The Chemistry of Cellobiose and Lactose. Part 7.[1] Selective Benzoylation of Methyl β-Lactoside †

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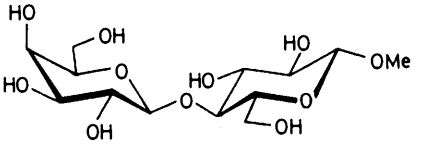
The selective benzoylation of methyl β-lactoside with various proportions of benzoyl chloride in pyridine has been studied. The 3',6'-dibenzoate, the 3',6,6'-tribenzoate, the 2,3',6,6'-tetrabenzoate, and the 2,2',3',4',6,6'-hexabenzoate have each been isolated, in yields of between 21 and 31%. The 2,3',4',6,6'- and 2,2',3',6,6'-pentabenzoates were also encountered, but in much lower yields. From these results it was deduced that the order of reactions of the seven hydroxy-groups in methyl β-lactoside is 6' > 3' > 6 > 2 > 2',4' > 3.

RESEARCH during the last decade has shown that although primary hydroxy-groups are normally the most reactive towards acylating agents, secondary hydroxy-groups within a carbohydrate molecule often show significant differences in reactivity.[2] For example, benzoylation of methyl α-D-glucopyranoside, -galactopyranoside, and -mannopyranoside with 3 mol. equiv. of reagent gave the 2,3,6-triester in each case, and benzoylation of the gluco- and manno-pyranosides with 2 mol. equiv. of reagent gave the 2,6- and the 3,6-dibenzoate, respectively, in high yields.[3,4] From these and other studies the following facts have emerged. (*a*) Acyl chlorides and acyl anhydrides show marked differences in reactivity towards particular hydroxy-groups; the chlorides seem to be more regioselective.[5,6] (*b*) Bulkier acyl chlorides result in greater regioselectivity; benzoyl chloride seems particularly good in this respect. (*c*) Hydroxy-groups, on pyranoid rings, which have a vicinal *cis*-hydroxy- or alkoxyl-group show enhanced reactivity [2,7] (*cf.* the 2-OH of methyl α-D-glucopyranoside and the 3-OH of methyl α-D-mannopyranoside). (*d*) Axial hydroxy-groups are usually less reactive than equatorial groups.

We have been interested for many years in the chemistry of the readily available disaccharides sucrose,[8] trehalose,[9] maltose,[10] cellobiose,[1] and lactose,[1] and have carried out some limited selective acylation and sulphonylation studies on these disaccharides and their derivatives. In particular, we and others have observed that the 6'-hydroxy-group of methyl β-maltoside is more reactive than that at C-6,[11] and that in maltose,[12] methyl β-maltoside,[13] cellobiose,[14] and lactose,[15] the 3-hydroxy-group has a particularly low reactivity towards benzoyl chloride and that the corresponding polybenzoates with this hydroxy-group unsubstituted can be obtained in reasonable yields. This led us to investigate the selective benzoylation of methyl β-lactoside (1) in greater detail in order to establish the order of reactivity of the seven hydroxy-groups towards benzoyl chloride.



(1)

We first attempted to establish whether the two primary hydroxy-groups could be selectively benzoylated; accordingly the lactoside (1) was treated with 2.5 mol. equiv. of benzoyl chloride in pyridine. T.l.c. indicated a surprisingly complex mixture comprising one major component (*A*) and several minor components. Column chromatography afforded the component (*A*) crystalline in 31% yield. Elemental analysis indicated that it was a dibenzoate, and mass spectrometry of the derived pentakistrimethylsilyl ether indicated that both benzoyl groups resided on the non-reducing galactopyranosyl ring [the ion resulting from cleavage of the C(1')–O(4) bond was observed at *m/e* 515.192 5 ($C_{26}H_{35}O_7Si_2$) corresponding to (12) [16]]. An ion at *m/e* 393.155 2 ($C_{19}H_{29}O_5Si_2$) arose from (12) by loss of benzoic acid, and this suggested that one of the benzoates was at C-3'. The ^{1}H n.m.r. spectrum of the dibenzoate was not well resolved; the only recognisable methine resonance was to low field of all others at τ 4.32, and appeared as a double doublet with splittings of 10 and 3.6 Hz, consistent with it being due to H-3'. Its low field position suggests that there must be a benzoyl group at C-3'. The remaining benzoyl group is presumably at C-6'; thus the product was identified as methyl β-lactoside 3',6'-dibenzoate (2).

When the benzoylation of methyl β-lactoside (1) was

† Preliminary communication, R. S. Bhatt, L. Hough, and A. C. Richardson, *Carbohydrate Res.*, 1974, **32**, C4.

[1] Part 6, R. G. Edwards, L. Hough, and A. C. Richardson, *Carbohydrate Res.*, 1977, **55**, 129.

[2] A. H. Haines, *Adv. Carbohydrate Chem. Biochem.*, 1976, **33**, 11.

[3] J. M. Williams and A. C. Richardson, *Tetrahedron*, 1967, **23**, 1369.

[4] A. C. Richardson and J. M. Williams, *Tetrahedron*, 1967, **23**, 1641.

[5] K. Capel, J. Steffkova, and J. Jary, *Coll. Czech. Chem. Comm.*, 1968, **33**, 1750, and earlier papers.

[6] K. W. Buck, A. B. Foster, A. R. Perry, and J. M. Webber, *J. Chem. Soc.*, 1963, 4171.

[7] A. C. Richardson, *Carbohydrate Res.*, 1967, **4**, 415; S. E. Creasey and R. D. Guthrie, *ibid.*, 1972, **22**, 487; J. M. Macleod, L. R. Schroeder, and P. A. Sieb, *ibid.*, 1973, **30**, 337.

[8] L. Hough, S. P. Phadnis, and E. Tarelli, *Carbohydrate Res.*, 1975, **44**, C12.

[9] C. K. Lee, G. G. Birch, and A. C. Richardson, *Carbohydrate Res.*, 1976, **49**, 153, and earlier papers in the series.

[10] P. L. Durette, L. Hough, and A. C. Richardson, *J.C.S. Perkin I*, 1974, 97, and earlier papers in the series.

[11] R. T. Sleeter and H. B. Sinclair, *J. Org. Chem.*, 1970, **35**, 3804.

[12] W. E. Dick, B. G. Baker, and R. G. Hodge, *Carbohydrate Res.*, 1968, **6**, 52.

[13] Unpublished results.

[14] I. M. Vasquez, I. M. E. Thiel, and J. O. Deferrari, *Carbohydrate Res.*, 1976, **47**, 241.

[15] I. M. Vasquez, I. M. E. Thiel, and J. O. Deferrari, *Carbohydrate Res.*, 1973, **26**, 351.

[16] R. S. Bhatt, L. Hough, and A. C. Richardson, *Carbohydrate Res.*, 1976, **49**, 103.

repeated with 5.2 mol. equiv. of benzoyl chloride, a complex mixture was obtained which contained four major components [(*B*)—(*E*) in order of decreasing t.l.c. mobility]. Chromatography afforded (*B*), (*D*), and (*E*) crystalline in yields of **9**, **21**, and **31**%, respectively. Component (*C*) was obtained in **9**% yield as a syrup contaminated with a little (*B*).

Elemental analysis indicated that (*B*) was a pentabenzoate, which was confirmed by mass spectrometry and n.m.r. spectroscopy. The mass spectrum of the derived bistrimethylsilyl ether showed ions at *m/e* **547** and **457** assigned to (**13**) and (**19**), respectively. This showed that of the five benzoate groups, two were located in the reducing ring and the remaining three in the non-reducing galactopyranosyl moiety. In addition, the ion at *m/e* **547** fragmented with the loss of the elements of benzoic acid to give an intense peak at *m/e* **425**, which strongly suggested that there was a benzoyl group at C-**3**′. The 220 MHz ^{1}H n.m.r. spectrum (Table) indicated that benzoate groups were located at C-**2**, -**2**′, and -**3**′: resonances due to the protons at these positions were at relatively low field, whereas those due to H-**3** and H-**4**′ were at much higher field, suggesting that the hydroxy-groups at these positions were not substituted. Hence, on the assumption that both primary hydroxy-groups were substituted, (*B*) was identified as methyl β-lactoside **2**,**2**′,**3**′,**6**,**6**′-pentabenzoate (**6**).

Further support for the structure of (*B*) was provided by its behaviour with the sulphuryl chloride. It is well established that the replacement of a hydroxy-group by chlorine upon treatment with sulphuryl chloride occurs by S_N2 displacement of the first formed chlorosulphate ester ($ROSO_2Cl$) with chloride;[17] consequently the reaction is subject to the various polar and steric restraints which have been outlined by Richardson for nucleophilic displacement reactions of sulphonate esters.[18] Hence in the case of methyl β-lactoside (**1**) chlorination at C-**3**, -**4**′, -**6**, and -**6**′ should occur with ease, whereas chlorination at C-**3**′ should occur only after displacement at C-**4**′, which removes the impeding **4**′-axial group. This pattern of chlorination has been recently confirmed by us.[16] With this in mind (*B*) was treated with sulphuryl chloride in pyridine to give a dichloride in **70**% yield. Since both hydroxy-groups of *B* had undergone displacement by chlorine, they must be at C-**3** and C-**4**′, in accord with the structure (**6**). The 220 MHz ^{1}H n.m.r. spectrum of the dichloride was largely first-order (Table), and the observed chemical shifts and coupling constants were in accord with the structure (**8**).

As mentioned above, component (*C*) was not obtained pure, but on reaction with sulphuryl chloride as above, it gave a crystalline monochloro-pentabenzoyl derivative. The mass spectrum of its trimethylsilyl ether showed ions at *m/e* **547** (**14**) and **403** (1 Cl) (**20**), indicating that chlorine had been introduced into the reducing ring and that the hydroxy-group in the non-reducing ring was inert towards sulphuryl chloride, suggesting that the remaining OH was at either C-**2**′ or C-**3**′. Since the chlorine in the reducing ring must be at C-**3**, (*C*) must be either the **2**′,**3**- o the **3**,**3**′-diol. However the ion at *m/e* **547** (**14**) fragmented further by the loss of the elements of benzoic acid to give an intense peak at *m/e* **425**, which indicated that a benzoyl group

^{1}H N.m.r. parameters at 220 MHz; first-order chemical shifts (τ values) and coupling constants (Hz)

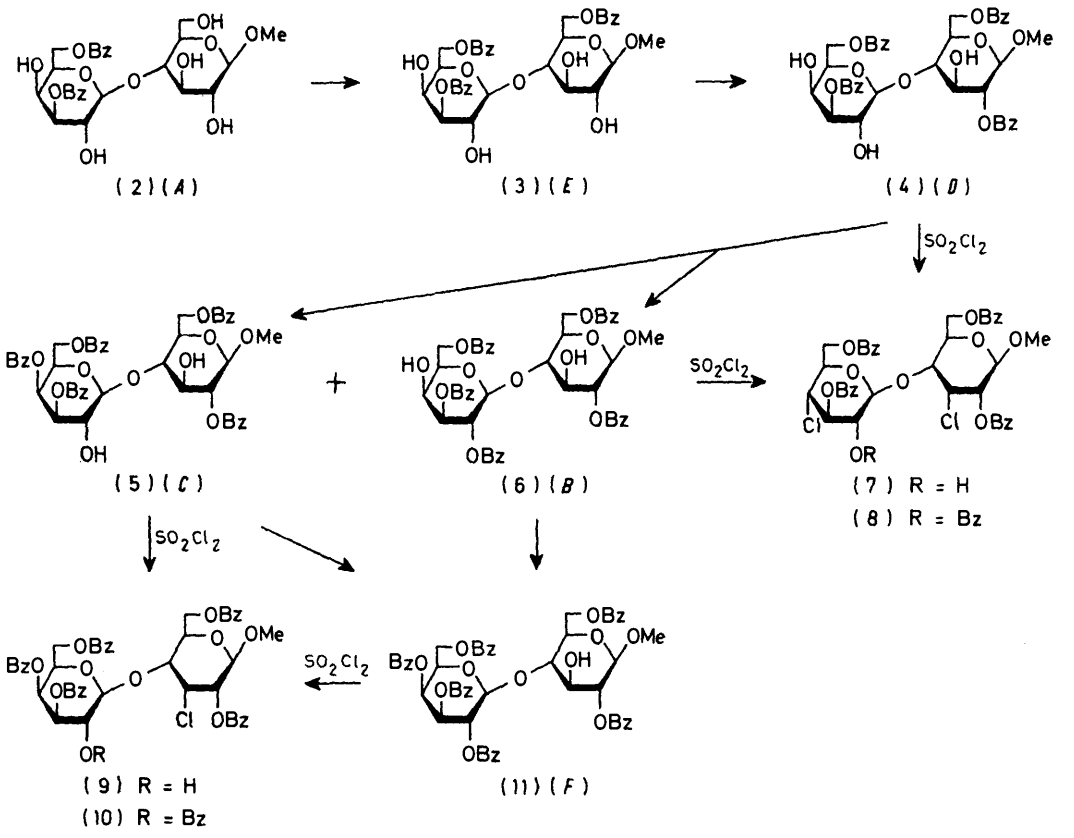
	(3)	(6)	(7)	(8)	(9)	(9) [a]	(10)	(11)
Solvent	$(CD_3)_2SO$–D_2O	$CDCl_3$	$(CD_3)_2CO$	C_6D_6	C_6D_6	C_6D_6	C_6D_6	$CDCl_3$
H-1	5.81d	5.53d	4.93d	5.64d		5.43d	5.43d	5.48d
H-2	6.13t	4.80t	4.48m	4.44dd	4.64dd	4.39dd	4.44d	4.75t
H-3	6.87t	*ca.* 5.81t		4.72t	4.72t	4.61t	4.67t	5.88t
H-4	6.49t	6.15t		6.07dd			5.96dd	6.07t
H-5	6.20m	6.32m	5.62ddd	5.88m			5.88m	6.26m
H-6a			5.16dd	5.16dd		5.12m	5.47m	
H-6b			5.50dd	5.82dd				
H-1′	5.32d	5.06d	4.89d	5.06d	4.94d	4.99d	5.05d	4.96d
H-2′		4.11t	6.21t	4.36t	6.15m	3.99t	3.66dd	4.09dd
H-3′	5.06dd	4.66dd	4.76t	4.20t	4.47dd	4.74dd	4.34dd	4.42dd
H-4′	5.90m	5.61d	5.70t	6.44t	3.99d	3.99d	3.93d	4.03d
H-5′	6.35t	5.98t	5.80m	6.58m	6.15m	6.56t	6.24t	
H-6′a			5.05dd	5.48dd			5.56dd	
H-6′b			5.41dd	5.57dd			5.65dd	
$J_{1,2}$	8	8	8	7.5	7	7.5	7.5	7.5
$J_{2,3}$	8	10		3.5	3.5	3.5	3	9
$J_{3,4}$	8	10		3	3	3.5	3	9
$J_{4,5}$		10	10	9			10	9
$J_{5,6a}$			2	2				
$J_{5,6b}$			5	6				
$J_{6a,6b}$			12	12				
$J_{1',2'}$	8	8	8	7.5	75.	7.5	7.5	7.5
$J_{2',3'}$	10	10.2	9	10	10	10.5	10	10
$J_{3',4'}$	10	3	9	10	3.5	3.6	3.5	3
$J_{4',5'}$	*ca.* 1	*ca.* 1	9	9	*ca.* 1	*ca.* 1	*ca.* 1	*ca.* 1
$J_{5',6'a}$	8		2	2			4.5	
$J_{5',6'b}$	8		5	5			7	
$J_{6'a,6'b}$			12	12			12	

[a] After addition of trichloroacetyl isocyanate for *in situ* formation of the 2-carbamate.

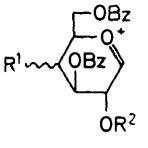
[17] H. J. Jennings and J. K. N. Jones, *Canad. J. Chem.*, 1965, **43**, 2372.

[18] A. C. Richardson, *Carbohydrate Res.*, 1969, **10**, 395.

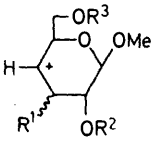
was present at C-3; hence (*C*) must be the 2,3′,4′,6,6′-pentabenzoate (5) and the derived chloride must have structure (9). The ^{1}H n.m.r. spectrum of the 3-chloride (9) was in accord with this (Table); particularly noteworthy was a 2.16 p.p.m. downfield shift of the H-2′ resonance on addition of trichloroacetyl isocyanate to the solution, giving, *in situ*, the 2′-carbamate (RO·CO·NH·CO·CCl_3).[19]



SCHEME



(12) R^1 = $OSiMe_3$, R^2 = $SiMe_3$ (*m/e* 515)
(13) R^1 = $OSiMe_3$, R^2 = Bz (*m/e* 547)
(14) R^1 = OBz, R^2 = $SiMe_3$ (*m/e* 547)
(15) R^1 = ^{35}Cl, R^2 = Bz (*m/e* 493)
(16) R^1 = ^{35}Cl, R^2 = $SiMe_3$ (*m/e* 461)



(17) R^1 = $OSiMe_3$, R^2 = R^3 = $SiMe_3$ (*m/e* 393)
(18) R^1 = $OSiMe_3$, R^2 = $SiMe_3$, R^3 = Bz (*m/e* 425)
(19) R^1 = $OSiMe_3$, R^2 = R^3 = Bz (*m/e* 457)
(20) R^1 = ^{35}Cl, R^2 = R^3 = Bz (*m/e* 403)

Component (*D*) was a tetrabenzoate and the mass spectrum of its tristrimethylsilyl ether showed ions at *m/e* 515 (12) and 457 (19) which indicated that each of the pyranosyl rings had two benzoyl groups attached. The ion at *m/e* 515 lost benzoic acid to give a very intense peak at *m/e* 425, which indicated the presence of a 3′-benzoyl group. The tetrabenzoate (*D*) reacted with sulphuryl chloride to give a crystalline dichloride. The mass spectrum of the trimethylsilyl ether of the dichloride showed ions at *m/e* 461 (1 Cl) (16) and 403 (1 Cl) (20), which indicated that each ring had a chlorine atom attached. For reasons outlined above these must be at C-3 and C-4′, on the assumption that both primary positions are substituted. Since the mass spectrum of (*D*) had already shown the presence of a 3′-*O*-benzoyl group, the tetrabenzoate (*D*) must be methyl β-lactoside 2,3′,6,6′-tetrabenzoate (4), and the derived dichloride must have structure (7). N.m.r. data (Table) added further weight to these assignments.

Component (*E*) was a tribenzoate. The mass spectrum of its tetrakistrimethylsilyl ether showed ions at *m/e* 515 (12) and 425 (18), indicative of two benzoyl groups in the non-reducing ring and one in the other. The ready loss of the elements of benzoic acid from the ion at

[19] V. W. Goodlett, *Analyt. Chem.*, 1965, **37**, 431.

m/e 515 to give an intense ion at *m/e* 393 suggested that there was a benzoyl group at C-3′. The ^{1}H n.m.r. spectrum in [$^2H_6$]dimethyl sulphoxide (Table) showed four hydroxy-resonances at τ 4.37, 4.51, 4.61, and 5.07 as doublets indicating that the four hydroxy-groups were secondary. The H-3′ resonance at τ 5.06 confirmed the presence of a benzoyl group at C-3′. This indicated that (*E*) was the 3′,6,6′-tribenzoate (3).

Finally when methyl β-lactoside (1) was treated with 6.8 mol. equiv. of benzoyl chloride, a mixture was obtained which contained a new benzoate (*F*), the major component, with lesser amounts of the two pentabenzoates (*B*) and (*C*). The major product (*F*) was isolated in 33% yield by chromatography. The mass spectrum of the trimethylsilyl ether of (*F*) showed ions *m/e* 579 and 457 (19), indicating that the non-reducing ring was fully benzoylated and that the lone hydroxy-group was on the reducing ring. By analogy with the former products, (*F*) must be the 2,2′,3′,4′,6,6′-hexabenzoate (11). This was confirmed by the ^{1}H n.m.r. spectrum (Table) in which the H-3 triplet at τ 5.94 was positively identified by spin decoupling. The high-field position of this resonance was consistent with the presence of a 3-hydroxy-group. In addition the hexabenzoate also reacted smoothly with sulphuryl chloride to give the 3-chloride (10) in 70% yield.

Our results demonstrate that methyl β-lactoside shows a marked selectivity in its reactions with benzoyl chloride, and suggests that other related disaccharides might display a similar selectivity. Although several other, unidentified benzoylated derivatives of (1) were detected in the reaction mixtures in addition to compounds (*A*)—(*F*), they were all very minor products. Hence it appears that the major course of the reaction is as shown in the Scheme, and it is possible to say that the order of benzoylation of the seven hydroxy-groups is 6′ > 3′ > 6 > 2 > 2′,4′ > 3.* The low reactivity of the 3-hydroxy-group was not particularly surprising since this had also been shown in β-maltose,[12] methyl β-maltoside,[13] β-lactose,[14] and β-cellobiose,[15] and seems to be a general feature of 1,4-linked disaccharides. The hydroxy-groups adjacent or near to the interglycosidic linkage (the 2′-, 3-, and 6-hydroxy-groups) seem to display unexpectedly low reactivity; we have commented on this fact previously.[10]

Models of the conformation of methyl β-lactoside (1) indicate that the inner hydroxy-groups in this region are much more hindered than those at the periphery of the molecule, that is HO-2, HO-3′, HO-4′, and HO-6′. The high reactivity of HO-3′ is probably due to the *cis*-orientation of HO-4′, which has previously been observed to have an activating effect on adjacent hydroxy-groups.[2,7]

EXPERIMENTAL

For general notes see ref. 20. Silica gel G (Merck 7734) was used for column chromatography.

* It has been assumed that the 6′-hydroxy-group is benzoylated prior to the secondary 3′-hydroxy-group.

Selective Benzoylation of Methyl β-Maltoside.—(a) *With 2.5 mol. equiv.* A stirred solution of methyl β-lactoside (1 g, 2.81 mmol) in pyridine (12 cm^3) was cooled to −20 °C and treated dropwise with benzoyl chloride (0.8 cm^3, 6.94 mmol) of benzoyl chloride. When the addition was complete, the reaction mixture was allowed to rise to room temperature and the mixture then stored at this temperature for 20 h. T.l.c. (chloroform–methanol, 5 : 1) indicated a relatively complex mixture with one major component. The mixture was then processed in the usual way by extraction with chloroform and the resulting syrup fractionated by dry-packed column chromatography [21] [chloroform–methanol (15 : 1) as solvent]. Early fractions contained mixtures of minor components which were discarded. These were followed by fractions of the major component (*A*) which were evaporated to give a crystalline solid. Recrystallisation from chloroform–ethanol–light petroleum gave *methyl* 4-O-(3,6-*di*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*glucopyranoside* (2) (0.49 g, 31%), m.p. 188—191°, $[\alpha]_D$ +26.8° (*c* 1 in methanol) (Found: C, 57.2; H, 5.9. $C_{27}H_{32}O_{13}$ requires C, 57.45; H, 5.7%); *m/e* (of pertrimethylsilyl ether) 713 (0.3%), 543 (0.2), 515 (15.8), 393 (5.3), 361 (2.7), 303 (13.3), 271 (33.5), 217 (56.2), 204 (100), 122 (0.4), 105 (30.7), and 73 (29.8) [accurate mass measurements: 515.192 5 ($C_{26}H_{35}O_7Si_2$), 393.155 2 ($C_{19}H_{29}O_5Si_2$), 361.168 3 ($C_{15}H_{33}O_4Si_3$), 303.105 0 ($C_{16}H_{19}O_4Si$), 303.144 8 ($C_{13}H_{27}O_4Si_2$), and 271.118 7 ($C_{12}H_{23}O_3Si_2$)].

(b) *With 5.2 mol. equiv.* The above reaction was repeated with the lactoside (1) (2 g, 5.62 mmol) and benzoyl chloride (3.4 cm^3, 29.27 mmol). T.l.c. (chloroform–methanol, 20 : 1) indicated that a complex mixture had been formed, comprising four main components (*B*)—(*E*) and several minor ones. Dry-packed column chromatography [21] with ethyl acetate–light petroleum (1 : 2) gave the four major products.

The first eluted component (*B*) afforded a crystalline solid which was recrystallised from chloroform–light petroleum to give *methyl* 2,6-*di*-O-*benzoyl*-4-O-(2,3,6-*tri*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*glucopyranoside* (6) (0.43 g, 9%), m.p. 253—255°, $[\alpha]_D$ +56° (*c* 1 in chloroform) (Found: C, 65.5; H, 5.1. $C_{48}H_{44}O_{16}$ requires C, 65.75; H, 5.0%); *m/e* (for pertrimethylsilyl ether) 777 (0.05%), 607 (0.05), 547 (3.0), 457 (0.74), 425 (1.5), 367 (0.15), 335 (0.2), 303 (2.7), 249 (0.84), 245 (0.23), 122 (3.0), 105 (100), and 73 (2.4).

The second component (*C*) to be eluted was methyl 2,6-di-*O*-benzoyl-4-*O*-(3,4,6-tri-*O*-benzoyl-β-D-galactopyranosyl)-β-D-glucopyranoside (5), obtained as a syrup (0.45 g, 9%) contaminated with the isomeric pentabenzoate (6). However, on reaction with sulphuryl chloride it gave a pure chloro-derivative (see below).

The third component (*D*), eluted in later fractions, afforded a crystalline solid. Recrystallisation from chloroform–light petroleum afforded *methyl* 2,6-*di*-O-*benzoyl*-4-O-(3,6-*di*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*glucopyranoside* (4) (0.92 g, 21%), m.p. 118—120°, $[\alpha]_D$ +31° (*c* 1 in chloroform) (Found: C, 63.6; H, 5.3. $C_{41}H_{40}O_{15}$ requires C, 63.7; H, 5.2%); *m/e* (for pertrimethylsilyl ether) 777 (0.14%), 607 (0.14), 575 (0.14), 515 (0.5), 457 (0.7), 425 (0.22), 393 (0.4), 367 (0.2), 335 (0.23), 303 (0.7), 271 (1.0), 245 (0.7), 217 (5.0), 204 (0.32), 122 (5.6), 105 (100), and 73 (1.4).

[20] R. S. Bhatt, L. Hough, and A. C. Richardson, *Carbohydrate Res.*, 1975, **43**, 57.
[21] L. Hough, A. K. Palmer, and A. C. Richardson, *J.C.S. Perkin I*, 1972, 2513.

Chloroform–ethyl acetate (2 : 1) then eluted the fourth component (*E*). The crystalline solid so obtained was recrystallised from chloroform–light petroleum to give *methyl* 6-O-*benzoyl*-4-O-(3,6-*di*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*glucopyranoside* (3) (1.1 g, 29%), m.p. 238—240°, $[\alpha]_D$ +44° (*c* 1 in methanol) (Found: C, 60.8; H, 5.6. $C_{34}H_{36}O_{14}$ requires C, 61.1; H, 5.4%); *m/e* 543 (0.3%), 515 (7.5), 425 (3.8), 393 (1.7), 335 (0.3), 303 (3.3), 271 (5.3), 217 (11.9), 213 (9.5), 204 (42.1), 122 (1.7), 105 (100), and 73 (56.2).

(c) *With* 6.8 *mol. equiv.* The above reaction was repeated with the lactoside (2 g, 5.62 mmol) and benzoyl chloride (4.4 cm³, 38.1 mmol. The crude product was a mixture of a major product (*F*) [the second most mobile in the t.l.c. system used (chloroform–methanol, 15 : 1)] and several slower-moving minor products most of which are described above, together with a faster-moving component assumed to be the heptabenzoate. Chromatography on a dry-packed column of silica gel with dichloromethane–ethyl acetate (20 : 1) as solvent gave the component (*F*) as a crystalline solid. Recrystallisation from propan-2-ol gave *methyl* 2,6-*di*-O-*benzoyl*-4-O-(2,3,4,6-*tetra*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*glucopyranoside* (11) (1.8 g, 33%), m.p. 119—121°, $[\alpha]_D$ +96° (*c* 1 in chloroform) (Found: C, 67.3; H, 5.0. $C_{55}H_{48}O_{17}$ requires C, 67.35; H, 4.9%); *m/e* (of trimethylsilyl ether) 841 (0.2%), 809 (0.4), 607 (0.2), 579 (15), 457 (3), 425 (0.5), 367 (0.5), 335 (1.5), 303 (0.8), 245 (0.8), 122 (23.7), 105 (100), and 73 (6.7).

Reactions of the Benzoates with Sulphuryl Chloride.—(a) The 2,2′,3′,6,6′-pentabenzoate (6) (1 g, 1.14 mmol) was dissolved in pyridine (6 cm³) and cooled to between −20 and −30 °C. Sulphuryl chloride (0.4 cm³, 4.95 mmol) was then added dropwise and the mixture was allowed to attain room temperature, then stored for a further 20 h. The mixture was then poured into ice–water, and the product extracted with chloroform. The extract was washed successively with M-sulphuric acid, saturated sodium hydrogen carbonate solution, and water, dried ($MgSO_4$), and evaporated to leave a syrup. A solution of the syrup in the minimum of chloroform was then applied to a short dry-packed column of silica gel and decolourising charcoal (1 : 1 v/v), which was then eluted with chloroform–ethyl acetate (15 : 1). The crystalline solid obtained was recrystallised thrice from chloroform–light petroleum to give *methyl* 2,6-*di*-O-*benzoyl*-3-*chloro*-3-*deoxy*-4-O-(2,3,6-*tri*-O-*benzoyl*-4-*chloro*-4-*deoxy*-β-D-*glucopyranosyl*)-β-D-*allopyranoside* (8) (0.72 g, 70%), m.p. 136—139°, $[\alpha]_D$ +39° (*c* 1 in chloroform) (Found: C, 63.2; H, 4.8; Cl, 7.6. $C_{48}H_{42}Cl_2O_{14}$ requires C, 63.1; H, 4.6; Cl, 7.8%); *m/e* 757 (0.12%), 755 (0.28), 555 (0.05), 553 (0.08), 495 (0.94), 493 (2.66), 405 (0.21), 403 (0.59), 373 (0.53), 371 (1.50), 367 (0.12), 335 (0.6), 283 (0.07), 281 (0.14), 251 (0.08), 249 (0.17), 122 (7.5), 105 (100), and 73 (19.9).

(b) The crude 2,3′,4′,6,6′-pentabenzoate (5) (0.5 g) was treated with sulphuryl chloride as above. The product was shown by t.l.c. (chloroform–ethyl acetate, 15 : 1) to be a mixture of two components, in which the minor product was chromatographically coincident with the dichloride (8). Fractionation on a dry-packed column of silica gel with dichloromethane–ethyl acetate (20 : 1) as eluant gave the faster moving component crystalline, which was indistinguishable from the 3,4′-dichloride (8) (m.p. and mixed m.p. 136—139°). Later fractions afforded the major component as a crystalline solid. Recrystallization from chloroform–light petroleum gave *methyl* 2,6-*di*-O-*benzoyl*-3-*chloro*-3-*deoxy*-4-O-(3,4,6-*tri*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*allopyranoside* (9) (0.28 g, 54%), m.p. 107—109.5°, $[\alpha]_D$ +11.3° (*c* 1 in chloroform) (Found: C, 64.3; H, 4.9; Cl, 3.8. $C_{48}H_{43}ClO_{15}$ requires C, 64.4; H, 4.8; Cl, 4.0%); *m/e* (trimethylsilyl ether) 809 (0.1%), 555 (0.1), 553 (0.23), 547 (2.1), 523 (0.07), 521 (0.18), 425 (0.33), 405 (0.33), 403 (1.05), 371 (0.06), 367 (0.1), 303 (2.7), 283 (0.07), 281 (0.2), 251 (1.24), 249 (4.73), 245 (0.4), 122 (6.7), 105 (100), and 73 (4.73).

(c) The 2,3′,6,6′-tetrabenzoate (4) (1 g, 1.3 mmol) was treated with sulphuryl chloride (0.6 cm³, 7.4 mmol) as above to give a product containing a single major component, isolated by dry-packed [21] column chromatography with ethyl acetate–light petroleum as eluant. The resulting crystalline solid was recrystallised from ethyl acetate–light petroleum to give *methyl* 2,6-*di*-O-*benzoyl*-3-*chloro*-3-*deoxy*-4-O-(3,6-*di*-O-*benzoyl*-4-*chloro*-4-*deoxy*-β-D-*glucopyranosyl*)-β-D-*allopyranoside* (7) (0.63 g, 62%), m.p. 195—196°, $[\alpha]_D$ −3° (*c* 1 in chloroform) (Found: C, 60.9; H, 4.7; Cl, 8.9. $C_{41}H_{38}Cl_2O_{13}$ requires C, 60.8; H, 4.7; Cl, 8.8%); *m/e* (of trimethylsilyl ether) 523 (0.06%), 521 (0.1), 463 (0.1), 461 (0.3), 405 (0.2), 403 (0.6), 373 (0.06), 371 (0.09), 367 (0.07), 341 (0.4), 339 (1.1), 303 (0.4), 283 (0.06), 281 (0.08), 251 (0.06), 249 (0.1), 245 (0.2), 219 (0.4), 217 (1.1), 122 (1.2), 105 (100), and 73 (3.4) [accurate mass measurements: 461.118 2 ($C_{23}H_{26}O_6{}^{35}ClSi$), 397.147 9 ($C_{22}H_{25}O_5Si$), 339.082 6 ($C_{16}H_{20}O_4{}^{35}Cl$), 310.079 6 ($C_{15}H_{19}O_3{}^{35}ClSi$), 303.104 7 ($C_{16}H_{19}O_4Si$)].

(d) The 2,2′,3′,4′,6,6′-hexabenzoate (11) (3 g, 3.06 mmol) was treated as above with sulphuryl chloride (1 cm³, 12.37 mmol). On pouring the mixture into ice–water, a solid was precipitated which was collected, dissolved in the minimum of chloroform, and passed through a short dry-packed column of silica gel and decolourising charcoal (1 : 1 v/v) and eluted with chloroform–ethyl acetate (10 : 1). The eluate gave a syrup which slowly crystallised. Three recrystallisations from chloroform–light petroleum gave *methyl* 2,6-*di*-O-*benzoyl*-3-*chloro*-3-*deoxy*-4-O-(2,3,4,6-*tetra*-O-*benzoyl*-β-D-*galactopyranosyl*)-β-D-*allopyranoside* (10) (2.3 g, 75%), m.p. 104—106°, $[\alpha]_D$ +62° (*c* 1 in chloroform) (Found: C, 66.3; H, 4.9; Cl, 3.5. $C_{55}H_{47}ClO_{16}$ requires C, 66.1; H, 4.7; Cl, 3.6%); *m/e* 579 (7.9%), 555 (0.1), 553 (0.2), 457 (0.3), 405 (0.4), 403 (1.2), 373 (0.1), 371 (0.2), 367 (0.3), 335 (2), 283 (0.2), 281 (0.5), 251 (0.1), 249 (0.2), 245 (0.4), 122 (17.8), and 105 (100).

One of us (R. S. B.) thanks Queen Elizabeth College for a postgraduate scholarship. We are indebted to The Physico-chemical Measurements Unit (Harwell) for the 220 MHz ^1H n.m.r. spectra and some mass spectral determinations.

[7/399 *Received*, 7*th March*, 1977]