$ 2.3 Hz, H-6), 4.27 (d, 1 H, $J_{3,4}$ 5.9 Hz, H-3), 4.17 (dd, 1 H, $J_{11ax,11eq}$ 10.6, $J_{1,11eq}$ 5.3 Hz, H-11*eq*), 3.91 (dpseudo-t, 1 H, $J_{1,7} + J_{1,11ax}$ 19.0, $J_{1,11eq}$ 5.3 Hz, H-1), 3.68 (pseudo-t, 1 H, $J_{6,7} + J_{1,7}$ 18.7 Hz, H-7), 3.64 (pseudo-t, 1 H, $J_{11ax,11eq} + J_{1,11ax}$ 20.7 Hz, H-11*ax*), and 3.30 (s, 3 H, MeO); ^{13}C, δ 137.2, 128.7, 127.9, 126.0 (C_6H_5), 104.2, 99.6, 98.6 (C-3,4, Ph), 77.8, 77.9 (C-6,7), 77.0 (CH_2NO_2), 68.2 (C-11), 63.4 (C-1), and 55.1 (MeO) (Found: C, 52.50; H, 5.55; N, 3.89. $C_{15}H_{19}NO_8$ calc.: C, 52.77; H, 5.61; N, 4.12%).

Eluted second was methyl 5,7-*O*-benzylidene-3-deoxy-3-nitro-D-*glycero*-α-D-*ido*-heptoseptanoside (**4**; 0.70 g, 68%), m.p. 233–234° (from ether–hexane), $[\alpha]_D^{25}$ +52° (*c* 1, methanol); ν_{max}^{KBr} 3386, 1562, 1381, 1282, 1234, 1188, 1140, 1100, 1060, 978, 921, and 771 cm^{-1}. For ^1H- and ^{13}C-n.m.r. data, see Tables I and III (Found: C, 53.00; H, 5.42; N, 4.30. $C_{15}H_{19}NO_8$ calc.: C, 52.77; H, 5.61; N, 4.12%).

Conventional treatment of **4** (0.43 g, 1.2 mmol) with acetic anhydride–acetic acid–acetyl chloride (1:1:2 mL) gave, after column chromatography (1:1 ether–hexane), the 2,4-diacetate **5** (0.25 g, 49%), m.p. 185–186°, $[\alpha]_D^{25}$+66°(*c* 1, chloroform); ν_{max}^{KBr} 1750, 1565, 1371, 1337, 1310, 1289, 1214, 1136, 1101, 1082, 1068, 1050, 1029, 992, 977, 920, and 885 cm^{-1}. For ^1H- and ^{13}C-n.m.r. data, see Tables I and III) (Found: C, 53.78; H, 5.40; N, 3.18. $C_{19}H_{23}NO_{10}$ calc.: C, 53.64; H, 5.45; N, 3.31%).

(*b*) *With methyl nitroacetate.* Conventional treatment of the crude product (6-h reaction) with acetic anhydride–acetic acid–acetyl chloride (4:4:8 mL) at room temperature (16 h) and crystallisation from ether gave methyl 2,4-di-*O*-acetyl-5,7-*O*-benzylidene-3-deoxy-3-*C*-methoxycarbonyl-3-nitro-D-*glycero*-α-D-*talo*-heptoseptanoside (**6**; 0.49 g, 26%), m.p. >260°, $[\alpha]_D^{25}$ +66° (*c* 1, chloroform), ν_{max}^{KBr} 1783, 1566, 1374, and 1332 cm^{-1}. For ^1H- and ^{13}C-n.m.r. data, see Tables I and III (Found: C, 52.30; H, 5.10; N, 3.15. $C_{21}H_{25}NO_{12}$ calc.: C, 52.17; H, 5.21; N, 2.90%).

Column chromatography (2:1 ether–hexane) of the material in the mother liquor gave 2,4-di-*O*-acetyl-5,7-*O*-benzylidene-3-deoxy-3-*C*-methoxycarbonyl-3-nitro-D-*glycero*-α-D-*ido*-heptoseptanoside (**7**; 0.54 g, 29%), m.p. 190–191°, $[\alpha]_D^{25}$ +53° (*c* 1, chloroform); ν_{max}^{KBr} 1758, 1568, 1368, and 1351 cm^{-1}. For ^1H- and ^{13}C-n.m.r. data, see Tables I and III (Found: C, 52.25; H, 5.18; N, 2.75. $C_{21}H_{25}NO_{12}$ calc.: C, 52.17; H, 5.21; N, 2.90%).

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