P.M.R. SPECTROSCOPY OF DIMETHYL ETHERS OF D-GALACTOPYRANOSE AND ITS DERIVATIVES

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ABSTRACT

P.m.r. parameters (determined at 100 MHz for solutions in deuterium oxide) are presented for di-*O*-methyl derivatives of D-galactopyranose (ten), methyl D-galactopyranoside (ten), and galactitol (five). The effects, on the methoxyl and anomeric-proton chemical-shifts, of anomeric change, methylation of neighboring hydroxyl groups, and change in configuration of adjacent carbon atoms bearing hydroxyl or methoxyl groups (other than at C-1) are discussed.

INTRODUCTION

In a recent paper[1], we described the p.m.r. spectroscopy of monomethyl ethers of D-galactopyranose and its derivatives in solution in deuterium oxide, with particular reference to methoxyl proton chemical-shifts. The influence of adjacent, equatorially and axially attached hydroxyl or methoxyl groups on the chemical shifts of methoxyl protons was observed. Our investigations into the p.m.r. spectroscopy of methyl ethers of D-galactopyranose and its derivatives have now been extended to include the dimethyl ethers of D-galactopyranose and its derivatives. The trimethyl ethers of D-galactopyranose and its derivatives will be discussed in a subsequent communication.

RESULTS AND DISCUSSION

Table I gives the p.m.r. parameters for the following dimethyl ethers of D-galactopyranose and its derivatives: 2,3-di-*O*-methyl-α- and β-D-galactopyranose (**1** and **2**), 2,4-di-*O*-methyl-α- and β-D-galactopyranose (**3** and **4**), 2,6-di-*O*-methyl-α- and β-D-galactopyranose (**5** and **6**), 3,4-di-*O*-methyl-α- and β-D-galactopyranose (**7** and **8**), and 4,6-di-*O*-methyl-α- and β-D-galactopyranose (**9** and **10**); methyl 2,3-di-*O*-methyl-α- and β-D-galactopyranoside (**11** and **12**), methyl 2,4-di-*O*-methyl-α- and

TABLE I

P.M.R. PARAMETERS[a] FOR DIMETHYL ETHERS OF D-GALACTOPYRANOSE AND ITS DERIVATIVES

Compound		*Position(s) of O-methyl substitution*	*H-1*		$J_{1,2}$[b]		*1-OMe*		*2-OMe*		*3-OMe*		*4-OMe*		*6-OMe*	
α	β		α	β	α	β	α	β	α	β	α	β	α	β	α	β
1	**2**	2,3	4.51	5.38	2.3	7.1			6.56[c]	6.43	6.59[c]	6.57[c]				
3	**4**	2,4	4.575	5.455	3.6	7.7			6.55	6.445			6.500	6.495		
5	**6**	2,6	4.54	5.41'	3.6	8.0			6.56	6.43					6.64	6.63
7	**8**	3,4	4.78	5.45	3.7	7.6					6.485	6.485	6.485	6.485		
9[d]	**10**	4,6	4.79	5.48	3.6	7.5							6.505	6.49	6.615	6.60
11	**12**[e]	1,2,3	4.92	5.64	~3	7.0	6.62	6.43	6.55	6.465	6.59	6.58				
13[f]	**14**	1,2,4	4.99	5.705	3.6	7.9	6.615	6.45	6.56	6.45			6.50	6.495		
15	**16**	1,2,6	4.96	5.68	3.6	7.8	6.62[g]	6.445[h]	6.56	6.455[h]					6.61[g]	6.61
17	**18**	1,3,4	5.20	5.72	3.8	7.7	6.61	6.45			6.50	6.49	6.50	6.49		
19	**20**[d]	1,4,6	5.20	5.73	3.5	7.6	6.60[i]	6.45					6.49	6.49	6.585[i]	6.58
	21	2,3							6.52		6.53					
	22	2,4							6.495				6.525			
	23	2,6							6.50						6.605	
	24	3,4									6.53		6.53			
	25	4,6											6.53		6.59	

[a]Determined at 100 MHz for solutions in deuterium oxide at 32°. Chemical shifts are relative to internal sodium 4,4-dimethyl-4-silapentanesulfonate (τ' scale). [b]Observed spacings (Hz) of the doublets. [c]These assignments may have to be interchanged. [d]Compare with ref. 2. [e]Compare with ref. 3. [f]Compare with ref. 4. [g,h,i]These assignments may have to be reversed.

TABLE II

P.M.R. PARAMETERS[a] FOR INTERMEDIATES USED IN THE SYNTHESIS OF DIMETHYL ETHERS OF D-GALACTOPYRANOSE AND ITS DERIVATIVES

Compound	*Galactose C–H protons*	J	*Methoxyl protons*[b]	*Substituent protons*[c]
26[d]	H-1, 5.495; other, 5.6–6.5	$J_{1,2}$ ~2	C-1, 6.595	C_6H_5CH, 2.4–2.8(m); C_6H_5CH, 4.495; (OH, 6.86)
27	H-1, 5.21; other, 5.7–6.8	$J_{1,2}$ 3.5	C-1, 6.61; C-2, 6.52 C-6, 6.61	CMe_2: 8.48, 8.67
28	H-1, 5.82; other, 5.8–6.9	$J_{1,2}$ 7.8	6.42, 6.44 C-6, 6.57	CMe_2: 8.46, 8.64
29	H-1, 5.69; H-2, 4.65; H-3, 6.66; H-4,5, 6.1–6.5; H-6, 5.17 H-6′, 5.42	$J_{1,2}$ 8.0, $J_{2,3}$ 10.2, $J_{3,4}$ 2.8, $J_{5,6}$ 7.0, $J_{5,6'}$ 4.8, $J_{6,6'}$ −12.0	6.37, 6.50, 6.50	
30	H-1, 5.82; other 5.1–6.7	$J_{1,2}$ 7.0	C-1, 6.47; C-4, 6.54; C-6, 6.70	$C_6H_5CH_2$, 2.5–2.9(m); $C_6H_5CH_AH_BO$(C-2): H_A, 5.14(d); H_B, 5.38(d); $J_{A,B}$ 11.0; $C_6H_5CH_2O$(C-3), 5.35

[a]Determined at 60 MHz for solutions in chloroform-*d* at 37°. Chemical shifts are relative to internal tetramethylsilane (τ scale). J = observed spacings (Hz). [b]3-Proton singlets. [c]Singlets, unless otherwise stated; d = doublet, m = multiplet. [d]Compare with ref. 9.

and β-D-galactopyranoside (**13** and **14**), methyl 2,6-di-*O*-methyl-α- and β-D-galactopyranoside (**15** and **16**), methyl 3,4-di-*O*-methyl-α- and β-D-galactopyranoside (**17** and **18**), and methyl 4,6-di-*O*-methyl-α- and β-D-galactopyranoside (**19** and **20**); and 2,3-di-*O*-methyl-D-galactitol (**21**), 2,4-di-*O*-methyl-D-galactitol (**22**), 2,6-di-*O*-methyl-D-galactitol (**23**), 3,4-di-*O*-methylgalactitol (**24**), and 4,6-di-*O*-methyl-D-galactitol (**25**).

The effects of introducing an additional methoxyl group into the monomethyl ethers of D-galactopyranose and its derivatives[1] were investigated by comparing the results in Table I with those found for the monomethyl ethers.

P.m.r. spectra of dimethyl ethers of D-*galactopyranose.* — (*a*) *Assignment of methoxyl signals.* Methoxyl signals (see Table I) for the anomers of the dimethyl ethers investigated, except 2,3-di-*O*-methyl-D-galactose [(**1**+**2**), obtained as an equilibrated syrup], were distinguished as before[1], the change in the proportions of the anomers being noted as their deuterium oxide solutions equilibrated. The spectra of compounds **1**–**10** are more complex than those of the monomethyl ethers, due to the presence of an additional methoxyl group. Methoxyl signals in the spectra of **3**–**6**, **9**, and **10** were identified by using the chemical shifts obtained for the methoxyl groups of the appropriate monomethyl ethers[1], with the assumption that methylation of hydroxyl groups two or more carbon atoms removed from the carbon atom bearing the methoxyl group under consideration would have a negligible effect on its chemical shifts. Thus, the 2-methoxyl groups in **3**, **4**, **5**, and **6**, the 4-methoxyl groups in **3**, **4**, **9**, and **10**, and the 6-methoxyl groups in **5**, **6**, **9**, and **10** were assumed to have the same chemical shifts as they have in 2-*O*-methyl-D-galactose, 4-*O*-methyl-D-galactose, and 6-*O*-methyl-D-galactose, respectively. The chemical shifts of the 2- and 6-methoxyl groups in the spectrum of 2,3,4,6-tetra-*O*-methyl-α- and β-D-galactopyranose[5] were used for obtaining the 2-methoxyl signal in the spectrum of **2**, and for confirming the assignments made for the 6-methoxyl signals in the spectra of **9** and **10**. It is not yet possible to identify the remaining three, upfield signals in the spectrum of 2,3-di-*O*-methyl-D-galactose (**1**+**2**) by inspection alone, as it is not yet known which one of the three signals is produced by the 3-methoxyl group in the β anomer (**2**). However, by comparing the spectrum of (**1**+**2**) with those of 2,3,4,6-tetra-*O*-methyl-α-D-galactopyranose[5] (to obtain the 2-methoxyl signal of **1**) and methyl 2,3-di-*O*-methyl-α- and β-D-galactopyranoside (**11** and **12**, to identify the 3-methoxyl signals; see later), the chemical shifts of the methoxyl groups of **1** and **2** were attributed as shown in Table I. All four methoxyl signals in the spectrum of the 3,4-di-*O*-methyl-D-galactoses (**7** and **8**) appear at the same chemical shift.

(*b*) *Chemical shifts of anomeric protons.* For the compounds having a methoxyl group on C-2 (**1**–**6**), the anomeric protons resonate at τ′ 4.51–4.58 (α anomers) and 5.38–5.46 (β anomers), a difference of 0.87 p.p.m. on the average. For the compounds having a hydroxyl group on C-2 (**7**–**10**), the H-1 signals appear upfield by 0.20–0.28 p.p.m. (α anomers) and 0–0.10 p.p.m. (β anomers), *i.e.*, closer together.

The variations in the observed spacings of the anomeric-proton doublets ($J_{1,2}$) possibly indicate distortions of the *C1* conformation of the D-galactose structure.

(*c*) *Chemical shifts of methoxyl-group protons.* The 2-methoxyl signals of

compounds **1–6** appear at approximately the same chemical shifts as in the p.m.r. spectrum of 2-*O*-methyl-D-galactose[1] (τ' 6.56 for the α anomer, and 6.43 for the β anomer), the methoxyl groups of the β anomers (**2**, **4**, and **6**) absorbing about 0.12 p.p.m. lower than those of the α anomers (**1**, **3**, and **5**). These observations agree, also, with those found for 2,3,4,6-tetra-*O*-methyl-D-galactose[5]. Methylation of the neighboring (equatorial) hydroxyl group on C-3 has no significant effect on the (equatorial) 2-methoxyl chemical-shifts for either an axially or equatorially attached hydroxyl group at C-1 (see Table I). Similarly, the 3-methoxyl signals in the spectrum of 2,3-di-*O*-methyl-D-galactose (**1**+**3**) appear at about the same chemical shifts as in the p.m.r. spectrum of 3-*O*-methyl-D-galactose[1], indicating that methylation of the (equatorial) 2-hydroxyl group has little influence on the chemical shift of the neighboring, equatorial 3-methoxyl group (axial hydroxyl group on C-4).

On the other hand, methylation of the adjacent, axial 4-hydroxyl group produces a downfield shift of ~0.10 p.p.m. in the 3-methoxyl signal for both anomers (equatorial hydroxyl group at C-2), as may be seen by comparing the 3-methoxyl signals of 3-*O*-methyl-D-galactose[1] with those of **7** and **8**. A similar difference in chemical shift (which may be merely coincidental) is observed on comparing the p.m.r. spectrum of 3-*O*-methyl-β-D-glucose[6] with that of methyl 2,3,4,6-tetra-*O*-methyl-β-D-glucopyranoside[7], the chemical shift of the 3-methoxyl group decreasing by ~0.10 p.p.m. on methylation of the (equatorial) 4-hydroxyl group. (For D-galactose derivatives, methylation at O-2 does not influence the 3-methoxyl chemical shift, and this may also be true of similar derivatives of D-glucose.) Methylation of an axially attached, anomeric hydroxyl group, however, has negligible effect on the chemical shift of the equatorial 2-methoxyl group in the D-galactose series (see later).

The 4-methoxyl signals for compounds **3**, **4**, and **7–10** appear at τ' 6.485–6.505, methylation of the neighboring, equatorial hydroxyl group on C-3 having a negligible effect on the chemical shifts of the 4-methoxyl group for both anomers. The (primary) 6-methoxyl signals appear at highest field (τ' 6.60–6.64 for **5**, **6**, **9**, and **10**), the signals for the α anomers being ~0.01 p.p.m. toward higher field, compared with those of the β anomers.

Anomeric change does not affect the 3-, 4-, and 6-methoxyl signals significantly, the signals due to the β anomers usually appearing at only slightly lower field (0–0.02 p.p.m.) than those of the α anomers.

P.m.r. spectra of dimethyl ethers of methyl D-*galactopyranosides.* — (*a*) *Assignment of methoxyl signals.* The p.m.r. spectra of compounds **11–16**, **18**, and **20** were obtained for pure specimens of the methyl α- or β-glycosides. P.m.r. parameters for **17** and **19** were deduced from the spectra of mixtures of the α and β glycosides, prepared from the pure methyl β-glycosides (**18** and **20**, respectively; see Experimental section).

The methoxyl-signal assignments indicated in Table I for compounds **11–20** were made as follows. The 1- and 2-methoxyl signals of **11** and **12** were obtained by comparison with the 1- and 2-methoxyl signals in the spectra of methyl 2,3,4,6-tetra-*O*-methyl-α- and β-D-galactopyranoside[5], respectively, the remaining signals in the

spectra of **11** and **12** being due to the 3-methoxyl group. The 1- and 2-methoxyl signals of methyl 2-*O*-methyl-α- and β-D-galactopyranoside[1] were used to identify the signals from the 1- and 2-methoxyl groups in the spectra of compounds **13–16**. The chemical shifts of the remaining 4-methoxyl (in the spectra of **13** and **14**) and 6-methoxyl signals (in the spectra of **15** and **16**) were confirmed by comparison of these spectra with those of 2,4-di-*O*-methyl-D-galactose (**3**+**4**) and 2,6-di-*O*-methyl-D-galactose (**5**+**6**), respectively. However, there is some uncertainty about the 1- and 6-methoxyl assignments for **15**, as their signals appear close to one another (0.01 p.p.m. separation). The 1-methoxyl signals in the spectra of **17–20** were identified by comparison with the spectra of methyl 3-*O*-methyl-α- and β-D-galactopyranoside[1] (for **17** and **18**) and methyl 4-*O*-methyl-α- and β-D-galactopyranoside[1] (for **19** and **20**). Comparison of the spectra of **17** and **18** with that of 3,4-di-*O*-methyl-D-galactose (**7**+**8**) identified the 3- and 4-methoxyl signals. The 4-methoxyl signals for **19** and **20** were obtained by comparison of the spectra of these compounds with that of 4,6-di-*O*-methyl-D-galactose (**9**+**10**), the remaining high-field signals being attributed to the 6-methoxyl groups.

(*b*) *Chemical shifts of anomeric protons.* For compounds having a 2-methoxyl group in addition to the methoxyl group at C-1, the anomeric-proton signals appear at τ′ 4.92–4.99 for the α glycosides (**11**, **13**, and **15**) and at 5.64–5.71 for the β glycosides (**12**, **14**, and **16**). These two ranges include the values found for the chemical shifts of the anomeric protons in methyl 2-*O*-methyl-α- and β-D-galactopyranoside[1] (τ′ 4.95 and 5.67, respectively). The anomeric protons absorb at τ′ 5.20 (α glycosides, **17** and **19**) and 5.72–5.73 (β glycosides, **18** and **20**) for compounds not having a methoxyl group on C-2; for methyl α- and β-D-galactopyranoside, the anomeric-proton signals appear at τ′ 5.17 and 5.71, respectively. It may be concluded that methylation of an additional hydroxyl group in methyl α- and β-D-galactopyranoside has a negligible effect on the anomeric-proton signals, unless the 2-hydroxyl group is methylated; in this case, the H-1 signals absorb 0.22–0.25 p.p.m. downfield for α glycosides and 0–0.07 p.p.m. downfield for β glycosides. The same observations were made [section (*a*) just preceding] for the D-galactopyranose anomers.

The anomeric-proton signals in the spectra of the methyl glycosides (**11–20**) appear, on the average, 0.415 p.p.m. (α anomers) and 0.26 p.p.m. (β anomers) upfield from those of the corresponding derivatives of D-galactopyranose (**1–10**). This result was also found when there are no[1], or one[1], or four[5] methyl ether groups in the sugar.

(*c*) *Chemical shifts of methoxyl-group protons.* As had been observed for the monomethyl ethers of methyl D-galactopyranosides studied[1], the chemical shifts of the anomeric methoxyl groups (axial or equatorial) are not affected appreciably by methylation of the neighboring (equatorial) 2-hydroxyl group; this may be seen by comparing the 1-methoxyl chemical-shifts for compounds **17–20** with the corresponding values for compounds **11–16**. It has also been found[1,5] that the introduction of a glycosidic methyl group (axial or equatorial) has a negligible effect on the chemical shift of a neighboring (equatorial) 2-methoxyl group. This is true for either a hydroxyl

or a methoxyl group (equatorial) on C-3, as may be seen by comparing the chemical shifts of the 2-methoxyl groups for compounds **11–16** with those for compounds **1–6**.

The observations made in the immediately preceding section (*c*) regarding the effects of neighboring hydroxyl or methoxyl groups on the chemical shifts of the 3- and 4-methoxyl groups apply to the methyl glycosides as well. Whereas methylation at O-2 does not change the 3-methoxyl chemical shifts (compare methyl 3-*O*-methyl-α- and β-D-galactopyranoside[1] with **11** and **12**), methylation of the axial 4-hydroxyl group produces a downfield shift (of 0.08 p.p.m.) of the 3-methoxyl signal (compare methyl 3-*O*-methyl-α- and β-D-galactopyranoside[1] with **17** and **18**). Conversely, methylation at O-3 has no influence on the 4-methoxyl chemical-shift (compare methyl 4-*O*-methyl-α- and β-D-galactopyranoside[1] with **17** and **18**).

There appears to be a slight decrease (of ~0.02 p.p.m.) in the chemical shifts of the 6-methoxyl groups when a glycosidic methyl group is introduced. This decrease is also observed on comparing the spectra of 2,3,4,6-tetra-*O*-methyl-α- and β-D-galactopyranose with those of methyl 2,3,4,6-tetra-*O*-methyl-α- and β-D-galactopyranoside[5]. Anomeric change (α to β) produces downfield shifts of both the 1-methoxyl (0.17 p.p.m.) and 2-methoxyl (0.10 p.p.m.) signals. Similar observations were made for the p.m.r. spectra of the anomers of methyl 2-*O*-methyl-D-galactopyranoside[1] and methyl 2,3,4,6-tetra-*O*-methyl-D-galactopyranoside[5]. The 3-, 4-, and 6-methoxyl signals for the α glycosides appear at the same, or slightly higher (≤0.01 p.p.m.), field than the corresponding signals for the β glycosides.

The complexity of the electrical fields[8] originating from the dipoles in the methoxyl groups produced on methylation of hydroxyl groups, and of their possible effects on anomeric-proton and methoxyl-group chemical-shifts, is too great to permit any explanations to be proposed at this stage regarding the influence of methylation upon the chemical shifts of neighboring protons.

P.m.r. spectra of dimethyl ethers of galactitol. — (*a*) *Assignment of methoxyl signals.* Except for the spectrum of 3,4-di-*O*-methylgalactitol (**24**), the spectra of the dimethyl ethers of galactitol studied showed two separate methoxyl signals each. Methoxyl signals in the spectra of **22**, **23**, and **25** were identified by using the methoxyl chemical-shifts obtained from the spectra of the monomethyl ethers of galactitol[1] and 2,3,4,6-tetra-*O*-methyl-D-galactitol[5], and by assuming absence of interaction between the methoxyl groups in compounds **22**, **23**, and **25**. Only one methoxyl signal (integrating for 6 protons) was produced by the 3- and 4-methoxyl signals in the spectrum of **24**. The 2-methoxyl signal of **21** was deduced by comparing the spectrum of **21** with that of 2,3,4,6-tetra-*O*-methyl-D-galactitol.

(*b*) *Chemical shifts of methoxyl-group protons.* The chemical shift of the 3-methoxyl signal in the spectrum of **21** agrees with the value for that of the 3-methoxyl group of 2,3,4,6-tetra-*O*-methyl-D-galactitol[5], showing that, in contrast to the observations already discussed for the D-galactose and methyl D-galactoside derivatives, the 3-methoxyl signal of the galactitol derivative is not affected by methylation of the neighboring 4-hydroxyl group. Both the 2- and the 3-methoxyl signal in the spectra of the monomethyl-galactitols[1] are shifted slightly upfield (~0.02 p.p.m.) by methyl-

ation of the neighboring 3- and 2-hydroxyl groups, respectively (as in compound **21**). Methylation of the neighboring 3-hydroxyl group has a negligible effect on the chemical shift of the 4-methoxyl group, however, as may be seen by comparing the spectrum of 4-*O*-methyl-D-galactitol[1] with that of compound **24**.

EXPERIMENTAL

General. — 100-MHz spectra (see Table I) were recorded at 32° with a Varian Associates HA-100 spectrometer, for 5–10% solutions in deuterium oxide. Sodium 4,4-dimethyl-4-silapentanesulfonate was used as the internal standard (τ' scale). 60-MHz spectra of the intermediates (see Table II) were recorded at 37° with a Varian Associates A-60 instrument.

Mixtures of methyl 3,4-di-*O*-methyl-α- and β-D-galactopyranoside (**17** and **18**) and methyl 4,6-di-*O*-methyl-α- and β-D-galactopyranoside (**19** and **20**) were obtained by treating **18** and **20**, respectively, with 2% methanolic hydrogen chloride. P.m.r. spectra of these mixtures (both of which contained ~80% of the α glycoside) were used to obtain the p.m.r. parameters for **17** and **19**.

Acid hydrolysis (0.5M sulfuric acid) of **12**, **15**, **18**, and **20** gave 2,3-di-*O*-methyl-D-galactose[11] (**1**+**2**), 2,6-di-*O*-methyl-D-galactose[18] (**5**+**6**), 3,4-di-*O*-methyl-D-galactose[19] (**7**+**8**), and 4,6-di-*O*-methyl-D-galactose[21] (**9**+**10**), respectively.

Methyl ethers of galactitol were prepared by reduction[22] of the appropriate dimethyl ethers of D-galactopyranose with sodium borohydride.

Compounds **11**–**16**, **18**, and **20** were synthesized by known methods, with slight modifications as indicated. P.m.r. parameters for the intermediate compounds used in the synthesis of these dimethyl ethers of methyl D-galactopyranoside are listed in Table II.

*Methyl 2,3-di-*O*-methyl-α-*D*-galactopyranoside* (**11**). — Methyl 4,6-*O*-benzylidene-α-D-galactopyranoside[10] (**26**) was converted by methylation into methyl 4,6-*O*-benzylidene-2,3-di-*O*-methyl-β-D-galactopyranoside[11]. Removal of the benzylidene group by hydrolysis with 90% trifluoroacetic acid[12] afforded[13] compound **11**.

*Methyl 2,3-di-*O*-methyl-β-*D*-galactopyranoside* (**12**). — Methyl 4,6-*O*-benzylidene-β-D-galactopyranoside[1] was methylated[14] to yield methyl 4,6-*O*-benzylidene-2,3-di-*O*-methyl-β-D-galactopyranoside[14]. The benzylidene group was removed by acid hydrolysis[15] to produce compound **12**.

*Methyl 2,4-di-*O*-methyl-α- and β-*D*-galactopyranoside* (**13** *and* **14**). — Methyl glycosidation of 2,4-di-*O*-methyl-D-galactopyranose with 2% methanolic hydrogen chloride afforded a mixture of **13** and **14**. The two glycosides were separated by fractional recrystallization[16].

*Methyl 2,6-di-*O*-methyl-α-*D*-galactopyranoside* (**15**). — Methyl 3,4-*O*-isopropylidene-2-*O*-methyl-α-D-galactopyranoside[1] was methylated to produce methyl 3,4-*O*-isopropylidene-2,6-di-*O*-methyl-α-D-galactopyranoside[17] (**27**). Hydrolysis of **27** with 90% trifluoroacetic acid[12] for 6 min at 20° afforded **15** as a brown syrup.

*Methyl 2,6-di-*O*-methyl-β-*D*-galactopyranoside* (**16**). — Methyl 3,4-*O*-isopropylidene-2,6-di-*O*-methyl-β-D-galactopyranoside[18] (**28**), prepared from methyl 3,4-*O*-

isopropylidene-β-D-galactopyranoside[1], was treated with 90% trifluoroacetic acid, as for the hydrolysis of **27**, to produce[18] compound **16**.

*Methyl 3,4-di-*O*-methyl-β-*D*-galactopyranoside* (**18**). — Denitration of methyl 3,4-di-*O*-methyl-β-D-galactopyranoside 2,6-dinitrate[1,19] (**29**) afforded[19] **18**, identical with the glycoside obtained during the synthesis of methyl 3-*O*-methyl-β-D-galactopyranoside[1].

*Methyl 4,6-di-*O*-methyl-β-*D*-galactopyranoside* (**20**). — Two methylations[20] of methyl 2,3-di-*O*-benzyl-β-D-galactopyranoside[1] gave methyl 2,3-di-*O*-benzyl-4,6-di-*O*-methyl-β-D-galactopyranoside[21] (**30**); this was reductively de-*O*-benzylated[1] to produce[21] compound **20**.

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