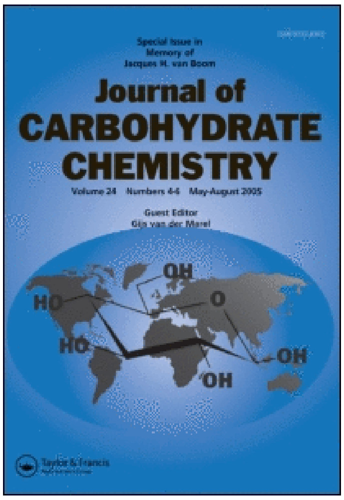


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# Concise Synthesis of a Hexasaccharide Related to the Adhesin Receptor of *Streptococcus oralis* ATCC 55229

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# Concise Synthesis of a Hexasaccharide Related to the Adhesin Receptor of *Streptococcus oralis* ATCC 55229



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A concise synthesis of a hexasaccharide related to the adhesin receptor of *Streptococcus oralis* ATCC 55229 (previously characterized as *Streptococcus sanguis* H1) has been achieved in excellent yield. A general glycosylation condition has been used throughout the synthetic scheme. All glycosylation steps and protecting group functionalization steps are high yielding and suitable for scale-up preparation.

**Keywords** Hexasaccharide; *Streptococcus oralis*; Glycosylation; Adhesin

## INTRODUCTION

Most microbial infections initiate with protein-carbohydrate interactions, which play a key role in the effective adhesion of bacteria, viruses, or protozoa to the host.[1] Microbial cell-wall glycolipids,[2] glycoproteins,[3] and capsular polysaccharides[4] are known to contain receptors for carbohydrate-binding proteins playing crucial roles at the initial stage of microbial adhesion to the host. Dental plaque formation is a common phenomenon in the human oral environment due to the aggression of a diverse range of microbes.[5] It has been well established that specific interactions between bacterial adhesins and carbohydrates play significant roles in the initiation and maturation of dental plaque formation.[6] In the past, a number of studies have been carried out

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Glyc-(1→$PO_4$)
↓
6
→3)-β-D-Gal*f*-(1→3)-α-L-Rha*p*-(1→2)-α-L-Rha*p*-(1→3)-α-D-Gal*p*-(1→3)-β-D-Gal*p*-(1→4)-β-D-Glc*p*-(1→

**Figure 1:** Structure of the adhesin receptor of *Streptococcus oralis* ATCC 55229.

for the identification and biochemical characterization of specific molecular mediators of interbacterial aggregation responsible for plaque formations.[7] The frequently found bacterial species acting as primary colonizers in dental plaque are *Streptococcus oralis*, *Actinomyces viscosis,* and *Actinomyces naeslundii*.[8] To date, a few adhesin receptor polysaccharides have been identified and characterized to study their role in dental plaque formation. A number of carbohydrate receptor molecules having significant antigenicity have been isolated from *Streptococcus mitis* 522, *S. oralis* ATCC 10557, *S. oralis* 34, and *S. oralis* C104 strains, which are found in the matured dental plaque.[9] The complete structure of an antigenic hexasaccharide repeating unit of the adhesin receptor polysaccharide from *S. oralis* ATCC 55229 (previously characterized as *Streptococcus sanguis* H1) has been reported by Glushka et al. (Fig. 1).[10]

The development of glycoconjugate vaccines against microbial infections has been of considerable interest for a long time, which has been reflected in several reports in the recent past.[11] Although oligosaccharides can be isolated from natural sources, their limited availability cannot always meet the required quantity for their extensive biological studies. Efficient chemical synthetic strategies could offer access to larger quantities of natural oligosaccharides and its several analogs. In order to determine the relation between structure and immunological specificity, it is quite logical to prepare oligosaccharides related to the repeating unit of the antigenic polysaccharide. The synthesized oligosaccharide could also be utilized as a molecular probe for studying the immunochemical behavior of the antigen. In this report, we describe a concise chemical synthesis of a hexasaccharide related to the repeating unit of the adhesin receptor polysaccharide of *S. oralis* ATCC 55229 as its

→3)-α-D-Gal*f*-(1→3)-α-L-Rha*p*-(1→2)-α-L-Rha*p*-(1→3)-α-D-Gal*p*-(1→3)-β-D-Gal*p*-(1→4)-β-D-Glc*p*-(1→

**Figure 2:** Structure of the synthesized hexasaccharide related to the adhesin receptor of *Streptococcus oralis* ATCC 55229 in which the D-Gal*f* unit is linked through an α-linkage.

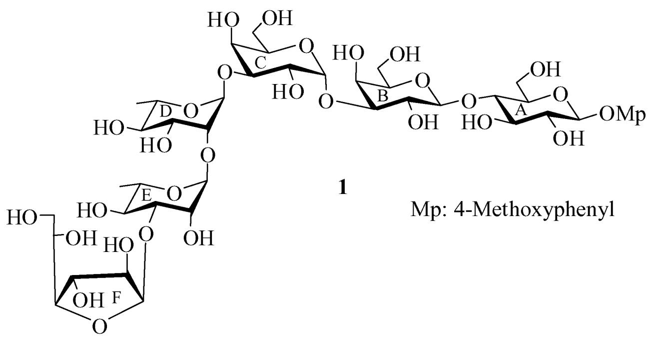


Figure 3: Chemical structure of the synthesized hexasaccharide as 4-methoxyphenyl glycoside.



4-methoxyphenyl glycosides (Figs. 2 and 3). A 1,2-*cis* linked D-galactofuranose moiety is present in the nonreducing terminus in the synthesized hexasaccharide, whereas in the natural glycan repeating unit the D-galactofuranose moiety is 1,2-*trans* linked. The 4-methoxyphenyl group could serve as a temporary anomeric protecting group, which could be removed easily for the preparation of glycoconjugate molecule.

## RESULTS AND DISCUSSION

The synthesis of the hexasaccharide was achieved by sequential glycosylation of suitably protected monosaccharide derivatives prepared from commercially available reducing sugars using literature-reported reaction conditions (Fig. 4).

4-Methoxyphenyl (4-*O*-acetyl-2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1$\rightarrow$4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (**2**)[12] was prepared from D-lactose following an earlier reported procedure. Ethyl 4,6-*O*-benzylidene-1-

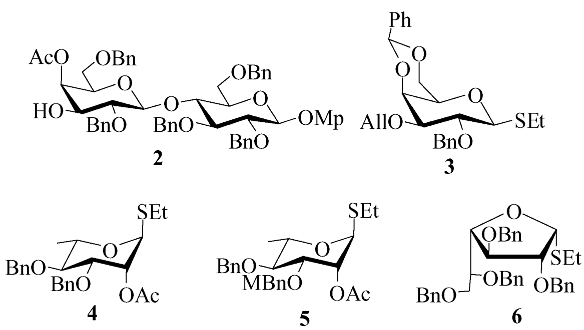
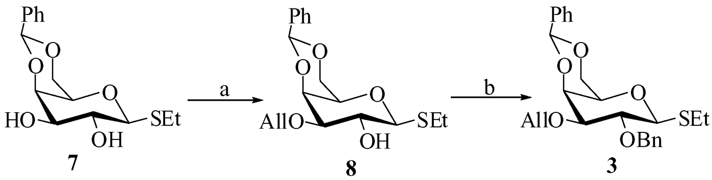


Figure 4: Suitably protected mono- and disaccharide intermediates used for the synthesis of target hexasaccharide **1**.



**Scheme 1:** Reagents: (a) (i) $Bu_2SnO$, $CH_3OH$, 80°C, 3 h; (ii) allyl bromide, CsF, DMF, rt, 12 h; (b) benzyl bromide, NaOH, TBAB, THF, rt, 4 h, overall 92%.

thio-$\beta$-D-galactopyranoside (**7**),[13] derived from D-galactose, was selectively 3-*O*-allylated via stanylidene acetal formation to give compound **8**, which was benzylated using benzyl bromide and sodium hydroxide to furnish compound **3** in 92% overall yield (Sch. 1). Starting from L-rhamnose, compounds **4**[14] and **5**[15] were prepared using similar reaction conditions reported earlier. Compound **6**[16] was prepared by mercury (II) chloride-catalyzed cyclization of acyclic D-galactose diethyldithioacetal.

Stereoselective glycosylation of disaccharide acceptor **2** with thioglycoside derivative **3** in the presence of *N*-iodosuccinimide (NIS) and trimethylsilyl trifluoromethanesulfonate (TMSOTf)[17] furnished trisaccharide derivative **9** in 89% yield. Formation of compound **9** was confirmed from its spectral analysis [signals at $\delta$ 5.15 (d, $J = 3.2$ Hz, H-$1_C$), 4.75 (d, $J = 8.7$ Hz, H-$1_A$), and 4.47 (d, $J = 7.8$ Hz, H-$1_B$) in $^1$H and $\delta$ 102.9 (C-$1_A$), 102.4 (C-$1_B$), 100.8 (Ph*C*H), and 93.6 (C-$1_C$) in the $^{13}$C NMR spectra]. 1,2-*Cis* glycosylation of the D-galactose derivative was supported by the coupling constant ($J = 3.2$ Hz) of the H-1 of the D-galactose residue in compound **9**. Removal of allyl group using palladium chloride in sodium acetate buffer medium[18] afforded trisaccharide acceptor **10** in 77% yield. Stereoselective glycosylation of compound **10** with thioglycoside derivative **4** using NIS-TMSOTf[17] furnished tetrasaccharide derivative **11** in 92% yield, which was deacetylated using sodium methoxide to give tetrasaccharide acceptor **12** in 98% yield. Presence of signals at $\delta$ 102.8 (C-$1_A$), 102.4 (C-$1_B$), 100.6 (Ph*C*H), 100.2 (C-$1_D$), and 93.5 (C-$1_C$) in the $^{13}$C NMR spectra confirmed the formation of compound **11**. Exclusive formation of 1,2-*trans* glycoside was achieved due to the presence of the neighboring participating *O*-acetyl group in the C-2 position of the L-rhamnosyl thioglycoside derivative. NIS-TMSOTf-mediated[17] stereoselective glycosylation of compound **12** with thioglycoside derivative **5** furnished pentasaccharide derivative **13** in 83% yield. Presence of signals at $\delta$ 102.8 (C-$1_B$), 102.7 (C-$1_A$), 101.4 (C-$1_E$), 100.7 (Ph*C*H), 99.1 (C-$1_D$), and 95.1 (C-$1_C$) in the $^{13}$C NMR spectra supported the formation of compound **13**. In this case also, exclusive formation of 1,2-*trans* glycoside was achieved due to the presence of the neighboring participating *O*-acetyl group in the C-2 position of the L-rhamnosyl thioglycoside derivative. Oxidative removal of 4-methoxybenzyl group using 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ)[19] in a biphasic reaction condition resulted in the formation of pentasaccharide acceptor **14** in 73% yield. Stereoselective glycosylation of compound **14** with thioglycoside derivative **6** using NIS-TMSOTf[17] furnished hexasaccharide derivative **15** in 78% yield, which was confirmed from its spectral analysis. Presence of signals at $\delta$ 108.4 (C-$1_F$), 102.7 (C-$1_A$), 102.4 (C-$1_B$), 101.3 (2 C, C-$1_D$, C-$1_E$), 100.5 (Ph*C*H), and 93.8 (C-$1_C$) in the $^{13}$C NMR spectra supported the formation of compound **15**. Although in the $^1$H NMR spectrum of compound **15** H-$1_F$ appeared in a multiplet, the presence of a signal at $\delta$ 108.4 in the $^{13}$C NMR spectrum unambiguously confirmed the formation of 1,2-*cis* glycosylation of D-galactofuranose moiety.[16] Hydrogenolysis of the hexasaccharide derivative **15** over Pearlman's catalyst[20] followed by deacetylation furnished pure hexasaccharide **1** in overall 76% yield. Formation of compound **1** was confirmed from its 1D and 2D NMR and mass spectral analysis. Presence of signals at $\delta$ 5.16 (br s, 2 H, H-$1_E$, H-$1_F$), 5.10 (br s, H-$1_C$), 4.97 (d, $J$ = 7.8 Hz, H-$1_A$), 4.92 (br s, H-$1_D$), and 4.47 (d, $J$ = 7.6 Hz, H-$1_B$) in the $^1$H NMR and at $\delta$ 109.1 (C-$1_F$), 102.8 (C-$1_B$), 101.8 (C-$1_E$), 101.1 (C-$1_A$), 100.5 (C-$1_D$), and 95.5 (C-$1_C$) in the $^{13}$C NMR spectra unambiguously confirmed the formation of target hexasaccharide **1** (Sch. 2).

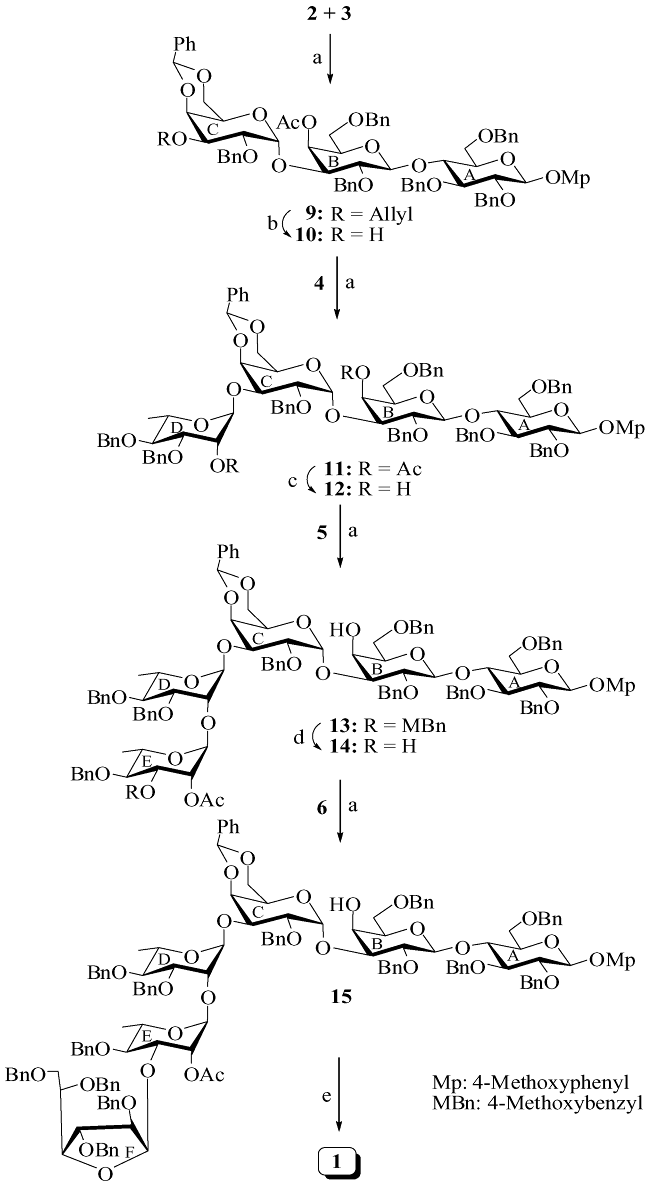
In summary, synthesis of a hexasaccharide related to the hexasaccharide adhesin receptor of *S. oralis* ATCC 55229 as its 4-methoxyphenyl glycoside has been achieved in a concise manner using a sequential stereoselective glycosylation strategy. Most of the glycosylation steps are highly stereoselective and reproducible for scale-up preparation. The 4-methoxyphenyl group has been chosen as the temporary protecting group at the reducing end for its easy removal whenever required for the preparation of glycoconjugates.



## EXPERIMENTAL

### General Procedure

All reactions were monitored by thin layer chromatography over silica gel-coated TLC plates. The spots on TLC were visualized by warming ceric sulphate (2% $Ce(SO_4)_2$ in 2N $H_2SO_4$)-sprayed plates in a hot plate. Silica gel 230–400 mesh was used for column chromatography. $^1$H and $^{13}$C NMR, 2D COSY, and HSQC spectra were recorded on a Brucker Advance DPX 300 MHz using $CDCl_3$ and $D_2O$ as solvents and TMS as internal reference unless stated otherwise. Chemical shift value is expressed in $\delta$ ppm. ESI-MS data were recorded on a MICROMASS QUATRO II triple quadrupole mass spectrometer. Elementary analysis was carried out on a Carlo ERBA-1108 analyzer. Optical rotations were measured at 25°C on a Rudolf Autopol III polarimeter. Commercially available grades of organic solvents of adequate purity are used in many reactions.




**Scheme 2:** Reagents: (a) *N*-iodosuccinimide, trimethylsilyl trifluoromethane sulfonate, MS 4Å, $CH_2Cl_2$, −40°C, 1 h, 89% for **9**, 92% for **11**, 83% for **13**, 78% for **15**; (b) $PdCl_2$, NaOAc, AcOH-$H_2O$, rt, 12 h, 77%; (c) $CH_3ONa$, $CH_3OH$, rt, 3 h, 98%; (d) DDQ, $CH_2Cl_2$, $H_2O$, rt, 2 h, 73%; (e) (i) $CH_3ONa$, $CH_3OH$, rt, 3 h; (ii) $H_2$, 20% $Pd(OH)_2$-C, rt, 24 h, 76%.

## Ethyl 3-*O*-allyl-2-*O*-benzyl-4,6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside (3)

To a solution of compound **7** (5 g, 16 mmol) in anhydrous $CH_3OH$ (120 mL) was added dibutyltin oxide (4.8 g, 19.3 mmol), and the reaction mixture was allowed to stir at 80°C for 3 h. The solvents were removed under reduced pressure and the crude mass was dissolved in anhydrous DMF (50 mL). To the reaction mixture were added cesium fluoride (2.5 g, 16.45 mmol) and allyl bromide (2.5 mL, 28.9 mmol) and the reaction mixture was allowed to stir at rt for 12 h. The solvents were removed under reduced pressure and the crude residue was dissolved in $CH_2Cl_2$ (150 mL). The organic layer was washed with 1 N HCl and water in succession, dried ($Na_2SO_4$), and concentrated. To a solution of the crude product in anhydrous THF (70 mL) were added powdered NaOH (1.8 g, 45 mmol), benzyl bromide (3.8 mL, 32 mmol), and tetrabutylammonium bromide (200 mg, 0.62 mmol) and the reaction mixture was allowed to stir briskly at rt for 4 h. The reaction was quenched by addition of satd. $NH_4Cl$ and concentrated under reduced pressure. The crude mass was dissolved in $CH_2Cl_2$ (150 mL) and the organic layer was washed with water, dried ($Na_2SO_4$), and concentrated. The crude product was purified over $SiO_2$ using hexane-EtOAc (7:1) as eluant to give pure compound **3** (6.5 g, 92%). Colorless oil; IR (neat): 3448, 2986, 1752, 1375, 1235, 1090, 1057, 919, 719 $cm^{-1}$; $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ 7.52–7.24 (m, 10 H, Ar-H), 6.0–5.88 (m, 1 H, C*H*=$CH_2$), 5.50 (s, 1 H, PhC*H*), 5.32–5.15 (m, 2 H, CH=C$H_2$), 4.87–4.70 (2 d, $J$=10.2 Hz, 2 H, PhC$H_2$), 4.42 (d, $J$=9.6 Hz, 1 H, H-1), 4.33 (d, $J$ = 12.3 Hz, 1 H, H-$6_a$), 4.22–4.18 (m, 3 H, H-4, OC$H_2$-CH=$CH_2$), 4.0 (d, $J$=12.3 Hz, H-$6_b$), 3.81 (t, $J$ = 9.3 Hz, 1 H, H-2), 3.50 (dd, $J$ = 9.2, 3.4 Hz, 1 H, H-3), 3.37 (br s, 1 H, H-5), 2.86–2.70 (m, 2 H, SC$H_2CH_3$), 1.33 (t, $J$ = 7.4 Hz, 3 H, $SCH_2CH_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$): $\delta$ 138.4–137.9 (Ar-C), 134.9 (*C*H=$CH_2$), 129.0–126.5 (Ar-C), 117.4 (CH=*C*$H_2$), 101.5 (Ph*C*H), 84.4 (C-1), 80.9 (C-5), 76.8 (C-3), 75.6 (Ph*C*$H_2$), 74.2 (O*C*$H_2$CH=$CH_2$), 71.2 (C-4), 69.8 (C-2), 69.4 (C-6), 23.8 (S*C*$H_2CH_3$), 15.0 ($SCH_2$*C*$H_3$); ESI-MS: 465.2 $[M+Na]^+$; Anal. Calcd. for $C_{25}H_{30}O_5S$ (442.18): C, 67.85; H, 6.83; found: C, 67.69; H, 7.00.

## 4-Methoxyphenyl (3-*O*-allyl-2-*O*-benzyl-4,6-*O*-benzylidene-$\alpha$-D galactopyranosyl)-(1$\rightarrow$3)-(4-*O*-acetyl-2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1$\rightarrow$4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (9)

To a solution of compound **2** (4 g, 4.25 mmol) and compound **3** (2.8 g, 6.33 mmol) in anhydrous $CH_2Cl_2$ (50 mL) was added MS-4 (5 g) and the reaction mixture was allowed to stir at rt for 1 h under argon. The reaction mixture was cooled to −40°C and *N*-iodosuccinimide (NIS; 1.7 g, 7.55 mmol) and TMSOTf (25 $\mu$L) were added to it. After stirring at same temperature for 1 h, the reaction mixture was quenched with $Et_3N$ (0.2 mL), filtered through a Celite bed, and washed with $CH_2Cl_2$ (100 mL). The organic layer was washed with aq. $Na_2S_2O_3$ and water in succession, dried ($Na_2SO_4$), and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (5:1) as eluant to furnish pure **9** (5 g, 89%). Colorless solid; m.p. 110–112°C; IR (KBr): 3018, 2925, 2361, 1742, 1505, 1453, 1364, 1217, 1099, 1062, 758, 668 cm$^{-1}$; $[\alpha]_D^{25}$ +140 (*c* 1.2, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.36–7.06 (m, 35 H, Ar-H), 6.90 (d, $J$=9.0 Hz, 2 H, Ar-H), 6.66 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 5.94–5.81 (m, 1 H, C$H$=$CH_2$), 5.42 (d, $J$ = 2.9 Hz, 1 H, H-$4_B$), 5.20 (s, 1 H, PhC$H$), 5.15 (d, $J$ = 3.2 Hz, 1 H, H-$1_C$), 5.26–5.06 (m, 2 H, CH=C$H_2$), 4.94–4.83 (m, 3 H, PhC$H_2$), 4.75 (d, $J$ = 8.7 Hz, 1 H, H-$1_A$), 4.70–4.49 (m, 6 H, PhC$H_2$), 4.47 (d, $J$ = 7.8 Hz, 1 H, H-$1_B$), 4.39–4.32 (m, 2 H, PhC$H_2$), 4.21 (d, $J$ = 12.0 Hz, 1 H, PhC$H_2$), 4.10–4.06 (m, 2 H, OC$H_2$-CH = $CH_2$), 4.01–3.93 (m, 2 H, H-$3_A$, H-$6_{aC}$), 3.86 (dd, $J$ = 9.2, 3.4 Hz, 1 H, H-$2_C$), 3.77–3.69 (m, 4 H, H-$4_C$, H-$5_C$, H-$6_{abA}$), 3.68–3.62 (m, 2 H, H-$3_B$, H-$3_C$), 3.66 (s, 3 H, OC$H_3$), 3.55–3.48 (m, 3 H, H-$2_A$, H-$2_B$, H-$5_A$), 3.45–3.36 (m, 3 H, H-$4_A$, H-$5_B$, H-$6_{bC}$), 3.29–3.20 (m, 2 H, H-$6_{abB}$), 1.58 (s, 3 H, COC$H_3$); $^{13}$C NMR (75 MHz, $CDCl_3$): $\delta$ 169.7 ($C$O$CH_3$), 155.3–137.9 (Ar-C), 135.4 ($C$H=$CH_2$), 128.7–118.5 (Ar-C), 116.6 (CH=$C$H$_2$), 114.5 (Ar-C), 102.9 (C-$1_A$), 102.4 (C-$1_B$), 100.8 (Ph$C$H), 93.6 (C-$1_C$), 82.7 (C-$5_A$), 81.4 (C-$2_B$), 79.3 (C-$2_A$), 76.1 (C-$3_A$), 75.5 (2 C, C-$4_A$, C-$5_C$), 75.4 (2 C, 2 Ph$C$H$_2$), 75.3 (C-$3_C$), 75.2 (Ph$C$H$_2$), 74.5 (C-$4_C$), 74.1 (Ph$C$H$_2$), 73.6 (2 C, 2 Ph$C$H$_2$), 73.1 (C-$2_C$), 72.3 (C-$5_B$), 70.9 (O$C$H$_2$CH=$CH_2$), 69.2 (C-$6_C$), 68.4 (C-$6_A$), 67.7 (C-$6_B$), 64.8 (C-$4_B$), 62.2 (C-$3_B$), 55.5 (O$C$H$_3$), 20.3 (CO$C$H$_3$); ESI-MS: 1343.5 [M+Na]$^+$; Anal. Calcd. for $C_{79}H_{84}O_{18}$ (1320.57): C, 71.80; H, 6.41; found: C, 71.64; H, 6.58.



## 4-Methoxyphenyl (2-*O*-benzyl-4,6-*O*-benzylidene-$\alpha$ D-galactopyranosyl)-(1→3)-(4-*O*-acetyl-2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (10)

To a solution of compound **9** (4 g, 3.03 mmol) in AcOH-$H_2O$ (60 mL; 20:1 v/v) were added NaOAc·3$H_2O$ (1.6 g, 16 mmol) and $PdCl_2$ (380 mg, 2.14 mmol) and the reaction mixture was allowed to stir at rt for 12 h. The solvents were removed under reduced pressure and the crude product was purified over $SiO_2$ using hexane-EtOAc (4:1) as eluant to give pure **10** (3 g, 77%). Colorless oil; IR (neat): 3423, 3020, 2359, 1741, 1593, 1504, 1426, 1368, 1216, 1058, 761, 670 cm$^{-1}$; $[\alpha]_D^{25}$ +118 (*c* 1.2, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.41–7.14 (m, 35 H, Ar-H), 6.97 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 6.75 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 5.50 (d, $J$ = 3.0 Hz, 1 H, H-$4_B$), 5.27 (d, $J$ = 3.1 Hz, 1 H, H-$1_C$), 5.23 (s, 1 H, PhC$H$), 5.01–4.89 (m, 3 H, PhC$H_2$), 4.83–4.80 (m, 2 H, H-$1_A$, PhC$H_2$), 4.77–4.70 (m, 2 H, PhC$H_2$), 4.65–4.51 (m, 4 H, H-$1_B$, PhC$H_2$), 4.48–4.41 (m, 2 H, PhC$H_2$), 4.30 (d, $J$ = 12.0 Hz, 1 H, PhC$H_2$), 4.10–3.92 (m, 3 H, H-$3_A$, H-$6_{aA}$, H-$6_{aC}$), 3.85–3.83 (m, 2 H, H-$4_C$, H-$6_{bA}$), 3.78–3.68 (m, 3 H, H-$2_C$, H-$3_B$, H-$3_C$), 3.73 (s, 3 H, OC$H_3$), 3.62–3.57 (m, 4 H, H-$2_A$, H-$2_B$, H-$5_A$, H-$5_C$), 3.51–3.41 (m, 3 H, H-$4_A$, H-$5_B$, H-$6_{bC}$), 3.34–3.28 (m, 2 H, H-$6_{abB}$), 1.72 (s, 3 H, COC$H_3$); $^{13}$C NMR

(75 MHz, $CDCl_3$): δ 169.9 (*C*O$CH_3$), 155.2–114.4 (Ar-C), 102.8 (C-$1_A$), 102.4 (C-$1_B$), 100.8 (Ph*C*H), 93.1 (C-$1_C$), 82.7 (C-$5_A$), 81.5 (C-$2_B$), 79.3 (C-$2_A$), 76.5 (C-$3_A$), 76.1 (C-$4_A$), 75.9 (C-$5_C$), 75.6 (C-$4_C$), 75.5 (Ph*C*$H_2$), 75.3 (Ph*C*$H_2$), 75.1 (Ph*C*$H_2$), 73.6 (3 C, 3 Ph*C*$H_2$), 73.2 (C-$2_C$), 72.3 (C-$5_B$), 69.0 (C-$6_C$), 68.5 (C-$3_C$), 68.4 (C-$6_A$), 67.6 (C-$6_B$), 64.9 (C-$4_B$), 62.0 (C-$3_B$), 55.5 (O*C*$H_3$), 20.4 (CO*C*$H_3$); ESI-MS: 1303.5 $[M+Na]^+$; Anal. Calcd. for $C_{76}H_{80}O_{18}$ (1280.53): C, 71.23; H, 6.29; found: C, 71.05; H, 6.50.

## 4-Methoxyphenyl (2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-*O*-benzyl-4,6-*O*-benzylidene-α-D-galactopyranosyl)-(1→3)-(4-*O*-acetyl-2,6-di-*O*-benzyl-β-D galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (11)



To a solution of compound **10** (2.8 g, 2.18 mmol) and compound **4** (1.2 g, 2.79 mmol) in anhydrous $CH_2Cl_2$ (30 mL) was added MS-4 (3 g) and the reaction mixture was allowed to stir at rt for 1 h under argon. The reaction mixture was cooled to −40°C and NIS (750 mg, 3.33 mmol) and TMSOTf (20 μL) were added to it. After stirring at same temperature for 1 h, the reaction mixture was quenched with $Et_3N$ (0.2 mL) and filtered through a Celite bed and washed with $CH_2Cl_2$ (100 mL). The organic layer was washed with aq. $Na_2S_2O_3$ and water in succession, dried ($Na_2SO_4$), and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (4:1) as eluant to furnish pure **11** (3.3 g, 92%). Colorless solid; IR (neat): 3461, 2924, 2856, 2362, 1744, 1605, 1505, 1454, 1368, 1232, 1063, 739, 697 $cm^{-1}$; $[\alpha]_D^{25}$ +212 (*c* 1.2, $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$): δ 7.42–7.16 (m, 45 H, Ar-H), 6.97 (d, *J* = 9.0 Hz, 2 H, Ar-H), 6.76 (d, *J* = 9.0 Hz, 2 H, Ar-H), 5.47 (d, *J* = 2.9 Hz, 1 H, H-$4_B$), 5.44–5.43 (m, 1 H, H-$2_D$), 5.24 (s, 1 H, PhC*H*), 5.22 (d, *J* = 3.1 Hz, 1 H, H-$1_C$), 5.06 (br s, 1 H, H-$1_D$), 5.02–4.90 (m, 4 H, PhC$H_2$), 4.86–4.80 (m, 2 H, H-$1_A$, PhC$H_2$), 4.78–4.58 (m, 5 H, PhC$H_2$), 4.56–4.45 (m, 5 H, H-$1_B$, PhC$H_2$), 4.40–4.25 (m, 2 H, PhC$H_2$), 4.10–3.96 (m, 4 H, H-$3_A$, H-$5_D$, H-$6_{aA}$, H-$6_{aC}$), 3.91–3.80 (m, 5 H, H-$2_C$, H-$3_D$, H-$4_C$, H-$6_{bA}$, H-$6_{bC}$), 3.77–3.70 (m, 2 H, H-$3_B$, H-$3_C$), 3.74 (s, 3 H, OC$H_3$), 3.65–3.57 (m, 3 H, H-$2_A$, H-$2_B$, H-$5_A$), 3.54–3.46 (m, 2 H, H-$4_A$, H-$5_C$), 3.39 (t, *J* = 9.3 Hz each, 1 H, H-$4_D$), 3.35–3.24 (m, 3 H, H-$5_B$, H-$6_{abB}$), 2.15, 1.59 (2 s, 6 H, 2 COC$H_3$), 1.25 (d, *J* = 6.1 Hz, 3 H, CC$H_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$): δ 169.9, 169.8 (2 *C*O$CH_3$), 155.3–114.5 (Ar-C), 102.8 (C-$1_A$), 102.4 (C-$1_B$), 100.6 (Ph*C*H), 100.2 (C-$1_D$), 93.5 (C-$1_C$), 82.6 (C-$5_A$), 81.4 (C-$2_B$), 79.8 (C-$2_A$), 79.2 (C-$4_D$), 77.7 (C-$3_C$), 77.4 (C-$3_D$), 76.3 (C-$4_A$), 75.9 (C-$5_C$), 75.5 (Ph*C*$H_2$), 75.4 (C-$4_C$), 75.2 (Ph*C*$H_2$), 75.0 (Ph*C*$H_2$), 74.7 (Ph*C*$H_2$), 74.6 (C-$2_C$), 74.2 (Ph*C*$H_2$), 73.5 (2 C, 2 Ph*C*$H_2$), 73.1 (C-$5_D$), 72.3 (C-$5_B$), 71.6 (Ph*C*$H_2$), 69.1 (C-$2_D$), 68.9 (C-$6_C$), 68.4 (C-$6_A$), 68.0 (C-$3_A$), 67.6 (C-$6_B$), 64.6 (C-$4_B$), 61.8 (C-$3_B$), 55.4 (O*C*$H_3$), 21.0, 20.3 (2 CO*C*$H_3$), 18.1 (C*C*$H_3$);

ESI-MS: 1671.7 [M+Na]$^+$; Anal. Calcd. for $C_{98}H_{104}O_{23}$ (1648.70): C, 71.34; H, 6.35; found: C, 71.18; H, 6.50.

### 4-Methoxyphenyl (3,4-di-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1$\rightarrow$3)-(2-*O*-benzyl-4,6-*O*-benzylidene-$\alpha$-D-galactopyranosyl)-(1$\rightarrow$3)-(2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1$\rightarrow$4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (12)

A solution of compound **11** (3 g, 1.82 mmol) in 0.1 M $CH_3ONa$ in $CH_3OH$ (60 mL) was allowed to stir at rt for 4 h and neutralized with Dowex-50W X8 ($H^+$) resin. The reaction mixture was filtered and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (2:1) as eluant to give pure **12** (2.8 g, 98%). White solid, m.p. 96–98°C; IR (KBr): 3486, 3032, 2924, 2858, 2363, 1507, 1454, 1365, 1225, 1065, 828, 748, 698 cm$^{-1}$; $[\alpha]_D^{25}$ +68 (*c* 1.2, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.44–7.21 (m, 45 H, Ar-H), 6.98 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 6.74 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 5.29 (s, 1 H, PhC*H*), 5.05 (br s, 1 H, H-$1_D$), 5.02–4.88 (m, 3 H, PhC$H_2$), 4.84 (d, $J$ = 8.7 Hz, 1 H, H-$1_A$), 4.80–4.76 (m, 3 H, H-$1_C$, PhC$H_2$), 4.73–4.57 (m, 6 H, PhC$H_2$), 4.51–4.36 (m, 6 H, H-$1_B$, PhC$H_2$), 4.07–4.02 (m, 2 H, H-$3_A$, H-$5_D$), 3.98–3.96 (m, 1 H, H-$2_D$), 3.94–3.90 (m, 3 H, H-$4_B$, H-$6_{abA}$), 3.88–3.79 (m, 5 H, H-$2_C$, H-$3_D$, H-$4_C$, H-$6_{abC}$), 3.73 (s, 3 H, OC$H_3$), 3.71–3.68 (m, 1 H, H-$3_C$), 3.63–3.57 (m, 3 H, H-$2_A$, H-$2_B$, H-$5_A$), 3.52–3.45 (m, 4 H, H-$3_B$, H-$4_A$, H-$4_D$, H-$5_C$), 3.42–3.32 (m, H-$5_B$, H-$6_{abB}$), 1.25 (d, $J$ = 6.3 Hz, 3 H, CC$H_3$); $^{13}$C NMR (75 MHz, $CDCl_3$): $\delta$ 155.3–114.5 (Ar-C), 102.8 (C-$1_B$), 102.6 (C-$1_A$), 101.9 (C-$1_D$), 100.7 (Ph*C*H), 95.1 (C-$1_C$), 82.8 (C-$5_A$), 81.5 (C-$2_B$), 79.9 (C-$4_D$), 79.7 (C-$2_A$), 78.8 (C-$3_C$), 78.1 (C-$3_D$), 77.9 (C-$4_A$), 76.4 (2 C, C-$4_C$, C-$5_C$), 75.6 (Ph*C*$H_2$), 75.5 (C-$2_C$), 75.3 (Ph*C*$H_2$), 75.1 (Ph*C*$H_2$), 74.8 (Ph*C*$H_2$), 74.5 (Ph*C*$H_2$), 74.3 (C-$5_D$), 73.5 (Ph*C*$H_2$), 73.4 (Ph*C*$H_2$), 73.0 (C-$5_B$), 72.2 (Ph*C*$H_2$), 69.0 (C-$6_C$), 68.9 (C-$2_D$), 68.5 (C-$6_A$), 68.2 (C-$6_B$), 67.8 (C-$3_A$), 64.6 (C-$4_B$), 62.5 (C-$3_B$), 55.4 (O*C*$H_3$), 18.0 (C*C*$H_3$); ESI-MS: 1587.7 [M+Na]$^+$; Anal. Calcd. for $C_{94}H_{100}O_{21}$ (1564.68): C, 72.10; H, 6.44; found: C, 71.93; H, 6.65.

### 4-Methoxyphenyl [2-*O*-acetyl-4-*O*-benzyl-3-*O*-(4-methoxybenzyl)-$\alpha$-L-rhamnopyranosyl]-(1$\rightarrow$2)-(3,4-di-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1$\rightarrow$3)-(2-*O*-benzyl-4,6-*O*-benzylidene-$\alpha$-D-galactopyranosyl)-(1$\rightarrow$3)-(2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1$\rightarrow$4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (13)

To a solution of compound **12** (2.5 g, 1.6 mmol) and compound **5** (900 mg, 1.95 mmol) in anhydrous $CH_2Cl_2$ (30 mL) was added MS-4 (3 g) and the reaction mixture was allowed to stir at rt for 1 h under argon. The reaction mixture was cooled to −40°C and NIS (500 mg, 2.22 mmol) and TMSOTf (10 $\mu$L) were added to it. After stirring at same temperature for 1 h, the reaction mixture was quenched with $Et_3N$ (0.1 mL) and filtered through a Celite bed and washed with $CH_2Cl_2$ (80 mL). The organic layer was washed with aq. $Na_2S_2O_3$ and water in succession, dried ($Na_2SO_4$), and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (3:1) as eluant to furnish pure **13** (2.6 g, 83%). Colorless oil; IR (neat): 3453, 3020, 2360, 1596, 1424, 1216, 1050, 762, 670 $cm^{-1}$; $[\alpha]_D^{25}$ +191 ($c$ 1.2, $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$): $\delta$ 7.41–7.20 (m, 52 H, Ar-H), 6.98 (d, $J = 9.0$ Hz, 2 H, Ar-H), 6.81–6.73 (m, 4 H, Ar-H), 5.51–5.47 (m, 1 H, H-$2_E$), 5.27 (s, 1 H, PhC$H$), 5.04 (d, $J = 12.1$ Hz, 1 H, PhC$H_2$), 4.99–4.95 (m, 3 H, H-$1_D$, H-$1_E$, PhC$H_2$), 4.90–4.79 (m, 5 H, H-$1_A$, PhC$H_2$), 4.73–4.66 (m, 3 H, H-$1_C$, PhC$H_2$), 4.64–4.55 (m, 5 H, PhC$H_2$), 4.53–4.31 (m, 8 H, H-$1_B$, PhC$H_2$), 4.06–3.95 (m, 1 H, H-$3_A$), 3.98–3.87 (m, 5 H, H-$2_D$, H-$5_D$, H-$5_E$, H-$6_{abA}$), 3.86–3.76 (m, 6 H, H-$2_C$, H-$3_E$, H-$4_B$, H-$4_C$, H-$6_{abC}$), 3.75, 3.73 (2 s, 6 H, 2 OC$H_3$), 3.71–3.68 (m, 1 H, H-$3_C$), 3.66–3.54 (m, 4 H, H-$2_A$, H-$2_B$, H-$3_D$, H-$5_A$), 3.52–3.44 (m, 3 H, H-$4_A$, H-$4_D$, H-$4_E$), 3.41–3.36 (m, 3 H, H-$3_B$, H-$5_B$, H-$5_C$), 3.33–3.27 (m, 2 H, H-$6_{abB}$), 2.13 (s, 3 H, COC$H_3$), 1.28–1.24 (m, 6 H, 2 CC$H_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$): $\delta$ 169.8 ($C$OCH$_3$), 159.3–113.8 (Ar-C), 102.8 (C-$1_B$), 102.7 (C-$1_A$), 101.4 (C-$1_E$), 100.7 (Ph$C$H), 99.1 (C-$1_D$), 95.1 (C-$1_C$), 82.9 (C-$5_A$), 81.5 (C-$2_B$), 80.0 (C-$4_D$), 79.9 (C-$4_E$), 79.6 (C-$2_A$), 78.9 (C-$3_E$), 77.9 (C-$3_C$), 77.3 (2 C, C-$3_D$, C-$4_A$), 76.4 (2 C, C-$4_C$, C-$5_C$), 75.7 (Ph$C$H$_2$), 75.6 (Ph$C$H$_2$), 75.5 (C-$2_C$), 75.4 (Ph$C$H$_2$), 75.1 (Ph$C$H$_2$), 74.9 (Ph$C$H$_2$), 74.7 (C-$5_E$), 74.6 (Ph$C$H$_2$), 74.5 (C-$5_D$), 73.6 (Ph$C$H$_2$), 73.5 (Ph$C$H$_2$), 73.1 (C-$5_B$), 72.3 (Ph$C$H$_2$), 71.4 (Ph$C$H$_2$), 69.0 (C-$6_C$), 68.9 (C-$2_D$), 68.6 (C-$6_A$), 68.5 (C-$2_E$), 68.4 (C-$3_A$), 68.3 (C-$6_B$), 64.5 (C-$4_B$), 62.5 (C-$3_B$), 55.5 (O$C$H$_3$), 21.1 (CO$C$H$_3$), 18.2 (C$C$H$_3$), 18.1 (C$C$H$_3$); ESI-MS: 1985.8 $[M+Na]^+$; Anal. Calcd. for $C_{117}H_{126}O_{27}$ (1962.85): C, 71.54; H, 6.47; found: C, 71.37; H, 6.70.

## 4-Methoxyphenyl (2-*O*-acetyl-4-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1→2)-(3,4-di-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1→3)-(2-*O*-benzyl-4,6-*O*-benzyli-dene-$\alpha$-D-galactopyranosyl)-(1→3)-(2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (14)

To a solution of compound **13** (2.2 g, 1.12 mmol) in $CH_2Cl_2$ and water (50 mL, 1:1) was added DDQ (380 mg, 1.67 mmol) and the reaction mixture was allowed to stir at rt for 2 h. The reaction mixture was diluted with $CH_2Cl_2$ (100 mL) and the organic layer was washed successively with satd. aq $NaHCO_3$ and water, dried ($Na_2SO_4$), and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (5:1) to furnish pure **14** (1.5 g, 73%). Colorless oil; IR (neat): 3468, 2935, 2370, 1736, 1721, 1394, 1232, 1076, 769 $cm^{-1}$; $[\alpha]_D^{25}$ +126 ($c$ 1.2, $CHCl_3$); $^1H$ NMR (300

MHz, $CDCl_3$): $\delta$ 7.42–7.13 (m, 50 H, Ar-H), 6.98 (d, $J = 9.0$ Hz, 2 H, Ar-H), 6.76 (d, $J = 9.0$ Hz, 2 H, Ar-H), 5.32–5.29 (m, 1 H, H-$2_E$), 5.23 (s, 1 H, PhC*H*), 5.18 (d, $J = 2.7$ Hz, 1 H, H-$1_C$), 5.02 (br s, 1 H, H-$1_E$), 5.0–4.85 (m, 4 H, H-$1_D$, PhC$H_2$), 4.83–4.76 (m, 3 H, H-$1_A$, PhC$H_2$), 4.75–4.54 (m, 7 H, PhC$H_2$), 4.53–4.40 (m, 6 H, H-$1_B$, PhC$H_2$), 4.28 (d, $J = 12.0$ Hz, 1 H, PhC$H_2$), 4.22–4.13 (m, 1 H, H-$3_A$), 4.12–4.04 (m, 1 H, H-$5_D$), 4.02–3.89 (m, 5 H, H-$5_E$, H-$6_{abA}$, H-$6_{abC}$), 3.87–3.80 (m, 6 H, H-$2_A$, H-$2_C$, H-$2_D$, H-$3_E$, H-$4_B$, H-$4_C$), 3.75 (s, 3 H, OC$H_3$), 3.78–3.72 (m, 2 H, H-$2_B$, H-$3_C$), 3.70–3.67 (m, 1 H, H-$3_D$), 3.66–3.57 (m, 3 H, H-$4_A$, H-$4_D$, H-$4_E$), 3.56–3.42 (m, 3 H, H-$3_B$, H-$5_A$, H-$5_C$), 3.40–3.26 (m, 3 H, H-$5_B$, H-$6_{abB}$), 2.06 (s, 3 H, COC$H_3$), 1.25–1.22 (m, 6 H, 2 CC$H_3$); $^{13}$C NMR (75 MHz, $CDCl_3$): $\delta$ 169.6 (*C*OCH$_3$), 102.9 (C-$1_A$), 102.5 (C-$1_B$), 101.5 (C-$1_E$), 101.1 (Ph*C*H), 100.6 (C-$1_D$), 93.7 (C-$1_C$), 82.8 (C-$5_A$), 81.7 (C-$2_B$), 81.5 (C-$4_D$), 80.2 (C-$4_E$), 80.0 (C-$2_A$), 79.8 (C-$3_E$), 79.5 (C-$3_C$), 79.2 (C-$3_D$), 79.1 (C-$4_A$), 77.2 (C-$5_C$), 76.4 (C-$4_C$), 75.9 (C-$2_C$), 75.5 (Ph*C*H$_2$), 75.4 (2 C, C-$5_D$, C-$5_E$), 75.1 (Ph*C*H$_2$), 73.9 (Ph*C*H$_2$), 73.6 (2 C, 2 Ph*C*H$_2$), 73.4 (C-$5_B$), 72.8 (Ph*C*H$_2$), 72.5 (Ph*C*H$_2$), 72.4 (Ph*C*H$_2$), 72.0 (Ph*C*H$_2$), 70.4 (C-$2_D$), 69.7 (C-$6_C$), 69.0 (C-$6_A$), 68.4 (C-$2_E$), 68.0 (C-$3_A$), 67.7 (C-$6_B$), 64.9 (C-$4_B$), 61.9 (C-$3_B$), 55.5 (O*C*H$_3$), 20.3 (CO*C*H$_3$), 18.3, 18.2 (2 *C*CH$_3$); ESI-MS: 1865.8 [M+Na]$^+$; Anal. Calcd. for $C_{109}H_{118}O_{26}$ (1842.79): C, 70.99; H, 6.45; found: C, 70.82; H, 6.61.



## 4-Methoxyphenyl (2,3,5,6-tetra-*O*-benzyl-$\alpha$-D-galactofuranosyl)-(1$\rightarrow$3)-(2-*O*-acetyl-4-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1$\rightarrow$2)-(3,4-di-*O*-benzyl-$\alpha$-L-rhamnopyranosyl)-(1$\rightarrow$3)-(2-*O*-benzyl-4,6-*O*-benzylidene-$\alpha$-D-galactopyranosyl)-(1$\rightarrow$3)-(2,6-di-*O*-benzyl-$\beta$-D-galactopyranosyl)-(1$\rightarrow$4)-2,3,6-tri-*O*-benzyl-$\beta$-D-glucopyranoside (15)

To a solution of compound **14** (1.2 g, 0.65 mmol) and compound **6** (450 mg, 0.77 mmol) in anhydrous $CH_2Cl_2$ (20 mL) was added MS-4 (2 g) and the reaction mixture was allowed to stir at rt for 1 h under argon. The reaction mixture was cooled to $-40^\circ$C and NIS (200 mg, 0.88 mmol) and TMSOTf (5 $\mu$L) were added to it. After stirring at same temperature for 1 h, the reaction mixture was quenched with $Et_3N$ (0.1 mL) and filtered through a Celite bed and washed with $CH_2Cl_2$ (100 mL). The organic layer was washed with aq. $Na_2S_2O_3$ and water in succession, dried ($Na_2SO_4$), and concentrated under reduced pressure to give the crude product, which was purified over $SiO_2$ using hexane-EtOAc (3:1) as eluant to furnish pure **15** (1.2 g, 78%). Colorless oil; IR (neat): 3460, 3030, 2400, 1572, 1447, 1234, 1076, 792, 680 cm$^{-1}$; $[\alpha]_D^{25}$ +96 (*c* 1.2, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.42–7.13 (m, 70 H, Ar-H), 7.02 (d, $J = 9.2$ Hz, 2 H, Ar-H), 6.78 (d, $J = 9.2$ Hz, 2 H, Ar-H), 5.48–5.47 (m, 1 H, H-$2_E$), 5.44 (d, $J = 3.4$ Hz, 1 H, H-$1_F$), 5.25 (s, 1 H, PhC*H*), 5.17 (d, $J = 3.2$ Hz, 1 H, H-$1_C$), 5.05–5.03 (m, 2 H, H-$1_D$, H-$1_E$), 4.99–4.92 (m, 2 H, PhC$H_2$), 4.90–4.80 (m, 4 H, H-$1_A$, PhC$H_2$), 4.78–4.70 (m, 3 H, PhC$H_2$), 4.68–4.58 (m, 5 H, PhC$H_2$), 4.57–4.38 (m, 12 H, H-$1_B$, PhC$H_2$), 4.36–4.22 (m, 4 H, H-$3_F$, H-$6_{aF}$, PhC$H_2$), 4.16–4.13 (m, 1 H, H-$3_A$), 4.12–4.04 (m, 3 H, H-$2_D$, H-$5_D$, H-$5_E$), 4.03–3.98 (m, 2 H, H-$4_F$, H-$6_{bF}$), 3.97–3.90 (m, 2 H, H-$2_F$, H-$5_F$), 3.88–3.80 (m, 7 H, H-$2_C$, H-$3_B$, H-$3_E$, H-$6_{abA}$, H-$6_{abC}$), 3.75 (s, 3 H, OC$H_3$), 3.74–3.71 (m, 2 H, H-$2_A$, H-$4_B$), 3.68–3.60 (m, 5 H, H-$2_B$, H-$3_C$, H-$3_D$, H-$4_A$, H-$4_C$), 3.56–3.44 (m, 3 H, H-$4_D$, H-$4_E$, H-$5_A$), 3.38–3.29 (m, 4 H, H-$5_B$, H-$5_C$, H-$6_{abB}$), 2.05 (s, 3 H, COC$H_3$), 1.28–1.23 (m, 6 H, 2 CC$H_3$); $^{13}$C NMR (75 MHz, $CDCl_3$): $\delta$ 169.7 (*C*O$CH_3$), 155.2–113.5 (Ar-C), 108.4 (C-$1_F$), 102.7 (C-$1_A$), 102.4 (C-$1_B$), 101.3 (2 C, C-$1_D$, C-$1_E$), 100.5 (Ph*C*H), 93.8 (C-$1_C$), 89.2 (C-$3_F$), 83.6 (C-$2_F$), 82.8 (C-$2_B$), 82.7 (C-$5_A$), 81.4 (2 C, C-$4_D$, C-$4_E$), 80.9 (C-$3_D$), 80.5 (C-$4_A$), 80.1 (C-$2_A$), 80.0 (C-$3_E$), 78.9 (C-$3_C$), 77.2 (C-$5_C$), 76.3 (C-$4_C$), 75.8 (C-$2_C$), 75.3 (2 C, C-$5_E$, Ph*C*$H_2$), 75.1 (Ph*C*$H_2$), 74.7 (C-$5_D$), 73.7 (Ph*C*$H_2$), 73.5 (4 C, 4 Ph*C*$H_2$), 73.4 (C-$4_F$), 73.2 (Ph*C*$H_2$), 73.1 (Ph*C*$H_2$), 72.3 (2 C, C-$5_B$, C-$5_F$), 72.0 (Ph*C*$H_2$), 71.9 (Ph*C*$H_2$), 71.5 (Ph*C*$H_2$), 71.4 (Ph*C*$H_2$), 70.6 (C-$6_F$), 69.0 (C-$6_C$), 68.5 (C-$2_D$), 68.3 (C-$6_A$), 68.2 (C-$2_E$), 68.1 (C-$3_A$), 67.8 (C-$6_B$), 64.9 (C-$4_B$), 61.9 (C-$3_B$), 55.6 (O*C*$H_3$), 20.3 (CO*C*$H_3$), 18.0, 17.9 (2 C*C*$H_3$); ESI-MS: 2387.0 [M+Na]$^+$; Anal. Calcd. for $C_{143}H_{152}O_{31}$ (2365.03): C, 72.57; H, 6.47; found: C, 72.38; H, 6.70.



## 4-Methoxyphenyl ($\alpha$-D-galactofuranosyl)-(1→3)-($\alpha$-L-rhamnopyranosyl)-(1→2)-($\alpha$-L-rhamnopyranosyl)-(1→3)-($\alpha$-D-galactopyranosyl)-(1→3)-($\beta$-D-galactopyranosyl)-(1→4)-$\beta$-D-glucopyranoside (1)

A solution of compound **15** (1 g, 0.42 mmol) in 0.1 M $CH_3ONa$ in $CH_3OH$ (20 mL) was allowed to stir at rt for 2 h and neutralized with Amberlite IR-120 ($H^+$) resin. The reaction mixture was filtered and evaporated to dryness. To a solution of the crude product in $CH_3OH$ (20 mL) was added 20% $Pd(OH)_2$-C (200 mg) and the reaction mixture was allowed to stir at rt under a positive pressure of hydrogen for 24 h. The reaction mixture was filtered through a Celite bed and then washed with $CH_3OH$-$H_2O$ (60 mL; 3:1 v/v). The combined filtrate was evaporated under reduced pressure to furnish compound **1**, which was purified through a Sephadex LH-20 column using $CH_3OH$-$H_2O$ (4:1) as eluant to give pure compound **1** (340 mg, 76%). Glassy solid; $[\alpha]_D^{25}$ +3.3 (*c* 1.0, $H_2O$); IR (KBr): 1605, 1472, 1357, 1046, 699 cm$^{-1}$; $^1$H NMR (300 MHz, $D_2O$): $\delta$ 7.06 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 6.93 (d, $J$ = 9.0 Hz, 2 H, Ar-H), 5.16 (br s, 2 H, H-$1_E$, H-$1_F$), 5.10 (br s, 1 H, H-$1_C$), 4.97 (d, $J$ = 7.8 Hz, 1 H, H-$1_A$), 4.92 (br s, 1 H, H-$1_D$), 4.47 (d, $J$ = 7.6 Hz, 1 H, H-$1_B$), 4.30–4.09 (m, 4 H, H-$2_E$, H-$2_F$, H-$3_F$, H-$4_F$), 4.08–4.0 (m, 4 H, H-$2_D$, H-$3_C$, H-$4_B$, H-$4_C$), 3.98–3.87 (m, 4 H, H-$3_D$, H-$5_C$, H-$5_F$, H-$6_{aA}$), 3.86–3.61 (m, 15 H, H-$2_C$, H-$3_A$, H-$3_B$, H-$3_E$, H-$4_A$, H-$5_B$, H-$5_D$, H-$5_E$, H-$6_{bA}$, H-$6_{abB}$, H-$6_{abC}$, H-$6_{abF}$), 3.75 (s, 3 H, OC$H_3$), 3.60–3.37 (m, 5 H, H-$2_A$, H-$2_B$, H-$4_D$, H-$4_E$, H-$5_A$), 1.25–1.21 (m, 6 H, 2 CC$H_3$); $^{13}$C NMR (75

MHz, $D_2O$): $\delta$ 154.7, 150.9, 118.2 (2 C), 114.9 (2 C) (Ar-C), 109.1 (C-$1_F$), 102.8 (C-$1_B$), 101.8 (C-$1_E$), 101.1 (C-$1_A$), 100.5 (C-$1_D$), 95.5 (C-$1_C$), 82.9 (2 C, C-$3_F$, C-$4_F$), 80.9 (C-$2_F$), 78.6 (C-$2_D$), 78.3 (C-$4_A$), 77.3 (C-$3_E$), 75.9 (C-$3_C$), 74.9 (C-$2_A$), 74.8 (3 C, C-$3_A$, C-$5_A$, C-$5_B$), 74.3 (C-$4_D$), 72.6 (2 C, C-$4_E$, C-$5_F$), 72.1 (C-$3_B$), 70.7 (C-$3_D$), 70.5 (2 C, C-$5_D$, C-$5_E$), 69.5 (C-$5_C$), 69.1 (C-$2_B$), 68.8 (C-$2_E$), 67.8 (C-$4_B$), 64.8 (C-$2_C$), 62.8 (C-$4_C$), 62.5 (C-$6_C$), 60.9 (C-$6_F$), 60.7 (C-$6_B$), 59.9 (C-$6_A$), 55.6 (O*C*$H_3$), 16.7, 16.6 (2 *C*$CH_3$); ESI-MS: 1087.3 $[M+Na]^+$; Anal. Calcd. for $C_{43}H_{68}O_{30}$ (1064.38): C, 48.49; H, 6.44; found: C, 48.30; H, 6.70.

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