Organofluorine Compounds and Fluorinating Agents, 24[+]

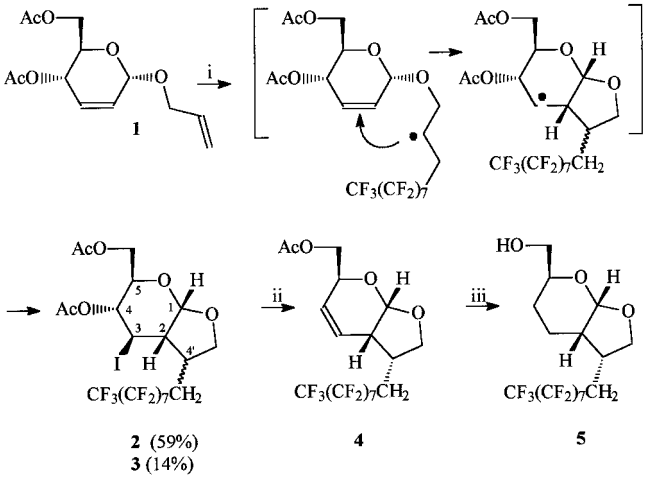
Chiral Perfluoroalkyl-Substituted Hexahydrofuro[2,3-*b*]pyran Derivatives Based on a Carbohydrate Precursor

Martin Hein[a] and Ralf Miethchen*[a]

Keywords: Allyl glycosides / Cyclizations / Domino reactions / Mesogens / Perfluoroalkylations

(4′*R*)-4,6-Di-*O*-acetyl-1,2,3-trideoxy-3-iodo-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-α-D-glucopyranoso[1,2-*b*]furan (**2**) and its (4′*S*) diastereomer (**3**) were prepared by dithionite-mediated addition of 1-iodoperfluorooctane to allyl 4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranoside (radical "domino reaction"). Subsequently, the major product [(4′*R*) form] was deprotected via **4** to the hexahydrofuro[2,3-*b*]pyran derivative **5**, which was used as a fluorinated building block to prepare the nonamphiphilic chiral mesogens **6**–**8** by "Mitsunobu" etherification and **9** by esterification. The reagents used to transform **5** to **6**–**9** were 4-cyanophenol, 4-(4-cyanophenyl)phenol, 4-(4-heptyloxybenzoyloxy)phenol, and 4-heptyloxybenzoyl chloride.

Radical addition of 1-haloperfluoroalkanes to double bonds, initiated by sodium dithionite, is one of the most convenient methods for attaching perfluoroalkyl chains to organic substrates.[1−5] See ref.[5−7] and papers cited therein for other initiation methods. Dithionite-mediated perfluoroalkylations of allyl 2,3,4,6-tetra-*O*-acetyl-β-D-glucoside were recently used to prepare (2-halo-3-perfluoralkylpropyl) β-D-glucopyranosides in good yields.[7][8]



Scheme 1. **2**, **4**, **5**: (4′*R*) diastereomer; **3**: (4′*S*) diastereomer; i: $CF_3[CF_2]_7I/Na_2S_2O_4/NaHCO_3$, 0°C; ii: Zn/Cu/DMF, 115°C; iii: (1) CsF/Al_2O_3/MeOH, r.t., (2) H_2/Pd/C/EtOAc/MeOH

We investigated dithionite-mediated additions of 1-iodoperfluoroalkanes to allyl 4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranoside (**1**), to prepare chiral, fluorinated building blocks for the synthesis of chiral nonamphiphilic mesogens (Scheme 1). A perfluoroalkyl radical firstly attacks **1** at the terminal double bond anchored to the carbohydrate ring, to form a prochiral radical. This radical intermediate does not bind iodine to form the corresponding (2-iodo-3-perfluoroalkylpropyl) glycoside,[9] but attacks, with cyclization, the ring double bond. This radical propagation results in the formation of two new chiral centres and a new prochiral radical, followed by the addition of an iodine atom (Scheme 1). This reaction is an example of a highly selective radical "domino reaction".[10] Only one pair of diastereomers, the hexahydrofuro[2,3-*b*]pyran derivatives **2** [(4′*R*) form] and **3** [(4′*S*) form], was obtained. This means that total control is exerted over two of the three stereogenic centres. Ring junction is exclusively *cis*, and the iodine atom is transferred to the equatorial position. The diastereomers **2** and **3** were separated by fractional crystallization and column chromatography. The *endo* stereoisomer **2** (yield: 59%) was favoured over the *exo* isomer **3** (yield: 14%). This result corresponds to similar radical cyclizations reported in ref.[11][12]

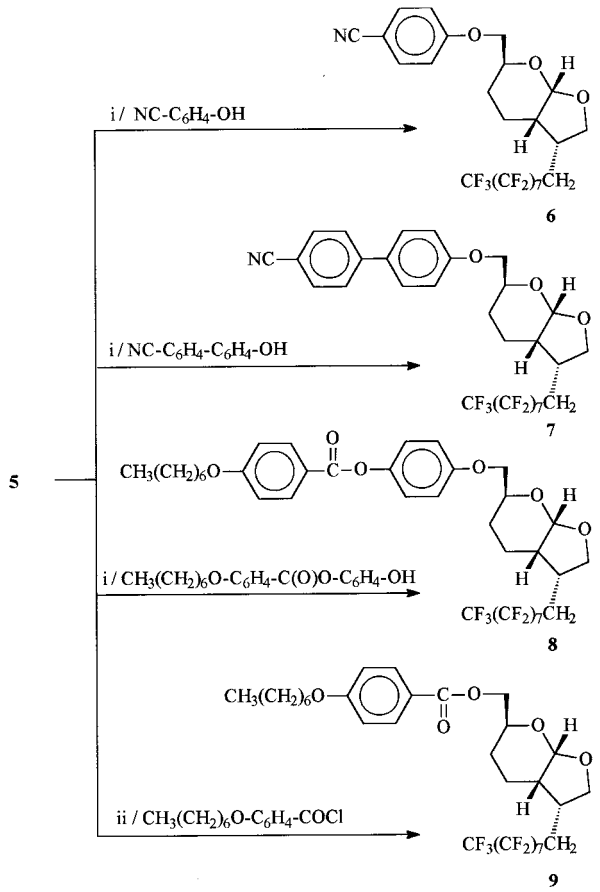
Only the major product **2** was used for the subsequent reactions shown in Scheme 1. Treatment of **2** with activated zinc (Zn/Cu) in DMF at 115°C resulted in reductive β-elimination of iodide and acetate, respectively, in the 3- and 4-positions, to form the dihydropyran derivative **4** (yield 90%). The next two synthetic steps for the preparation of hexahydrofuro[2,3-*b*]pyran **5** were slightly simplified. After deacetylation of **4** with alumina-supported cesium fluoride,[13] the crude product obtained, without further purification, was hydrogenated with H_2/Pd/C in ethyl acetate/methanol (Scheme 1). The crystalline product **5** was obtained in a yield of 85% (relative to **4**). It is noticeable that when compound **5** is heated, an enantiotropic *smectic* mesophase (m.p. 105−106°C, c.p. 116−117°C) results. Compound **4** is monotropically liquid-crystalline (m.p. 72−73°C, c.p. 56°C), that is, the clearing point (c.p.) is lower than the melting point (metastable mesophase).

[+] Part 23: H. Klein, R. Miethchen, H. Reinke, M. Michalik, *J. Prakt. Chem.* **1999**, *341*, 41−46.

[a] Fachbereich Chemie, Organische Chemie, Universität Rostock
Buchbinderstraße 9, D-18051 Rostock, Germany
Fax: (internat.) + 49-(0)381/498-1819
E-mail: ralf.miethchen@chemie.uni-rostock.de

  1434−193X/99/0909−2429 $ 17.50+.50/0

The structures proposed for **2**−**5** agree with their ^{1}H- and ^{13}C-NMR data, which were also compared with data of previously reported similar derivatives.[11][12] Thus, there is a good correspondence between the key data of **2** and **3** and the structural similar diastereomers (4′*R*)- and (4′*S*)-4,6-di-*O*-acetyl-3-bromo-1,2,3-trideoxy-4′-(tosylmethyl)-2′,3′,4′,5′-tetrahydro-α-D-glucopyranoso[1,2-*b*]furan reported by Nouguier et al.,[11][12] who used NOE measurements to confirm the structures.[11] Various coupling constants, for example, $^3J_{4',5'a}$ and $^3J_{4',5'b}$ were compared, and it was deduced that the conformations of diastereomers **2** and **3** are similar to those of the reference substances. The relatively large 3-H/4-H and 2-H/3-H coupling constants of **2** ($^3J_{3,4} \approx 10.4$ Hz, $^3J_{2,3} \approx 10.5$ Hz) and **3** ($^3J_{3,4} = {}^3J_{2,3} \approx 10.5$ Hz) indicate a *trans*-diaxial arrangement of these three *vicinal* protons, that is, the iodine atom in the 3-position of derivatives **2** and **3** is equatorially arranged. The configuration at C-4′ could be assigned in each case by comparing the $^3J_{2,4'}$ couplings of **2** and **3**. The 2-H/4′-H coupling constant of approximately 5.8 Hz for the major product **2** indicates an eclipsed arrangement of 2-H and 4′-H; this contrasts with the smaller (approximately 1.9 Hz) 2-H/4′-H coupling constant of the minor product **3**. The 2-H/4′-H coupling constants of the reference substances are 5.7 Hz and 2.2 Hz.[11][12]



Scheme 2. i: DEAD/PPh_3/−15°C to r.t. (toluene); ii: pyridine/0°C to r.t. (CH_2Cl_2)

To obtain new types of chiral mesogens with specific properties, the fluoroalkyl compound **5** was etherified with 4-cyanophenol, 4-(4-cyanophenyl)phenol, or 4-(4-heptyloxybenzoyloxy)phenol, and esterified with 4-heptyloxybenzoic acid. Diethyl azodicarboxylate (DEAD) and triphenylphosphane ("Mitsunobu conditions"[14]) were used for the etherifications (Scheme 2).

A specific temperature range must be used if good yields are to be obtained from the Mitsunobu etherifications of **5**. Controlled warming up from −15°C to room temp. slowly increases the solubility of the components in toluene in such a way that side reactions are suppressed. The ethers **6**−**8** were isolated in yields of 82−89%. The ester **9** was obtained in 87% yield from the reaction between **5** and 4-heptyloxybenzoyl chloride in the presence of pyridine (Scheme 2).

Compounds **5**−**8** have liquid-crystalline properties, that is, smectic A, B, and C* phases were observed. In a separate paper we discuss the thermal behaviour of these compounds in more detail, and also report on the mesogenic properties of further perfluoroalkyl-substituted carbohydrate-based mesogens prepared by us.[15]

Experimental Section

General: Column chromatography: silica gel 60 (63−200 μm) (Merck), thin-layer chromatography (TLC): silica gel foils 60 F_{254} (Merck). − NMR: AC 250 and ARX 300, shifts referred to TMS (^{1}H/^{13}C) and $CFCl_3$ (^{19}F). − Melting points were obtained with a polarizing microscope Leitz (Laborlux 12 Pol) equipped with a hot stage (Mettler FP 90). − Chemicals: palladium on activated charcoal (Fluka), 4-cyanophenol (Fluka), 4-(4-cyanophenyl)phenol (Aldrich), 4-heptyloxybenzoic acid (Aldrich).

(4′*R*)-4,6-Di-*O*-acetyl-1,2,3-trideoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-3-iodo-α-D-glucopyranoso[1,2-*b*]furan (2) and (4′*S*)-4,6-Di-*O*-acetyl-1,2,3-trideoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-3-iodo-α-D-glucopyranoso[1,2-*b*]furan (3): To a stirred solution of allyl 4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranoside (**1**)[16] (1.0 g, 3.7 mmol) in MeCN/H_2O (20 mL, v/v = 2.5:1), under argon at 0°C, were added, in succession, 1-iodoperfluorooctane (1.96 mL, 7.4 mmol), 0.5 g $NaHCO_3$, and $Na_2S_2O_4$ (0.64 g, 3.7 mmol). The mixture was allowed to warm up to 5°C within 2.5 h. It was then extracted twice with 70 mL of diethyl ether and the combined organic phases were washed several times with saturated aq. NaCl solution and finally with water. After drying (Na_2SO_4), the solvent was evaporated under reduced pressure and the residue was dissolved in 15−20 mL of boiling MeOH. On cooling to room temp. pure crystals of compound **2** (1.54 g) formed. Precipitation of **3** occurs only below about 10°C. Column-chromatographic purification (eluent: freshly distilled heptane/THF = 9:1; **2**: R_f = 0.17; **3**: R_f = 0.14) of the filtrate yielded 0.42 g (14%) of the minor product **3** {m.p. 77−79°C, $[\alpha]_D^{26} = +33.3$ (c = 1.37, $CHCl_3$)} and a further 0.25 g of **2** {yield 1.79 g, 59%; m.p. 109−110°C, $[\alpha]_D^{26} = +16.2$ (c = 1.47, $CHCl_3$)}.

2: ^{1}H NMR (250 MHz, C_6D_6): δ = 5.36 (dd, 1 H, $^3J_{3,4} \approx 10.5$ Hz, $^3J_{4,5} \approx 9.9$ Hz, 4-H), 4.82 (d, 1 H, $^3J_{1,2} \approx 4.1$ Hz, 1-H), 4.43 (dd, 1 H, $^2J_{6a,6b} \approx 12.3$ Hz, $^3J_{5,6a} \approx 4.8$ Hz, 6a-H), 4.12 (dd, 1 H, $^3J_{5,6b} \approx 2.5$ Hz, 6b-H), 3.87 (ddd, 1 H, 5-H), 3.78 (ddd, 1 H, $J_{5'a,F} \approx 3.7$ Hz, $^3J_{5'a,\,4'} \approx 8.1$ Hz, 5′a-H), 3.44 (dd, 1 H, $^3J_{2,3} \approx$

10.5 Hz, 3-H), 3.15 (dd, 1 H, $^2J_{5'a,5'b} \approx 8.9$ Hz, $^3J_{5'b,4'} \approx 10.5$ Hz, 5′b-H), 2.51−2.79 (m, 1 H, CH_aCF_2), 2.26 (m, 1 H, 4′-H), 2.15 (ddd, 1 H, $^3J_{2,4'} \approx 5.8$ Hz, 2-H), 1.83, 1.80 (both s, 6 H, 2 CH_3), 1.67−1.95 (m, 1 H, CH_bCF_2). − $^{13}C\{^1H\}$ NMR (63 MHz, C_6D_6): δ = 170.1, 168.8 (both s, 2 CO), 101.8 (s, C-1), 71.4 (s, C-4), 70.3 (s, C-5), 69.0 (d, $^4J_{C\text{-}5',F} \approx 6.0$ Hz, C-5′), 62.5 (s, C-6), 48.5 (s, C-2), 33.9 (d, $^3J_{C\text{-}4',Fa,b} \approx 3.5$ Hz, C-4′), 30.3 (t, $^2J_{C,Fa,b} \approx 21.5$ Hz, CH_2CF_2), 24.9 (s, C-3), 20.4, 20.4 (both s, 2 CH_3). − $^{19}F\{^1H\}$ NMR (235 MHz, C_6D_6) δ = −80.7 (t, $^3J_{F,F} \approx 10.0$ Hz, CF_3), −110.2 to −115.9 (m, $^3J_{Fa,F} \approx {}^3J_{Fb,F} \approx 14.0$ Hz, $^2J_{Fa,Fb} \approx 268.0$ Hz, α-CF_2), −121.2, −121.4, −121.4, −122.3, −123.0, −125.8 (m, 6 CF_2). − $C_{21}H_{18}F_{17}IO_6$ (816.3): calcd. C 30.90, H 2.22, I 15.55; found C 30.88, H 2.21, I 15.19.

3: ^1H NMR (250 MHz, C_6D_6): δ = 5.32 (dd, 1 H, $^3J_{3,4} \approx 10.4$ Hz, $^3J_{4,5} \approx 9.4$ Hz, 4-H), 4.78 (d, 1 H, $^3J_{1,2} \approx 4.2$ Hz, 1-H), 4.42 (dd, 1 H, $^2J_{6a,6b} \approx 12.3$ Hz, $^3J_{5,6a} \approx 4.6$ Hz, 6a-H), 4.11 (dd, 1 H, $^3J_{5,6b} \approx 2.4$ Hz, 6b-H), 3.85 (ddd, 1 H, 5-H), 3.78 (dd, 1 H, $^2J_{5'a,5'b} \approx 9.6$ Hz, $^3J_{5'a,4'} \approx 7.3$ Hz, 5′a-H), 3.58 (dd, 1 H, $^3J_{2,3} \approx 10.5$ Hz, 3-H), 3.13 (dd, 1 H, $^3J_{5'b,4'} \approx 4.1$ Hz, 5′b-H), 2.25 (m, 1 H, 4′-H), 1.92 (ddd, 1 H, $^3J_{2,4'} \approx 1.9$ Hz, 2-H), 1.83, 1.80 (both s, 6 H, 2 CH_3), 1.48−1.90 (m, 2 H, CH_2CF_2). − $^{13}C\{^1H\}$ NMR (63 MHz, C_6D_6): δ = 170.1, 168.7 (both s, 2 CO), 99.7 (s, C-1), 71.5 (s, C-5), 70.2 (s, C-4), 69.4 (t, $^4J_{C\text{-}5',Fa,b} \approx 2.0$ Hz, C-5′), 62.6 (s, C-6), 53.0 (s, C-2), 37.2 (t, $^3J_{C\text{-}4',Fa,b} \approx 2.0$ Hz, C-4′), 34.7 (t, $^2J_{C,Fa,b} \approx 21.0$ Hz, CH_2CF_2), 30.5 (s, C-3), 20.4, 20.3 (both s, 2 CH_3). − $^{19}F\{^1H\}$ NMR (235 MHz, C_6D_6): δ = −80.8 (t, $^3J_{F,F} \approx 9.0$ Hz, CF_3), −112.6 (t, $^3J_{F,F} \approx 16.0$ Hz, α-CF_2), −121.2, −121.5, −121.5, −122.4, −122.8, −125.9 (m, 6 CF_2). − $C_{21}H_{18}F_{17}IO_6$ (816.3): calcd. C 30.90, H 2.22, I 15.55; found C 30.87, H 2.25, I 15.40.

(4′*R*)-6-*O*-Acetyl-1,2,3,4-tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-α-D-*erythro*-hex-3-enopyranoso[1,2-*b*]furan (4): A suspension of zinc (2.0 g, 30.6 mmol) and $Cu(OAc)_2 \cdot H_2O$ (0.25 g) in 30 mL of DMF was stirred at 115°C under argon until the copper was completely deposited on the zinc (green solution discoloured). Under argon, a solution of **2** (1.45 g, 1.78 mmol) in 10 mL of DMF was added dropwise rapidly, followed by further stirring at 115−120°C for 15 min. Subsequently, the reaction mixture was cooled down, diluted with about 50 mL of EtOAc, and filtered through Celite. After concentration of the filtrate under reduced pressure and chromatographic purification of the syrupy residue (R_f = 0.25; eluent: heptane/EtOAc = 3.5:1), 1.02 g (90%) of the crystalline product **4**[17] [m.p. 72−73°C (MeOH/H_2O), c.p. 56°C] was obtained; $[\alpha]_D^{26}$ = −33.2 (*c* = 1.00, $CHCl_3$). − ^1H NMR (250 MHz, $CDCl_3$): δ = 5.99 (m, 1 H, $^3J_{3,4} \approx 10.6$ Hz, 3-H or 4-H), 5.76 (m, 1 H, 3-H or 4-H), 5.66 (d, 1 H, $^3J_{1,2} \approx 4.4$ Hz, 1-H), 4.47 (m, 1 H, 5-H), 4.09−4.27 (m, 2 H, 6a-H, 6b-H), 4.03 (ddd, 1 H, $^2J_{5'a,5'b} \approx 8.2$ Hz, $^3J_{5'a,4'} \approx 6.8$ Hz, $J \approx 1.4$ Hz, 5′a-H), 3.59 (dd, 1 H, $^3J_{5'b,4'} \approx 9.3$ Hz, 5′b-H), 2.72−2.93 (m, 2 H, 4′-H, 2-H), 1.89−2.50 (m, 5 H, CH_2CF_2, CH_3). − $^{13}C\{^1H\}$ NMR (63 MHz, $CDCl_3$): δ = 170.9 (s, CO), 129.9 (s), 123.0 (d, $J_{C,F} \approx 1$ Hz, C-3, C-4), 100.7 (s, C-1), 71.3 (d, $^4J_{C\text{-}5',F} \approx 3$ Hz, C-5′), 66.1 (s, C-5), 65.4 (s, C-6), 38.4 (s, C-2), 34.4 (t, $^3J_{C\text{-}4',Fa,b} \approx 2$ Hz, C-4′), 29.4 (t, $^2J_{C,Fa,b} \approx 22$ Hz, CH_2CF_2), 20.8 (s, CH_3). − $^{19}F\{^1H\}$ NMR (235 MHz, $CDCl_3$): δ = −80.6 (t, $^3J_{F,F}$ = 10 Hz, CF_3), −111.4 to −114.7 (m, $^3J_{Fa,F} \approx {}^3J_{Fb,F} \approx 14$ Hz, $^2J_{Fa,Fb}$ = 271 Hz, α-CF_2), −121.3, −121.6, −121.6, −122.4, −123.2, −125.9 (m, 6 CF_2). − $C_{19}H_{15}F_{17}O_4$ (630.3): calcd. C 36.21, H 2.40; found C 36.37, H 2.49.

(4′*R*)-1,2,3,4-Tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-α-D-*erythro*-hexopyranoso-[1,2-*b*]furan (5): Alumina-supported CsF[13] (70 mg, 1/15 equiv.) was added to a solution of **4** (1.0 g, 1.58 mmol) in 25 mL of dry MeOH; the mixture was stirred at room temp. for about 12 h. A solution of $CaCl_2 \cdot 6H_2O$ (100 mg) in 250 μL of water was added and stirring was continued for 20 min. After filtration through Celite, the solution was concentrated under reduced pressure, the residue was dissolved in 100 mL of EtOAc and the solution was washed with aq. $CaCl_2$ solution (20%) and conc. NaCl solution. After drying (Na_2SO_4) of the organic phase and evaporation of the solvent under reduced pressure, the residue was dissolved in 30 mL of EtOAc/MeOH (2:1, v/v). Pd/C (10%) (30 mg) was added under argon and the mixture was stirred at room temp. for 4.5 h under H_2 (1 atm). When the reaction was finished (TLC control), the suspension was filtered through Celite and the filtrate was concentrated under reduced pressure. The syrupy residue was dissolved in aqueous MeOH with slight warming. Compound **5** (0.85 g, 85%) crystallized on cooling; m.p. 105−106°C, c.p. 116−117°C, $[\alpha]_D^{26}$ = +18.2 (*c* = 1.04, $CHCl_3$). − ^1H NMR (250 MHz, $CDCl_3$): δ = 5.43 (d, 1 H, $^3J_{1,2} \approx 3.6$ Hz, 1-H), 3.46−4.09 (m, 5 H, 5-H, 6a-H, 6b-H, 5′a-H, 5′b-H), 2.80 (m, 1 H, 4′-H), 1.28−2.40 (m, 7 H, 2-H, 3a-H, 3e-H, 4a-H, 4e-H, CH_2CF_2). − $^{13}C\{^1H\}$ NMR (63 MHz, $CDCl_3$) δ = 102.0 (s, C-1), 70.7 (s, C-5), 68.8 (d, $^4J_{C\text{-}5',F} \approx 2.0$ Hz, C-5′), 65.6 (s, C-6), 36.3 (s, C-2), 33.4 (t, $^3J_{C\text{-}4',Fa,b} \approx 2.0$ Hz, C-4′), 28.4 (t, $^2J_{C,Fa,b} \approx 22.0$ Hz, CH_2CF_2), 24.3 (s, C-4), 19.2 (s, C-3). − $^{19}F\{^1H\}$ NMR (235 MHz, $CDCl_3$) δ = −80.6 (t, $^3J_{F,F} \approx 9.0$ Hz, CF_3), −111.7 to −114.9 (m, $^3J_{F,F} \approx 14.0$ Hz, $^2J_{Fa,Fb} \approx 268.0$ Hz, α-CF_2), −121.4, −121.7, −121.7, −122.5, −123.3, −125.9 (m, 6 CF_2). − $C_{17}H_{15}F_{17}O_3$ (590.3): calcd. C 34.59, H 2.56; found: C 34.41, H 2.53.

(4′*R*)-6-*O*-(4-Cyanophenyl)-1,2,3,4-tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-α-D-*erythro*-hexopyranoso[1,2-*b*]furan (6): A 40% solution of DEAD (150 μl, 0.34 mmol) in toluene was added dropwise, at −15°C under argon and with vigorous stirring, to a mixture of PPh_3 (90 mg, 0.34 mmol) and 4-cyanophenol (40 mg, 0.34 mmol) in 5 mL of dry toluene. The furo[2,3-*b*]pyran **5** (100 mg, 0.17 mmol) was added in solid form; the reaction mixture was further stirred for 24 h, with slow (over about 15 h) warming to room temp. After dilution with EtOAc, the mixture was filtered through Celite, the filtrate was concentrated under reduced pressure, and the residue was dissolved in 5−10 mL of boiling MeOH. Most of pure product **6** crystallized upon cooling. Yield: 105 mg (89%), m.p. 128−129°C, c.p. 170−171°C, $[\alpha]_D^{26}$ = +5.6 (*c* = 1.11, $CHCl_3$). − ^1H NMR (300 MHz, $CDCl_3$): δ = 7.51−7.60 (m, 2 H, aromatic H), 6.91−7.00 (m, 2 H, aromatic H), 5.45 (d, 1 H, $^3J_{1,2} \approx 3.5$ Hz, 1-H), 3.94−4.17 (m, 4 H, 5-H, 6a-H, 6b-H, 5′a-H), 3.73 (dd, 1 H, $J_{H,H} \approx 8.4$ Hz, $J_{H,H} \approx 10.4$ Hz, 5′b-H), 2.82 (m, 1 H, 4′-H), 1.36−2.39 (m, 7 H, 2-H, 3a-H, 3e-H, 4a-H, 4e-H, CH_2CF_2). − $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): δ = 162.0 (s, quat. C_{arom}), 133.9 (s, 2 aromatic CH), 119.1 (s, CN), 115.3 (s, 2 aromatic CH), 104.2 (s, quat. C_{arom}), 102.0 (s, C-1), 70.7 (s, C-5), 68.8 (d, $^4J_{C\text{-}5',F} \approx 2.5$ Hz, C-5′), 68.3 (s, C-6), 36.1 (s, C-2), 33.3 (t, $^3J_{C\text{-}4',Fa,b} \approx 1.5$ Hz, C-4′), 28.4 (t, $^2J_{C,Fa,b} \approx 21$ Hz, CH_2CF_2), 25.0 (s, C-4), 19.2 (s, C-3). − $^{19}F\{^1H\}$ NMR (235 MHz, $CDCl_3$): δ = −80.6 (t, $^3J_{F,F} \approx 10.0$ Hz, CF_3), −111.7 to −114.8 (m, $^3J_{F,F} \approx 14.0$ Hz, $^2J_{Fa,Fb} \approx 270.0$ Hz, α-CF_2), −121.2, −121.6, −121.6, −122.4, −123.2, −125.8 (m, 6 CF_2). − $C_{24}H_{18}F_{17}NO_3$ (691.4): calcd. C 41.69, H 2.62, N 2.03; found C 41.61, H 2.68, N 2.00.

(4′*R*)-6-*O*-[4-(4-Cyanophenyl)phenyl)]-1,2,3,4-tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-2′,3′,4′,5′-tetrahydro-αD-*erythro*-hexopyranoso[1,2-*b*]furan (7): The same procedure described for **6** was used to etherify **5** (100 mg, 0.17 mmol) with 4′-cyano-4-hydroxybiphenyl (0.34 mmol) in toluene (5 mL). However, an additional equivalent of PPh_3 (0.17 mmol) and DEAD

(0.17 mmol) was added after 24 h at 0°C. The mixture was allowed to warm up to room temp. within 6−10 h and stirring was continued for a further 18−20 h at room temp. After working up analogously to **6**, the crude product was crystallized from boiling MeOH by adding a small amount of EtOAc; yield of **7**: 110 mg (84%); m.p. 133−134°C, c.p. 260°C, $[\alpha]_D^{26}$ = +2.1 (*c* = 1.13, $CHCl_3$). − ^{1}H NMR (250 MHz, $CDCl_3$): δ = 7.58−7.72 (m, 4 H, aromatic H), 7.47−7.55 (m, 2 H, aromatic H), 6.97−7.05 (m, 2 H, aromatic H), 5.48 (d, 1 H, $^3J_{1,2} \approx$ 3.3 Hz, 1-H), 3.96−4.21 (m, 4 H, 5-H, 6a-H, 6b-H, 5′a-H), 3.75 (dd, 1 H, $J_{H,H} \approx$ 8.5 Hz, $J_{H,H} \approx$ 10.2 Hz, 5′b-H), 2.84 (m, 1 H, 4′-H), 1.35−2.42 (m, 7 H, 2-H, 3a-H, 3e-H, 4a-H, 4e-H, CH_2CF_2). − ^{13}C{^{1}H} NMR (63 MHz, $CDCl_3$): δ = 159.5 (s, quat. C_{arom}), 145.2 (s, quat. C_{arom}), 132.6 (s, 2 aromatic CH), 131.8 (s, quat. C_{arom}), 128.3 (s, 2 aromatic CH), 127.1 (s, 2 aromatic CH), 119.0 (s, CN), 115.3 (s, 2 aromatic CH), 110.2 (s, quat. C_{arom}), 102.1 (s, C-1), 70.7 (s, C-5), 68.9 (d, $^4J_{C-5',F} \approx$ 2.0 Hz, C-5′), 68.5 (s, C-6), 36.2 (s, C-2), 33.4 (t, $^3J_{C-4',Fa,b} \approx$ 2.0 Hz, C-4′), 28.5 (t, $^2J_{C,Fa,b} \approx$ 22.0 Hz, CH_2CF_2), 25.0 (s, C-4), 19.3 (s, C-3). − ^{19}F{^{1}H} NMR (235 MHz, $CDCl_3$): δ = −80.5 (t, $^3J_{F,F} \approx$ 9.0 Hz, CF_3), −111.6 to −114.8 (m, $^3J_{F,F} \approx$ 13.0 Hz, $^2J_{Fa,Fb} \approx$ 270.0 Hz, α-CF_2), −121.3, −121.6, −121.6, −122.4, −123.1, −125.8 (m, 6 CF_2). − $C_{30}H_{22}F_{17}NO_3$ (767.5): calcd. C 46.95, H 2.89, N 1.83; found C 46.79, H 2.93, N 1.97.

(4′*R*)-1,2,3,4-Tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-6-*O*-[4-(4-heptyloxybenzoyloxy)phenyl]-2′,3′,4′,5′-tetrahydro-α-D-*erythro*-hexopyranoso[1,2-*b*]furan (8): The procedure described for **6** was used for the etherification of **5** (100 mg, 0.17 mmol) with 4-(4-heptyloxybenzoyloxy)phenol (0.34 mmol) in toluene (5 mL). However, an additional equivalent of PPh_3 (0.17 mmol) and DEAD (0.17 mmol) was added after 24 h at 0°C. The mixture was allowed to warm up to room temp. within 6−10 h and stirring was continued for a further 18−20 h at room temp. After working up analogously to **6**, the crude product was crystallized from boiling MeOH after the addition of a small volume of EtOAc; yield of **8**: 125 mg (82%), m.p. 155−156°C, c.p. 216−217°C, $[\alpha]_D^{26}$ = +12.6 (*c* = 0.75, $CHCl_3$). − ^{1}H NMR (250 MHz, $CDCl_3$): δ = 8.07−8.15 (m, 2 H, aromatic H), 7.05−7.13 (m, 2 H, aromatic H), 6.89−6.99 (m, 4 H, aromatic H), 5.48 (d, 1 H, $^3J_{1,2} \approx$ 3.4 Hz, 1-H), 3.91−4.17 (m, 6 H, 5-H, 6a-H, 6b-H, 5′a-H, $ArOCH_2$), 3.74 (dd, 1 H, $J_{H,H} \approx$ 8.5 Hz, $J_{H,H} \approx$ 10.4 Hz, 5′b-H), 2.82 (m, 1 H, 4′-H), 1.24−2.42 (m, 17 H, 2-H, 3a-H, 3e-H, 4a-H, 4e-H, CH_2CF_2, 5 alkyl CH_2), 0.89 (t, 3 H, $^3J_{H,H} \approx$ 6.5 Hz, CH_3). − ^{13}C{^{1}H} NMR (63 MHz, $CDCl_3$): δ = 165.2, 163.5 (2 s, CO, quat. C_{arom}), 156.4 (s, quat. C_{arom}), 144.8 (s, quat. C_{arom}), 132.2 (s, 2 aromatic CH), 122.5 (s, 2 aromatic CH), 121.7 (s, quat. C_{arom}), 115.3 (s, 2 aromatic CH), 114.3 (s, 2 aromatic CH), 102.1 (s, C-1), 71.0 (s, C-6 or $ArOCH_2$), 68.8 (d, $^4J_{C-5',F} \approx$ 2.0 Hz, C-5′), 68.5 (s, C-5), 68.3 (s, C-6 or $ArOCH_2$), 36.3 (s, C-2), 33.4 (t, $^3J_{C-4',Fa,b} \approx$ 1.5 Hz, C-4′), 31.7, 29.1, 29.0 (s, 3 CH_2), 28.5 (t, $^2J_{C,Fa,b} \approx$ 22.0 Hz, CH_2CF_2), 25.9 (s, CH_2), 25.2 (s, C-4), 22.6 (s, CH_2), 19.3 (s, C-3), 14.0 (s, CH_3). − ^{19}F{^{1}H} NMR (235 MHz, $CDCl_3$) δ = −80.6 (t, $^3J_{F,F} \approx$ 10.0 Hz, CF_3), −111.6 to −114.8 (m, $^3J_{F,F} \approx$ 14.0 Hz, $^2J_{Fa,Fb} \approx$ 271.0 Hz, α-CF_2), −121.3, −121.6, −121.6, −122.4, −123.2, −125.8 (m, 6 CF_2). − $C_{37}H_{37}F_{17}O_6$ (900.7): calcd. C 49.34, H 4.14; found C 49.18, H 4.20.

(4′*R*)-1,2,3,4-Tetradeoxy-4′-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-heptadecafluorononyl)-6-*O*-(4-heptyloxybenzoyl)-2′,3′,4′,5′-tetrahydro-α-D-*erythro*-hexopyranoso[1,2-*b*]furan (9): A mixture of 4-heptyloxybenzoic acid (85 mg, 0.36 mmol) and 2 mL of $SOCl_2$ was refluxed under argon for 1 h. After evaporation of the $SOCl_2$ under reduced pressure, the residue was dissolved in 0.5 mL of dry CH_2Cl_2. This solution was added dropwise at 0°C through a syringe to a stirred mixture of **5** (140 mg, 0.23 mmol), dry pyridine (2 mL) and dry CH_2Cl_2 (1 mL). The mixture was allowed to warm up to room temp. over 30 min and stirring was continued for 1 h at this temp. Finally, the solution was concentrated under reduced pressure and the syrupy residue was purified by column chromatography (R_f = 0.40; eluent: heptane/EtOAc = 3.5:1). Yield of **9**: 170 mg (87%), m.p. 104−105°C (MeOH), $[\alpha]_D^{26}$ = +7.1 (*c* = 0.87, $CHCl_3$). − ^{1}H NMR (250 MHz, $CDCl_3$): δ = 7.95−8.02 (m, 2 H, aromatic H), 6.84−6.91 (m, 2 H, aromatic H), 5.45 (d, 1 H, $^3J_{1,2} \approx$ 3.5 Hz, 1-H), 3.94−4.34 (m, 6 H, 5-H, 6a-H, 6b-H, 5′a-H, $ArOCH_2$), 3.71 (dd, 1 H, $J_{H,H} \approx$ 8.5 Hz, $J_{H,H} \approx$ 10.3 Hz, 5′b-H), 2.81 (m, 1 H, 4′-H), 1.22−2.40 (m, 17 H, 2-H, 3a-H, 3e-H, 4a-H, 4e-H, CH_2CF_2, 5 alkyl CH_2), 0.89 (t, 3 H, $^3J_{H,H} \approx$ 6.7 Hz, CH_3). − ^{13}C{^{1}H} NMR (72 MHz, $CDCl_3$): δ = 166.2, 163.1 (two s, CO, quat. C_{arom}), 131.7 (s, 2 aromatic CH), 122.1 (s, quat. C_{arom}), 114.0 (s, 2 aromatic CH), 102.0 (s, C-1), 68.8 (d, $^4J_{C-5',F} \approx$ 2.0 Hz, C-5′), 68.3 (s, C-5), 68.2, 66.7 (two s, C-6, $ArOCH_2$), 36.1 (s, C-2), 33.3 (t, $^3J_{C-4',Fa,b} \approx$ 1.5 Hz, C-4′), 31.7, 29.1, 29.0 (all s, 3 CH_2), 28.4 (t, $^2J_{C,Fa,b} \approx$ 22.0 Hz, CH_2CF_2), 25.9 (s, CH_2), 25.0 (s, C-4), 22.6 (s, CH_2), 19.2 (s, C-3), 14.0 (s, CH_3). − ^{19}F{^{1}H} NMR (235 MHz, $CDCl_3$): δ = −80.6 (t, $^3J_{F,F} \approx$ 10.0 Hz, CF_3), −111.6 to −114.8 (m, $^3J_{Fa,F} \approx$ $^3J_{Fb,F} \approx$ 14.0 Hz, $^2J_{Fa,Fb} \approx$ 271.0 Hz, α-CF_2), −121.3, −121.6, −121.6, −122.4, −123.2, −125.8 (m, 6 CF_2). − $C_{31}H_{33}F_{17}O_5$ (808.6): calcd. C 46.05, H 4.11; found C 46.05, H 4.25.

Acknowledgments

We are grateful to Dr. Manfred Michalik (Institut für Organische Katalyseforschung e.V., Rostock) for recording the NMR spectra and the Fonds der Chemischen Industrie for financial support of our research.

[1] R. Miethchen, M. Hein, H. Reinke, *Eur. J. Org. Chem*. **1998**, 919−923.
[2] G. Rong, R. Keese, *Tetrahedron Lett*. **1990**, *31* 5615−5616.
[3] W. Y.Huang, Y. Xie, *Chinese J. Chem*. **1991**, *9*, 351−359.
[4] W. Y.Huang, *J. Fluorine Chem*. **1992**, *58*, 1−8.
[5] C. Zur, R. Miethchen, *Eur. J. Org. Chem*. **1998**, 531−539.
[6] S. Zhu, C. Qing, *J.* Zhou, *J.* Zhang, B. Xu, *J. Fluorine Chem*. **1996**, *79*, 77−79.
[7] B. Yu, J. Zhang, S. Lu, Y. Hui, *Synlett* **1998**, 29−30.
[8] M. Hein, R. Miethchen, *Tetrahedron Lett*. **1998**, *39*, 6679−6682.
[9] An intermediate formation of a (2-iodo-3-perfluoroalkylpropyl) glycoside can be excluded, because an alkyl iodide cannot be activated by a dithionite initiator.
[10] L. F. Tietze, *Chem. Rev.* **1996**, *96*, 115−136.
[11] R. Nouguier, C. Lesueur, E. De Riggi, M. P. Bertrand, A. Virgili, *Tetrahedron Lett*. **1990**, *31*, 3541−3544.
[12] C. Lesueur, R. Nouguier, M. P. Bertrand, P. Hoffmann, A. De Mesmaeker, *Tetrahedron* **1994**, *50*, 5369−5380.
[13] T. Ando, J. Yamawaki, T. Kawate, S. Sumi, T. Hanafusa, *Bull. Chem. Soc. Jpn.* **1982**, *55*, 2504−2507.
[14] Review: D. L. Hughes, *Org. React*. **1992**, *42*, 335−656.
[15] M. Hein, R. Miethchen, D. Schwaebisch, C. Schick, *Liq. Cryst.*, submitted.
[16] J. S. Panek, M. A. Sparks, *Tetrahedron Lett*. **1988**, *29*, 4517−4520.
[17] The R_f values of **2** and **4** are very similar, however, in contrast to starting material **2**, **4** does not have a UV absorption peak at about 254 nm.

Received February 1, 1999
[O99045]