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Sulfonic acid analogues of the sialyl Lewis X tetrasaccharide

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Abstract

Sulfonomethyl mimics of 2-ulosonic acids were prepared by addition of the ethyl methanesulfonate carbanion on aldonolactone derivatives, and these were converted into new analogues of the sialyl Lewis X tetrasaccharide.

1. Introduction

Selectins are carbohydrate-binding transmembrane glycoproteins expressed on platelets (P-selectins), leukocytes (L-selectins) and on the endothelial cells (E- and P-selectins), and their role is to mediate the first steps of the recruitment of leukocytes from the blood stream in a series of normal and pathologic situations.[1] The carbohydrate ligands which are recognized by these selectins have been identified: E-selectin recognizes the sialyl Lewis X (sLe X, or sLe^X) tetrasaccharide[2] on the surface of leukocytes, P-selectin also binds sLe X on leukocytes,[3] and L-selectin weakly recognizes sLe^X on endothelial cells.[4]

The selectin–carbohydrate interaction appears at the very early stage of the inflammatory reactions or metastasis. When tissue injury occurs, cytokines are released to signal endothelial cells to synthesize E-selectins which recruit leukocytes to the site of injury. The selectins slow down the leukocytes in the blood vessels, which then roll along the endothelium by binding to glycoproteins bearing sialyl Lewis X ligands. A subsequent tight interaction between integrins, leukocytes and the intercellular adhesion molecule (ICAM-1) with the endothelial cells allows the extravasation of neutrophils to the site of injury. When too many leukocytes are recruited, however, normal cells will also be damaged, causing inflammation. Control of this process by inhibiting the adhesion step has been considered as a new anti-inflammatory strategy[5] (many acute inflammatory symptoms such as asthma, lung injury,[6] myocardial

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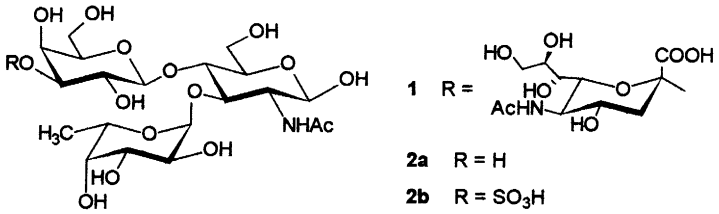
infarct and arthritis[7] may be treated by this approach). New antitumor agents could also be developed on the basis of the inhibition of this adhesion process.

Since one of the major natural ligands of the selectins is the sialyl Lewis X tetrasaccharide containing glycopeptide, this tetrasaccharide (**1**, Scheme 1) may be taken as a lead structure for the development of glycomimetics which structurally resemble and functionally mimic the natural oligosaccharide. These compounds, designed as selectin receptor antagonists, are currently being evaluated as potential anti-adhesive, anti-inflammatory, and anti-metastatic drugs.



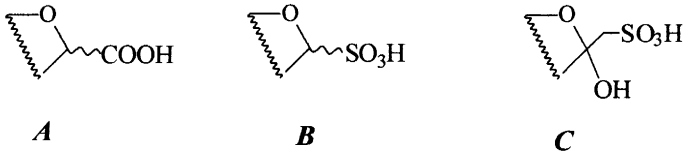
Scheme 1. The sialyl Lewis X tetrasaccharide **1**, the Lewis X trisaccharide **2a**, and the sulfated Lewis X trisaccharide **2b**

A structure–activity relationship of the functional groups of sLe^X involved in binding[8] to selectins by systematic replacement of the functional groups with hydrogen has been reported. It is known that the fucose and some of the galactose hydroxyl groups are essential in binding. Furthermore, the acid function in the sialic acid moiety is crucial but can be replaced, for example by sulfate groups.[9]

Sulfated Lewis X trisaccharide **2b** exists as a natural analogue of sLe^X **1** and shows superior binding to selectins.[10] This paper describes the synthesis of sulfonic acid analogues of the sLe^X tetrasaccharide in which the sialic acid is replaced by an anomeric sulfonomethyl-type sugar moiety. The sulfonic acid analogue, being a stronger acid than its carboxylic counterpart, might bind effectively to the bioreceptors. Moreover, it should be resistant against esterases.

2. Results and discussion

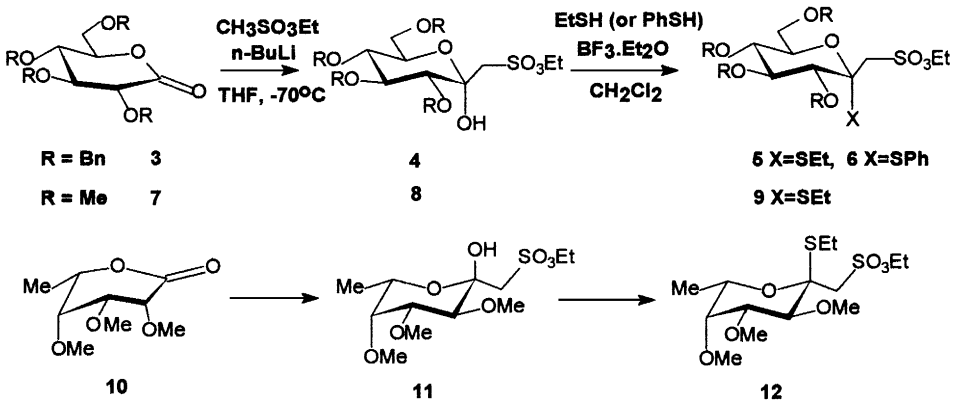
The synthesis of the sulfonic acid analogues of the sLe^X tetrasaccharide was planned by the introduction of an anomeric sulfonic acid moiety into an sLe X mimic via a glycosylation reaction. Preliminary results have been reported.[11] Direct substitution of the carboxyl group in *N*-acetylneuraminic acid, or aldose-2-ulosonic acid ***A*** in general, by an SO_3H group would result in an unstable *O*,*S*-acetal ***B***, therefore introduction of the sulfonomethyl moiety ***C*** might be a more promising approach (Scheme 2).



Scheme 2.

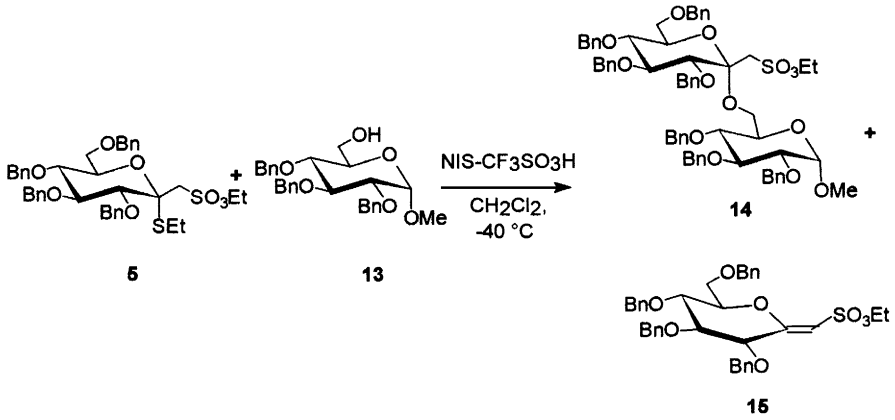
For the synthesis of the glycosyl donors type ***C***, first the protected D-aldonolactones **3**,[12] **7**,[13] and the L-aldonolactone **10**[14] were prepared by the Dess–Martin periodinane method[15] which permitted higher yields in comparison to the previously published procedures. The lactones were reacted with the ethyl methanesulfonate anion, generated with *n*-butyllithium (Scheme 3). Nucleophilic addition of the sulfonate ester carbanion to the lactones gave 1-ethylsulfonyl-D-hept-2-uloses **4**, **8** or the 1-ethylsulfonyl-L-hept-2-ulose **11**, respectively, each in the α-anomeric form. The reaction of **4**, **8** or **11** with ethanethiol in the presence of Lewis acid resulted in the α-thioglycosides **5**, **9** or **12**. The phenylthioglycoside **6**

was also synthesized from **4** in this way. Because of the lack of an anomeric proton, the anomeric configuration was determined on the basis of the NMR C1–H3 three-bond coupling constant[16] which is dependent on the dihedral angle in a manner similar to $^{3}J_{H,H}$ (the values of $^{3}J_{C1,H3}$ proved to be less than 5 Hz in all cases).



Scheme 3. Syntheses of anomeric sulfonic acid-type glycosyl donors

Since the objective was the substitution of *N*-acetylneuraminic acid with sulfonomethyl derivatives in sialyl Lewis X tetrasaccharide analogues, the glycosylation properties of **5** were investigated. The primary hydroxyl group in **13**[17] could be glycosylated stereoselectively by the van Boom activation methodology[18] to obtain **14**; however, formation of the elimination product **15** was also observed (Scheme 4).

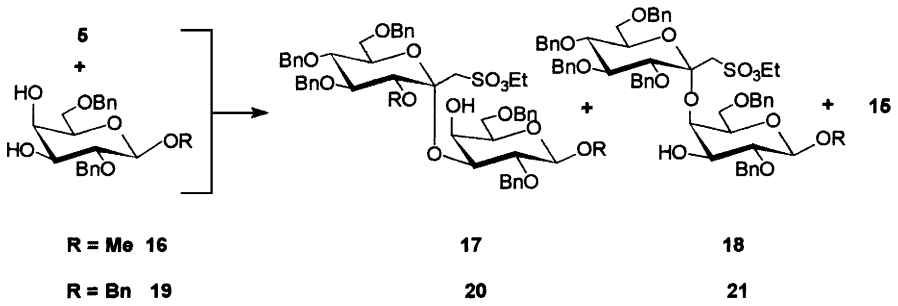


Scheme 4. Glycosylation of the primary hydroxyl group with the sulfonomethyl donor

Attempted glycosylation of benzyl 2,4,6-tri-*O*-benzyl-β-D-galactopyranoside[19] with **5** failed, presumably because of steric congestion around the secondary 3-OH group. In this case only the elimination product **15** could be detected.

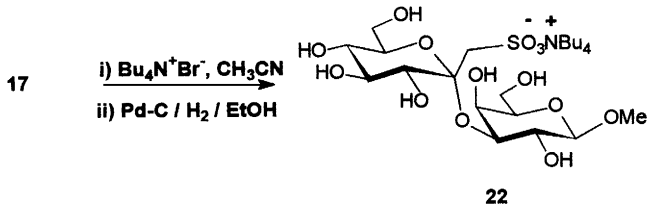
Glycosylation of **16**,[20] having two adjacent free hydroxyls, with **5** afforded a separable 3:1 mixture of the regioisomeric disaccharides **17** and **18** as reported earlier;[11] formation of the elimination product **15** was also observed. Compound **19**[21] was also glycosylated with **5** and the same pattern of products was observed as in the case of the aglycone **16** (Scheme 5).

The main product **20** was originally planned to be converted to a glycosyl donor via debenzylation, acetylation and thioglycoside formation. However, this route had to be changed, since catalytic hydro-



Scheme 5. Glycosylation of the secondary hydroxyl group with the sulfonomethyl donor

genation of **20** led to its decomposition, probably because of the cleavage of the sulfonic ester bond. Nevertheless, deprotection of the disaccharide **17** could be readily carried out when nucleophilic attack by bromide ion was followed by catalytic hydrogenation to obtain **22** (Scheme 6).



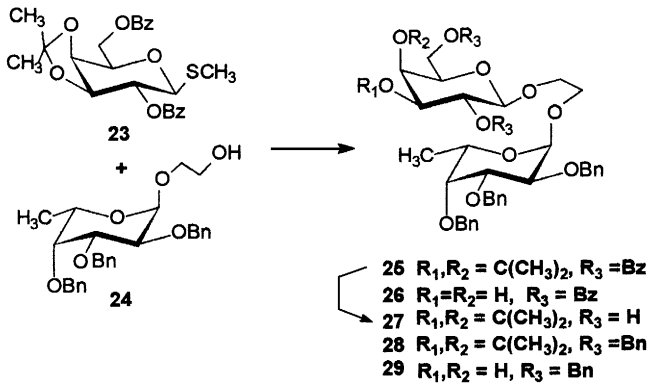
Scheme 6. Deprotection of the sulfonic acid-containing disaccharide

By this sequence, the sulfonomethyl moiety could be introduced into the sialyl Lewis X analogues only in the final step. Consequently, the sulfonic acid mimics of the sLe X tetrasaccharide were planned to be synthesized by the following method: (i) preparation of an aglycone molecule which structurally resembles the Lewis X trisaccharide; (ii) glycosylation of this aglycone with an anomeric sulfonomethyl-type donor; (iii) deprotection of the obtained sulfonomethyl analogue.

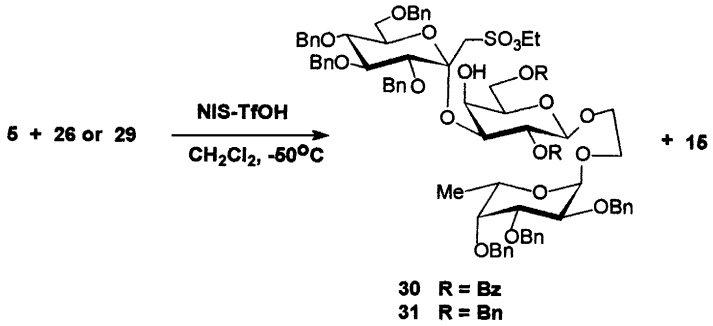
The pseudo-trisaccharide **25** which was considered as a suitable aglycone was synthesized via glycosylation of **24** with **23**[22] by using the methyl triflate (MeOTf) activation method.[23]

Compound **25** can be considered as a mimic of the Lewis X trisaccharide containing all of the hydroxyls which are essential for binding to selectins, and in which the GlcNAc residue is substituted by an ethylene glycol bridge. While GlcNAc contains none of the functional groups important for binding, it is likely to be critical in the structural organization of the tetrasaccharide. For this purpose a cyclohexyl group appears to be the best mimic of the pyranose ring. However, ethanediol-containing analogues[24] proved to be almost equally effective. Therefore, the latter strategy was chosen as a much cheaper and simpler type of mimic. Following deisopropylidenation of **25**, **26** was glycosylated with **5** using *N*-iodosuccinimide–trifluoromethanesulfonic acid (NIS–TfOH) activation in dichloromethane. The planned pseudo-tetrasaccharide **30** was thus obtained in a regioselective reaction (Scheme 8) in a low yield (~35%), together with the elimination product **15**.[11]

Attempts to reduce the proportion of elimination product including change of solvent and leaving group were unsuccessful. The donor **6** was unreactive, an overnight reaction at room temperature led only to about 60% conversion and, unfortunately, the ratio of the elimination product was as high as earlier. Therefore, to increase the yield of the glycosylation, the acceptor part was modified. Compound **25** was converted into a more reactive aglycone **29** by changing the benzoyl ester groups into benzyl ethers (Scheme 7). Then **29** was glycosylated with **5** using the above-mentioned activation. However, the enhanced reactivity of the aglycone did not lead to an increased formation of the glycosylated product; the yield of **31** was as low as ~36% (Scheme 8).

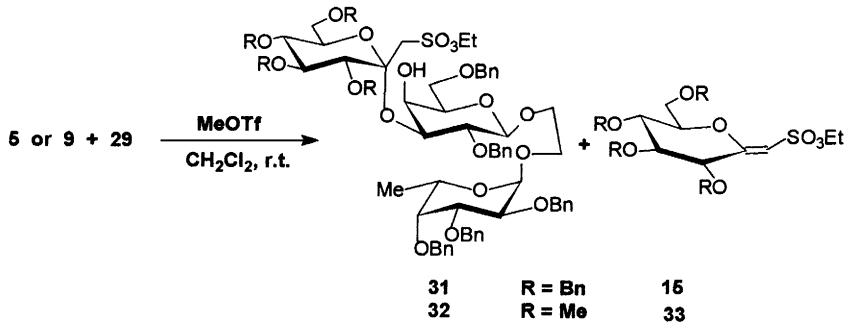


Scheme 7. Synthesis of the aglycone part of the sLe^X mimics



Scheme 8. Synthesis of the sLe^X mimic using NIS–TfOH activation

By application of methyl trifluoromethanesulfonate (MeOTf) as the promoter for coupling of **5** to **29**, the formation of the elimination product decreased and the pseudo-tetrasaccharide **31** could be isolated with ~48% yield (Scheme 9). The elimination product **15** could also be isolated in a yield of 30%.

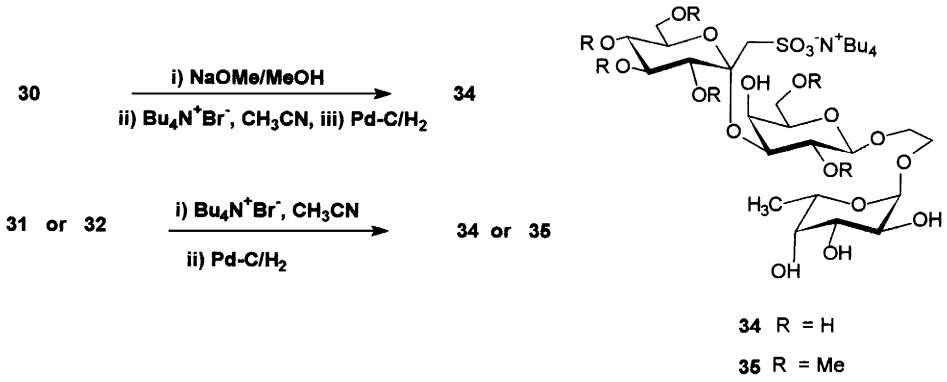


Scheme 9. Synthesis of sLe^X mimics using methyl triflate activation

Two permethylated sulfonomethyl derivatives **9** and **12** were also used for the glycosylation of the aglycone **29** to obtain the sulfonic acid-type sLe X analogues possessing a partly apolar character. Data in the literature suggest that introduction of a long-chain apolar aglycone[25] or hydrophobic moiety at 3-position of the galactose residue[26] of the sLe X mimics induces stronger selectin-inhibitory effects, due to the interaction of these apolar moieties with the hydrophobic part of E- and P-selectins.[27] The goal was to study the influence of the decreased polarity on the ability of binding to selectins. Derivatives containing permethylated sugar parts fulfill such an expectation concerning the apolar moiety.

Since the methyl triflate-activation of the anomeric sulfonomethyl-type donor proved to be better than the NIS–TfOH in decreasing the formation of the elimination product, this method was used in the further coupling reactions. Thus, compound **29** was glycosylated with the permethylated donor **9** using MeOTf as the promoter, to obtain **32** with an isolated yield of 55%. Formation of the elimination product **33** with moderate yield (~20%) was also observed (Scheme 9).

Then the protecting groups were removed from **31** or **32** via nucleophilic attack by bromide ion and subsequent catalytic hydrogenation to result in the tetrabutylammonium salts **34** and **35** (Scheme 10). Compound **30** was also converted to **34** by means of a three-step deprotection procedure starting with catalytic debenzoylation. The pseudotetrasaccharides **34** and **35** are sulfonic acid-type mimics of the sialyl Lewis X tetrasaccharide.



Scheme 10. Deprotection of the sLe^X mimics

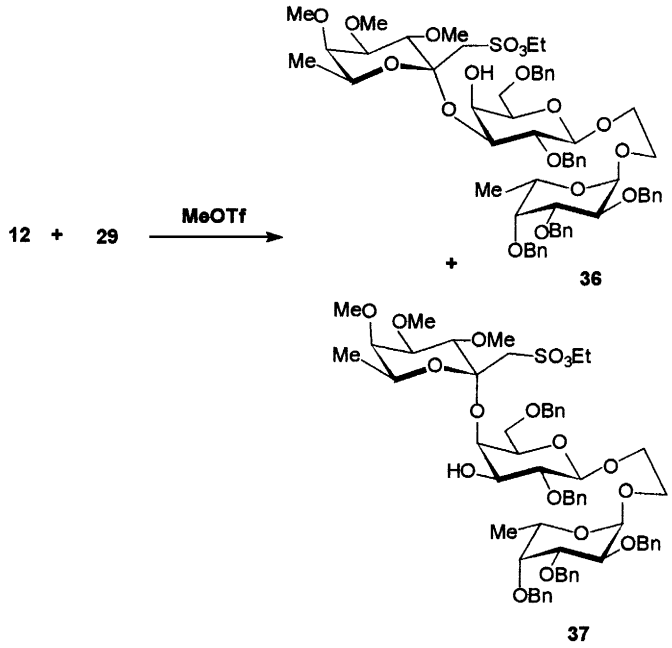
The donor **12** was also used for the glycosylation of **29** to give a separable 4:1 mixture of the regioisomeric pseudo-tetrasaccharides **36** and **37**. In this case the formation of the elimination product from **12** was not observed, indicating the different ability of the various donors for elimination (Scheme 11).

Removal of the protecting groups from **36** was attempted via nucleophilic attack by bromide ion and subsequent catalytic hydrogenation. However, surprisingly, after the 2-step deprotection only the pseudo-trisaccharide part of the molecule could be isolated in a free form (Scheme 12).

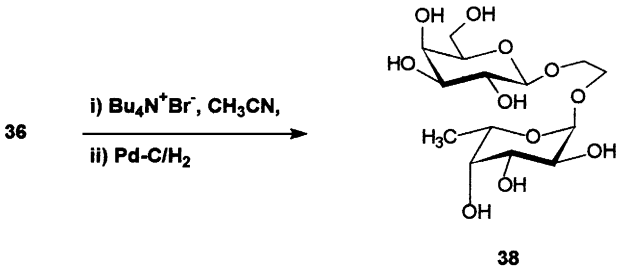
The syntheses of further sialyl Lewis X analogues combining sulfonyl moiety is in progress in our laboratory.

3. Conclusion

Several new sulfonic acid-type analogues of the sialyl Lewis X tetrasaccharide were synthesized in glycosylation reactions by using the sulfonomethyl analogues of aldose-2-ulosonic acids as donors. However, formation of elimination products from the 1-sulfonomethyl-2-thioglycosides is a competitive reaction. Decomposition of the sulfonic acid ethyl ester was observed during catalytic hydrogenation. Therefore, in the deprotection procedure of this type of derivatives conversion of the sulfonic ester into salt is necessary before catalytic hydrogenation.



Scheme 11. Synthesis of the sLe^X mimic using the L-fucono derivative as the donor



Scheme 12.

4. Experimental

Optical rotations were measured at room temperature with a Perkin–Elmer 241 automatic polarimeter. TLC was performed on Kieselgel 60 F_{254} (Merck) with detection by charring with 50% aqueous sulfuric acid. Column chromatography was performed on silica gel 60 (Merck, 0.063–0.200 mm). The organic solutions were dried over $MgSO_4$ and concentrated in vacuo. The ^1H (200, 360 and 500 MHz) and ^{13}C NMR (50, 90, 125 MHz) spectra were recorded with Bruker WP-200 SY, Bruker AM-360 and Bruker Avance DRX-500 spectrometers in $CDCl_3$ solutions. Chemical shifts are referenced to Me_4Si (^1H) or to the residual solvent signals (^{13}C). The $^{13}C/^1H$ correlations through one-bond as well as long-range couplings were obtained from sensitivity enhanced[28] gradient HSQC[29] and gradient HMBC[30] experiments, respectively. Typical time domain data matrices for the heterocorrelated measurements were of 2 K×512 data points in size. The band-selective 2D homo- and heterocorrelated experiments were executed as described recently.[31]

4.1. General method **A** for the oxidation with Dess–Martin's periodinane

A solution of a protected sugar with free anomeric hydroxyl group (10 mmol) in dichloromethane (50 mL) was treated with Dess–Martin's periodinane[15] (1.2 equiv., 12 mmol) at room temperature and stirred for a further 30 min. Usual work-up gave the aldono-lactones.

4.2. General method **B** for carbanion addition

A solution of diisopropylamine (1.1 equiv., 1.1 mmol) in dry THF (10 mL) was treated with 2.5 M *n*-BuLi in hexane (1.1 equiv., 1.1 mmol) at −15°C under argon atmosphere. After 15 min the solution was cooled to −60°C and ethyl methanesulfonate was added (1.1 equiv., 1.1 mmol). The mixture was kept at −60°C for 15 min, then it was cooled to −78°C and the aldonolactone derivative (1 equiv., 1.0 mmol) was added. The mixture was kept at −78°C for 30 min, and then it was allowed to warm up to room temperature, and concentrated. The residue was diluted with 10 ml of water and extracted with dichloromethane (3×30 mL). The organic layer was dried and evaporated. The product was purified by column chromatography.

4.3. General method **C** for thioglycoside formation

The protected 1-deoxy-1-ethylsulfonato-hept-2-ulose was dissolved in abs. dichloromethane, 1.1 equiv. of ethanethiol (or thiophenol) and 2 equiv. of $BF_3 \cdot Et_2O$ were added at 0°C, and the solution was allowed to warm up to room temperature. When TLC showed complete conversion (~6 h) of the starting material, the solution was diluted with dichloromethane, extracted with water until neutral and the organic layer was dried and evaporated.

4.4. General method **D** for the coupling reaction using NIS–TfOH activation

The donor (1.2–1.6 equiv.) and the acceptor compounds were dissolved in abs. dichloromethane, 4 Å molecular sieves were added and the mixture was stirred for 3 h. It was then cooled to −45°C and a solution of 1.3 equiv. of NIS and 0.13 equiv. of TfOH in abs. THF was added. The mixture was kept at −45°C until the TLC showed the complete conversion of the donor (~30 min). After usual work-up the product was purified by column chromatography.

4.5. *2,3,4,6-Tetra*-O-*benzyl*-D-*glucono-1.5-lactone* ***3***

2,3,4,6-Tetra-*O*-benzyl-D-glucose[32] was converted by method ***A*** to **3** (85%), $[\alpha]_D$ +79.6 (c 0.3, $CHCl_3$), R_f 0.5 (dichloromethane:acetone 99:1). Lit.[12]: $[\alpha]_D$ +78 (c 1.0, $CHCl_3$). ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 169.28 (*C*-1), 137.49, 136.92 (quaternary aromatic), 128.41, 128.07, 127.95, 127.79 (aromatic), 80.95, 78.13, 76.64 (*C*-2, *C*-3, *C*-4), 73.89, 73.68, 73.54 (CH_2-Ph), 68.25 (CH_2-6). Anal. calcd for $C_{34}H_{34}O_6$: C 75.82, H 6.36. Found: C 75.80, H 6.39.

4.6. *3,4,5,7-Tetra*-O-*benzyl-1-deoxy-1-ethylsulfonato*-α-D-gluco-*hept-2-ulose* ***4***

Compound **3** was converted by method ***B*** to yield **4** (80%), $[\alpha]_D$ −12.5 (c 0.3, $CHCl_3$), R_f 0.28 (hexane:ethyl acetate 7:3). ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 138.17, 137.90, 137.78, 137.29 (quaternary aromatic), 128.64, 128.55, 128.27, 127.67 (aromatic), 95.67 (*C*-2), 82.79, 80.78, 77.85, 71.79

(*C*-3, *C*-4, *C*-5, *C*-6), 75.03, 74.86, 73.29, 71.79 (*C*H_2-Ph), 68.27, 67.83 ($SO_3CH_2CH_3$, *C*H_2-7), 55.15 (*C*H_2-1), 14.83 ($SO_3CH_2CH_3$). Anal. calcd for $C_{37}H_{42}O_9S$: C 67.05, H 6.39, S 4.84. Found: C 67.02, H 6.33, S 4.87.

4.7. Ethyl 3,4,5,7-tetra-O-*benzyl-1-deoxy-1-ethylsulfonato-2-thio-α*-D-gluco-*hept-2-ulopyranoside* ***5*** *and phenyl 3,4,5,7-tetra*-O-*benzyl-1-deoxy-1-ethylsulfonato-2-thio-α*-D-gluco-*hept-2-ulopyranoside* ***6***

Compound **3** was converted to **5** or **6**, respectively, by method ***C***. Compound **5** (96%): $[\alpha]_D$ +59.9 (c 0.61, $CHCl_3$), R_f 0.5 (hexane:ethyl acetate 7:3). ^{13}C NMR (benzene-d_6, 125MHz) δ (ppm): 89.7 (*C*-2), 84.7 (*C*-4), 80.7 (*C*-3), 79.8 (*C*-5), 75.0 (*C*-6), 69.3 (*C*-7), 66.8 ($SO_3CH_2CH_3$), 56.7 (*C*-1, $J_{H3,C1}$=2.7 Hz), 20.1 (SCH_2CH_3), 15.1 ($SO_3CH_2CH_3$), 13.9 (SCH_2CH_3). Anal. calcd for $C_{39}H_{46}O_8S_2$: C 66.26, H 6.56, S 9.07. Found: C 66.22, H 6.58, S 9.05.

Compound **6** (91%): $[\alpha]_D$ +87.6 (c 0.44, $CHCl_3$), R_f 0.5 (hexane:ethyl acetate 7:3) ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 91.92 (*C*-2), 83.55 (*C*-4), 79.29 (*C*-3), 78.32 (*C*-5), 74.25 (*C*-6), 69.26 (*C*-7), 67.33 ($SO_3CH_2CH_3$), 54.32 (*C*-1), 14.78 (SCH_2CH_3). Anal. calcd for $C_{43}H_{46}O_8S_2$: C 68.41, H 6.15, S 8.48. Found: C 68.71, H 6.17, S 8.50.

4.8. 2,3,4,6-Tetra-O-*methyl*-D-*glucono-1,5-lactone* ***7***

2,3,4,6-Tetra-*O*-methyl-D-glucose[13b] was converted by method ***A*** to furnish **7** (85%), $[\alpha]_D$ +105.3 (c 1.5, $CHCl_3$), R_f 0.5 (hexane:acetone 65:35). Lit.[13a]: $[\alpha]_D$ +107.4 (c 1.0 $CHCl_3$), ^{1}H NMR,[13b] ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 168.7 (*C*-1), 81.2, 78.8, 77.3, 76.9 (*C*-2, *C*-3, *C*-4, *C*-5), 70.8 (*C*-6), 60.3, 59.1, 58.5, 57.9 (OCH_3). Anal. calcd for $C_{10}H_{18}O_6$: C 51.27, H 7.75. Found: C 51.25, H 7.73.

4.9. 1-Deoxy-1-ethylsulfonato-3,4,5,7-tetra-O-*methyl-α*-D-gluco-*hept-2-ulose* ***8***

Compound **7** was converted by method ***B*** into **8** (50%), $[\alpha]_D$ +43.4 (c 0.6, $CHCl_3$), R_f 0.34 (hexane:ethyl acetate 1:1). ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 95.76 (*C*-2), 84.39, 84.09, 79.50, 71.63 (*C*-3, *C*-4, *C*-5, *C*-6), 70.85, 67.99 ($SO_3CH_2CH_3$, *C*-7), 61.27, 60.74, 60.39, 59.05 (OCH_3), 55.36 (*C*-1), 14.91 ($SO_3CH_2CH_3$). Anal. calcd for $C_{13}H_{26}O_9S$: C 43.57, H 7.31, S 8.95. Found: C 43.55, H 7.35, S 8.96.

4.10. Ethyl 1-deoxy-1-ethylsulfonato-3,4,5,7-tetra-O-*methyl-2-thio-α*-D-gluco-*hept-2-ulopyranoside* ***9***

Compound **8** was converted by method ***C*** to give **9** (94%), $[\alpha]_D$ +119.8 (c 1.14, $CHCl_3$), R_f 0.33 (hexane:ethyl acetate 7:3). ^{1}H NMR ($CDCl_3$, 500 MHz) δ (ppm): 4.29 (2H, q, J=7.3 Hz, $SO_3CH_2CH_3$), 4.05 (1H, d, $J_{3,4}$=9.5 Hz, H-3), 3.82 (1H, d, $J_{1a,1b}$=15 Hz, H-1a), 3.79 (1H, $J_{5,6}$=9.7 Hz, $J_{6,7a}$=5.5 Hz, $J_{6,7b}$=1.8 Hz, H-6), 3.64 (1H, d, H-1b), 3.63 (3H, s, OCH_3), 3.63 (1H, t, $J_{3,4}$=$J_{4,5}$=9.5 Hz, H-4), 3.59 (3H, s, OCH_3), 3.56 (1H, dd, H-7a), 3.51 (1H, m, H-7b), 3.50, 3.33 (2×3H, 2 s, 2×OCH_3), 3.12 (1H, m, H-5), 2.39 (2H, q, J=7.5 Hz, SCH_2CH_3), 1.19 (3H, t, J=6.7 Hz, SCH_2CH_3), 1.35 (3H, t, J=7.3 Hz, $SO_3CH_2CH_3$). ^{13}C NMR ($CDCl_3$, 125 MHz) δ (ppm): 88.71 (*C*-2), 85.63 (*C*-4), 80.61 (*C*-3), 79.62 (*C*-5), 73.70 (*C*-6), 71.31 (*C*-7), 67.27 ($SO_3CH_2CH_3$), 61.27, 60.61, 60.46, 59.17 (4×OCH_3), 55.90 (*C*-1, $^3J_{H3,C1}$=4.2 Hz), 19.71 (SCH_2CH_3), 15.10 ($SO_3CH_2CH_3$), 13.88 (SCH_2CH_3). Anal. calcd for $C_{15}H_{30}O_8S_2$: C 44.76, H 7.54, S 15.93. Found: C 44.74, H 7.56, S 15.91.

4.11. 2,3,4-Tri-O-*methyl*-L-*fucono-1,5-lactone* ***10***

2,3,4-Tri-*O*-methyl-L-fucose[33] was converted by method ***A*** to yield **10** (70%), $[\alpha]_D$ −124.3 (c 1.0, $CHCl_3$), R_f 0.72 (hexane:acetone 1:1). Lit.[14]: $[\alpha]_D$ −138 to −36 (c 1.0, H_2O). ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm) 170.38 (*C*-1), 82.26, 78.56, 77.31, 75.61 (*C*-2, *C*-3, *C*-4, *C*-5), 61.56, 60.99, 58.40 (O*C*H_3), 17.01 (*C*H_3-6). Anal. calcd for $C_9H_{16}O_5$: C 52.93, H 7.90. Found: C 52.94, H 7.93.

4.12. 1-Deoxy-1-ethylsulfonato-3,4,5-tri-O-*methyl*-α-L-fuco-*hept-2-ulose* ***11***

Compound **10** was converted by method ***B*** to yield **11** (97%), $[\alpha]_D$ −34.7 (c 1.0, $CHCl_3$), R_f 0.54 (hexane:acetone 1:1). ^{13}C NMR ($CDCl_3$, 50 MHz) δ (ppm): 96.06 (*C*-2), 81.62, 80.35, 79.36, 67.73 (*C*-3, *C*-4, *C*-5, *C*-6), 67.94 (S*C*H_2CH$_3$), 61.84, 61.40, 57.95 (O*C*H_3), 55.54 (*C*-1), 16.30, 15.02 (*C*H_3-7, SO_3CH_2*C*H_3). Anal. calcd for $C_{12}H_{24}O_8S$: C 43.89, H 7.37, S 9.76. Found: C 43.88, H 7.39, S 9.76.

4.13. Ethyl 1-deoxy-1-ethylsulfonato-3,4,5-tri-O-*methyl-2-thio*-α-L-fuco-*hept-2-ulopyranoside* ***12***

Compound **11** was converted by method ***C*** into **12** (95%), $[\alpha]_D$ −119.2 (c 1.26, $CHCl_3$), R_f 0.41 (hexane:ethyl acetate 7:3). ^1H NMR ($CDCl_3$, 500 MHz) δ (ppm): 4.41 (1H, d, $J_{3,4}$=9.7 Hz, H-3), 4.37 (1H, m, SO_3C*H*$_2$CH$_3$a), 3.97 (1H, m, $J_{5,6}$ <0.5 Hz, $J_{6,7}$=6.5 Hz, H-6), 3.89 (1H, d, $J_{1a,1b}$=15.3 Hz, H-1a), 3.67 (1H, dd, $J_{4,3}$=9.7 Hz, $J_{4,5}$=2.5 Hz, H-4), 3.61 (1H, d, H-1b), 3.42 (1H, t, H-5), 3.30, 3.16 (2×3H, 2 s, 2×OC*H*$_3$), 2.42 (1H, m, SC*H*$_2$CH$_3$a), 2.32 (1H, m, SC*H*$_2$CH$_3$b), 2.07 (3H, s, OC*H*$_3$), 1.35 (3H, t, J=7.0 Hz, SO_3CH_2C*H*$_3$), 1.27 (3H, d, H-7), 1.21 (3H, t, J=7.8 Hz, SCH_2C*H*$_3$). ^{13}C NMR ($CDCl_3$, 125 MHz) δ (ppm): 89.70 (*C*-2), 83.34 (*C*-4), 78.54 (*C*-5), 76.84 (*C*-3), 69.80 (*C*-6), 67.98 (SO_3*C*H_2CH$_3$), 61.69, 61.41, 57.69 (3×O*C*H_3), 56.78 (*C*-1, $^3J_{H3,C1}$=2.4 Hz), 20.21 (S*C*H_2CH$_3$), 16.44 (SO_3CH_2*C*H_3), 15.30 (*C*-7), 14.20 (SCH_2*C*H_3). Anal. calcd for $C_{14}H_{28}O_7S_2$: C 45.14, H 7.58, S 17.21. Found: C 45.14, H 7.56, S 17.20.

4.14. Methyl 2,3,4-tri-O-*benzyl-6*-O-*(3,4,5,7-tetra*-O-*benzyl-1-deoxy-1-ethylsulfonato*-α-D-gluco-*hept-2-ulopyranosyl)*-α-D-*glucopyranoside* ***14*** *and 2,6-anhydro-3,4,5,7-tetra*-O-*benzyl-1-ethylsulfonato*-D-gluco-*hept-1-enitol* ***15***

Compound **13** was glycosylated with **5** (1.2 equiv.) by method ***D***, to yield **14** and **15** which were separated by column chromatography (hexane:ethyl acetate 8:2).

Compound **14** (60%): $[\alpha]_D$ +55.4 (c 3.63, $CHCl_3$), R_f 0.46 (hexane:ethyl acetate 7:3). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 4.94–4.39 (14 d, 14H, 7×OC*H*$_2$Ph), 4.48 (1H, d, $J_{1,2}$=9.5 Hz, H-1), 4.11 (1H, d, $J_{3',4'}$=9.5 Hz, H-3′), 4.08 (2H, m, SO_3C*H*$_2$CH$_3$), 3.98 (1H, t, $J_{4',5'}$=9.5 Hz, H-4′), 3.89 (1H, t, $J_{3,2}$=$J_{3,4}$=9.2 Hz, H-3), 3.77 (1H, m, $J_{5',6'}$=10.5 Hz, $J_{6',7a'}$=1.0 Hz, $J_{6',7b'}$=3.5 Hz, H-6′) 3.65 (1H, H-5), 3.63, 3.55 (2H, dd, J_{gem}=10 Hz, H-7a′, H-7b′) 3.62 (1H, t, H-5′), 3.43, 3.33 (2H, 2 d, J_{gem}=15.5 Hz, H-1a′, H-1′b), 3.53, 3.39 (2H, 2d, H-6a,b), 3.37 (1H, t, $J_{2',3'}$=9.5 Hz, H-2′), 3.32 (1H, t, H-4), 3.25 (3H, s, OCH_3), 1.12 (3H, t, J=7.1 Hz, SO_3CH_2C*H*$_3$), ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 99.20 (C-2′), 97.74 (C-1), 82.97 (C-4′), 82.09 (C-3), 80.12 (C-2), 79.76 (C-3′), 78.04 (C-4), 77.94 (C-5′), 75.76, 75.29, 75.02, 74.79, 74.70, 73.29, 73.17 (7×O*C*H_2Ph), 72.96 (C-6′), 69.67 (C-5), 68.69 (C-7′), 67.60 (SO_3*C*H_2CH$_3$), 60.43 (C-6), 55.13 (OMe), 51.53 (C-1′), 15.15 (SO_3CH_2*C*H_3). Anal. calcd for $C_{65}H_{72}O_{14}S$: C 70.38, H 6.54, S 2.89. Found: C 70.36, H 6.57, S 2.90.

Compound **15** (30%): $[\alpha]_D$ +64.1 (c 0.23, $CHCl_3$), R_f 0.54 (hexane:ethyl acetate 7:3). ^1H NMR (500 MHz, $CDCl_3$) δ (ppm): 5.79 (1H, s, H-1), 4.59–4.24 (8 d, 8H, 4×OC*H*$_2$Ph), 4.37 (1H, m, H-6), 3.96

(1H, dd, $J_{4,5}$=5.3 Hz, $J_{5,6}$=9.8 Hz, H-5), 3.80 (1H, t, $J_{4,3}$=4.8 Hz, H-4), 3.76 (1H, d, H-3) 3.73 (1H, dd, $J_{7a,7b}$=11.5 Hz, $J_{7a,6,}$=2.0 Hz, H-7a), 3.62 (1H, dd, $J_{6,7b}$=3.3 Hz, H-7b), 3.08 (2H, q, J_{gem}=7.3 Hz, $SO_3CH_2CH_3$), 0.962 (3H, t, J=7.0 Hz, $SO_3CH_2CH_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 161.54 (C-2), 105.37 (C-1), 82.50 (C-4), 78.56 (C-6), 77.44 (C-3), 77.27 (C-5), 73.58, 73.53, 72.9, 72.11 (4×OCH_2Ph), 67.97 (C-7), 67.97 ($SO_3CH_2CH_3$), 14.85 ($SO_3CH_2CH_3$).

*4.15. Methyl 2,6-di-*O*-benzyl-3-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethylsulfonato-α-*D*-gluco-hept-2-ulopyranosyl)-β-*D*-galactopyranoside **17** and methyl 2,6-di-*O*-benzyl-4-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethylsulfonato-α-*D*-gluco-hept-2-ulopyranosyl)-β-*D*-galactopyranoside **18***

Compound **15** was glycosylated with **5** (1.5 equiv.) by method ***D***, to yield **15**, **17** and **18** which were separated by column chromatography (hexane:ethyl acetate 7:3) (compound **15** was isolated with a yield of 13%).

Compound **17** (58%): $[\alpha]_D$ +41.1 (c 0.59, $CHCl_3$), R_f 0.40 (hexane:ethyl acetate 7:3). ^{1}H NMR ($CDCl_3$, 500 MHz) δ (ppm): 4.94, 4.71; 4.86, 4.45; 4.85, 4.77; 4.76, 4.49; 4.38, 4.22 (10 d, 10H, 5×OCH_2Ph), 3.51 (2H, d, H′-1a,b), 4.23 (1H, d, $J_{3',4'}$ =9.6 Hz, H′-3), 4.22, 3.99 (1H, d, OCH_2Ph), 4.21 (1H, m, $J_{6',7a'}$=3.5 Hz, $J_{6',7b'}$=1.0 Hz, H′-6), 4.16 (1H, d, $J_{1,2}$=7.7 Hz, H-1), 4.05 (2H, m, $SO_3CH_2CH_3$), 4.00 (1H, t, $J_{4',5'}$=9.3 Hz, H′-4), 3.78 (1H, d, $J_{3,4}$=3.0 Hz, $J_{4,5}$ <0.5 Hz, H-4) 3.71 (1H, t, $J_{5',6'}$=9.6 Hz, H′-5), 3.70 (1H, H-3), 3.63 (2H, m, H-6), 3.46 (1H, t, H-2), 3.40 (1H, t, $J_{5,6}$=5.8 Hz, H-5), 3.35 (1H, dd, $J_{7a',7b'}$=11.5 Hz, H′-7a), 3.28 (1H, m, H′-7b), 1.05 (3H, t, J=7.0 Hz, $SO_3CH_2CH_3$). ^{13}C NMR ($CDCl_3$, 125 MHz) δ (ppm): 104.80 (*C*-1), 99.63 (*C*′-2), 83.00 (*C*′-4), 79.88 (*C*′-3), 77.80 (*C*-2), 77.80 (*C*′-5), 75.38, 75.20, 75.04, 74.94 (4×OCH_2Ph), 74.17 (*C*-3), 73.66, 73.03 (2×OCH_2Ph), 72.85 (*C*-5), 72.47 (*C*′-6), 69.13 (*C*-6), 68.82 (*C*-4), 68.19 (*C*′-7), 68.19 ($SO_3CH_2CH_3$), 56.89 (OCH_3), 53.26 (*C*′-1), 15.12 ($SO_3CH_2CH_3$). Anal. calcd for $C_{58}H_{66}O_{14}S$: C 68.35, H 6.53, S 3.15. Found: C 68.35, H 6.57, S 3.1.

Compound **18** (19%): $[\alpha]_D$ +34.9 (c 0.73, $CHCl_3$), R_f 0.29 (hexane:ethyl acetate 7:3). ^{1}H NMR (benzene-d_6, 500 MHz) δ (ppm): 5.16, 4.98; 5.05, 4.92; 4.74, 4.38; 4.70, 4.64 (8 d, each 1H, 4×OCH_2Ph), 4.58 (1H, d, $J_{3',4'}$=9.7 Hz, H′-3), 4.42 (1H, m, H′-6), 4.38, 4.25 (2H, 2 d, OCH_2Ph), 4.29 (1H, d, $J_{1a',1b'}$=12.8 Hz, H′-1a), 4.24 (1H, t, $J_{4',5'}$=9.4 Hz, H′-4), 4.20 (1H, d, $J_{1,2}$=7.2 Hz, H-1), 4.16, 4.10 (2H, 2d, OCH_2Ph), 4.08 (2H, m, $SO_3CH_2CH_3$), 3.84 (1H, dd, $J_{5,6a}$=6.1 Hz, $J_{6a,6b}$=9.7 Hz, H-6a), 3.75 (1H, dd, H-2), 3.67 (1H, d, H′-1b), 3.66 (1H, d, $J_{4,3}$=1.0 Hz, $J_{4,5}$ <0.5 Hz, H-4), 3.65 (1H, dd, $J_{7a',7b'}$=10.5 Hz, $J_{7a',6'}$=1.0 Hz, H′-7a), 3.57 (1H, t, $J_{5',6'}$=9.5 Hz, H′-5), 3.57 (1H, m, H-3), 3.50 (1H, m, H-6b), 3.50 (1H, dd, $J_{6',7b'}$=6.7 Hz, H′-7b), 3.40 (1H, t, $J_{5,6b}$=6.1 Hz, H-5), 0.95 (3H, t, J=7.3 Hz, $SO_3CH_2CH_3$). ^{13}C NMR (benzene-d_6, 125 MHz) δ (ppm): 105.43 (*C*-1), 99.73 (*C*′-2), 83.28 (*C*′-3), 81.33 (*C*′-4), 78.98 (*C*′-5), 73.49 (*C*′-6), 69.42 (*C*′-7), 67.65 ($SO_3CH_2CH_3$), 80.95 (*C*-2), 75.85, 75.22, 75.22, 74.90 (4×OCH_2Ph), 73.99 (*C*-5), 73.84 (*C*-3), 73.59, 72.97 (2×OCH_2Ph), 72.95 (*C*-4), 69.42 (*C*-6), 52.69 (*C*′-1, $J_{C1',H3'}$ <1 Hz), 15.00 ($SO_3CH_2CH_3$).

*4.16. Benzyl 2,6-di-*O*-benzyl-3-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethylsulfonato-α-*D*-gluco-hept-2-ulopyranosyl)-β-*D*-galactopyranoside **20** and benzyl 2,6-di-*O*-benzyl-4-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethylsulfonato-α-*D*-gluco-hept-2-ulopyranosyl)-β-*D*-galactopyranoside **21***

Compound **19** was glycosylated with **5** (1.5 equiv.) by method ***D***, to yield **15**, **20** and **21** which were separated by column chromatography (hexane:ethyl acetate 7:3) (compound **15** was isolated with a yield of 15%).

Compound **20** (59%): $[\alpha]_D$ +27.6 (c 0.59, $CHCl_3$), R_f 0.35 (hexane:ethyl acetate 7:3). ^{1}H NMR ($CDCl_3$, 500 MHz) δ (ppm): 4.93, 4.70; 4.92, 4.43; 4.85, 4.55; 4.83, 4.75; 4.73, 4.45 (10 d, each 1H,

5×OC*H*$_2$Ph), 4.49 (2H, s, *OCH$_2$Ph*), 4.35, 4.18 (2H, 2 d, OC*H$_2$*Ph), 4.34 (1H, d, $J_{1,2}$=8.0 Hz, H-1), 4.23 (1H, d, H′-1a), 4.22 (1H, d, $J_{3',4'}$=9.5 Hz, H′-3), 4.16 (1H, m, $J_{5',6'}$=9.8 Hz, $J_{6',7a'}$=3.0 Hz, $J_{6',7b'}$=1.0 Hz, H′-6), 4.03 (2H, m, $SO_3CH_2CH_3$), 3.99 (1H, t, $J_{4',5'}$=9.2 Hz, H′-4), 3.77 (1H, d, $J_{4,3}$=3.2 Hz, $J_{4,5}$ <0.5 Hz, H-4), 3.70 (1H, dd, $J_{3,2}$=9.0 Hz, H-3), 3.68 (1H, t, H′-5), 3.65 (2H, d, $J_{6,5}$=5.7 Hz, H-6a,b), 3.54 (1H, dd, H-2), 3.50 (1H, d, H′-1b), 3.39 (1H, t, H-5), 3.27 (1H, dd, $J_{7a',7b'}$=11.5 Hz, H′-7a), 3.21 (1H, dd, H′-7b), 1.03 (3H, t, J=7.0 Hz, $SO_3CH_2CH_3$). ^{13}C NMR ($CDCl_3$, 125 MHz) δ (ppm): 102.25 (*C*-1), 99.59 (*C*′-2), 82.96 (*C*′-4), 79.81 (*C*′-3), 77.72 (*C*′-5), 77.72 (*C*-2), 75.33, 75.15, 74.93, 74.86 (4×OCH_2Ph), 74.26 (*C*-3), 73.50, 72.98 (2×OCH_2Ph), 72.91 (*C*-5), 72.43 (*C*′-6), 70.65 (OCH_2Ph), 69.13 (*C*-6), 68.78 (*C*-4), 68.17 ($SO_3CH_2CH_3$), 68.10 (*C*′-7), 53.15 (*C*′-1), 15.07 ($SO_3CH_2CH_3$). Anal. calcd for $C_{64}H_{70}O_{14}S$: C 70.17, H 6.45, S 2.92. Found: C 70.34, H 6.47, S 3.01.

Compound **21** (18%): $[\alpha]_D$ +30.55 (c 0.63, $CHCl_3$), R_f 0.24 (hexane:ethyl acetate 7:3). ^{1}H NMR (500 MHz, benzene-d_6) δ (ppm): 5.16, 4.99; 5.05, 4.90; 4.89, 4.57; 4.73, 4.38; 4.71, 4.65 (10 d, each 1H, 5×OC*H$_2$*Ph), 4.59 (1H, d, H′-3), 4.47 (1H, d, $J_{1,2}$=7.4 Hz, H-1), 4.43 (1H, m, H′-6), 4.39, 4.26 (2H, d, OC*H$_2$*Ph), 4.29 (1H, d, $J_{1a',1b'}$=14.8 Hz, H′-1a), 4.26 (1H, t, $J_{3',4'}$=$J_{4',5'}$=9.5 Hz, H′-4), 4.19, 4.14 (2H, d, OC*H$_2$*Ph), 4.11 (2H, q, J=7.1 Hz, $SO_3CH_2CH_3$), 3.81 (1H, m, H-2), 3.79 (2H, m, H-6a,b), 4.73, 4.38 (2H, d, OCH_2Ph), 3.67 (1H, d, H′-1b), 3.66 (1H, d, $J_{3,4}$=1 Hz, H-4), 3.66 (1H, dd, H′-7a), 3.60 (1H, dd, $J_{3,2}$=9.9 Hz, H-3), 3.56 (1H, t, $J_{5',6'}$=9.5 Hz, H′-5), 3.49 (1H, dd, $J_{7a',7b'}$=10.2 Hz, $J_{6',7b'}$=7.0 Hz, H′-7b), 3.44 (1H, m, H-5), 0.98 (3H, t, J=7.1 Hz, $SO_3CH_2CH_3$). ^{13}C NMR (125 MHz, benzene-d_6) δ (ppm): 103.20 (*C*-1), 99.67 (*C*′-2), 83.21 (*C*′-4), 81.15 (*C*′-3), 80.86 (*C*-2), 78.89 (*C*′-5), 75.80, 75.22, 75.22, 74.99 (4×OCH_2Ph), 74.11 (*C*-5), 73.79 (*C*-3), 73.54 (OCH_2Ph), 73.36 (*C*′-6), 72.94 (*C*-4), 72.94, 70.92 (2×OCH_2Ph), 69.56 (*C*-6), 69.34 (*C*′-7), 67.83 ($SO_3CH_2CH_3$), 52.52 (*C*′-1, $J_{C1',H3'}$=4.5 Hz), 15.02 ($SO_3CH_2CH_3$).

4.17. Methyl 3-O-*(1-deoxy-1-tetrabutylammoniumsulfonato-α*-D-gluco-*hept-2-ulopyranosyl)-β*-D-*galactopyranoside **22***

Compound **17** (120 mg, 0.1 mM) was treated with Bu_4NBr (40 mg, 1.2 equiv.) in acetonitrile (3 mL) at reflux temperature for 1 h, when TLC showed the disappearance of **17**. The mixture was evaporated, the residue was dissolved in ethanol (3 ml), and 10% Pd–C (10 mg) was added. The mixture was stirred for 2 days under H_2, when TLC (acetone:water 9:1, R_f 0.3) indicated a complete conversion, then it was filtered and concentrated. Column chromatography (acetone:water 9:1) of the residue gave **22** (83%), having $[\alpha]_D$ +44.3 (c 1.10, H_2O). ^{1}H NMR (500 MHz, D_2O) δ (ppm): 4.84 (1H, dd, $J_{7a',7b'}$=12.5 Hz, H-7a′), 4.38 (1H, m, $J_{6',7a'}$=2.6 Hz, $J_{6',7b'}$=5.2 Hz, H-6′), 4.36 (1H, d, $J_{1,2}$=7.9 Hz, H-1), 4.12 (1H, d, $J_{3',4'}$=9.8 Hz, H-3′), 4.00 (1H, H-3), 4.00 (1H, H-4), 3.85 (1H, t, $J_{4',5'}$=9.8 Hz, H-4′), 3.78 (1H, H-6a), 3.74 (1H, dd, H-7b′), 3.73 (1H, H-6b) 3.72 (1H, H-5), 3.59 (1H, H-2), 3.53 (1H, d, $J_{1a',1b'}$=14.0 Hz, H-1a′), 3.47 (1H, d, H-1b′), 3.46 (1H, t, $J_{5',6'}$=9.7 Hz, H-5′), 3.18, 1.64, 1.35, 0.93 (nBu). ^{13}C NMR (125 MHz, D_2O) δ (ppm): 106.52 (C1), 102.78 (C′2), 77.28 (C5), 75.82 (C′6), 75.62 (C3), 75.32 (C′4), 74.80 (C′3), 72.37 (C2), 71.95 (C′5), 71.60 (C4), 63.75 (C6), 63.46 (C′7), 56.96 (C′1, $J_{C1',H3'}$=2.0 Hz), 60.82, 25.82, 21.84, 15.50 (*n*Bu). Anal. calcd for $C_{30}H_{61}O_{14}SN$: C 52.08, H 8.89, S 4.63, N 2.02. Found: C 52.06, H 8.90, S 4.61, N 2.00.

4.18. Hydroxyethyl 2,3,4-tri-O-*benzyl-α*-L-*fucopyranoside **24***

To a solution of ethyl 2,3,4-*O*-tri-*O*-benzyl-1-thio-α-L-fucopyranoside[23] (500 mg, 1.0 mM) and ethylene glycol (0.58 mL, 10.4 mM, 10 equiv.), in dichloromethane:DMF 3:1, 4 Å molecular sieves were added, and the mixture was stirred overnight under Ar. Then $Bu_4N^-Br^+$ (330 mg, 1.0 mM, 1 ekv.)

and $CuBr_2$ (348 mg, 1.56 mM, 1.5 ekv.) were added, and stirring was continued overnight, when TLC (dichloromethane:ethyl acetate 85:15) showed the formation of a single main product (R_f 0.25). The mixture was filtered through a layer of Celite, diluted with dichloromethane, and washed with water, until neutral. After concentration, column chromatography (dichloromethane:ethyl acetate 85:15) of the residue gave **24**, as a colorless syrup (410 mg, 82%); R_f 0.25 (dichloromethane:ethyl acetate 85:15), $[\alpha]_D$ −40.74 (c 0.45 $CHCl_3$); ^{13}C NMR ($CDCl_3$, 50 MHz): δ (ppm): 141.97, 141.72, 141.47 (quaternary aromatic), 101.99 (C-1), 77.01, 76.32 (3×$CH_2C_6H_5$), 74.26, 65.06 (-CH_2-CH_2-), 19.85 (C-6).

*4.19. 1,2-(2′,6′-Di-*O*-benzoyl-3′,4′-*O*-isopropylidene-β-*D*-galactopyranosyloxy)-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)ethane **25***

A mixture of **23**[22] (675 mg, 1.47 mM, 1.5 equiv.), **24** (470 mg, 0.98 mM), and molecular sieves (4 Å, 3 g) in dichloromethane was stirred overnight. MeOTf (1.2 mL, 6.86 mM, 7 equiv.) was added, and stirring was continued overnight, when TLC (dichloromethane:ethyl acetate 95:5) showed the reaction to be complete (**25**, R_f 0.6). The mixture was neutralized (Et_3N), filtered through a pad of Celite, diluted with dichloromethane, washed with water and concentrated. Column chromatography (dichloromethane:ethyl acetate 98:2) of the residue afforded **25**, as a syrup (700 mg, 80%), $[\alpha]_D$ −13.05 (c 0.45, $CHCl_3$). ^{13}C NMR ($CDCl_3$, 50 MHz), δ (ppm): 166.17, 165.14 (2×COC_6H_5), 110.63 ($C(CH_3)_2$), 99.58 (C-1), 97.8 (C-1′), 74.64, 73.31, 72.85 (3×$C_6H_5CH_2$-), 67.89, 67.012 (-CH_2CH_2-), 63.69 (C-6′), 27.59, 26.24 ($C(CH_3)_2$), 16.48 (C-6). Anal. calcd for $C_{52}H_{56}O_{13}$: C 70.25, H 6.35. Found: C 70.23, H 6.30.

*4.20. 1,2-(2′,6′-Di-*O*-benzoyl-β-*D*-galactopyranosyloxy)-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)-ethane **26***

To a solution of **25** (140 mg, 0.15 mM) in methanol (2 mL) 0.3 mL of aq. 1 M HCl was added. The mixture was stirred at 40°C overnight, when TLC (dichloromethane:ethyl acetate 7:3) revealed the disappearance of **25.** The mixture was concentrated, diluted with dichloromethane, washed with aq. 5% $NaHCO_3$ and water, dried, filtered and concentrated. Column chromatography (dichloromethane:ethyl acetate 7:3) of the residue afforded **26** as a syrup (110 mg, 83%), $[\alpha]_D$ −32.9 (c 0.36, $CHCl_3$), R_f 0.37. ^{13}C NMR ($CDCl_3$, 50 MHz): δ (ppm): 166.45 (2×COC_6H_5), 100.45 (C-1′), 97.92 (C-1), 67.58 (-CH_2CH_2-), 62.98 (C-6), 16.47 (C-6′). Anal. calcd for $C_{49}H_{52}O_{13}$: C 69.33, H 6.17. Found: C 69.34, H 6.18.

*4.21. 1,2-(3′,4′-*O*-Isopropylidene-β-*D*-galactopyranosyloxy)-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyl-oxy)ethane **27***

To solution of **25** (700 mg, 0.78 mM) in methanol (8 mL) NaOMe was added (pH 9). The mixture was stirred overnight, when TLC showed the appearance of a single product (R_f 0.22, dichloromethane:ethyl acetate 1:1). The mixture was neutralized with Amberlite IR-120, filtered, and concentrated. Column chromatography (dichloromethane:ethyl acetate 1:1) of the residue gave **27** (83%), $[\alpha]_D$ −18.8 (c 0.21, $CHCl_3$). ^{13}C NMR ($CDCl_3$, 50 MHz): δ (ppm): 138.23, 138.45,138.72 (quaternary aromatic), 110.2 ($C(CH_3)_2$), 102.96 (C-1), 97.9 (C-1′), 73.11, 73.04, 73.02 (3×$CH_2C_6H_5$), 68.91, 67.02 (-CH_2CH_2-), 62.71 (C-6′), 28.0, 26.24 ($C(CH_3)_2$), 16.53 (C-6).

*4.22. 1,2-(2′,6′-Di-*O*-benzyl-3′,4′-*O*-isopropylidene-β-*D*-galactopyranosyloxy)-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)ethane* ***28***

To a cooled solution of **27** (300 mg,0.35 mM) in dry DMF, 80% NaH (35 mg, 3 equiv.) and benzyl bromide (90 L, 0.7 mM, 2 equiv.) were added. TLC (hexane:ethyl acetate 3:2, R_f 0.56) indicated the benzylation to be completed in 2 h. After destroying the excess of NaH with MeOH the mixture was diluted with ethyl acetate, washed with water (3×), dried, filtered, and concentrated. Compound **27** was converted to **29** without further purification.

*4.23. 1,2-(2′,6′-Di-*O*-benzyl-β-*D*-galactopyranosyloxy)-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)-ethane* ***29***

Compound **28** was converted into **29** as described above for the synthesis of **26**. The product was purified by column chromatography. Compound **29** (81% from **27**) has R_f 0.38 (dichloromethane:ethyl acetate 7:3), $[\alpha]_D$ −20.9 (c 0.59, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm): 4.89–4.48 (10H, 5×C*H*$_2$Ph), 4.75 (1H, d, $J_{1,2}$=3.8 Hz, H-1), 4.35 (1H, d, $J_{1',2'}$=6.7 Hz, H-1′), 3.99, 3.71 (2H, -CH_2CH_2-), 3.91 (1H, d, $J_{2,3}$=10.2 Hz, H-2), 3.85 (1H, d, $J_{3',4'}$=2.3 Hz, H-4′), 3.80 (1H, m, H-5), 3.78 (1H, d, $J_{3,4}$=3.2 Hz, H-3), 3.69 (2H, -CH_2CH_2-), 3.68 (1H, m, J_{gem}=9.8 Hz, H-6a′), 3.63 (1H, m, H-6b′), 3.50 (1H, m, $J_{5',6a'}$=4.4 Hz, $J_{5',6b'}$=5.6 Hz, H-5′), 3.41 (1H, m, H-4), 3.40 (1H, d, H-2′), 3.40 (1H, d, H-3′), 0.99 (3H, d, $J_{5,6}$=5.6 Hz, H-6). ^{13}C NMR (125 MHz, $CDCl_3$) δ (ppm): 103.28 (C′1), 98.16 (C1), 79.30 (C3), 78.97 (C′2), 77.61 (C4), 76.39 (C2), 74.75, 74.36, 73.65, 73.12, 73.12, (O*C*H$_2$Ph), 73.26 (C′5), 73.00 (C′3), 69.36 (C′6), 68.82 (C′4), 68.16, 67.45 (O*C*H$_2$*C*H$_2$O), 66.27 (C5), 16.63 (C6). Anal. calcd for $C_{49}H_{56}O_{11}$: C 71.69, H 6.88. Found: C 71.68, H 6.85.

*4.24. 1,2-[2′6′-Di-*O*-benzoyl-3-*O*-(3′′,4′′,5′′,7′′-tetra-*O*-benzyl-1′′-deoxy-1′′-ethylsulfonato-α-*D*-gluco-hept-2′′-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)-ethane* ***30***

Compound **26** was glycosylated with **5** (1.6 equiv.) by method ***D*** to yield **30** (35%) and **15** (50%), after column chromatography (toluene:acetone 85:15). Compound **30** has $[\alpha]_D$ +22.6 (c 0.17, $CHCl_3$); ^{13}C NMR (125 MHz, benzene): δ 166.2, 165.3 (2 CO), 100.6 (C-1), 100.3 (C-2′′), 98.1 (C-1′), 64.0 (C-6′), 67.5, 67.7, 68.6 (CH_2-CH_2, C-7′′, $SO_3CH_2CH_3$), 53.9 (C-1′′, $J_{H3'',C1''}$ <1 Hz) 16.9 (C-6), 15.1 ($SO_3CH_2CH_3$); ESI+Q1MS: M+Na^+ 1515.7.

*4.25. 1,2-[2′6′-Di-*O*-benzyl-3-*O*-(3′′,4′′,5′′,7′′-tetra-*O*-benzyl-1′′-deoxy-1′′-ethylsulfonato-α-*D*-gluco-hept-2′′-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyl-oxy)ethane* ***31***

(A) Compound **29** was glycosylated with **5** (1.6 equiv.) by method ***D*** to yield **31** (36%) and **15** (46%). (B) A mixture of **29** (1 g, 1.22 mM), **5** (1.28 g, 1.82 mM) and molecular sieves (4 Å) in dichloromethane was stirred overnight under Ar. Then MeOTf (1.6 mL, 14.56 mM, 8 equiv.) was added, and the stirring was continued for 2 days, when TLC (hexane:ethyl acetate 3:2) showed the disappearance of **5**. The mixture was neutralized with Et_3N, diluted with dichloromethane, filtered, washed with water (3×), dried, and concentrated. Column chromatography (toluene:acetone 85:15) of the residue afforded **31** (1.27 g, 48%) as a colorless syrup, and **15** (30%). Compound **31** has $[\alpha]_D$ +6.44 (c 0.62, $CHCl_3$); ^{1}H NMR (500 MHz, benzene-d_6/TMS) δ (ppm): 5.55, 4.24; 5.17, 5.02; 5.52, 4.02; 4.98, 4.89 (8 d, 8H,

4×OC*H*$_2$Ph), 4.92 (1H, d, $J_{1,2}$=3.6 Hz, H-1), 4.84, 4.55 (d, OC*H*$_2$Ph), 4.72 (1H, d, $J_{3'',4''}$=9.4 Hz, H″-3), 4.67, 4.47; 4.52, 4.46 (2 d, 2H, 2×OC*H*$_2$Ph), 4.49 (m, $J_{6'',5''}$=10 Hz, H″-6), 4.44 (1H, H′-1), 4.43, 4.24; 4.39, 4.33 (2 d, 2H, 2×OC*H*$_2$Ph), 4.32 (1H, t, $J_{4'',5''}$=9.4 Hz, H″-4), 4.18 (1H, dd, $J_{2,3}$=10.2 Hz, H-2), 4.05 (2H, q, J=7.0 Hz, $SO_3CH_2CH_3$), 3.99, 3.75 (OC*H*$_2$CH$_2$O), 3.96 (1H, m, H″-5) 3.94 (1H, dd, $J_{3,4}$=3.0 Hz, H-3), 3.92 (1H, H″-1a), 3.84 (1H, H′-4), 3.83 (1H, m, $J_{5,4}$=1.1 Hz, $J_{5,6}$=6.5 Hz, H-5), 3.83 (1H, H″-1b), 3.81 (1H, dd, $J_{6a',6b'}$=10.0 Hz, $J_{6a',5'}$=7.0 Hz, H′-6a), 3.79 (1H, H′-3), 3.79 (1H, H′-2), 3.70 (1H, dd, $J_{6b',5'}$=5.9 Hz, H′-6b), 3.70, 3.57 (OCH$_2$C*H*$_2$O), 3.40 (2H, m, H″-7a,b) 3.36 (1H, H′-5), 3.29 (1H, dd, H-4), 1.22 (3H, d, $J_{6,5}$=6.5 Hz, H-6), 0.89 (3H, t, J=7.1 Hz, $SO_3CH_2CH_3$). ^{13}C NMR (125 MHz, benzene-d$_6$) δ (ppm): 103.83 (C′1), 100.22 (C″2), 98.32 (C1), 83.63 (C″4), 80.80 (C″3), 79.48 (C3), 78.84 (C4), 78.43 (C″5), 78.42 (C′2), 77.43 (C2), 75.73, 75.52, 75.34, 75.20, 74.97, 73.66, 73.41, 73.23, 72.87 (9×OCH$_2$Ph), 74.77 (C′5), 72.96 (C″6), 73.37(C′3), 69.99 (C′6), 69.38 (C′4), 68.65 (C″7), 68.21, 67.76 (OCH$_2$CH$_2$O), 67.87 ($SO_3CH_2CH_3$), 66.77 (C5), 53.93 (C″1, $J_{C1'',H3''}$ <0.5 Hz), 17.02 (C6), 15.13 ($SO_3CH_2CH_3$). Anal. calcd for $C_{86}H_{96}O_{19}S$: C 70.47, H 6.60, S 2.19. Found: C 70.45, H 6.62, S 2.19

*4.26. 1,2-[2′6′-Di-*O*-benzyl-3-*O*-(3″,4″,5″,7″-tetra-*O*-methyl-1″-deoxy-1″-ethylsulfonato-α-*D*-gluco-hept-2″-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)-ethane **32**, and 2,6-anhydro-3,4,5,7-tetra-*O*-methyl-1-ethylsulfonato-*D*-gluco-hept-1-enitol **33***

Compound **29** was glycosylated with **9** as described for synthesis of **31** by using MeOTf (8 equiv.). The products were separated by column chromatography (toluene:acetone 9:1) to obtain **32** (55%) and **33** (20%). Compound **32**: $[\alpha]_D$ +3.8 (c 0.63, $CHCl_3$); ^{1}H NMR (500 MHz, benzene-d$_6$/TMS) δ (ppm): 5.19, 4.55; 5.02, 4.53 (4H, 4 d, 2×OC*H*$_2$Ph), 4.91 (1H, d, $J_{1,2}$=3.7 Hz, H-1), 4.70, 4.51; 4.55, 4.49 (4H, 4 d, 2×OC*H*$_2$Ph), 4.48 (1H, H′-1), 4.42, 4.38 (2H, 2d, OC*H*$_2$Ph), 4.30 (1H, m, $J_{6'',5''}$=10.2 Hz, $J_{6'',7''}$=2.6 Hz, H″-6), 4.18 (1H, dd, $J_{2,3}$=10.2 Hz, H-2), 4.17 (1H, d, $J_{3'',4''}$=9.2 Hz, H″-3), 4.11 (2H, m, $SO_3CH_2CH_3$), 4.00, 3.76 (OC*H*$_2$CH$_2$O), 3.95 (1H, dd, $J_{3,4}$=3.0 Hz, H-3), 3.86 (1H, H′-6a), 3.83 (1H, H″1a), 3.83 (1H, t, $J_{5,4}$ <0.5 Hz, $J_{5,6}$=6.4 Hz, H-5), 3.78 (1H, H′-4), 3.77 (1H, H′-6b), 3.77 (1H, t, $J_{4'',5''}$=9.2 Hz, H″-4), 3.75 (1H, H′-2), 3.75 (1H, H′-5), 3.73 (1H, H″-1b), 3.69, 3.57 (OCH$_2$C*H*$_2$O), 3.59, 3.51, 3.37, 3.01 (12H, 4 s, 4×OMe), 3.40 (1H, H′-3), 3.37 (1H, m, H″-5), 3.30 (1H, dd, H-4), 3.16 (2H, H″-7a,b), 1.22 (3H, t, H-6), 0.98 (3H, t, J=7.0 Hz, SO_3CH_2CH). ^{13}C NMR (125 MHz, benzene-d$_6$) δ (ppm): 103.82 (C′1), 100.08 (C″2), 98.34 (C1), 85.57 (C″4), 81.49 (C″3), 79.70 (C″5), 79.50 (C3), 78.78 (C4), 78.29 (C′2), 77.39 (C2), 75.37, 74.77, 73.71, 73.23, 72.91 (OCH$_2$-Bn),74.41 (C′5), 73.41 (C′3), 72.64 (C″6), 70.87 (C″7), 70.03 (C′6), 69.32 (C′4), 67.96, 67.90 (OCH$_2$CH$_2$O), 67.90 ($SO_3CH_2CH_3$), 66.77 (C5), 60.82, 60.40, 60.10, 58.59 (OMe), 53.92 (C″1, $J_{C1'',H3''}$ <0.5 Hz), 20.58 (C6), 17.01 ($SO_3CH_2CH_3$). Anal. calcd for $C_{62}H_{80}O_{19}S$: C 64.12, H 6.94, S 2.76. Found: C 64.14, H 6.96, S 2.77.

Compound **33**: $[\alpha]_D$ +97.59 (c 0.30, $CHCl_3$). ^{13}C NMR ($CDCl_3$, 90 Hz) δ (ppm): 161.69 (C2), 103.94 (C1), 83.59 (C4), 79.33 (C6), 78.15 (C3), 77.88 (C5), 70.31 (C7), 66.59 ($SO_3CH_2CH_3$), 59.40, 58.99, 58.65, 58.26 (4×OCH$_3$), 14.79 ($SO_3CH_2CH_3$).

*4.27. 1,2-[3-*O*-(1″-Deoxy-1″-tetrabutylammoniumsulfonato-α-*D*-gluco-hept-2″-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(α-*L*-fucopyranosyloxy)ethane **34***

Compound **31** was converted to **34** as described for synthesis of **22**. Compound **34** (84%); $[\alpha]_D$ −11.7 (c 0.79, H$_2$O); ^{1}H NMR (500 MHz, D$_2$O): δ 4.9 (1H, d, H-1, $J_{1,2}$=4.5 Hz), 4.5 (1H, d, H-1′, $J_{1',2'}$=8.8 Hz), 3.4, 3.5 (2H, 2 d, H-1$_a$″, H-1$_b$″, J_{gem}=14 Hz). ^{13}C NMR (125 MHz, D$_2$O): δ 105.7 (C-1′), 101.7

(C-1), 75.8 (C-6′′), 75.3 (C-4′′), 74.9 (C-3′′), 72.0 (C-5′′), 71.7, 69.8 (-CH_2-CH_2-), 63.7 (C-7′′), 63.5 (C-6′), 59.1 (C-1′′, $J_{C1''',H3''}$ <1 Hz), 18.0 (C-6). Anal. calcd for $C_{37}H_{73}O_{19}SN$: C 51.20, H 8.48, S 3.69, N 1.61. Found: C 51.21, H 8.49, S 3.68, N 1.60.

*4.28. 1,2-[3-*O*-(3,4,5,7-Tetra-*O*-methyl-1′′-deoxy-1′′-tetrabutylammoniumsulfonato-α-*D*-gluco-hept-2′′-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(α-*L*-fucopyranosyloxy)-ethane **35***

Compound **32** was converted to **35** as described for synthesis of **22**. Compound **35** (87%): $[\alpha]_D$ +4.7 (c 0.04, H_2O); ^{1}H NMR (500 MHz) δ (ppm): 4.84 (1H, d, $J_{1,2}$=4.0 Hz, H-1), 4.51 (1H, m, $J_{6'',5''}$=10.2 Hz, H′′-6), 4.39 (1H, d, $J_{1',2'}$=7.9 Hz, H′-1), 4.05 (1H, q, $J_{5,4}$ <0.5 Hz, $J_{5,6}$=6.7 Hz, H-5), 4.02, 3.80 (2H, OC$H_2$$CH_2$O), 3.99 (1H, d, $J_{3'',4''}$=9.8 Hz, H′′-3), 3.89 (1H, H′-4), 3.87 (1H, H′-3), 3.81, 3.64 (2H, OCH_2CH_2O), 3.79 (1H, H-3), 3.71 (1H, H-4), 3.69 (1H, H-2), 3.68 (1H, H′′-4), 3.67 (2H, H′-6a,b), 3.60 (1H, H′-5), 3.58 (2H, H′′-7a,b), 3.55 (1H, dd, $J_{2',3'}$=10.0 Hz, H′-2), 3.60, 3.58, 3.47, 3.35 (12H, 4 s, 4×OMe), 3.40 (1H, d, H′′-1a), 3.35 (1H, d, H′′1b), 3.18 (1H, t, $J_{5'',4''}$=$J_{5'',6''}$=9.8 Hz, H′′-5), 3.12, 1.57, 1.30, 0.89 (Bu), 1.14 (3H, d, $J_{6,5}$=6.7 Hz, H-6). ^{13}C NMR (125 MHz, D_2O) δ (ppm): 104.24 (C′1), 101.32 (C′′2), 99.91 (C1), 84.90 (C′′4), 81.85 (C′′3), 80.44 (C′′5), 75.72 (C′5), 74.29 (C′3), 73.05 (C4), 72.19 (C′′7), 72.00 (C′′6), 70.78 (C′2), 70.78 (C3), 70.09 (C′4), 70.11, 68.25 (OCH_2CH_2O), 69.32 (C2), 67.78 (C5), 62.20 (C′6), 61.60, 61.29, 60.84, 59.75 (OMe), 54.86 (C′′1), 59.23, 24.31, 20.34, 14.01 (Bu), 16.48 (C6). Anal. calcd for $C_{41}H_{81}O_{19}SN$: C 53.29, H 8.83, S 3.47, N 1.52. Found: C 53.27, H 8.80, S 3.45, N 1.51.

*4.29. 1,2-[2′6′-Di-*O*-benzyl-3-*O*-(3′′,4′′,5′′-tri-*O*-methyl-1′′-deoxy-1′′-ethylsulfonato-α-*L*-fuco-hept-2′′-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)-ethane **36** and 1,2-[2′6′-di-*O*-benzyl-4-*O*-(3′′,4′′,5′′-tri-*O*-methyl-1′′-deoxy-1′′-ethylsulfonato-α-*L*-fuco-hept-2′′-ulopyranosyl)-β-*D*-galactopyranosyloxy]-(2,3,4-tri-*O*-benzyl-α-*L*-fucopyranosyloxy)ethane **37***

Compound **29** was glycosylated with **12** as described for synthesis of **31** by using MeOTf (8 equiv.). The products were separated by column chromatography to yield **36** (52%) and **37** (12%). Compound **36** has $[\alpha]_D$ −42.9 (c 0.24, $CHCl_3$); ^{1}H NMR (500 MHz, benzene-d_6/TMS) δ (ppm): 5.08, 4.86; 5.03, 4.53 (4H, 4 d, 2×OCH_2Ph), 4.98 (1H, d, $J_{1,2}$=3.6 Hz, H-1), 4.73, 4.55; 4.59, 4.50 (4H, 4 d, 2×OCH_2Ph), 4.53 (d, $J_{3'',4''}$=10.1 Hz, H′′-3), 4.41, 4.35 (2H, 2 d, OCH_2Ph), 4.34 (1H, d, $J_{1',2'}$=7.4 Hz, H′-1), 4.21 (1H, dd, $J_{2,3}$=10.1 Hz, H-2), 4.09 (1H, q, $J_{6'',5''}$ <0.5 Hz, $J_{6'',7''}$=6.6 Hz, H′′-6), 4.04, 3.92 (2H, 2 d $J_{1a'',1b''}$=15.9 Hz, H′′-1a,b), 4.04, 3.74 (2H, OC$H_2$$CH_2$O), 4.03, 3.99 (2H, m, SO_3C$H_2$$CH_3$), 4.02 (1H, dd, $J_{3,4}$=2.3 Hz, H-3), 4.01 (1H, H′-4), 3.92 (1H, H-5), 3.89 (1H, dd, $J_{3',2'}$=9.9 Hz, $J_{3',4'}$=4.0 Hz, H′-3), 3.82 (1H, dd, H′-2), 3.81 (1H, dd, $J_{4'',5''}$=2.9 Hz, H′′-4), 3.81, 3.66 (2H, H′-6a,b), 3.74, 3.63 (2H, OCH_2CH_2O), 3.67, 3.33, 3.20 (9H, 3 s, 3×OMe), 3.38 (1H, dd, $J_{4,5}$=1.1 Hz, H-4), 3.34 (1H, H′-5), 2.99 (1H, dd, H′′5), 1.24 (3H, d, $J_{6,5}$=6.5 Hz, H-6), 1.22 (3H, d, H′′7), 0.932 (3H, t, J=7.0 Hz, SO_3CH_2CH_3). ^{13}C NMR (125 MHz, benzene-d_6) δ (ppm): 104.00 (C′1), 101.30 (C′′2), 98.38 (C1), 82.47 (C′′4), 79.49 (C3), 78.92 (C′′5), 78.87 (C4), 78.62 (C′′3), 78.33 (C′2), 77.36 (C2), 75.81, 75.39, 73.57, 61.26, 57.27 (5×OCH_2Ph), 74.22 (C′3), 73.01 (C′5), 69.70 (C′4), 69.48 (C′′6), 69.45 (C′6), 68.83, 67.48 (OCH_2CH_2O), 67.10 (SO_3C$H_2$$CH_3$), 66.83 (C5), 54.63 (C′′1, $J_{C1,H3}$ <0.5 Hz), 17.05 (C6), 16.36 (C′′7), 15.02 (SO_3CH_2CH_3). Anal. calcd for $C_{61}H_{78}O_{18}S$: C 64.76, H 6.95, S 2.83. Found: C 64.44, H 6.96, S 2.79.

Compound **37**: $[\alpha]_D$ −34.3 (c 0.29, $CHCl_3$); ^{1}H NMR (500 MHz, benzene-d_6/TMS) δ (ppm): 5.19 (2H, s, OCH_2Ph), 5.04, 4.53; 4.77, 4.57; 4.61, 4.35; 4.58, 4.52 (8H, 8 d, 4×OCH_2Ph), 5.00 (1H, d, $J_{1,2}$=3.7 Hz, H-1), 4.88 (1H, 3′-OH), 4.65 (1H, d, $J_{3'',4''}$=10.0 Hz, H′′-3), 4.42 (1H, d, $J_{1',2'}$=7.0 Hz,

H′-1), 4.20 (1H, dd, $J_{2,3}$=10.2 Hz, H-2), 4.11 (2H, m, $SO_3CH_2CH_3$), 4.01 (1H, H′′-6), 4.00 (dd, $J_{3,4}$=3.0 Hz, H-3), 3.97, 3.82 (2H, OCH_2CH_2O), 3.90, 3.77 (2H, 2 d, $J_{1a',1b'}$=13.7 Hz, H′′-1a,b), 3.88 (1H, d, $J_{5,4}$ <0.5 Hz, $J_{5,6}$=6.4 Hz, H-5), 3.84 (d, $J_{4',3'}$=2.4 Hz, $J_{4',5'}$ <0.5 Hz, H′-4), 3.68 (2H, OCH_2CH_2O), 3.60 (1H, H′-2), 3.60 (1H, H′-3), 3.60, 3.26, 3.06 (9H, 3 s, 3×OMe), 3.54 (2H, 2 d, $J_{6',5'}$=7.0 Hz, H′-6a,b), 3.41 (1H, dd, $J_{4'',5''}$=2.9 Hz, H′′-4), 3.33 (1H, d, H-4), 3.24 (1H, H′-5), 2.72 (1H, d, $J_{5'',6''}$ <0.5 Hz, H′′-5), 1.23 (3H, d, H-6), 1.10 (3H, d, $J_{6'',7''}$=6.4 Hz, H′′-7), 0.96 (3H, t, J=7.1 Hz, $SO_3CH_2CH_3$). ^{13}C NMR (125 MHz, benzene-d_6) δ (ppm): 104.29 (C′1), 99.51 (C′′2), 98.52(C1), 83.11 (C′′4), 80.62 (C′2), 79.44 (C3), 78.92 (C′′3), 78.92 (C′′5), 78.92 (C4), 77.56 (C2), 75.43, 74.53, 73.66, 73.38, 73.02 (5×OCH_2Ph), 74.33 (C′3), 72.59 (C′4), 72.41 (C′5), 69.35, 67.52 (OCH_2CH_2O), 68.40 (C′′6), 68.32 (C′6), 67.89 ($SO_3CH_2CH_3$), 66.79 (C5), 61.26, 60.67, 57.90 (3×OMe), 53.57 (C′′1, $J_{C1,H3}$ <0.5 Hz), 17.03 (C6), 16.31 (C′′7), 15.03 ($SO_3CH_2CH_3$).

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