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FLUORINATED CARBOHYDRATES

PART III[1]. 2-DEOXY-2-FLUORO-D-GLUCOSE AND 2-DEOXY-2-FLUORO-D-MANNOSE*

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ABSTRACT

Reaction of fluoroxytrifluoromethane at *ca.* −80° with 3,4,6-tri-*O*-acetyl-D-glucal affords trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranoside (**2**, 26%), 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranosyl fluoride (**3**, 34%), trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranoside (**4**, ~6%), and 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranosyl fluoride (**5**, ~8%). The structures of compounds **2**–**5** have been established by n.m.r. spectroscopy.

Acid hydrolysis of **2** or **3** affords 2-deoxy-2-fluoro-D-glucose (**7**), and of **4** or **5**, 2-deoxy-2-fluoro-D-mannose (**9**). Some properties and derivatives of **7** and **9** are described.

INTRODUCTION

Of particular interest in a study[2] of antitumour activity and structure–activity relationships[3] involving substrates of hexokinase isozymes of normal and cancerous tissue[4] are the deoxyfluoro-D-glucoses and their glycosyl fluorides, especially[3] compounds fluorinated at C-2.

In seeking synthetic routes to 2-deoxy-2-fluoro-D-glucose and 2-deoxy-2-fluoro-D-mannose (and other fluorinated sugars), it is necessary to bear in mind that conventional evaluation of *in vivo* antitumour activity against a range of experimental animal tumours can involve decagram quantities of materials. For this reason, the first synthesis[5] of 2-deoxy-2-fluoro-D-glucose, which involves 8 stages from starch as a precursor of 1,6-anhydro-D-glucopyranose, is largely deprived of convenience.

Addition to glycals is an obvious approach to 2-deoxy-2-fluoro sugars, but it is

*Dedicated to Professor F. Micheel in celebration of his 70th birthday.
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necessary to use reagents which generate electrophilic fluorine, otherwise glycosyl fluorides will be formed[6]. The direct addition of fluorine to glycals has not been reported, although adequate control of the reagent is now possible[7]. The combination lead tetra-acetate–hydrogen fluoride has been shown to generate lead(IV) diacetate difluoride *in situ* and effects[8] *cis* addition of fluorine to steroid olefins, but with 3,4,6-tri-*O*-acetyl-D-glucal, a rearrangement occurs and 3,4,6-tri-*O*-acetyl-2,5-anhydro-1-deoxy-1,1-difluoro-D-mannitol is formed[9].

The reported[10] reaction of fluoroxyperfluoroalkanes with activated olefins, in a manner which involves effectively electrophilic fluorine, prompted an investigation[11] of the reaction of 3,4,6-tri-*O*-acetyl-D-glucal with fluoroxytrifluoromethane (CF_3OF).

RESULTS AND DISCUSSION

Treatment of 3,4,6-tri-*O*-acetyl-D-glucal (**1**) in chlorotrifluoromethane at *ca.* −80° with fluoroxytrifluoromethane (1.2 mol.) gave a mixture of four products which could be separated by chromatography on Kieselgel to give, in order of elution, trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranoside (**2**, 26%), 3.4.6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranosyl fluoride (**3**, 34%), trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranoside (**4**, ~6%), and 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranosyl fluoride (**5**, ~8%). The yields are for recrystallized products and, undoubtedly, could be increased by further chromatography. The pairs of compounds **2** and **4** and **3** and **5** reflect the two modes of reaction[10] (see formula **1**) of fluoroxytrifluoromethane with an activated double bond, *viz.*, normal addition to give the trifluoromethyl glycosides **2** and **4** and, with loss of carbonyl fluoride, to give the vicinal difluorides **3** and **5**.

The structures of compounds **2**–**5** were established by n.m.r. spectroscopy. The essential data are given in Table I; a full analysis of the data for **2**–**5** and for related compounds will be published elsewhere. The α-D-*gluco* configuration of **2** and **3** is unequivocally established by the magnitude of the ^1H–^1H coupling constants[12] and the close similarity between the respective J values suggests that both derivatives have the *CI*(D) conformation. Conformation **3** would be expected to be preferred, since it contains four equatorial substituents and an axial anomeric fluorine atom; a large anomeric effect[13] has been observed[14] for glycopyranosyl fluorides. The value (23.8 Hz) of J (F-1/H-2) for **3** is close to that for other derivatives of α-D-glucopyranosyl fluoride[6], and the values (11.5, 12.0 Hz) of J (F-2/H-3) are similar to those[15] (12.8 in each case) for J (F-3/H-2) and J (F-3/H-4) in 3-deoxy-3-fluoro-β-D-glucopyranose tetra-acetate[16]. The small magnitude (<0.5 Hz) of J (F-2/H-1) for **2** and **3** reflects the high, total electronegativity of the substituents attached to C-1 and C-2 and, in particular, the antiplanar relationship between the C-2–F-2 and C-1–O-5 bonds[17].

The magnitude of the ^1H–^1H coupling constants for **4** and **5** also unequivocally establishes the *manno* configuration and the *CI*(D) conformation, and confirmation is provided by the magnitude (20–25 Hz) of J (F-2/H-3) which is characteristic[6,18] of

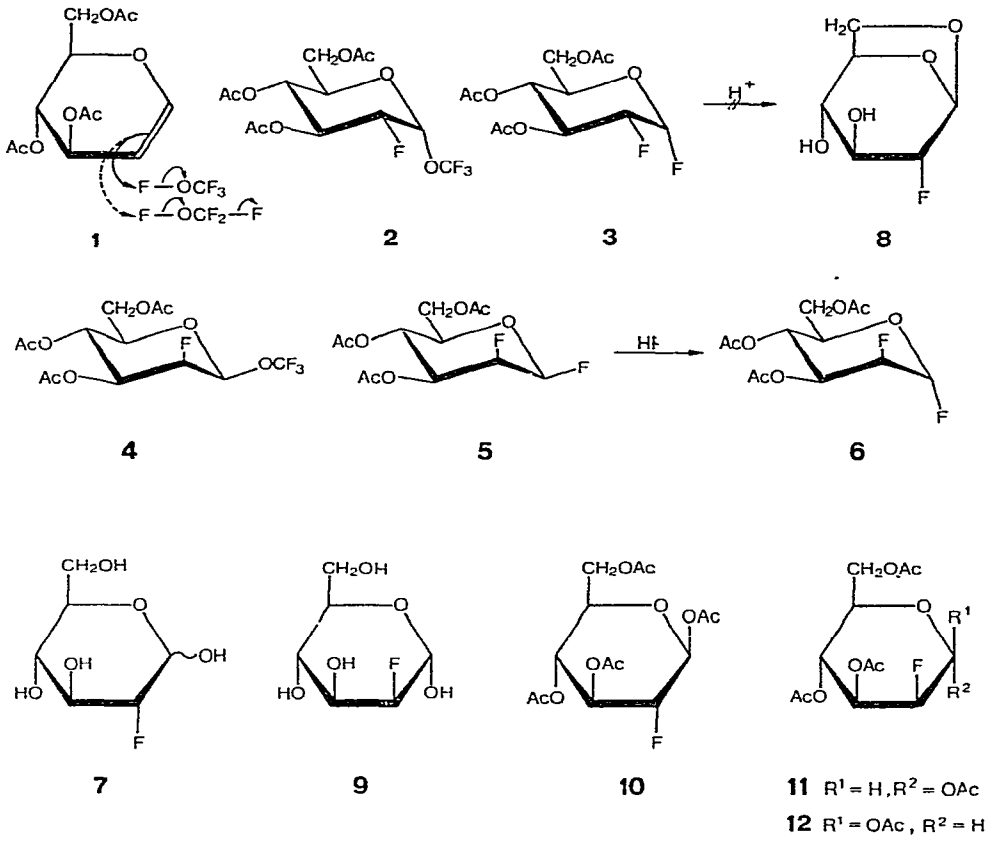

TABLE I

COUPLING CONSTANTS[a] (*J* Hz) FOR THE PRODUCTS ARISING FROM THE REACTION OF 3,4,6-TRI-*O*-ACETYL-D-GLUCAL WITH FLUOROXYTRIFLUOROMETHANE

	H-1/H-2	*H-2/H-3*	*H-3/H-4*	*H-4/H-5*	*F-1/H-2*	*F-2/H-1*	*F-2/H-3*
2	3.9	9.7	9.4	9.4		<0.5	11.5
3	2.9	9.5	9.5	9.5	23.8	<0.5	12.0
4	~1.0	2.5	9.7	9.0		16	~25
5	1.0	2.6	8.7	7.5	7.6	12.8	21.4

[a]Data for solutions in $CDCl_3$ measured with a modified Varian HA-100 spectrometer operating in the locked, field-sweep mode at 94 MHz for ^{19}F resonances and in the frequency-sweep mode for ^{1}H resonances.

trans-diaxial orientation. The n.m.r. data do not unequivocally establish, but are consistent with, the β-D orientation at the anomeric centre. The low value (~2 Hz) for *J* (F-1/H-2) for 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl fluoride has been ascribed[18] to the antiplanar arrangement of the C-2–O-2/C-1–F-1 and C-2–H-2/C-1–O-5 bonds. Thus, the relatively high (7.6 Hz) value of *J* (F-1/H-2) for **5** suggests that

the C-1–F-1 bond is not antiplanar to an electronegative substituent. Moreover, the vicinal coupling constants between nuclei which are nominally *trans*-diaxial in the mannopyranosyl fluoride **5** are significantly smaller than in the trifluoromethyl analogue **4**. This difference is consistent with the presence of an equatorial fluorine atom at the anomeric centre in **5** and would be expected on the basis of the large anomeric effect[13,14] of a glycosidic fluorine atom causing a time-averaged decrease in the coupling constants as a consequence of partial destabilisation of the conformation **5**.

The α-D-*gluco* and β-D-*manno* configurations of the products **2**–**5** arising from the reaction of **1** with fluoroxytrifluoromethane would be expected on mechanistic grounds, since *cis*-addition of the reagent to activated double bonds is very strongly favoured[19]. Confirmation of the β-D configuration of **5** is provided by treatment with liquid hydrogen fluoride at *ca.* −10° which results[20] in extensive if not complete anomerisation to give 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-mannopyranosyl fluoride (**6**). Because of the strong anomeric effect[13,14], the rearrangement of an *eq* (β) D-glycosyl fluoride into the thermodynamically more-stable *ax* (α) anomer is to be expected. It is well established[6,21] that hexopyranose penta-acetates react with liquid hydrogen fluoride to give glycosyl fluorides having an *ax* fluorine atom.

The optical rotation data (for chloroform solutions) for **5** and **6** are also consistent with the assigned configurations: $[\alpha]_D$ values **5** −3.5°, β-D-mannopyranose penta-acetate[22] −24°, **6** +27°, α-D-mannopyranose penta-acetate[22] +57°.

The preponderance of the products **2** and **3** having the *gluco* configuration arising from the addition of fluoroxytrifluoromethane to the glucal **1** parallels the reaction of **1** with, for example, chlorine[23] and nitrosyl chloride[24], for which a rationalisation has been presented[23] in stereo-electronic terms.

Hydrolysis of the trifluoromethyl glucoside **2** (boiling 5M hydrochloric acid, 4 h) or the glucosyl fluoride **3** (boiling M acid, 30 min) gave 2-deoxy-2-fluoro-D-glucose (**7**) in high yield (85–90%). 1,6-Anhydro-2-deoxy-2-fluoro-D-glucopyranose[5] (**8**) was not formed (t.l.c.) during, and therefore cannot be an intermediate in, the acid hydrolysis of **3**, since it requires more vigorous conditions (boiling M acid, 24 h) for hydrolysis.

Thus, at least 60% of the product mixture **2**–**5** can be used efficiently for the synthesis of 2-deoxy-2-fluoro-D-glucose. The total reaction sequence involves 4 stages starting from D-glucose and provides a convenient access to the fluoro sugar **7**.

The trifluoromethyl mannoside **4** and the mannosyl fluoride **5** also underwent normal hydrolysis to give 2-deoxy-2-fluoro-D-mannose (**9**) in good yield (65–80%).

No significant mutarotation could be detected following the dissolution of 2-deoxy-2-fluoro-D-glucose (m.p. 160–165°) or 2-deoxy-2-fluoro-D-mannose (m.p. 131–132°) in water. In some instances, information on the anomeric composition of fluoro sugars in aqueous solution can easily be obtained from ^{19}F n.m.r. data. This is particularly true for the 3-, 4-, and 6-deoxyfluoro derivatives of D-glucose, where the ^{19}F resonances associated with the α- and β-pyranose forms are widely separated[25]. The following data were obtained for a solution of 2-deoxy-2-fluoro-D-glucose in D_2O (external reference, C_6F_6): α-anomer, +3057 Hz, $J_{F,2}$ 49, $J_{F,3}$ 14, $J_{F,1}$ 0.5 Hz (*cf.* $J_{F\text{-}2,1}$ <0.5 Hz for the α-D-*gluco* compounds **2** and **3**): β-anomer, +3041 Hz, $J_{F,2}$ 50,

$J_{F,3}$ 15, $J_{F,1}$ 2.5 Hz: relative integrated areas $\alpha:\beta \sim 1:2$ (*cf.* the corresponding ratio[13] of 1:1.8 for an aqueous solution of D-glucose). A closely similar $\alpha\beta$-ratio was obtained for a solution of **7** in deuteriomethyl sulphoxide (internal reference, MeCN) from the signals for the protons in the anomeric hydroxyl groups[26]: α-anomer, OH-1, δ 6.78 (doublet, J 4 Hz); β-anomer, OH-1, δ 7.10 (doublet, J 6 Hz). Thus, the isolated, crystalline form of 2-deoxy-2-fluoro-D-glucose contains a nearly equilibrium mixture of α- and β-pyranose forms.

In a parallel series of observations on 2-deoxy-2-fluoro-D-mannose (**9**), the following data were obtained: ^{19}F resonances (D_2O), α-pyranose, +3560 Hz, $J_{F,2}$ 47, $J_{F,3}$ 30, $J_{F,1}$ 7 Hz; β-pyranose, +5300 Hz, $J_{F,2}$ 52, $J_{F,3}$ 30, $J_{F,1}$ 20 Hz; relative integrated areas, $\alpha:\beta \sim 7:3$ (*cf.* the corresponding ratio[13] of 6.6:3 for an aqueous solution of D-mannose): the anomeric configurations were assigned on the basis of the magnitude of the $J_{F,1}$ values[6]. For a solution in deuteriomethyl sulphoxide: α-pyranose, OH-1, δ 6.72 (doublet, J 6 Hz) and, after the addition of D_2O, H-1, δ 5.15 (quartet, $J_{F,1}$ 7, $J_{1,2}$ 1 Hz); signals for the β-anomer could not be detected. Thus, the α-D configuration may be assigned to the isolated form of **9**. Moreover, the above data suggest that the failure to observe mutarotation on dissolution of **9** in water is probably due to a very rapid establishment of equilibrium.

The extensive coupling[1,16,27] (geminal, vicinal, and long-range, variously, ^4J and ^5J) between the fluorine atom and ring protons in deoxyfluorohexoses allows the ^{19}F resonances to be used to assess both conformation and anomeric configuration. Moreover, since ^{19}F resonances can be measured for aqueous solutions of deoxyfluorohexoses, the effect of added enzymes, such as hexokinase isozymes, can be observed, and an approach to the study of enzyme–substrate complexes is thereby provided.

Treatment of 2-deoxy-2-fluoro-D-glucose with pyridine–acetic anhydride gave an $\alpha\beta$-mixture of tetra-acetates from which a pure anomer could not be isolated. Treatment of the $\alpha\beta$-mixture in sequence with hydrogen bromide–acetic acid and silver acetate–acetonitrile gave the β-tetra-acetate. Both the α- and β-tetra-acetates of 2-deoxy-2-fluoro-D-mannose could be isolated from the $\alpha\beta$-mixture obtained by using the pyridine–acetic anhydride reagent (see Experimental for the n.m.r. data).

The formation of 3,4,6-tri-*O*-acetyl-2,5-anhydro-1-deoxy-1,1-difluoro-D-mannitol on treatment of 3,4,6-tri-*O*-acetyl-D-glucal with lead tetra-acetate–hydrogen fluoride has been postulated[9] to involve the intermediate formation and subsequent rearrangement of a 1,2-difluoride. However, the *cis*-1,2-difluorides **3** and **5** were recovered unchanged after treatment with the above reagent.

EXPERIMENTAL

Melting points are corrected. Optical rotations were obtained (unless stated otherwise) for *ca.* 1% solutions in chloroform by using a Perkin–Elmer 141 polarimeter. Thin-layer chromatography (t.l.c.) was performed on Kieselgel (Merck, 7731), and detection was effected with conc. sulphuric acid. Column chromatography was effected on Kieselgel 7734, by the dry-column technique[28].

Handling of fluoroxytrifluoromethane. — The reagent (Peninsular Chemical Co.) was transferred from a cylinder into a gas burette (150 ml) by displacement of Voltalef 15 oil (oligomeric mixture of chlorofluorocarbons, Ugine Kuhlmann, K. W. Chemicals, Ltd., London). Following admixture with nitrogen (to moderate the otherwise very vigorous reaction), the reagent was passed through water (to remove COF_2), dried using molecular sieves (type 4A), and then passed into the reaction vessel at *ca.* −80°. The effluent gases were passed through a cold trap into aqueous sodium iodide. The apparatus was of glass with Teflon connections, and all joints were greased with Voltalef 90. Titration of the iodine liberated from sodium iodide can be used to assay the purity of the reagent and the amount consumed ($CF_3OF + NaI + H_2O \rightarrow I_2 + 2NaF + CO_2 + 2HF$). Decomposition of CF_3OF inside the cylinder occurred at the rate of ~5% per month. The major impurities are COF_2, CO_2, and $(CF_3O)_2$.

*Reaction of 3,4,6-tri-*O*-acetyl-*D*-glucal* (**1**) *with fluoroxytrifluoromethane.* — A solution of **1** (17.5 g) in chlorotrifluoromethane (Freon 11, 800 ml) at *ca.* −80° was stirred with calcium oxide (10 g) to remove hydrogen fluoride and purged with nitrogen. Fluoroxytrifluoromethane (~1.2 equiv.) diluted with nitrogen was passed into the solution during 4 h [the reaction can be monitored by observing the disappearance of the i.r. band at 1650 cm^{-1} (C=C)], followed by nitrogen for 30 min to remove excess of reagent. The reaction mixture was filtered into saturated, aqueous sodium hydrogen carbonate (500 ml), and the residue was washed with dichloromethane (100 ml). The combined organic layers were washed with water (250 ml), dried ($CaCl_2$), and evaporated to give a mixture (18.2 g) of four products which could be resolved by t.l.c. [Kieselgel, light petroleum–ether (1:1), detection with conc. sulphuric acid, R_F values 0.5 (two spots vary close together), 0.3, and 0.25] and g.l.c. [Pye 104 chromatograph, SE 30, 170°, flame-ionization detection, retention distances, 3.2 (major), 4.2 (minor), 4.5 (major), and 5.3 cm (minor)].

A solution of the mixture (18.2 g) in chloroform (100 ml) was evaporated in the presence of Kieselgel (30 g), and the residue was added to the top of a column of dry Kieselgel (210 g). Elution with light petroleum (b.p. 40–60°)–ether (4:1) gave, after crystallization in each case from ether–light petroleum (b.p. 100–120°), trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranoside (**2**, 4.1 g, 17%), m.p. 84–85°, $[\alpha]_D$ +158° (Found: C, 41.2; H, 4.3; F, 20.2. $C_{13}H_{16}F_4O_8$ calc.: C, 41.5; H, 4.3; F, 20.2%), followed by 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-α-D-glucopyranosyl fluoride (**3**, 5.3 g, 27%), m.p. 91–92°, $[\alpha]_D$ +138° (Found: C, 46.2; H, 5.2; F, 12.7. $C_{12}H_{16}F_2O_7$ calc.: C, 46.45; H, 5.2; F, 12.3%). Further elution with a 2:1 solvent mixture afforded trifluoromethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranoside (**4**, 1.4 g, 5.8%), m.p. 96–97°, $[\alpha]_D$ −21° (Found: C, 41.7; H, 4.0; F, 19.9%), followed by 3,4,6-tri-*O*-acetyl-2-deoxy-2-fluoro-β-D-mannopyranosyl fluoride (**5**, 1.5 g, 7.5%), m.p. 113–114°, $[\alpha]_D$ −3.5° (Found: C, 46.8; H, 5.4; F, 12.5%).

Column chromatography of the combined products from the mother liquors and the material contained in the overlapping fractions from the first chromato-

graphic separation gave further amounts of the pure components, giving total yields of the major components in excess of the percentages **2**, 26; **3**, 34.

2-Deoxy-2-fluoro-D-glucose (**7**). — (*a*) The trifluoromethyl glucoside **2** (1.5 g) was added to boiling 0.1M hydrochloric acid (10 ml) and 10M acid (10 ml) was then added dropwise during 5 min. The hydrolysis was monitored by t.l.c. (ethyl acetate–ethanol, 1:1) and was essentially complete in 4 h, giving a single product (R_F 0.9). The cooled mixture was neutralised (Ag_2CO_3), filtered, and concentrated. A solution of the residue in methanol (10 ml) was concentrated in the presence of Kieselgel (2 g), and the residue was added to the top of a column of dry Kieselgel (30 g). Elution with ethyl acetate–ethanol (1:1) and recrystallisation from ethyl acetate–methanol afforded **7** (0.66 g, 91%), m.p. 160–165°, $[\alpha]_D$ +56° (*c* 1, water; no mutarotation was observed during 12 h) (Found: C, 39.5; H, 6.3; F, 10.6. $C_6H_{11}FO_5$ calc.: C, 39.55; H, 6.05; F, 10.45%). The fluoro sugar had the same mobility in t.l.c. and the same i.r. spectrum as the sample (m.p. 160–165°) of 2-deoxy-2-fluoro-D-glucose[5] kindly provided by Dr. Pacák. The wide and variable m.p. range of the fluoro sugar probably reflects variations in the proportions of α- and β-anomers under different conditions of crystallisation.

(*b*) Treatment of the glucosyl fluoride **3** (355 mg) with boiling M hydrochloric acid (5 ml) for 30 min, followed by work up as in (*a*), afforded **7** (177 mg, 85%), m.p. 155–164°.

2-Deoxy-2-fluoro-D-mannose (**9**). — (*a*) Treatment of the trifluoromethyl mannoside **4** (2.63 g) with boiling 5M hydrochloric acid (25 ml) for 3 h resulted in complete hydrolysis. The cooled hydrolysate was neutralised ($PbCO_3$) and then worked up as for 2-deoxy-2-fluoro-D-glucose. Elution of the crude product from Kieselgel (50 g) with ethyl acetate gave **9** (0.86 g, 67%), m.p. 131–132°, $[\alpha]_D^{25}$ +19° (*c* 0.8, water; no mutarotation was observed during 3 h) (Found: C, 39.2; H, 5.8; F, 10.2. $C_6H_{11}FO_5$ calc.: C, 39.55; H, 6.05; F, 10.45%).

(*b*) When the mannopyranosyl fluoride **5** (913 mg) was treated with boiling 2M hydrochloric acid (15 ml) for 5 h, followed by work up as in (*a*), **9** (415 mg, 77%) was obtained having m.p. 130–131°, $[\alpha]_D$ +19° (*c* 1.4, water).

Acetates of 2-deoxy-2-fluoro-D-glucose (**7**) *and 2-deoxy-2-fluoro-D-mannose* (**9**). — (*a*) Compound **7** (440 mg) was treated with pyridine–acetic anhydride (3 ml, 1:2) at room temperature in the usual way. The resultant mixture (853 mg, m.p. 40–50°, $[\alpha]_D$ +64°, α:β ratio *ca.* 1:2) of αβ-tetra-acetates was dissolved in a 45% solution (5 ml) of hydrogen bromide in acetic acid. After 3 h at room temperature, the solvents were removed *in vacuo* at <30°. A solution of the residue in acetonitrile (20 ml) was added to a suspension of silver acetate (2 g) in acetonitrile (5 ml), and the mixture was stirred for 3 days at room temperature. Ether (100 ml) was added to the mixture which was then filtered and evaporated in the presence of Kieselgel (2 g). The residue was added to the top of a column of dry Kieselgel (25 g) and eluted with light petroleum(b.p. 40–60°)–ether (2:1). Recrystallisation of the major product gave 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-fluoro-β-D-glucose (**10**, 520 mg, 61%), m.p. 91–92°, $[\alpha]_D^{25}$ +50° (Found: C, 48.0; H, 5.4; F, 5.4. $C_{14}H_{19}FO_9$ calc.: C, 48.0; H, 5.4; F, 5.4%).

N.m.r. data: ^{19}F resonances ($CDCl_3$, internal reference $CFCl_3$, 94.1 MHz) β-anomer, +201.4 Hz, $J_{F,1}$ 3.3, $J_{F,2}$ 50.5, $J_{F,3}$ 14.2, $J_{1,2}$ 8.1, $J_{2,3}$ 9.2 Hz.

(*b*) Treatment of **9** (750 mg) with acetic anhydride–pyridine (6 ml, 2:1), at room temperature in the usual manner, gave a product which was eluted from Kieselgel with light petroleum (b.p. 40–60°)–ether (4:1) to give 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-fluoro-α-D-mannose (**11**, 932 mg, 65%), b.p. 146°/0.07 mm, m.p. 66–68° [from light petroleum (b.p. 40–60°)–ether], $[\alpha]_D^{25}$ +60° (Found: C, 48.3; H, 5.5; F, 5.7%). N.m.r. data: ^{19}F resonance, +201.2 Hz, $J_{F,1}$ 6.6, $J_{F,2}$ 48.9, $J_{F,3}$ 24.5, $J_{1,2}$ 2.2, $J_{2,3}$ 2.3 Hz.

Subsequent elution with a 2:1 solvent mixture gave the β-tetra-acetate **12** (171 mg, 12%), m.p. 107–108° [from ether–light petroleum (b.p. 60–80°)], $[\alpha]_D$ −14° (Found: C, 48.5; H, 5.7; F, 5.9%). N.m.r. data: ^{19}F resonance, +220.0 Hz, $J_{F,1}$ 18.9, $J_{F,2}$ 50.7, $J_{F,3}$ 25.6, $J_{1,2}$ 0.5, $J_{2,3}$ 2.4 Hz.

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