Available online at www.sciencedirect.com
SCIENCE DIRECT®
Carbohydrate Research 340 (2005) 1461–1468
Carbohydrate RESEARCH

# Adamantoylated monosaccharides: new compounds for modification of the properties of cyclodextrin-containing materials

Cécile Binkowski, Vincent Lequart,* Frédéric Hapiot, Sébastien Tilloy, Roméo Cecchelli, Eric Monflier and Patrick Martin

*Laboratoire de la Barrière Hémato Encéphalique, Université d'Artois, Faculté Jean Perrin, rue Jean Souvraz SP 18, F-62307 Lens, France*

Received 8 June 2004; accepted 10 March 2005

**Abstract**—Adamantoyl glycosides were obtained in good yields by coupling adamantanecarboxylic acid with monosaccharides. They form very stable inclusion complexes with β-cyclodextrin, as shown by $^1$H NMR measurements.


*Keywords:* Adamantoyl glycosides; β-Cyclodextrin; Inclusion complex

## 1. Introduction

Modification of the properties of cyclodextrin-containing materials by the non-covalent anchoring of organic molecules has been the subject of many investigations during the past five years. Among the various possible organic groups able to interact with cyclodextrins, adamantyl derivatives constitute very good candidates, since the adamantyl shape fits precisely into the β-cyclodextrin cavity, leading to a high association constant ($K_A$) on the order of $10^3$–$10^5$ $M^{-1}$.[1,2]

Thus, new associating polymer systems, characterized by viscosity enhancement and pH-dependent aggregation, have been elaborated starting from an adamantane end-capped poly(ethylene oxide) or poly(β-malic acid-*co*-β-ethyladamantyl malate) and a β-cyclodextrin polymer.[3–5] The same behavior has been observed upon addition of polyethylene glycol (PEG) end-capped with adamantyl moieties to cyclodextrin–chitosan solutions.[6,7] Optical biosensors have also been elaborated with similar systems, in which antibodies were bound to adamantyl dextrans immobilized onto gold surfaces covered by polymers of β-cyclodextrin.[8] The cyclodextrin–adamantane interaction also constitutes the main concept around which the elaboration of stabilized nanoparticles has been developed. For example, multiple host–guest interactions between an adamantyl polymer and a bilayer vesicle made of amphiphilic cyclodextrins substituted with *S*-dodecyl groups have been described, leading to potential drug-delivery systems.[9] The adamantyl moiety has also been attached to a PEG polymer functionalized by a glycosylated (galactose or glucose)[10–12] or a transferrin ligand.[13] In the two last cases, the resulting vehicles were capable of nonviral and tumor-targeted gene delivery. As a general rule, saccharides and oligosaccharides are well known as efficient ligands toward cellular receptors such as lectins, promoting molecular transport through biological barriers. Recently, it has even been shown that monosaccharides included in amphiphilic cyclodextrins are transferred through a bulk liquid membrane.[14]

In order to elaborate glycosylated cyclodextrin materials for biological applications, we have been interested in the interaction of adamantoyl glycosides and β-cyclodextrin. In particular, we would like to know more about the association constant between an adamantoyl group chemically grafted onto a saccharide and a native β-cyclodextrin. Four potential ligands for receptor-mediated

* Corresponding author. Tel.: +33 (0)32179173; fax: +33 (0)321791736; e-mail: vincentlequart@yahoo.fr

0008-6215/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.carres.2005.03.017

targeting have retained our attention: D-glucose, D-galactose, L-fucose, and L-rhamnose. Each of them has been grafted onto an adamantoyl group and the resultant compounds were included in the β-cyclodextrin cavity to form new supramolecular compounds. We describe here the synthesis of the adamantoyl glycosides and the determination by $^1$H NMR measurements of their association constants with the β-cyclodextrin.

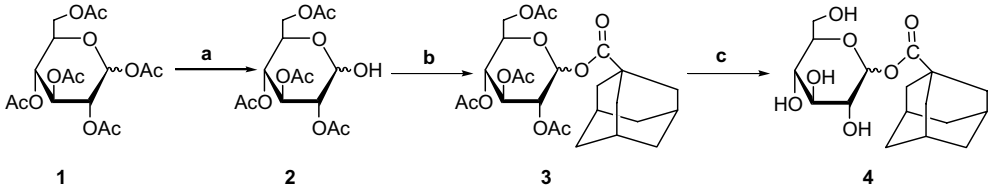
## 2. Results and discussion

The adamantyl group was introduced onto glycosyl derivatives by ester bond formation. The general procedure is described in Scheme 1.

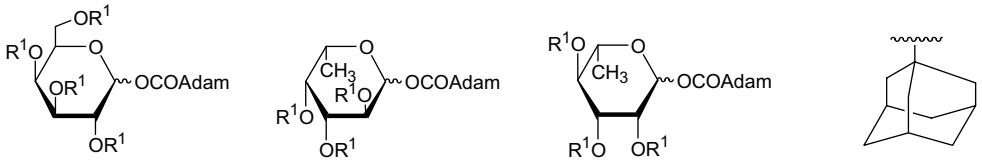
The sugar-functionalized adamantane **4** was prepared in three steps starting from D-glucopyranose pentaacetate (**1**). The C-1 acetyl group was selectively removed with benzylamine[15] to give 2,3,4,6-tetra-*O*-acetyl-D-glucopyranose (**2**) in 89% yield. Treatment of **2** with 1-adamantanecarboxylic acid, *N*,*N*′-dicyclohexylcarbodiimide (DCC)[16] and 4-dimethylaminopyridine (DMAP) provided compound **3** (83% yield, α/β 1:1). The mixture was chromatographed on silica gel (9:1 hexane–EtOAc) to separate the α- and β-anomers. Zemplén deprotection of the acetylated groups afforded the expected adamantoyl glucosides **4**α and **4**β.

According to the same procedure, three other glycosyl derivatives (AdamGal **6**, AdamFuc **8**, and AdamRham **10**) were prepared starting from the corresponding peracetylated monosaccharides D-galactose, L-fucose, and L-rhamnose. The separation of the α- and β-acetylated glycosides were possible after chromatographic separation on silica gel (9:1 hexane–EtOAc) except for the galactoside derivative **5**. The structures of these compounds are given in Scheme 2.

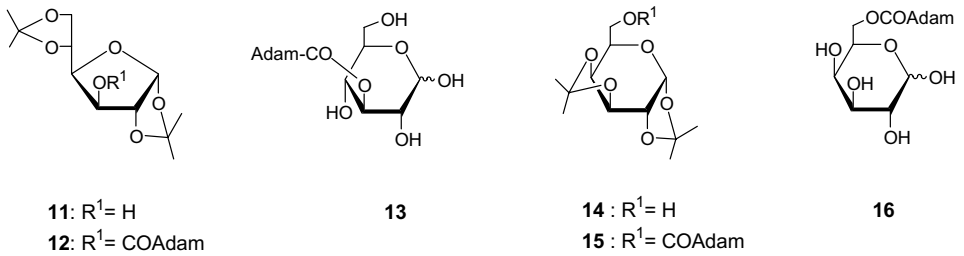
In order to compare the position effect on monosaccharides of the adamantoyl group, we also introduced this adamantoyl group at the 3-position of D-glucopyranose and the 6-position of D-galactopyranose. Compound **13** was readily prepared in two steps starting from 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**11**, Scheme 3).[17] Reaction of the diacetal **11** with 1-adamantanecarboxylic acid in the presence of DCC and DMAP afforded




**Scheme 1.** General procedure for synthesis of adamantoylated monosaccharides. Reagents and conditions: (a) $BnNH_2$, THF, rt; (b) $AdamCO_2H$, DCC, DMAP, $CH_2Cl_2$, rt; (c) NaOMe, MeOH, rt.




**Scheme 2.** Structures of adamantoyl glycoside derivatives based on the monosaccharides D-galactose (**5** and **6**), L-fucose (**7** and **8**), and L-rhamnose (**9** and **10**).




**Scheme 3.** Structures of adamantoyl glycoside derivatives with the adamantoyl part attached at the 3-position (**13**) and 6-position (**16**).

**17:** $R^1$ = Ac, $R^2$ = Br
**18:** $R^1$ = Ac, $R^2$ = O-$C_4H_8$-OH
**19:** $R^1$ = Ac, $R^2$ = O-$C_4H_8$-OCO-Adam
**20:** $R^1$ = H, $R^2$ = O-$C_4H_8$-OCO-Adam

**21:** $R^1$ = Ac, $R^2$ = Br
**22:** $R^1$ = Ac, $R^2$ = O-$C_4H_8$-OH[12]
**23:** $R^1$ = Ac, $R^2$ = O-$C_4H_8$-OCO-Adam
**24:** $R^1$ = H, $R^2$ = O-$C_4H_8$-OCO-Adam

**Scheme 4.** Adamantoylated glycosyl derivatives containing an alkyl spacer between the adamantoyl part and the monosaccharide moiety.

compound **12** after column chromatography on silica gel. Removal of the isopropylidene groups with 9:1 $CF_3CO_2OH$–$H_2O$ afforded the expected adamantoyl derivative **13** in 71% yield.

By the same method, we also prepared the galactosyl derivative **16**, starting from 1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose **14** (Scheme 3).[18] The adamantoyl group was first attached at the 6-position (69% yield) and the isopropylidene groups were then removed, giving compound **16** in 71% yield.

In order to compare the influence of the sugar part on the association constant, an alkyl chain was intercalated between the sugar and adamantoyl moieties. We thus synthesized two other derivatives, starting from peracetylated glucose or fucose (Scheme 4).

Reaction of butan-1,4-diol with tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**17**) or 2,3,4-tri-*O*-acetyl-α-L-fucopyranose bromide (**21**) in the presence of AgOTf by the method of Hanessian and Banoub[19] provided the desired products **18** and **22**. The adamantoyl group was then introduced by the method already described, using 1-adamantanecarboxylic acid, DCC and DMAP. Zemplén deprotection of the acetylated groups afforded the expected adamantoyl glycosides **20** and **24**.

The ability of adamantoyl glycosides to form inclusion complexes with the native β-cyclodextrin was investigated by $^1$H NMR spectroscopy. The stoichiometry of the inclusion complexes was determined by the continuous variation technique (Job's method)[20,21] and the association constants $K_A$ at 298 K of these complexes was determinated by computer fitting of the chemical-shift titration curves of the adamantoyl protons.[22] For all monosaccharides, the Job's plots were highly symmetrical and showed a maximum at $r = 0.5$, undoubtedly indicating the formation of a 1:1 inclusion complex.[20] The values of these association constants derived from the titration curves were found to lie between $3.6 \times 10^4$ $M^{-1}$ and $1.9 \times 10^6$ $M^{-1}$ (Table 1).

These values clearly indicate that all modified monosaccharides are very strongly bound to the cyclodextrin, proving that the adamantoyl moiety is a valuable group for increasing the affinity of monosaccharides toward cyclodextrin. Interestingly, it seems that the carbohydrate moiety also plays an important role in stabilizing the inclusion complex, as the association constants depend on the position of the adamantoyl group on the monosaccharide. In particular, the molecular recognition was the highest when the adamantoyl group was introduced at the anomeric position (see **4** and **6**). Therefore, in addition of the strong interaction between the adamantoyl moiety and the cavity of the cyclodextrin, hydrogen bonds between the cyclodextrin and the four hydroxyl groups of the adamantoyl glucoside **4** or the adamantoyl galactoside **6** derivatives are also thought to be responsible for the strength of the host–guest interaction. This hypothesis was confirmed by the results obtained with the more lipophilic saccharides **8** and **10**, which present lower association constants than those of the hydrophilic derivatives **4** and **6**. Compounds **8** and **10** have only three hydroxyl groups, whose ability of forming hydrogen bonds with the hydroxyl groups of the cyclodextrin is thus lower. Finally, we note that the anomeric configuration has a small effect on the association-constant values. Comparing adamantoyl glucosides **4**α and **4**β, the association constant is significantly higher when the adamantoyl group is attached in the β-orientation.

With the alkyl spacer-containing compounds **20**β and **24**α, the association constants are $1.8 \times 10^4$ and $4.8 \times 10^4$ $M^{-1}$ respectively. It is noteworthy that, when comparing the two glucosylated derivatives **4**β and **20**β, a very strong decrease in the association constant is observed when a spacer is introduced between the glucose and adamantoyl parts ($1.9 \times 10^6$ vs $1.8 \times 10^4$ $M^{-1}$, respectively). Once more, this clearly shows that the glucose moiety takes part in the association with cyclodextrin. More precisely, when the affinity of the sugar for the cyclodextrin is strong, the addition of a spacer moves the saccharide away from the hydroxyl groups of the cyclodextrin and the association constant decreases. On the other hand, for fucosylated derivatives **8**α and **24**α, the spacer has only a moderate influence on the association constant ($3.9 \times 10^4$ vs $4.8 \times 10^4$ $M^{-1}$). Therefore, when the interaction between the saccharide and the cyclodextrin is quite low, the addition of an alkyl spacer between the sugar moiety

**Table 1.** Association constants $K_A$ at 298 K

| Compound | **4**α | **4**β | **6** | **8**α | **8**β | **10**α | **10**β | **13** | **16** |
|---|---|---|---|---|---|---|---|---|---|
| $K_A$ ($M^{-1}$) | $1.5 \times 10^6$ | $1.9 \times 10^6$ | $8.1 \times 10^5$ | $3.9 \times 10^4$ | $3.6 \times 10^4$ | $5.1 \times 10^4$ | $4.6 \times 10^4$ | $2.2 \times 10^5$ | $4.3 \times 10^5$ |

and the adamantoyl group does not significantly modify the stability of the inclusion complex. In that case, the value of the association constant is rather the result of the adamantoyl–cyclodextrin interaction.

In conclusion, grafting of the adamantoyl group onto monosaccharides has led to new compounds that interact strongly with β-cyclodextrin. The interaction between those two compounds is due not only to the strong interaction between the adamantoyl group and the lipophilic cavity of the cyclodextrin, but depends also on the number of hydrogen bonds between the hydroxyl groups of the saccharide and those of the cyclodextrin. The ability of these compounds to bind to more sophisticated cyclodextrin-containing materials and to generate particular biological properties is now under investigation.

## 3. Experimental

### 3.1. General methods

Melting points were determined on an electrothermal automatic apparatus, and are uncorrected. NMR spectra were recorded with a Bruker WB-300 instrument for solutions in $CDCl_3$ (internal $Me_4Si$). All compounds were characterized by acquisition of $^1H$, $^{13}C$, DEPT, $^1H$–$^1H$ COSY, and $^1H$–$^{13}C$ correlated experiments. Reactions were monitored by high-performance liquid chromatography (HPLC, Variant) using a reverse-phase column RP-18 (E. Merck). Analytical thin-layer chromatography (TLC) was performed on E. Merck aluminum-backed silica gel (Silica Gel F254). IR spectra were recorded with a Bruker Vector 22 instrument. Column chromatography was performed on silica gel (60 mesh, Matrex) by gradient elution with hexane–acetone or hexane–EtOAc (in each case the ratio of silica gel to product mixture to be purified was 30:1).

**3.1.1. Determination of stoichiometry.** The continuous variation method was adopted to determine the stoichiometry of the β-CD–adamantoyl complex. A series of samples containing varied ratios (from 0 to 1) of β-CD and the adamantoyl derivative was prepared, keeping the total concentration of species constant (1 mM in this present case). The differences of chemical shift in the $^1H$ NMR spectra for the adamantoyl proton were measured as a function of the molar ratio ($r$). The ΔΔH(Adam)* [Adam] was traced as a function of the molar ratio ($r$).

**3.1.2. Determination of the association constant.** One proton of the adamantoyl group (Adam) was chosen for evaluating the association constant by $^1H$ NMR spectroscopy. Assuming a 1:1 inclusion mechanism, the observed chemical shift of the protons the adamantoyl group ($\delta_{OBS}$) and the complex concentration [COMP] are described as follows:

$$\delta_{OBS} = (\delta_{Adam.}[Adam.] + \delta_{COMP}[COMP])/[Adam.]_T \quad (1)$$

$$[COMP] = -1/2[(1/K_A + [\beta\text{-CD}]_T + [Adam.]_T)^2 - 4[\beta\text{-CD}]_T[Adam.]_T]^{1/2} + 1/2(1/K_A + [\beta\text{-CD}]_T + [Adam.]_T) \quad (2)$$

where $K_A$, $T$, and $\delta_{Adam.}$ denote the formation constant, the total, and the chemical shift of protons of the adamantoyl group in the absence of β-CD, respectively. For a given value of $K_A$, [COMP] is known and $\delta_{COMP}$ may be calculated from (**1**) for each $[CD]_T$. The standard deviation over $\delta_{COMP}$ had then to be minimized relative to $K$. The adamantoyl concentration was fixed at 1 mM and β-CD varied from 0 to 3 mM.

### 3.2. 2,3,4,6-Tetra-*O*-acetyl-1-*O*-adamantoyl-D-glucopyranose (3)

To a solution of 2,3,4,6-tetra-*O*-acetyl-D-glucopyranose (**2**) (1.0 g, 2.9 mmol) in $CH_2Cl_2$ (10 mL) was successively added DCC (2.3 g, 11.5 mmol), DMAP (0.7 g, 2.9 mmol), and 1-adamantanecarboxylic acid (1.0 g, 5.8 mmol). After 3 h at 50 °C, the mixture was diluted with $CH_2Cl_2$ (10 mL), filtered, and the filtrate evaporated. Chromatography of the residue on a column of silica gel (9:1 hexane–EtOAc) gave **3** in 83% yield, α/β 1:1; anomer **3**α; oil; IR; $\nu$ 1741.5 $cm^{-1}$ (*C*O); $^1H$ NMR ($CDCl_3$, 300 MHz): $\delta$ 6.34 (d, 1H, $J_{1,2}$ 3.6 Hz, H-1), 5.46 (t, 1H, $J_{3,4}$ 9.3 Hz, H-3), 5.17 (t, 1H, H-4), 5.09 (dd, 1H, $J_{2,3}$ 10.2 Hz, H-2), 4.28 (m, 1H, $J_{6a,6b}$ 11.9 Hz, $J_{5,6a}$ 4.6 Hz, H-6a), 4.10 (m, 2H, $J_{5,6b}$ 2.3 Hz, H-5, H-6b), 2.10–1.96 (4s, 12H, $CH_3$CO), 2.16–1.70 (m, 15H, Adam); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): $\delta$ 175.6 (*C*OAdam), 171.0–169.8 ($CH_3$*C*O), 89.0 (C-1), 70.4 (C-3), 70.3 (C-5), 69.9 (C-2), 69.3 (C-4), 61.9 (C-6), 41.6, 38.8, 36.7, 28.1 (Adam), 21.1–20.8 ($CH_3$CO); anomer **3**β; white crystals; mp 175–178 °C; IR; $\nu$ 1740.9 $cm^{-1}$ (*C*O); $^1H$ NMR ($CDCl_3$, 300 MHz): $\delta$ 5.68 (d, 1H, $J_{1,2}$ 7.8 Hz, H-1), 5.23 (m, 2H, H-2, H-3), 5.16 (dd, 1H, $J_{3,4}$ 9.2 Hz, $J_{4,5}$ 9.8 Hz, H-4), 4.29 (dd, 1H, $J_{6a,6b}$ 12.4 Hz, $J_{5,6a}$ 4.0 Hz, H-6a), 4.08 (dd, 1H, $J_{5,6b}$ 1.9 Hz, H-6b), 3.83 (m, 1H, H-5), 2.10–2.02 (4s, 12H, $CH_3$CO), 2.16–1.70 (m, 15H, Adam); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): $\delta$ 175.9 (*C*OAdam), 171.0–169.5 ($CH_3$*C*O), 91.9 (C-1), 73.0 (C-3, C-5), 70.5 (C-2), 68.4 (C-4), 61.9 (C-6), 41.1, 38.8, 36.7, 28.0 (Adam), 21.1–20.9 ($CH_3$CO). Anal. Calcd for $C_{25}H_{34}O_{11}$: C, 58.81; H, 6.71. Found: C, 58.75; H, 6.69.

### 3.3. 1-*O*-Adamantoyl-α-D-glucopyranose (4α)

To a stirred solution of **3**α (500 mg, 0.98 mmol) in MeOH (0.5 mL) was added NaOMe (4 mg, 0.01 mmol).

After 1 h at rt, the mixture was evaporated. Chromatography of the residue on a column of silica gel (1:1 hexane–EtOAc) gave **4**α in 55% yield as a oil; IR; *v* 3348.1 (OH), 1726.1 $cm^{-1}$ (*C*OAdam); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 178.4 (*C*OAdam), 91.6 (C-1), 72.4 (C-3), 70.3 (C-5), 68.0, 67.1 (C-2, C-4), 61.8, (C-6), 40.8, 39.2, 36.9, 28.5 (Adam). Anal. Calcd for $C_{17}H_{26}O_7$: C, 59.63; H, 7.66. Found: C, 59.51; H, 7.56.

### 3.4. 1-*O*-Adamantoyl-β-D-glucopyranose (4β)

A procedure similar to that for the preparation of **4**α was employed. Treatment of **3**β (500 mg, 0.98 mmol) in MeOH (0.5 mL) with NaOMe (4.0 mg, 0.01 mmol) gave **4**β in 58% yield as a white crystalline material; mp 94–96 °C; $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 178.4 (*C*OAdam), 94.7 (C-1), 72.1 (C-3), 71.2, (C-5), 67.9, 67.2 (C-2, C-4), 61.3 (C-6), 40.8, 39.2, 36.9, 28.5 (Adam). Anal. Calcd for $C_{17}H_{26}O_7$: C, 59.63; H, 7.66. Found: C, 59.60; H, 7.63.

### 3.5. 2,3,4,6-Tetra-*O*-acetyl-1-*O*-adamantoyl-D-galactopyranose (5)

A procedure similar to that for the preparation of **3** was employed. Treatment of 2,3,4,6-tetra-*O*-acetyl-D-galactopyranose (1.0 g, 2.9 mmol), 1-adamantanecarboxylic acid (1.0 g, 5.8 mmol) with DCC (2.3 g, 11.5 mmol), DMAP (0.7 g, 2.9 mmol) at 50 °C gave **5** in 89% yield as white crystals, α/β 1:4; mp 133–135 °C; $^1H$ NMR ($CDCl_3$, 300 MHz): δ 6.32 (d, 1H, $J_{1,2}$ 2.9 Hz, H-1α), 5.60 (d, 1H, $J_{1,2}$ 8.3 Hz, H-1β), 5.45 (dd, 1H, $J_{4,5}$ 0.7 Hz, H-4α), 5.36 (dd, 1H, $J_{4,5}$ 1.0 Hz, H-4β), 5.29 (dd, 1H, $J_{2,3}$ 10.4 Hz, H-2β), 5.25 (dd, 1H, $J_{2,3}$ 9.8 Hz, H-2α), 5.01 (dd, 1H, $J_{3,4}$ 3.4 Hz, H-3β), 4.97 (dd, 1H, H-3α), 4.01–4.06 (m, 2H, H-6β), 3.97 (m, 1H, H-5α, H-5β), 2.10–1.93 (4s, 12H, $CH_3CO$), 2.11–1.68 (m, 15H, Adam); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.0, 175.6 (*C*OAdam), 171.0–169.8 ($CH_3CO$), 92.4 (C-1β), 89.6 (C-1α), 72.0 (C-5β, C-5α), 71.2 (C-3β), 69.1 (C-3α), 68.1 (C-2β), 68.0, 67.8, 67.1 (C-2α, C-4α), 67.2 (C-4β), 61.6 (C-6α), 61.3 (C-6β), 41.1, 39.7, 36.7, 28.1 (Adam), 21.0–20.9 ($CH_3CO$). Anal. Calcd for $C_{25}H_{34}O_{11}$: C, 58.81; H, 6.71. Found: C, 58.72; H, 6.67.

### 3.6. 1-*O*-Adamantoyl-D-galactopyranose (6)

A procedure similar to that for the preparation of **4** was employed. Treatment of **5** (500 mg, 0.98 mmol) in MeOH (0.5 mL) with NaOMe (4.0 mg, 0.01 mmol) gave **6** in 64% yield as white crystals, α/β 1:2; $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.2 (*C*OAdam), 94.7 (C-1β), 91.3 (C-1α), 72.6, 72.1 (C-3), 71.0, 70.7 68.1, 67.5, 67.1 (C-2, C-4, C-5), 62.4, 61.3 (C-6), 41.0–28.4 (Adam). Anal. Calcd for $C_{17}H_{26}O_7$: C, 59.63; H, 7.66. Found: C, 59.55; H, 7.58.

### 3.7. 2,3,4-Tri-*O*-acetyl-1-*O*-adamantoyl-L-fucopyranose (7)

A procedure similar to that for the preparation of **3** was employed. Treatment of 2,3,4-tri-*O*-acetyl-L-fucopyranose (1 g, 3.4 mmol), 1-adamantanecarboxylic acid (1.24 g, 13.6 mmol) with DCC (7.11 g, 13.6 mmol), DMAP (1.42 g, 3.4 mmol) at 50 °C gave **7** in 66% yield, α/β 1:1; anomer **7**α, oil, $^1H$ NMR ($CDCl_3$, 300 MHz): δ 6.36 (d, 1H, $J_{1,2}$ 3.2 Hz, H-1), 5.35 (m, 2H, H-3, H-4), 5.31 (m, 1H, H-2), 3.92 (m, 1H, $J_{5,6}$ 6.0 Hz, H-5), 2.17–1.93 (3s, 9H, $CH_3CO$), 2.16–1.69 (m, 15H, Adam), 1.19 (d, 3H, H-6); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.0 (*C*OAdam), 171.0–170.2 ($CH_3CO$), 89.8 (C-1), 71.0 (C-3), 68.5 (C-4), 67.6 (C-5), 67.1 (C-2), 41.1, 38.8, 36.7, 28.8 (Adam), 21.2–21.0 ($CH_3CO$), 16.4 (C-6); anomer **7**β, white crystals, mp 138–140 °C; $^1H$ NMR ($CDCl_3$, 300 MHz): δ 5.65 (d, 1H, $J_{1,2}$ 8.2 Hz, H-1), 5.34 (dd, 1H, $J_{2,3}$ 10.0 Hz, H-2), 5.27 (d, 1H, H-4), 5.07 (dd, 1H, $J_{3,4}$ 3.3 Hz, H-3), 3.95 (m, 1H, $J_{5,6}$ 6.0 Hz, H-5), 2.16–1.70 (m, 15H, Adam), 2.15–1.90 (3s, 9H, $CH_3CO$), 1.23 (d, 3H, H-6); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.2 (*C*OAdam), 171.0–169.8 ($CH_3CO$), 92.5 (C-1), 71.6 (C-3), 70.7 (C-5), 70.5 (C-4), 68.3 (C-2), 41.1, 38.9, 36.3, 28.2 (Adam), 21.1–20.9 ($CH_3CO$), 16.3 (C-6). Anal. Calcd for $C_{25}H_{34}O_{10}$: C, 60.72; H, 6.93. Found: C, 60.65; H, 6.89.

### 3.8. 1-*O*-Adamantoyl-α-L-fucopyranose (8α)

A procedure similar to that for the preparation of **4**α was employed. Treatment of **7**α (500 mg, 1.1 mmol) in MeOH (0.5 mL) with NaOMe (5 mg, 0.11 mmol) gave **8**α in 51% yield as white crystals; mp 77–79 °C; $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.8 (*C*OAdam), 94.6 (C-1), 74.9 (C-2), 72.0, 71.7 (C-3, C-4), 70.8 (C-5), 16.7 (C-6), 41.4–28.2 (Adam). Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.41; H, 7.85.

### 3.9. 1-*O*-Adamantoyl-β-L-fucopyranose (8β)

A procedure similar to that for the preparation of **4**α was employed. Treatment of **7**β (500 mg, 1.1 mmol) in MeOH (0.5 mL) with NaOMe (5 mg, 0.11 mmol) gave **8**β in 50% yield as an oil; $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): δ 176.8 (*C*OAdam), 92.4 (C-1), 74.9 (C-2), 71.8, 71.4 (C-3, C-4), 70.8 (C-5), 16.6 (C-6), 41.4–28.2 (Adam). Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.46; H, 7.94.

### 3.10. 2,3,4-Tri-*O*-acetyl-1-*O*-adamantoyl-L-rhamnopyranose (9)

A procedure similar to that for the preparation of **3** was employed. Treatment of 2,3,4-tri-*O*-acetyl-L-rhamnopyranose (1 g, 3.4 mmol), 1-adamantanecarboxylic acid

(1.24 g, 13.6 mmol) with DCC (7.11 g, 13.6 mmol), DMAP (1.42 g, 3.4 mmol) at 50 °C gave **9** in 85% yield, α/β 1/3; anomer **9**α, oil, $^1$H NMR ($CDCl_3$, 300 MHz): δ 6.00 (d, 1H, $J_{1,2}$ 1.2 Hz, H-1), 5.28 (m, 1H, H-3), 5.25 (m, 1H, H-4), 5.11 (m, 1H, $J_{2,3}$ 3.4 Hz, H-2), 3.91 (m, 1H, $J_{5,6}$ 6.3 Hz, H-5), 2.22–2.00 (3s, 9H, $CH_3CO$), 2.00–1.61 (m, 15H, Adam), 1.24 (d, 3H, H-6); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 175.4 (*C*OAdam), 170.6–170.2 ($CH_3CO$), 90.8 (C-1), 70.7 (C-4), 69.4, 69.0 (C-3, C-2), 69.2 (C-5), 41.1, 38.8, 36.7, 28.8 (Adam), 21.2–21.0 ($CH_3CO$), 17.8 (C-6); anomer **9**β, white crystals, mp 133–135 °C; $^1$H NMR ($CDCl_3$, 300 MHz): δ 5.81 (d, 1H, $J_{1,2}$ 1.0 Hz, H-1), 5.48 (dd, 1H, $J_{2,3}$ 3.4 Hz, H-2), 5.09 (m, 2H, H-3, H-4), 3.67 (m, 1H, $J_{4,5}$ 9.6 Hz, $J_{5,6}$ 6.2 Hz, H-5), 1.29 (d, 3H, H-6); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 90.7 (C-1), 71.8 (C-5), 71.0, 70.9 (C-3, C-4), 68.9 (C-2), 17.7 (C-6). Anal. Calcd for $C_{25}H_{34}O_{10}$: C, 60.72; H, 6.93. Found: C, 60.68; H, 6.91.

### 3.11. 1-*O*-Adamantoyl-α-L-rhamnopyranose (10α)

A procedure similar to that for the preparation of **4**α was employed. Treatment of **9**α (500 mg, 1.1 mmol) in MeOH (0.5 mL) with NaOMe (5 mg, 0.11 mmol) gave **10**α in 45% yield as white crystals; mp 125–126 °C; IR; *ν* 3291.5 (OH), 1726.1 cm$^{-1}$ (*C*OAdam); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.1 (*C*OAdam), 93.5 (C-1), 73.0 (C-2), 72.0 (C-3), 71.3, 71.0 (C-4, C-5), 41.5-36.7 (Adam), 18.0 ($C_6$). Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.49; H, 7.92.

### 3.12. 1-*O*-Adamantoyl-β-L-rhamnopyranose (10β)

A procedure similar to that for the preparation of **4**α was employed. Treatment of **9**β (500 mg, 1.1 mmol) in MeOH (0.5 mL) with NaOMe (5 mg, 0.11 mmol) gave **10**β in 50% yield as white crystals; mp 133–134 °C; $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.1 (*C*OAdam), 93.5 (C-1), 73.0 (C-2), 72.0 (C-3), 71.3, 71.0 (C-4, C-5), 41.5-36.7 (Adam), 18.0 ($C_6$). Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.44; H, 7.89.

### 3.13. 3-*O*-Adamantoyl-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (12)

A procedure similar to that for the preparation of **3** was employed. Treatment of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose **11**[17] (1 g, 3.8 mmol), 1-adamantanecarboxylic acid (1.38 g, 7.7 mmol) with DCC (3.17 g, 15.4 mmol), DMAP (0.47 g, 3.8 mmol) at 50 °C gave **12** in 69% yield as white crystals; mp 110–112 °C; $^1$H NMR ($CDCl_3$, 300 MHz): δ 5.87 (d, 1H, $J_{1,2}$ 3.7 Hz, H-1), 4.51 (d, 1H, H-2), 4.31 (q, 1H, H-5), 4.11 (dd, 1H, $J_{4,5}$ 7.4 Hz, H-4), 4.00 (d, 1H, $J_{3,4}$ 3.6 Hz, H-3), 4.05 (m, 2H, H-6), 2.08–1.72 (m, 15H, Adam), 1.59–1.44 (4s, 12H, $CH_3$); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.4 (*C*OAdam), 112.1, 109.3 ($C_{iso}$), 105.7 (C-1), 82.9 (C-3), 82.5 (C-2), 81.6 (C-4), 72.9 (C-5), 67.6 (C-6), 41.1–38.9 (Adam), 27.2–24.5 ($CH_3$). Anal. Calcd for $C_{23}H_{34}O_7$: C, 65.38; H, 8.11. Found: C, 65.26; H, 8.04.

### 3.14. 3-*O*-Adamantoyl-D-glucose (13)

A suspension of diacetal derivative **12** (500 mg, 1.8 mmol) in a solution of 9:1 $CF_3CO_2OH$–water (0.5 mL) was stirred at rt. After 30 min, the solvent was removed by co-evaporation with toluene (5 mL). Chromatography of the residue on a column of silica gel (2:3 hexane–EtOAc) gave **13** in 71% yield as white crystals, α/β 3:7; mp 142–144 °C; IR; *ν* 3370.2 (OH), 1718.9 cm$^{-1}$ (*C*OAdam); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.7 (*C*OAdam), 97.6 (C-1β), 93.0 (C-1α), 78.1, 77.4 (C-3); 77.4, 75.8, 72.8, 71.3, 69.0, (C-2, C-4, C-5), 61.6 (C-6), 41.1, 39.4–37.0 (Adam). Anal. Calcd for $C_{17}H_{26}O_7$: C, 59.64; H, 7.65. Found: C, 59.58; H, 7.57.

### 3.15. 6-*O*-Adamantoyl-1,2:5,6-di-*O*-isopropylidene-α-D-galactofuranose (15)

A procedure similar to that for the preparation of **3** was employed. Treatment of 1,2:5,6-di-*O*-isopropylidene-α-D-galactofuranose **14**[18] (1 g, 3.8 mmol), 1-adamantanecarboxylic acid (1.38 g, 7.7 mmol) with DCC (3.17 g, 15.4 mmol), DMAP (0.47 g, 3.8 mmol) at 50 °C gave **15** as white crystals in 76% yield; mp 122–123 °C; $^1$H NMR ($CDCl_3$, 300 MHz): δ 5.55 (d, 1H, $J_{1,2}$ 5.0 Hz, H-1), 4.62 (dd, 1H, $J_{3,4}$ 7.9 Hz, H-3), 4.38 (dd, 1H, $J_{2,3}$ 2.4 Hz, H-2), 4.33 (d, 1H, $J_{4,5}$ 1.8 Hz, H-4), 4.13 (m, 1H, $J_{5,6}$ 6.2 Hz, H-5), 4.05 (m, 2H, H-6), 2.10–1.72 (m, 15H, Adam), 1.59–1.44 (4s, 12H, $CH_3$); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.3 (*C*OAdam), 110.0, 109.2 ($C_{iso}$), 96.7 (C-1), 71.5 (C-4), 71.1 (C-2), 70.9 (C-3), 66.6 (C-5), 63.5 (C-6), 41.1–36.9 (Adam), 26.4, 24.9 ($CH_3$). Anal. Calcd for $C_{23}H_{34}O_7$: C, 65.38; H, 8.11. Found: C, 65.26; H, 8.07.

### 3.16. 6-*O*-Adamantoyl-D-galactose (16)

A suspension of diacetal derivative **15** (500 mg, mmol) in a solution of 9:1 $CF_3CO_2OH$–water (0.5 mL) was stirred at rt. After 30 min, the solvent was removed by co-evaporation with toluene (5 mL). Chromatography of the residue on a column of silica gel (2:3 hexane–EtOAc) gave **16** in 71% yield as white crystals, α/β 3:1; mp 101–102 °C; IR; *ν* 3379.2 (OH), 1703.9 cm$^{-1}$ (*C*OAdam); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): δ 176.3 (*C*OAdam), 98.1 (C-1β), 93.4 (C-1α); 74.0, 72.7 (C-3); 73.2, 70.4, 69.8, 69.2 (C-2, C-4, C-5); 65.6 (C-6); 40.8–36.7 (Adam). Anal. Calcd for $C_{17}H_{26}O_7$: C, 59.64; H, 7.65. Found: C, 59.55; H, 7.54.

### 3.17. 4-(2,3,4,6-Tetra-*O*-acetyl-α-D-glucopyranosyloxy)-butanol (18)

To a stirred solution of tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**17**, 1 g, 2.4 mmol) and 1,4-butandiol (441 mg, 4.8 mmol) and 4 Å MS (1 g) in anhyd $CH_2Cl_2$ (10 mL), was added tetramethylurea (0.28 mL, 2.4 mmol) and AgOTf (0.54 g, 2.4 mmol) at 0 °C in the dark. After stirring for 12 h, the reaction was quenched with $Et_3N$, filtered and then evaporated. Chromatography of the residue on a column of silica gel (3:2 hexane–EtOAc) gave **18** in 75% yield as an oil; $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 5.17 (t, 1H, $J_{3,4}$ 9.4 Hz, H-3), 5.06 (t, 1H, $J_{4,5}$ 9.8 Hz, H-4), 4.96 (dd, 1H, $J_{2,3}$ 9.5 Hz, H-2), 4.48 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 4.25 (dd, 1H, $J_{6a,6b}$ 12.3 Hz, $J_{5,6a}$ 4.7 Hz, H-6a), 4.11 (dd, 1H, $J_{5,6b}$ 2.5 Hz, H-6b), 4.19–4.00 (m, 2H, $CH_{2\delta}$), 3.89, 3.50 (2m, 2H, $CH_{2\alpha}$), 3.67 (m, 1H, H-5), 2.12–1.97 (4s, 12H, $CH_3CO$), 2.03 (m, 2H, $CH_{2\delta}$), 1.91 (m, 2H, $CH_{2\chi}$); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): $\delta$ 171.2–169.8 ($CH_3CO$), 101.0 (C-1), 73.1 (C-3), 72.0 (C-5), 71.7 (C-2), 70.3 ($CH_{2\alpha}$), 68.8 (C-4), 62.4 ($CH_{2\delta}$), 62.2 (C-6), 29.4, 26.1 ($CH_{2\beta}$, $CH_{2\chi}$), 21.1–20.9 ($CH_3CO$). Anal. Calcd for $C_{18}H_{28}O_{11}$: C, 51.43; H, 6.71. Found: C, 51.37; H, 6.64.

### 3.18. 4-Adamantoyloxy-1-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyloxy)butane (19)

A procedure similar to that for the preparation of **3** was employed. Treatment of **18** (0.5 g, 1.2 mmol), 1-adamantanecarboxylic acid (2.8 g, 2.4 mmol) with DCC (1.3 g, 4.8 mmol), DMAP (0.14 g, 1.2 mmol) at 50 °C gave **19** in 74% yield as an oil; IR ($cm^{-1}$); $\nu$ 1746.7 ($CH_3CO$), 1723.5 $cm^{-1}$ (Adam); $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 5.13 (t, 1H, $J_{3,4}$ 9.4 Hz, H-3), 5.00 (t, 1H, $J_{4,5}$ 9.6 Hz, H-4), 4.91 (dd, 1H, $J_{2,3}$ 9.4 Hz, H-2), 4.45 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 4.20 (dd, 1H, $J_{6a,6b}$ 12.2 Hz, $J_{5,6a}$ 4.6 Hz, H-6a), 4.05 (dd, 1H, $J_{5,6b}$ 2.5 Hz, H-6b), 4.04, 3.82 (m, 2H, $CH_{2\delta}$), 3.82, 3.55 (2m, 2H, $CH_{2\alpha}$), 3.63 (m, 1H, H-5), 2.02–1.91 (4s, 12H, $CH_3CO$), 1.97 (m, 2H, $CH_{2\delta}$), 1.58 (m, 2H, ($CH_{2\chi}$)), 2.16–1.67 (m, 15H, Adam); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): $\delta$ 178.0 (*C*OAdam), 171.0–169.6 ($CH_3CO$), 101.2 (C-1), 73.2 (C-3), 72.2 (C-5), 71.7 (C-2), 69.8 ($CH_{2\alpha}$), 68.8 (C-4), 63.9 ($CH_{2\delta}$), 62.3 (C-6), 41.1, 39.2, 36.2, 28.3 (Adam), 26.3, 25.2 ($CH_{2\beta}$, $CH_{2\chi}$), 21.1–20.9 ($CH_3CO$). Anal. Calcd for $C_{29}H_{42}O_{12}$: C, 59.78; H, 7.27. Found: C, 59.71; H, 7.21.

### 3.19. 4-Adamantoyloxy-1-(α-D-glucopyranosyloxy)-butane (20)

A procedure similar to that for the preparation of **4** was employed. Treatment of **19** (500 mg, 1.0 mmol) in MeOH (1 mL) with NaOMe (5.5 mg, 0.1 mmol) gave **20** in 67% yield as white crystals; mp 75–77 °C; IR; $\nu$ 3356.1 (OH), 1723.4 $cm^{-1}$ (*C*OAdam); $[M+Na]^{+\bullet}$ $m/z$ 437.4; $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 4.32 (d, 1H, $J_{1,2}$ 8.0 Hz, H-1), 4.08 (t, 2H, $CH_{2\delta}$), 3.93, 3.57 (2m, 2H, $CH_{2\alpha}$), 3.86 (m, 2H, H-6), 3.62–3.53 (m, 2H, H-3, H-4), 3.39 (m, 1H, $J_{2,3}$ 9.5 Hz, H-2), 3.32 (m, 1H, H-5), 2.04–1.69 (m, 15H, Adam), 1.71 ($CH_{2\delta}$, $CH_{2\chi}$); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): $\delta$ 178.4 (*C*OAdam), 103.2 (C-1), 76.8 (C-3) 76.0 (C-5), 73.8 (C-2), 69.9 ($CH_{2\alpha}$), 69.8 (C-4), 64.2 ($CH_{2\delta}$), 61.8 (C-6), 41.1, 39.2, 36.9, 28.5 (Adam), 26.3, 25.7 ($CH_{2\beta}$, $CH_{2\chi}$). Anal. Calcd for $C_{21}H_{34}O_8$: C, 60.85; H, 8.27. Found: C, 60.75; H, 8.19.

### 3.20. 4-(2,3,4-Tri-*O*-acetyl-β-L-fucopyranosyloxy)butanol (22)

A procedure similar to that for the preparation of **18** was employed. Treatment of **21** (1 g, 2.8 mmol), 1,4-butandiol (512 mg, 5.7 mmol) with tetramethylurea (330 mg, 2.8 mmol) and AgOTf (627 mg, 2.8 mmol) at 0 °C in the dark gave **22** in 71% yield as an oil; $^1$H NMR ($CDCl_3$, 300 MHz): 5.22 (d, 1H, H-4), 5.17 (dd, 1H, $J_{2,3}$ 10.4 Hz, H-2), 5.00 (dd, 1H, $J_{3,4}$ 3.4 Hz, H-3), 4.43 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 3.94, 3.63, 3.50 (3m, 4H, $CH_{2\delta}$, $CH_{2\alpha}$), 3.79 (dq, 1H, $J_{4.5}$ 1.0 Hz, $J_{5,6}$ 6.4 Hz, H-5), 2.18–1.70 (m, 15H, Adam), 2.16–1.97 (3s, 9H, $CH_3CO$), 2.00 ($CH_{2\delta}$), 1.63 ($CH_{2\chi}$), 1.21 (d, 2H, H-6); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): $\delta$ 171.1–170.0 ($CH_3CO$), 101.5 (C-1), 71.7 (C-3), 70.7 (C-4), 70.2 ($CH_{2\alpha}$), 69.5, 69.4 (C-2, C-5), 62.7 ($CH_{2\delta}$), 29.8 ($CH_{2\chi}$), 26.2 ($CH_{2\beta}$, $CH_{2\chi}$), 21.2–21.0 ($CH_3CO$), 16.4 (C-6). Anal. Calcd for $C_{18}H_{28}O_{10}$: C, 53.46; H, 6.98. Found: C, 53.40; H, 6.94.

### 3.21. 4-Adamantoyloxy-1-(2,3,4-tri-*O*-acetyl-β-L-fucopyranosyloxy)butane (23)

A procedure similar to that for the preparation of **3** was employed. Treatment of **22** (500 mg, 1.4 mmol), 1-adamantanecarboxylic acid (0.5 g, 2.8 mmol) with DCC (1.14 g, 5.5 mmol), DMAP (0.17 g, 1.4 mmol) at 50 °C gave **23** in 68% yield as an oil; IR: 1746.8 ($CH_3CO$), 1723.8 $cm^{-1}$ (*C*OAdam); $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 5.24 (d, 1H, H-4), 5.19 (dd, 1H, $J_{2,3}$ 10.4 Hz, H-2), 5.02 (dd, 1H, $J_{3,4}$ 3.4 Hz, H-3), 4.44 (d, 1H, $J_{1,2}$ 7.9 Hz, H-1), 4.13–4.05 (m, 2H, $CH_{2\delta}$), 3.92, 3.49 (2m, 2H, $CH_{2\alpha}$), 3.80 (m, 1H, $J_{5,6}$ 6.4 Hz, H-5), 2.18–1.94 (3s, 9H, $CH_3CO$), 2.17–1.71 (m, 15H, Adam), 2.03 (m, 2H, $CH_{2\beta}$), 1.91 (m, 2H, $CH_{2\chi}$), 1.23 (d, 2H, H-6); $^{13}$C NMR ($CDCl_3$, 75.5 MHz): $\delta$ 178.0 (*C*OAdam), 171.1–169.8 ($CH_3CO$), 101.5 (C-1), 71.8 (C-3), 70.7 (C-4), 69.5, 69.4 (C-2, C-5), 69.7 ($CH_{2\alpha}$), 64.0 ($CH_{2\delta}$), 41.1, 39.0, 36.8, 28.3 (Adam), 26.4, 25.5 ($CH_{2\beta}$, $CH_{2\chi}$), 21.1–21.0 ($CH_3CO$), 16.4 (C-6). Anal. Calcd for $C_{29}H_{42}O_{11}$: C, 61.47; H, 7.47. Found: C, 61.39; H, 7.40.

### 3.22. 4-Adamantoyloxy-1-(β-L-fucopyranosyloxy)butane (24)

A procedure similar to that for the preparation of **4** was employed. Treatment of **23** (500 mg, 1.4 mmol) in MeOH (5 mL) with NaOMe (6.2 mg, 0.14 mmol) gave **24** in 71% yield as an oil; IR; $\nu$ 3370.0 (OH), 1723.3 $cm^{-1}$ (*C*OAdam); $[M+Na]^{+\bullet}$ *m/z* 421.5; $^1H$ NMR ($CDCl_3$, 300 MHz): $\delta$ $^1H$ NMR ($CDCl_3$, 300 MHz): $\delta$ 4.19 (d, 1H, $J_{1,2}$ 7.2 Hz, H-1), 4.08–3.92 (m, 2H, $CH_{2\alpha}$), 3.92, 3.54 (2m, 2H, $CH_{2\delta}$), 3.72 (d, 1H, $J_{3,4}$ 2.5 Hz, H-4), 3.61 (m, 1H, $J_{2,3}$ 10.1 Hz, H-2), 3.60–3.51 (2m, 2H, H-3, H-5), 2.05–1.70 (m, 15H, Adam), 2.00, 1.88 (m, 4H, $CH_{2\delta}$, $CH_{2\chi}$), 1.32 (d, 2H, H-6); $^{13}C$ NMR ($CDCl_3$, 75.5 MHz): $\delta$ 178.3 (*C*OAdam), 103.4 (C-1), 74.4 (C-3), 72.0 (C-4), 71.7 (C-5), 71.0 (C-2), 69.8 ($CH_{2\alpha}$), 64.2 ($CH_{2\delta}$), 41.1, 39.2, 36.9, 28.3 (Adam), 26.3, 25.8 ($CH_{2\beta}$, $CH_{2\chi}$), 16.7 (C-6). Anal. Calcd for $C_{21}H_{34}O_7$: C, 62.30; H, 8.60. Found: C, 62.25; H, 8.56.


## Acknowledgements

We thank the Ministère de la Recherche for financial support and Professor J. Banoub for helpful discussions.


## References


1. Connors, K. A. *J. Pharm. Sci.* **1995**, *84*, 843–848.
2. Eftink, M. R.; Andy, M. L.; Bystrom, K.; Perlmytter, H. D.; Kristol, S. *J. Am. Chem. Soc.* **1989**, *111*, 6765–6772.
3. Amiel, C.; Sébille, B. *Adv. Colloid Interface Sci.* **1999**, *79*, 105–122.
4. Sandier, A.; Brown, W.; Mays, H. *Langmuir* **2000**, *16*, 1634–1642.
5. Moine, L.; Amiel, C.; Brown, W.; Guerin, P. *Polym. Int.* **2001**, *50*, 663–676.
6. Auzély-Velty, R.; Rinaudo, M. *Macromolecules* **2002**, *35*, 7955–7962.
7. Binello, A.; Cravotto, G.; Nano, G. M.; Spagliardi, P. *Flavour Flag. J.* **2004**, *19*, 394–400.
8. David, C.; Millot, M.; Renard, E.; Sébille, B. *J. Incl. Phenom.* **2002**, *44*, 369–372.
9. Ravoo, B. J.; Jacquier, J.-C.; Wenz, G. *Angew. Chem., Int. Ed.* **2003**, *42*, 2066–2070.
10. Pun, S. H.; Davis, M. E. *Bioconjugate Chem.* **2002**, *13*, 630–639.
11. Garcia-Lopez, J. J.; Hernandez-Mateo, F.; Isac-Garcia, J.; Kim, J. M.; Roy, R.; Santoyo-González, F.; Vargas-Berenguel, A. *J. Org. Chem.* **1999**, *64*, 522–531.
12. García-Barrientos, A.; Garcia-Lopez, J. J.; Isac-Garcia, J.; Ortega-Caballero, F.; Uriel, C.; Vargas-Berenguel, A.; Santoyo-González, F. *Synthesis* **2001**, 1057–1064.
13. Bellocq, N. C.; Pun, S. H.; Jensen, G. S.; Davis, M. E. *Bioconjugate Chem.* **2003**, *14*, 1122–1132.
14. Kida, T.; Ohe, T.; Higashimoto, H.; Harada, H.; Nakatsuji, Y.; Ikeda, I.; Akashi, M. *Chem. Lett.* **2004**, *33*, 258–259.
15. Schmidt, R. R.; Wegmann, B.; Jung, K. H. *Liebigs Ann. Chem.* **1991**, 121–124.
16. Hu, X.; Chen, H.; Zhang, X. *Angew. Chem., Int. Ed.* **1999**, *38*, 3718–3720.
17. Schmidt, O. *Methods Carbohydr. Chem.* **1962**, *2*, 318–325.
18. Collins, P. M.; Munasinghe, V. R. N. *Carbohydrates*; University Press: London G.B., 1987.
19. Hanessian, S.; Banoub, J. *Adv. Chem. Ser.* **1976**, *39*, 36–41.
20. Schneider, H. J.; Hacket, F.; Rüdiger, V.; Ikeda, H. *Chem. Rev.* **1998**, *98*, 1755–1786.
21. Gil, V. M. S.; Oliveira, N. C. *J. Chem. Educ.* **1990**, *67*, 473–478.
22. Landy, D.; Fourmentin, S.; Salome, M.; Surpateanu, G. J. *Incl. Phenom.* **2000**, *38*, 187–190.