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Note

Synthesis of 2,3- or 1,2-unsaturated derivatives of 2-deoxy-2-trifluoromethylhexopyranoses ☆

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Abstract—The attempted conversion, by treatment with CsF/TBFA in MeCN, of acetylated derivatives of 2-chlorodifluoromethyl-2-deoxyhexopyranoses into their corresponding 2-trifluoromethyl derivatives was always accompanied by an elimination reaction. Thus, representative educts with the D-*gluco*- and D-*manno*-configuration gave derivatives of 2,3-dideoxy-2-trifluoromethyl-D-*erythro*-hex-2-enopyranose and 1,5-anhydro-2-deoxy-2-trifluoromethyl-D-*arabino*-hex-1-enitol, respectively. X-ray analyses are given for 1,3,4,6-tetra-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-α-D-mannopyranose and 4,6-di-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-α-D-*erythro*-hex-2-enopyranose.

Keywords: Unsaturated sugars; Trifluoromethylated sugars; Trifluoromethylated anhydrohex-1-enitols; Nucleophilic fluorination; Glycals

Interest in fluorinated analogues of natural substances is increasing continuously, with applications mainly directed towards bioorganic chemistry.[2–5] The interest in fluorinated carbohydrates where fluorine is attached to an alkyl substituent has appeared much more recently; for a recent review see Ref. 6. Trifluoromethyl substituted carbohydrates are very attractive species of physiological interest. Especially, 2-trifluoromethyl substituted carbohydrates are even stabilized at their anomeric centre by the fluorinated moiety. The choice of effective methods suitable for a selective introduction of trifluoromethyl groups into natural substances is as ever small.[6,7] One of the convenient strategies is the dithionite-mediated addition of CBr_2F_2 or $CBrClF_2$ to glycals followed by a nucleophilic fluorination of the introduced CF_2–X-group by fluoride ions. Whereas the addition procedure has been repeatedly demonstrated with various glycals,[8–10] the subsequent halogen exchange was only reported for two CF_2Br-substituted monosaccharides.[8] As part of our ongoing efforts in the synthesis of new trifluoromethylated analogues of natural substances, we investigated the exchange of chloride by fluoride in 2-chlorodifluoromethyl substituted monosaccharides using a TBAF/CsF reagent combination. The starting materials **2**,[9] **3**, **5**,[9] **6**[9] and **7** were synthesized as reported in a previous paper[9] and as shown in the Scheme 1, respectively. However, our statement in Ref. 9 about the high stereoselectivity of the chlorodifluoromethylation of glycals has to be corrected by latest findings. Firstly, *gluco* as well as *manno*-configurated diastereomers are formed from glucal **1** and secondly, the reaction is sensitive to modifications of the synthesis protocol. As shown in Scheme 1, an unsaturated secondary product, 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-chlorodifluoromethyl-2-deoxy-D-*arabino*-hex-1-enitol (**5**), which shows exactly the same R_f-value as the starting material **1**, was now additionally detected. The latter is probably formed from a glycosyl bromide precursor. It is to mention in this connection that TLC controls during the reaction indicated the presence of a relatively reactive intermediate (temporary spot), which was not isolable. Presumably, this intermediate is a

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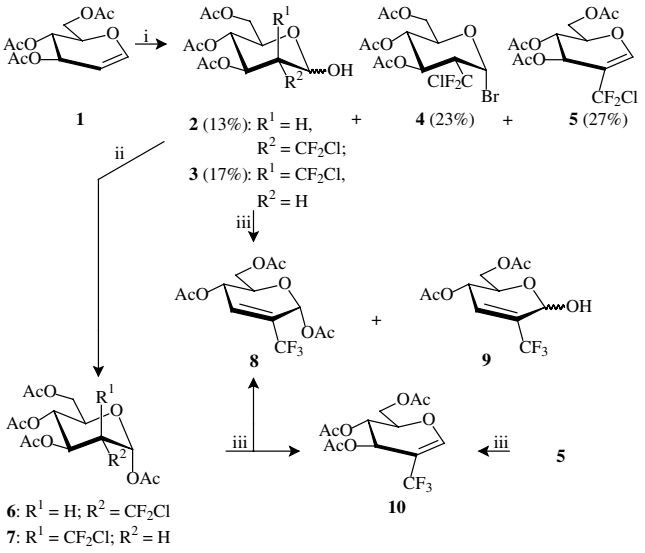


Scheme 1. Reagents and conditions: (i) $CBrClF_2$, $Na_2S_2O_4$, $NaHCO_3$, $MeCN/H_2O$, −10 °C to rt, 8–9 h; (ii) Ac_2O, pyridine, 12 h, rt; (iii) CsF, Bu_4NF, MeCN, 2 h, rt.

D-mannopyranosyl bromide, possibly the reactive precursor of products **3** and **5**.

The pyranose derivatives **2** and **3** accumulate as one column chromatographic fraction, and are relatively difficult to separate, whereas separation of the corresponding 1-*O*-acetyl-derivatives is more easy. The two crystalline diastereomers **6** and **7**, generated by acetylation of **2** and **3**, respectively, were suitable for X-ray analyses. Their molecular structures are presented in Ref. 9 (α-D-*gluco*-derivative **6**) and in Figure 1 (α-D-*manno*-derivative **7**).

The conversion of chlorodifluoromethyl groups into trifluoromethyl groups was realized by treatment of compounds **2**, **3**, **6** and **7** with the reagent combination TBAF/CsF in dry acetonitrile. Because fluoride ions are strong bases but relatively bad nucleophiles, the fluorinations were always accompanied by β-elimination reactions, so that exclusively unsaturated trifluoromethyl derivatives were obtained. The fluorination of a mixture of **2** and **3** yielded two trifluoromethyl substituted products, the pseudoglycals **8** (18%) and **9** (25%) (Scheme 1). The location of the acetyl group in **8** is surprising. The same 2-enopyranose derivative **8** (43%) is obtained besides 1-enitol **10** (9%) on treatment of a mixture of the 1-*O*-acetyl derivatives **6** and **7** with TBAF/CsF (Scheme 1).

It is noteworthy that all TBAF/CsF batches should be worked up after about 2 h, because overstepping of this reaction time reduces the yields of the desired products due to secondary reactions. This means that ~6–24% of unreacted starting material has to be accepted. A comparative study starting with the single compounds **6** and **7**, respectively, has shown that the fluorination proceeds faster in the case of the D-*manno*-derivative **7**. Indeed the maximum yields of **8** (43%) and **10** (9%) are similar as for the mixture of **6** and **7**; with 6% of recovered starting material in the case of the D-*manno*-derivative **7** and 24% in the case of the D-*gluco*-derivative **6**.

Furthermore, it is noteworthy that the activity of fluoride ions is very sensitive towards moisture and that a combination of TBAF and CsF gave always better yields of the desired products than CsF or TBAF alone.

The inclusion of the 2-chlorodifluoromethyl derivative **5** in the investigations with TBAF/CsF should help to clear, whether the fluorination follows the pathway in Scheme 2 reported in former papers,[8,11] or whether an 'allylic' positioned chloride (like that of the chlorodifluoromethyl group in **5**) is likewise reactive enough to achieve fluorination. The result is that the weakly nucleophilic but strongly basic fluoride ions give only

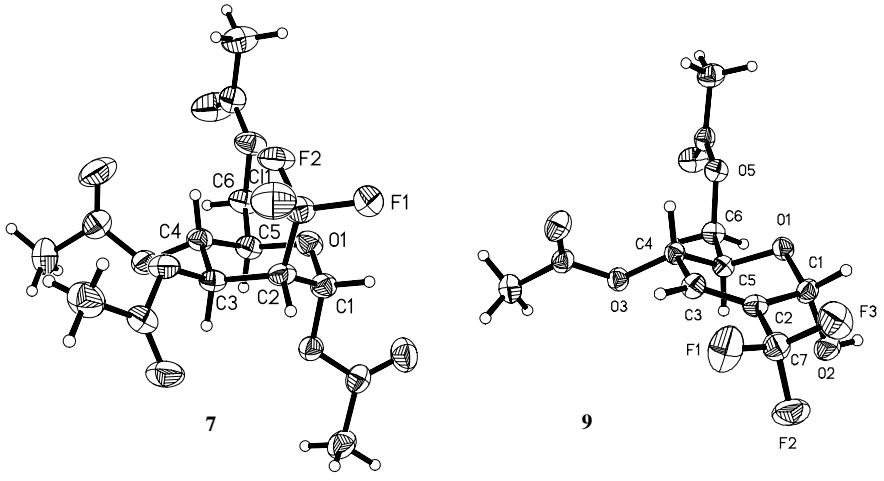
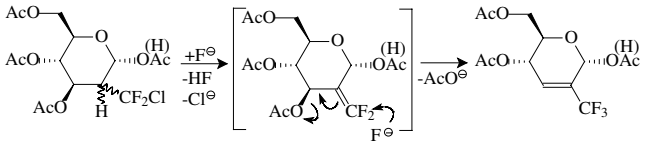


Figure 1. Molecular structures of 1,3,4,6-tetra-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-α-D-mannopyranose (**7**) and 4,6-di-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-α-D-*erythro*-hex-2-enopyranose (**9α**) with 50% probability for the thermal ellipsoids.



Scheme 2. Possible fluorination pathway for **2/3**.

about 2% yield of the desired product **10** besides a nonidentified by-product (6%); 63% of the starting material **5** were recovered. This behaviour is a strong argument for the sequence depicted in Scheme 2. Only strong nucleophiles are able to replace the chloride of **5** as shown by heating the compound in a 1% methanolic sodium methoxide yielding a carboxylic acid ester function from the chlorodifluoromethyl group.[9]

The structures of the new compounds **3**, **7**–**10** are supported by their ^{1}H, ^{13}C and ^{19}F NMR spectra. The signal assignment in the ^{1}H and ^{13}C NMR spectra was performed by recording DEPT and two-dimensional ^{1}H, ^{1}H and ^{13}C, ^{1}H correlation spectra. For the CF_2Cl-substituted monosaccharides **3** and **7**, the triplet ($^{2}J_{C\text{-}2,F} \approx 21$ Hz) of the ring C-atom 2 at δ 52.1 and 50.5 ppm, respectively, as well as the triplet ($^{1}J_{C,F}$ 296–297 Hz) of the CF_2Cl-group (δ 128.3 and 127.5 ppm, respectively) is characteristic. The ^{19}F doublets of the CF_2Cl-group were found for **3** at δ −47.2 and −49.3 ppm and for **7** at δ −48.0 and −49.7 ppm with geminal F–F-couplings of 171–175 Hz. The trifluoromethyl group of the unsaturated sugars **8**, **9** and **10** gives ^{19}F singlets at −66.1 (**8**), −66.2 (**9**) and −63.3 ppm (**10**), respectively.

X-ray analyses confirm the $^{4}C_1$ chair conformation of the 2-chlorodifluoromethyl derivatives **6**[9] and **7** (Fig. 1). The crystals of compound **7** contain two independent molecules within the asymmetric unit; for the puckering parameters[12] of these six-membered rings see Table 1. The C–C-bond length between the ring C-atom and the carbon atom of the CF_2Cl-groups is 152.1(7) pm in the case of the *gluco*-derivative **6** and for the *manno*-diastereomer **7** the distances are 152.3(3) and 152.4(3) pm.

Crystals suitable for an X-ray analysis were obtained from the syrupy mixture of 4,6-di-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-α/β-D-*erythro*-hex-2-enopyranose (**9**). The α-anomer (Fig. 1) crystallized from toluene on evaporation of the solvent at room temperature. The length of the C–C-double bond is 132.2 (2) pm and the distance of C-atom 2 and CF_3-group is 150.0 (2) pm.

CCDC 233308 (**7**) and CCDC 237090 (**9α**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033; e-mail: deposit@ccdc.cam.ac.uk).

Table 1. Puckering parameter of compound **7**

Compound	Puckering amplitude (Q)/Å	Θ(°)	ϕ(°)
7/ring 1	0.544 (2)	7.2 (2)	2.3 (2)
7/ring 2	0.548 (2)	83.9 (18)	114 (5)
9	0.534 (1)	53.1 (2)	319.7 (2)

1. Experimental

1.1. General

Column chromatography: particle size for silica gel 63–200 μm; thin layer chromatography (TLC): E. Merck Silica Gel 60 F_{254} foils; NMR: BRUKER equipments AC 250 and ARX 300; internal standard TMS. Melting points were measured using a polarising microscope Leitz (Laborlux 12 Pol) equipped with a hot stage (Mettler FP 90). Chemicals: CsF (Fluka), TBAF 1.1 M in THF (Aldrich).

For the X-ray structure determination of **7**, an X8 Apex with CCDC area detector and Mo-Kα-radiation ($\lambda = 0.71073$ Å, graphite monochromator) was used. The structure was solved by direct methods (SHELXS-97[13]). The refinement was done by the full-matrix least-squares method of Bruker SHELXTL, Vers.5.10, Copyright 1997, Bruker Analytical X-ray Systems. All nonhydrogen atoms were refined anisotropically. The hydrogen atoms were put into theoretical positions and refined using the riding model.

1.1.1. 3,4,6-Tri-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-D-glucopyranose (2) and 3,4,6-tri-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-D-mannopyranose (3), 3,4,6-tri-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-α-D-glucopyranosyl bromide (4) and 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-chlorodifluoromethyl-2-deoxy-D-*arabino*-hex-1-enitol (5). To a stirred soln of 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-deoxy-D-*arabino*-hex-1-enitol (3,4,6-tri-*O*-acetyl-D-glucal (**1**, 2.72 g, 10 mmol) in 2:1 MeCN–water (60 mL) kept under Ar for 1 h, $NaHCO_3$ (4.0 g) was added and the resulting suspension was cooled to −10 °C (Ar). Subsequently, an excess of $CBrClF_2$ was condensed into the mixture using an acetone–dry ice cooled trap and $Na_2S_2O_4$ (1.74 g, 10 mmol) was added. Then the mixture was allowed to warm up to ~20–22 °C within 2–3 h to achieve continuous refluxing. After 1 h the addition of $Na_2S_2O_4$ (1.74 g) was repeated, and again after further 3 h, while stirring was continued for a further 1 h. Diethyl ether (40 mL) and water (40 mL) were then added. The organic phase was separated, washed with brine (2 × 20 mL), dried (Na_2SO_4) and concentrated under diminished pressure. The syrupy residue (3.4 g), which showed 4 spots on TLC (3:1 toluene–EtOAc), was

separated by column chromatography (9:1 toluene–EtOAc) yielding successively **2** (0.50 g, 13%), colourless syrup, R_f 0.26 (3:1 toluene–EtOAc), ^{1}H, ^{13}C and ^{19}F NMR spectra of **2** were identical with those given for the compound in Ref. 9; **3** (0.62 g, 17%), colourless syrup, R_f 0.21 (3:1 toluene–EtOAc); **4** (1.02 g, 23%), colourless syrup, R_f 0.52 (3:1 toluene–EtOAc), ^{1}H, ^{13}C and ^{19}F NMR spectra of **4** were identical with those given for the compound in Ref. 9; **5** (0.96 g, 27%), colourless syrup, R_f 0.46 (3:1 toluene–EtOAc), ^{1}H, ^{13}C and ^{19}F NMR spectra of **5** were identical with those given for the compound in Ref. 9.

Compound **3**: ^{1}H NMR (250 MHz, $CDCl_3$): δ 5.71 (d, 1H, $J_{1,2} \approx 2.4$ Hz, H-1), 5.48 (dd, 1H, $J_{2,3} \approx 5.3$, $J_{3,4} \approx 8.7$ Hz, H-3), 5.39 (t, 1H, $J_{3,4} \approx 8.7$ Hz, H-4), 4.19 (dd, $J_{5,6a} \approx 7.2$, $J_{6a,6b} \approx 14.3$ Hz, H-6a), 4.11 (dd, 2H, $J_{5,6b} \approx 7.2$, $J_{6a,6b} \approx 14.3$ Hz, H-5, H-6b), 3.46 (br s, 1H, OH, HO-1), 3.33–3.18 (m, 1H, H-2), 2.07, 2.06, 2.03 (3s, 9H, $3\times CH_3$); ^{13}C NMR (63 MHz, $CDCl_3$): δ 171.3, 170.5, 169.9 ($3\times C{=}O$), 128.3 (t, $J_{C,F} \approx 297$ Hz, CF_2Cl), 91.4 (t, $J_{C,F} \approx 4$ Hz, C-1), 69.0 (C-3), 66.9 (C-4), 62.9 (C-6), 61.9 (C-5), 52.1 (t, $J_{C,F} \approx 21$ Hz, C-2), 21.2, 21.1, 21.1 ($3\times CH_3$); ^{19}F NMR (235 MHz, $CDCl_3$): δ −47.2 (d, $J_{F_a,F_b} \approx 171$ Hz, F_a), −49.3 (d, $J_{F_a,F_b} \approx 171$ Hz, F_b). Anal. Calcd for $C_{13}H_{17}ClF_2O_8$ (374.72) C, 41.67; H, 4.57. Found C, 41.66; H, 4.72.

1.1.2. 1,3,4,6-Tetra-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-α-D-glucopyranose (6) and 1,3,4,6-tetra-*O*-acetyl-2-chlorodifluoromethyl-2-deoxy-α-D-mannopyranose (7).

A crude 1:1.3 mixture of **2/3** (1.13 g, 3.0 mmol) was dissolved in Ac_2O (10 mL) at rt followed by dropwise addition of pyridine (10 mL) with stirring. Stirring was continued overnight. Then, the soln was concentrated under diminished pressure and the crystalline mixture of **6/7** (1.20 g) was separated by column chromatography yielding successively: **6**, (0.44 g, 35%), colourless crystals ($CHCl_3$), mp 99 °C, R_f 0.58 (1:1 heptane–EtOAc) and **7**, (0.56 g, 45%), colourless crystals (pentane), mp 88 °C, R_f 0.46 (1:1 heptane–EtOAc), $[\alpha]_D^{22}$ +42.2 (*c* 1.08, $CHCl_3$).

Compound **6**: ^{1}H NMR (300 MHz, $CDCl_3$)[†]: δ 6.51 (d, 1H, $J_{1,2} \approx 3.4$ Hz, H-1), 5.75 (dd, 1H, $J_{2,3} \approx 11.2$, $J_{3,4}$ 9.3 Hz, H-3), 5.11 (dd, 1H, $J_{3,4} \approx 9.3$, $J_{4,5} \approx 10.3$ Hz, H-4), 4.30 (dd, 1H, $J_{5,6a} \approx 4.2$, $J_{6a,6b} \approx 12.7$ Hz, H-6a), 4.13–4.02 (m, 2H, H-5, H-6b), 3.17–3.03 (m, 1H, H-2), 2.15, 2.07, 2.03, 2.03 (4s, 12H, $4\times CH_3$).

Compound **7**: ^{1}H NMR (250 MHz, $CDCl_3$): δ 6.57 (d, 1H, $J_{1,2} \approx 3.0$ Hz, H-1), 5.43 (dd, 1H, $J_{2,3} \approx 4.8$, $J_{3,4} \approx 7.8$ Hz, H-3), 5.40 ('t', 1H, $J_{3,4} \approx J_{4,5} \approx 7.8$ Hz, H-4), 4.18 (d, 2H, $J_{5,6} \approx 4.0$ Hz, H-6a, H-6b), 4.08–3.99 (m, 1H, H-5), 3.29-3.15 (m, 1H, H-2), 2.15, 2.07, 2.07, 2.05 (4s, 12H, $4\times CH_3$); ^{13}C NMR (63 MHz, $CDCl_3$): δ 170.7, 170.0, 169.3, 168.3 ($4\times C{=}O$), 127.5 (t, $J_{C,F} \approx 295$ Hz, CF_2Cl), 89.8 (t, $J_{C,F} \approx 4.3$ Hz, C-1), 70.8 (C-5), 68.3 (C-3), 66.1 (C-4), 62.4 (C-6), 50.5 (t, $J_{C,F} \approx 21$ Hz, C-2), 21.0, 20.9, 20.8, 20.7 ($4\times CH_3$); ^{19}F NMR (235 MHz, $CDCl_3$): δ −48.0 (d, $J_{F_a,F_b} \approx 175$ Hz, F_a), −49.7 (d, $J_{F_a,F_b} \approx 175$ Hz, F_b). Anal. Calcd for $C_{15}H_{19}ClF_2O_9$ (416.76): C, 43.23; H, 4.60. Found C, 43.52; H, 4.75.

[†] The ^{1}H NMR spectrum of **6** was corrected from mistakes in Ref. 9.

1.2. Nucleophilic fluorination—General procedure

To a soln of the crude 1:1.3 diastereoisomeric mixture of **2/3** or **6/7**, respectively, (1.4 mmol), in dry MeCN (10 mL), CsF (0.26 g, 1,68 mmol) was added with stirring and careful exclusion of humidity under Ar. After cooling the suspension to 0 °C, TBAF (2.5 mL, 1.1 M in THF) was added and stirring was continued for 2 h at rt. Diethyl ether (30 mL) was then added and the mixture was washed with a saturated aq NaCl/$CaCl_2$ soln (2×20 mL), dried (Na_2SO_4) and concentrated under diminished pressure. The residue was purified by column chromatography (4:1, heptane–EtOAc) yielding successively and, respectively, either **8/9** or **8/10**.

1.2.1. 1,4,6-Tri-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-α-D-*erythro*-hex-2-enopyranose (8) and 4,6-di-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-D-*erythro*-hex-2-enopyranose (9).

From **2/3** (0.52 g), a syrupy crude product was obtained. After chromatographic separation, 86 mg (18%) of **8**: colourless syrup, R_f 0.41 (1:1 heptane–EtOAc), $[\alpha]_D^{21}$ +63.6 (*c* 1.23, $CHCl_3$) and 104 mg (25%) of **9**: colourless syrupy crystals, R_f 0.33 (1:1 heptane–EtOAc) were obtained. Some crystals of the pure α-anomer of **9** could be obtained from a toluene soln of the α/β anomeric mixture of **9** by evaporation of the solvent at rt, mp 97.5–99.5 °C.

Compound **8**: ^{1}H NMR (250 MHz, $CDCl_3$): δ 6.60 (br s, 1H, $J_{3,4} \approx 1.4$ Hz, H-3), 6.54 (s, 1H, H-1), 5.53–5.44 (m, 1H, H-4), 4.28–4.20 (m, 2H, H-6a, H-6b), 4.20 (dd, 1H, $J_{4,5} \approx 2.5$, $J_{5,6} \approx 9.8$ Hz, H-5), 2.14, 2.14, 2.08 (3s, 9H, $3\times CH_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.8, 170.0, 168.9 ($3\times C{=}O$), 134.0 (C-3), 129.0 (q, $J_{C,F} \approx 32$ Hz, C-2), 121.4 (q, $J_{C,F} \approx 273$ Hz, CF_3), 84.7 (C-1), 68.4 (C-5), 63.8 (C-4), 62.1 (C-6), 20.7, 20.7, 20.6 ($3\times CH_3$); ^{19}F NMR (235 MHz, $CDCl_3$): δ −66.1 (s, CF_3). Anal. Calcd for $C_{13}H_{15}F_3O_7$ (340.25): C, 45.89; H, 4.44. Found: C, 45.97; H, 4.59.

Compound **9**: ^{1}H NMR (250 MHz, $CDCl_3$): δ 6.50–6.46 (m, 1H, $J_{3,4} \approx 3.2$ Hz, H-3), 5.62 (s, 1H, H-1), 5.47–5.37 (m, 1H, $J_{3,4} \approx 3.2$ Hz, H-4), 4.26 (m, 2H, H-5, H-6a), 4.12 (dd, $J_{5,6} \approx 4.6$, $J_{6a,6b} \approx 12.2$ Hz, H-6b), 3.51 (br s, 1 H, OH, OH-1), 2.13, 2.10 (2s, 6H, $2\times CH_3$); ^{13}C NMR (125 MHz, $CDCl_3$): δ 170.9, 170.2 ($2\times C{=}O$), 132.6 (q, $J_{C,F} \approx 5$ Hz C-3), 131.2 (q, $J_{C,F} \approx 32$ Hz, C-2), 121.7 (q, $J_{C,F} \approx 274$ Hz, CF_3), 87.1 (C-1), 66.5 (C-5), 64.3 (C-4), 62.5 (C-6), 20.9, 20.8 ($2\times CH_3$); ^{19}F NMR (235 MHz, $CDCl_3$): δ −66.2 (s, CF_3). Anal. Calcd for $C_{11}H_{13}F_3O_6$ (298.22): C, 44.30; H, 4.39. Found: C, 44.58; H, 4.53.

1.3. 1,4,6-Tri-*O*-acetyl-2,3-dideoxy-2-trifluoromethyl-α-D-*erythro*-hex-2-enopyranose (8) and 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-deoxy-2-trifluoromethyl-D-*arabino*-hex-1-enitol (10)

From **6/7** (0.58 g), 227 mg (53%), ratio 4.8:1 (^{1}H NMR); **8**: 184 mg (44%), colourless syrup, R_f 0.41 (1:1 heptane–EtOAc); **10**: 43 mg (9%), colourless syrup, R_f 0.41 (1:1 heptane–EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.20–7.18 (m, 1H, H-1), 5.66–5.64 (m, 1H, H-3), 5.17 ('t', 1H, $J_{3,4} \approx J_{4,5} \approx 3.3$ Hz, H-4), 4.52–4.48 (m, 1H, H-5), 4.44 (d, 1H, $J_{6a,6b} \approx 11.6$ Hz, H-6a), 4.18 (dd, 1H, $J_{5,6b} \approx 4.0$, $J_{6a,6b} \approx 11.6$ Hz, H-6b), 2.09, 2.09, 2.07 (3s, 9H, $3\times CH_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.3, 169.3, 169.3 ($3\times C{=}O$), 148.2 (q, $J_{C,F} \approx 9$ Hz, C-1), 125.9 (q, $J_{C,F} \approx 281$ Hz, CF_3), 107.1 (d, $J_{C,F} \approx 25$ Hz, C-2), 74.2 (C-5), 65.8 (C-4), 61.8 (C-3), 60.9 (C-6), 20.8, 20.7, 20.6 ($3\times CH_3$); ^{19}F NMR (235 MHz, $CDCl_3$): δ −63.3 (s, CF_3). Anal. Calcd for $C_{13}H_{15}F_3O_7$ (340.25): C, 45.89; H, 4.44. Found: C, 45.43; H, 4.22.

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References

1. Schwäbisch, D.; Hein, M.; Miethchen, R. *J. Fluorine Chem.* **2004**, *125*, 119–124.
2. Tsuchiya, T. *Adv. Carbohydr. Chem. Biochem.* **1990**, *48*, 91–277.
3. *Fluorine in Bioorganic Chemistry*; Welch, J. T., Eswarakrishnan, S., Eds.; J. Wiley & Sons: New York, 1991.
4. Riess, J. G.; Greiner, J. In *Carbohydrates as Organic Raw Materials II*; Descotes, G., Ed.; VCH: Weinheim, 1993; p 209.
5. Kissa, E. In *Fluorinated Surfactants and Repellents*, 2nd ed.; *Surfactant Science Series*; Marcel Dekker: New York, 2001; 97.
6. Plantier-Royon, R.; Portella, C. *Carbohydr. Res.* **2000**, *327*, 119–146, and papers cited therein.
7. McClinton, M. A.; McClinton, D. A. *Tetrahedron* **1992**, *48*, 6555–6666.
8. Miethchen, R.; Hein, M.; Reinke, H. *Eur. J. Org. Chem.* **1998**, 919–923.
9. Tews, S.; Miethchen, R.; Reinke, H. *Synthesis* **2003**, 707–716, Erratum: *Synthesis* (2003) 1136.
10. Miethchen, R.; Tews, S.; Shaw, A. K.; Röttger, S.; Reinke, H. *J. Carbohydr. Chem.* **2004**, *23*, 147–161.
11. Rico, J.; Cantacuzene, D.; Wakselman, C. *Tetrahedron Lett.* **1981**, *22*, 3405–3408.
12. Cremer, D.; Pople, J. A. *J. Am. Chem. Soc.* **1975**, *97*, 1354–1358.
13. Sheldrick, G. M. Universität Göttingen, 1997.