Tetrahedron 64 (2008) 10497–10500

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Synthesis of 2,3-unsaturated glycosides via metal-free Ferrier reaction

Kavita De, Julien Legros, Benoit Crousse *, Danièle Bonnet-Delpon

Laboratoire BioCIS-CNRS, Faculté de Pharmacie, Univ Paris Sud, rue JB Clément, F-92296 Chatenay-Malabry, France

ARTICLE INFO

Article history:
Received 21 July 2008
Received in revised form 2 September 2008
Accepted 3 September 2008
Available online 11 September 2008

Keywords:
Fluorine
Hexafluoropropan-2-ol
Sugar
Glycals

ABSTRACT

Hexafluoroisopropanol (HFIP) is explored as an effective medium for the synthesis of 2,3-unsaturated glycosides through allylic rearrangement of 3,4,6-tri-*O*-acetyl glucal. This metal-free, exclusively solvent-promoted Ferrier glycosylation, affords products in good to excellent yields and with good α-selectivity.

1. Introduction

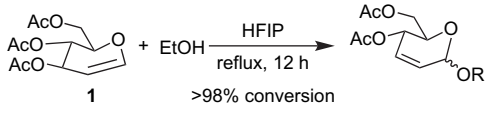
2,3-Unsaturated-*O*-glycosides are useful chiral intermediates in the synthesis of a variety of important compounds: nucleosides,[1] antibiotics[2] and several biologically active natural products.[3] One elegant way to synthesize these molecules goes through an acid-catalyzed Ferrier reaction between a glycal and an alcohol as nucleophile.[4] After the pioneer work of Ferrier and Prasad who used $BF_3 \cdot Et_2O$,[4c] numerous examples involving either Lewis or Brønsted acids have been described.[5] In order to obtain greener and safer processes, avoiding heavy metals is a current target for synthetic chemists. In this line, we[6] and others[7] have demonstrated the usefulness of fluorous alcohols as reaction solvent: various useful organic transformations can be conducted in trifluoroethanol (TFE) or hexafluoroisopropanol (HFIP) under mild conditions, without using any external promoter. Reactions are generally selective and without effluents, allowing thus a facile isolation of the product and a recovery of the solvent by distillation. In some rare cases, fluoroalcohols can be involved in the reaction;[8,9] in particular we recently reported the facile self-promoted addition of HFIP onto the 3,4,6-tri-*O*-acetyl glucal through Ferrier reaction, by simple heating of the substrate in the fluoro alcohol.[9] We now found out that performing the same reaction, still in HFIP, but also in presence of another alcohol, led to the selective addition of the latter onto the acetyl glucal to yield the corresponding Ferrier product.

2. Results and discussion

According to our previous work on the competitive addition of alcohols on enol ethers in HFIP,[9] it seemed reasonable to envision that using a more nucleophilic alcohol ROH in this reaction should create a competition with HFIP, and the fluorinated solvent should thus just act as a promoter to facilitate the addition of ROH. For this purpose, the reaction was first assessed with ethanol as nucleophilic partner by adding various amounts to a solution of 3,4,6-tri-*O*-acetyl glucal **1** HFIP, followed by reflux heating (Table 1).

When **1** was treated with 1 equiv of ethanol in HFIP (25 equiv) for 12 h at reflux, the Ferrier reaction took place with quantitative conversion to afford the HFIP addition product **2a** as the major product, along with some traces of the ethanol product **2b** (**2a**/**2b**, 90:10). However, when 10 equiv of ethanol was used, the expected

Table 1
EtOH versus HFIP addition onto **1**



1 >98% conversion **2a** [R = $(CF_3)_2CH$)] + **2b** [R = Et]

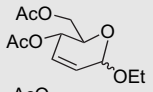
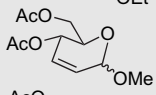
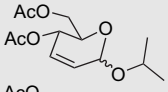
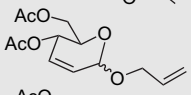
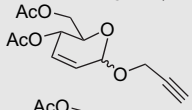
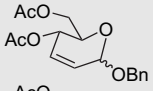
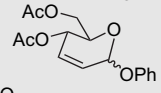
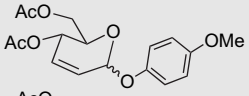
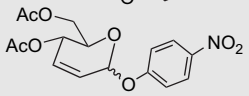
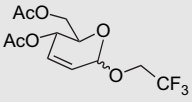
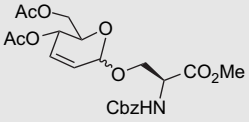
Entry	EtOH (equiv)	**2a**/**2b**
1	0	100:0[a]
2	1	90:10
3	3	50:50
4	10	10:90[b]

[a] Compound **2a** was isolated in 95% yield.
[b] Compound **2b** was isolated in 88% yield.

* Corresponding author. Fax: +33 1 46 83 57 40.
E-mail address: benoit.crousse@u-psud.fr (B. Crousse).

0040-4020/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2008.09.005

Table 2
Glycosylation of 3,4,6-tri-*O*-acetyl glucal with various alcohols and phenols[a]

Entry	Alcohol	Product	Yield (%)	α/β[b]
1	EtOH	 **2b**	88	67:33
2	MeOH	 **2c**	93	70:30
3	$(CH_3)_2CHOH$	 **2d**	96	70:30
4	Allyl alcohol	 **2e**	95	82:18
5	Propargyl alcohol	 **2f**	82	80:20
6	$PhCH_2OH$	 **2g**	83	60:40
7	PhOH	 **2h**	92	80:20
8	4-MeO–C_6H_4OH	 **2i**	95	80:20
9	4-NO_2–C_6H_4OH	 **2j**	65[c]	85:15
10	CF_3CH_2OH	 **2k**	60[c] 84[d]	70:30 55:45
11	L-CbzNH–Ser–OMe	 **2l**	71	85:15

[a] The reactions were performed at reflux of HFIP (25 equiv) for 12 h with 10 equiv of the alcohol.
[b] The ratio was determined on the basis of the integration of the anomeric protons in the ^1H NMR spectrum.
[c] Compound **2a** was also obtained in notable amounts (ca. 30%).
[d] The reaction was performed in TFE as single solvent at 60 °C.

product **2b** was obtained in 88% yield, as a mixture of α and β anomers (70:30). It is worth noting that the presence of HFIP is absolutely required: as expected, when the reaction was performed in ethanol only, the substrate **1** did not react.

Encouraged by these results, this methodology was extended to other alcohols such as alkyl, allyl, propargyl and benzyl alcohols, as well as phenols (Table 2, entries 1–9). For all these reagents, the reaction proceeded smoothly under the same conditions. Products were obtained in excellent yields (82–96%), as a mixture of α and β anomers with α being favoured (α/β, 60:40 to 82:18). As expected, the α/β ratios were in the same range as those reported in the literature.[5] The poor nucleophile *p*-nitrophenol also reacted, but the product **2j** was isolated in 65% yield, along with 30% of the adduct **2a** (entry 9). Similarly, with trifluoroethanol the reaction afforded a mixture of the corresponding product **2k** in moderate yield (60%), here also accompanied with **2a** (entry 10). However, surprisingly TFE was also able to promote its self addition: by dissolving glucal **1** in neat TFE (25 equiv), product **2k** was afforded after 12 h at 60 °C in much better yields (84%, entry 10). This self-promoted addition of HFIP and TFE offers a new clean preparation of fluoroacetals in carbohydrate series.[10] Finally, we were pleased to find that the multifunctionalized *N*-protected serine could also react with glucal **1** in HFIP through its hydroxyl moiety to afford **2l** (71% yield, entry 11).

However, the question about the precise nature of the reaction mechanism in HFIP arises. To make this clear, we studied the case of the reaction of triacetyl glucal **1** with ethanol (Scheme 1).

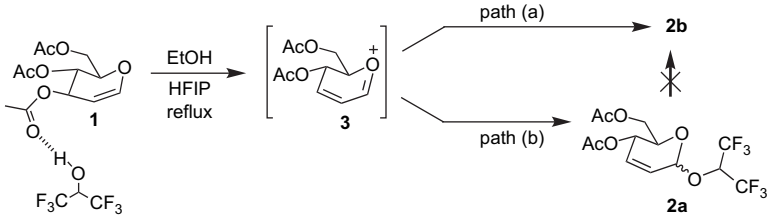
Due to hydrogen bonding properties of HFIP,[11] it is reasonable to assume that the latter assists the leaving of the acetyl moiety, leading to the oxonium **3**, the widely accepted intermediate of the reaction.[12] Then, two pathways can be envisioned from **3** to product **2b**: either ethanol adds directly onto **3** [path (a)], or it goes through the product intermediate **2a** [path (b)]. In order to determine, which of these two paths is followed, we used the HFIP adduct **2a** (α/β, 75:25)[9] and put it under the conditions described in Table 1 (EtOH, 10 equiv; HFIP, 25 equiv). After 12 h at 60 °C, no product **2b** was obtained and the starting material **2a** remained unchanged. Consequently, it can be deduced that the conversion of the glucal **1** into the addition products reported in Table 1 involves **3** as sole intermediate. Thus, HFIP may only act as an assisting agent for the leaving of the acetate moiety from **1**.

In conclusion, we have developed an efficient methodology for the synthesis of 2,3-unsaturated-*O*-glycosides via Ferrier rearrangement. The reaction is performed in HFIP as solvent and requires no use of any acid or metal promoter.

3. Experimental section

3.1. Materials and methods

Hexafluoroisopropanol (HFIP) was kindly provided by Central Glass Co. Ltd. and 1,1,1-trifluoroethanol was purchased from Fluorochem. 3,4,6-tri-*O*-Acetyl glucal was bought from Sigma Aldrich. Melting points were recorded on a Stuart SMP10 apparatus. IR spectra were recorded on a Bruker Vector 22 FTIR. NMR spectra were recorded on Brucker AC 200 and 300 instruments, in $CDCl_3$. Chemical shifts are given in parts per million (ppm) from TMS as internal standard for ^1H and ^{13}C NMR, and from $CFCl_3$ for ^{19}F NMR. The optical rotations were measured on a PolAAr 3 polarimeter.



Scheme 1.

3.2. General procedure for the synthesis of 2,3-unsaturated-*O*-glycosides in HFIP

To a stirred mixture of 3,4,6-tri-*O*-acetyl-D-glucal (0.184 mmol, 50 mg) in HFIP (0.5 mL) was added the alcohol (10 equiv) and the reaction mixture was heated at reflux (60 °C). After 12 h stirring, the reaction was complete (TLC monitoring). Then HFIP was evaporated under vacuum and the product was purified by column chromatography using cyclohexane/ethyl acetate (cyclohexane/AcOEt 90:10) as eluent.

3.2.1. Hexafluoroisopropyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2a**)[9]

White oil; $[\alpha]_D$ 208.2 (*c* 0.8, MeOH); ^{1}H NMR (200 MHz, $CDCl_3$): δ 2.07 (s, 3H, –CO–CH_3), 2.09 (s, 3H, –CO–CH_3), 3.98–4.06 (m, 1H, H-5), 4.15 (d, *J*=4 Hz, 2H, H-6), 4.51 (sept, *J*=6 Hz), 5.22 (br s, 1H, H-1), 5.29 (dd, *J*=9.6, 1.6 Hz, 1H, H-4), 5.79 (ddd, *J*=2, 2.4, 10.2 Hz, 1H, H-2), 5.95–5.99 (d, *J*=10.4 Hz); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.7, 20.9, 62.2, 64.6, 68.1, 72 (sept, *J*=33 Hz), 121.2 (q, *J*=283 Hz), 121.7 (q, *J*=284 Hz), 125, 131.5, 170.1, 170.6; ^{19}F NMR (188 MHz, $CDCl_3$): δ −74.2 (m, 3F), −74.0 (m, 3F). Anal. calcd for $C_{13}H_{14}F_6O_6$: C 41.06, H 3.71; found: C 41.30, H 3.85.

3.2.2. Ethyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2b**)[13]

White oil; $[\alpha]_D$ 120 (*c* 1.2, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.25 (t, *J*=7.2 Hz, 3H, –O–CH_2–CH_3), 2.11 (s, 3H, –CO–CH_3), 2.12 (s, 3H, –CO–CH_3), 3.58–3.63 (m, 1H, –O–HCH–CH_3), 3.83–3.88 (m, 1H, –O–HCH–CH_3), 4.12–4.31 (m, 3H, H-5, Ha-6, Hb-6), 5.07 (s, 1H, H-1), 5.34 (dd, *J*=1.2, 9.6 Hz, 1H, H-4), 5.84–5.98 (m, 2H, H-2, H-3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 15.3, 20.7, 20.9, 63.0, 64.3, 65.3, 66.8, 94.5, 128.0, 129.0, 170.3, 170.7; ESI *m*/*z* (rel int.): 281.2 $[M+Na]^+$ (100).

3.2.3. Methyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2c**)[14]

Colourless oil; $[\alpha]_D$ 124 (*c* 1.2, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.02 (s, 3H, –$OCOCH_3$), 2.04 (s, 3H, –$OCOCH_3$), 3.39 (s, 3H, OCH_3), 3.96–4.04 (m, 1H, H-5), 4.13–4.19 (m, 2H, H-6a, H-6b), 4.86 (br s, 1H, H-1), 5.25 (dd, *J*=9.0, 1.57 Hz, 1H, H-4), 5.77–5.91 (m, 2H, H-2, H-3); ^{13}C NMR (75 MHz, $CDCl_3$): 20.8, 21.0, 56.0, 63.0, 65.3, 66.9, 95.5, 127.7, 129.3, 170.3, 170.8; ESI *m*/*z* (rel int.): 267.1 $[M+Na]^+$ (100).

3.2.4. Isopropyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2d**)[15]

Colourless oil; $[\alpha]_D$ 97 (*c* 0.7, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.11 (d, *J*=6.3 Hz, 3H, –O–CH(CH_3)CH_3), 1.18 (d, *J*=6.3 Hz, 3H, –O–CH(CH_3)CH_3), 2.01 (s, 3H, –$OCOCH_3$), 2.02 (s, 3H, –$OCOCH_3$), 3.87 (hept, *J*=6.2 Hz, 1H, –O–CH(CH_3)CH_3), 4.01–4.19 (m, 3H, H-5, Ha-6, Hb-6), 5.06 (br s, 1H, H-1), 5.23 (dd, *J*=9.6, 1.5 Hz, 1H, H-4), 5.70–5.87 (m, 2H, H-2, H-3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.8, 21.0, 22.00, 23.5, 63.2, 65.4, 66.8, 70.8, 92.9, 128.5, 128.8, 170.3, 170.8; ESI *m*/*z* (rel int.): 295.2 $[M+Na]^+$ (100).

3.2.5. Allyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2e**)[13]

White oil; $[\alpha]_D$ 91 (*c* 0.45, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.01 (s, 3H, –$OCOCH_3$), 2.03 (s, 3H, –$OCOCH_3$), 3.97–4.25 (m, 5H, H-5, Ha-6, Hb-6, Ha-1′, Hb-1′), 5.01 (br s, 1H, H-1), 5.1–5.27 (m, 3H, Ha-3′, Hb-3′, H-4), 5.78–5.94 (m, 3H, H-2, H-3, H-2′); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.8, 21.0, 63.0, 65.3, 67.0, 69.3, 93.7, 117.6, 127.8, 129.3, 134.1, 170.3, 170.8; ESI *m*/*z* (rel int.): 293.2 $[M+Na]^+$ (100).

3.2.6. Prop-2-ynyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2f**)[14]

White solid, mp 59 °C; $[\alpha]_D$ 110 (*c* 0.8, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.02 (s, 3H, –$OCOCH_3$), 2.04 (s, 3H, –$OCOCH_3$), 2.40 (t, *J*=1.8 Hz, 1H, –C≡CH), 3.99–4.06 (m, 1H, H-5), 4.15 (dd, *J*=5.1, 12 Hz, 2H, Ha-6, Hb-6), 4.25 (d, *J*=2.4 Hz, 2H, Ha-1′, Hb-1′), 5.18 (br s, 1H, H-1), 5.27 (dd, *J*=9.6,1.5 Hz, 1H, H-4), 5.75–5.88 (m, 2H, H-2, H-3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.8, 21.0, 55.1, 62.8, 65.2, 67.2, 74.9, 79.1, 92.8, 127.3, 129.8, 170.2, 170.8; ESI *m*/*z* (rel int.): 291.2 $[M+Na]^+$ (100).

3.2.7. Benzyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2g**)[13]

Colourless oil; $[\alpha]_D$ 150 (*c* 0.8, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.01 (s, 3H, –$OCOCH_3$), 2.03 (s, 3H, –$OCOCH_3$), 4.00–4.24 (m, 3H, H-5, Ha-6, Hb-6), 4.53 (d, *J*=12 Hz, 1H, –O–HCH–Ph), 4.74 (d, *J*=12 Hz, 1H, –O–HCH–Ph), 5.06 (br s, 1H, H-1), 5.27 (dd, *J*=9.6, 1.2 Hz, 1H, H-4), 5.79–5.85 (m, 2H, H-2, H-3), 7.27–7.30 (m, 5H, Ph); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.9, 21.0, 62.9, 65.3, 67.1, 67.3, 93.6, 127.8, 127.9, 128.0, 128.5, 129.4, 138.2, 170.3, 170.9; ESI *m*/*z* (rel int.): 344.3 $[M+Na]^+$ (100).

3.2.8. Phenyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2h**)[13]

White solid, mp 50 °C (lit. 47–48 °C); $[\alpha]_D$ 102 (*c* 0.65, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.91 (s, 3H, –$OCOCH_3$), 2.04 (s, 3H, –$OCOCH_3$), 4.05–4.25 (m, 3H, H-5, Ha-6, Hb-6), 5.31 (d, *J*=9 Hz, 1H, H-4), 5.63 (br s, 1H, H-1), 5.94–5.98 (m, 2H, H-2, H-3), 6.94–7.05 (m, 3H, Ph), 7.19–7.26 (m, 2H, Ph); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.7, 21.0, 62.6, 65.0, 67.8, 92.9, 117.0, 122.5, 127.1, 129.5, 130.1, 157.1, 170.3, 170.8; ESI *m*/*z* (rel int.): 329.3 $[M+Na]^+$ (100).

3.2.9. p-Methoxyphenyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2i**)[13]

White solid, mp 69 °C (lit. 69–70 °C); $[\alpha]_D$ 104 (*c* 1.4, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.95 (s, 3H, –$OCOCH_3$), 2.04 (s, 3H, –$OCOCH_3$), 3.69 (s, 3H, –OCH_3), 4.07–4.21 (m, 3H, H-5, Ha-6, Hb-6), 5.29 (d, *J*=9.0 Hz, 1H, H-4), 5.49 (br s, 1H, H-1), 5.93 (br s, 2H, H-2, H-3), 6.75 (dd, *J*=9.0 Hz, 2H, Ph), 6.97 (dd, *J*=9 Hz, 2H, Ph); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.8, 21.0, 55.7, 62.8, 65.2, 67.7, 94.1, 114.6, 118.7, 127.3, 130.0, 151.2, 155.3, 170.3, 170.8; ESI *m*/*z* (rel int.): 359.1 $[M+Na]^+$ (100).

3.2.10. p-Nitrophenyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2j**)[13]

White solid, mp 90 °C (lit. 94–95 °C); $[\alpha]_D$ 170 (*c* 0.6, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.89 (s, 3H, –$OCOCH_3$), 2.05 (s, 3H, –$OCOCH_3$), 4.05–4.23 (m, 3H, H-5, Ha-6, Hb-6), 5.34 (dd, *J*=9.6, 1.2 Hz, 1H, H-4), 5.74 (br s, 1H, H-1), 5.93 (dd, *J*=1.8, 10.2 Hz, 1H, H-3), 6.04 (d, *J*=10.2 Hz, 1H, H-2), 7.11 (d, *J*=9.0 Hz, 2H, Ph), 8.15 (d, *J*=9.0 Hz, 2H, Ph); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.6, 20.9, 62.34, 64.7, 68.4, 92.6, 116.6, 125.7, 125.8, 131.2, 142.6, 161.8, 170.1, 170.5; ESI *m*/*z* (rel int.): 374.2 $[M+Na]^+$ (100).

3.2.11. Trifluoroethyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2k**)

Colourless oil; $[\alpha]_D$ 79 (*c* 0.8, MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.09 (s, 3H), 2.1 (s, 3H), 3.93–4.13 (m, 3H, H-5, OCH_2), 4.21–4.23 (m, 2H, H-6), 5.11 (br s, 1H, H-1), 5.33 (dd, *J*=9.6, 1.5 Hz, 1H, H-4), 5.83–5.88 (m, 1H, H-2), 5.96 (d, *J*=10.2 Hz, 1H, H-3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.6, 20.9, 62.6, 65.0 (t, *J*=34 Hz), 67.5, 94.5, 121.9, 123.7 (q, *J*=276 Hz), 126.2, 130.4, 170.2, 170.7; ^{19}F NMR (188 MHz, $CDCl_3$): δ −74.64 (t, *J*=9 Hz); ESI *m*/*z* (rel int.): 335.2 $[M+Na]^+$ (100).

3.2.12. 2-(N-Benzyloxycarbonylamino)-3-methoxycarbonylethyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside (**2l**)[13]

Colourless oil; $[\alpha]_D$ 46 (*c* 1.5, MeOH); ^{1}H NMR (200 MHz, $CDCl_3$): δ 2.04 (s, 3H, –$OCOCH_3$), 2.07 (s, 3H, –$OCOCH_3$), 3.76 (s, 3H, –OCH_3),

3.96–4.05 (m, 3H, H-5, Ha-6, Hb-6), 4.18–4.20 (m, 2H, βCH_2), 4.51–4.58 (m, 1H, αCH), 4.98 (br s, 1H, H-1), 5.13 (br s, 2H, $PhCH_2$), 5.26 (dd, J=10.2 Hz, 1H, H-4), 5.73 (ddd, J=2.2, 4.2, 8.8 Hz, 1H, H-2), 5.87 (dd, J=0.4, 9.8 Hz, 1H, H-3), 7.35 (br s, 5H, Ph); ^{13}C NMR (75 MHz, $CDCl_3$): 20.7, 21.0, 52.7, 54.5, 62.8, 65.00, 67.1, 67.4, 69.5, 95.1, 127.01, 128.2, 128.6, 129.6, 136.2, 156.00, 170.3, 170.5, 170.8; ESI m/z (rel int.): 488.3 [M+Na] (100).

Acknowledgements

Central Co. Ltd. is gratefully acknowledged for kind gift of HFIP. We thank the Indo-French program CEFIPRA/IFCPAR for financial support and for the PhD fellowship of K.D.

References and notes

1. (a) Bracchero, M. P.; Cabrera, E. F.; Gomez, G. M.; Peredes, L. M. R. *Carbohydr. Res.* **1998**, *308*, 181; (b) Schmidt, R. R.; Angerbauer, R. *Carbohydr. Res.* **1979**, *72*, 272.
2. Williams, N. R.; Wanders, J. D. *The Carbohydrates Chemistry and Biochemistry*; Academic: New York, NY, 1980; p 761.
3. (a) Fraser-Reid, B. *Acc. Chem. Res.* **1985**, *18*, 347; (b) Ferrier, R. J. *Adv. Carbohydr. Chem. Biochem.* **1969**, *24*, 199.
4. (a) Ferrier, R. J.; Zubkov, O. A. *Org. React.* **2003**, *62*, 569; (b) Ferrier, R. J. *Top. Curr. Chem.* **2001**, *215*, 153; (c) Ferrier, R. J.; Prasad, N. J. *J. Chem. Soc.* **1969**, 570.
5. (a) For recent examples, see Smitha, G.; Reddy, C. S. *Synthesis* **2004**, 834; (b) Agarwal, A.; Rani, S.; Vankar, Y. D. *J. Org. Chem.* **2004**, *69*, 6137; (c) Misra, A. K.; Tiwari, P.; Agnihotri, G. *Synthesis* **2005**, 260; (d) Suryakiran, N.; Malla Reddy, S.; Srinivasulu, M.; Venkateswarlu, Y. *Synth. Commun.* **2008**, *38*, 170; (e) Zhang, G.; Liu, Q.; Shi, L.; Wang, J. *Tetrahedron* **2008**, *64*, 339 and references cited therein.
6. For reviews on fluorous alcohols as solvents, see: (a) Bégué, J.-P.; Bonnet-Delpon, D.; Crousse, B. *Synlett* **2004**, 18; (b) Bégué, J.-P.; Bonnet-Delpon, D.; Crousse, B. In *Handbook of Fluorous Chemistry*; Gladysz, J. A., Curran, D. P., Horvath, I. T., Eds.; Wiley-VCH: Weinheim, 2004; p 341; For some representative examples of the use of fluorous alcohols in our group, see: (c) Legros, J.; Crousse, B.; Ourévitch, M.; Bonnet-Delpon, D. *Synlett* **2006**, 1899; (d) Ravikumar, K. S.; Kesavan, V.; Crousse, B.; Bonnet-Delpon, D.; Bégué, J.-P. *Organic Synthesis*; Wiley: New York, NY, 2003; Coll. Vol. 80, p 184; (e) Spanedda, M. V.; Hoang, V. D.; Crousse, B.; Bonnet-Delpon, D.; Bégué, J.-P. *Tetrahedron Lett.* **2003**, *44*, 217; (f) Di Salvo, A.; Spanedda, M. V.; Ourévitch, M.; Crousse, B.; Bonnet-Delpon, D. *Synthesis* **2003**, 2231; (g) Magueur, G.; Crousse, B.; Ourévitch, M.; Bégué, J.-P.; Bonnet-Delpon, D. *J. Org. Chem.* **2003**, *68*, 9763.
7. For a review on the use of fluorinated alcohols, as cosolvents and additives, see: Shuklov, I. A.; Dubrovina, N. V.; Börner, A. *Synthesis* **2007**, 2925.
8. (a) Grellepois, F.; Chorki, F.; Crousse, B.; Ourévitch, M.; Bonnet-Delpon, D.; Bégué, J. P. *J. Org. Chem.* **2002**, *67*, 1253; (b) Neimann, K.; Neumann, R. *Org. Lett.* **2000**, *2*, 2861.
9. Di Salvo, A.; David, M.; Crousse, B.; Bonnet-Delpon, D. *Adv. Synth. Catal.* **2006**, *348*, 118.
10. (a) Thanh Nga, T. T.; Ménage, C.; Bégué, J.-P.; Bonnet-Delpon, D.; Gantier, J.-C. *J. Med. Chem.* **1998**, *41*, 4101; (b) Gueyrard, D.; Rollin, P.; Thanh Nga, T. T.; Ourévitch, M.; Bégué, J.-P.; Bonnet-Delpon, D. *Carbohydr. Res.* **1999**, *318*, 171.
11. (a) Berrien, J.-F.; Ourévitch, M.; Morgant, G.; Ghermani, N. E.; Crousse, B.; Bonnet-Delpon, D. *J. Fluorine Chem.* **2007**, *128*, 839; (b) Berkessel, A.; Adrio, J. A.; Hüttenhain, D.; Neudörfl, J. M. *J. Am. Chem. Soc.* **2006**, *128*, 8421; (c) Eberson, L.; Hartshorn, M. P.; Persson, O.; Radner, F. *Chem. Commun.* **1996**, 2105.
12. Li, J. J. *Name Reactions*; Springer: Berlin, 2003.
13. Yadav, J. S.; Subba Reddy, B. V.; Sunder Reddy, J. S. *J. Chem. Soc., Perkin Trans. 1* **2002**, 2390.
14. Boga, S. B.; Narasimhan, K. K. *Arkivoc* **2004**, 87.
15. Naik, P. U.; Nara, S. J.; Hajani, J. R.; Salunkhe, M. M. *J. Mol. Catal. A: Chem.* **2005**, *234*, 35.