Elemental fluorine. Part 5.[1,2] Reactions of 1,3-dithiolanes and thioglycosides with fluorine–iodine mixtures

Richard D. Chambers,*[,a] Graham Sandford,*[,a] Matthew E. Sparrowhawk[a] and Malcolm J. Atherton[b]

[a] *Department of Chemistry, University of Durham, South Road, Durham DH1 3LE, UK*
[b] *BNFL Fluorochemicals Ltd., Bldg. 619, Salwick, Preston PR4 0XJ, UK*

1,3-Dithiolanes, prepared from diaryl ketones, react with elemental fluorine–iodine mixtures to give the corresponding difluoromethylene derivatives. Under the same conditions, thioglycosides give glycosyl fluorides in good yields. Reaction of 1,3-dithiolanes with fluorine in aqueous acetonitrile provides a remarkably mild method for efficient deprotection to the parent ketone.

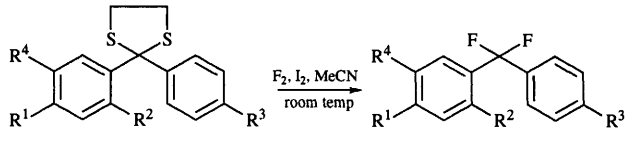
Introduction

The selective fluorination of organic compounds has received considerable attention because of the profound effect that fluorine containing groups can have on the chemical, physical and biological properties of such substrates,[3,4] as exemplified by the development of many pharmaceuticals and plant protection agents incorporating fluorine in their structures.[5] For instance, the introduction of a CF_2 group into a molecule is an important target because of a possible relationship between the difluoromethylene moiety and an ether oxygen [3,4] and many methods for such a process have been described. In particular, the functional group interconversion of carbonyl groups to CF_2 may be achieved either directly, by reagents such as SF_4, DAST or MoF_6,[6,7] or indirectly by the fluorination of carbonyl derivatives such as hydrazones[8] or diazo[9] compounds by iodine monofluoride or fluorine.

An alternative approach is the fluorination of 1,3-dithiolanes, prepared from the parent carbonyl compounds, by reagents which may be considered to consist of a combination of a source of electrophilic halonium and nucleophilic fluoride ions, such as *N*-bromosuccinimide–pyridine·HF,[10] *N*-bromosuccinimide–$Et_4NH_2F_3$,[11] SO_2Cl_2–pyridine·HF[12] or *p*-difluoroiodotoluene.[13] Similarly, the introduction of CFH moieties into organic substrates by analogous fluorodesulfurisation processes involving the transformation of C–S to C–F bonds have been described.[14,15]

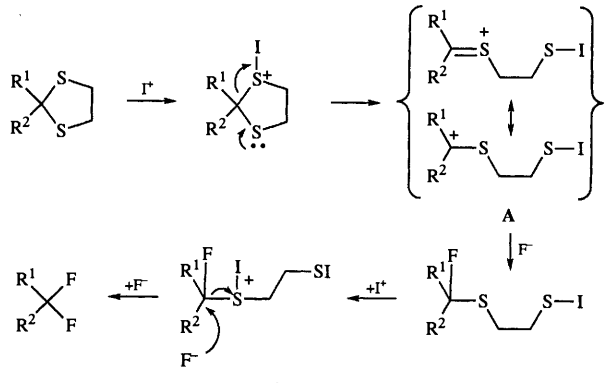
In this series of papers,[1] we are exploring the use of elemental fluorine in organic chemistry and here we report the conversion of 1,3-dithiolanes[2] and thioglycosides to the corresponding difluoromethylenes and glycosyl fluorides respectively. We also discovered that 1,3-dithiolanes undergo conversion to the parent carbonyls upon reaction with F_2 in wet acetonitrile, by a remarkably mild deprotection route.

Table 1 Reaction of diaryl 1,3-dithiolanes to give *gem*-difluoro compounds



1a–h **2a–h**

Thiolane	R^1	R^2	R^3	R^4	*gem*-Difluoride	Yield (%)
1a	H	H	H	H	**2a**	81
1b	Me	Me	H	H	**2b**	81
1c	Cl	H	H	H	**2c**	69
1d	Br	H	H	H	**2d**	87
1e	F	H	H	H	**2e**	84
1f	F	H	F	H	**2f**	74
1g	H	H	H	CF_3	**2g**	No reaction
1h	NO_2	H	H	H	**2h**	No reaction



Scheme 1

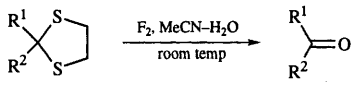
Results and discussion

A series of diaryl 1,3-dithiolanes **1a–f** were converted to the corresponding *gem*-difluoro compounds **2a–f** by simply passing fluorine gas, diluted to a 10% mixture in dry nitrogen (v/v), through a stirred solution of the thiolane and iodine in dry acetonitrile at room temperature (Table 1).

It is probable that the fluorinating agent is iodine monofluoride[16] generated *in situ* and that the mechanism of reaction with thiolanes (Scheme 1) involves carbocationic intermediates.[10,12] However, the exact nature of the fluorinating species in the present system has not been established. The results demonstrate that the presence of electron donating substituents in the aromatic ring clearly encourages the fluorination process whilst electron withdrawing groups inhibit reaction. Furthermore, substituents which can stabilise the intermediate carbocation **A** favour fluorination and hence the results are entirely consistent with the proposed mechanism.

We observed that if the solvent was not scrupulously dry, then this led to a dramatic reduction in the yield of the difluorinated products. Moreover, analysis of the product mixture revealed the presence of the starting ketone, rather than simply the unreacted 1,3-dithiolane. This is a remarkable finding for a reaction carried out under such mild conditions because deprotection of 1,3-dithiolanes to the parent carbonyls is notoriously difficult, and many reagents,[17] including positive halogen compounds (NBS–aqueous acetone),[18] HgO,[19]

Table 2 Deprotection of 1,3-dithiolanes with fluorine in aqueous MeCN

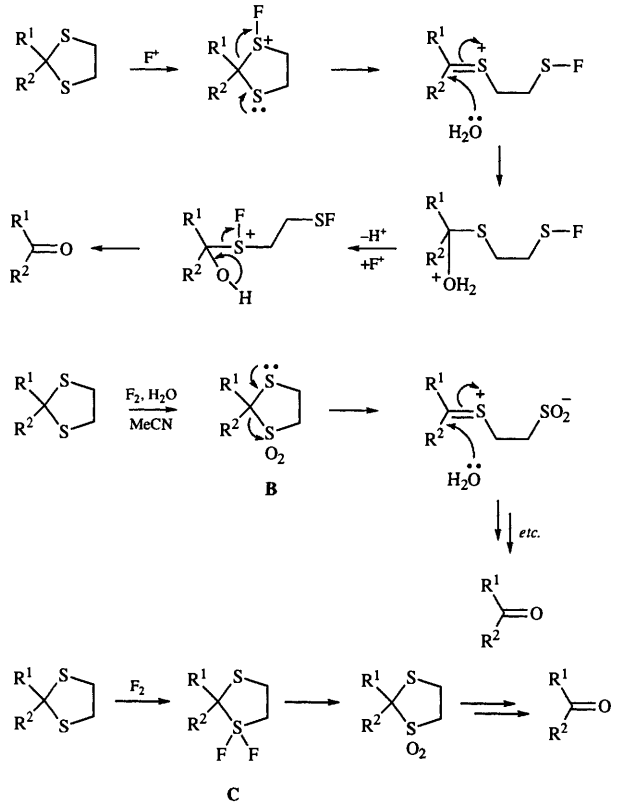


1a, c, i–l **3a–f**

Thiolane	R^1	R^2	Ketone	Yield (%)
1a	Ph	Ph	**3a**	89
1c	4-ClC_6H_4	Ph	**3b**	85
1i	Pr	Ph	**3c**	70
1j	Me	Bu	**3d**	79
1k	Et	Pentyl	**3e**	81
1l	$-(CH_2)_{11}-$		**3f**	81

DMSO at high temperature,[20] $Tl(NO_3)_3$,[21] SeO_2[22] and DDQ,[23] have been developed in an attempt to provide a general methodology for this synthetically useful transformation. Consequently, we have also explored the use of fluorine as an efficient deprotecting agent. Passing dilute fluorine through solutions of various 1,3-dithiolanes **1a,c,i–l** in aqueous acetonitrile gave the parent ketone and the results are collated in Table 2. This is a very simple procedure but it is clear that this is one of the most efficient methods reported so far. Furthermore, the examples illustrated in Table 2 demonstrate that the deprotection procedure is more general than the fluorination process described above.

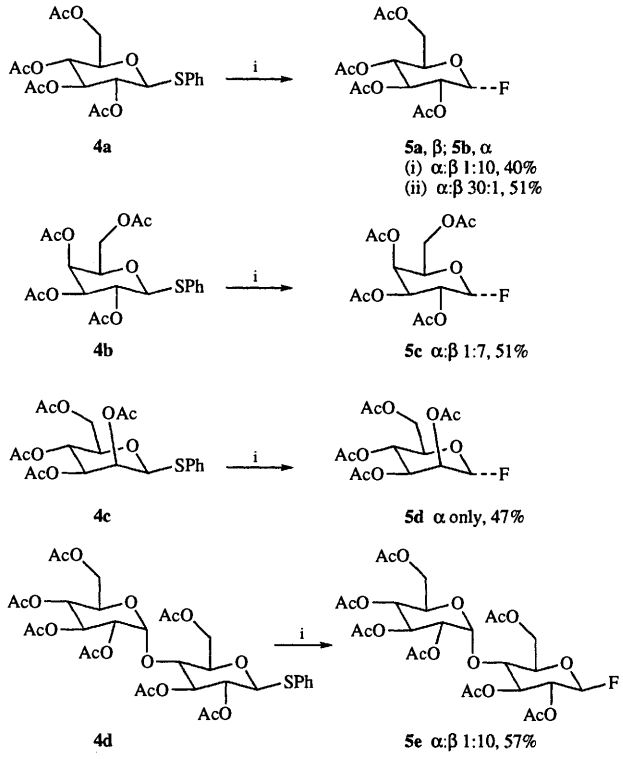
The mechanism of the deprotection reaction has not yet been fully established, although three possibilities are suggested (Scheme 2). First, the C–S bond may be weakened by the co-



Scheme 2

ordination of fluorine with sulfur followed by nucleophilic attack by water in a process analogous to the pathway outlined for fluorodesulfurisation in Scheme 1. Second, oxidation of the thiolane to a sulfoxide **B**, by a process similar to that reported by Rozen,[24] followed by ring opening, or finally, fluorination of the sulfur atom to an SF_2 species **C** followed by hydrolysis, are all possible reaction pathways.

Transformation of C–S bonds to C–F using fluorine could clearly be extended to other systems where intermediate stabilised carbocations can be generated. This is illustrated by the conversion of thioglycosides **4a–d** to synthetically useful[25] glycosyl fluorides **5a–e** in good yield by the fluorine–iodine method (Scheme 3). The proportion of α and β anomers formed



Scheme 3 *Reagents and conditions:* i, F_2, I_2, MeCN, room temp.; ii, F_2, I_2, MeCN, 4 Å molecular sieves, room temp.

can be determined by ^{19}F NMR,[26] in which the α and β anomers can be distinguished by chemical shift[26] (*e.g.* δ_F −150 for α-glucosyl fluoride **5b** and δ_F −142 for the β anomer **5a**), and is found to vary with the particular reaction conditions employed, suggesting that the product may be variously formed under either kinetic or thermodynamic control, depending on the reaction conditions. So far, however, under a variety of conditions, we have been unable to extend this methodology to systems derived from dialkyl or aryl alkyl ketones, where the corresponding intermediate carbocations (see Scheme 1) are less stable.

Experimental

All materials were either obtained commercially (Aldrich) or prepared by literature procedures; 1,3-dithiolanes **1a–l** from reaction of ketones with ethane-1,2-dithiol[27] and thioglycosides **4a–d** from the corresponding glycosyl bromides and benzenethiol.[28–31] All solvents were dried before use by literature procedures. NMR spectra were recorded in deuteriochloroform on either a Varian Gemini 200, a Varian VXR 400S or a Bruker AC250 NMR spectrometer with tetramethylsilane and trichlorofluoromethane as internal standards. In ^{19}F NMR spectra, upfield shifts are quoted as negative. *J* Values are given in Hz. Mass spectra were recorded on either a VG 7070E spectrometer or a Fisons VG Trio 1000 spectrometer coupled with a Hewlett-Packard 5890 series II gas chromatograph. IR spectra were recorded on a Perkin-Elmer 1600 FT IR spectrometer while elemental analyses were obtained on either a Perkin-Elmer 240 or a Carlo Erba

Elemental Analyser. Melting points were recorded at atmospheric pressure and are uncorrected.

Preparation of difluoromethylene compounds 2a–f

General procedure. A solution containing the 1,3-dithiolane **1a–h** (6 mmol) and iodine (14 mmol) in acetonitrile (40 ml) was placed in a PTFE reaction vessel. Elemental fluorine (14 mmol), diluted to a 10% mixture in dry nitrogen (v/v), was then passed through the stirred solution at a rate of 10 ml min^{-1}. The reaction mixture was then poured into a solution of 5% aqueous sodium metabisulfite (50 ml), and extracted with dichloromethane (3 × 50 ml). The organic extracts were washed sequentially with aqueous sodium hydrogen carbonate and water, then dried ($MgSO_4$). Solvent was removed under reduced pressure. Pure difluoromethylene products **2a–f** were isolated by flash column chromatography on silica gel using 9:1 hexane–diethyl ether as eluent. All yields quoted (Table 1) are for pure, isolated products which were homogeneous by GC–MS and spectral and physical data are consistent with the literature data.

Difluorodiphenylmethane[12] **2a.** A colourless liquid (81%); δ_H(200 MHz) 7.4 (m, Ar-H); δ_C(100 MHz) 120.7 (t, $^1J_{CF}$ 239.2, CF_2), 125.8 (t, $^3J_{CF}$ 5.7, Ar-C_{ortho}), 128.7 (s, Ar-C_{para}), 129.8 (t, $^4J_{CF}$ 1.7, Ar-C_{meta}), 137.7 (t, $^2J_{CF}$ 28.4, Ar-C_{ipso}); δ_F(235 MHz) −89.3 (s); *m/z* (EI^+) 204 (M^+, 92%), 183 (31), 127 (100), 77 (16), 51 (10).

1-(2,4-Dimethylphenyl)-1-phenyldifluoromethane[12] **2b.** A colourless liquid (81%); δ_H(200 MHz) 2.1 (3 H, s, CH_3), 2.2 (3 H, s, CH_3), 7.2–7.5 (8 H, m, Ar-H); δ_F(235 MHz) −86.7 (s); *m/z* (EI^+) 232 (M^+, 84%), 197 (34), 154 (100), 127 (36), 105 (18), 77 (13).

1-(4-Chlorophenyl)-1-phenyldifluoromethane[32] **2c.** A colourless liquid (69%); δ_H(200 MHz) 7.4–7.6 (m, Ar-H); δ_C(100 MHz) 120.3 (t, $^1J_{CF}$ 241.4, CF_2), 125.7 (t, $^3J_{CF}$ 5.0, Ar-C2′), 127.3 (t, $^3J_{CF}$ 5.0, Ar-C2), 128.5 (s, Ar-C4′), 128.6 (s, CCl), 130.0 (t, $^4J_{CF}$ 2.0, Ar-C3′), 136.0 (t, $^4J_{CF}$ 2.0, Ar-C3), 136.2 (t, $^2J_{CF}$ 30.2, Ar-C1), 137.1 (t, $^2J_{CF}$ 30.2, Ar-C1′); δ_F(235 MHz) −89.3 (s); *m/z* (EI^+) 240 (M^+, 20%), 238 (M^+, 56), 203 (76), 183 (47), 163 (34), 161 (89), 127 (100), 77 (30).

1-(4-Bromophenyl)-1-phenyldifluoromethane[12] **2d.** A colourless liquid (86%); δ_H(200 MHz) 7.2–7.5 (m, Ar-H); δ_C(100 MHz) 120.3 (t, $^1J_{CF}$ 242.2, CF_2), 124.4 (t, $^4J_{CF}$ 2.3, CBr), 125.8 (t, $^3J_{CF}$ 5.7, Ar-C2′), 127.6 (t, $^3J_{CF}$ 5.5, Ar-C2), 128.5 (s, Ar-C4′), 130.1 (t, $^4J_{CF}$ 1.9, Ar-C3), 131.7 (s, Ar-C3′), 136.9 (t, $^2J_{CF}$ 28.7, Ar-C1′), 137.3 (t, $^2J_{CF}$ 28.3, Ar-C1); δ_F(235 MHz) −89.6 (s); *m/z* (EI^+) 284 (M^+, 64%), 282 (M^+, 74), 207 (43), 205 (47), 203 (100), 183 (77), 127 (81), 77 (8), 75 (12).

1-(4-Fluorophenyl)-1-phenyldifluoromethane[12] **2e.** A colourless liquid (84%); δ_H(200 MHz) 7.0–7.7 (m, Ar-H); δ_C(100 MHz) 115.4 (d, $^2J_{CF}$ 21.7, Ar-C3), 120.4 (t, $^1J_{CF}$ 241.4, CF_2), 125.8 (t, ^3J 5.3, Ar-C2′), 128.1 (dt, $^3J_{CF}$ 8.7, $^3J_{CF}$ 5.5, Ar-C2), 128.5 (s, Ar-C4′), 130.0 (t, $^4J_{CF}$ 2.9, Ar-C3′), 133.7 (td, $^2J_{CF}$ 27.2, $^4J_{CF}$ 3.4, Ar-C1), 137.4 (t, $^2J_{CF}$ 28.3, Ar-C1′), 163.5 (d, $^1J_{CF}$ 249.4, C-F); δ_F(235 MHz) −88.0 (2 F, s, CF_2), −111.4 (1 F, s, Ar-F); *m/z* (EI^+) 222 (M^+, 100%), 201 (29), 183 (11), 145 (80), 127 (43), 95 (12), 51 (11).

Bis(4-fluorophenyl)difluoromethane[12] **2f.** A colourless liquid (74%); δ_H(200 MHz) 7.2–7.6 (m, Ar-H); δ_C(100 MHz) 115.6 (d, $^2J_{CF}$ 22.0, Ar-C_{meta}), 120.1 (t, $^1J_{CF}$ 241.8, CF_2), 128.1 (dt, $^3J_{CF}$ 8.4, $^3J_{CF}$ 5.4, Ar-C_{ortho}), 133.6 (td, $^2J_{CF}$ 28.9, $^4J_{CF}$ 3.3, Ar-C_{ipso}), 163.6 (dt, $^1J_{CF}$ 250.0, $^5J_{CF}$ 2.0, C-F); δ_F(235 MHz) −86.9 (2 F, s, CF_2), −111.1 (2 F, s, Ar-F); *m/z* (EI^+) 240 (M^+, 69%), 221 (30), 201 (14), 145 (100), 126 (19), 95 (12), 75 (10).

Conversion of 1,3-dithiolanes 1a,c,i–l to ketones 3a–f

General procedure. A solution containing a 1,3-dithiolane (6 mmol) **1a,c,i–l** and water (2 ml) in acetonitrile (35 ml) was placed in a PTFE reaction vessel. Fluorine (12 mmol) as a 10% mixture in nitrogen was passed through the solution, at a rate of 15 ml min^{-1}. The reaction mixture was poured into 10% aqueous sodium hydrogen carbonate and extracted with dichloromethane. The extract was washed sequentially with water and brine, dried ($MgSO_4$) and solvent was removed under reduced pressure. The ketones **3a–f** were purified by flash column chromatography on silica gel using a 9:1 hexane–diethyl ether system as eluent. All yields are quoted for pure, isolated products and given in Table 3. Spectral and physical properties of ketones **3a–f** were consistent with those of authentic samples (Aldrich Chemical Co.).

Preparation of glycosyl fluorides 5a–e

General procedure. Elemental fluorine (2.5 mmol), diluted to a 10% solution in nitrogen, was passed through a mixture of thioglycoside **4a–d** (1.7 mmol), iodine (0.43 g, 1.7 mmol) and 4 Å molecular sieves (if required) (1 g) in dry acetonitrile (15 ml). After the addition of fluorine was complete the solution was poured into 10% aqueous sodium metabisulfite and extracted with dichloromethane. The organic layer was washed sequentially with 10% aqueous sodium hydrogen carbonate and water, dried ($MgSO_4$) and evaporated to a thick yellow syrup. ^{19}F NMR analysis of the product mixture showed the anomeric (α:β) ratio[26] of the glycosyl fluorides (Scheme 3). Purification of the product mixture by column chromatography on silica gel with ethyl acetate–light petroleum (1:1) as eluent yielded pure samples of the major anomer of the glycosyl fluoride **5a–e** formed in each reaction.

Tetra-*O*-acetyl-β-D-glucopyranosyl fluoride[26] **5a.** (320 mg, 54%) White crystals; mp 87–88 °C (lit.,[26] 89 °C) from diethyl ether; $[\alpha]_D$ +20.8 (lit.,[26] $[\alpha]_D$ +20.0); R_F 0.52 (Found: C, 47.7; H, 5.55. Calc. for $C_{14}H_{19}O_9F$: C, 48.0; H, 5.4%); δ_H(400 MHz) 2.04, 2.05, 2.10, 2.11 (each 3 H, s, CH_3), 3.90 (1 H, ddd, $J_{4,5}$ 9.4, $J_{5,6a}$ 4.6, $J_{5,6b}$ 2.8, H5), 4.22 (1 H, dd, $J_{6a,6b}$ 12.4, $J_{5,6b}$ 2.8, H6b), 4.27 (1 H, dd, $J_{6a,6b}$ 12.4, $J_{5,6a}$ 4.6, H6a), 5.11 (1 H, m, H2), 5.21 (2 H, m, H3 and H4), 5.37 (1 H, dd, $^1J_{HF}$ 52.7, $J_{H1,H2}$ 5.4, H1); δ_C(100 MHz) 20.6 and 20.7 (s, CH_3 groups overlapping), 61.7 (s, C6), 67.4 (s, C4), 71.1 (d, $^2J_{CF}$ 28.6, C2), 71.8 (d, $^3J_{CF}$ 8.4, C3), 72.0 (d, $^3J_{CF}$ 4.2, C5), 106.2 (d, $^1J_{CF}$ 219.7, C1), 169.1, 169.3, 170.0 and 170.6 (s, C=O); δ_F(235 MHz) − 141.88 (dd, $^1J_{HF}$ 52.7, $^2J_{HF}$ 12.5, F1); *m/z* (CI^+, NH_3) 331 (M^+ − F, 100%).

Tetra-*O*-acetyl-α-D-glucopyranosyl fluoride[26] **5b.** (303 mg, 51%) White crystals; mp 109–112 °C (lit.,[26] 110–112 °C) from ethanol; R_F 0.57 (Found: C, 47.7; H, 5.6. Calc. for $C_{14}H_{19}O_9F$: C, 48.0, H, 5.4%); δ_H(400 MHz) 2.02, 2.04, 2.10 and 2.16 (all 3 H, s, CH_3), 4.18 (1 H, ddd, $J_{H5,H4}$ 10.5, $J_{H5,H6a}$ 4.0, $J_{H5,H6b}$ 2.0, H5), 4.15 (1 H, dd, $J_{H6a,H6b}$ 12.3, $J_{H6b,H5}$ 2.0, H6b), 4.29 (1 H, dd, $J_{H6a,H6b}$ 12.3, $J_{H6a,H5}$ 4.0, H6a), 4.95 (1 H, ddd, $J_{H2,F1}$ 23.6, $J_{H2,H3}$ 10.2, $J_{H2,H1}$ 3.0, H2), 5.15 (1 H, t, $J_{H4,H3}$ 9.6, H4), 5.49 (1 H, t, $J_{H3,H2}$ 10.2, H3), 5.75 (1 H, dd, $J_{H1,F1}$ 53.0, $J_{H1,H2}$ 3.0, H1); δ_C(100 MHz) 20.5, 20.6 and 20.7 (s, CH_3 overlapping), 61.2 (s, C6), 67.3 (s, C4), 69.4 (s, C3), 69.8 (d, $^3J_{CF}$ 4.2, C5), 70.2 (d, $^3J_{CF}$ 24.7, C2), 103.7 (d, $^1J_{CF}$ 229.6, C1), 169.4, 169.9, 170.0 and 170.6 (all s, C=O); δ_F(235 MHz) −150.22 (dd, $^1J_{HF}$ 53.0, $^2J_{HF}$ 23.6, F1); *m/z* (CI^+, NH_3) 368 (M^+ + 18, 100%).

Tetra-*O*-acetyl-β-D-galactopyranosyl fluoride[26] **5c.** (300 mg, 51%) White crystals; mp 101–103 °C (lit.,[26] 103–104 °C) from diethyl ether; R_F 0.45; δ_H(400 MHz) 2.01, 2.07, 2.11, 2.18 (all 3 H, s, CH_3), 4.06 (1 H, t, $J_{5,6}$ 6.5, H5), 4.21 (2 H, dd, $J_{5,6}$ 6.5, $J_{6a,6b}$ 1.6, H6), 5.05 (1 H, dd, $J_{2,3}$ 10.4, $J_{3,4}$ 3.2, H3), 5.26 (1 H, dd, J_{HF} 54.0, $J_{1,2}$ 7.2, H1), 5.42 (1 H, m, H4), 5.31 (1 H, m, H2); δ_C(100 MHz) 20.53, 20.60 and 20.67 (each s, CH_3 groups), 61.29 (s, C6), 66.37 (s, C4), 68.75 (d, $^2J_{CF}$ 24.8, C2), 69.89 (d, $^3J_{CF}$ 10.7, C3), 71.17 (d, $^3J_{CF}$ 4.5, C5), 107.08 (d, $^1J_{CF}$ 218.6, C1); δ_F(235 MHz, $CDCl_3$) −143.11 (dd, J_{HF} 54.0, J_{HF} 12.0).

Tetra-*O*-acetyl-α-D-mannopyranosyl fluoride[26] **5d.** (265 mg, 47%) A clear oil; R_F 0.52; δ_H(400 MHz) 2.1, 2.3, 2.6 and 2.9 (each 3 H, s, CH_3 groups), 4.12–4.20 (2 H, m, H5 and H6a), 4.30 (1 H, dd, $J_{6a,6b}$ 12.8, $J_{5,6b}$ 5.2, H6b), 5.32–5.36 (2 H, m, H3 and H4), 5.40 (1 H, m, H2), 5.58 (1 H, dd, $J_{H1,F}$ 48.4, $J_{H1,H2}$ 2.0, H1); δ_C(100 MHz) 20.54, 20.60 and 20.67 (each s, CH_3 groups), 61.83 (s, C6), 64.99 (s, C4), 67.63 (d, $^2J_{CF}$ 39.3, C2), 68.13 (s, C5), 70.85 (d, $^3J_{CF}$ 3.0, C-3), 104.70 (d, $^1J_{CF}$ 223.9, C1), 169.53,

169.62, 169.69 and 170.53 (each s, C=O groups); δ_F(235 MHz) −138.8 (d, J_{HF} 48.4, F1).

2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-β-D-glucopyranosyl fluoride 5e. (375 mg, 57%) White crystals; R_F 0.62; δ_H(400 MHz) 2.01, 2.03, 2.05, 2.06, 2.10, 2.11 and 2.12 (each 3 H, s, CH_3 groups), 3.99 (1 H, m, H5′), 4.01 (1 H, m, H5), 4.08 (1 H, dd, $J_{H6a',H6b'}$ 12.6, $J_{H5',H6a'}$ 2.4, H6a′), 4.16 (1 H, t, $J_{H4,H5}$ 8.4, H4), 4.22 (1 H, dd, $J_{H6a,H6b}$ 12.0, $J_{H5,H6b}$ 4.4, H6b), 4.25 (1 H, dd, $J_{H6a',H6b'}$ 12.6, $J_{H5',H6b'}$ 4.0, H6b′), 4.55 (1 H, dd, $J_{H6a,H6b}$ 12.0, $J_{H5,H6a}$ 3.2, H6a), 4.85 (1 H, dd, $J_{H2',H3'}$ 10.8, $J_{H1',H2'}$ 4.0, H2′), 4.95 (1 H, m, H2), 5.07 (1 H, t, $J_{H4',H5'}$ 10.0, H4′), 5.14 (1 H, t, $J_{H3,H4}$ 7.0, H3), 5.38 (1 H, t, $J_{H3',H4'}$ 10.0, H3′), 5.42 (1 H, d, $J_{H1',H2'}$ 4.0, H1′), 5.43 (1 H, dd, $J_{H1,F}$ 52.5, $J_{H1,H2}$ 4.8, *H1*); δ_C(100 MHz) 20.56, 20.60, 20.62, 20.69, 20.79 and 20.86 (each s, CH_3 groups), 61.49 (s, C6′), 62.64 (s, C6), 67.98 (s, C4′), 68.60 (s, C5′), 69.29 (s, C3′), 70.15 (s, C2′), 71.23 (d, $^2J_{CF}$ 31.6, C2), 71.97 (s, C4), 72.29 (s, C5), 74.02 (d, $^3J_{CF}$ 5.3, C3), 95.90 (s, C1′), 105.46 (d, $^1J_{CF}$ 219.7, C1), 169.36, 169.43, 169.98, 170.04, 170.45, 170.55 (each s, C=O groups); δ_F(376 MHz) −131.9 (dd, $^1J_{HF}$ 52.5, $^2J_{HF}$ 8.3, F1); *m/z* (CI^+, NH_3) 656 (M^+ + 18, 52%).

Acknowledgements

We thank BNFL Fluorochemicals Ltd. for financial support of this work and Dr H. Iman for experimental assistance.

References

1 Part 4, see R. D. Chambers, C. J. Skinner, M. J. Atherton and J. S. Moilliet, *J. Chem. Soc., Perkin Trans. 1*, 1996, 1659.
2 For a preliminary communication, see R. D. Chambers, G. Sandford and M. Atherton, *J. Chem. Soc., Chem. Commun.*, 1995, 177.
3 G. Resnati, *Tetrahedron*, 1993, **49**, 9385.
4 J. T. Welch, *Tetrahedron*, 1987, **43**, 3123.
5 R. E. Banks, B. E. Smart and J. C. Tatlow, *Organofluorine Chemistry. Principles and Commercial Applications*, Plenum Press, New York, 1994.
6 M. R. C. Gerstenburger and A. Haas, *Angew. Chem., Int. Ed. Engl.*, 1981, **20**, 647.
7 J. A. Wilkinson, *Chem. Rev.*, 1992, **92**, 505.
8 S. Rozen, M. Brand, D. Zamir and D. Hebel, *J. Am. Chem. Soc.*, 1987, **109**, 896.
9 T. B. Patrick, J. J. Schiebel and G. L. Cantrell, *J. Org. Chem.*, 1981, **46**, 3917.
10 S. C. Sondej and J. A. Katzenellenbogen, *J. Org. Chem.*, 1991, **51**, 3508.
11 M. Kuroboshi and T. Hiyama, *Synlett*, 1991, 909.
12 G. K. S. Prakash, D. Hoole, V. P. Reddy and G. A. Olah, *Synlett*, 1993, 691.
13 W. B. Motherwell and J. A. Wilkinson, *Synlett*, 1991, 191.
14 S. Caddick, W. B. Motherwell and J. A. Wilkinson, *J. Chem. Soc., Chem. Commun.*, 1991, 674.
15 M. Kuroboshi and T. Hiyama, *J. Synth. Org. Chem. Jpn.*, 1993, **51**, 1124.
16 S. Rozen and D. Zamir, *J. Org. Chem.*, 1991, **56**, 4695.
17 P. C. B. Page, M. B. van Niel and J. C. Prodger, *Tetrahedron*, 1989, **45**, 7643.
18 E. J. Corey and B. W. Erickson, *J. Org. Chem.*, 1971, **36**, 3553.
19 Q. N. Porter and J. H. P. Utley, *J. Chem. Soc., Chem. Commun.*, 1978, 255.
20 C. Srinivasa Rao, H. I. Chandrasekharam and H. Junjappa, *Tetrahedron Lett.*, 1992, **33**, 8163.
21 K. Fuji, K. Ichikawa and E. Fujita, *Tetrahedron Lett.*, 1978, **19**, 3561.
22 S. A. Haroutouian, *Synthesis*, 1995, 39.
23 L. Mathew and S. Sankararaman, *J. Org. Chem.*, 1993, **58**, 7576.
24 S. Rozen and Y. Bareket, *Tetrahedron Lett.*, 1994, **35**, 2099.
25 T. Benneche, *Synthesis*, 1995, 1.
26 L. D. Hall, J. F. Manville and N. S. Bhacca, *Can. J. Chem.*, 1969, **47**, 1.
27 B. S. Ong, *Tetrahedron Lett.*, 1980, **21**, 4225.
28 R. L. Whistler and M. L. Wolfrom, eds., *Methods in Carbohydrate Chemistry*, Academic Press, New York, 1963.
29 A. B. Landge, T. R. Ingle and J. L. Bose, *Indian J. Chem.*, 1969, **7**, 1200.
30 F. D. Tropper, F. O. Andersson and C. Grand-Maitre, *Synthesis*, 1991, 734.
31 T. Kametani, K. Kawamura and T. Honda, *J. Am. Chem. Soc.*, 1987, **109**, 3010.
32 F. Mathey and J. Bensoam, *Tetrahedron*, 1975, **31**, 391.

Paper 6/01452F
Received 29*th February* 1996
Accepted 3*rd May* 1996